International Council for the Exploration of the Sea

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1 On the models used in WGHARP assessments

Report from intersessional work by correspondence of a WGHARP modeling subgroup.

Members: Skaug (chair), Bøthun, Harbitz, Golikov and Korzhev.

The group received the following documents: Korzhev (2004) and Harbitz (2004a, b). This report summarizes the finding in these documents.

The following table summarizes the terms of reference given to the group, and the status of these task.

	Task	Status
1	Comparison of model formulations	
A	Comparison of NE and NW models	Not done yet, but will be discussed during visit of Canadian scientist to Tromsø in December 2004
B	NE versus simple replacement yield model	This has not been done yet, but will be discussed during visit of Canadian scientist to Tromsø.
C	NE versus Ulltang model	Not considered relevant because models are so similar
2	Advice on Model Formulations – Sensitivity Simulations	
A	Run NE model starting in 20th century w/out K assumption	This was done as part of the assessment at the 2003 meeting.
B	Run NE model removing various data components	Not relevant for current model because little data to remove
C	Evaluate sensitivity to input parameters	Addressed in Korzhev (2004) and Harbitz (2004a,b); see discussion below
D	Evaluate importance of valid age structure importance	Not relevant, because the current model does not have age structure input
e	Track survival rates for realism	Not done
f	Run models with real and simulated data sets	
g	Density dependence	Not relevant because it has been removed from model

1.1 Two-age model versus full age structure

In the assessments done at the 2000-meeting of WGHARP a population dynamic model with two age classes (0-group and 1+ animals) was used, while the model used at the 2003 meeting had a full age-structure. As a response to this, both Korzhev (2004) and Harbitz (2004a, b) compare the two model formulations. Both analyses show that the 2-stage model and the fully age-structured model yield very similar results for appropriately chosen parameter values (Table 4 in Korzhev 2004; Figure 1 and 2 in Harbitz 2004a).

1.2 Sensitivity to input parameters

Both Korzhev (2004) and Harbitz (2004a, b) consider the sensitivity of the model output (number of 1+ animals) to changes in the input parameters. This is done by changing one input parameter at the time, keeping the other parameters fixed. While Korzhev (2004) keeps the parameter *K* (size of 1+ population in 1946) fixed, Harbitz (2004a) re-estimates *K* for each sensitivity experiment. Figure 4 in Harbitz (2004a) brings the attention to a model output that is useful for sensitivity analyses:

$$\lambda = \frac{N_{1+}}{N_0}.$$

Because this is the factor used to scale pup counts into estimates of 1+ population size, this is an important quantity for sensitivity tests.

Korzhev (2004, Table 1) finds the model is most sensitive to *f* (average birth rate among all 1+ females). Harbitz (2004a, Figure 4) finds that λ is not very sensitive to neither the mortality ratio M_0/M_{1+} nor M_{1+}, which is reassuring. Table 1 in Korzhev (2004) shows that N_{1+} itself is much more sentive than λ (according to Figure 4 in Harbitz 2004a), although the results of Korzhev (2004) and Harbitz (2004a) may not be directly comparable at this point, due to the fact that *K* is re-estimated in one case, but not in the other.

1.3 Equilibrium considerations

Although all recent WGHARP assessments have been done without the assumption that the population is in equilibrium, it may be valuable to study the mathematical properties of the model under this assumption. Because the assumption of equilibrium (N_{1+} is constant over time) predicts that there must be a relationship between at least two biological parameters in the model, Harbitz (2004a, Figure 3) studied the relationship between the mortalities M_0 and M_{1+}. The main finding there is that, for what has previously been considered a reasonable range of M_{1+} (0.09—0.12) by the working group, the predicted value of M_0/M_{1+} may exceed 0.5, which is the largest values considered so far by the working group.

1.4 Modification of assessment model

The assessment model that was used at the 2003-meeting of WGHARP has been modified so that it can account for uncertainty associated with all input parameters (*K*, *f*, M_0 and M_{1+}). Prior distributions (mean and standard deviation) for these parameters are read from file. The program itself and associated files are available from:

http://whale.imr.no/RMP5/
Username: whalepaper
Password: g,hj883

Future activities

The following issues should be discussed at the next WGHARP meeting:

Lack of fit to historic age-data: The model for White Sea Harps does not adequately describe the age distribution on whelping grounds for the period 1959-1964, while it has a good fit for the period of 1973-2000. Golikov has noted that this is related to the aging method/procedure used at the time.

The appropriateness of fitting the model to data from SevPINRO on age distribution of females on whelping grounds. This has not been done in previous assessments, but would provide much information if the data could be regarded as being representative. This is related to issue 1).

The number of age classes to use in the model. Results mentioned above indicate that this is not critical, but Korzhev notes that in the 20 age model, the "plus group " contains up to 20 % of all number 1 +, and further the data from whelping grounds include aged females till 36-38 years, therefore it is recommended to use 30 age model.

We expect to receive further input on these points during the spring.

1.5 Documents

Korzhev V.A. (2004) Estimation of sensitivity of model of dynamics of number for White Sea/ Barents Sea harp seals to entrance parameters, PINRO, Murmansk, June, 2004. (Included as Appendix 1)

Harbitz, A. (2004a). Senitivity analysis 181104. (Included as Appendix 2)

Harbitz, A. (2004b) Sensitivity of White Sea /Barents Sea harp seal numbers with respect to model parameters. (Attached as PDF-file)

2 On The Implementation of Biological Reference Points for Harp and Hooded Seals

Report from intersessional work by correspondence of a WGHARP subgroup

In our last WGHARP (Joint ICES/NAFO Working Group on Harp and Hooded Seals) meeting in Archangelsk in September 2003 we discussed the establishment of biological reference points for harp and hooded seals. A conceptual framework for applying the precautionary approach (PA) to Atlantic seal management, developed primarily to fit the management of northwest Atlantic harp seals, was outlined and discussed. The group agreed that this framework (the '3-tier') could be a way forward to establish biological reference points (BRPs) for other harp seal populations, and presumably also for the hooded seal populations. It was agreed, therefore, that if ACFM found the approach useful and acceptable, a WGHARP subgroup (Haug, Filin, Hammill, Merrick and Stenson) would collaborate via correspondence to further develop ways to apply the PA to providing advice for harp and hooded seals.

The following report summarize the intersessional work of the subgroup, and is intended to be a background document when WGHARP discusses this issue at its next meeting in St. John's, Newfoundland, Canada, 30 August – 3 September 2005. First, we repeat the ACFM response to the WGHARP 2003 report on BRPs.

ACFMs response

ACFM discussed the WGHARP report, BRPs included, at the October 2003 meeting in the ICES Headquarter in Copenhagen. ACFM gave the following introductory comment to the request to assess and establish biological limits for Greenland Sea harp seals, Greenland Sea hooded seals and White Sea/Barents Sea harp seals:

"One such limit may be the historical minimum population size that may represent Nlim (as suggested by ACFM). A second biological limit could be the population level that would result in a low level of probability that the population is at the minimum size (i.e., Npa). The aim of management is not to keep the seal stocks at its current levels, but to harvest the seal stocks sustainable without risking stock collapse."

ACFM gave the following comments to the PA conceptual framework suggested by WGHARP for future management of harp and hooded seals:

"Biological limits of yield reflecting very low risk of collapse must be developed within a Precautionary Approach framework. ICES discussed a recent approach on the application of the Precautionary Approach (PA) and conservation reference points to the management of harp and hooded seals, originally developed for the stocks in the Northwest Atlantic. Within this framework, conservation, precautionary and target reference points can be identified and linked to specific actions to aid in managing the resource. For seals, abundance and yield should be identified in terms of numbers rather than as biomass (as done in fish).

Harp and hooded seals are commercially exploited to varying levels throughout the North Atlantic. The availability of scientific information concerning the status of these resources (abundance, reproductive and mortality rates) also varies between the species. A conceptual framework for applying the PA to Atlantic seal management was outlined. For a data rich species, one target, one precautionary and one conservation reference level are proposed. A target reference level could be established at 70% (N_{70}) of the pristine population size or a proxy of the pristine population (e.g. maximum population size). When populations fall below N_{70}, conservation objectives assume a greater role in the setting of harvest levels, and measures are put in place to allow the population to increase above the precautionary reference level. A precautionary level is established at 50% of the estimated pristine population size, while a conservation limit (or limit reference point) resulting in closure of commercial harvesting is established at 30% of the estimated maximum population size. It should be stressed that the percentages given above are just meant as an example, in this case taken from a framework suggested for the Northwest Atlantic population of harp seals. The suggested percentages resulted from a review of general models used in fisheries literature and of an approach developed in the conservation literature.

In the northwest Atlantic, it is required that populations have at least three abundance estimates, that the most recent abundance estimate is no more than 5 years old, and that recent data on fecundity or mortality rates are available – otherwise the population would be considered data poor, and requires a more risk adverse approach to their management. In data poor situations, the uncertainty associated with the resource's status and the impact of a particular management action increases and as a result, more caution is required. This could be accomplished by identifying the maximum allowable removals that will ensure that the acceptable risk of the population falling below this reference point is only 5%. This level has been referred to as the Potential Biological Removal (PBR) and can be approximated using default values and an estimate of abundance. Since the only data required is an estimate of population size, this or a similar approach is appropriate for data poor species. The PBR approach has the added advantage that the simulation trials used to establish the appropriate population size (N_{Min}) ensured that the formulation is robust when the model assumptions are relaxed and plausible uncertainties are included.

