Thank you for the opportunity to comment on the 2007-08 SQU6T OPERATIONAL PLAN: INITIAL POSITION PAPER.

Recommendations for rational, science-based management of NZ sea lions:

- Use the US PBR method for setting bycatch limits (as was done before 2004)

- The Breen-Kim model has been shown to produce unreliable results and should not be used for management advice unless and until these problems can be solved (this is unlikely without a major change in modelling approach - see below)

- Take into account the increasing catch rate: It is now very difficult to estimate the actual number of sea lions caught - observer coverage needs to be increased, and cover nets used over SLEDs to allow estimation of catch rate (including trends in catch rate)

- Take into account the evidence for population decline

- Encourage the fishery to change to jigging (based on a detailed analysis of the economics of jigging)

Attached are two critiques of the Breen-Kim model. The first is a 2006 paper summarising criticisms raised at technical working group meetings organised by DOC and Mfish and raised in independent reviews of the model. The second paper discusses the proposed changes to the model to deal with some of the key technical problems.

It is good to see that the many problems with the Breen-Kim model are finally starting to be addressed. Although, unfortunately this seems to have escaped the notice of managers who are continuing to use the Breen-Kim model for setting limits on sea lion bycatch. This is totally inappropriate, for the reasons outlined in the two attached papers and summarised below. The "acknowledged limitations with the Breen-Kim model" are sufficiently serious that it is incapable of providing robust management advice.

It is extremely misleading to imply that bycatch limits as high as 513 sea lions could possibly be regarded as sustainable and should be part of the range considered by the minister. Bycatch limits on the order of 80 sea lions could conceivably be taken year after year without major impact on the population. This is certainly not the case for the upper limit (513). At scientific fora this distinction is understood. In the public arena it is not. And to include catch limits of that magnitude in the IPP (and worse, in frequent public statements by managers and politicians) is extremely misleading and biases public consultation on the issue.

Brief summary of the main problems with the Breen-Kim model:

Problems with model structure:

1. The model fails to predict recent reductions in pup numbers
2. The model's estimate of maximum population growth rate is not credible
3. Bycatch is modelled deterministically and assumed to be known without error
4. Fishing effort data are assumed to be known without error
5. Spatial structure is ignored
6. Population structure is unrealistic
7. Catastrophes are ignored
8. Arbitrary decisions in model structure
9. Need for exploring alternative model structures

Problems with input data or how these are handled by the model:

10. Late season pup mortality is not included in the model
11. Bycatch from fisheries other than the SQU6T fishery is not included in the model
12. Pups that die as a consequence of their mother's death as bycatch are not included in the model
13. The use of SLEDs makes it difficult to estimate the true catch rate
14. Time trend in strike rate

Implications for management:

1. **The Breen/Kim model lacks the "robustness" of the PBR approach (Wade 1998)**

The PBR approach was designed to achieve a 95% probability that there will be less than 10% delay in time to recovery and to perform adequately even when there are precision and accuracy (bias) problems with the input data. The Breen-

Kim model lacks these characteristics. It has not been designed to ensure that recovery time meets statutory or otherwise acceptable standards, and it has not been shown to be robust to biases in input data or model uncertainty.

2. **Lack of clear management goals**
It is very difficult to obtain consensus on regulatory decision rules when there is no firm consensus on elementary standards and basic goals. The legislative goal of ensuring that the species reaches a non-threatened status as soon as possible has been lost sight of in the modelling exercise.

3. Lack of metapopulation dynamics among the four subpopulations, and lack of focus on recolonisation and species recovery
The series of abundance data for sea lions is too short, and covers too small a range of population sizes to be able to yield estimates of parameters like carrying capacity and maximum population growth rate. The model is basically unable to estimate these parameters, and a number of add-hoc ways of forcing the model to come up with biological estimates have been added to the model. This does not fix the basic mis-match between the modelling approach and the sorts of data available for marine mammal populations. The NIWA model for Hector's dolphin has exactly the same problem, for the same reasons. A different modelling approach is needed.

4. It is unclear how problems with input data may have affected the results
The conclusions of the model depend on arbitrary decisions about how to deal with the input data, such as the weighting of the respective data sets, enforcing penalties extraneous to the prior, the diagnosis and adjustment for inconsistencies between data sources, and the partitioning of process variance and parameter uncertainty variance. It is unclear how slightly different decisions would have affected the conclusions. There are concerns about biases in some of the input data sets. For example, there appears to be a positive relationship between observer coverage and the estimated catch rate. This may have affected the estimation of other parameters such as population growth rate and carrying capacity.

