SC/67A/SCSP/13

Addendum of the NEWREP-NP proposed revised research plan

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INTERNATIONAL WHALING COMMISSION

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Addendum of the NEWREP-NP proposed revised research plan

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NOTE: this document assembles some additional information of the proposed revised research plan for NEWREP-NP. Specifically the additional information is as follows:

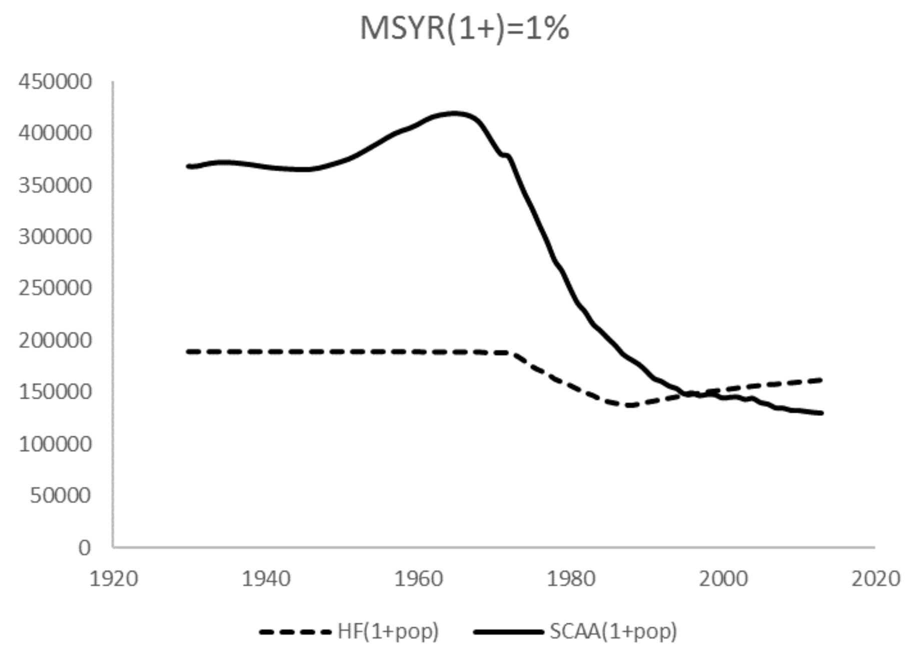
- Basis and analytical methods related to the selection of the sample size for common minke whales (Annex 11 and section 3.1.3 of the research plan)
- Basis and analytical methods related to the selection of the sample size for sei whales (Annex 16 and section 3.2.3 of the research plan)
- Assessment of the potential effect of catches on the stocks of minke and sei whales (sections 4.1 and 4.2 of the research plan)

ANNEX 11

Selection of sample size for the North Pacific common minke whale

General background and rationale for the sample size on the Pacific side of Japan (sub-areas 7-9)

The SCAA assessment of Antarctic minke whale populations by Punt *et al*. (2014) was a watershed advance for the IWC SC because, through its ability to take account of age in addition to survey abundance data, it pointed to the extent of recruitment changes[1] that could occur, and its results did not conform particularly closely to the behaviour predicted by the standard population models used to assess and hence to provide baseline *ISTs* for baleen whale populations. Figure 1 contrasts the results from an application by GOJ (2016) of the Punt *et al.* SCAA methodology to those that would follow from a FITTER approach necessitated if only catch and survey abundance information were available (as required for the RMP).



[1] Recruitment refers to the numbers of young whales added to the population each year (also called a 'cohort'). This cannot be determined well if only a series of abundance estimates of the whole population are available. The availability of age data, however, allows estimates of total population numbers to be split into the numbers of each cohort present that year. From one survey only, such estimates would not be precise, but the accumulation of age data over successive years allows for multiple estimates of the size of each cohort, and it is effectively the combination of these which ultimately allows for reasonable estimates of annual recruitment to be obtained.