ICES notices the similarity between the suggested framework for seals and the framework used in the management of fish resources. ICES will further develop the seal framework and will propose reference points, if possible, for the different harp and hooded seal populations.

As yet, no reference points are proposed for the individual stocks of harp and hooded seals in the Northeast Atlantic. Until such reference points are established ICES suggests that harvesting could be continued at recent levels or at levels that will sustain the stocks at present level with high probability."

Evidently, ACFM has given WGHARP the green light to further define BRPs, if possible, for the different harp and hooded seal populations. There is one important correction to be made to the ACFM response: ACFM defines the N_{70} (70%) level as a target reference point. This is not correct – the N_{70} level is meant to be a first precautionary reference point. When a population falls below the N_{70} level, conservation objectives are assumed to play a greater role in the setting of harvest levels, and measures are put in place to allow the population to recover to above the precautionary (N_{70}) reference level. When the population is between N_{70} and N_{100}, managers are virtually free to set harvest levels that may either reduce, stabilise, reduce or increase the population. N_{50} is a second precautionary reference point where more strict control rules must be implemented, whereas the N_{30} reference point is the ultimate limit point at which all harvest must be stopped.

WGHARPs summary from Archangelsk

At the WGHARP meeting in Archangelsk we agreed on a number of points that will help define BRPs for harp and hooded seals:

1. There is a common management framework (now also accepted by ACFM) that can be applied to different stocks though reference points and control rules may be different for different stocks. As such, a hierarchy of reference points can be defined for different stocks
2. Abundance is the metric to be used in establishing the reference points, though other population metrics (e.g., condition) will be useful in establishing management response
3. The use of N_{MSY} and N_{LOSS} is inappropriate for marine mammals.
4. The carrying capacity of the environment ('K') is difficult to estimate for seals and, therefore, should not be used as an upper reference point for these populations
5. Some stocks will be considered data poor and will be managed under a different set of control rules. This argues for frequent (every 5 years or less), precise (CV < 30%) abundance surveys.
6. The method of assessing harp and hooded seals demands periodic estimates of pup production. Given the high proportion of pups in the current harvest, there will be a time lag between a harvest and when the effects of that harvest will be evident in the breeding population (owing to the delay between birth and sexual maturity), it is important to ensure that there are precautionary reference levels that allow for this time lag.

WGHARP also identified several technical issues that would have to be resolved. These include:

1. How should the reference points be defined? For example, should N_{CRIT} be defined on a purely biological basis or are both biology and economics relevant?
2. How are data rich, data poor and data inadequate stocks defined, and what rules should be applied for managing these stocks?
3. What control rules are appropriate for the various states of the stocks?

Where do we go from here?

The last three unresolved technical questions are obviously something WGHARP must address. The question of data rich vs. data poor is important. There is an obvious lack of recent data on hooded seals in all areas. Therefore, the subgroup suggest that WGHARP postpone any BRP-discussion involving hooded seals until updated relevant information is available (i.e., after 2005 when there are plans for hooded seal surveys both in the northwest Atlantic and in the Greenland Sea). The primary focus in this first phase will therefore be harp seals.

The northwest Atlantic population of harp seals is the most data rich - the availability of data from this population is better than for both the White Sea population and the Greenland Sea population, although we have recent abundance estimates for both the latter. Our Canadian colleagues are quite close to having developed a set of BRPs for the northwest Atlantic harp seals. The subgroup feel that it might be possible also to develop BRPs for the two remaining harp seal populations using the same framework as in the west.

Nevertheless, this does not prevent us from establishing a conceptual framework for 'data rich' vs. 'data poor' stocks that applies to both harp and hooded seals. In the original framework for the northwest Atlantic harp seals it was suggested that 'data rich' could mean a stock has a minimum of 3 surveys with the most recent less than 4 years old, along with data on reproduction rates and harvests – with these data it was assumed that a reasonable evaluation of the population dynamics could be made. Estimates of mortality would be nice but hard to obtain other than as estimated by the models. Anything else could be considered 'data poor'.

The subgroup also considered that data poor versus rich stocks could be defined based on the following characteristics of the available survey data:

1. Precision of the survey (there needs to be a CV threshold (#30%?) for the survey to be considered useful);
2. Completeness of the data (e.g., should surveys of less than the majority of the full stock's range be considered poor?);
3. Age of the most recent survey (this perhaps should not be greater than 5-8 years);
4. Frequency of the surveys (we need multiple, relatively recent surveys to be able to discern trends and properly manage the stock – this could be a time series of 3 or more surveys);
5. Time interval between surveys (back-to-back surveys have some problems and probably should just be averaged, but surveys spaced a decade apart also have some issues in the management process - the period between surveys should be greater than 1(?) year but less than 5-8(?) years).

Ultimately, WGHARP needs to agree upon these guidelines. They will be important for the design of a future monitoring scheme for the stocks in question This is basically the approach suggested in the original framework for northwest Atlantic harp seals, so that data poor stocks default to PBR, and the 3-tiers take on a different meaning. This should apply to both harp and hooded seals. Some default control rules on how to use PBR with data poor stocks are necessary, and could be:

1. If stock has no adequate abundance estimates, then no harvest should occur.
2. If stock has 1 recent, precise abundance estimate, and the abundance is greater than N_{lim}, use PBR.
3. If the stock has >1 recent, precise estimates, and abundance is greater than N_{lim}, use the appropriate WGHARP models (assuming that data is available to support the models).

The percentages chosen in the original suggested Canadian framework (the '3-tier') were 70 (first precautionary), 50 (second precautionary) and 30 (limit). The subgroup agrees that these values could be appropriate also for the other harp seal populations (and presumably also for the hooded seals). The 30% threshold may need more discussion - it may for example not be precautionary for inherently small stocks. On a longer term, probably all precautionary levels (buffers and limits) should be worked out for each actual species. Some work on these issues is now in progress, including modelling which is looking at the implications of setting reference points at various levels considering the fact that pup production surveys are used as basis, and harvest contains mostly pups. Once these studies are completed we may have a better feel for appropriate levels for reference points.

WGHARP has previously stated that it was not particularly happy with the ACFM suggestion that the lower limit reference point could be the historical minimum population. The subgroup thinks that while the historical minima is informative of the stock's ability to recover, it doesn't seem like a particularly useful approach to establishing N_{lim} because:

1. Probably only northwest Atlantic harp seals have the data to even support this approach, and

2. Just because a stock has recovered from this level once doesn't mean it will next time.

The subgroup suggests WGHARP use the data only to evaluate the N_{lim} chosen.

The maximum population size is also an important matter that needs to be solved for each population. We understand that in Canada the present population size is used as maximum size in the BRP framework. Would that be an appropriate approach also for the White Sea population? And what about the Greenland Sea population? This is something for WGHARP to consider.

<u>White Sea harp seals</u>

The White Sea population is another likely candidate to fit into a BRP framework because the availability of recent data is relatively good. The subgroup has noticed that this population had shown recent characteristics that could be indications of density dependent reactions (reduced reproductive rates, occasional invasions of seals to new areas (Norway) resulting from food shortage in traditional areas). Thus, the present population size could be close to what could be expected as a maximum for this population. Looking at the exploitation history may also support this view.

The initial fishery was shore based, taking place along the coasts of the White Sea and around the Kanin Peninsula, and presumably of a very small magnitude. Offshore hunting started in 1867. Prior to 1875 there were many years without catch information at all, but it is assumed that the catches were probably quite small, supposedly annually in the hundreds. After 1875 the total catches increased, with levels between 15 000 and 60 000 up to around 1900, above 100 000 after this year, and with the largest catches taken in the 1920s and 1930s (annual average of 200 000 – 300 000 animals). The catch numbers prior to World War II are very unreliable, and most probably only the numbers available from 1946 on should be used in any analyses.

While exploitation was low during World War II, the total hunting pressure increased from 1946 on with average catches between 150 000 and 200 000 up to 1955. Quotas for the Soviet catches were introduced unilaterally in 1955 (100 000 seals) and were gradually reduced until 1965 when a quota of 34 000 seals was implemented for the total catch (taken by Norway and Soviet together). Adult females were protected in the whelping patches from 1963, and Soviet catches of 1+ seals were stopped in 1965. Catches increased in the late 1970s and in the 1980s (annual quotas increased to 50 000 in 1977, 60 000 in 1981, 75 000 in 1982, a maximum of 82 000 in 1983, then decreased to 80 000 in 1984-1987). The total quota was reduced to 70 000 in 1988 and further down to 40 000 in 1989-1998. Although there is no hard evidence of changes in population size of White Sea harp seals from the 1960s onwards (no time series available), there may be good reason to expect an increase in numbers owing to the implementation of several catch regulations such as full protection of whelping females from 1963, a stop in Soviet catches of 1+ animals and a general decrease in catches due to a new quota system from 1965, and the general lack of capacity to take recommended TACs in the most recent (15) years. In 2004 there was no harvest at all from this population, and the majority of catches in 1965-2003 were pups.

