CCAMLR SCIENTIFIC ABSTRACTS 2006

CONTENTS

PREFACE

CCAMLR Scientific Abstracts provides a comprehensive record of all scientific papers presented for the consideration of the annual meetings of the CCAMLR Commission and Scientific Committee and of their subsidiary bodies.

This volume contains abstracts of scientific papers as presented and discussed at the 2006 meetings of the CCAMLR Scientific Committee and its working groups. It is published only in English.

Publication of an abstract does not imply in any way that the paper was reviewed by the Scientific Committee or its working groups, or was used in the work of CCAMLR.

There are four categories of papers:

(i) scientific papers published elsewhere, for which the full reference and published abstract are given;

(ii) scientific papers submitted for publication, i.e. in *CCAMLR Science* or elsewhere, which are listed as 'submitted' or 'in press' with details of the publisher, if known;

(iii) scientific papers not intended for publication, which are listed as 'unpublished'; and

(iv) supplementary scientific papers (i.e. listing of data submitted, summary of analyses performed, etc.) not intended for publication, for which the title alone is listed.

All abstracts are listed in groups by respective CCAMLR bodies at meetings of which these papers were submitted. Each abstract is preceded with a unique CCAMLR document number, e.g. SC-CAMLR-XXII/BG/11 (background document number 11 submitted at the Twenty-second Meeting of the Scientific Committee); or WG-EMM-03/8 (document number 8 submitted at the 2003 meeting of the Working Group on Ecosystem Monitoring and Management).

Unpublished papers must not be cited without written permission of the author(s). Addresses of principal authors are given for this purpose.

Commission

CCAMLR-XXV/BG/16

Conserving pattern and process in the Southern Ocean: designing a marine protected area for the Prince Edward Islands. A.T. Lombard, B. Reyers, L.Y. Schonegevel, J. Cooper, L.B. Smith-Adao, D.C. Nel, P.W. Froneman, I.J. Ansorge, M.N. Bester, C.A. Tosh, T. Strauss, T. Akkers, O. Gon, R.W. Leslie and S.L. Chown (Marine Biology Research Institute, University of Cape Town, Rondebosch 7701, South Africa, gemsbok@meb.co.za), 46 pp. (English, unpublished).

South Africa is currently proclaiming a Marine Protected Area (MPA) in the Exclusive Economic Zone (EEZ) of its sub-Antarctic Prince Edward Islands. The objectives of the MPA are to: (i) contribute to a national and global representative system of MPAs; (ii) serve as a scientific reference point to inform future management; (iii) contribute to the recovery of Patagonian toothfish (*Dissostichus eleginoides*); and (iv) reduce the bird by-catch of the toothfish fishery, particularly of albatrosses and petrels. This study employs systematic conservation planning methods to delineate an MPA within the EEZ that will conserve biodiversity patterns and processes within sensible management boundaries, while minimising conflict with the legal toothfish fishery. After collating all available distributional data on species, benthic habitats and ecosystem processes, C-Plan software was used to delineate an MPA with three management zones: four IUCN Category Ia reserves (13% of EEZ); two Conservation Zones (21% of EEZ); and three Category IV reserves (remainder of EEZ). Compromises between conservation target achievement and the area required by the MPA are apparent in the final reserve design. The proposed MPA boundaries are expected to change over time as new data become available and as impacts of climate change become more evident.

CCAMLR-XXV/BG/18

Area-based conservation and management measures utilised under CCAMLR. Submitted by IUCN (IUCN – The World Conservation Union, with the support of the Federal Public Service, Public Health, Food Chain Security and Environment Belgium), 10 pp. (English, unpublished).

Existing area-based conservation and management measures available under CCAMLR provide a broad conservation and management framework under which the entire CCAMLR Area could be considered to have a level of protection similar to an IUCN Category IV (Habitat/Species Management) protected area. Category IV areas are defined as 'subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species'. Recent discussion within CCAMLR forums has focused on the need for further protection to be afforded to, *inter alia*, representative, vulnerable or scientific areas, and it has been noted that this type of protected area may have considerable potential for furthering CCAMLR's objectives. Such additional protection might be established using CCAMLR's existing provisions for closed areas and special areas for protection or scientific study. This would complement the existing area-based management system, and thus achieve additional benefits for fisheries and biodiversity conservation on an ecosystems basis.

A range of area-based measures have been designated by the Commission, but no areas of fishing activity have been permanently closed to all types of living resource extraction, and most conservation measures, including with respect to closed areas, must be reviewed and renewed on an annual basis. Current area-based measures focus on fisheries management,

and do not address the protection of representative ecosystem areas or the wider objectives of biodiversity conservation. No marine area has yet been designated as a 'special area for protection and scientific study' under the terms of Article IX of the CAMLR Convention.

The identification and protection of representative ecosystem and habitat areas, unique areas and highly biodiverse areas would contribute to CCAMLR's objective to conserve Antarctic marine living resources within the context of the wider ecosystem. The designation of such areas would complement existing area-based measures by providing a system of areas to be maintained undisturbed for reference and scientific study and by affording stricter protection if and where necessary.

The term 'Marine Protected Area' (MPA) can be applied to all types of area-based fisheries conservation and management measures. The Commission has noted that MPAs have considerable potential for furthering the objectives of CCAMLR, in applications including the protection of ecosystem processes, habitats and biodiversity, and the protection of particular species (including population and life-history stages).

It is important that any additional protection is designated within, and contributes to, the wider framework of existing area-based conservation and management. MPAs can complement the existing management measures by supporting CCAMLR objectives, and by helping to achieve fisheries objectives in an ecosystem management context. MPAs designated to protect areas for scientific research would also make a valuable contribution to the understanding of ecosystem component dynamics related to harvesting and environmental factors, enabling improved decision-making with regard to fisheries management and would provide additional protections to representative, scientific and vulnerable areas.

CCAMLR-XXV/BG/30
Achieving a network of marine protected areas in the CCAMLR Area. ASOC, 5 pp. (English, unpublished).

Scientific Committee

SC-CAMLR-XXV/BG/11
Fishing equipment, marine debris and hydrocarbon soiling associated with seabirds at Bird Island, South Georgia, 2005/06. R.T.E. Snape (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom), 17 pp. (English, unpublished).

This report describes and quantifies occurrences of fishing gear, marine debris and oil associated with seabirds at Bird Island, South Georgia, from 1 April 2005 to 31 March 2006. It is the 13th such annual report. As in previous years, more items of marine debris and fishing gear (mostly longlining gear) were found in association with wandering albatrosses than with any other species. Although the total number of items encountered has decreased significantly since a peak between 2000 and 2002, more items were encountered this season than in the previous season for all species monitored with the exception of black-browed albatross. Entanglements continue to be observed at a rate similar to that of previous seasons, hooks being typical of those used in the Patagonian toothfish industry. Whilst the occurrence of debris and fishing gear at Bird Island remains substantially lower than during a peak that occurred half a decade ago, the recent increase is of concern.

SC-CAMLR-XXV/BG/12

Beach debris survey – Main Bay, Bird Island, South Georgia, 2004/05. H.F. Taylor and S. Robinson (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom), 20 pp. (English, unpublished).

During the 15th year of standardised beach surveys of man-made debris at Bird Island, South Georgia, a total of 251 items was collected. This represents an encouraging reduction of 43% on the 361 items recorded in 2003/04 that corresponded to the highest levels of summer beach debris since the 1999/2000 season. The distribution of debris between summer and winter was more biased than in the previous recording period with only 23% of the total number of debris items being collected in winter compared to 36% last season. The total weight of debris collected has remained relatively stable with 4.1 kg collected this year, whilst 5.4 kg was gathered in 2003/04. For the second consecutive year, nylon line has been absent from the shores of Bird Island, having once been at a peak of 546 pieces in 1995/96. Over the same 15-year period packaging bands are still regularly recovered from the beaches and these findings reaffirm that the ban on their use on board fishing vessels brought into force by CCAMLR in 1995/96 has yet to prove entirely effective and should continue. The proportion of miscellaneous debris is commensurate with 2003/04 (98.5%) but when actual quantities of debris are considered since 1990 when the survey began, the amount of miscellaneous debris is much higher, though not at the peak levels of 2003/04. This indicates that debris is still being lost by vessels into the marine environment and marine vessels working in this region should therefore continue to make efforts to comply with not only the correct waste disposal procedures for fishing-related waste, but also domestic waste.

SC-CAMLR-XXV/BG/13

Entanglement of Antarctic fur seals (*Arctocephalus gazella*) by man-made debris at Bird Island, South Georgia, during the 2005 winter and 2005/06 breeding season. D.L.D. Malone (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom), 20 pp. (English, unpublished).

Results of the survey of entanglements of Antarctic fur seals at Bird Island, South Georgia, for the 16th consecutive winter (2005) and 18th consecutive summer (2005/06) are reported here. Two entanglements were observed in the winter, a decrease of 60% from the previous year, and the lowest number seen since records began in 1990. One of these involved a male pup entangled in fishing net and was classified as being very severe. The other observed entanglement during winter occurred to an adult female entangled in a plastic packing band causing slight constriction to the individual involved. In contrast, there was double the number of observed entanglements during the summer of 2005/06 compared to the previous summer. Of these 14% caused severe injury to the seal involved. Half of these entanglements involved juveniles. Of the entanglements where the animal could be sexed, females made up the majority during summer, in contrast to previous years. The majority (63%) of summer entanglements was caused by plastic packaging bands, this is a 67% increase from the previous year's observations. Fishing nets were responsible for entanglements in both winter (50%) and summer (14%). The presence of plastic packaging bands and fishing nets during both seasons highlights the need for continued monitoring and increased effort in ensuring correct disposal of debris with the potential to entangle wildlife at sea.

SC-CAMLR-XXV/BG/14

Beach debris survey, Signy Island, South Orkney Islands, 2005/06. M. Dunn (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom), 12 pp. (English, unpublished).

During the 2005/06 austral summer, the 16th annual beach debris survey was carried out at Signy Island, South Orkney Islands. Debris was cleared each month between December and March from the three study beaches. The debris was counted, measured and classified by type, material, mass and size categories. A total of 27 items weighing 24.36 kg was collected. The number of items found was lower than the total found during the previous season, although the total mass of the waste recovered had increased (a decrease of 28.94% and increase of 55.04% since 2004/05 respectively). There was a fall in the number of plastic packaging bands (9) from the total recorded the previous season (12), this decrease representing a contrast to the rise in packaging bands experienced over the previous four seasons with the exception of 2003/04, and marking a return to what has otherwise proved a declining trend since 1993/94. These findings highlight the fact that they continue to appear as beach debris and indicate that the ban on their use on board fishing vessels brought into force by CCAMLR in 1995/96 has yet to prove entirely effective and should continue. Plastic waste was predominant, as in previous seasons, making up 55.42% of all items recorded, followed by metal at 28.74%. The results of this season's litter survey clearly show that the longevity of plastics and other materials with a high resistance to degradation in the marine environment remains a problem. The need for continued monitoring to ensure that vessels are aware of, and comply with, regulations prohibiting the disposal of debris at sea is paramount.

SC-CAMLR-XXV/BG/15

Entanglement of Antarctic fur seals (*Arctocephalus gazella*) in man-made debris at Signy Island, South Orkney Islands, 2005/06. M. Dunn (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom), 8 pp. (English, unpublished).

The results of the eighth annual survey of entanglements of Antarctic fur seals at Signy Island, South Orkney Islands, are reported for the 2005/06 summer season. There was one sighting of a seal wearing a neck collar of man-made debris. Data are compared with results from a parallel study undertaken at Bird Island, South Georgia, in 2005/06. In the case of Bird Island, data indicated that the number of entangled fur seals had decreased by 75% compared to the previous year, this being the lowest number recorded at Bird Island between the austral summers of 1988/89 and 2003/04. Although such a decrease is encouraging, the number of seals with neck collars at Bird Island highlights the need for CCAMLR Members to continue their campaign to ensure that vessels are aware of, and comply with, regulations prohibiting the disposal of man-made debris at sea.

SC-CAMLR-XXV/BG/18

Bioregionalisation of Antarctic waters using an ecosystem approach. K.V. Shust (VNIRO, 17a V. Krasnoselskaya, Moscow 107140, Russia, kshust@vniro.ru, antarctica@vniro.ru), 9 pp. (English, unpublished).

Characteristics of the composition (structure) and distribution of Antarctic marine living resources are determined according to the position of the Southern Ocean and the geographic isolation of this enormous water basin. This basin itself and the great extent of the circumpolar waters lead to both the formation of the Antarctic Circumpolar Current system (ACC), and to the circumpolar distribution of whales, seals, seabirds, fish, squid, species of macro- and mesoplankton, algae and protozoa, in other words all the components of

ecosystem and food chains. The natural boundary formed by the Antarctic Convergence (AC) in different sectors of Antarctica is located at different latitudes, and the structure of the ACC varies enormously under the influence of submarine topography.

As a result of these general geological and oceanographic features of the Antarctic region, as is well known, it is possible to identify a diversity of insular, coastal and open-sea areas, using the appropriate maps of the currents, composition of bioresource species and discrete ecosystem. Shust (2001) takes into consideration the general geological and oceanographic features of the Antarctic area responsible for the formation of biotops/ecosystems of various sizes in which it is possible, based on the composition of fish fauna (especially of the most highly abundant species), to identify eight ichthyo-geographic zones (IZs). This work could be of use for the bioregionalisation of the Southern Ocean.

SC-CAMLR-XXV/BG/19

Potential for the achievement of marine protected area objectives using CCAMLR conservation measures. S.M. Grant (Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 IER, United Kingdom, suan@bas.ac.uk), 7 pp. (English, unpublished).

1. This paper considers how the conservation and protection objectives identified in the 2005 CCAMLR Workshop on Marine Protected Areas (MPAs) (SC-CAMLR-XXIV, paragraphs 3.44 to 3.73) might be achieved using conservation measures implemented by the Commission.
2. The 2005 Workshop noted that conservation outcomes appropriate for achieving the objectives of CCAMLR include maintenance of biological diversity as well as the maintenance of ecosystem processes, and recommended that attention may need to be given to the protection of representative, scientific and vulnerable areas.
3. Protection of such area types may be achieved through the implementation of closed areas on an indefinite long-term or short-term review basis, according to requirements. CCAMLR Ecosystem Monitoring Program (CEMP) sites, seasonal closures, gear restrictions and other area-based management measures could also be used to achieve specific objectives relating to marine protected areas, including the zonation of multiple-use areas.
4. Consideration should also be given to harmonising the implementation of these measures with the ATCM, to achieve common marine conservation objectives.

Joint Assessment Group (JAG)

JAG-06/4

Methods for the estimation of IUU fishing. D.J. Agnew, I. Payne, G. Parkes and R. Mitchell (Marine Resources Assessment Group Ltd, 18 Queen Street, London W1J 5PN, United Kingdom, d.agnew@imperial.ac.uk), 14 pp. (English, unpublished).

Current methods for assessing IUU separate into accounting and estimation techniques.

Accounting methods require catch, trade or documentation systems, e.g. estimation of IUU fishing effort from various sources combined with estimates of catch rate from licensed fisheries; comparison of trade-based estimates (including documentation schemes) and reported catch; detailed investigations of the catches of States not party to RFMOs; and incorporation of estimates of by-catch and bird/mammal interactions.

Estimation methods require good information from observer and surveillance systems and may incorporate estimation with population models, e.g. estimates using the number of IUU vessels observed, assumed behaviour and catch rates, where air/sea/satellite surveillance

provides the principal data source; models of IUU behaviour and surveillance encounter probabilities; estimates of unaccounted catches made using population models; and quasi quantitative Monte-Carlo integration of all historical sources.

The effective assessment of the extent of IUU fishing and its ecosystem impacts remains a restrictive factor in the development of the preventative management of IUU fishing. It is proposed here that better global monitoring would be best served by a network of institutions capable of undertaking monitoring of IUU activities in various categories for different ocean regions, and capable of disseminating its results, and influencing decision-making within a region and within relevant RFMOs. Work also needs to be undertaken on developing new methods for estimating IUU fishing, including the use of observer schemes and new technologies especially in high-seas waters.

JAG-06/8

A qualitative system for reporting the relative reliability or uncertainty of information on IUU vessels fishing in the CAMLR Convention Area. Delegation of New Zealand, 3 pp. (English, unpublished).

JAG-06/10

Evaluations of the impact of alternative estimates of illegal catch on estimates of CCAMLR yields from a statistical catch-at-age model. A. Dunn (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 13 pp. (English, unpublished).

The estimation of stock status and yield using statistical catch-at-age models relies on an accurate knowledge of the total removals. However, the estimation of IUU catch can be difficult. Presented here is an initial analysis using simulations from a statistical catch-at-age model to consider the impact of the inclusion of inaccurate IUU catches on estimates of initial and current biomass. The simulations were conducted using a limited range of scenarios for a hypothetical stock with a hypothetical catch history.

The results for these simulations suggest that, in general, underestimating IUU catch resulted in a more conservative estimate of both initial and current biomass than scenarios where IUU catch was overestimated. Across most scenarios the inclusion of an overestimate of IUU catch almost always resulted in a greater overestimate of productivity, and hence an overestimate of the initial and current biomass. However, the simulated scenarios here all considered short series of IUU catch, over periods of the fishery before or during the period when observations were made on stock status, and with the exception of tagging data, used observation types that were relative, not absolute, indices of abundance.