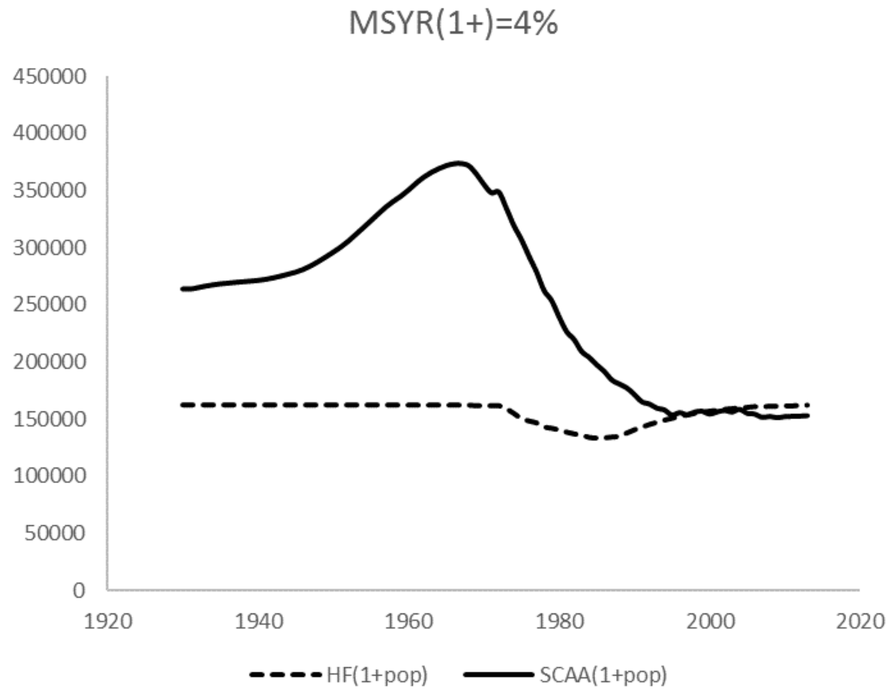


Figure 1: Two approaches to conditioning potential *IST*s for the I stock of Antarctic minke whales are compared. The first uses the conventional approach for baseline trials in RMP *Implementations*, with only past catch and survey abundance estimates (in this instance from the IDCR-SOWER cruises) available, and is calculated here using the FITTER-with-fixed-MSYR methodology. The second uses the SCAA approach of Punt *et al*. (2014), as implemented by GOJ (2016), which can in addition take age data into account. Results are shown for the 1+ population trajectory for two different values of MSYR(1+). The very different perception of the dynamics of the population that follows once age data are available for use in the conditioning, and show that catches have not been the primary determinant of the population's behaviour, is readily evident.

The considerable difference is obvious; self-evidently optimal management based the scenario (and associated sensitivities) provided by the SCAA, which can estimate recruitment directly through the availability of age data, would be very different to that from the deterministic stock-recruitment relationship scenarios (as, e.g., the FITTER methodology has to assume), which at best would need to consider a very wide range of robust tests, resulting in an inefficient approach (less allowable catch for the same perceived risk).

The Punt *et al*. (2014) analysis constitutes an important step in contributing to the evolution of the RMP towards a more efficient version which is based on better conditioned operating models, and is stock specific (as are the various current AWMPs) rather than generic as at present. Age data contribute to this better conditioning through allowing much improved estimation of recruitment and its changes and may also be able to improve the performance of a refined version of the RMP, as has been demonstrated in the case of Antarctic minke whales (GOJ, 2016). The NEWREP-NP proposal, with its analyses, has the intent that the age data to be collected will contribute to this evolutionary process.

The JARPN II Final review workshop report, endorsed by the IWC SC, noted that 'if the *Implementation Simulation Trials* (*IST*s) for the western North Pacific minke whales are to be revised in future, the age data should be included in the conditioning process' (SC/66b/Rep06, Report of the Expert Panel of the final review on the western North Pacific Japanese Special Permit program (JARPN II), 4.4.1). The example above shows that age data, whenever potentially available, are needed for conditioning such trials so that recruitment and its changes may be reflected far better. This is the primary reason why the proponents support the use of age data for the conditioning of the next set of *ISTs* for the North Pacific common minke whale, which they understand to be endorsed also by the IWC SC. Naturally recruitment is hardly estimable for other than past years spanned by the collection of age data, so for future sets of *ISTs* also to best reflect underlying dynamics, age data must continue to be collected, notwithstanding the fact that the impact of data from the first few years of NEWREP-NP to the next NP common minke whale *Implementation Review* may not be that large.

The proponents' approach is entirely in line with fisheries management approaches elsewhere, including in the development of MPs in other Regional Fisheries Management Organizations (RFMO). There a high premium is placed on obtaining and improving age data and/or on equivalent information to provide information on recruitment changes. Further comments on this and other aspects of the use of age data in fisheries management may be found in Adjunct 1. Furthermore Adjunct 2 provides an example of how the availability of age data aids the estimation of the extent of the impact of environmental factors on recruitment trends – a matter of importance at this time given concerns about the possible impacts of Climate Change.