The mean number of animals taken annually in 1946-2004 from the White Sea population is 72 588. From 1953 on, the catch statistics are split between pups and age 1+ animals. The average annual numbers of pups and 1+ animals taken for the period 1953-2004 were 40 445 and 18 696, respectively. If we let one 1+ animal be balanced by 2.5 pups (as is done in quota allocations), the total annual number of "1+ equivalents" in the period would be 34 874. The present level of "sustainable removal" is 45 200 1+ animals (if $M_{1+} = 0.09$ and $M_0 = 5\ M_{1+}$). The Russian aerial surveys in 1998-2003 have yielded results that may indicate some stabilization in pup production.

<u>Greenland Sea harp seals</u>

For the Greenland Sea harp seals the data availability has improved due to a successful aerial survey of pup production in 2002. There are no signs of reductions in reproductive rates or other indications of possible density dependent effects. It would, therefore, be more difficult to come to conclusions about maximum population size. The history of exploitation may, however, give some guidance to what could be expected:

The Greenland Sea (West Ice) stock of harp seals has been subject to commercial exploitation for centuries. Knowledge of the Greenland Sea catches in the 18th and the first two-thirds of the 19th century, performed by Dutch, British, German and Danish ships, is poor. Norwegian sealers appeared for the first time in the Greenland Sea in 1846, and have subsequently participated with increased effort. Exploitation levels reached a historical maximum in the 1870s and 1880s when annual catches of harp seals (pups and adults) varied between 50 000 and 120 000. This assumed overexploitation probably drove the stock to an all time low, and the competition for a limited supply of seals in the 1870s resulted in the disappearance of all non-Norwegian fleets. It was evident that the catch levels in the 1870s were higher than the stock could sustain, and some regulatory measures (mainly designed to protect adult females) were taken in 1876. In the first decades of the 20[th] century the annual harp seal catches varied between 10 000 and 20 000 animals, whereas an increase to around 40 000 seals per year occurred in the 1930s.

The pre World War II catch statistics is even more uncertain for this population than for the White Sea population. Analyses should therefore only include data from 1941 on. After a 5 year pause in the sealing operations during World War II, total annual catches quickly rose to a postwar maximum of about 70 000 in 1948, but then followed a decreasing trend until quotas were imposed in 1971. From 1955 to 1994 a minor part of the catches were taken by the Soviet Union / Russia, and the total annual catches have varied between a few hundreds to about 17 000 from 1971 to present. It is likely that the population may have increased in size after 1971.

The mean number of animals taken annually in 1946-2003 from the Greenland Sea population is 17 092 (12 684 pups, 4408 1+ animals, 10 750 "1+ equivalents"). The present level of "sustainable removal" is 8 200 1+ animals (if M_{1+} = 0.12 and $M_0 = 3\ M_{1+}$).

<u>BRPs for the northeast Atlantic harp seal stocks?</u>

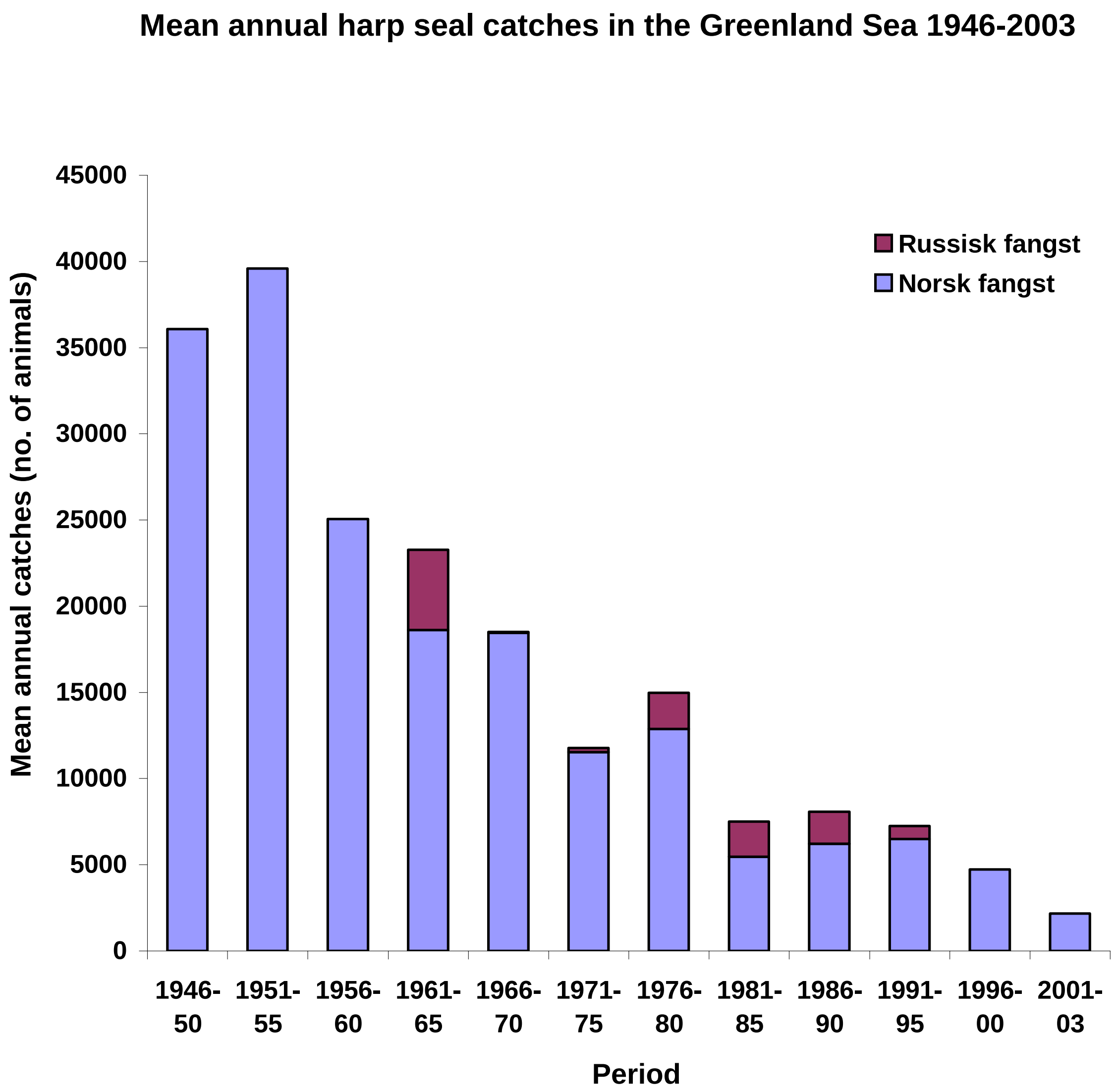
Would it be appropriate to define present White Sea harp seal population level as the maximum that could be expected given the present state of the Barents Sea / White Sea ecosystem? And is it appropriate to say something about the present Greenland Sea harp seal population level in relation to the maximum that could be expected given the present state of the Greenland and Barents Sea ecosystems? Recent tagging experiments with satellite tags have shown that this population also uses the Barents Sea as feeding grounds in summer and autumn.

