Annex K1

Report of the Working Group on Ecosystem Modelling

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1.1. INTRODUCTORY ITEMS

1.1.1. Conveners opening remarks

Gales welcomed the participants to the meeting and noted that this was a new Working Group, created this year. He encouraged the working group members to engage with the issue of developing ecosystem models and the estimation of input parameters. He further noted that this year the most important item of business was the forthcoming IWC-CCAMLR workshop to be held sometime in 2008. He noted that EM had been allocated only 2 sessions in which to complete its work, but may have the option of one or two more, dependant upon progress through the agenda.

1.1.2. Election of Chair, appointment of rapporteurs

Gales was elected Chair. Leaper (Rebecca) and Childerhouse agreed to act as rapporteurs.

1.1.3. Adoption of Agenda

The adopted Agenda is given in Appendix 1.

1.1.4. Review of documents

Documents considered were SC/59/EM1, SC/59/O9-14, 17, SC/59/IA8, 12, SC/59/ForInfo2-6, 36, 37, 41, 45.

1.2 Review progress on joint CCAMLR/IWC workshop on modelling Antarctic krill predators

Paper SC/59/EM1 dealt with the Joint IWC/CCAMRL workshop and provided an update of progress and correspondence between the two Steering Groups. Gales reminded the participants of the terms of reference for the workshop:

1. For models on the Antarctic marine ecosystem, and in particular predator-prey relationships, that could be developed for providing management and conservation advice relevant to CCAMLR and IWC, consider the types, relative importance and uncertainties associated with input data for those models, in order to understand what is needed to reduce uncertainties and errors in their use.

2. Review the available input data from published and unpublished sources that are currently available for such models.

3. Summarise the nature of input data (e.g. abundance estimates, trend estimates, foraging scales, seasonal diet etc), based on metadata (see definition below), by describing methodology, broad levels of uncertainty, time series, spatial extent and determine the appropriate scale at which those input data are relevant to these modelling efforts.

4. Identify and prioritise the gaps in knowledge and types of analyses and field research programs needed to reduce important uncertainties in ecosystem models being developed for CCAMLR and IWC and how scientists from the two Commissions can best collaborate and share data to maximise the rate of development and scientific quality of modelling efforts and input data.

He noted the differences in spatial scale for the management areas of CCAMLR and IWC and noted the importance of providing data in such a way that the data can be applied to both spatial data forms. Seven physical and ecological parameters were listed in EM1 (including Cetaceans, Seals, etc) and for each of these it was proposed that small groups be established to review the available input data, and to summarise the nature of the input data (e.g. uncertainty, time series, spatial extent etc.) based on metadata and to provide a report on these prior to the workshop in 2008. These reviews will provide the foundation for discussion at the workshop. Gales reported that the Australian Antarctic Division has offered to host and manage the metadata records through its Data Centre as well as provide some secretariat support.

Preparations for the workshop have so far been organised by the Joint Steering Group from SC-CCAMLR and SC-IWC and it was agreed that this group would continue to prepare for the 2008 workshop. The workshop was currently envisaged as a stand-alone workshop to be held early in 2008. For reasons of budget and to allow adequate time for the workshop preparations the WG agreed that consideration should be given to running the meeting in association with the CCAMLR EMM meeting in mid 2008. This issue would be pursued by the Joint Steering Committee. Gales noted that the budget required for the workshop will depend upon the amount of support that is required for the group of experts (about 11 people) in the workshop preparations and the number of participants requiring support to attend the meeting. CCAMLR have already agreed to provide support toward the workshop preparations (Aus$5,000). Up to Aus$90,000 might be required if all experts preparing material require payment – but this cost can be potentially decreased if national delegates can do the work at no cost. CCAMLR headquarters in Hobart, with support from the CCAMLR Secretariat has been offered as host for the meeting at a cost of about Aus$10,000. Attendance and support of the 11 experts is estimated to cost approximately Aus$77,000. It is anticipated that the budget will be shared equally between CCAMLR and the IWC.

With respect to the TOR of SC/59/EM1, it was noted that there was no TOR that dealt specifically with the issue of the types of model of interest and therefore it would be difficult to prioritise the types of data and types of input parameters that are required. Members agreed that this was an important point and Gales explained that indeed it would be useful to have a description of the model types available, and a discussion about how data inputs may differ between approaches. Hammond suggested that the outputs of the forthcoming FAO workshop on ecosystem approaches to fisheries management (July, 2007) would likely help provide context to the IWC/CCAMLR workshop with respect to model types. From the point of view the WG, Butterworth explained that there were currently two model types under consideration, the 'small type' model (e.g. Scotia Sea) and the 'large type' model (Antarctic wide). With respect to preparing pre-documentation for the workshop, some members suggested that baleen whales should be the main focus for this committee, while others suggested that toothed whales were an equally important component of the Antarctic marine ecosystem. Gales explained that for this workshop at least, the focus would be on krill and krill predators. With respect to pre-documentation, it was agreed that a list of potential names should be developed by the joint CCAMLR/IWC steering group. In the event that researchers were funded for the preparation of pre-documentation for this workshop, the WG agreed that it would be useful to set contract deadlines to ensure that products would be delivered on time.