In general, these simulated scenarios suggest that (i) inclusion of an overestimate of IUU catch, in some scenarios, is not conservative, (ii) the time period when the IUU catch occurs within the time period of the model can impact the level of model bias, and (iii) the use of a greater number of types of observations may assist in reducing the bias. In general, until a greater understanding of how different models react to inaccurate estimates of IUU catch, it may be prudent to conduct sensitivity trials for each specific case.

Working Group on Ecosystem Monitoring and Management

WG-EMM-06/7

By-catch of small fish in a sub-Antarctic krill fishery. K.A. Ross, L. Jones, M. Belchier and P. Rothery (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom, katherine@wift.org.uk), 28 pp. (English, unpublished).

By-catch of small (<150 mm) fish and squid in the 2004 krill fishery around the sub-Antarctic island of South Georgia was estimated to provide information on the ecological impact of the fishery and the biology of the by-catch species. Unprocessed krill catches were sampled on board four commercial vessels to describe and quantify by-catch. Most hauls (67%) contained small fish and the assemblage varied independently with locality, time of day and water depth but not fishing depth or krill density. Notothenioids, myctophids and squid were represented by 15 taxa, including commercially exploited *Champsocephalus gunnari*. *Lepidonotothen larseni*, muraenolepidids, *Krefftichthys anderssoni* and *Gymnoscopelus nicholsi* occurred in the greatest number of hauls, where mean catches (standardised to volumes of water trawled) were 26×10^5, 7×10^5, 8×10^5 and 10×10^5 individuals m^{-3}.

WG-EMM-06/8

Development of foraging behaviour and evidence of extended parental care in the gentoo penguin (*Pygoscelis papua*). M. Polito and W.Z. Trivelpiece (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA, polito_mike@yahoo.com), 33 pp. (English, unpublished).

Radio telemetry and observations were used to study the activity patterns and behaviour of gentoo penguin chicks during their fledging period, defined as the time between a chick's first trip to sea and its final dispersal from the breeding colony. The study was conducted at a colony of approximately 2 500 breeding pairs of gentoo penguins in Admiralty Bay, King George Island, South Shetland Islands, during the 2004/05 austral summer. Gentoo penguins exhibited delayed dispersal of young coupled with extended parental provisioning, behaviours not observed in other *Pygoscelis* species. Chicks took their first trip to sea at a mean age of 70 days, before finally departing the colony at an average age of 82 days. During this fledging period, individual chicks made an average of five trips to sea. Trip duration increased significantly with chick age, as trips to sea become more similar to adult foraging trips in both timing and duration. Behavioural observations confirmed that many chicks were still being fed during this fledging period, with parental feeding behaviours most often observed in the late afternoon to evening hours. It is hypothesised that these behaviours not only provide the opportunity for chicks to gain experience at sea prior to dispersal, but also allow them to develop foraging behaviours and skills at this time. These results have implications to differences in life history traits and population trends among gentoo penguins and their congeners, the Adélie and chinstrap penguins.

WG-EMM-06/9

Impact of predation by Cape fur seals (*Arctocephalus pusillus*) on Cape gannets (*Morus capensis*) at Malgas Island, Western Cape, South Africa. A.B. Makhado, R.J.M. Crawford and L.G. Underhill (Branch Marine and Coastal Management, Department of Environmental Affairs and Tourism, Private Bag X2, Rogge Bay 8012, South Africa and Avian Demography Unit, Department of Statistical Sciences, University of Cape Town, Rondebosch 7701, South Africa), (*African Journal of Marine Science*, submitted), 15 pp. (English).

Cape fur seals (*Arctocephalus pusillus*) were estimated to kill some 6 000 Cape gannet (*Morus capensis*) fledglings around Malgas Island in the 2000/01 breeding season, 11 000 in 2003/04 and 10 000 in 2005/06. This amounted to about 29, 83 and 57% of the overall production of fledglings at the island in these breeding seasons respectively. Preliminary modelling suggests this predation is not sustainable. There was a 25% reduction in the size of the colony, the second largest of only six extant Cape gannet colonies, between 2001/02 and 2005/06. There has been a large increase in predation by Cape fur seals on seabirds around southern African islands since the mid-1980s, coincidental with both an increase in the seal population and altered management of the islands. At Malgas Island, most gannet fledglings were killed between 1000 h and 1800 h, the period when most are in the water around the island, from mid-January to mid-March, the main fledging period. The Cape gannet is classified as Vulnerable.

WG-EMM-06/10

Demography of Antarctic krill in the Lazarev Sea (Subarea 48.6) in the 2005/06 season. V. Siegel (Institut für Seefischerei, Palmaille 9, 22767 Hamburg, Germany, volker.siegel@ish.bfa-fisch.de), 14 pp. (English, unpublished).

A standardised krill net sampling survey was conducted in the Lazarev Sea (Subarea 48.6) in December 2005. Krill densities were low in the Lazarev Sea. No substantial day/night differences were observed in the catches. Spatial distribution of krill density and size/age classes are discussed for the Lazarev Sea. Recruitment indices were calculated for one-year-old (R_1) and two-year-old krill (R_2), showing high values for both recruitment indices. New information is given on the development of maturity stages in the early phase of the spawning season.

WG-EMM-06/11

Descriptive analysis of mesopelagic backscatter from acoustic data collected in the Ross Sea. R.L. O'Driscoll (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, r.odriscoll@niwa.co.nz), 29 pp. (English, unpublished).

This report presents results from a pilot study to investigate the use of acoustics to estimate middle trophic level prey organisms (e.g. krill and mesopelagic fish) in the Ross Sea. Single-frequency (38 kHz) acoustic data were available from New Zealand longline vessels participating in the exploratory fishery for toothfish in 2002/03 and 2005/06, and multi-frequency (12, 38 and 120 kHz) acoustic data were collected from the research vessel *Tangaroa* during a voyage to the western Ross Sea in February–March 2006. Analyses were carried out to assess data quality, describe different mark types, and quantify spatial and vertical distribution of acoustic backscatter in the upper 1 000 m of the water column.

There were clear spatial patterns in the amount and type of mesopelagic backscatter observed. There was much more backscatter in the upper 1 000 m and a wider variety of mark types north of 67°S. Common mark types in the northern region included a surface layer at less than 50 m depth, schools and layers centred on about 200 and 400 m depth, and a diffuse deep scattering layer centred at 750 m depth. Average acoustic density was lower south of 70°S, and most of the backscatter was from schools and layers shallower than 100 m.

Near-bottom marks were associated with areas shallower than 1 000 m on the Ross Sea shelf edge. In general, the amount of backscatter observed in the Ross Sea was much lower than that observed in shelf areas off New Zealand (Chatham Rise and Campbell Plateau).

Little direct information is available on the species composition of different mark types in the Ross Sea. However, different acoustic responses across the three frequencies available on the *Tangaroa* provided some clues about the likely identity of the key scatterers. Marks shallower than 100 m depth were typically much stronger on 120 kHz than on 38 kHz, and weak on 12 kHz. This type of acoustic response is typical of krill or other large zooplankton. Schools and layers at 200–400 m depth showed a more consistent response across all three frequencies and may have been associated with small fish. This study identified key areas and mark types for further research, including directed sampling, and showed how fishing vessels could be used to opportunistically collect acoustic data.

WG-EMM-06/12

A spatial multi-species operating model (SMOM) of krill–predator interactions in small-scale management units in the Scotia Sea. É. Plagányi and D. Butterworth (Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa, eva@maths.uct.ac.za), 28 pp. (English, unpublished).

A Spatial Multi-species Operating Model (SMOM) of the underlying krill–predator–fishery dynamics is developed in response to requests for scientific advice regarding the subdivision of the precautionary catch limit for krill among 15 small-scale management units (SSMUs) in the Scotia Sea to reduce the potential impact of fishing on land-based predators. The model is intended to complement the outputs from the KPFM. The model includes all 15 SSMUs and uses an annual time step to update the numbers of krill in each of the SSMUs, as well as the numbers of predator species in each of these areas. The model currently includes only two predator groups (penguins and seals) but is configured so that there is essentially no upper limit on the number of predator species which can be included. Given the numerous uncertainties regarding the choice of parameter values, a Reference Set is used in preference to a single Reference Case operating model. The initial Reference Set used comprises 12 alternative combinations that essentially try to bound the uncertainty in the choice of survival estimates as well as the breeding success relationship. The model is coded in AD Model Builder and quickly generates large numbers of stochastic replicates to explore different hypotheses such as that related to the transport of krill. The SMOM developed here is intended for use as an operating model in a formal management procedure (MP) framework described in an accompanying paper. Different MPs are simulation-tested with their performances being compared on the basis of an agreed set of performance statistics which essentially compare the risks of reducing the abundance of predators below certain levels, as well as comparing the variability in future average krill catches per SSMU associated with each MP.

WG-EMM-06/13

Time series of Drake Passage Oscillation Index (DPOI) from 1952 to 2006, Antarctica. M. Naganobu and K. Kutsuwada (National Research Institute of Far Seas Fisheries, Yokohama, 236-8648 Japan, naganobu@affrc.go.jp), 7 pp. (English, unpublished).

An assessment of the environmental processes influencing variability in the recruitment and density of Antarctic krill (*Euphausia superba* Dana) is important as variability in krill stocks affects the Antarctic marine ecosystem as a whole. Naganobu et al. (1999) had assessed variability in krill recruitment and density in the Antarctic Peninsula area with an environmental factor; strength of westerly winds (westerlies) determined from sea-level pressure differences across the Drake Passage, between Rio Gallegos, Argentina, and Base

Esperanza, at the tip of the Antarctic Peninsula from 1982 to 1998. Fluctuations in the westerlies across the Drake Passage were referred to as the Drake Passage Oscillation Index (DPOI). Significant correlations were found between krill recruitment and DPOI. Additionally, a new time series of DPOI from January 1952 to March 2006 was calculated. This paper also attempts to make a comparison between DPOI and oceanic condition of the surface layer around the South Shetland Islands, and suggests a response from DPOI to the oceanic condition.

WG-EMM-06/14

Progress towards a trophic model of the ecosystem of the Ross Sea, Antarctica, for investigating effects of the Antarctic toothfish fishery. M. Pinkerton, S. Hanchet and J. Bradford-Grieve (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, m.pinkerton@niwa.co.nz), 23 pp. (English, unpublished).

This paper reports on the further development of a carbon-budget trophic model of the Ross Sea with which to investigate effects of the fishery for Antarctic toothfish (*Dissostichus mawsoni*). The Ross Sea is a low primary production system, with production being localised in space and time. In the relative absence of krill, Antarctic silverfish (*Pleuragramma antarctica*) are probably the major middle-trophic level link between primary production and the larger predators. Mesozooplankton (mainly copepods), and demersal fish (especially *Macrourus whitsoni*, *Bathyraja eatonii*, *Chionodraco hamatus* and *C. antarcticus*) are other key linking species. The trophic model presented here is not complete and should be considered a work in progress. Overall, the model is close to balance, with total exports of organic carbon (mainly respiration) exceeding primary production by 7%. However, individual groups are generally not balanced, due in part to limited information on diet fractions of Ross Sea organisms. Methods to adjust diet fractions to take into account the relative abundances of prey items are suggested but not applied. The current version of the trophic model suggests that Antarctic toothfish have the potential to exert considerable predation pressure on some species of demersal fish. The significance of toothfish in the diets of predators (especially Weddell seal, type-C killer whale, sperm whale) cannot be tested reliably by the current version of the model, which is not spatially or seasonally resolved, and does not consider sub-populations of predators. More complete information on the abundances and diets of top predators in the Ross Sea are needed, especially with regard to the spatial, seasonal and interannual variability of these properties, and the population structures. Other recommendations for fieldwork, and work currently under way or planned by New Zealand scientists in the Ross Sea, are given.

WG-EMM-06/15

An overview of a large ecosystem survey of the southwest Indian Ocean sector of the Southern Ocean (CCAMLR Division 58.4.2). S. Nicol, S. Kawaguchi, T. Jarvis, G. Williams, N. Bindoff, D. Thiele, J. Schwarz, A. Davidson, S. Wright, J. Gedamke and P. Thompson (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, steve.nicol@aad.gov.au) (IWC SC Meeting Document Number SC/58/E27), 42 pp. (English, unpublished).

This document outlines the preliminary results of an Australian survey of CCAMLR Division 58.4.2 (the southwest Indian Ocean sector of the Southern Ocean 30–80°E) in January–March 2006, which was designed around an acoustic biomass survey for krill and a large-scale oceanographic survey. The survey is intended to produce a new estimate of krill biomass (B_0) for this division so that a revised precautionary catch limit can be established by CCAMLR. The survey utilised a standardised design as adopted in previous B_0 surveys in the

CCAMLR Area and was designed so that the results would be compatible with the 1996 BROKE (Baseline Research on Oceanography, Krill and the Environment) survey of the adjacent CCAMLR Division 58.4.1 which collected information on a wide range of ecological parameters. The survey was conducted from a single ship, the RSV *Aurora Australis*, and consisted of 11 meridional transects, between 30° and 80°E. On each transect a range of under-way data was obtained and on six transects detailed sampling was conducted at predetermined stations. This background paper provides an overview of what was achieved by this survey; the detailed results are currently being analysed and are being prepared for a special issue of *Deep-Sea Research* for publication in 2008.

WG-EMM-06/16

Biomass of Antarctic krill (*Euphausia superba*) off east Antarctica (30–80°E) in January–March 2006. T. Jarvis, E. van Wijk, N. Kelly, S. Kawaguchi and S. Nicol (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, toby.jarvis@aad.gov.au), 42 pp. (English, unpublished).

A multidisciplinary, single-ship survey of CCAMLR Division 58.4.2 was conducted in January–March 2006, during which time multi-frequency echosounder data were collected for the purposes of estimating the biomass (B_0) of Antarctic krill (*Euphausia superba*). The mean density of *E. superba*, integrated to 250 m depth across the survey area (1 566 157 km^2), was 10.15 g m^{-2}. The total biomass was estimated to be 15.89 million tonnes with a CV of 47.93%. Most of the *E. superba* detected (80%) were in relatively weak aggregations (s_A <100 m^2 nmi^{-2} for each 2 km-alongtrack integration interval), with 50% of integration intervals containing backscattering values <10 m^2 nmi^{-2}. Half of the biomass was found within 100 km of the 1 000 m isobath, although aggregations often extended to the northern ends of the transects at 62°S. The majority of acoustic detections were in the top 100 m of the water column, centred around 50 m depth.

WG-EMM-06/17

Winter distribution of chinstrap penguins from two breeding sites in the South Shetland Islands of Antarctica. W.Z. Trivelpiece, S. Buckelew, C. Reiss and S.G. Trivelpiece (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA wayne.trivelpiece@noaa.gov), 16 pp. (English, unpublished).

Satellite telemetry was used to determine the winter movements and distributions of eight chinstrap penguins known to breed at one of two colonies in the South Shetland Islands, Antarctic Peninsula region, during the 2000 and 2004 austral winters. Six birds from a breeding site in Admiralty Bay on King George Island (62°10'S 58°27'W) were instrumented with satellite tags following their annual moult; similarly, two birds were tagged at their breeding site on Cape Shirreff, Livingston Island (62°28'S 60°46'W). Chinstrap penguins were tracked successfully for one to six months following dispersal from their respective breeding colonies using the ARGOS satellite system. Data analyses revealed that four of the birds instrumented in the 2000 winter, two from each colony, foraged largely on the shelf to the north and northeast of the South Shetland Islands. Similarly, two birds tagged at Admiralty Bay in 2004 also dispersed to the Drakes Passage side of the South Shetland Islands. In contrast to the inshore locations utilised by all the penguins in 2000, both of the 2004 winter birds foraged well offshore, 350 to 500 km north of the islands. Bathymetry and hydrological data, including SST and geostrophic velocities, suggest that the chinstrap penguins used markedly different winter foraging habitats in the 2000 and 2004 winters. The final two chinstrap penguins from Admiralty Bay, one each from the 2000 and 2004 winter, proceeded directly to the Elephant Island area and spent the next 2–5 months continually

migrating eastward. Both of these penguins followed the Scotia Arc with the chinstrap penguin tagged in 2004 tracked to the vicinity of the South Orkney Islands where its signal was lost in April, a distance of 800 km from its breeding colony. The bird tagged in the 2000 winter continued towards the South Sandwich Islands until its signal was lost at 58°30'S 36°10'W in late July, over 1 300 km from its breeding colony. The migration path of both these birds was remarkably similar to the only other record of a chinstrap penguin's winter migration reported by Wilson et al. (1998). These results suggest that chinstrap penguins breeding in the same colonies during the summer have different migratory routes and winter habitats. The different migratory routes may reflect individual ties to different ancestral epicentres of chinstrap populations; one older and local in the South Shetland Islands and one relatively recent, arising from the emigration of chinstrap penguins that occurred during the expansion of this species in numbers and range in the middle of the past century.

WG-EMM-06/19

Further progress on modelling the krill–predator dynamics of the Antarctic ecosystem. M. Mori and D.S. Butterworth (Institute of Cetacean Research, 4-5 Toyomi-cho, Chuo-ku, Tokyo, 104-0055 Japan, mori@cetacean.jp) (IWC SC Meeting Document Number *SC/58/E14*), 15 pp. (English, unpublished).