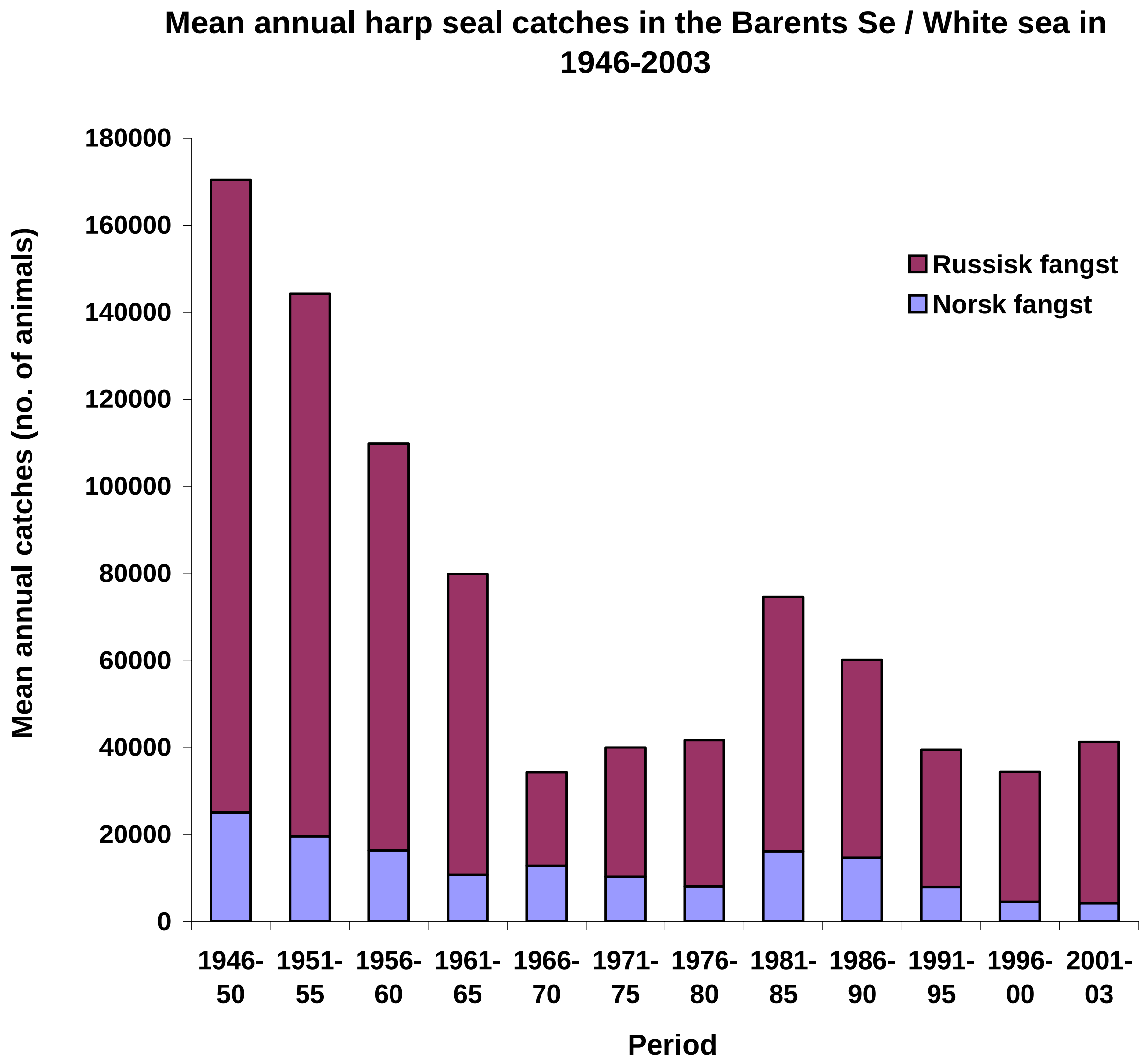
We know that the northwest Atlantic harp seal population increased rapidly when the Canadian catches were substantially decreased in 1982-1995. Greenland catches from the same population have increased in the same period. In the northeast Atlantic the hunting pressure has been reduced, as compared with previous catches, for a much longer period (from 1965 in the White Sea population, from 1971 for the Greenland Sea population). The hunting pressure is still low in both these populations. The mean annual number of 1+ equivalents taken from the White Sea population in 1966-2004 is 27 000. A comparable number for the Greenland Sea population in 1971-2003 is 6 100 1+ equivalents. Is it likely that the low hunting pressure in the recent 3-4 decades can have resulted in similar development in the northeast Atlantic harp seal populations as that seen in the northwest?

The subgroup felt that it might be possible to develop and suggest BRP frameworks for the two northeast Atlantic populations under the following conditions:

1. WGHARP agrees that 3-tier framework is only applicable to data-rich stocks. WGHARP must also agree to how we would manage data-poor stocks. If WGHARP agrees that the two northeast Atlantic harp seals stocks are data-rich then we can move to the next step in the discussion.
2. The subgroup suggests that WGHARP use for N_{max} the highest recorded abundance estimate in the time series, which meets our precision/accuracy criteria for a good estimate (not the 5-year rule though). Using the current population estimate doesn't necessarily satisfy the conceptual model (where $N_{max} \sim K$). When the current estimate is lower than the historical maxima, this approach is less precautionary; otherwise, it is an OK approach.
3. N_{70} and N_{50} would then be set for these stocks as a direct function of N_{max}
4. Finally, WGHARP should think about the N_{lim} idea. Does the group conceptualise this as the point where we would consider listing the species as threatened under the Canadian Species At Risk Act (SARA; www.sararegistry.gc.ca) and US Endangered Species Act (www.nmfs.noaa.gov/prot_res/overview/es.html), while the N_{70} equates with the point where Canada would list the species as of special concern under SARA or the US as depleted under its Marine Mammal Protection Act (www.nmfs.noaa.gov/prot_res/overview/mm.html)? If yes, then we can provide some new guidance on this.

For your help, we also include figures showing annual catches of harp seals from the Greenland Sea and the Barents Sea-White Sea in 1946-2003. Russian (red) and Norwegian (blue) catches are indicated. We apologize the mix of Norwegian and English legends.


Mean annual harp seal catches in the Greenland Sea 1946-2003
Mean annual catches (no. of animals)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
Russisk fangst
Norsk fangst
1946-50
1951-55
1956-60
1961-65
1966-70
1971-75
1976-80
1981-85
1986-90
1991-95
1996-00
2001-03
Period


Mean annual harp seal catches in the Barents Se / White sea in 1946-2003
Mean annual catches (no. of animals)
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
Russisk fangst
Norsk fangst
1946-50
1951-55
1956-60
1961-65
1966-70
1971-75
1976-80
1981-85
1986-90
1991-95
1996-00
2001-03
Period

3 On The Transfer of Seal Quotas

The Institute of Marine Research (IMR) in Norway has received a question from the Norwegian Ministry of Fisheries (NMF) regarding sealing in the Greenland Sea:

NMF refers to the fact that Canada is now giving 3-year-quotas for harp seals with some flexibility to transfer "unharvested" animals over from one year to another. Their question is if something similar could be done for the harp and hooded seal populations in the Greenland Sea. They are particularly interested if this would be possible for hooded seals (partly due to reductions in quotas based on the precautionary approach advice given by WGHARP in 2003). Would it be possible to transfer "unused" quotas from one year to the next? In this case it would mean transferring quotas unused in 2004 to be added to the 2005 quotas.

Quotas set and catches in the Greenland Sea in 2004 were:

Harp seals:

Quota: 15 000 1+ animals (each 1+ animal equaling 2 pups). In the 2003 meeting WGHARP identified the sustainable catch level (that would stabilise the population at present level) as 8 200 1+ animals.

Catches: 8288 pups and 1607 1+ animals.

Hooded seals:

Quota: 5 600 1+ animals (each 1+ animal equaling 1.5 pups). In the 2003 meeting WGHARP identified the sustainable catch level (that would stabilise population at present level) under a precautionary approach as 5 600 animals (i.e., with no multiplier between 1+ animals and pups).

Catches: 4202 pups and 649 1+ animals.

NMF has requested that IMR, in close cooperation with WGHARP, consider this question and provide an answer in due time before the 2005 sealing season. Therefore, the question has been discussed by correspondence by WGHARP members.

When Canada allowed the harp seal quota roll over, it was based upon a very specific management goal (maximize economic return but keep the population above the first precautionary point). There was a good understanding of the population dynamics, and the impact of the harvest levels had been modelled. Also, it was a transfer of a small proportion (<10%) of the annual quota. Under these conditions, modelling did not find a large impact.

The Canadian management model set a three-year quota, including provision for transfers between years, at the start of the three year period under consideration. This is conceptually different from setting a one-year quota, and then in what appears to be an *ad hoc* fashion, thinking about carrying over some of the "unused" quota, when the hunts did not reach their targets. If NMF are referring to the Canadian 3-year quota system, and asking for advice, then perhaps the answer is to advise setting 3-year quotas, for example 2005-2007, or for a later period, with some levels of quota transfer which would have to be calculated by modelling. When Canada looked at the issue for harp seals, a maximum was set each year that allowed a carry over of ~7.5%. Given the low catches in the Greenland Sea the past few years, adding in the unused quota to the next year's could result in a very large take (primarily of pups) which might not be sustainable. Thus, developing an alternate management model that includes carrying over a small proportion of the annual quota seems reasonable. Nevertheless, unfilled quotas from 2004 seems irrelevant since advising quota transfers from the 2004 catches seems quite different from what the Canadian approach set out to do.

The Canadian process was also based upon a good understanding of the history and current status of the Northwest Atlantic harp seal population. Unfortunately, the situation in the Greenland Sea is very different; present knowledge of the status of the harp and hooded seal populations is much poorer. There are still no good population models for either of the species, although they are under development intersessionally by members of WGHARP. For hooded seals, the present knowledge is so incomplete that the latest advice was based on a PBR (Data poor) approach.

While the Canadian management model has an explicit management objective, management objectives for the northeast Atlantic stocks have been less clear. Based on a recent governmental white paper, however, the Norwegian Storting (Parliament) voted in support of a new management policy approach for marine mammals earlier this year. The policy includes:

- Facilitate adjustments of catch capacity to the resource base.
- Increase catch quotas for the harp seal stocks substantially from the current levels to reduce these stocks to levels that will give the maximum long-term harvest of seals.
- Increase the hooded seal stock level as compared with present level in order to get a better long term output.

It is emphasized that no harvest driven stock changes should be performed in such a way the resulting levels falls below precautionary or limit reference levels. The WGHARP subgroup, dealing intersessionally with questions relating to the implementation of biological reference points, has concluded that it might be possible, under certain conditions, to develop and suggest biological reference points for the two northeast Atlantic harp seal populations. This will certainly be a matter of discussion at the next WGHARP meeting next year, and WGHARP feels that any changes in the managements of the hunts of harp seals should await the results of this discussion.

Surveys of hooded seals are due in 2005, both in the Greenland Sea (last survey in 1997) and in Canada (last survey in 1990). In Canada there have been no changes in the hooded seal quotas in recent years because of the lack of current information on the status of the population. Decisions on the allowable catch of hooded seals will not be made until a new abundance estimate (from the 2005 survey) is available. It is unrealistic to define biological reference points for hooded seals before the 2005 estimates become available. With all the uncertainties relating to the Greenland Sea hooded seals it appears prudent to advise NMF to postpone any major change to the management of hunts of hooded seals until the 2005 surveys are carried out, and the results analysed.