An important consideration was the scheduled timing and location of the Joint Workshop. The preference would be to have a stand-alone meeting, but given the cost implications, the group agreed that affiliating the meeting to an existing IWC or CCAMLR meeting would be the best option. Several possible meetings were considered: CCAMLR-SC (April, 2008), IWC-SC 60 (May, 2008), and CCAMLR EMM (July, 2008). Some members expressed a preference for a July meeting, but April would be acceptable if sufficient work could be completed prior to April. However, it was thought that it might be too ambitious to set a time frame of less than 6 months for the workshop, given the large amount of material that would need to be prepared. With respect to pre-documentation, the CCAMLR EMM meeting (July) would allow time for the IWC-SC 60 (May) meeting to check and report on the reviews. Associating with the CCAMLR EMM meeting (July, 2008) would also be desirable, but there were already several other CCAMLR sub-group meetings associated with this meeting already. On consideration of the available options, members agreed that the preferred option would be to affiliate the workshop with the CCAMLR EMM meeting in July 2008. It was recommended that the Joint CCAMLR/IWC Steering Committee remain in place and coordinate with both organisations and await confirmation of meeting location and dates for EMM. The Steering group would report back to this WG at the next meeting.

1.3 Review collaboration with FAO

Butterworth provided some background of this item. FAO is holding an Expert Consultation on 'modelling ecosystem interactions for informing an ecosystem approach to fisheries' scheduled for July, 2007. Several Committee participants have been invited to attend this consultation. Given the obvious relevance of the consultation to the work of the Committee, those invited were requested to report back to the Committee at IWC/60.

1.4 Review of progress in the development of ecosystem models

SC/59/O11 explained the concept of the ecosystem models developed in the JARPN II Program. The primary purpose of JARPN II was to study the interactions between fisheries and whales in the marine ecosystem of the western North Pacific. These ecosystem models could contribute to improved fisheries management. Three modelling approaches were in progress: Ecopath with Ecosim, Multspec-type model and Bayesian assessment. The former two were applied to the offshore area and the latter to the coastal area. The progress and work plan for each approach was presented in SC/59/O12, SC/59/O13 and SC/59/O14. The WG thanked the authors for bringing this paper to the group.

SC/59/O12 described a practical Multspec-type model under construction for the offshore survey area of JARPN II. The model took into account the prey-predator relationships between anchovy/saury and minke/sei/Bryde's whales. Other supplementary prey (krill, copepoda and others) were included in the model as constant biomass. Daily consumption by cetaceans was assumed to be equal to the necessary energy. The proportion of each prey taken by cetaceans was calculated as the product of prey biomass, overlap of distribution and prey preference. While the modelling was at an initial stage, test runs for prediction were made under both a moratorium and some whaling. The work plans were presented to the WG to review future work.

In discussion, the authors were asked whether the model had accounted for other changes in the system e.g. how fishing pressure had changed the pelagic biomass component of the model. The authors responded that fishing pressure was considered with the assessment conducted by the Fisheries Research Agency.

SC/59/O13 described how in order to evaluate the possible impact of minke whales migrating to the JARPN II survey area on Japanese commercially important fisheries resources, an initial ecosystem model of the JARPN II survey area (using the Ecopath-with-Ecosim software) could be used. Input parameters for this model were based on the newly collected provisional data sets obtained from the JARPN II survey. As an initial test run, the impact of no harvesting of the minke whales on Japanese commercially important fishes was made, for a 50 year time period. When running the harvesting scenario, uncertainties in the functional response curve and the trophic flow of the ecosystem were also considered. In this model run, increases in minke whale biomass had some effect on Pacific saury, but there was very little effect on other species considered in the model. The model run also predicted that the magnitude of the impact of the change in biomass of minke whales on Pacific saury varied by: (1) the functional response curve assumed for minke whales; (2) the magnitude of the trophic flow, and (3) the combination of the two. It was predicted that the biomass of Pacific saury would decrease by a maximum of 36% over the 50 year time period compared to the current level and that this was due to the increased predation pressure by the minke whales under a zero harvesting strategy, over 50 years. Further work would take into account the effect of the equilibrium condition in Ecopath, would try to fit the model to available time-series data, and would also consider the effect of quasi-decadal alternations in dominant species replacement due to, for example, environmental forcing. In addition further work on possible impact of Bryde's whales, sei whales and sperm whales would be examined in near future.

The authors were asked how the increase in biomass of minke whales over the 50 year period in the absence of whaling been estimated. The authors explained that they had used ECOPATH to describe the trophic flow under a constant rate and then applied ECOSIM to the dynamic process and ran it for 50 years. They examined the minke and prey species abundance changes and trophic model changes, and then used four trophic functional response curves to investigate changes. It was noted that the example model results presented in Fig. 2. in SC/59/013 indicated that the largest impact on ecosystem appeared to come from commercial fishing and whaling. It was not clear if this pattern was consistent over all the model runs. In addition, members questioned whether there were any observed changes in carrying capacity when running the mode for 50 years in the absence of catch. The authors responded they had yet to examine this but would consider it in the future.