This paper addresses work conducted on the Mori-Butterworth multi-species model of the Antarctic ecosystem subsequent to the Ulsan meeting of the IWC Scientific Committee. Points raised about the model during that meeting are addressed in turn. Results are quoted that suggest that krill is indeed unable to fully utilise the primary production available. The precision of parameters estimated when fitting the model to abundance and trend data is reported. The model is extended to include an 'other predators' variable (reflecting squid, fish and seabirds) so that the crabeater seal variable does not have to act as a surrogate for these in addition to the seals themselves. This results in an improved fit of the model to available abundance estimates for crabeater seals. A list of topics for possible further work on the model is presented. The development of an improved set of abundance and trend estimates for the various krill predators is seen as a priority for improving the reliability of current models, and it is suggested that this should be a key focus of the proposed joint IWC-CCAMLR workshop on this topic.

WG-EMM-06/20

A comparison of model predictions from KPFM1 and KPFM2. J. Hinke, G. Watters, S. Hill and K. Reid (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, 1352 Lighthouse Avenue, Pacific Grove, CA 93950, USA, jefferson.hinke@noaa.gov), 24 pp. (English, unpublished).

Two versions of the krill–predator–fishery model are compared to demonstrate the extent to which the predictions of KPFM1 can be reproduced with KPFM2. Also discussed is the incorporation of seasonality into parameter estimates and a necessary change in the predator recruitment function of KPFM2. These comparisons provide a preliminary indication that the substantial changes in the structure and logic of KPFM2 have not caused substantial changes in model results. In essence, KPFM1 has become a special case of KPFM2. KPFM2 thus offers a flexible framework with functionality that the user can opt to use, should the user be able to provide defensible parameter estimates.

WG-EMM-06/21

Comparison of long-term trends in abundance, recruitment and reproductive success of five populations of *Pygoscelis* penguins in the South Shetland Islands, Antarctica. J.T. Hinke, K. Salwicka, S.G. Trivelpiece, G.M. Watters and W.Z. Trivelpiece (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, Pacific Grove, CA 93950, USA, jefferson.hinke@noaa.gov), 41 pp. (English, unpublished).

Responses of predator populations to environmental variability in the Antarctic have tended to exhibit site- and species-specific differences owing to variation in geographic settings and predator life-history strategies. Five populations of *Pygoscelis* penguins from King George Island and Livingston Island, South Shetland Islands, Antarctica, were examined to compare up to 25 years of data on the responses of sympatric congeners to recent changes in their Antarctic ecosystem. A simple linear regression and correlation analyses were used to detect and compare trends in indices of population abundance, recruitment and summer breeding performance of the Adélie (*P. adeliae*), gentoo (*P. papua*) and chinstrap (*P. antarctica*) penguins. In general, the different trends in abundance and recruitment indices for each species, despite generally similar indices of summer performance, point to life-history-specific vulnerabilities during winter that contribute to differential survival rates of the penguins. In particular, significant relationships between indices of penguin and krill recruitment suggest that penguin populations in the South Shetland Islands may live under an increasingly krill-limited system that has disproportionate effects on the survival of juvenile birds.

WG-EMM-06/22

KPFM2, be careful what you ask for – you just might get it. G.M. Watters, J.T. Hinke, K. Reid and S. Hill (Protected Resources Division, Southwest Fisheries Science Center, 1352 Lighthouse Avenue, Pacific Grove, CA 93950, USA, george.watters@noaa.gov), 48 pp. (English, unpublished).

The krill–predator–fishery model that was presented to WG-EMM in 2005 has been substantially revised. The new version of the model is called KPFM2, and all four changes which WG-EMM indicated would be required to use the model for providing advice on the allocation of catch among the SSMUs have been addressed (i.e. add seasonality, consider alternative movement hypotheses, add thresholds in krill density that cause fishing to cease, and compute a performance measure that compares the distribution of simulated catch to the distribution of historical catch). A substantial number of other features has also been added to the model. Many of these features were suggested at the 2005 meeting of WG-EMM but not recorded as requirements; the authors have made a serious attempt to address most suggestions. These additional features include:

- predators that can forage outside their natal SSMUs;
- predators whose survival is a function of their foraging performance;
- differential competitive strengths among predators and the fishery;
- control over the seasonal timing of fishing and predator breeding that allows fishing and breeding to overlap or be disjunct;
- a facility for conducting simplified management strategy evaluations;
- general improvements to the flexibility, performance and usability of the model.

In our opinion, KPFM2 can be a useful tool for evaluating the outcomes of the six management procedures that are candidates for allocating the precautionary krill catch among SSMUs.

WG-EMM-06/23

The krill maturity cycle: a conceptual description of the seasonal cycle in Antarctic krill. S. Kawaguchi, T. Yoshida, L. Finley, P. Cramp and S. Nicol (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, so.kawaguchi@aad.gov.au), 29 pp. (English, unpublished).

A long-term study on the maturity cycle of Antarctic krill was conducted in a research aquarium. Antarctic krill were either kept individually or in a batch for 8 months under different temperature and food conditions, and the succession of female maturity stages and intermoult periods were observed. In all cases regression and re-maturation of external sexual characteristics were observed, but there were differences in length of the cycle and intermoult periods between the experimental conditions. Based on these results, and information available from previous studies, a conceptual model describing the seasonal cycle of krill physiology is suggested which provides a framework for future studies and highlights the importance of its link to the timings of the environmental conditions.

WG-EMM-06/24

Learning about Antarctic krill from the fishery. S. Kawaguchi and S. Nicol (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, so.kawaguchi@aad.gov.au), 28 pp. (English, unpublished).

Antarctic krill has been studied for many decades, but an understanding of its biology enabling reliable predictions about the reaction of its populations to environmental change is still a long way off. This is partly due to certain difficulties in relation to logistics, operations and survey design associated with scientific surveys that have been obstacles for the better understanding of krill biology. The krill fishery is the largest fishery in the Southern Ocean, continuously operating since the early 1970s. Recent studies revealed its potential to be used as a unique source for scientific discussions to understand krill biology. In this paper, after a brief overview of krill fishery operation and krill biology, how current data collection through the fishery operation could contribute to a greater understanding of krill biology is examined, and future priorities for fisheries-related research in relation to recent changes in the Southern Ocean environment are suggested.

WG-EMM-06/25 Rev. 1

Intra-annual variability in the abundance of Antarctic krill (*Euphausia superba*) at South Georgia, 2002–2005: within-year variation provides a new framework for interpreting previous 'annual' krill density estimates. R.A. Saunders, J.L. Watkins, K. Reid, E.J. Murphy, P. Enderlein, D.G. Bone and A.S. Brierley (Pelagic Ecology Research Group, Gatty Marine Laboratory, University of St Andrews, St Andrews, Fife KY16 8LB, United Kingdom, ras19@st-andrews.ac.uk), 22 pp. *CCAMLR Science*, submitted (English).

Upward-looking acoustic Doppler current profilers (300 kHz) and echo sounders (125 kHz) were deployed on moorings on- and off-shelf to the northwest of South Georgia to measure abundance of Antarctic krill continuously between 14 October 2002 and 29 December 2005. A distinct seasonal pattern in krill abundance was detected that recurred consistently over all three years. Krill densities in winter were predominantly low (mean = 18.7 g m^{-2} SD 24.3) but rose substantially by summer in each year (mean = 89.5 g m^{-2} SD 64.2). A simple polynomial regression model with time as the independent variable explained 71% of the observed week-week variation. Mooring estimates of krill abundance were not statistically different ($P > 0.05$) from estimates derived from standard ship-based krill surveys in adjacent periods suggesting that the mooring point estimates had relevance in a wider spatial context (ship surveys cover c. 100 x 100 km). Mooring data were used to

explore whether high-frequency temporal variation (i.e. within-year) could have led to the perceived between-year variation from previous summer surveys in the South Georgia western core box region between 1990 and 2005. Comparison of these 'snap-shot' ship survey estimates with the observed pattern of within-year variability showed that some of the alleged 'year-to-year' variation could be attributed just to sampling at different dates of year. However, there were some survey estimates that were significantly different ($P < 0.01$) from the regression-predicted within-year variation. Years that stand out for markedly low krill abundance (i.e. densities below the range expected due to intra-annual variation) were 1993/94, 1998/99 and 1999/2000. High values were observed in 2003. Moorings provide valuable data that could be important for ecosystem-based management at South Georgia because, for example, they will enable predator–prey functional responses to be explored there for the first time at appropriate temporal scales, and will enable hypotheses relating variation in krill abundance to physical oceanographic variability to be tested.

WG-EMM-06/26

Integrated analyses of circumpolar climate interactions and ecosystem dynamics in the Southern Ocean (ICED). E.J. Murphy, E. Hofmann and R. Cavanagh (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom, e.murphy@bas.ac.uk), 8 pp. (English, unpublished).

ICED is a multidisciplinary, international initiative recently launched in response to the increasing need to develop integrated circumpolar analyses of Southern Ocean ecosystems. The long-term goal of ICED is to develop a coordinated circumpolar approach to understand climate interactions in the Southern Ocean, the implications for ecosystem dynamics, the impacts on biogeochemical cycles, and the development of management procedures. CCAMLR community scientists have been instrumental in developing this initiative, and a key aim of ICED is to link with CCAMLR scientists to develop management procedures that include relevant aspects of the wider operation of ocean ecosystems. This document describes the current status of ICED and is aimed at further developing links with the CCAMLR scientific community in order to maximise the impact of science on the management of Southern Ocean ecosystems.

WG-EMM-06/27

The possible influence of continuous krill fishing technology using an 'air-bubbling suspension system' on ecosystem elements. S.M. Kasatkina and V.A. Sushin (AtlantNIRO, 5 Dmitry Donskoy Street, Kaliningrad 236000 Russia, ks@atlant.baltnet.ru), 14 pp. (English, unpublished).

The authors show that the potential expansion of the krill fishery in the near future, together with the introduction of highly intensive fishing and processing technologies, call for studies of the influence of the fishery on ecosystem components which go beyond the framework of traditional investigations of predator–krill–fishery interactions. In this case, in addition to traditional commercial statistics (vessel location, fishing effort etc.), trawl design and fishing methods should be examined as elements of krill fishing technology to be studied. Trawl design and fishing method are the only factors which determine catchability, selectivity and ecological compatibility of the gear during fishing and, as such, define the influence of the fishing process on components of the ecosystem such as juvenile fish, larvae, immature and adult krill and other small pelagic species. Apparently, the ecological compatibility of krill processing technology, including waste recovery, may become a constituent part of the influence of the fishery on ecosystem components, from the water itself to phyto- and zooplankton, krill, and further through trophic relationships to fish, birds and mammals.

The authors discuss potential major sources and scenarios of the influence on the ecology of the continuous krill fishing technology using the 'air-bubbling suspension system',

compared with conventional fishing methods. It is shown that not only hydrobionts, which are in close contact with the trawl, will be exposed to ecosystem influence, but also that marine animals (seals, fish, for instance), though not fished by trawl, can be exposed to indirect ecological pressure through the influence of this technology on environmental conditions. The authors therefore conceive it to be expedient that the introduction of fishing technology using air-bubbling suspension systems be preceded by the design implementation and conduct of specific investigations. Some proposals for such investigations are outlined.

WG-EMM-06/28

An illustrative management procedure for exploring dynamic feedback in krill catch limit allocations among small-scale management units. É. Plagányi and D. Butterworth (Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa, eva@maths.uct.ac.za), 17 pp. (English, unpublished).

A management procedure (MP) approach is proposed to assist in advising regarding the subdivision of the precautionary catch limit for krill among 15 small-scale management units (SSMUs) in the Scotia Sea to reduce the potential impact of fishing on land-breeding predators. The spatial multi-species operating model (SMOM) developed in Plagányi and Butterworth (2006) is used as an operating model which simulates the 'true' dynamics of the resource with tests across a wide range of scenarios for the underlying dynamics of the resource. Unlike static catch allocation options, the illustrative MPs developed here have a feedback structure, and hence are able to react and self-correct. It is important, as with the static allocation options, to ensure that the likely performances of these MPs in terms of low risk to predators within each SSMU are reasonably robust to the primary uncertainties about such dynamics. An MP module separate from the operating model contains the methods and rules that are used to subdivide the krill catch between SSMUs. Different MPs are then simulation-tested with their performances being evaluated on the basis of a set of performance statistics which essentially compare the risks of reducing the abundances of predators (and krill) below certain levels, as well as the variability in future average krill catches per SSMU associated with each MP.

The key assumption made here is that data will be regularly available in future to monitor the impacts of different krill catch limits. For illustrative purposes, it is assumed that two main sources of data will be available for use in an MP: (i) indices of absolute or relative abundance, or performance of the various predators (i.e. the CEMP series), and (ii) survey estimates of krill absolute or relative abundance per SSMU. The approach proposed is readily modified if, for example, no krill abundance indices are available. Given that 'future' data are required as inputs to test an MP including feedback, these data are generated with random variation about their underlying values and assuming the same variance as estimated from the past data.

WG-EMM-06/29

Managing ecosystem uncertainty: critical habitat and dietary overlap of top predators in the Ross Sea. D. Ainley, V. Toniolo, G. Ballard, K. Barton, J. Eastman, B. Karl, S. Focardi, G. Kooyman, P. Lyver, S. Olmastroni, B.S. Stewart, J.W. Testa and P. Wilson (HT Harvey and Associates, San Jose, CA, USA), 12 pp. (English, unpublished).

Three types of data are summarised in order to increase appreciation among fishery managers of the close spatial and temporal ecological overlaps among top predators in the Ross Sea Shelf Ecosystem (RSShE). This includes data on diet, foraging behaviour and habitat use. Murphy (1995) demonstrated that space–time overlap is critical to predicting the degree to which a fishery might affect a food web. The fisheries contemplated in this paper are those for Antarctic toothfish and the Antarctic minke whale, though other species might

also soon be exploited in the Ross Sea region. In addition to those two predators, other trophic competitors (and in two cases predatory species) were also included: killer whale (type C), Weddell seal, emperor penguin, Adélie penguin, and four species of flighted birds.

Using data from satellite tags attached to top predators that occur at colonies and haul-outs along the coast of Victoria Land from 1990 to 2004, the foraging ranges from these sites and the habitats used for foraging were summarised. Also summarised are data on diet and overlaps in foraging behaviour among these predators from analyses of scats and stomach contents and time-depth recorders collected from 1976 to 2002. Finally, results of ship-based surveys of birds and cetaceans made from 1976 to 1981 are presented. Though many of those species have not yet been studied using satellite telemetry, their diets have been investigated.

Most top predators in the Ross Sea feed at relatively great depths, perhaps because this affords them access to waters under sea-ice, which persists in this region except for late summer. Three of them are able to exploit the entire water column of the shelf, with others foraging from near surface to mid-depths. The major geographic habitats used include waters that are or were part of the marginal ice zone that rings the Ross Sea polynya during spring and summer when primary production is in full swing. Waters over shallow banks, especially in the western region, also appear to be important habitats. Even for colonies of these predators that are near the shelfbreak, their foraging efforts appear to be restricted to waters overlying the upper slope and shelf although deeper waters are well within range. In the RSShE, the main prey species consumed by most of the listed predators is the Antarctic silverfish, which is a major predator of ice krill. Based on frequency of occurrence in the diet, the prevalence of silverfish among diving predators averages 70% (range 45–95%) and among near-to-surface predators averages 31% (range 4–53%). The other main prey species of RSShE top predators is ice krill. Antarctic krill replaces ice krill in the predators' diets over the Ross Sea continental slope and outer shelf waters.

The key, and perhaps critical, foraging habitats of the seals and penguins from the colonies and haul-outs studied so far along the Victoria Land coast occur almost entirely within CCAMLR SSRU 881J and the southern third of 881H, one of the main SSRUs for harvests of Antarctic toothfish. Recommendations are made for research needs related to top predators, including further assessments of population size and diet (including studies of fatty acid composition) from autumn to early spring when sea-ice is most extensive, and simultaneous tracking of toothfish and cetaceans, especially the toothfish-eating killer whale.

WG-EMM-06/30 Rev. 1

A compilation of parameters for a krill–fishery–predator model of the Scotia Sea and Antarctic Peninsula. S. Hill, K. Reid, S. Thorpe, J. Hinke and G. Watters (British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom, sih@bas.ac.uk), 43 pp. *CCAMLR Science*, submitted (English).

The compilation and derivation of parameters for use in krill–fishery–predator models of the Scotia Sea–Antarctic Peninsula region is described in this paper. The primary aim is to provide input for the model developed by Watters et al. (2006), which was used to define the required parameters. However, these parameters should be applicable to other models of the system. The methods used here include the use of weighted averages to derive 'generic' parameters from multiple species in a taxonomic group, and the derivation of potential krill transport rates from the OCCAM global ocean circulation model. This parameter set, like most others, is associated with considerable uncertainty, which must be taken into account when it is used. The sources, assumptions and calculations have therefore been documented at every stage of the compilation process. The calculations suggest that myctophid fish are the major consumers of Antarctic krill in the Scotia Sea–Antarctic Peninsula region.

WG-EMM-06/31

Preliminary report from New Zealand research voyages to the Balleny Islands in the Ross Sea region, Antarctica, January to March 2006. B.R. Sharp (New Zealand Ministry of Fisheries, PO Box 1020, Wellington, New Zealand, ben.sharp@vanuatu.com.vu/), 24 pp. (English, unpublished).