To conclude, WGHARP feels that it cannot advice a quota rollover until more data is available (relates particularly to hooded seals) and some modelling and simulations are done. The latter should preferably be done with improved models which are presently, and intersessionally, under development and revision by a WGHARP modelling subgroup. Although the results for Canadian harp seals indicate that a rollover, especially a rollover of a single year, is not likely to have much of an impact it is not known if this applies to populations in the Greenland Sea. Nevertheless, this issue is best addressed at the next WGHARP meeting (30 August- 3 September 2005).That being so, WGHARP advises NMF that "unused" quotas from 2004 should not be transferred to 2005.

Appendix 1

Estimation of sensitivity of model of dynamics of number for White Sea/ Barents Sea harp seals to entrance parameters.

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Introduction

At last meeting of working group WGHARP in September in Arkhangelsk 2003г. it was recommended to estimate sensitivity of model of dynamics of number for for White Sea/ Barents Sea harp seals, used Working group, to entrance parameters. Detailed the model is described in work Skaug and Øien (Skaug and Øien, ICES CM 2001/ACFM:08, SEA-102). In this model in a population two age groups are considered only: recruitment (number of puppies) and an adult part of a population (age 1+). In 2003 Skaug and Øien have improved model, having entered age structure (0-20 years).

Using the description of model and algorithm of calculations from work Skaug and Øien, we in 2002 have developed the program of an estimation of number of a seal in EXCEL in two variants: a) without division of an adult part of a population on age, б) in view of age structure of a population. Results of the executed calculations of number of a population harp seal correspond to the results received by Working group ICES at use of the uniform entrance data (fig. 1). It has allowed us to execute check of sensitivity of model (realized in EXCEL) to entrance parameters.

Population dynamic model

That it was clear, about what parameters there is a speech, we repeat the brief description of 2 age models Skaug and Øien. All designations of parameters are accepted same, as well as at Skaug and Øien. In model the following parameters and designations are used**:**

K – Population size in 1945;
M_0 – Pup mortality;
M_{1+} - mortality among 1+ animals;
$P_{i,t}$ – proportion of females at age *I* being reproductively active in year *t*;
F - pregnancy rate.

As the population in model is not structured on age the special parameter (f) is entered, meaning a share самок in a population annually giving posterity:

$$f = F \frac{\sum_i p_i \exp(-iM)}{\sum_i \exp(-iM)} ,$$

t - index of year,

$N_{0,t}$ - Number of pups born in the year ***t***,
$N_{1+,t}$ - Number of adults alive at the beginning of year ***t***,
$C_{0,t}$ - Catch of pups in numbers in year ***t,***
$C_{0,t}$ - Catch of adults in numbers in year ***t,***

Values t change from 1 up to $T_{p.}$ (t: 1, …, T, … . T_p). Value t = 0 is used for initialization; t = 1 – the first year with catch data; t = T – year in which the estimation is done, , t = T_p – year for which the prediction is made. When $1 \leq t \leq T$ the historical catches are used. When t> T the catches are determined by the quota (with allocation of corresponding quotas on extraction of adult animals and puppies).

Development of adult population:

$N_{1+, 0} = K$,
$N_{1+, t} = (N_{1+, t-1} – C_{1+, t-1})\exp(-M_{1+}) + (N_{0, t-1} - C_{0, t-1}) \exp(-M_0)$, $t=1,…,T_p$.

Pup production:

$N_{0, 0} = 0.5fK$,
$N_{0, t} = 0.5f(N_{1+, t-1} - C_{1+, t-1})\exp(-M_{1+})$, $t=1,…,T_p$.

Input data:

- Values of parameters of model ((K, M_0, M_{1+}, f),
- Catch in numbers of pups and of 1+ animals in years.

Working group ICES on seals in 2000 г in calculations used the following values of biological parameters:

$K = 1799800$, $M = 0.1$, $M_0/M = 3.0$, $f = 0.42$, $p_5=0.1$,
$P_6=0.18$, $p_7=0.35$, $p_8=0.6$, $p_9=0.7$, $p_{10}=0.94$.
Data ICES on a catch of a seal are taken from work Skaug and Øien, ICES CM 2001.

Output data:

- Number of puppies,
- Number of adult seals.

As a measure of the future development of the estimated population, a quantity that relates future (T_p) witch current (T) is used ($T_p=T+10$):

$$D_{1+} = \frac{N_{T_p,1+}}{N_{T,1+}}.$$

If value $D_{1+} > 1$ it is considered, that a catch is conducted without damage to a population. On this basis quotas catch of seals are determined. Working group ICES on seals in 2000 г in calculations used the following values of parameters:
$K = 1799800$, $M = 0.1$, $M_0/M = 3.0$, $f = 0.42$ $\sigma =0,01$, $p_5=0.1$,
$P_6=0.18$, $p_7=0.35$, $p_8=0.6$, $p_9=0.7$, $p_{10}=0.94$, $p_{11}=1.0$.

The analysis of sensitivity of model.

The analysis of sensitivity of 2-ages model to change of parameters is executed in 2002 on the period of 1946-2010 with the entrance data from work Skaug and Øien (Skaug and Øien, ICES CM 2001).

Studying a degree of influence of separate parameters on behaviour of model, it is possible to estimate their importance from the point of view of approximation of model reality. It is possible to assume, that for a population of the harp seal, as well as for the majority of kinds of fishes of the Barents Sea, cyclic changes of number of a stock are characteristic. Taking into account periodicity of fluctuations of resulting characteristics of a population it is intuitively clear, that their sensitivity change of separate parameters in different points of a vital trajectory of a population will be various. Two basic conclusions from here follow: first, a measure of sensitivity of model should be average size of a deviation of the resulting characteristic, caused by change of any parameter, on all interval of time during which changes of an investigated stock is reproduced; second, this interval should be big enough and contain in itself some full cycles of changes of an examined parameter.

In the executed analysis we changed values of parameters f, K M_0, M_{1+}/M_0 on ±1, 2, 3, 4, 5 % and 10 % from their estimations used by Working group IKES are consecutive. As a measure of sensitivity of model we considered average (for the period 1946-2010) a deviation of number of an adult part of population (age 1 +) from initial value. During researches 64-years dynamics of a stock (1946-2010) was simulated. Results of the analysis are reflected in Table 1 and on Figure 2.

Table 1.

Deviations of number of an adult part of a population of harp seal (in %), caused by change of values of parameters of model

Change of value of parameter (%)	f	K	M_0	M_1+/M_0
+1	10.85	5.48	-9.60	-2.37
+2	22.56	10.97	-18.47	-4.69
+3	35.22	16.45	-26.65	-6.95
+4	48.87	21.94	-34.21	-9.15
+5	63.60	27.42	-41.17	-11.31
+10	156.20	54.84	-68.62	-21.34
-1	-10.03	-5.48	10.40	2.43
-2	-19.31	-10.97	21.65	4.92
-3	-27.87	-16.45	33.84	7.47
-4	-35.78	-21.94	47.02	10.08
-5	-43.07	-27.42	61.27	12.76
-10	Collapse in 1989.	-54.84	151.96	27.16

The submitted data testify that the greatest relative changes of number of harp seal causes change of a share females in a population, giving posterity, (a variable f) and natural mortality (M_0). At increase of absolute value of parameter f the relative mistake is higher, than at reduction of his value (see tab. 3.). Change of value of parameter f on +3 % results in change of average for the period of value of number of adult more than on +30 %, and change on +5 % - more than on +60 % accordingly. At increase in a relative mistake f up to 5 %, change of a relative mistake of number on years accepts parabolic character (fig. 5), and the mistake (2010) grows by final year of the considered (examined) period up to +150 %. At reduction of value f on 5 % the deviation of number of seals approximately in 2 times is less, than at increase, and the mistake for (2010) year achieves 87 % (fig. 5). Thus, reaction of model to reduction of value f is weaker, than on increase in his value.

Natural mortality of adult animals (M_{1+}) is accepted equal $3M_0$. Sensitivity of model change of value of relation M_{1+}/M_0 in 4 times is higher, than to change of value M_0.

The parameter f calculation on the basis of shares proportion of females at age being reproductively active (p_i, i=1,…,10) which are accepted by constants for all years and parameter F. Hence, accuracy of an estimation f depends on accuracy of values of these parameters. The analysis of sensitivity of parameter f to change of values of parameters p_i.и F shows, that the greatest changes f are caused by changes of values of a share proportion of females being reproductively active in old ages (in the age of 8-10 years) (tab. 2).

Table 2.

Influence of change of values of parameters F and P5-P10 (shares половозрелых animals in the age of 5-10 years) on size of parameter f.