Paper SC/59/014 presented the basic framework of Bayesian assessment model to investigate the effects of consumption by marine mammals on sandlances in the north western Pacific coastal region of Japan. The purpose of the model was to improve the management of sandlances in the region. The authors proposed that for modelling purposes, the main predator would be the fur seal and the main prey the sandlance. The fur seal was described as a transient visitor to the region rather than a permanent resident, and hence was not regarded as a closed population. Conversely, the sandlance was regarded as a closed population, and therefore the authors used a single-species model of the sandlance with only part of the fur seal population resident in spring. The model was based on a Bayesian state-space model, which incorporated various uncertainties. However, the authors noted that at this early stage the paucity of information on fur seals prevented robust parameter estimation. The authors described how they had new data, especially for sandlance schooling behaviour as a result of the predation by the fur seal as well as abundance and consumption on the fur seals. The authors expected that they would be able to submit the quantitative results of this model to the next SC, and that the model could be extended to incorporate the minke whale using parameters collected by JARPNII. The committee thanked the authors for bringing this paper to the WG and encouraged further work.

In the context of discussions on the development of ecosystem models, the group discussed the concept of competition as used in mathematical modelling and in the ecological literature. It noted that the term has led to confusion because of differences between the term's meaning in the ecological literature and its mathematical interpretation for modelling purposes. In the mathematical sense, competition (as a competitive interaction term in equations) is regarded as always occurring when predators share a common diet item, but that relationship can scale down to very small levels, or even zero under some circumstances. From an ecological context, prey overlap and competition are two different concepts and the latter may or may not occur with the former. In the ecological literature the term 'competition' can be defined as 'the negative effects which one organism has upon another by consuming, or controlling access to, a resource that is limited in availability' (Keddy, P.A. 1989. Competition. Chapman and Hall, London. 202 pp.). These interactions can be intra-specific or inter-specific. When the limited resource is a shared prey species, the competition may be direct (interference competition) or indirect (exploitation competition); in each case one group of animals or species would limit the availability (amount) of prey to the meaningful disadvantage of another predator that uses that same resource. In scenarios where the available production rate of the shared prey is greater than the consumption rate of the two predator species, and the consumption by one predator does not alter the prey's availability (at any scale) to the other predator, then competition does not occur. Consequently, a shared prey, or trophic overlap may or may not lead to competition, and if competition does arise it may do so across a wide range of scales in time and space. It was further noted that in circumstances where competition might occur, niche separation (spatial, temporal or trophic –through prey switching) may mediate the competition to the extent that there are no meaningful life history consequences for the predator. For example, in the oceanic waters of the Southern Ocean, Antarctic krill is preyed upon by most large predators, including fish, squid, flighted seabirds, penguins, seals and whales. The standing biomass of krill is controlled by a variable balance between top-down forcing through predator grazing, and bottom-up forcing from physical and biological conditions that control the productivity of krill. Trophic overlap is thus the norm in this ecosystem, but competition between predators may or may not occur, and if it does it may or may not be sufficiently influential to produce a measurable signal in a particular species' demographics. The Working Group agreed that in future discussions and reports members should be clear about the distinction of trophic overlap and competition in its ecological sense. It was further suggested that findings make clear that in circumstances where one or more predators exhibit trophic overlap, inverse inter- or intra-specific correlations alone establish only that data are consistent with a competition hypothesis and do not necessarily exclude other hypotheses with different implications. Ainley highlighted the point that interference competition, whereby a predator can inhibit the access of a predator to prey without directly affecting consumption, is important and referred members to an example of this type of competition between Adéile penguins and minke whales in the Ross Sea (Ainley, *et al*. 2006a). Corkeron pointed out that the Multispec modelling approaches developed to examine the cod-capelin-herring fishery system in the absence of marine mammals from the Northern hemisphere, informed on competition parameters.