This paper explains the background and scientific rationale behind New Zealand's decision to send two separate research voyages to the Balleny Islands, located north of the Ross Sea, in the Antarctic summer of early 2006. The first of these voyages involved a dedicated research expedition to the Balleny Islands exclusively, utilising the RV *Tiama*, a 15 m expedition yacht. The second voyage included supplemental sampling in the Balleny Islands area as part of a larger Ross Sea expedition utilising the RV *Tangaroa*. The successful completion of these voyages represents a considerable step forward for New Zealand's approach to the Balleny Islands. This paper provides a preliminary summary of the scientific sampling activities carried out by each expedition, and discusses how the resulting data will likely inform the design of subsequent research activities in the area.

WG-EMM-06/32

A review and update of krill biomass trends in the South Shetland Islands, Antarctica, using the simplified stochastic wave born approximation. C.S. Reiss and A.M. Cossio (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA, christian.reiss@noaa.gov), 19 pp. (English, unpublished).

Using data collected from US AMLR surveys conducted in the South Shetland Islands, the trends in biomass, size-frequency distribution and proportional recruitment of Antarctic krill (*Euphausia superba*) between 1997 and present are reviewed. Over the last five years proportional recruitment has been extremely low, and the population has aged, suggesting there has been little recruitment since the 2000/01 season. Relative biomass, estimated from acoustic surveys, and calculated using both the Greene et al. (1991) and the simplified stochastic distorted wave borne approximation (SDWBA) target strength algorithms are compared. Biomass estimates from the two algorithms are highly correlated (>0.95), with identical CVs. Use of acoustic windows based on the range of krill size increases variability in biomass estimates and CVs. These data suggest that future development focus on better propagating error through levels of analysis, to better account for process and model error structure, now that a physically based krill target strength model has been developed.

WG-EMM-06/33

Recent Ukrainian studies in Antarctica relating to a proposed marine protected area. Delegation of Ukraine, 7 pp. (English, unpublished).

This paper presents descriptions of a number of biological and ecological investigations conducted by Ukrainian researchers in Antarctica in the vicinity of the Argentine Islands Archipelago. The principal activities were: investigations of bird populations, krill populations, comprehensive meteorological observations, hydrological research, and studies of long-term variations in atmospheric ozone-depleting organic halides, the dynamics of ice caps and glaciers and the influence of pollution on the environment.

WG-EMM-06/34

The state of krill (*E. superba*) fisheries in Subareas 48.1 and 48.2 in February–May 2006. V.A. Bibik (YugNIRO, 2 Sverdlov Street, Kerch 98300, Ukraine, bibik@ker.post.crimea.ua), 3 pp. (English, unpublished).

Brief description of scientific observations on board the Ukrainian krill vessel *Konstruktor Koshkin* in Subareas 48.1 and 48.2 in the last fishing season.

WG-EMM-06/35

A non-parametric algorithm to model movement between polygon subdomains in a spatially explicit ecosystem model. T. Lenser and A. Constable (Bio Systems Analysis Group, Institute of Computer Science, FSU Jena, Germany, thlenser@inf.uni-jena.de), 19 pp. (English, unpublished).

Many modern spatially explicit ecosystem models use modelling subdomains of different shape and size ('polygons') to resolve space, and movement of biomass between them forms an important part of the modelling effort. In marine applications, a flow field grid describing the water movement usually forms the basis for movement of passive or nearly passive biomass. Grid-based advection algorithms are not designed to model movement on the larger scale of polygons, resulting in disproportionately large computational costs and difficult communication between model layers. In this paper, a simple and effective algorithm to model movement at the polygon level is proposed, preserving the general properties of biomass distribution in comparison to a grid-scale model. A non-parametric description of interpolygon movement in the domain is generated which is used to approximately replicate the observed movement pattern. To estimate the movement description, the moves of passive numerical drifters between polygons are observed. The resulting algorithm outperforms the conventional polygon-based transport equation approach both in artificial and realistic scenarios.

WG-EMM-06/36

Estimates of krill biomass of commercial significance in small-scale management units applying geostatistics techniques. S.M. Kasatkina and P.S. Gasyukov (AtlantNIRO, 5 Dmitry Donskoy Street, Kaliningrad 236000, Russia, ks@atlant.baltnet), 17 pp. (English, unpublished).

Krill density and biomass distributions were analysed, using as examples SGE and SGW, which are located in ecologically crucial areas affecting land-based predators around South Georgia, since they are the traditional krill fishing areas. Data collected during the CCAMLR-2000 Survey and the Russian survey in 2002 were used. Acoustic survey data for the period 2000–2002 were processed applying geostatistical methods.

It was revealed that there is significant interannual and seasonal variability in the size and fishable part of the standing stock in each SSMU. The relationship between the biomass available to the fishery and the total biomass may vary between SSMUs, e.g. in SGE this relationship based on the two surveys data constituted 0.18 and 0.40, and in SGW, 0.06 and 0.24 respectively. The 2002 survey indicated that there may be significant differences between commercially exploitable biomass in areas with a comparable total biomass, e.g. total biomass constituted 1.0587 million tonnes to the east of 37°W and 1.000 million tonnes to the west of 37°W, but the commercially exploitable biomass was 0.41985 and 0.24 million tonnes respectively.

The option 'standing stock of krill in the SSMUs', considered here as a basis for subdividing catch limits among the SSMUs in the Scotia Sea, must be supplemented by an estimate of the fishable biomass within the SSMUs.

The success of any assessment of the standing stock and its fishable part will depend on refinements in acoustic data processing. The methods specially designed for spatially distributed data are preferable. Specific studies are necessary to compare the precision of different methods of spatial data processing, such as classic geostatic methods, Maximum Entropy method and Bayesian geostatic methods based on the maximum Entropy principle.

WG-EMM-06/37

Regionalisation of the Southern Ocean: a statistical framework. B. Raymond and A. Constable (Antarctic Climate and Ecosystems Cooperative Research Centre, Private Bag 80, Hobart 7001, Tasmania, Australia), 17 pp. (English, unpublished).

Large ecosystems are often partitioned into spatial compartments (bio- or biophysical regions and/or ecoregions) in order to better understand the relative importance of ecosystem processes or for the purposes of managing human activities in relatively ecologically discrete areas. Regionalisation algorithms attempt to partition a broad spatial area into discrete spatial regions, each with relatively homogeneous and predictable ecosystem properties but with properties different from neighbouring regions. The Southern Ocean has been divided into regions before, primarily based on frontal features. In this paper, a method developed for a regionalisation of the southern Indian Ocean is demonstrated in order to facilitate the development of ecosystem models for the area. Here, this work is extended to other areas of the Southern Ocean to see how well the approach might be applied more generally and therefore be of assistance to large-scale ecological modelling and, perhaps, to CCAMLR in its work to develop a bioregionalisation of its Convention Area. This paper describes the steps and issues in undertaking a regionalisation and presents a statistical method for achieving a regionalisation of the Southern Ocean in an objective and consistent manner. Results are presented for each of the three CCAMLR Areas. It is concluded that it is tractable to resolve the challenges facing the subdivision of the ocean into meaningful regions for the purposes of modelling and management.

WG-EMM-06/38 Rev. 1

Using the EPOC modelling framework to assess management procedures for Antarctic krill in Statistical Area 48: evaluating spatial differences in productivity of Antarctic krill. A.J. Constable (Antarctic Climate and Ecosystems Cooperative Research Centre, Private Bag 80, Hobart 7001, Tasmania, Australia and Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, andrew.constable@aad.gov.au), 18 pp. (English, unpublished).

Spatially explicit simulation models of the Antarctic marine ecosystem are needed to evaluate management procedures for the Antarctic krill fishery. The key issues to be resolved in the development of a harvest strategy are whether: (i) spatial differences in the productivity of krill give rise to differential affects on predators in different locations, (ii) movement of krill between locations ameliorate any local fluctuations in krill abundance, and (iii) fishery behaviour could be constrained by regional differences in krill dynamics and cause differential impacts on predators as a result, particularly as the fishery expands to take the large-scale catch limit. A fourth issue is to determine whether climate change will impact on the krill-based food web and whether the potential for achieving conservation objectives for predators could be affected by those changes. Productivity of krill can be impacted by sea temperature and available production. Similarly, survivorship and successful recruitment of juvenile krill is likely to be dependent on the dynamics of sea-ice. This paper uses the Ecosystem Productivity, Ocean and Climate (EPOC) modelling framework to develop a spatially explicit model of Antarctic krill (*Euphausia superba*) within a wider ecosystem context (ocean, productivity, krill and predators) in the southwest Atlantic in order to explore the potential for spatial differences in krill productivity and their affects on predator productivity and fisheries. It uses satellite data as proxies for the key physical environmental drivers that may affect productivity. Illustrative results show that spatial and temporal variability of krill productivity is likely and that attention needs to be given to appropriately parameterising models to explore the sensitivity of management outcomes to these differences.

WG-EMM-06/39

A life table for female Antarctic fur seals breeding at Cape Shirreff, Livingston Island. M.E. Goebel, B.I. McDonald, J.D. Lipsky, V.I. Vallejos, R.A. Vargas, O. Blank, D.P. Costa and N.J. Gales (Antarctic Ecosystem Research Division, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, CA 92037, USA, mike.goebel@noaa.gov), 23 pp. (English, unpublished).

Mark–resight data were analysed for five cohorts (1997–2001) to estimate age-specific juvenile survival, age at first reproduction, and resight probabilities. Longitudinal histories of presence and pregnancy of adult females (aged by cementum annuli) were used to estimate age-specific survival and natality. Data on tagged juveniles were collected from 1998–2005 and for adult females from 2000–2005. These data are used to construct an age-dependent life table for female fur seals breeding at Cape Shirreff and to estimate net reproductive rate, mean generation time and the intrinsic rate of growth for the population.

WG-EMM-06/P1

Seabird research at Cape Shirreff, Livingston Island, Antarctica, 2005/06. Leung, E.S.W., R.A. Orben and W.Z. Trivelpiece. *AMLR 2005/2006 Field Season Report* (in prep.).

WG-EMM-06/P2

The effects of global climate variability in pup production of Antarctic fur seals. Forcada, J., P.N. Trathan, K. Reid and E.J. Murphy. 2005. *Ecology*, 86 (9): 2408–2417.

WG-EMM-06/P3

Contrasting population changes in sympatric penguin species in association with climate warming. Forcada, J., P.N. Trathan, K. Reid, E.J. Murphy and J.P. Croxall. 2006. *Global Change Biology*, 12 (3): 411–423.

WG-EMM-06/P4

Foraging dynamics of macaroni penguins *Eudyptes chrysolophus* at South Georgia during brood-guard. Trathan, P.N., C. Green, J. Tanton, H. Peat, J. Poncet and A. Morton. 2006. *Mar. Ecol. Progr. Ser.*, 323: 239–251.

WG-EMM-06/P5

Spatial and temporal variability in the fish diet of Antarctic fur seal *Arctocephalus gazella* in the Atlantic sector of the Southern Ocean. Reid, K., D. Davis and I.J. Staniland. *Can. J. Zool.* (in press).

WG-EMM-06/P6

Effects of variability in prey abundance on reproduction and foraging in chinstrap penguins (*Pygoscelis antarctica*). Croll, D.A., D.A. Demer, R.P. Hewitt, J.K. Jansen, M.E. Goebel and B.R. Tershy. 2006. *J. Zool.*, 269 (4): 506–513.

Working Group on
Fish Stock Assessment
Subgroup on Assessment Methods

WG-FSA-SAM-06/5

Proposed trawl survey report format. R.L. O'Driscoll (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, r.odriscoll@niwa.co.nz), 31 pp. (English, unpublished). (Appendix 1 is from: R.L. O'Driscoll and N.W. Bagley. 2006. Trawl survey of hoki, hake and ling in the Southland and sub-Antarctic areas, November–December 2004 (TAN0414). *New Zealand Fisheries Assessment Report 2006/2*: 60 pp.

Trawl surveys are used in the CAMLR Convention Area to estimate abundance of juvenile toothfish (*Dissostichus eleginoides*) and icefish (*Champsocephalus gunnari*). Documentation of some past trawl surveys has been insufficient to allow members of WG-FSA to fully interpret the survey results. This document suggests a standard pro forma for reporting trawl survey results to WG-FSA based on survey reports for bottom-trawl surveys for hoki (*Macruronus novaezelandiae*) in the New Zealand EEZ.

WG-FSA-SAM-06/6

Using mark–recapture and catch-at-age data to estimate fishing and natural mortality for the Patagonian toothfish at South Georgia. R.M. Hillary and D.J. Agnew (Renewable Resources Assessment Group, Royal School of Mines Building, Imperial College, Prince Consort Road, SW7 2BP London, United Kingdom, r.hillary@imperial.ac.uk), 12 pp. (English, unpublished).

This paper develops a Bayesian mark–recapture model for estimating both fishing and natural mortality, and integrates catch-at-age data into the estimation model, to aid in distinguishing between natural and fishing mortality. The model essentially follows tagged cohorts, with the estimated parameters being the fishing and natural mortality vectors for that particular cohort.

The model was tested against simulated data, and performed as expected. Mark–recapture data from toothfish at South Georgia were analysed with the model. The ages covered by the analysed cohorts ranged from 5 to 13. In the model runs, while fishing mortality-at-age was estimated, only one value of the natural mortality was permitted, as allowing both to vary can produce either non-sensical or non-convergent results. For all the cohorts the model was applied to, a consistent picture emerged. Both natural and fishing mortality were estimated to be lower than those estimated in previous stock assessments using both mark–recapture and catch data. There was additionally some suggestion of age structure in the natural mortality-at-age.

WG-FSA-SAM-06/7

A von Bertalanffy growth model for Division 58.5.2 fitted to length-at-age data and a comparison of predicted with observed growth from mark–recapture data. S.G. Candy, A.J. Constable, T. Lamb and R. Williams (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, steve.candy@aad.gov.au), 35 pp. *CCAMLR Science*, submitted (English).

Length-at-age data for the Patagonian toothfish (*Dissostichus eleginoides*) caught by trawl in the Heard Island fishery were fitted using a von Bertalanffy (VB) growth model taking into account variable probability (VP) sampling of fish that were aged. Sub-sampling of random length-frequency (LF) data used to obtain the samples of fish for ageing used length-bin sampling involving a fixed sample size per bin. Estimation of the VB parameters used a

definition of the maximum likelihood which took into account VP sampling due to length-dependent selectivity of trawl fishing and also accounted for the additional affect of length-bin sampling on sampling probabilities. Estimation of the trawl selectivity curve is described elsewhere and assumed known for this study with its most important feature being a sharp decline in selectivity from 100% at 1 000 mm down to 1% by 1 600 mm. The VB curve fitted to the length-at-age data assuming normal errors with constant coefficient of variation using iteratively weighted least squares (IWLS) substantially under-predicted mean length-at-age for older ages compared to VB curve fitted using the same error model and VP maximum likelihood (MLP) with length-bin relative probabilities defined using fishing selectivity alone. When length-bin sampling frequencies for aged fish relative to those for the LF sample were also included in defining relative probabilities, the VP maximum likelihood (MLPLB) and IWLS estimated curves were more similar. Predicted and observed values of annual growth rate (AGR) for lengths measured at release and first recapture in mark–recapture studies were compared where predictions used the VB parameter estimates obtained from the length-at-age data and the Fabens form of the VB growth model. Formulae for adjusting predictions for bias imparted by the use of the Fabens model were developed based on assumptions about the distribution of age-at-first-capture and showed that the bias is relatively small for the range of release lengths in the data. Predictions of AGR using the MLPLB estimated VB parameters were closer to the mean trend in observed values with release length than those obtained using IWLS estimated parameters. A young-age adjustment (less than five years old) to the VB model is also given in order to give more realistic predictions of mean length-at-age for young fish.

WG-FSA-SAM-06/8

Revised estimates of the biological parameters for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea. A. Dunn, P.L. Horn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 14 pp. (English, unpublished).

This report updates the estimates of the biological parameters for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea (Subarea 88.1 and SSRUs 882A–B). This paper presents revised estimates of the von Bertalanffy growth curves, length–weight relationship and natural mortality based on CCAMLR observer data collected from commercial fishing operations in the Ross Sea. In addition, meta-data were reviewed for plausible estimates of the steepness parameter of the stock-recruitment relationship and recruitment variability of Antarctic toothfish.

WG-FSA-SAM-06/9

A descriptive analysis of the toothfish (*Dissostichus* spp.) tagging program in the Ross Sea up to 2005/06. A. Dunn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 24 pp. (English, unpublished).

A descriptive analysis of the toothfish tagging program carried out in Subareas 88.1 and 88.2 since 2001 is presented. The paper updates tag–release and tag–recapture data for fish that were both released and recaptured from New Zealand vessels. It also presents release and recapture data for non-New Zealand vessels for the first time. However, tag data were only available for all these vessels for 2005 and for about half of these vessels for 2004.

A reported total of 8 888 Antarctic toothfish have been released and 176 recaptured, and 635 Patagonian toothfish released and 23 recaptured. Tagging rates by area over the past three years have been in the same proportion as the catch by area. However, recapture rates have tended to be higher in the northern and eastern SSRUs 881C and 882E. About 20% of the recaptures could not be matched to a release observation, mainly because of missing

release data. It is recommended that all outstanding release and recapture data be provided to the Secretariat as soon as possible so that the analysis can be updated in time for the 2006 WG-FSA meeting.