5. **The "adaptive" approach is a return to unsustainable management practices of the past**
The adaptive rule (rule 4) aims to vary the bycatch rate depending on population size, using pup counts as an index of abundance. There are a number of problems with this. Marine mammal populations are difficult to census, and it usually takes many years to detect population trends. In addition, pup counts are an indirect measure of abundance, and are not necessarily a straight-forward indication of trends in population size. For example, if pup counts increase this could mean that either the population size (number of breeding females) has increased or the reproductive rate has increased (average number of offspring produced per female). If the latter, then this could indicate that a reduction in population size has led to reduced competition for resources and therefore to the increased pupping rate. The PBR method was developed in order to get away from management methods that rely on detecting population declines before management action is taken. The adaptive rule reverts to management practices that are out of date, due to their failure to meet basic standards of scientific and management performance.

6. **Need to decide beforehand how to react to catastrophes**
Decision rules need to be in place on how to deal with catastrophes. The lack of proper management response to the 1997-98 mass mortality (and subsequent smaller events) and the subsequent decline in pup production illustrates this. Straight after the 1997-98 event, it was entirely predictable that at around this time there would be a reduction in the number of breeding females and therefore a reduction in the number of pups. Yet, the Breen-Kim model failed to predict this and failed to provide appropriate management advice.

General critiques of this particular modelling approach are starting to appear in the literature (e.g. Lonergan, 2007, Marine Mammal Science 23: 721-729).
The only rational option is to return to using the PBR method, designed by the US National Marine Fisheries Service and set catch limits for sealions with the methods in use before 2004.

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Attachment 1

The Breen-Kim model: A basis for providing robust management advice?

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May 2006

The fishing industry initiated the development of a management model for NZ sea lion, as an alternative to the PBR approach (developed by the US National Marine Fisheries Service) that has been used since 1991 to calculate annual bycatch limits for NZ sea lion. Initially, Hilborn and Maunders were hired by the fishing industry to develop an alternative model. The model has been further developed by Breen and Kim, with funding from MFish, DOC and the fishing industry.

The model has been discussed in a lengthy series of technical meetings in New Zealand, coordinated by DOC and MFish. It has also been formally reviewed by Dr Paul Wade, a senior scientist from the US National Marine Mammal Lab and by Professor Dan Goodman, Director of the Environmental Statistics Group at Montana State University. Both are leading international experts in this field. The following is a summary of the main criticisms of the model, drawing on the critiques of Wade and Goodman as well as discussions in the technical working group meetings.

It is clear from these criticisms that the model is not a robust basis for management and that alternative, robust methods are readily available. For example, the PBR, or MALFIRM approach (the basis for setting NZ sealion bycatch limits from 1991 to 2004) has been thoroughly tested and provides robust advice in situations when the input data are uncertain or biased (e.g. fishing effort, catch rate, sea lion population size). By comparison, the fishing industry model is highly experimental, and could not be said to provide robust advice. It also ignores delays in population recovery (see points 2 and 3 below) which are the basis of the key statutory goal for management of marine mammal bycatch in New Zealand.

Main criticisms:

1. **The Breen/Kim model lacks the "robustness" of the PBR approach (Wade 1998)**

   The PBR approach was designed to achieve a 95% probability that there will be less than 10% delay in time to recovery and to perform adequately even when there are precision and accuracy (bias) problems with the input data. The Breen-Kim model lacks these characteristics. It has not been designed to ensure that recovery time meets statutory or otherwise acceptable standards, and it has not been shown to be robust to biases in input data or model uncertainty.

2. **Lack of clear management goals**

   It is very difficult to obtain consensus on regulatory decision rules when there is no firm consensus on elementary standards and basic goals. The legislative goal of ensuring that the species reaches a non-threatened status as soon as possible appears to have been lost sight of in this modelling exercise.

3. **Lack of consideration of delays in recovery**

Breen and Kim's model does not use delays in population recovery as a performance criterion, even though this criterion is technically useful because of its relative insensitivity to uncertainty about K. Management rules should also include the probability of declining below 60% of K and how to respond to sustained periods of population decline.