CCAMLR (2006a, 2006b) and *Ainley et al*. (2006b) discussed ecological interactions in the Ross Sea Ecosystem. The first paper, CCAMLR (2006a) reviewed the state of knowledge existing about the Ross Sea. Due to the continuous efforts by 3 national Antarctic research programs (USA, NZ and Italy) and intermittent efforts by others including Japan, the Ross Sea is one of the best researched sections of Antarctic waters and certainly is the best known of its continental shelves. It contains 3 of the 4 longest uninterrupted biological data sets in the Antarctic, spanning 50 years since IGY: population structure and trends of Adélie penguins and Weddell seals, and community changes of the nearshore benthos. Its sea ice microbial community is better researched than elsewhere and its oceanography, sea ice and glacial ice is the best known owing to interest in the fate of the West Antarctic Ice Sheet. Analysis of sediment and ice cores and subfossil remains of penguins and seals has revealed much of its Holocene history. The second paper CCAMLR (2006b), reviews examples of how long-term research has revealed the interaction of top-down and bottom-up processes, as well as pelagic-benthic coupling, in the Ross Sea. It reviews interactions between whales and penguins, including trophic competition and as well the role of minke whales as 'ecosystem engineers' (providing breathing holes for other vertebrates); and the cascading effects of Weddell seal predation of Antarctic toothfish, with resulting detritus enrichment of benthic communities. The third document Ainley *et al*. (2006b) reviews the trophic overlap in the Ross Sea of the major top-trophic predators: silverfish, toothfish, killer whales, minke whales, Weddell seals, and Emperor and Adélie penguins. All feed mainly on two prey over the shelf: Antarctic silverfish and crystal krill; and all forage in the same areas in similar portions of the water column. Thus there is great potential for competition, either exploitative or interference, with the further potential that if any one of these predators increases or decreases, ripple effects will likely occur among the others, thus changing the Ross Sea trophic structure. Therefore, the removal of toothfish and minke whales is no small matter from an ecological perspective.

The WG thanked Ainley for presenting these papers. They noted that the Ross Sea ecosystem has unique features and that further investigations of the distribution and abundance of minke whales and their interactions with other species such as penguins would be important to study. The authors of CCAMLR (2006a, 2006b) and Ainley *et al.* (2006b) were asked whether any data had been collected on ice krill through net or hydroacoustic methods. The authors explained that ice krill have not received the same level of study as Antarctic krill, partly because they are difficult to sample, but there had been some surveys by Italy and Japan. Murase commented that some analyses exploring the relationship of minke whale abundance to their prey (ice krill) and environmental factors had been brought to this WG (SC/59/IA12) and added to our knowledge of the Ross Sea region. JARPA data had also provided information on minke whale diet in this region.

Ainley *et al*. (2007) described how investigations of the ecological structure and processes of the Southern Ocean in recent years almost exclusively have taken a bottom-up, forcing-by-physical-processes approach relating various species' population trends to climate change. Just 20 years ago, however, researchers focused on a broader set of hypotheses, in part formed around a paradigm positing interspecific interactions as central to structuring the ecosystem (forcing by biotic processes, top-down), and particularly on a "krill surplus" caused by the removal from the system of more than a million baleen whales. Since then, this latter idea has disappeared from favour with little debate. Moreover, it recently has been shown that concurrent with whaling was a massive depletion of finfish in the Southern Ocean, a finding also ignored in deference to climate-related explanations of ecosystem change. The authors present two examples from the literature, one involving gelatinous organisms and the other involving penguins, in which climate has been used to explain species' population trends but which could better be explained by including species interactions in the modelling. The authors conclude by questioning the almost complete shift in paradigms that has occurred and discuss whether it is leading Southern Ocean marine ecological science in an instructive direction. With respect to the penguin-minke whale-killer whale interaction described in this paper Wade thought it would be difficult to attribute reduction in minkes to killer whales in this region because the Type B killer whale was a penguin not minke whale predator. The authors replied that Type A killer whales in the region predated both seals and king penguins and therefore the diet of killer whale ecotypes for this region were yet to be fully resolved.

With respect to trends in Adélie and minke whale abundance, Murase noted that it was difficult to reconcile increases seen in Adélie penguins in the Ross Sea region, with the argument for the reverse trend described in Ainley *et al.* (2007) at a time when IDCR/SOWER CPII reported high numbers of minke whales. In discussion of the direct relationships and trends in these two species, it was noted that this is a complex system and that other factors such as oceanographic variables and food supply may be important to this relationship.

Nicol *et al*. (2007) was presented as a response to Ainley *et al.* (2007) which suggested that recent investigations of the ecological structure and processes of the Southern Ocean have "almost exclusively taken a bottom-up, forcing-by-physical-processes approach relating individual species' population trends to climate change". This suggestion was examined and it was concluded that, in fact, there has been considerable research effort into ecosystem interactions over the last 25 years, particularly through research associated with management of the living resources of the Southern Ocean. Future Southern Ocean research will make progress only when integrated studies are planned around well structured hypotheses that incorporate both the physical and biological drivers of ecosystem processes. There was some discussion of the arguments presented in Ainley *et al.* (2007) and Nicol *et al.* (2007) and members commented that both had merits.