Several large-scale movements have now been reported from the tagging data. Five fish tagged at McMurdo Sound have moved over 800 km, whilst a further four fish tagged in the fishery have moved over 300 km. However, the majority (>80%) of Antarctic toothfish have moved less than 50 km. In 2006, New Zealand vessels greatly increased the size of toothfish being tagged so that for the first time the size distribution of the tagged fish was almost identical to the size composition of the catch.

WG-FSA-SAM-06/10

Developments towards an investigation of potential bias from the analysis of tag–release and recapture data in Ross Sea Antarctic toothfish abundance estimates. A. Dunn (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 12 pp. (English, unpublished).

This report outlines developments towards evaluating bias in abundance estimates for the current tag–recapture program for Antarctic toothfish in the Ross Sea. An initial approach is presented that uses the current data on catch (C2 data), tag–recovery effort and tag–release data from Dunn et al. (2005), but ignores movements of tagged and untagged fish.

The results suggest that as the spatial pattern of tag releases and recovery effort has changed over the years that the tagging program has operated, these patterns can introduce different levels of bias into the estimates of total population abundance.

WG-FSA-SAM-06/11

Preliminary assessment models of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea including data from the 2005/06 season. A. Dunn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 30 pp. (English, unpublished).

This paper provides an update of the Bayesian sex- and age-structured population stock assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea (Subarea 88.1 and SSRUs 882A–B), by including tag–recapture data for 2005/06 from New Zealand vessels. The updated assessment resulted in a similar, though slightly higher, estimate of initial and current biomass as the 2005 base-case model. The inclusion of the 2005 release and the 2006 recapture data had the effect of only slightly modifying the estimates from the models, suggesting that the new data had a similar pattern to that of previous years.

Model sensitivities using tag–recapture data from all vessels, revised biological parameters, and an alternative method of parameterising the tag–release data are also presented. Inclusion of 'all vessels' tagging data resulted in a much more optimistic assessment, but was due to the increased numbers scanned, but smaller increase in the reported numbers recaptured. It is likely that this assessment would change once the outstanding tag–release and tag–recapture data are used within the analysis.

The assessment using the revised biological parameters was slightly more optimistic in terms of B_0 than the 2006 reference case, with the use of the lower M (0.13 y^{-1} rather than 0.15 y^{-1}) resulting in a more optimistic estimate of B_0. However, as the changes in growth, length-weight and M all imply slightly lower productivity, the yield estimate from the revised parameters model is likely to be slightly lower than for the 2006 reference case.

As for the 2005 base cases, model fits to the data were mostly adequate, with the tag–release and recapture data providing the most information on stock size.

WG-FSA-SAM-06/12

An update on the development of a management procedure for the toothfish (*Dissostichus eleginoides*) resource in the Prince Edward Islands vicinity. A. Brandão and D.S. Butterworth (Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa, bela@maths.uct.ac.za), 24 pp. (English, unpublished).

Two operating models (OMs) reflecting an 'Optimistic' and a 'Pessimistic' current status for the toothfish resource in the Prince Edward Islands region that were developed last year are updated given further data. These models are for use for initial trials of candidate management procedures (MPs) which could provide future catch limit recommendations for this resource. Deterministic projections under a constant future catch suggest that the two scenarios will only be qualitatively distinguished in the short-term by an increase in the mean length of longline-caught toothfish over the next five years for the 'pessimistic', but not the 'optimistic' case. Accordingly the performance of a simple MP control rule, based on recent trends in both CPUE and this mean length, is investigated. This MP is able to secure a faster increase in the catch limit for the optimistic case, and some recovery in abundance for the pessimistic scenario, but neither is as appreciable as one might wish. Suggestions for future work are made.

WG-FSA-SAM-06/13

Review of some assumptions for modelling Patagonian toothfish dynamics in CCAMLR Subarea 48.3. A. Aubone, P.A. Martínez and O.C. Wöhler (Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Paseo Victoria Ocampo No. 1, 7600 Mar del Plata, Argentina, aaubone@inidep.edu.ar), 10 pp. (English, unpublished).

During the 2005 meeting of WG-FSA, two different methods for assessing Patagonian toothfish stock in CCAMLR Subarea 48.3 were available to the Working Group: CASAL and ASPM (WG-FSA-05/16 and 05/73). Although the underlying basic age-structure population dynamics models in both cases were similar, there were considerable differences in assumptions and implementations of the two methods. In this paper, the related effects are discussed considering a constant *h* parameter and deterministic recruitment over time versus considering a fitted *h* parameter and variable recruitment. The first alternative produces a more stable population structure and would introduce bias in the biomass and spawning stock biomass estimates. In the second case (variable recruitment and fitted *h*), the model has more flexibility to fit the changes in population structure and abundance. The parameter *r* from the stock-recruitment relationship is also analysed, in relation to the current underlying assumption of fish stock resilience.

WG-FSA-SAM-06/14

An investigation of integrated stock assessment methods for Patagonian toothfish (*Dissostichus eleginoides*) in Division 58.5.2 using CASAL. A. Constable, S. Candy and I. Ball (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, andrew.constable@aad.gov.au), 28 pp. (English, unpublished).

This paper follows preliminary work in 2005 in developing an integrated assessment for Patagonian toothfish in Division 58.5.2. It focuses on developing a 'base-case' assessment, which is primarily based on the 2005 assessment implemented in the Generalised Yield Model (GYM) using survey data of the abundances of juvenile fish but adding fishery catch-at-length data, including a standardised catch-per-unit-effort (CPUE) series. The base-case scenario was then extended to include estimates of IUU catch and mark–recapture data. Key sensitivity trials were also used to explore the tension between estimating natural mortality and selectivity for the different fisheries. The results of this work show that an integrated

assessment for *Dissostichus eleginoides* in Division 58.5.2 seems tractable. The recruitment series derived from surveys has similarities with the recruitment series estimated by Welsford et al. (2006), but with a recognition that some age classes are only partially selected in these surveys. Although computer processing time is substantially increased, the inclusion of the catch-at-length and the mark–recapture data generally improves the confidence in the estimates of B_0 and the recruitment series. Despite these results, there is considerable tension in the estimation model between natural mortality and fishing selectivities. The uncertainty arising from this tension will need to be explored further in order to appropriately accommodate this uncertainty in the estimate of long-term annual yield. Further discussion is needed on the choices being made in how the datasets are used in this assessment and the approaches being used to estimate the key parameters. An important stage in the development of this assessment will be to evaluate the robustness of these assessments to the uncertainties identified here as well as uncertainties in the spatial dynamics of the stock and the fisheries.

WG-FSA-SAM-06/15

Review of the use of survey data and length-at-age models in the assessment of *Dissostichus eleginoides* in the vicinity of Heard Island and McDonald Islands (Division 58.5.2). D.C. Welsford, A.J. Constable and G.B. Nowara (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, dirk.welsford@aad.gov.au), 25 pp. (English, unpublished).

This paper reviews the data used to estimate the abundance of juvenile *Dissostichus eleginoides* in Division 58.5.2 and examines the sensitivity of the assessment of yield to these results. Primarily, it is proposed to revise the use of historical survey data by reassigning them to the strata established in 2003. In addition, the sensitivity of the estimates of abundance to the latest length-at-age model is examined. The best fits using CMIX to estimate cohort densities were obtained using the updated assignment of survey data to the 2003 stratification along with the latest estimates of length-at-age. The quality of model fit and estimates of abundance of specific cohorts were sensitive to the number of cohorts assumed to be represented in the length-density data. Assuming survey design produces unbiased estimates of length density, it is suggested that best estimates of cohort abundance will be achieved when the mixture analysis is informed by accurate estimates of length-at-age, an independent estimate of relative abundance of cohorts present in any survey year, such as could be derived through an age–length key, and vulnerability of the stock to the surveys. The consequences to the 2005 assessment of yield of toothfish of changing the time series of abundance of juvenile fish and the length-at-age model were examined. Yield estimates were found to be most sensitive to the estimated recruitment series interacting with the estimate of mortality and the cohort abundances from CMIX, and to a lesser extent the estimated fishing vulnerabilities. A scenario equivalent to that used to recommend yield in Division 58.5.2 for 2005/06, incorporating the latest estimates of length-at-age, selectivity and the mixtures estimated from the assignment of RSTS hauls, resulted in an increase in estimated yield.

WG-FSA-SAM-06/16

Application of continuous time Markov chains to modelling animal movement: estimation of movement rates and retention times for Patagonian toothfish. C. Wilcox, M. Bravington and D. Peel (CSIRO Marine and Atmospheric Research, GPO Box 1538, Hobart 7001, Tasmania, Australia), 27 pp. (English, unpublished).

The study of animal movement and distribution has been a central focus in ecology since the inception of the science. However, continuous-time, discrete-state models have received relatively little application in data analyses or prediction in movement studies. Here a

continuous-time, discrete-state stochastic model, a continuous time Markov chain (CTMC), is developed for analysing movement data, including an inferential framework which can accommodate heterogeneous sampling effort. The accuracy of estimates arising from this model is explored using simulated data with known movement rates. Finally, the model is applied to estimate the equilibrium distribution of Patagonian toothfish in the region around Heard Island and MacDonald Islands in the Australian Antarctic zone using mark–recapture data from the Australian Patagonian toothfish fishery.

Working Group on Fish Stock Assessment

WG-FSA-06/5

Use of a Spanish type deep-water longline system as modified for Russian research on Ross Sea toothfish during the 2004/05–2005/06 seasons. N.V. Kokorin and I.G. Istomin (VNIRO, 17a V. Krasnoselskaya, Moscow 107140, Russia, antarctica@vniro.ru), 19 pp. (English, unpublished).

A description is given of the design of a longline using the Spanish system in the European hake (*Merluccius merluccius*) fishery in the coastal and deep waters of the North Atlantic and its modifications for use in the fisheries for Antarctic toothfish (*Dissostichus mawsoni*) and Patagonian toothfish (*D. eleginoides*) in waters of the Antarctic Region. The operational experience of two Russian-flagged vessels (*Yantar* and *Volna*) in the use of the Spanish longline system in Antarctic waters (seasons 2004/05–2005/06) is described.

WG-FSA-06/9

Maturity stages of gonads of Antarctic toothfish (*Dissostichus mawsoni*) from the southern Ross Sea (Subarea 88.1) from December 2005 to February 2006. V.G. Prutko (YugNIRO, 2 Sverdlov Street, Kerch 98300, Ukraine, vgprut@ker.post.crimea.ua), 6 pp. (English, unpublished).

Data on length and gonad-weight distribution, maturity and gonadosomatic index (GSI) of Antarctic toothfish *Dissostichus mawsoni* were collected from Subarea 88.1 on board the Russian-flagged longliner *Yantar* during the 2005/06 season.

It is suggested that the predominant part of Antarctic toothfish population observed in SSRUs H, K, L in December 2005–February 2006 will not be ready for participation in spawning of the current year. Ovaries of the most females weighed less than 2.0 kg; average GSI value of all the females examined did not exceed 2.0%.

WG-FSA-06/10

Species composition of fish from Antarctic toothfish (*Dissostichus mawsoni*) stomachs of the Ross Sea. A.V. Balushkin and V.G. Prutko* (*YugNIRO, 2 Sverdlov Street, Kerch 98300, Ukraine, vgprut@ker.post.crimea.ua), 6 pp. (English, unpublished).

Data on Antarctic toothfish stomach contents were collected from Subarea 88.1 on board the Russian-flagged longliner *Yantar* in the 2005/06 season. The results demonstrated that the main diet of toothfish in the Ross Sea was not cephalopods, but bottom and demersal fish, *Macrourus whitsoni* in particular. The list of 25 fish species of 14 families is given.

WG-FSA-06/12

Comparison of census methods for black-browed albatrosses breeding at the Ildefonso archipelago, Chile. G. Robertson, K. Lawton, C.A. Moreno, R. Kirkwood and J. Valencia (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, graham.robertson@aad.gov.au), 19 pp. (English, unpublished).

Although a breeding population of black-browed albatrosses has been known to exist at the Ildefonso archipelago, Chile, for more than 90 years, the population has never been censused using scientifically defendable methods. To estimate population size, and examine the accuracy and practicality of various census methods, the population was censused in the 2002/03 breeding season using: (i) ground-truthed aerial photography, (ii) yacht-based photography, (iii) ground counts, (iv) quadrat sampling and (v) point-distance sampling. Compared to ground-truthed aerial photography (judged the most accurate), yacht-based photography underestimated population size by 55%, ground counts by 13%, quadrat sampling by 11% and point-distance sampling by 9%. Ground-truthed air photography revealed that in the 2002/03 breeding season 47 000 pairs of black-browed albatrosses bred at the Ildefonso archipelago. After the Falkland/Malvinas Islands, South Georgia and Diego Ramirez, the Ildefonso archipelago holds the fourth largest population of black-browed albatrosses in the world.

WG-FSA-06/13

A brief report on scientific observation on board the fishing vessel *Mellas* (FAO Statistical Area 41, January to July 2006). S. Usachev (YugNIRO, 2 Sverdlov Street, Kerch 98300, Ukraine, usachev.s@gmail.com), 25 pp. (English, unpublished).

Information on the results of scientific observations during the fishery cruise on board the longliner *Mellas*, operating under the Ukrainian flag in FAO statistical Area 41 in the southwest Atlantic outside exclusive (marine) economic zones of other countries in Patagonian toothfish (*Dissostichus eleginoides*) fisheries are submitted. Data on the volume of biological material collected in the cruise, data on length–weight distribution ratios, sex ratios, parasitology of *D. eleginoides* and the taxonomic structure of catches are given.

WG-FSA-06/14

Standing stock, spatial distribution and biological features of demersal finfish from the 2006 US AMLR bottom trawl survey of the northern Antarctic Peninsula and Joinville/D'Urville Islands (Subarea 48.1). C.D. Jones and K.-H. Kock (Southwest Fisheries Science Center, 8604 La Jolla Shore Drive, La Jolla, CA 92037, USA, chris.d.jones@noaa.gov), 33 pp. (English, unpublished).

During February–March 2006, the US Antarctic Marine Living Resources (AMLR) Program, in collaboration with the German Federal Research Centre for Fisheries conducted a bottom trawl survey of the northern Antarctic Peninsula (southern Bransfield Strait) and Joinville/D'Urville Islands. This area included the likely historical fishing grounds of a trawl fishery for the spiny icefish (*Chaenodraco wilsoni*) conducted from the late 1970s to the mid-1980s, as well as rarely sampled shelf areas to the south. Estimates of seabed area by strata between 50 and 500 m for the region surveyed are computed. Information on demersal finfish biomass, spatial distribution, size and maturity composition, and dietary patterns from the survey is presented. Most biomass of finfish in this region occurs around the likely historical fishing grounds, north of Joinville Island. In addition to the inventory of species encountered, estimates of total stock biomass were computed for the eight most abundant demersal species: *Chaenodraco wilsoni*, *Chionodraco rastrospinosus*, *Cryodraco antarcticus*, *Gobionotothen gibberifrons*, *Lepidonotothen larseni*, *L. squamifrons*, *Notothenia coriiceps* and *Trematomus eulepidotus*. The species with the highest biomass was *G. gibberifron*s. Observations on

benthic by-catch, and differences in finfish species composition and abundance between this surveyed region and the adjacent South Shetland Islands region of Subarea 48.1 are given. High-Antarctic finfish fauna are considerably more prominent on the Antarctic Peninsula shelf region relative to the South Shetland Islands shelf region, and overall abundance of finfish is considerably lower. This is likely due to the influence of colder water from Weddell Sea outflow, lower productivity, and lower prey availability along the Antarctic Peninsula region. Biomass for all species of demersal finfish in this region is currently not at a level for which commercial exploitation would be advisable.

WG-FSA-06/15

Report of a new longline system in the exploratory fisheries for *Dissostichus* spp. in 2005/06. Delegation of Japan. 8 pp. (English, unpublished).

This document reports on how a new bottom longline system, replacing the Spanish longline system, was applied in exploratory longline fisheries for *Dissostichus* spp. during the 2005/06 season, with a particular focus on fishing gear and the line-setting and line-hauling processes. Explanations as to why no seabirds were caught during either line setting or line hauling are provided.

WG-FSA-06/17

The results of investigations on the feeding of Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea in 2005/06. A.F. Petrov (VNIRO, 17a V. Krasnoselskaya, Moscow 107140, Russia, antarctica@vniro.ru), 7 pp. (English, unpublished).

Studies of the diet composition of Antarctic toothfish were conducted from December to March over two fishery seasons (2004/05 and 2005/06) in different fishing areas of the Ross Sea located between 67°S and 76°S. A total of 192 longline sets were made. Over the two seasons, 3 000 stomachs (1 913 stomachs in 2005 and 1 087 ones in 2006) were analysed. In 2005, fish were caught at depths of 523–2 000 m. The total length (TL) of individuals ranged from 49 to 201 cm with weight from 0.8 to 123 kg. In 2006, *D. mawsoni* was caught at depths of 478–1 702 m and its TL ranged from 49 to 192 cm with weights from 0.8 to 110 kg. A substantial proportion of *D. mawsoni* stomachs were empty (42% in 2005 and 41% in 2006). Fish comprised the main food item (78% in 2005 and 54% in 2006), with Antarctic grenadier (*Macrourus whitsoni*) and icefishes *Channichthyidae* predominating. Squid were the second most frequently occurring.