	Deviation of values of parameter f (%) from initial size						
Change (in %) values of parameters F and P	**F**	P_5	P_6	P_7	P_8	P_9	P_{10}
+1	0.84	0.04	0.06	0.11	0.17	0.18	0.22
+2	1.68	0.08	0.13	0.22	0.34	0.36	0.44
+3	2.52	0.12	0.19	0.33	0.52	0.55	0.66
+4	3.36	0.15	0.25	0.44	0.69	0.73	0.88
+5	4.20	0.19	0.32	0.55	0.86	0.91	1.10
+10	8.40	0.39	0.63	1.11	1.72	1.82	2.21
-1	-0.84	-0.04	-0.06	-0.11	-0.17	-0.18	-0.22
-2	-1.68	-0.08	-0.13	-0.22	-0.34	-0.36	-0.44
-3	-2.52	-0.12	-0.19	-0.33	-0.52	-0.55	-0.66
-4	-3.36	-0.15	-0.25	-0.44	-0.69	-0.73	-0.88
-5	-4.20	-0.19	-0.32	-0.55	-0.86	-0.91	-1.10
-10	-8.40	-0.39	-0.63	-1.11	-1.72	-1.82	-2.21

In Table 2 results of change of value of parameter f are shown at change only one of parameters F, p_5-p_{10} (for example, p_5), thus other values do not change. If to assume, that we were mistaken at an estimation of a proportion females being reproductively active of all on 2 % at each age (5-10 years), and in one party (i.e. or have overestimated or have underestimated) value of parameter f will change on 1,6 % (Table. 3) that will correspond to change of number of an adult part of a population approximately on 15-20 %.

Table 3.

Change of values of parameters f depending on simultaneous change of parameters P_{5}-P_{10} (shares половозрелых animals in the age of 5-10 years).

		Change of parameters p_5-p_{10}, %								
Change of parameter **f**	1	2	3	4	5	6	7	8	9	10
	0.79	1.57	2.36	3.15	3.94	4.72	5.38	5.94	6.51	7.08

Age structure of a population.

At meeting WGHARP in Arkhangelsk in 2003 Skaug has transferred to us the program (with age structure) which was used in Arkhangelsk by Working group for an assessment and prognoses of a catch of seals. Using this program, we have tried to estimate possible(probable) deviations of number the populations connected to change of age structure of a population.

First we have defined competency of use of the model translated in EXCEL, in comparison with the original of model Skaug and Øien. We have executed calculations similar to calculations of Working group, having transformed 20-ти age model Skaug and Øien in 2-age (puppies – 0 group and adult animals age 1+) model, and have compared them to calculations on 2-age models, realized in EXCEL. Under both programs we have received close estimations (Table 4).

Table 4.

An estimation of number of harp seals in 2003 models with different age structure.

	M_{1+}=3M_0			**M1+=5M_0**		
	M_0=0.09	M_0=0.10	M_0=0.11	M_0=0.09	M_0=0.10	M_0=0.11
	Number of adult animals					
WG 2003	2058000	1961000	1867000	1829000	1720000	1616000
Skaug 2age	1922000	1839000	1759000	1772000	1680000	1592000
EXCEL 2age	1889837	1840802	1751760	1768759	1669161	1574714
Skaug 10age	2088000	1990000	1895000	1860000	1750000	1634000
EXCEL 10age	2070819	1987499	1879403	1851613	1734875	1624884
	Number of pups					
WG 2003	341900	328900	316100	329600	315600	301600
Skaug 2age	354000	340000	325900	332900	317100	301700
EXCEL 2age	348545	340290	324661	332373	314979	298375
Skaug 10age	338800	326000	331400	326800	312900.0	298300
EXCEL 10age	336377	325750	311045	325589	310506	295967

Forecasts of development of a stock till 2013 are practically identical are received on both models (tab. 6).

Table 6.

$M_{1+}=3M_0$

Option *	Catch level	Proportion of 1+ in catches	Pup catch	1 + catch	D1 +			D_{1+} Point				Skaug 2age
M_{1+} = 0.09					Lower CI	Point	Upper CI	Skaug 2age	EXCEL 2age	EXCEL 10age	Skaug 10age	
1	Current	7 % (current level)	37979	2992	1.29	1.3	1.31	1.5	1.5	1.3	1.3	1.5
2	Sustainable	7 %	152706	11494	0.93	0.98	1.02	0.99	0.99	0.94	0.94	0.99
3	Sustainable	100 %	0	75500	1.01	1.05	1.08	1.25	1.25	0.99	1.02	1.25
4	2 X sust.	7 %	305412	22988	0.45	0.53	0.62	0.43	0.33	0.52	0.51	0.43
5	2 X sust.	100 %	0	151000	0.62	0.69	0.76	0.84	0.84	0.61	0.66	0.84
M_{1+} = 0.10												
1	Current	7 % (current level)	37979	2992	1.03	1.05	1.07	1.3	1.3	1.12	1.12	1.3
2	Sustainable	7 %	97743	7357	0.96	0.99	1.01	1.05	1.05	0.96	0.96	1.05
3	Sustainable	100 %	0	47500	1.01	1.03	1.05	1.21	1.21	0.99	1	1.21
4	2 X sust.	7 %	195486	14714	0.66	0.71	0.77	0.64	0.64	0.68	0.69	0.64
5	2 X sust.	100 %	0	95000	0.77	0.81	0.85	0.96	0.96	0.75	0.79	0.96
M_{1+} = 0.11												
1	Current	7 % (current level)	37979	2992	1.01	1.02	1.03	1.14	1.14	0.99	0.99	1.14
2	Sustainable	7 %	46686	3514	0.99	1	1.01	1.10	1.10	0.97	0.97	1.10
3	Sustainable	100 %	0	22380	1.01	1.02	1.03	1.18	1.18	0.98	0.99	1.18
4	2 X sust.	7 %	93372	7028	0.84	0.87	0.89	0.91	0.91	0.84	0.84	0.91
5	2 X sust.	100 %	0	44760	0.89	0.91	0.93	1.06	1.06	0.87	0.89	1.06

$M_{1+}=5M_0$

Option *	Catch level	Proportion of 1+ in catches	Pup catch	1 + catch	D1 +			D1 + Point				
$M_{1+} = 0.09$					Lower CI	Point	Upper CI	Skaug 2age	EXCEL 2age	EXCEL 10age	Skaug 10age	
1	Current	7 % (current level)	37979	2992	1.15	1.16	1.17	1.22	1.22	1.13	1.13	1.22
2	Sustainable	7 %	102486	7714	0.96	0.99	1.01	0.97	0.97	0.96	0.96	0.97
3	Sustainable	100 %	0	45100	1.01	1.03	1.05	1.12	1.12	1.21	1	1.12
4	2 X sust.	7 %	204972	15428	0.65	0.71	0.76	0.59	0.59	0.64	0.69	0.59
5	2 X sust.	100 %	0	90200	0.76	0.8	0.85	0.87	0.87	0.71	0.78	0.87
$M_{1+} = 0.10$												
1	Current	7 % (current level)	37979	2992	1.01	1.02	1.03	1.04	1.04	0.99	0.99	1.04
2	Sustainable	7 %	45198	3402	0.99	1	1.01	1.02	1.02	0.97	0.97	1.02
3	Sustainable	100 %	0	19350	1.01	1.02	1.03	1.08	1.08	0.99	0.99	1.08
4	2 X sust.	7 %	90396	6804	0.86	0.88	0.9	0.86	0.86	0.85	0.85	0.86
5	2 X sust.	100 %	0	38700	0.9	0.92	0.94	0.98	0.98	0.88	0.9	0.98
$M_{1+} = 0.11$												
1	Current	7 % (current level)	37979	2992	0.88	0.89	0.9	0.89	0.89	0.86	0.86	0.89
2	Sustainable	7 %	1302	98	1	1	1	1.02	1.02	0.96	0.98	1.02
3	Sustainable	100 %	0	900	1	1	1	1.02	1.02	0.96	0.99	1.02
4	2 X sust.	7 %	2604	196	0.99	0.99	0.99	1.02	1.02	0.96	0.98	1.02
5	2 X sust.	100 %	0	1800	0.99	0.99	0.99	1.02	1.02	0.95	0.98	1.02

Unique difference in calculations on two 2-age models is marked in a variant « $\mathbf{M_0 = 3M_{1+}}$**., M0=0.09, 2 X sust ».** We cannot explain, than it is caused. Also we cannot explain a unique divergence in values D_{1+} by our calculations (on model Skaug and Øien with 20 age structure) and on the data resulted in the report of Working group. In a variant « M_{1+}=3M_0, M_{1+}=0.10, Catch level = current » we have received value D_{1+} =1.15, and under the report of Working group in this variant D_{1+} =1.05.

Insignificant distinctions in estimations on two 2-age models allow to draw a conclusion, that estimations of sensitivity of the model executed in EXCEL can be accepted and for model Skaug and Øien. At the same time, the executed calculations on 10-age model show, that with introduction in model of age structure results of estimations vary with increase in number of age groups though these changes are not so great. Calculations on 2, 10 and 20-age show model, that change of number of a population in 2003, connected to age structure makes from 3 up to 8 % for an adult part of a population, and 2-4 % for puppies at change M_{1+} from 0.09 till .

The conclusion.

The brief analysis shows various dependence of change of results of an estimation of number of seals, on change of values of entrance parameters. Most strongly 2 age model reacts to change of parameter f**.** Introduction in model of age structure for an adult part of a population, reduces this influence a little. However the role of parameter F (a birth rate among reproductively active females) considerably grows. In our opinion the further perfection of model of dynamics of number should go on a way of specification of values of entrance parameters. At the first stage at absence of techniques of definition of values of natural mortality, age of puberty, a birth rate among reproductively active females it is necessary to include in model an estimation uncertainty connected with these parameters by their casual choice from the certain range of values, using, for example, a method of Monte Carlo or a method bootstrap.