Wade *et al*. (2007) presented a paper re-examining the evidence for sequential megafaunal collapse and prey switching hypothesis in the north Pacific. Springer *et al.* (2003) contend that sequential declines occurred in North Pacific populations of harbour and northern fur seals, Steller sea lions, and sea otters. They hypothesized these declines were due to increased predation by killer whales, when industrial whaling's removal of large whales as a supposed primary food source precipitated a prey switch. Using a regional approach, Wade *et al.* (2007) re-examined whale catch data, killer whale predation observations, and the current biomass and trends of potential prey, and found little support for the prey-switching hypothesis. Large whale biomass in the Bering Sea did not decline as much as suggested by Springer *et al.,* and much of the reduction occurred 50-100 years ago, well before the declines of pinnipeds and sea otters began; thus, the need to switch prey starting in the 1970s is doubtful. With the sole exception that the sea otter decline followed the decline of pinnipeds, the reported declines were not in fact sequential (Demaster *et al.* 2006). Given this, it is unlikely that a sequential megafaunal collapse from whales to sea otters occurred. The spatial and temporal patterns of pinniped and sea otter population trends are more complex than Springer *et al.* suggest, and are often inconsistent with their hypothesis. Populations remained stable or increased in many areas, despite extensive historical whaling and high killer whale abundance. In particular, data from the west coast of N. America and the Commander Islands of Russia (just west of the U.S. Aleutian Islands) directly contradict their hypothesis; Trites *et al.* (2007) show this in detail for British Columbia. Furthermore, observed killer whale predation has largely involved pinnipeds and small cetaceans; there is little evidence that large whales were ever a major prey item in high latitudes; this has also been shown by Mizroch and Rice (2006) and Mehta *et al.* (in press). Small cetaceans (ignored by Springer *et al.*) were likely abundant throughout the period. Overall, the authors of Wade *et al.* (2007) suggest that the Springer *et al.* hypothesis represents a misleading and simplistic view of events and trophic relationships within this complex marine ecosystem.

Tamura asked the authors that given there was increase in the number of gray whales in the area, was there any information that indicated that killer whales were taking more whales (i.e. had there been a prey switch from whales to seals, and then back to whales). The authors explained that in the 1970's gray whales were already abundant and there was no evidence for predation on whales at that time, hence there has not been a switch back to whales because pinnipeds were always the preferred prey of killer whales. In relation to this point, it was asked what the potential effect of the large removal of a large number of porpoise in Aleutians islands in the 1970's-1980's. The authors explained that the gill-net fishery that killed the porpoises had operated further south than the region examined in this paper, and that there were still large numbers of pinnipeds available to killer whales. It was noted that analyses of historical data provided valuable insights into complex multi-species interactions.

1.5 Review of data relevant to parameter estimation and ecological interactions

SC/59/IA19 reviewed the JARPA surveys for the adequacy of coverage of strata, the sequence that strata were surveyed, the extent of sea ice during the surveys, and other related information. SC/59/IA19 concluded there were substantial differences in all these categories in the last three surveys (from 1999/00 to 2004/05) compared to the previous five surveys (from 1989/90 to 1998/99).

In Area IV:

- The sequence of surveys was changed and this caused the ice-edge strata to be surveyed on average one month later (in Feb/Mar rather than in Jan/Feb) during the last three surveys.
- Consequently, the ice extent was lower at the time of the survey and there were gaps in coverage between the north and south strata.

In Area V:

- The sequence of surveys was changed to first survey both eastern strata, and then survey both western strata.
- As a result, the SW ice-edge stratum was surveyed later during the last three surveys (in March rather than in January/February)
- In the east, the Ross Sea (SE stratum) was surveyed earlier during the last three surveys (January/February rather than February/March). Consequently, the extent of sea ice was greater in the Ross Sea during the time of the survey.

These changes affect interpretation of data collected during JARPA:

- The directional change in the timing of the surveys relative to the ice-edge over the time period covered confounds interpretation of trends in abundance of any whale species from JARPA data, as all or most species show a density relationship relative to the ice-edge.
- The change in the month of sampling adjacent to the ice-edge potentially confounds interpretation of trends in biological parameters. Seasonal changes in ice extent and character will likely influence prey distribution and availability, and thus condition and behaviour of

predators. Examples of trends that might be affected by these differences include: (1) trends in blubber thickness; and (2) trends in stomach contents.

Further analyses of JARPA data should attempt to account for these temporal and spatial differences. However, it is not clear that complex analysis methods and modelling can satisfactorily correct for fundamental changes in the sampling design through time.

SC/59/IA12 had also been presented and discussed in full in the IA WG, but it was useful to have some discussion in the context of data relevant to parameter estimation and ecological interactions. The authors of SC/IA/12 confirmed that the sequence of surveys had changed in the JARPA survey but the rationale as to why this had been was demonstrated by Area V East. The timing of the survey had been changed for logistical reasons, including for example, in the Ross Sea it is often difficult to survey due to large variation in the amount and location of ice cover. It was recognised that while there had been difficulties at the beginning of the JARPA survey, improvements had now been made to the survey design and that data were now collected in a systematic manner. With respect to trends in biological parameters, the authors of IA/SC/IA12 noted that some biological parameters are affected by ice edge (e.g. blubber thickness and thus ice edge was included in these analyses e.g. latitude as a covariate). However, other biological parameters are not related ice edge (e.g. age to sexual maturity) and so ice edge is less important. Polacheck commented that it would be better to analyse the time series data subsequent to the change in survey methodology than the full series of JARPA data. It was noted that the link between some biological parameters such as age to sexual maturity and ice edge was not clear. For example, minke whale populations were known to be spatially segregated by age, and that migration is a function of sex and age. As a consequence the spatial and temporal distribution of sampling effort is an important consideration and should be included *a priori* in the analysis. The authors commented that every effort was being made to address these issues and that members should refer to the report of the IA sub-committee for more discussion on this matter.