WG-FSA-06/19

Distribution of albatrosses and petrels in the WCPFC Convention Area and overlap with WCPFC longline fishing effort. C. Small (BirdLife International, prepared by Dr C. Small, BirdLife International Global Seabird Programme (cleo.small@rspb.org.uk) and F. Taylor (softfrog@lantic.net)), 34 pp. (English, unpublished).

This paper presents an analysis of the distribution of albatrosses and petrels in the area under the jurisdiction of the Western and Central Pacific Fisheries Commission (WCPFC), using data from the BirdLife Global *Procellariiform* Tracking Database.

- The WCPFC area includes 41% of the global breeding distribution of albatrosses and petrels.
- Albatross distribution is concentrated north of 20°N and south of 30°S.
- WCPFC longline fisheries set approximately 100 million hooks each year north of 20°N and below 30°S, representing 16% of WCPFC's total longline fishing effort.
- Some species spend a significant proportion (>40%) of their time in high-seas areas. Key high-seas areas include the Tasman Sea and areas north of the Hawaiian Islands. The distribution in high-seas areas emphasises the importance of WCPFC in bringing about a collaborative approach to reducing seabird by-catch.

- Few tracking data are available for giant petrels, petrels and shearwaters in the WCPFC area. Range maps indicate that several species, including species known to be vulnerable to by-catch, have ranges that span the tropical Pacific.

In light of these results, the WCPFC Ecosystem and Bycatch Group is invited to:

- consider the importance of the WCPFC area for albatross and petrel distribution;
- use the albatross and petrel tracking data to inform and assist in designing effective by-catch mitigation measures;
- consider the urgent need for collection of seabird by-catch data, especially north of 20°N and south of 30°S, but also in tropical areas, and including high-seas areas (where few seabird by-catch data are currently available);
- work with BirdLife International to extend the analysis in this paper to consider temporal and spatial overlap at a finer scale.

WG-FSA-06/20

***Saga Sea* krill harvesting and production.** T. Williksen (Aker Seafoods Antarctic AS, PO Box 1301, Vika, N-0122 Oslo, Norway), 6 pp. (English, unpublished).

The FT *Saga Sea* is a Norwegian registered factory trawler owned by Aker Seafoods Antarctic AS, and is licensed to fish krill in Subareas 48.1, 48.2, 48.3 and 48.4. Aker has developed a patented new environmentally friendly continuous trawling system, named Aker Eco Harvesting System. The system is described in the paper and is based on a conventional trawl with a connected rubber hose to the codend of the trawl. The catch is brought on board continuously through a suction-driven system. The system is completely closed. The vessel has a processing plant on board, which is approved for manufacturing food and feed grade products from Antarctic krill. Approved product categories are krill meal, krill oil, round frozen krill, krill mince and krill protein concentrates. The vessel has so far carried out two fishing trips since 19 June 2006. The last trip started in September. The vessel carries a UK (from MRAG) international scientific observer on board. There is an agreement between Aker Seafood Antarctic and The Institute of Marine Research in Norway to use the *Saga Sea* as a platform for collecting scientific data, and laboratory facilities are installed.

WG-FSA-06/21

Recommended changes to Conservation Measure 25-02 pertaining to the Spanish system of longline fishing. G. Robertson and C. Moreno (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, graham.robertson@aad.gov.au), 5 pp. (English, unpublished).

WG-FSA-06/22

Best-practice seabird by-catch mitigation for Spanish-rig longline vessels with emphasis on line weighting regimes. G. Robertson, C.A. Moreno, B. Wienecke, P. Gandini, G. McPherson and J.-P. Seco Pon (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, graham.robertson@aad.gov.au), 37 pp. (English, unpublished).

The Spanish system is used in a range of demersal and semi-pelagic longline fisheries throughout the southern hemisphere and has been the source of a large number of seabird fatalities. An experiment was conducted on a chartered Spanish-rig vessel to improve the sink rate of longlines to reduce interactions with seabirds. The benchmark sink rate was that of integrated weight (IW) longlines, as used by autoline vessels, that are effective in reducing the mortality of white-chinned petrels, one of the world's most difficult seabird species to deter from baited hooks. Results to shallow depth (0–2 m) were given priority because Spanish system gear, while fast to deeper depths (10–20 m), is slow to clear surface waters. The experiment determined the effect of setting speed (6, 8 and 10 knots), distance between

weights on longlines (30, 40 and 50 m) and mass of the weights (4, 6 and 8 kg) on sink time profiles of longlines. The variable was the sink time to six target depths from 1 to 20 m as determined by time-depth recorders attached to lines. Separately, a trial was conducted to determine differences in sink rates between traditional Spanish system line weights (netting bags of rocks) and elliptically-shaped steel weights. In the vessel charter experiment there was a statistically significant interaction between setting speed and distance between weights to ≤10 m depth. Overall, distance between weights and mass of the weights were the principal determinants of sink times to target depths. Longlines with weights 30 m apart and either 6 or 8 kg traditional weights, or 40 m and 8 kg weights, most closely approximated the sink profile of IW-autoline in the shallow depth ranges irrespective of setting speed. In the weight-comparison trial, 4 kg steel weights and 8 kg traditional weights sank at comparable rates and are considered to be interchangeable. Best-practice seabird by-catch mitigation for line setting operations would involve: (i) setting longlines with weights 30 m apart (minimises lofting in propeller turbulence), (ii) use of 5–6 kg elliptical steel weights instead of traditional weights, (iii) limiting setting speed to the 6–8 knots range, (iv) lining bait compartments of setting baskets and stern setting surfaces of vessels with marine grade stainless steel (to reduce incidences of hook-ups and line tension astern), (v) releasing line weights before line tension occurs (eliminates a source line tension astern), (vi) use of dual, hydraulically driven bird scaring streamer lines (to reduce crew workload and improve compliance) to CCAMLR standards and with 50–60 m aerial extent, and (vii) attaching streamer lines to vessels ≥5 m either side of the position the hook line leaves the vessel and use of a 'lazy' line to increase effectiveness in crosswinds and to enable streamer lines to be positioned according to weather conditions each time longlines are set. Strict compliance to the recommendations above has the potential to eliminate albatross mortality and reduce mortality of deep diving seabird species to very low levels.

WG-FSA-06/23

Possible impact of the new continuous krill fishing technology on juvenile fish and larvae. S.M. Kasatkina (AtlantNIRO, 5 Dmitry Donskoy Street, Kaliningrad 236000, Russia, ks@atlant.baltnet.ru), 5 pp. (English, unpublished).

The new continuous krill fishing system uses both a small-meshed midwater trawl and a powerful pumping system for continuous pumping of the catch from the trawl bag. The potential threats of the new technology to the Antarctic marine ecosystem are discussed. It is shown that the application of this fishing technology may result in considerable by-catch of juvenile fish and larvae in the krill fishery.

WG-FSA-06/24

Mercury concentrations in Patagonian toothfish (*Dissostichus eleginoides* Smitt 1898), among three distinct ocean basins. K. Dawson Guynn and M.S. Peterson (NOAA Fisheries National Seafood Inspection Laboratory, 100 Singing River Parkway Building 47C, Pascagoula Naval Station, Pascagoula, MS 39595, USA, kim.dawson.guynn@noaa.gov), 17 pp. (English, unpublished).

Patagonian toothfish (*Dissostichus eleginoides*) collections (n = 186) from three ocean basins were analysed for Hg concentration and comparisons were made by gender, total length (TL), wet weight (WW) and basin. There was no difference between TL-WW relationships by gender within any basin across the range examined. However, fish were significantly smaller within the Atlantic basin (mean = 84.52 cm; 5.57 kg; n = 142) than the Pacific (99.07 cm; 9.12 kg; n = 15) and Indian (102.72 cm; 14.0 kg; n = 29) basins, which were not different from each other. Similarly, Hg concentration did not differ by gender or size across the range examined and was less for Atlantic basin fish (mean = 0.23 ppm) than either Pacific (0.73 ppm) or Indian basin (0.80 ppm) fish, which did not differ.

The Pacific and Indian basin fish had Hg concentrations within the range found for other fish like shark, swordfish, tilefish and king mackerel, that are considered high in Hg concentration by the US Food and Drug Administration. In contrast, those from the Atlantic basin were found to have similar lower values in fish like haddock, halibut, cod, albacore tuna and orange roughy.

Explanation of these geographical differences in Hg may be: (i) the noted size differences among basins, or (ii) the actual sample locations and associated hydrogeographical and oceanographical conditions. For example, sampling sites for the Pacific Ocean lie well outside the Antarctic Convergence, whereas the Indian Ocean sites straddle the Convergence. The Atlantic sites lie well within the Antarctic Convergence, suggesting that the Polar Front may provide some type of hydrographic barrier, as suggested in other studies on Patagonian toothfish, to anthropogenic sources of contamination. With a steady global market demand for *Dissostichus*, this could pose a human health risk that has yet to be adequately explored.

WG-FSA-06/25

Information on the status of fjord fish (*Notothenia rossii, Gobionotothen gibberifrons* and *Notothenia coriiceps*) in the lower South Shetland Islands derived from a long-term monitoring program (1983–2006) at Potter Cover. E.R. Barrera-Oro and E.R. Marschoff (Instituto Antártico Argentino, Cerrito 1248, 1010 Buenos Aires, República Argentina, also: Museo Argentino de Ciencias Naturales 'Bernardino Rivadavia', División Ictiología, Angel Gallardo 470, C1405DJR Buenos Aires, Argentina, ebarreraoro@dna.gov.ar), 16 pp. *CCAMLR Science*, submitted (English).

The long-term monitoring program of demersal fish at inshore sites of the South Shetland Islands has continued at Potter Cove from 2000 to 2006, covering a continuous sampling period of 24 years, and at Harmony Cove, Nelson Island, in the austral summers from 2001 to 2003. The decline in trammel net catches of fjord fish of the species *Notothenia rossii* and *Gobionotothen gibberifrons* in relation to the non-commercially fished *N. coriiceps*, which was previously reported for the period 1983–1999, is still evident. At Potter Cove, despite an overall increasing trend of *N. rossii* catches from 1991 to 2006, the actual levels are half of those found in the early 1980s, while those of *G. gibberifrons* further declined and remain close to zero. At Harmony Cove, the relative abundance of *N. rossii* showed an increase in 2002 and 2003, whereas *G. gibberifrons* was absent in the catches. These trends are consistent with those observed in scientific cruises on the offshore populations in a similar period. Commercial fishing off the South Shetland Islands in the late 1970s is the most likely explanation for the decrease in recruitment to the inshore sub-populations of *N. rossii* and *G. gibberifrons*. No recovery of the stocks of these two fish species was observed, even more than two decades after the end of the commercial fishery. Both, present results of inshore monitoring and those of the offshore cruises since 1998 show that the populations of *N. rossii* and *G. gibberifrons* in the South Shetland Islands region cannot, at present, sustain a commercial fishery.

WG-FSA-06/26

Species profile for Antarctic toothfish (*Dissostichus mawsoni*). S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, PO Box 893, Nelson, New Zealand, s.hanchet@niwa.co.nz), 22 pp. (English, unpublished).

A toothfish species profile, covering aspects of the biology, fisheries and stock assessment of both toothfish species was completed by Everson (2002). Aspects of the biology of *D. mawsoni* were summarised by Hanchet et al. (2003), whilst more recent research has been reported in papers submitted to WG-FSA. The aim of the current work was to collate and summarise existing biological data on *D. mawsoni*. The report focuses primarily on data collected from the Ross Sea fishery because this is where most of the work has been carried

out, but data from the other areas and fisheries have been included when available. It is intended that this report form the basis of a species profile of *D. mawsoni* as requested at the 2005 CCAMLR meeting (SC-CAMLR-XXIV).

WG-FSA-06/27

Stomach contents of sub-adult Antarctic toothfish (*Dissostichus mawsoni*) from the western Ross Sea, Antarctica. D.W. Stevens (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, d.stevens@niwa.co.nz), 14 pp. (English, unpublished).

The stomach contents of 190 sub-adult (51–100 cm TL) Antarctic toothfish (*Dissostichus mawsoni*) caught by bottom longline in the western Ross Sea were analysed. Fish were sampled during the 2005 fishing season (December 2004 to June 2005) and caught in 398–1 678 m depths. Sub-adult *D. mawsoni* are primarily piscivorous, feeding on a wide variety of small- to medium-sized fish. Icefish (Channichthyidae) were the most important prey by frequency, weight and index of relative importance (IRI), while small notothens (Nototheniidae) were more numerous. Whitson's grenadier (*Macrourus whitsoni*), dragonfish (Bathydraconidae) and eel cods (Muraenolepididae) were also important. Glacial squid (*Psychroteuthis glacialis*) were found in about 20% of stomachs, but only 6% by IRI.

Samples were collected mainly from the continental slope along the northern edge of the Ross Sea. Although the study provides an important comparison of diet of adult and sub-adult fish collected from the same area, the results may not reflect the diet of the main part of the sub-adult population which is thought to reside on the main shelf to the south. It is therefore recommended that further stomach samples be collected from further south on the Ross Sea shelf.

WG-FSA-06/28

Preliminary analyses of an ectoparasite (*Eubrachiella antarctica*) as a marker for stock discrimination of Antarctic toothfish in the Ross Sea. P.J. Smith, A. McKenzie and L. Tubbs (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, p.smith@niwa.co.nz), 14 pp. (English, unpublished).

This project evaluated the prevalence and intensity of an ectoparasite (*Eubrachiella antarctica*) as a marker for stock discrimination of Antarctic toothfish in the Ross Sea. New Zealand Ministry of Fisheries observers on four toothfish longline vessels recorded the number of *E. antarctica* on the fins and in the buccal cavity of 621 large *Dissostichus mawsoni* (mostly 120–150 cm). Up to five *D. mawsoni* per set were examined for parasites in small-scale research units (SSRUs) 881C, 882E and 882F, and two fish per set in SSRUs 881H–881J. Up to 15 *E. antarctica*, one from each of the first 15 sets in each SSRU, were dissected out and stored in ethanol for laboratory identification. All the preserved copepod parasites were identified as female or male *E. antarctica*. *Dissostichus mawsoni* from SSRU 881H had a higher prevalence of *E. antarctica* compared to *D. mawsoni* from SSRUs 881C, 881I and 881J (and 882E), and higher intensity compared to *D. mawsoni* from SSRUs 881C, 881I and 881J. However, neither intensity nor prevalence were significantly different between SSRUs 881H and 882F. These area differences do not appear to be sampling artefacts produced by differences in host length structure, sex ratio, seasonality, or observer experience, but represent a regional difference in prevalence and intensity of *E. antarctica* on *D. mawsoni*. The small-scale regional differences suggested by the parasite marker are inconsistent with the genetic and tagging studies which suggest homogeneity at small spatial scales. Genetic, tagging and parasite studies measure different biological

parameters, and results from these independent studies provide a picture of toothfish movement over different time scales. The stability of this regional difference in prevalence and intensity of *E. antarctica* needs to be tested with large-scale sampling in future years.

WG-FSA-06/29

A characterisation of the toothfish fishery in Subareas 88.1 and 88.2 from 1997/98 to 2005/06. S.M. Hanchet, M.L. Stevenson and A. Dunn (National Institute of Water and Atmospheric Research (NIWA) Ltd, PO Box 893, Nelson, New Zealand, s.hanchet@niwa.co.nz), 25 pp. (English, unpublished).

The exploratory fishery for Antarctic toothfish (*Dissostichus mawsoni*) has been operating for nine years in Subarea 88.1 and for five years in Subarea 88.2 with a large amount of data collected on toothfish and the associated by-catch. All SSRUs in the two subareas except for 881D and 882C have now been fished. The 2006 *D. mawsoni* catch was the second highest on record with a total of 3 388 tonnes against a combined catch limit of 3 451 tonnes. The subarea catch limit was almost reached in both Subarea 88.1 and 88.2. The management of the SSRUs within the two subareas was changed for the 2006 season as part of a three-year experiment (SC-CAMLR-XXIV). One of the aims of the experiment was to simplify the administration of the fishery by having fewer catch limits. This appeared to be moderately successful, with only one catch limit being slightly exceeded in the 2006 season. Concentration of effort within a smaller spatial area also increased the recovery of tags by over 50% (Dunn and Hanchet, 2006).

Interesting patterns are beginning to emerge concerning the size distribution of fish from the different areas in Subareas 88.1 and 88.2. The occurrence of large adult fish from relatively shallow waters on the Ross Sea Shelf, as well as the occurrence of small juveniles in much deeper water on the continental slope in Subarea 88.2, suggests that depth alone does not explain all the variation in toothfish length in the areas. Further sampling from along the continental slope is needed to determine the extent of these small fish.

WG-FSA-06/30

Towards a seabird mortality risk assessment: distribution of seabirds in the WCPFC Convention Area and potential overlap with fisheries. S. Waugh (Ministry of Fisheries, PO Box 1020, Wellington, New Zealand, susan.waugh@fish.govt.nz), 10 pp. (English, unpublished).