4. **Lack of metapopulation dynamics among the four subpopulations, and lack of focus on recolonisation and species recovery**

   During the rather short period covered by the reliable pup count data, the annual counts have maintained fairly consistent numbers without a clear trend, and the recorded bycatch while varying considerably on an annual basis has still maintained a consistent average. This suggests that the population has successfully sustained this level of bycatch, but has been unable to grow and may not be able to cope with additional sources of mortality (e.g. pollution events, disease). It is not clear to what extent bycatch of sealions has prevented the establishment of additional breeding colonies.

   Data from the recently established colonies at Otago Peninsula and the Catlins could help create a more realistic model. Better linkages between modelling work and research on these newly established colonies would help the modelling work to focus on the goal of ensuring that the species reaches non-threatened status within 20 years. This is the legislative goal. Unfortunately, the approach proposed by the fishing industry does not include any performance criteria that relate to recovery of the species.

5. **Poor basis for conclusions about density dependence and where the population is with respect to K**

   The available data only span a period when the bycatch was operating more or less consistently for the duration, and when the pup counts were more or less stable, so there is virtually no signal to reveal density dependence. The density dependence parameters (z, Rmax, and K) used in the model were therefore determined almost entirely by the prior opinion about Rmax. Unfortunately, the conclusions about the resilience of the sea lion population to varying levels of bycatch depends primarily on these density dependence parameters.

   During the rather short period covered by the reliable pup count data, the annual counts have maintained fairly consistent numbers without a clear trend, and the recorded bycatch while varying considerably on an annual basis has still maintained a consistent average. This suggests that the population has successfully sustained this level of bycatch, but has been unable to grow and may not be able to cope with additional sources of mortality (e.g. pollution events, disease).

   Annual estimates of pup mortality during the same period, show considerable variation, suggesting that some significant short term sources of environmental variability do affect the population. Previous to this recent era, there are no quantitative data except for a handful of pup counts conducted with less trusted protocols at just one rookery.

   This information does not provide a basis for determining how much the population size has been depressed from its pre-exploitation equilibrium by the trawl bycatch, nor does it provide a basis for predicting how much the harvested equilibrium would shift if the bycatch level were to change.

6. **Biologically unrealistic results**

Some of the estimates of the model are biologically unrealistic. For example, the estimate of maximum population growth rate is 3%. For other seals and sealions this is typically around 12%. The Breen/Kim model uses a bycatch limit based on a population growth rate of 8% and applies it to a population with a maximum growth rate of 3%. This is clearly inappropriate.

7. It is unclear how problems with input data may have affected the results

The conclusions of the model depend on subtle decisions about how to deal with the input data, such as the weighting of the respective data sets, enforcing penalties extraneous to the prior, the diagnosis and adjustment for inconsistencies between data sources, and the partitioning of process variance and parameter uncertainty variance. It is unclear how slightly different decisions would have affected the conclusions. There are concerns about biases in some of the input data sets. For example, there appears to be a positive relationship between observer coverage and the estimated catch rate. This may have affected the estimation of other parameters such as population growth rate and carrying capacity.

8. The name "unconstrained fishing" for one of the model scenarios is misleading

The authors of the model persist in using the term "unconstrained fishing" (and this has been carried through into the IPP), despite criticism at technical group meetings and in several technical reviews. As pointed out by Goodman for example, the modeled bycatch rates are estimated from data from a period when there has been an incentive for the fishery to keep kills and kill per unit effort as low as possible, and in a period of consistent gear technology and fisheries management. A decision rule for managing the bycatch should be robust to possible changes in the fishery and its management, as well as to possible changes in the environment, and to uncertainties about the basic biology. In essence, the model assumes that the fishery will not grow or change in gear or efficiency in the next 100 years. By contrast, the PBR approach is proven to be robust in situations where there is increased demand for fishing effort.

9. The "adaptive" approach is a return to unsustainable management practices of the past

The adaptive rule (rule 4) aims to vary the bycatch rate depending on population size, using pup counts as an index of abundance. There are a number of problems with this. Marine mammal populations are difficult to census, and it usually takes many years to detect population trends. In addition, pup counts are an indirect measure of abundance, and are not necessarily a straight-forward indication of trends in population size. For example, if pup counts increase this could mean that either the population size (number of breeding females) has increased or the reproductive rate has increased (average number of offspring produced per female). If the latter, then this could indicate that a reduction in population size has led to reduced competition for resources and therefore to the increased pupping rate. The PBR method was developed in order to get away from management methods that rely on detecting population declines before management action is taken. The adaptive rule reverts to management practices that are out of date, due to their failure to meet basic standards of scientific and management performance.