Paper SC/59/O9 presented some additional analysis that has been made in response to the recommendation of 2006 JARPA review held in Tokyo, Japan. The annual trend in stomach contents weight per capita in the Antarctic minke whale was examined using data from all 18 JARPA surveys. Stepwise multiple linear regression analyses were conducted to investigate the trend of stomach contents weight per capita. The following covariates were incorporated into the analyses: “undigested stomach contents weight per capita”, “Body length”, “Sighting time of captured whales”, “Latitude and longitude of sampling position”, “Date of sampling”, “Sex”, “Chasing time” and “Year”. “Body length” was the best predictor of stomach contents weight followed by “Sighting time”, “Latitude of sampling position”, “Date” and “Year” in that order. “Longitude of sampling position”, “Sex”, and “Chasing time” were excluded. The coefficients of “year” were -0.693 kg/year (±0.199 SE), indicating that stomach contents weight decreased over the 11 year period. The direct interpretation of food availability on the decline in stomach contents in the minke whales with time (year) was difficult, since no long term krill abundance series were available. However, competition among krill feeders and/or the decrease of krill resources must be a candidate for the explanation of the decline.

Members thanked the authors for the further work that they had completed on this paper since the 2006 JARPA review. There was considerable discussion of the analyses presented in this paper, and a number of questions were raised. It was suggested that covariates such as (1) distance from the ice edge and (2) distance from the shelf break could also have some explanatory power. However, it was noted, that it can be difficult to define the location of the ice edge, and therefore this analysis would be complicated. For the existing analyses it was not immediately clear to some members that all the covariates had linear forms, and it was suggested that other functional forms (e.g. discrete) should be considered, in particular for both latitude and time of day. Other suggestions included examination of the interaction between latitude and date as this is related to how the ice edge moves south through the season and thus having the potential to help issues related to ice edge.

It was questioned how a sub-sample of 2519 individuals used in this study was selected from the >6000 individuals sampled. The authors responded that individuals for which digestion had not progressed were selected and whales with empty stomachs or that showed some degree of digestion were excluded from analysis. One member noted that this meant this research was representative of portion size rather than true consumption rates, and it was further suggested that it would be better to look at the entire sample of individual stomachs to determine whether the same patterns were evident across the whole dataset. A GLM modelling approach, using the proportion of stomachs that are empty, with the trend over time corrected for this factor, was suggested as a way to explore this data. One member questioned whether the potential biases related to the selectivity of catch had also been examined in these analyses, and the authors responded that as the samples were all from JARPA there were no biases in selectivity. Further to this point, others suggested that although length had been used as a variable, it may be worth incorporating a length covariate as a non linear (e.g. discrete) variable rather than continuous. There was a request for AIC values and details of results from non explanatory variables to also be presented for Table 2 in SC/59/O9. Taken together, members suggested that a GAM approach may be a useful step forward in dealing with these analyses issues. The Chair thanked the authors for bringing this new work in response to requests made at JARPA Review Meeting.

The authors of SC/59/O9 were able to conduct further analyses within the meeting schedule and on the basis of the suggestions made by the committee were able to re-examine the annual trend in energy storage in the Antarctic minke whale. Non linearity of effects such as date, time, body length, longitude and latitude were re-specified in the GLM as categorical variables and the issue of distance from ice-edge was approximated as a latitude-month interaction. The committee thanked the authors for their prompt work on these issues. One member commented that the small p values in the GLM output could indicate an over-fitting of the GLM model to the data. The authors concurred that this could be possible, but until a more thorough analysis was completed, this was difficult to determine. Gales commented that the use of newer technologies to determine ice edge, such as satellite data may improve the analysis and encouraged further work. The authors agreed to continue their work for next year.

Estimates of mean daily prey consumption by Antarctic minke whales in the Southern Ocean (SC/D06/J18) were discussed at the JARPA review workshop. These estimates were based on analysis of the diurnal variation of weight of stomach contents of Antarctic minke whales taken under JARPA. SC/59/IA8 examined the sensitivity of these estimates to some of the underlying assumptions. Estimates were particularly sensitive to assumptions about digestion rates for which data are not available. Estimates were also complicated by the lack of night time data between 22:00 and 03:00. The diurnal patterns in stomach contents weight would appear either consistent with no feeding during the period 03:00 to 18:00, or alternatively a prey consumption of 2.8% of whale body mass over the same period if it were assumed that 20% of prey remains undigested after four hours. The resulting range of estimates for mean daily consumption is around 1.5% – 7% of whale body mass. This range covers what might be considered the plausible range of values from other sources, including allometric comparisons of energy requirements. However, despite large sample sizes (6777 whales), the current data set was not able to narrow this range.