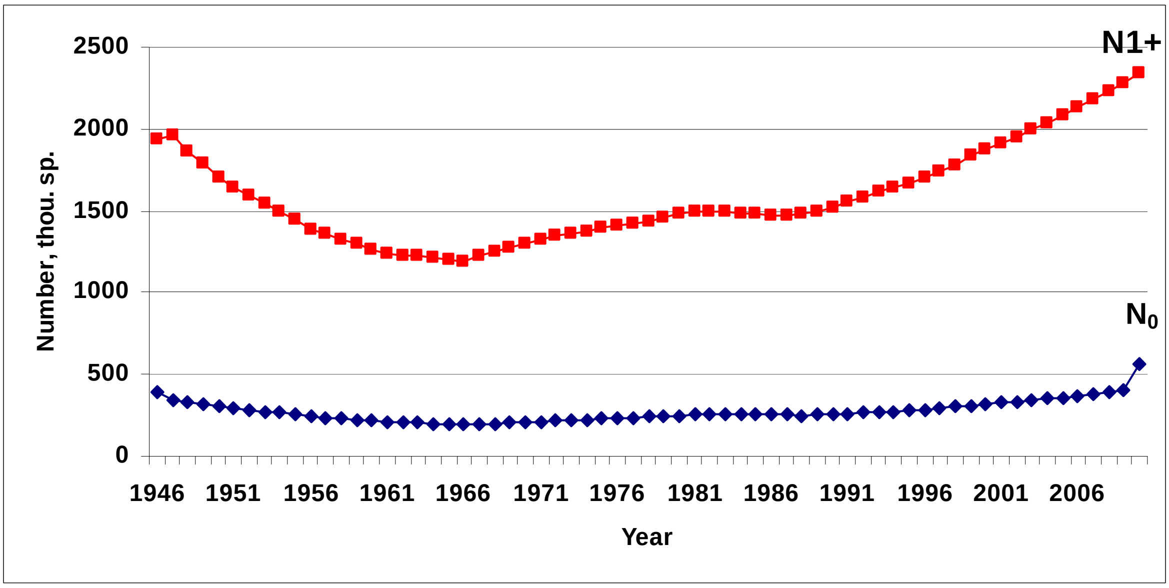

Figure 1. Estimation of number White Sea / Barents Sea harp seal in 1946-2010.
N_0 - number of pups,
N_1 - number of adult animals.

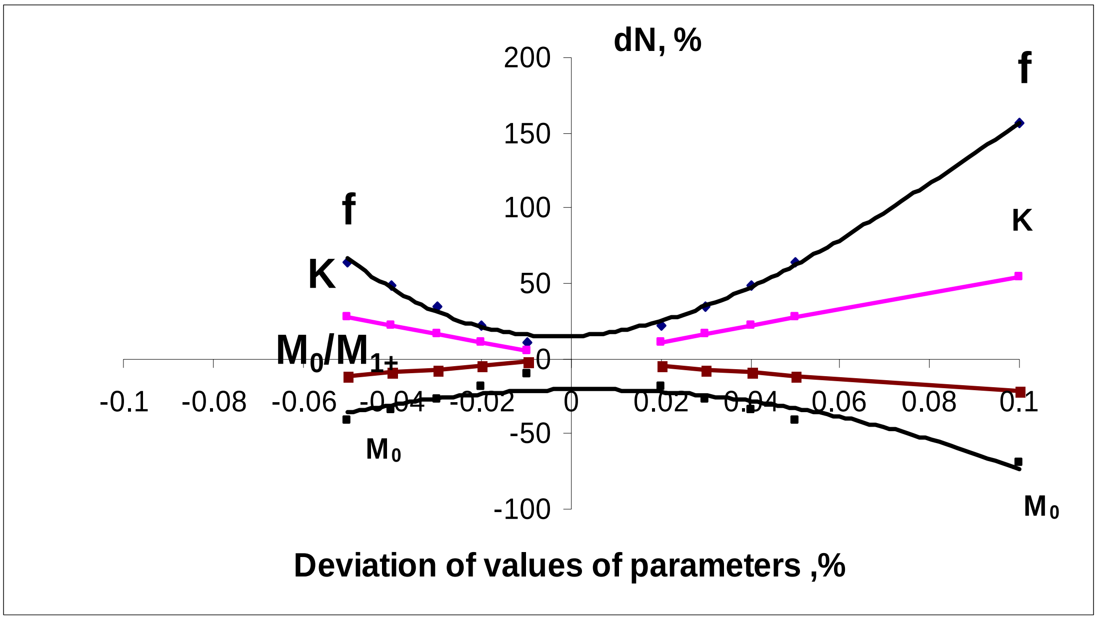

Figure 2. Influence of change of values of parameters f, K, M0 and M0/M1 + on average value of number of a population for the period (1946-2010).
dN-deviation of number of adults, %

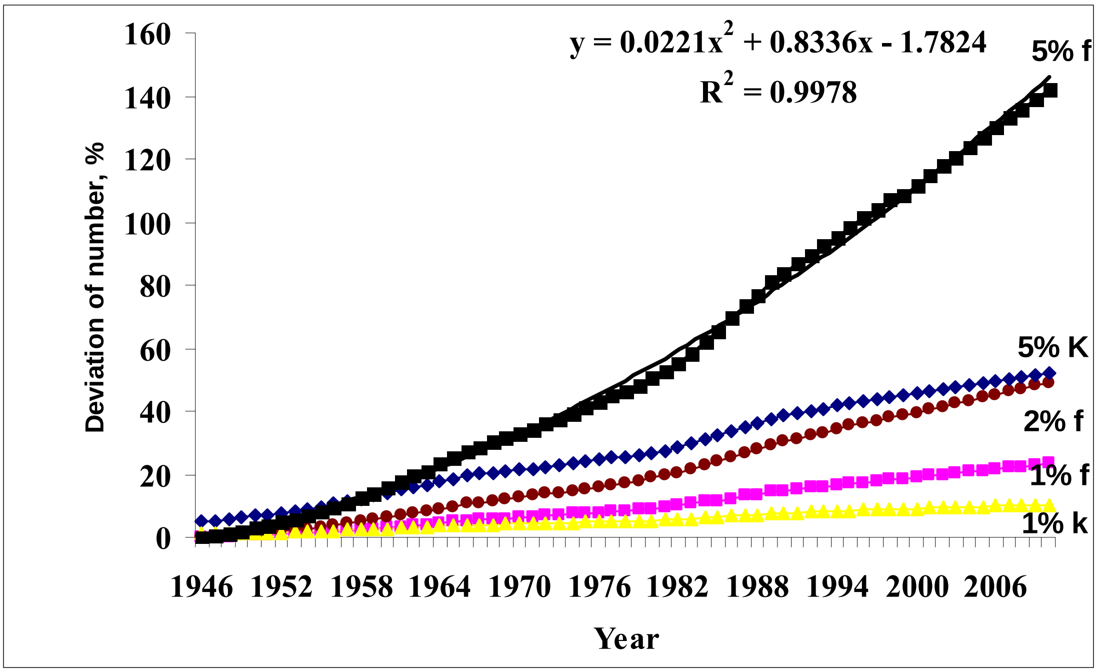

Figure 3. Change of number of an adult part of a population depending on changes параметров.f and K.

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Appendix 2

Sensitivity Analysis 071204

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1 Model must fit data

In our case there is a one-dimensional output from the model: The abundance in terms of number of seals at a particular year at one specific age or accumulated over several ages, e.g. pups and 1+ animals. Traditionally a sensitivity analysis then consists of analyzing how sensitive the output of the model is to changes in parameter values, one at a time, keeping the other parameters fixed.

The only parameter estimated is K, while the other parameters are changed deliberately. It is important to note that when each of these other parameters are changed, K should be estimated each time so that the model all the time is fit to data, e.g. the four pup abundance estimates from 1998, 2000 and 2002 along with the catch data from 1946.

2 Comparison between two-age and multi-age models

In the two-age model, the parameter f is introduced as the ratio between pups and 1+ females. Under equilibrium conditions f will be a constant, but the f-value will change from year to year when catch data are taken into account, and when parameter values that are not in accordance with the equilibrium condition are used. A two-age model approach where, for each run, the average f-value over years calculated by the multi-age model is therefore applied. In addition, a non-recursive model description is outlined that e.g. provides simple explicit expressions for the K-estimator as well as its variance. The outline of the non-recursive model is rather technical and is enclosed in the pdf-file "wgharphabitzmod04". Comparisons between the two models as a function of time (year) are shown in Figure 1 and 2 in terms of pup and 1+ abundances for different choices of M and M0/M. As a conclusion the two-age model deviates negligibly from the multi-age model, but requires input from the multi-age model to calculate an average f-value over years.

3 Model equivalent to exponential growth

It is useful to have in mind that the applied model is synonymous with exponential growth if no catch takes place: If the parameter values are chosen in accordance with an equilibrium condition without catch (exponential model with growth rate equal to zero), the catches will gradually decrease the abundance to zero. An instantaneous catch will result in a new equilibrium state at a lower level. For a choice of parameter values that are not in accordance with equilibrium, the abundance will either increase exponentially towards infinity, or decrease exponentially towards zero, if no catch takes place.