This paper reviews the distribution of seabird species in the WCPFC area. From a review of the distributions of 99 species of albatross and petrel, 16 species of albatross and 60 species of petrel occur within the area of the WCPFC, and are potentially vulnerable to fisheries by-catch. These include species with IUCN classification of Critically Endangered (n = 1), Endangered (n = 7), Vulnerable (n =26) and Near Threatened (n = 7). The remaining 30 species are classified by the IUCN as Least Concern. This paper, having identified key risks, is intended to assist with the development of advice on mitigation of seabird mortality in fisheries in the WCPFC Convention Area. Recommendations on future approaches to mitigating risk are made.

WG-FSA-06/31

Review of biological parameters for Ross Sea skates. M.P. Francis (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand), 18 pp. (English, unpublished).

Biological parameters were reviewed and updated for the two main species of skates taken as by-catch in the Ross Sea toothfish fishery: *Amblyraja georgiana* and *Bathyraja* cf. *eatonii.* Differences in length–weight relationships among regions raise doubt about the conspecificity of *A. georgiana* from the Ross Sea and South Georgia, and of *B.* cf. *eatonii* from the Ross Sea

and Heard Island and the MacDonald Islands. The taxonomy needs to be resolved before biological parameters derived from populations outside the Ross Sea can be applied to Ross Sea skates. Length–weight regression relationships for male and female *A. georgiana* and *B.* cf. *eatonii* from the Ross Sea are provided. Male and female relationships differ significantly for both species. Male *A. georgiana* attain 50% maturity at 92 cm total length (TL). The length-at-maturity of females is not well determined but is probably in the range 95–100 cm TL. Length-at-maturity of *B.* cf. *eatonii* is poorly determined, but is about 90–100 cm TL for males and 100–110 cm TL for females. The best available, but unvalidated, growth curve for *A. georgiana* for both sexes combined is: $TL_t = 101.3(1 - e^{-0.308[t+1.30]})$. The best estimate of longevity in *A. georgiana* is 14 years. However this may be a considerable underestimate, and true longevity may exceed 20 years. Age-at-sexual-maturity for *A. georgiana* is estimated to be about 6–7 years for males and 8–13 years for females. The most plausible range for the natural mortality rate, *M*, for *A. georgiana* is probably 0.15–0.25. No growth curve, longevity estimate or age-at-maturity estimate is available for *B.* cf. *eatonii*.

WG-FSA-06/32

Summary of Ross Sea skate tagging program results. S.L. Ballara, A. Dunn and M.P. Francis (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand), 10 pp. (English, unpublished).

Over 9 000 skates have been tagged and released in the Ross Sea over a period of seven years, and 47 (0.5%) have been recaptured. The recapture of tagged *Amblyraja georgiana* after up to four years at liberty shows that some skates survive and recover from being hauled out of depths of around 1 000 m and tagged. In-water tagging greatly reduces the incidence of broken jaws in skates, and probably increases the survival of released animals. Unfortunately, this means that length-at-release cannot be determined, so no useful data were gathered for estimating skate growth rates. *Amblyraja georgiana* moved very little, even after four years at liberty. There was no movement between SSRUs, and the maximum distance travelled was less than 70 km. The distance travelled did not increase with period-at-liberty for skates at liberty for more than nine months. It appears that this species makes only small-scale movements along depth contours.

WG-FSA-06/33

Some thoughts on the CCAMLR risk assessment for seabird–fishery interactions. S. Waugh (Ministry of Fisheries, PO Box 1020, Wellington, New Zealand, susan.waugh@fish.govt.nz), 10 pp. *CCAMLR Science*, submitted (English).

The CCAMLR system for assessing the risk of seabird mortalities in fisheries has been applied for 10 years and helps to define mitigation and monitoring requirements for fisheries within the waters of the CAMLR Convention Area. Annual review of the information used by the CCAMLR Working Group on Incidental Mortality Associated with Fishing for the assessments of risk, and performance of fisheries within these zones is undertaken, resulting in a dynamic system of assessment and response by the CAMLR Commission. Data used in the assessments relate primarily to seabird biology and their threat status – the areas most used by breeding and foraging seabirds of high-threat status are given highest risk ratings (six areas, levels 4–5). Those with few foraging birds and no breeding populations are given lowest ratings (six areas levels 1–2). A suite of mitigation measures has been specified for each risk rating, and these are refined annually with input from a technical working group. The thresholds and data-types used in the CCAMLR risk assessment system are documented and some recommendations made for minor modifications to this system to increase the transparency of the assessments.

WG-FSA-06/34

An updated descriptive analysis of the toothfish (*Dissostichus* spp.) tagging program in Subareas 88.1 and 88.2 up to 2005/06. A. Dunn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 24 pp. (English, unpublished).

A descriptive analysis of the toothfish tagging program carried out in Subareas 88.1 and 88.2 since 2001 is presented. The paper updates and revises tag–release and tag–recapture data which were presented in July 2006 at WG-FSA-SAM. In addition, the paper presents release and recapture data for non-New Zealand vessels for the 2005/06 season for the first time. However, tag data were still only available for about half of the non-New Zealand vessels for 2003/04.

A reported total of 10 775 Antarctic toothfish have been released and 225 recaptured, and 818 Patagonian toothfish released and 25 recaptured. Tagging rates by area over the past three years have been in the same proportion as the catch by area. However, recapture rates have tended to be higher in SSRUs 882E, 881C and 881H. About 17% of the recaptures could not be matched to a release observation, mainly because of missing release data.

Two fish tagged and recaptured in the fishery have moved over 200 km, but the majority (>80%) of Antarctic toothfish have moved less than 50 km. Sub-adult fish (80–100 cm) have tended to move further than adults over all time periods at liberty. In 2006, New Zealand vessels greatly increased the size of toothfish being tagged so that for the first time the size distribution of the tagged fish in the Ross Sea was very close to the size composition of the catch.

WG-FSA-06/35

Estimating fishing gear selectivity for trawlers using length-frequency data from concurrent commercial trawl and longline fishing for Patagonian toothfish in Division 58.5.2 and the ratio of their hazard functions. S.G. Candy (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, steve.candy@aad.gov.au), 23 pp. *CCAMLR Science*, submitted (English).

The upper arm of the length-dependent fishing selectivity function for trawlers fishing for Patagonian toothfish around Heard Island (Division 58.5.2) was modelled as the exponential of a quadratic function in length. This function was calibrated using random length-frequency (LF) data collected from commercial operations of trawlers and longliners fishing concurrently for three seasons assuming that, for the upper range of lengths, fish are fully selected by longliners but not by trawlers. To estimate the trawl gear selectivity while simultaneously adjusting for relative availability of length classes as a function of fishing depth, a log-linear hazard function for each gear type was fitted by a technique used to model grouped survival data. The hazard function relates to the event of a fish falling in a particular length bin, analogous to a death in a given time interval in survival analysis, and the ratio of the hazard function for trawlers to that of longliners, for the length range where this ratio is less than 1, defines the upper arm of the trawl gear selectivity function. This model of selectivity was estimated using the LF data and a fitted binomial generalised linear mixed model (GLMM). The GLMM was fitted to the number of fish in a bin using a complementary log-log link function and binomial sample size defined as the number of fish in that bin or a larger length bin. The resultant conditional binomial probability of the event is linked to an approximate integral of the hazard function to give the GLMM formulation. Random effects of haul identifier and 'season by length bin' were included in the GLMM which was fitted using an approximation to the marginal quasi-likelihood (MQL). The fitted trawl gear selectivity function showed a decline from 100 to 1% selection for a corresponding

length range of 1 030 to 1 610 mm and relative availability of fish was also predicted to decrease across a similar length range for the median trawl depth of 580 m relative to the median depth of longline sets of 1 200 m.

WG-FSA-06/41

Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters in 2004/05. B.P. Watkins, S.L. Petersen and P.G. Ryan (DST/NRF Centre of Excellence at the Percy FitzPatrick Institute, University of Cape Town, Rondebosch 7701, South Africa), 14 pp. (English, unpublished).

This study estimates the mortality of seabirds in the South African deep-water hake trawl fishery. Observations of interactions between seabirds and trawl gear were made on 331 trawls during 20 trips on 14 vessels between mid-2004 and the end of 2005. Long-winged albatrosses were killed most frequently, with shy albatrosses comprising 43% and black-browed albatrosses 37% of birds killed. Small numbers of white-chinned petrels (10%), Cape gannets (7%) and sooty shearwaters (3%) also were killed. Mortalities were greater in winter, when more birds attended fishing vessels, and most occurred during dumping of fishery wastes. Using a bootstrapping approach to estimate 95% confidence intervals (CIs), the average mortality rates were 0.56 (0.32–0.82) birds killed per hour during dumping in winter, 0.21 (0.07–0.38) during dumping in summer, 0.09 (0.02–0.19) when not dumping in winter, and 0.00 (–) when not dumping in summer. Serious warp strike incidents were independent of age among albatrosses, but there was a tendency for immature gannets to have a higher interaction rate than adults. Deaths resulting from entanglement in fishing nets occurred at an average rate of 3.02 (0.91–5.44) birds per 100 trawls. Estimating the total impact of the fishery requires assumptions about total fishing effort, the proportion of trawls where dumping takes place and the average duration of dumping. A simple model was developed which allowed these parameters to be varied, but the most sensitive parameters were by-catch rates. Based on conservative estimates of effort and dumping time, the total extrapolated mortality is some 18 000 (95% CI 8 000–31 000) birds killed per year, of which 85% are killed on warps and 15% entangled in nets. Of the birds killed, some 39% are shy albatrosses, 29% black-browed albatrosses, 14% Cape gannets and 9% white-chinned petrels, all listed as Globally Threatened or Near Threatened. Active mitigation measures are required to reduce trawl mortality in this fishery.

WG-FSA-06/42 Rev. 1

Report on a random stratified trawl survey to estimate distribution and abundance of *Dissostichus eleginoides* and *Champsocephalus gunnari* conducted in the Heard Island region (Division 58.5.2), May–June 2006. G.B. Nowara, R. Williams and T. Lamb (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, gabrielle.nowara@aad.gov.au), 13 pp. (English, unpublished).

Random stratified trawl surveys (RSTSs) of the distribution and abundance of demersal fish species on the Heard Island Plateau have been conducted annually since 1997. The survey conducted in May–June 2006 had two main aims:

- to assess the abundance and size structure of juvenile and adult *Dissostichus eleginoides* on the shallow and deep parts of the Heard Island Plateau;
- to assess the abundance and size structure of *Champsocephalus gunnari* on the Heard Island Plateau.

This paper describes the survey design and gear configuration used during the 2006 RSTS, conducted from on board the FV *Southern Champion*. It also describes the results of the survey, detailing the breakdown of catches overall and by stratum.

Dissostichus eleginoides were the most abundant fish species overall, with *Channichthys rhinoceratus*, *C. gunnari* and *Macrourus whitsoni* also locally abundant. Common by-catch included rocks, sponges, echinoderms, jellyfish and anemones.

WG-FSA-06/43 Rev. 1

Preliminary assessment of mackerel icefish (*Champsocephalus gunnari*), in the vicinity of Heard Island and McDonald Islands (Division 58.5.2), based on a survey in May–June 2006 using the Generalised Yield Model. D.C. Welsford (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, dirk.welsford@aad.gov.au), 11 pp. (English, unpublished).

A survey of mackerel icefish (*Champsocephalus gunnari*) was undertaken in Division 58.5.2 in the vicinity of Heard Island in May–June 2006 to provide the information for an assessment of short-term annual yield in the 2006/07 CCAMLR season. This paper provides a preliminary assessment of yield for the area of Division 58.5.2 to the west of 79°20'E using standard CCAMLR methods. A lack of evidence of strong year classes recruiting to the population has led to a significant decrease in the estimated biomass of mackerel icefish, and a recommended catch over the projection period nearly an order of magnitude less than that set in 2005. Taking into account the fact that the 4+ year class, which contributed an estimated 80% of the biomass present during the survey, are unlikely to be available to the fishery next year, yield estimates for 2006/07 are a further 70% lower.

WG-FSA-06/44 Rev. 1

Review of the use of survey data and length-at-age models in the assessment of *Dissostichus eleginoides* in the vicinity of Heard Island and McDonald Islands (Division 58.5.2). D.C. Welsford, A.J. Constable and G.B. Nowara (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, dirk.welsford@aad.gov.au), 25 pp. *CCAMLR Science*, submitted (English).

This paper reviews the allocation of historical survey data to the new strata and the implications of this review to estimating the abundance of juvenile fish using CMIX. In addition, the paper examines how the latest length-at-age model for Patagonian toothfish (*Dissostichus eleginoides*) in Division 58.5.2 could affect the estimates of juvenile abundance. Model estimates were best when incorporating the reassignment of hauls and the latest estimates of length-at-age, but quality of model fit and estimates of abundance of specific cohorts were sensitive to the number of cohorts assumed to be represented in the length-density data. Assuming survey design produces unbiased estimates of length density, it is suggested that best estimates of cohort abundance will be achieved when mixture analysis is informed by accurate estimates of length-at-age, an independent estimate of relative abundance of cohorts present in any survey year, such as could be derived through an age–length key, and the selectivity of the gear used in the surveys.

The consequences to the 2005 assessment of yield of toothfish of changing the time series of abundance of juvenile fish and the length-at-age model were also examined. Yield estimates were found to be most sensitive to the estimated recruitment series interacting with the estimate of mortality and the cohort abundances from CMIX, and to a lesser extent estimated fishing selectivities. A scenario equivalent to that used to recommend yield in Division 58.5.2 for 2005/06, incorporating the latest estimates of length-at-age, selectivity and the mixtures estimated from the assignment of RSTS hauls, resulted in a significant increase in estimated yield.

WG-FSA-06/45 Rev. 1

Preliminary assessment of Patagonian toothfish (*Dissostichus eleginoides*) in the vicinity of Heard Island and McDonald Islands (Division 58.5.2) based on a survey in May–June 2006 using the Generalised Yield Model. D.C. Welsford, A.J. Constable, T. Lamb and T. Robertson (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, dirk.welsford@aad.gov.au), 13 pp. (English, unpublished).

A survey of Patagonian toothfish (*Dissostichus eleginoides*) was undertaken in Division 58.5.2 in the vicinity of Heard Island in May–June 2006 to provide information for an assessment of short-term annual yield in the 2006/07 CCAMLR season. This paper provides a preliminary assessment of yield for the area of Division 58.5.2 to the west of 79°20'E using standard CCAMLR methods. It also investigates the impact on the recruitment series and predicted yields of:

(i) excluding the unusually high length-density data from the 1999 survey;
(ii) the exclusion of year classes <4+ and >6+ which have been included in previous assessments (WG-FSA-05) but are apparently not well selected;
(iii) research removals only and reported fishing only.

WG-FSA-06/47

Standardised CPUE analysis of the Antarctic toothfish (*Dissostichus mawsoni*) fishery in the Ross Sea for the years 1997/98 to 2005/06. A. Dunn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 13 pp. (English, unpublished).

The Ross Sea toothfish fishery has operated during the Antarctic summer (December–May) since 1997 in CCAMLR Subareas 88.1 and 88.2. Previously, standardised analyses of toothfish CPUE (catch per hook) have been carried out for the Ross Sea (Subarea 88.1 and SSRUs 882A–B) for the 1998 to 2005 fishing years. This report revises and updates the previous analyses with the addition of data from the 2006 season for the Ross Sea using the revised location data for: (i) all vessels, and (ii) core vessels that have been in the fishery for at least four years. Indices were estimated using both lognormal generalised linear models and a Tweedie mixed model.

The variables included in the analysis appeared reasonable and were consistent between the models presented here and CPUE analyses for previous years. The yearly indices were relatively stable between 1998 and 2003, with a decline in 2004, and an increase in 2005 and 2006. Possible explanations for the decline in 2004 were gear conflict and competition between vessels to set lines, in addition to extreme ice conditions that limited where lines could be set. None of these factors were believed to be important in 2005 or 2006.

The CPUE indices for the Ross Sea have increased more than 50% since the beginning for the fishery in 1998. Favourable ice conditions, fisher learning and experience, including improved knowledge of optimum fishing practise, and improvements in gear are the most likely explanations for the increase in CPUE indices, rather than toothfish abundance. Hence the CPUE indices developed here are of limited use as indices of toothfish abundance at the current time.

WG-FSA-06/48

Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in SSRU 882E including data from the 2005/06 season. A. Dunn and S.M. Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 14 pp. (English, unpublished).

This paper provides an update of the Bayesian sex- and age-structured population stock assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in SSRU 882E, using

revised catch, CPUE, catch-at-age and tag–recapture data from New Zealand and all vessels. The updated reference case resulted in a slightly higher estimate of initial biomass than in 2005, though this was mostly due to a different assumption of the level of natural mortality (M = 0.13 y^{-1}), and the revised length–weight and growth relationships. There was little difference between model runs using the New Zealand tag–release and recapture data and the all-vessel tag–release and recapture data (B_0 = 10 300 and 9 530 tonnes respectively).

Model fits to the data were adequate, with the tag–release and recapture data providing the most information on stock size, but none of the datasets had much information about the maximum size of the stock. Monte-Carlo Markov Chain (MCMC) diagnostics suggested no evidence of non-convergence. Reference-case MCMC estimates of initial (equilibrium) spawning stock abundance (B_0) were very uncertain, with the median estimated as 10 300 tonnes (95% credible intervals 5 340–25 210 tonnes), and current (B_{2006}) biomass estimated as 91.4% B_0 (95% CIs 83.4–96.5%).

Estimated yields, using the CCAMLR decision rules, were estimated to be 352 tonnes for the reference case and 366 tonnes for the all-vessels case, assuming a future fishing selectivity equal to the maturity ogive.