In discussion of SC/59/IA8 and SC/D06/J18, Gales reminded the committee that in the JARPA review, Tokyo, 2006, one unresolved aspect of this type of work was determining the seasonal aspect of feeding, which in turns helps give an idea of total consumption of Antarctic minke whales. The

WG summarised the three issues that would need to be resolved before we could move forward: (1) the length of feeding season; (2) to what extent consumption rate is sensitive to digestion rate (which is largely unknown); and (3) the extent of feeding at night. Members of the WG who had been involved in the work of SC/D06/J18 explained that due to logistical constraints they had not been able to assess night time feeding of minke whales and in addition assumed that minkes did not feed at night because their prey *Euphasia superba*, disperse at night. They also noted that the relationship between consumption and digestion rate was largely unknown, but that in their analysis had used available published estimates. The authors explained that although they recognised all the problems of estimating mean daily prey consumption in minke whales, they had based their analyses using other independent methods; similar to those reported in scientific work of this nature. Members agreed that while these questions were being investigated we were still a long way from getting empirical data for the parameters listed by the WG. It was suggested that the use of technologies such as time-depth recorders would prove invaluable determining whether minkes feed at night and the authors of SC/D06/J18 concurred that work of this nature is planned for the future. It was noted that until all these issues were resolved it would be difficult to move beyond only broad estimates and that although it is important to look at temporal trends, there is still some work to go to determine whether the current trends suggested in the data are real, or an artefact of sampling or analysis.

With respect to consumption rates, some noted that consideration of the sensitivity of ecosystem outputs to differences in parameter vales for consumption may be important. Corkeron noted that this issue had been discussed by NAMMCO, where ecosystem models have been used to assess marine mammal and fishery interactions. For example, if a consumption parameter drives a model then the precision of that estimate is important, if it does not, then we may be able to accept a lesser level of precision for an input parameter. Gales reminded the committee that and IWC workshop on the La Jolla meeting had concluded that we do not yet have models that are able to assess the effect of marine mammals on fisheries nor fisheries on marine mammals reliably, and that current models remain preliminary and exploratory.

Paper 59/SC/O10 was presented in response to the recommendation of the JARPA review held in Tokyo, Japan, 2006. The authors highlighted that this was one of the analyses developed in response to the request made at the JARPA meeting, to further explore trends in energy storage in minke whales including other covariates. The annual trend in energy storage in the Antarctic minke whale was examined using catch data from all 18 JARPA survey years. Stepwise multiple linear regression analyses clearly showed that blubber thickness at two positions and fat weight (blubber and visceral fat weight) of minke whales had been decreasing for nearly two decades. The decrease in blubber thickness was estimated at approximately 0.02 cm per year at a mid-lateral position, which corresponded to a decrease of 9% over the JARPA years. Furthermore, “date”, “extent of diatom adhesion”, “sex”, “body length”, “body weight”, “foetus length”, “latitude”, “age” and “longitude” were all identified as partially independent predictors of blubber thickness. At the anterior edge of the dorsal fin, the decrease was estimated at 0.12 cm per year or 36% over 18 years. The decrease in fat weight was estimated at 17 kg per year, which corresponded to 9.5% over 18 years. The direct interpretation of this substantial decline in energy storage in minke whales over time in terms of food availability was difficult, since no long-term krill abundance time series were available. However, competition among krill feeders combined with the resulting krill population change was considered by the authors as the most likely explanation of the decline, given the recent recovery of the stocks of large baleen whales.

Some discussion followed on how the new analyses addressed issues raised at the JARPA review. Aguilar noted that this analysis was better, but there still needs to be some consideration of what other variables might be included in the analysis. He also pointed out that special attention should be paid to exactly how they are modelled because there is known correlation between some variables and they are all not independent. In SC/59/O10 blubber thickness had been shown to decline by 0.2mm per year, and Cooke asked how big this change was compared to normal variability in blubber thickness. Tamura explained that this was difficult to estimate this for minke whales as measurements are taken from different locations (between 5 and 18) on the animal. Despite this, data had shown that average blubber thickness can be in the region of 3-5cm per annum at the mid lateral position, and that there is large seasonal variation. Gales noted that it is difficult to a find single point that is representative of blubber thickness in marine mammals, and that this had been demonstrated in studies of the Southern Elephant, where blubber thickness was shown to be highly variable.

Time permitted further analysis of the data presented in SC/59/O10, where girth and half girth measured in 4681 individuals were added as additional variables. A regression analysis showed a strong relationship between girth and blubber thickness (nearly 50%) and that this relationship held when additional variables were added to the regression. Therefore the point estimate of blubber thickness did not fluctuate too widely. Aguilar noted that blubber also serves as the primary thermoregulatory mechanism in marine mammals as well as an energy source. He encouraged researchers to investigate broader condition indices, including lipid concentration, and asked whether these data were available from the JARPA samples. The authors of SC/59/10 concurred that there were difficulties in investigating body condition, but while blubber thickness is not directly proportional to energy storage, it likely provided a reasonable indicator. Lipid concentration varies considerably between different locations on the same animal and to understand the total energy content would require considerable effort to actually determine this. In discussion of SC/59/O19, Aguilar also noted that the assumption that blubber was declining monotonically with energy decrease can be questioned and that this is often confounded by seasonal variation and the reproductive state of the whale, i.e. pregnant females. In addition lipid content is different in different parts of the whale, so it would be useful to use the most reliable location on the body and then develop a model of this for prediction. The authors explained that their analysis accounted for this by treating males and females separately and that the analysis had taken account seasonal variation. This has been examined and therefore sex has been included as an explanatory variable in the model and shown that rates of decline were consistent between males and females in this analysis.