A principal problem is that equilibrium conditions are assumed at 1945 and used to initiate the relation between pup and 1+ abundances in 1945, which corresponds to equilibrium parameter values, while non-equilibrium parameter values are used in all the actual runs of the model.

4 On the M0/M and N1+/N0 ratio

Two cases for the ratio M0/M are applied: 3 and 5. To our knowledge there is no justification in terms of data for this choice. Under equilibrium conditions, however, when f is given, there is a one-to-one correspondence between M0 and M. This is shown in Figure 3 for $f = 0.3$, 0.4 and 0.5, where $f = 0.4$ is close to the results from the multi-age runs. Interestingly, for $f = 0.4$ the ratio M/M0 varies between 7.5 and 5 as M varies from 0.09 to 0.11, and M0 is generally decreasing very fast as a function of M. This might indicate that also larger ratios than 5 should be applied.

In Figure 4 is shown how the ratio N1+/N0 varies over years with different M/M0 ratios for different values of M. As is seen, the N1+/N0 ratio varies roughly between 5 for M/M0 = 7 to 6 for M/M0 = 3, with more modest variations for different M-values. This indicates that the N1+/N0 ratio is not very sensitive to changes in the M0/M ratio, which might indicate that reasonable estimates of the pup abundance also provides reasonable estimates of the 1+ abundance.

5 The K-parameter

For a given choice of M, M0 and f, the K-value is estimated rather precisely. This must not be interpreted, however, as if the “carrying capacity” is precisely estimated, because the K-estimator is very sensitive to the choice of the parameters that are not estimated. This is clearly shown in Figure 2, right panel, where K is estimated to roughly 4 million for M = 0.11 and to roughly 2 million for M = 0.09, when M0/M = 5. This indicates that the term carrying capacity in this context makes little or no sense.

Another interesting feature shown in Figure 2, right panel, is that the abundance in 2002 is heavily increasing for M = 0.09, rather constant for M = 0.10 and heavily decreasing for M = 0.11. In addition, the three curves deviate substantially from each other over years, and indicate that the model has little, if any, predictive power as long as only data over such a small time span as 4 years are available.

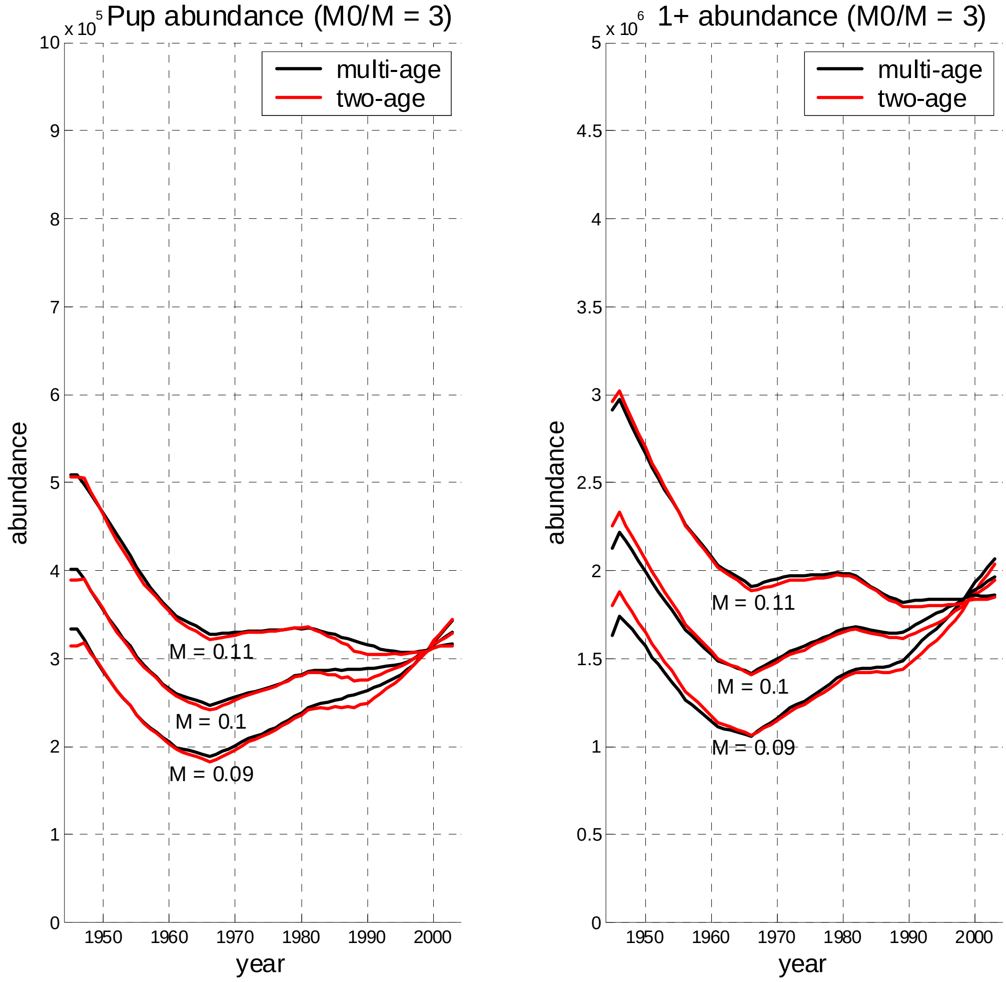
Pup abundance (M0/M = 3)
x 10^5
multi-age
two-age
M = 0.11
M = 0.1
M = 0.09
abundance
year
1+ abundance (M0/M = 3)
x 10^6
multi-age
two-age
M = 0.11
M = 0.1
M = 0.09
abundance
year

Figure 1

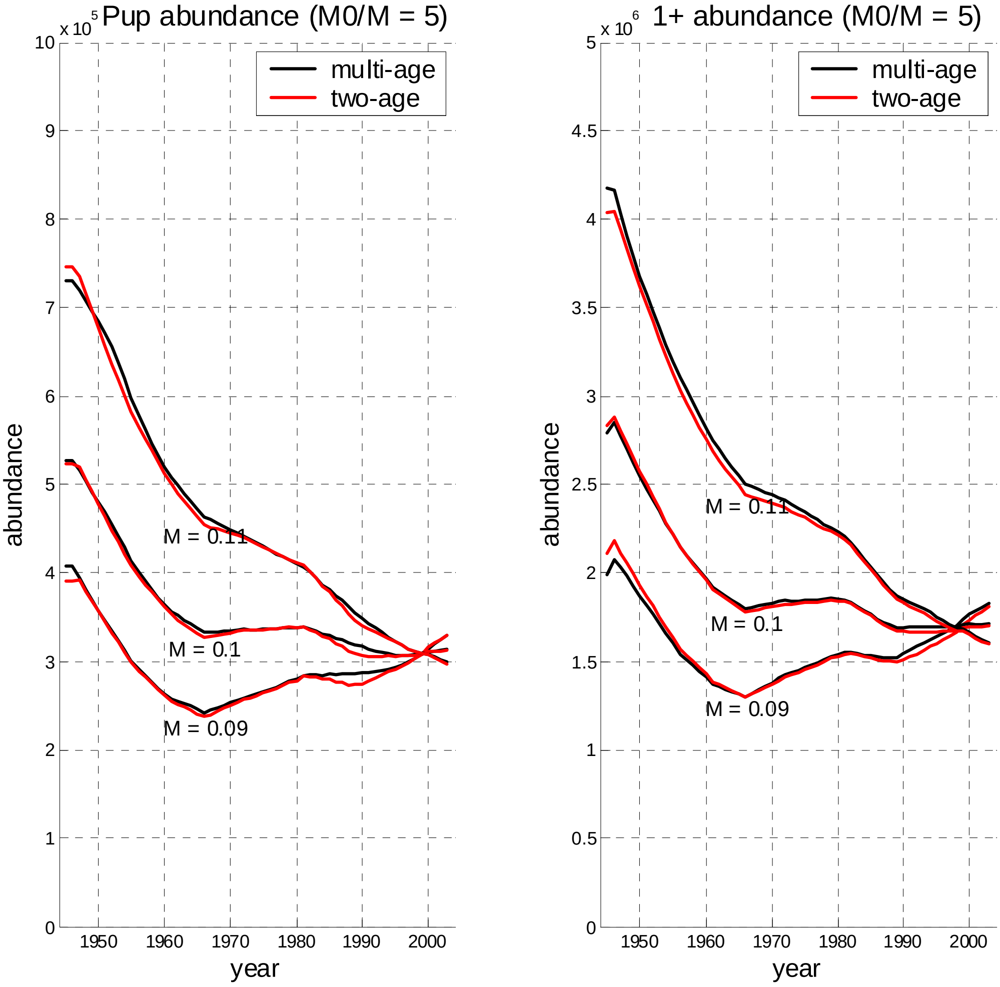
Pup abundance (M0/M = 5)
x 10^5
abundance
year
multi-age
two-age
M = 0.11
M = 0.1
M = 0.09
1+ abundance (M0/M = 5)
x 10^6
abundance
year
multi-age
two-age
M = 0.11
M = 0.1
M = 0.09

Figure 2