10. Need to decide beforehand how to react to catastrophes

The report acknowledges an expectation that "the chosen rules would be suspended as soon as a catastrophe was detected." It is best to have the decision rule for suspending the "chosen rules" in place in advance, so as not to run risks of harmful delays if new rules need to be invented, agreed to, and implemented on the fly when a problem is noted. Also it is good to analyze in advance the capabilities for detecting and interpreting changes in the status of the population, to ensure that the combined system of monitoring and management response is adequate. For example, this would include consideration of observer coverage, resolution of the pup censuses (including corrections for time in the breeding season and fraction of pups dead before the count), and commitment to continued marking and resighting studies and recording age and sex distribution of the catch, and determining the rookery of origin for sealions killed in fishing operations.

Discussion and conclusions:

It is not surprising that Goodman concluded that "exclusive reliance on these modeling results to justify adoption of an alternative management regime such as the "twice MALFIRM" or "adaptive rule," described in the report, would not constitute a management procedure that is "robust" in the sense of Wade (1998)". A robust method is available in the PBR or MALFIRM approach that has been used to set limits on sea lion bycatch so far (Wade 1998). Therefore, it would be imprudent to abandon this approach in favour of a management procedure that has a number of serious flaws as outlined above.

On the topic of whether the Breen/Kim model is an appropriate alternative to existing management methods, Goodman concludes that "it would be imprudent to bet the farm on this kind of a complex modeling analysis, without careful comparison to simpler analyses and common sense appraisals". So far, comparison with simpler analyses has found the Breen/Kim model wanting (e.g. see points 5 and 6 above).

The statutory goal for marine mammal populations in New Zealand is to control bycatch to levels that allow threatened populations to reach non-threatened status as soon as possible and in any case in no more than 20 years. Achieving this goal for NZ sea lion will be a major challenge. The species has been reduced to a small part of its original range, and may not recover to non-threatened within 20 years even if human impacts are reduced to very low levels (e.g. by using squid jigging instead of trawling in areas where sea lions are found). To demonstrate that this statutory goal is taken seriously by decision makers would mean reducing sea lion bycatch from recent levels (around 60-70 individuals per year) to as close to zero as practically achievable. Any initiatives in the opposite direction, involving increased quotas, clearly contradict the management goals set in the NZ Marine Mammals Protection Act.

Response to criticisms:

Surprisingly, there has been little if any response to these criticisms. This is despite the fact that the critiques to date have clearly indicated science and management solutions, including the following:

- Continue to use the PBR approach for setting bycatch limits until a better method becomes available

- Determine why the Breen/Kim model has such a difficult time estimating maximum population growth and determining where the population is with respect to carrying capacity (through sensitivity analyses and error checking)

- Include a more realistic level of "unconstrained" fishing effort

- Abandon attempts at "adaptive" management approaches based on estimates of population size (i.e. remove this option from the model)

- Include more explicit decision rules for dealing with catastrophes, and test these management responses for robustness

- Include recovery of the New Zealand sea lion population, and delays in time to recovery, in the performance criteria of the Breen/Kim model so that an appropriate comparison can be made

- If an alternative to the PBR is to be developed, ensure that it is tested for its robustness to problems with input data, in a similar way to the tests performed for the PBR method (again, this would allow a proper comparison to be made)

- Develop clear management goals, and ensure that any management models that are developed, by the fishing industry or others, achieve these management goals

Attachment 2

Problems with the Breen-Kim model
With suggestions for solutions and alternative models

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This report is a response to the discussion document by Breen, Gilbert and Fu (33B_IPA2006-09-Model.pdf) tabled at the Aquatic Environment Working Group meeting on 27 July 2007. The discussion document takes a major step in the right direction in listing the problems with the Breen Kim Model. Unfortunately, there was insufficient time at the meeting to discuss possible solutions and alternative models. Therefore I was asked by the chair of the AEWG to put my comments in writing. This paper explores directions for improving population models for NZ sealions by either modifying the Breen Kim model or changing to a different modelling approach.