Note that while age data could be used in a future RMP in a similar way to that in the proposal in Government of Japan (2016), the primary contribution of such data remains to the conditioning of *ISTs*, and (as has proven to be the preferred approach for other MPs internationally) their contribution to feedback adjustments to management measures might be through the regular re-conditioning of the *ISTs* rather than by changes to the MP itself.

Moving to the matter of sample size, it is perhaps helpful to first summarise the proponents' rationale for the number advanced, before elaborating upon it in more detail. This rationale is that:

- Age data are needed for improved conditioning of *IST*s for testing management procedures, to inform better on recruitment changes and hence improves the trials' realism
- Simulation results (see Adjunct 2) indicate that larger age samples would allow better estimation of recruitment changes for this NP minke situation
- On the other hand, operational considerations regarding the practically maximum sample size and the effect on the population must also be taken into account in determining the optimal sample size
- Therefore, the optimal sample size should meet both of these criteria: that it is operationally maximal and is also sufficient to provide meaningful improvement in the estimation of recruitment changes; simulation results (see Adjunct 3) indicate that is the case for this NP minke situation. (The matter of effect on the population is dealt with in Section 4.1 of the main text of Revised Research Plan.)

To elaborate then, given the clear and widely accepted benefits in principle of the inclusion of ageing data to the *IST* conditioning process, the only question that then remains is how much age data is needed to make a meaningful improvement to that NP minke whale conditioning. A detailed calculation for this would need to be based on the planned updated conditioned (including with the age data available at that time) set of NP minke *ISTs*, and consequently would need to await completion of that exercise which is the responsibility of the IWC SC.

However, in the interim, much simpler computations are adequate to bound the problem, and are conducted in Adjunct 3. These are based on a simpler model broadly accepted when presented to the JARPN II review, which was intended to be illustrative and to assist this bounding.

Note first that the model showed performance improved with increases in the sample size aged, and that these improvements are meaningful over the sample sizes examined which were consistent with what was operationally practical[2]. This last consideration then provides the desirable sample size, but always provided that a) the criterion of no adverse effect on the population is met, and b) that sample size is itself sufficient to provide a meaningful improvement in performance. The intent of the calculations of Adjunct 3 is to address this last question, and this is successfully achieved – note that this is an exercise for which primarily only relative measures of performance when comparing results with to those without ageing data are needed. Once the updated conditioning is complete, that could be used to update these overall results, though any difference would not be expected to be large, and the priority for such an update would not seem to be very high, and results from this bounding an illustrative exercise are sufficient to address the immediate question.

Given the relatively slow dynamics of minke whales, coupled to the nature of the information content of age data, the improvements to *IST*s achieved by use of these data take time to reveal their full extent (see the plots in Adjunct 3), so that there is a need to show results for projections over a number of decades, extending beyond

[2] Based on the scientific knowledge on minke whale distribution around Japan, estimated sampling efforts given the available research vessels (see Annex 21 of the proposed proposal) and the allocation of efforts to the two target species, annual sample size of 107 for minke whales was found to be optimal and feasible.

the time-frame of the current research program. Self-evidently the results for these larger numbers of years must be taken into account; otherwise the injudicious situation would arise that research with longer term benefits would never commence because those benefits could never become evident in the short term.

In summary it is considered that the annual sample size of 107 minke whales in sub-areas 7-9, which is the maximum feasible within the operational constraints of the program, is sufficient to result in meaningful improvement in the detection of minke whale recruitment changes.

This intended sample size applies to O stock whales. It is planned that 60% of this sample size be taken in coastal sub-areas (7CS and 7CN) and 40% in offshore sub-areas (7WR, 7E, 8 and 9). Evaluating an optimal coastal:offshore ratio for this sample would be an enormous task technically, but it seems reasonable to expect that a 50:50 split would be near optimal in terms of distinguishing possible differences between the two regions if any. Taking into account operational reasons as well, the ratio has been decided to be 60:40, noting that typically such "distinguishability" performance behaves quadratically, so does not deteriorate much with relatively small movement away from the actual optimal split. Hence it is planned that 64 animals will be sampled in coastal sub-areas and 43 in offshore sub-areas. Because around 20% of the animals in sub-areas 7CS and 7CN are from the J stock (Annex 7), the sample size in the coastal sub-areas needs to be adjusted upwards to 80 animals in total to achieve sampling of 64 O stock whales. Thus the total sample size planned on the Pacific side of Japan becomes 123 whales.