WG-FSA-06/49

The use of CCAMLR Statistical Subareas 88.1 and 88.2 and Division 58.4.1 by Macquarie Island giant petrels. R. Trebilco, R. Gales, B. Baker and A. Terauds (Biodiversity Conservation Branch, Department of Primary Industries and Water, GPO Box 44, Hobart 7001, Tasmania, Australia), 12 pp. (English, unpublished).

This paper presents results of the satellite-tracking of four adult southern giant petrels (*Macronectes giganteus*), four adult northern giant petrels (*Macronectes halli*), and two fledgling chicks of each species during the summer of 2005/06. Adults of both species spent time in areas under CCAMLR jurisdiction. Adult southern giant petrels spent 37% of their overall time at sea in Division 58.4.1, and 14% in Subarea 88.1, extensively utilising these regions during long foraging trips to the ice-edge zone during incubation. Northern giant petrels were tracked during chick rearing. While three of four tracked birds did not enter CCAMLR waters, one bird undertook a longer trip into Statistical Division 58.4.1, where it spent 6% of its overall time at sea. It is considered possible that this trip may have been indicative of trips undertaken earlier in the season (prior to hatching). Both southern and northern giant petrel fledglings crossed the Pacific Ocean, travelling east towards the South American continental shelf. Southern giant petrel chicks took a more southerly route, traversing Subareas 88.1 and 88.2 along this course, while the more northerly route taken by northern giant petrel chicks did not take them into CCAMLR waters.

WG-FSA-06/50

Antarctic toothfish stock assessment for the Ross Sea by means of the TSVPA separable cohort model. D. Vasilyev and K. Shust (VNIRO, 17a V. Krasnoselskaya, Moscow 107140, Russia), 32 pp. (English, unpublished).

WG-FSA-06/51

Report of the South Georgia groundfish survey (Subarea 48.3) in January 2006. M.A. Collins, C. Jones, J. Clark. S. Fielding, J. Slakowski, T. North, W. Reid and J. Watts (British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, United Kingdom, macol@bas.ac.uk), 40 pp. (English, unpublished).

The biennial South Georgia groundfish survey was undertaken in January 2006 on board the FPRV *Dorada*. Sixty-three random trawls were undertaken, with 12.3 tonnes of mackerel icefish caught, which produced biomass estimates of between 91 000 and 117 000 tonnes. The catches were dominated by fish of 20–25 cm (putative 2+), but unusually large numbers

of fish of ~50 cm were also caught to the north and northeast of South Georgia. Fish in spawning condition (stage IV) were found at the eastern end of the island and at Shag Rocks. Spent fish were found throughout the survey area, suggesting that spawning may occur from December. The diet of icefish was dominated by Antarctic krill (82 % by weight), with *Antarctomysis* sp. (*A. ohlini* and *A. maxima*) and *Themisto gaudichaudii* the other main prey species. Toothfish catches (548 kg) were dominated by the same single cohort that was first detected as putative 1+ fish in 2003. The toothfish diet was dominated by *Patagonotothen guntheri*. Acoustic observations were made in association with both demersal and pelagic data and will help discriminate icefish from other scatterers.

WG-FSA-06/52

Integrated weight longlines with paired streamer lines – best management practice for demersal longline fisheries: preliminary results. K. Dietrich, E. Melvin and L. Conquest (Washington Sea Grant, University of Washington, USA), 30 pp. (English, unpublished).

Minimising the time gear is available to seabirds by increasing the sink rate of longlines is one method to effectively reduce seabird by-catch rates. Normal unweighted longlines (UW) and integrated weight longlines (IW-50 g/m) were fished with and without paired streamer lines (PS) in seabird mitigation trials targeting Pacific cod in the Bering Sea, Alaska, USA. The objective was to evaluate IW as a practical seabird mitigation device using multiple criteria: catch rates of seabirds and fish, seabird behaviour, sink rate of the gear and breaking strength.

All mitigation technologies dramatically decreased seabird by-catch rates while having little to no effect on fish catch rates. Sink rate measurements demonstrated that IW longlines reduce risk to seabirds by minimising the distance astern that birds have access to sinking baits (~50% reduction). This study and data from 2000 and 2002, also clearly show that the sink rate varies dramatically by vessel.

Through independent tests, it was determined that IW breaking strength is 5% less than UW for new gear and 13% less for gear fished for five months; however, this difference did not manifest itself in the context of commercial fishing as increased line separations.

It is concluded that IW longlines deployed with paired streamer lines are the best mitigation practice available for autoline longline systems and recommendations are made for modifications to Conservation Measures 24-02 and 25-02.

WG-FSA-06/53

Assessment of toothfish in Subarea 48.3, 2006. D.J. Agnew, R. Hillary, M. Belchier, J. Clark and J. Pearce (Department of Biology, Faculty of Life Sciences, Imperial College, Prince Consort Road, London SW7 2BP, United Kingdom, d.agnew@imperial.ac.uk), 45 pp. (English, unpublished).

1. As requested by WG-FSA-SAM-06, a reference assessment for toothfish in Subarea 48.3 is provided. Sensitivity runs that include revised maturity and catch-weighted proportion-at-length data are provided. Additionally, a sensitivity run is provided which examines uncertainty in IUU catches from 1995, as requested by the Joint Assessment Group.

2. Also as requested by WG-FSA-SAM-06, a review of CPUE trends is provided and a model that uses age-based observations, specifically estimates of catches-at-age derived from otolith examination of a random sample of the catch is constructed.

3. All the assessments suggest that the spawning stock biomass (SSB) is now at, or close to, 50% of its unexploited level. Simple maximum of the posterior density (MPD) projections suggest that catches in the region 3 300–3 600 tonnes would be consistent with CCAMLR decision rules.

WG-FSA-06/54

Estimates of natural and fishing mortality from toothfish mark–recapture and catch-at-age data at South Georgia. R.M. Hillary and D.J. Agnew (Department of Biology, Faculty of Life Sciences, Imperial College London, London SW7 2BP, United Kingdom, r.hillary@imperial.ac.uk), 12 pp. *CCAMLR Science*, submitted (English).

This paper presents new results and estimation bias analyses for a Bayesian mark–recapture model, applied to the South Georgia toothfish tagging data. The updated model incorporates the data from all analysed cohorts in the estimation routine, and the potential estimation bias was examined, using simulated data. The results confirm earlier findings, with lower estimates of natural and fishing mortality, for the given age range, than are assumed and predicted by the current assessment, respectively. Also, some apparent estimation bias was found, which is similar, but lower than is seen in similar mark–recapture models of this type. Given the increasing number of releases and recaptures in all current tagging programs, it is suggested that this type of modelling approach can serve as both a useful tool for estimating key parameters like natural mortality, and a method for comparing parameter estimates of the exploitation rate predicted by the full assessment models currently being implemented.

WG-FSA-06/56

Results of the tagging experiment for *Dissostichus eleginoides* in Subarea 48.4. A. Payne and D.J. Agnew (Department of Biology, Faculty of Life Sciences, Imperial College, London SW7 2BP, United Kingdom), 5 pp. (English, unpublished).

Two vessels, the *Argos Helena* (UK) and the *San Aspiring* (New Zealand), fished around the South Sandwich Islands (Subarea 48.4) in 2006 following one vessel, the *Argos Helena*, fishing in 2005. During this time animals were tagged in order to continue a mark–recapture program started in 2005 to assess the toothfish population. This paper presents an analysis of the catch and tagging data and a proposal for continuing research in this area in 2007.

WG-FSA-06/57

Analysis of krill catch data from continuous and conventional trawls by the *Saga Sea* and *Atlantic Navigator*. D.J. Agnew, A. Payne, J. Hooper and J. Roe (Marine Resources Assessment Group Ltd, 18 Queen Street, London W1J 5PN, United Kingdom, d.agnew@imperial.ac.uk), 15 pp. (English, unpublished).

In this paper data are analysed on the distribution of catches, the size of krill and by-catch of larval fish taken by the *Saga Sea* fishing with continuous trawls in 2006, and the *Atlantic Navigator* which fished in 2005 using both continuous trawling and conventional trawling. The sizes of krill caught by both conventional and continuous trawling techniques appear to be very similar. Although there are few data for comparison, the by-catches of larval/juvenile fish in the continuous trawl also appear to be the same as those from conventional trawls.

WG-FSA-06/58

2006 assessment of the toothfish (*Dissostichus eleginoides*) resource in the vicinity of the Prince Edward Islands. A. Brandão and D.S. Butterworth (Marine Resource Assessment and Management Group (MARAM), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch 7701, South Africa, bela@maths.uct.ac.za), 35 pp. (English, unpublished).

The age-structured production model (ASPM) assessment of the Prince Edward Islands toothfish resource by Brandão and Butterworth (2005) that permitted annual fluctuations about a deterministic stock-recruitment relationship is updated to take account of further catch, GLM standardised CPUE and catch-at-length information that has become available for the years 2005 and 2006. The assessment allows for a second fleet to accommodate data from

a pot fishery that operated in 2004 and 2005. Updated biological parameter values for Subarea 48.3 are incorporated and lead to less optimistic results. The resource is estimated to be at about 40% of its average pre-exploitation level in terms of spawning biomass. It is suggested that it would be prudent to restrict annual legal catches to 500 tonnes or less, unless a large proportion of the catch is to be taken by pots (which avoid the cetacean predation associated with longlining). Specific issues raised at WG-FSA-SAM-06 about this assessment are addressed.

WG-FSA-06/59

A proposal methodology to assess the Patagonian toothfish stock abundance in Subarea 48.3 using the age-structured production model (ASPM). O.C. Wöhler and P.A. Martínez (Instituto Nacional de Investigación y Desarrollo Pesquero (INIDEP), Paseo Victoria Ocampo No. 1, 7600 Mar del Plata, Argentina, owohler@inidep.edu.ar), 15 pp. (English, unpublished).

The age-structured production model (ASPM) is an integrated modelling technique used in stock assessment of different *Dissostichus eleginoides* fisheries (Prince Edward Islands and Patagonian Shelf) and allows fitting to many different information sources, such as catch and age and size data from fishing fleet, surveys and other abundance indices. Last results obtained by the ASPM model used to assess the *D. eleginoides* biomass in Subarea 48.3 show an acceptable fit to CPUE series and catch-length proportions (WG-FSA-SAM-05/5 and WG-FSA-05/73). In this paper the methodology and assumptions for the 2006 *D. eleginoides* assessment in Subarea 48.3 using the ASPM are presented.

WG-FSA-06/60

Assessment models for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea including data from the 2005/06 season. A. Dunn and S.M Hanchet (National Institute of Water and Atmospheric Research (NIWA) Ltd, Private Bag 14-901, Kilbirnie, Wellington, New Zealand, a.dunn@niwa.co.nz), 26 pp. (English, unpublished).

This paper provides an update of the Bayesian sex- and age-structured population stock assessment model for Antarctic toothfish (*Dissostichus mawsoni*) in the Ross Sea (Subareas 88.1 and SSRUs 882A–B), using revised catch, CPUE, catch-at-age and tag–recapture data from New Zealand vessels. The updated reference case resulted in a much higher estimate of initial biomass, though this appeared to be almost entirely due to the impact of the catch-at-age data from the shelf fishery. Parameterising the model to better explain these data resulted in estimates of initial and current biomass that were very similar to those presented in 2005. The inclusion of the 2005 tag–release and the 2006 tag–recapture data had a small effect that slightly modified estimates from the models, suggesting that the new data had a similar pattern to that of previous years.

Preliminary models using tag–recapture data from all vessels are also presented. Inclusion of tagging data from all vessels resulted in a more optimistic assessment, and was due to the increased numbers scanned but smaller increase in the reported numbers recaptured. The reason for this is unclear, however, a number of the recaptured tags were not able to be linked to a release due to non-availability of some release data from non-New Zealand vessels. Further investigation is recommended.

Overall, model fits to the data were adequate, with the tag–release and recapture data providing the most information on stock size. Monte Carlo Markov Chain (MCMC) diagnostics suggested little evidence of non-convergence. MCMC estimates of initial (equilibrium) spawning stock abundance (B_0) for the preferred model were 80 510 tonnes (95% CIs 59 920–119 920 tonnes), and current (B_{2006}) biomass was estimated as 87% B_0. Estimated yields, using the CCAMLR decision rules, were estimated to be 3 046 tonnes.

WG-FSA-06/61

Seabird warp-strike form. Ministry of Fisheries (PO Box 1020, Wellington, New Zealand), 3 pp. (English, unpublished).

This form is used with the protocol for observing warp strikes in trawl fisheries.

WG-FSA-06/62

Seabird warp-strike measurement protocol for observers in New Zealand trawl fisheries. Ministry of Fisheries (PO Box 1020, Wellington, New Zealand), 13 pp. (English, unpublished).

This protocol is used for observing warp strikes in trawl fisheries.

WG-FSA-06/63

Marine mammals and demersal longline fishery interactions in Crozet and Kerguelen Exclusive Economic Zones: an assessment of the depredation level. C. Roche, N. Gasco, G. Duhamel and C. Guinet (CEBC-CNRS, UPR 1934, 79360 Villiers en Bois, France, roche@cebc.cnrs.fr), 17 pp. *CCAMLR Science*, submitted (English).

Killer whale (*Orcinus orca*), sperm whale (*Physeter macrocephalus*) and fur seal (*Arctocephalus* sp.) interactions with longline fishing operations were reported by observers on board vessels fishing for Patagonian toothfish in the Crozet and Kerguelen Exclusive Economic Zones between 2003 and 2005. At Crozet, 71% of the 1 308 longline sets showed marine mammal interactions involving killer whales and/or sperm whales. At Kerguelen, however, fur seals and/or sperm whales were present for 54% of the 6 262 longline sets monitored. Interactions occurred throughout all fishing areas, although contrasting situations regarding the marine mammal species were observed between localities. Depredation effect was assessed by comparing CPUEs of the longlines, in the absence/presence of any marine mammal species, alone or in association with other marine mammal species. At Crozet, CPUE was found to be reduced in the presence of both killer and sperm whales, whether alone or in association. An important photo-identification effort, focused mainly on killer whales, allowed 103 individuals to be identified. However, relatively few individuals are responsible for most of the interactions with the fishery. At Kerguelen, CPUE tended to decrease in the presence of sperm whales alone or in association with fur seals.

WG-FSA-06/64

An integrated stock assessment for the Patagonian toothfish (*Dissostichus eleginoides*) in Division 58.5.2 using CASAL. A. Constable, S. Candy, T. Lamb and I. Ball (Australian Government Antarctic Division, Department of the Environment and Heritage, Channel Highway, Kingston 7050, Tasmania, Australia, andrew.constable@aad.gov.au), 76 pp. *CCAMLR Science*, submitted (English).

This paper follows preliminary work in 2005 and early 2006 in developing an integrated assessment for Patagonian toothfish in Division 58.5.2. It focuses on developing an integrated assessment using CASAL and demonstrates that all data available for assessments, including surveys, fishery catch-at-length data, standardised catch-per-unit-effort (CPUE) series for trawl grounds, and length-binned mark–recapture data, can be incorporated into the model. Earlier difficulties in using CASAL have been resolved. The results presented here indicate a general downward bias in the expected recaptures showing that the mark–recapture observations indicate a smaller stock size than the other datasets. This is consistent with the problems discussed of the potential bias of a single-area model in trying to cover a highly spatially structured stock. It is recommended that the mark–recapture data not be included in the assessment of *Dissostichus eleginoides* in Division 58.5.2 until the spatial structure of the mark–recapture program can be incorporated appropriately in the assessment. The assessment of long-term annual yield using CASAL, 2 306 tonnes, is less than that using the

GYM, 2 483 tonnes. The reasons for this difference are discussed. It is concluded that an integrated assessment using CASAL is possible for *D. eleginoides* in Division 58.5.2. However, as expected, the assessment will be sensitive to the inclusion of different datasets and to the choices of parameters used in both the stock assessment and projections. An important outstanding issue, relevant to stock assessments generally, is the need to provide an estimate of natural mortality. It is suggested that the assessment not include tagging data at this stage and that yields be estimated by integrating across uncertainties in natural mortality. It is also recommended that work be undertaken to understand the spatial dynamics of *D. eleginoides* in the region and, therefore, how best to incorporate mark–recapture data in the assessment. Until that time, recruitment surveys provide the best means of establishing current stock status.

WG-FSA-06/P1
Can otolith elemental signatures record the capture site of Patagonian toothfish (*Dissostichus eleginoides*), a fully marine fish in the Southern Ocean? Ashford, J.R., C.M. Jones, E. Hofmann, I. Everson, C. Moreno, G. Duhamel and R. Williams. 2005. *Can. J. Fish. Aquat. Sci.*, 62: 2832–2840.

WG-FSA-06/P2
Can the chemistry of otolith nuclei determine population structure of Patagonian toothfish *Dissostichus eleginoides*? Ashford, J.R., A.I. Arkhipkin and C.M. Jones. 2006. *J. Fish Biol.*, 69: 708–721.

WG-FSA-06/P3
A case of giant squid attack on Antarctic toothfish *Dissostichus mawsoni* Norman, 1937 (*Perciformes, Nototheniidae*) caught on bottom-set longline in the Ross Sea. Petrov, A.F. 2006. *Voprosy Ichthyologii* (in Russian) (in press).