Summarising the key problems with the Breen Kim model, identified in the discussion document (Breen, Gilbert and Fu, 33B_IPA2006-09-Model.pdf):

Problems with model structure:

1. The model fails to predict recent reductions in pup numbers
2. The model's estimate of maximum population growth rate is not credible
3. Bycatch is modelled deterministically and assumed to be known without error
4. Fishing effort data are assumed to be known without error
5. Spatial structure is ignored
6. Population structure is unrealistic
7. Catastrophes are ignored
8. Arbitrary decisions in model structure
9. Need for exploring alternative model structures

Problems with input data or how these are handled by the model:

10. Late season pup mortality is not included in the model
11. Bycatch from fisheries other than the SQU6T fishery is not included in the model
12. Pups that die as a consequence of their mother's death as bycatch are not included in the model
13. The use of SLEDs makes it difficult to estimate the true catch rate
14. Time trend in strike rate

Most of the problems relating to data inputs (10-14 above) can be simply solved by including the relevant data (e.g. all categories of mortality). Deaths caused by late season pup mortality, by death of the mother as bycatch and due to bycatch in fisheries other than SQU6T should obviously be included in the model.

The issues relating to the structure and functioning of the model are much more serious. These indicate a fundamental mismatch between the model and the data. The model is clearly having difficulty estimating parameters like carrying capacity, maximum population growth rate and other parameters that relate to density dependent processes. This is basically due to the model trying to estimate parameters for which there is no information in the data (e.g. density dependence because the series of abundance estimates is too short and does not span a sufficiently wide range of population sizes). It is therefore futile to try to estimate these parameters within the model. This is acknowledged implicitly, by using very informative priors and penalties extraneous to the prior. It would make more sense to acknowledge this problem explicitly and modify model structure accordingly (see below).

1. Failure to predict recent reductions in pup numbers

This mismatch of the model with the population dynamics of NZ sealions in the Auckland Islands is surprising and of serious concern.

The model includes data from before and after the major mortality event in 1998. Even a very simple population model would have predicted that the loss of some 50% of pups and 20% of adults in 1998 would affect pup counts in the years to come. In the last few years, the pups from 1998 have reached sexual maturity. Clearly a reduction in pup production would have been expected within 6-8 years of the mortality event. A model that fails to reflect the dynamics of the NZ sealion population to this extent can not be expected to provide reliable advice on the sustainability or otherwise of different levels of bycatch.

Rather than creating "uncertainties about the ability of high-numbered harvest control rules to achieve the management criteria" this mismatch between model and reality casts serious doubt on the usefulness of the model in general, regardless of which harvest control rule is used.

The solutions proposed in the discussion paper (including increasing process error in the projections) are inadequate. There is a fundamental mismatch between the model and the data. This needs to be solved by modifying the underlying structure of the model (see below).

2. The model results in an estimate of maximum population growth rate that is not credible

Maximum population growth rates for pinnipeds are around 12% and this is the default value used in the method used for setting marine mammal bycatch limits in the USA (Wade 1998). Sealions tend to have lower growth rates than seals and the biological data for NZ sealion indicate a population growth rate of 8% (value used in MALFIRM calculations until 2004). The Breen Kim model results in maximum population growth rate estimate of 3% and this is after using what is described in the discussion document as a "strong prior". Without the strong prior, the estimate of <u>maximum</u> population growth rate is 0.

This is a very clear indication that there is something seriously wrong with the model structure and/or there is a serious mismatch between the modelling approach and the available data. A consistent criticism of this model (e.g. critiques by Professor Dan Goodman, Dr Paul Wade and myself) is that there is little if any information in the data to estimate maximum population growth, original population size and other parameters relating to the productivity of sealion populations at different population sizes. It is good to see that criticism acknowledged in the discussion paper.

Of the solutions proposed at the AEWG meeting, only the third option "develop a model structure that does not estimate density dependence" is an effective solution to this problem. Clearly, shifting density dependence from one survival estimate to another or from survival to reproduction does not get around the problem that "The model cannot estimate density-dependence based on the data; there is insufficient contrast in breeding population size and too short a time series of data in any case. Thus it is impossible to determine from the data where density-dependence really lies." As identified in the discussion document the low maximum population growth rate estimate may be "an artefact of the model parameterisation".

3. Bycatch is modelled inappropriately

In evaluating the performance of the different harvest control rules, bycatch was modelled deterministically as if exactly the number of sealions allowed to be taken each year (FRML) is actually taken. This is clearly inappropriate and resulted in serious underestimation of risk when the model was used to set a FRML last season.