Paper SC/59/017 examined some of the problems associated to the use of blubber thickness as a measure of body condition in large whales and identified four elements that were affecting precision and three that introduced potential biases into the measurement. The magnitude of the effect of the various factors was assessed using the Antarctic minke whale as an example. The authors concluded that blubber thickness may contain intrinsic errors of measurement and that its variation may significantly depart from being proportional to changes in overall body fat reserves. To avoid a bias in the index, the authors recommended that, together with blubber thickness, other morphometric and biochemical variables should be incorporated into an integrated energetic model.

The WG noted that the analysis of the trend data in energy stores of minke whales was of critical importance to the WG as it applied to the interpretation of multi species and ecosystem interactions in the Southern Ocean. On that basis the WG agreed to establish an intersessional email correspondence group (Walløe (Chair) Aguilar, Bjørge, Butterworth, Gunnlaugsson, Hester, Konishi, Leaper (Rebecca), Lockyer, Polacheck, Tamura and Vikingsson). The Terms of Reference for this group will be:

- Develop a data availability agreement for members of the WG for JARPA and commercial data relevant to the analysis of energy stores in minke whales.

- Review data relevant for studies on energy storage in minke whales available from JARPA and/or from commercial catches.
- Investigate whether samples of blubber or other relevant tissues from JARPA are available for analysis, and if so,
- Propose relevant chemical analysis to be done.
- Propose and facilitate different model/statistical analysis to investigate possible changes in energy storage with time based on the data obtained from the availability agreement and other relevant data.

Herman-Kock pointed out that data collected by CCAMLR in the last 18-20 years on the body condition of other vertebrate predators, such as gentoo penguins and fur seals may offer a broader context to within which to understand changes in whale body condition.

SC/59/IA12 examined the application of GAM modelling approaches to estimate the abundance of Antarctic minke whales using data obtained by the Kaiyo Maru-JARPA joint survey, in the Ross Sea in austral summer in 2005. The joint survey was designed as a multi-disciplinary study combing surveys on cetacean, krill and oceanography. A hierarchical structure with three strata of spatial models is considered in this study: (1) presence and absence of Antarctic and ice krill, (2) biomass density of Antarctic and ice krill and (3) school counts of Antarctic minke whales. Three abiotic factors, distance from physical boundary (combination of coast, ice edge and shelf ice lines) and integrated temperature and salinity mean from surface to 200m (ITEM-200 and ISAM-200) as well as latitude and longitude were used as covariates for models (1) and (2). Predicted surfaces of krill were also used as covariates in the model (3). Scales of interactions between Antarctic minke whales and the environmental factors were investigated at a segment length of 5 n.miles. Predicted school counts of Antarctic minke whales were low where ice krill was distributed, while it was high where Antarctic krill was distributed. Abundance of Antarctic minke whales could therefore relate to the biomass of Antarctic krill. School counts of Antarctic whales increased as ITEM-200 increased while they increased as ISAM-200 decreased. The analysis indicated that is still useful to detect the environmental effect on distribution pattern of cetaceans in the spatial context. Although the relationship between distribution patterns of krill and Antarctic minke whales can be studied using the spatial model, stomach content data of Antarctic minke whales are required to estimate the prey preference on two krill species. Continuation of the multi-disciplinal ecological survey like the JARPAII is critically important to detect interactions between fluctuations of abundance of Antarctic minke whales and their environment. The WG encouraged further development of such modelling approaches.

1.6 Other

No other issues were raised.

1.7 Work Plan

The WG **agreed** that planning for the Joint IWC/CCAMRL workshop would continue intersessionally through the Joint Steering Group.

1.8. Adoption of the Report

The report was adopted at 13:12hrs on 14th May 2007. The Chair thanked the members of this new WG for their valuable contributions and discussions and the rapporteurs for their hard work.

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Appendix 1

AGENDA

1.1. INTRODUCTORY ITEMS
  1.1.1. Convenors opening remarks
  1.1.2. Election of Chair, appointment of rapporteurs
  1.1.3. Adoption of Agenda
  1.1.4. Review of documents
1.2. Review progress on joint CCAMLR/IWC workshop on modelling Antarctic krill predators
1.3. Review collaboration with FAO
1.4. Review of progress in the development of ecosystem models
1.5. Review of data relevant to parameter estimation and ecological interactions
1.6. Other
1.7. Work Plan
1.8. Adoption of Report