The solution proposed in the discussion paper is “to include a simple implementation error sub-model”. No further information was provided at the meeting, in response to questions. Most population models dealing with bycatch already include stochasticity in bycatch (e.g. Wade 1998). The form of this sub-model will have a strong bearing on whether the final model provides a realistic assessment of risk to the sealion population.

4. Fishing effort data are assumed to be known without error

Clearly this is unrealistic and unacceptable in any kind of risk analysis model. Obviously fishing effort (and bycatch) need to be able to vary randomly in the model from year to year (e.g. based on past estimates).

5. Spatial structure is ignored

The spatial structure of the model is inadequate in several respects. For example, Professor Goodman pointed out that sealions at individual rookeries may not be affected by bycatch in the same proportion, and that this could lead to declines in some despite stability in others.

In addition, by focussing its attention solely on the sub-Antarctic population the model fails to provide any advice on the potential impact of bycatch on the recovery rate for the species as a whole.

6. Population structure is unrealistic

The model does not differentiate between males and females. To do so would require data on male survival, which are not available. The obvious solution is to model females only. This is the way that most population models are structured anyway. It would make it explicit that in order to estimate total population size, the total number of females is doubled.

7. Catastrophes are ignored

The proposal is not to model catastrophes, on the basis that in the event of a major catastrophe “managers would likely be loathe to continue to manage bycatch with a simple rule”. There are a number of problems with this argument. There has already been a catastrophe and the management reponse was to make a minor adjustment to that year’s catch limit and to otherwise ignore the catastrophe. The 1998 die-off resulted in large numbers of deaths of adults and pups. Together with smaller such events more recently, this has resulted in population declines. Yet bycatch continued virtually unabated. In fact the allowable level has increased dramatically in the last few years from approximately 60-70 a year to more than 100 a year. Given that we now have data on a catastrophe, that information should obviously be included in the model.

The model failed to predict the obvious consequences of the die off (e.g. reduction in pup numbers in subsequent years). Rather than abandoning the idea of modelling catastrophes it would seem essential to improve the model's ability to deal with them. Predicting the timing and exact magnitude of a catastrophe will obviously be very difficult. However, once one has occurred it needs to be incorporated in the model in a way that reflects processes in the real population. Furthermore, the model needs to be able to provide advice on precautionary management for this species, given that catastrophes are expected to occur from time to time. From the point of view of assessing the risk of bycatch to the population it will be less important exactly when these catastrophes occur, but very important to include them as part of the overall management context. Obviously, another die-off is a real possibility, and management of bycatch needs to be sufficiently cautious that the addition of human impact does not add to existing natural risks to the point of slowing population recovery of the species (e.g. establishment of additional breeding colonies).

8. Arbitrary decisions on model structure

In the construction of the Breen Kim model, a large number of arbitrary decisions have been made, many of which have a strong bearing on the estimated risk to the sealion population. For example, which parameters to estimate in an integrated way within the model and which to use independent estimates for. These decisions have been questioned at the technical working groups and in independent reviews of the model. However, until now there has been no indication that these features were to be tested or changed.

Professor Goodman, in his critique of the Breen Kim approach, pointed out that estimating parameters simultaneously from all the data sets with a Bayesian procedure, is a relatively new method of population modelling that appears to be gaining in popularity. However, he cautioned that "by virtue of its recent development, small numbers of experienced practitioners, and small portfolio of thoroughly examined case studies, there may as yet be unexplored methodological pitfalls, especially in complicated applications. For example, in reading the report I found myself wondering about some subtle decisions such as the weighting of the respective data sets, enforcing penalties extraneous to the prior, the diagnosis and adjustment for inconsistencies between data sources, and the partitioning of process variance and parameter uncertainty variance".

He pointed out that making different decisions would have led to different results. He questioned the "typical population trajectory" showing the reconstructed population in 1965 at about half its estimated numbers in 1993 (at the onset of good censusing, and close to the time when the bycatch data begin) with the population growing steadily for the intervening two and a half decades. He asked if this trajectory is really "typical" and stated that he could not diagnose it from the information provided. He asked "If this trajectory is typical, how can it be reconciled with the suppositions about the population's history and dynamics?" and stated that "For these reasons, I think it would be imprudent to bet the farm on this kind of a complex modeling analysis, without careful comparison to simpler analyses and common sense appraisals." He questioned whether "the proposed alternative bycatch control rules will confer sufficient protection against less favorable possibilities that could still be consistent with the available evidence" and pointed out that the Breen Kim model lacks the robustness of the US approach (e.g. Wade 1998).

The solutions proposed in the discussion document (page 8, ignoring the problem or penalising "incorrect" behaviour of the model) are clearly inadequate. This issue can be resolved only by exploring alternative model structures. This means running several different versions of the Breen Kim model, with different versions of model structure and inputs. In addition, it means running at least two different models to test the robustness of the Breen Kim approach against other model candidates (see below).

9. Need for exploring alternative model structures

Clearly, alternative model structures need to be explored, including models that do not estimate density dependence. The only question remaining is, what sorts of alternative models are most appropriate?

The most obvious option is the model developed by the US National Marine Fisheries Service for setting limits on marine mammal bycatch, the method used for setting sealion bycatch limits previously. This model should be used as a benchmark in the model structure testing exercise. In particular, the performance of the Breen Kim model should be tested against the US model in situations where there are uncertainties (imprecision and bias) in catch rate, maximum population growth rate, current compared to original population size, etc. There are major uncertainties around each of these parameters for NZ sealions.

The US method is robust to those uncertainties and performs well, for example when populations are depleted (below 30% of original population size) whether or not there is a reliable estimate of the level of depletion. It also performs well if the population size estimate is biased or imprecise, if the bycatch rate has been underestimated, and in other such challenging situations. The performance of the Breen Kim model in such circumstances is unknown.

At least one additional model structure should be explored, to allow the Breen Kim model to be evaluated against at least two other candidates. A comparison of 5 rather than 3 different models would be preferable. Obvious candidates for models 3 and 4 include the Catch Limit Algorithm developed by the Scientific Committee of the International Whaling Commission and a standard Population Viability Analysis model. There is a rich literature on these kinds of models. I would be happy to recommend specific models from the PVA literature, if this is not already common knowledge within the NIWA team.

In addition, as a means of testing and error checking the Breen Kim model, at least three different versions of it should be compared with each other. As pointed out by independent experts, and discussed at technical working group meetings, the large number of arbitrary decisions made in the construction of the Breen Kim model makes it very difficult to determine what drives specific conclusions from the model (e.g. population growth rates appear to be lower than for any other pinniped, the population appears to be close to carrying capacity when there are clear indications from field data that this is not the case, etc.).

At present, the Breen Kim model falls somewhere between a fully integrated model and a fully segregated model. Some parameters are estimated in an integrated way within the model, and some are estimated independently. It would make sense to explore the full range of models from fully segregated (the simple, commonsense approach advocated by Professor Goodman) and fully integrated.

10. Late season pup mortality is not included in the model
11. Bycatch from fisheries other than the SQU6T fishery is not included in the model
12. Pups that die as a consequence of their mother's death as bycatch are not included in the model

These problems can be simply solved by including the relevant data (e.g. all categories of mortality). Deaths caused by late season pup mortality, by death of the mother as bycatch and due to bycatch in fisheries other than SQU6T should obviously be included in the model.

13. The use of SLEDs makes it difficult to estimate the true catch rate

The use of SLEDs basically makes it impossible to estimate how many sealions are currently caught, making it impossible to incorporate a realistic level of bycatch in the model (including uncertainty of that estimate, and any trends in the estimate). It is essential that a sample of vessels either abandon the use of SLEDs or put cover nets on the SLEDs to allow estimation of catch rate.

14. Time trend in strike rate

The strike rate increases over time and clearly this needs to be included in the model. The proposal at the AEWG meeting to ignore this and test its effect only in a sensitivity trial is inadequate.

In Conclusion, there are a number of serious problems with the Breen Kim model and alternative models urgently need to be developed. In the meantime, a truly robust method for setting bycatch limits is available in the method developed by the US National Fisheries Service (Wade 1998).

In conjunction with this work, it would be very useful to better define the management goals for NZ sealion. There does not appear to be any clear guidance on the basic goals and standards, and the legislative goal of ensuring that the species reaches a non-threatened status as soon as possible appears to have been lost sight of in the modelling exercise. For example, delays in population recovery (of the species) would be an obvious criterion in any testing of alternative models for managing NZ sealion.