Rationale for the sample size selected for the area north of Hokkaido (sub-area 11)

For the area north of Hokkaido (sub-area 11), the main objective is to estimate the J-O mixing proportion in this subarea annually with a standard error of no more than 0.1 irrespective of the true proportion. The sample size selected is 47. The basis for the selection of this value is explained in Adjunct 4.

Total planned sample size

With 123 whales to be taken on the Pacific side of Japan, and 47 north of Hokkaido, the total sample size planned for common minke whales is 170.

References

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Punt, A., Hakamada, T., Bando, T. and Kitakado, T. 2014. Assessment of Antarctic minke whales using statistical catch-at-age analysis (SCAA). *J. Cetacean Res. Manage*. 14:93-116.

ADJUNCT 1

On the Use and Utility of Catch–at-Age Data in Marine Resource Assessment and Management

The inclusion of age data in fishery assessments is widespread in fishery management agencies worldwide, including in Regional Fisheries Management Organisations (RFMOs). This use can also extend there to the process of developing management procedures (MPs), certainly for conditioning the operating models used for testing those MPs, and sometimes directly in the MPs themselves. Generally a high premium is placed on obtaining and improving age data and/or equivalent information to provide information on recruitment changes.

Examples of this in RFMOs are provided, for example, by:

> **CCAMLR:** Further collection of age data for the assessment of toothfish stocks is recommended (e.g. CCAMLR 2016).
>
> **CCSBT:** Age data are used in conditioning the operating models used for MP selection for southern bluefin tuna (SBT), and indirectly (through recruitment indices) in the MP itself (e.g. CCSBT 2016).
>
> **ICCAT**: Age data are used in assessments of, for example, Atlantic bluefin tuna, and in the development of operating models for the MP in development for that resource (e.g. ICCAT 2014).
>
> **NAFO**: Age data were used in conditioning the operating models for the MP previously adopted for Greenland halibut, and are similarly in use for the revision of this MP that is currently in progress (e.g. NAFO 2010).
>
> **WCPFC**: Age data are used in the assessments of various stocks, including bigeye tuna (e.g. Harley *et al*. 2014).

Many of the species involved above are long-lived, some to four decades which approaches the longevity of many whale species, so that dynamics, time scales, and management concerns are not dissimilar from those for whales. One reason that perhaps increases the priority for ageing information for the species above compared to whales is its contribution towards estimation of abundance in absolute terms – whale sightings surveys provide better approximations to this than are obtainable from abundance indices for many fish species. Nonetheless the primary improvement provided by the availability of age data is the ability to assess year-class (recruitment) strength and its variations. The identification of (series of) good and of poor recruitment plays an important role in the management of these species despite their longevity, both as regards increasing and reducing catch limits. Thus there is, for example, absolute unanimity in the CCSBT Scientific Committee on the need for recruitment monitoring inputs in the MP used to recommend catch limits for SBT, following experience in that case of the consequences of a run of poor recruitments across the turn of the century.

These same considerations apply to whales, where the absence of age data accordingly necessitates more conservative management than might otherwise be necessary, i.e. lower catches for the same perceived risk.

The current IWC RMP relies (historical catches aside) on the input of survey based indices of abundance (with CVs) only. The assessment of the US Southern New England/Mid-Atlantic winter flounder (NEFSC 2011) provides a note of caution in this regard. If survey indices of abundance only were considered, that stock appeared perfectly healthy; however a full assessment taking age data into account as well led to a different appreciation, suggesting a resource appreciably reduced in abundance over recent decades. This points again to the sound management of a marine resource requiring that age information (in addition to survey-based indices in isolation) be obtained and taken into account whenever possible.

References

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Commission for the Conservation of Southern Bluefin Tuna. 2016, Report of the Seventh Operating Model and Management Procedure Technical Meeting, 3-4 September 2016, Kaohsiung, Taiwan. 22 pp. Available at https://www.ccsbt.org/sites/ccsbt.org/files/userfiles/file/docs_english/meetings/meeting_reports/ccsbt_23/report_of_OMMP7.pdf

Harley, S. J., Davies, N., Hampton, J., and McKechnie, S. 2014. Stock assessment of bigeye tuna in the Western and Central Pacific Ocean. Technical Report WCPFC-SC10-2014/SA-WP-01, WCPFC Scientific Committee, Majuro. 115pp.

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ADJUNCT 2

Enhancement of the Detection of the Effects of Environmental Factors on Whale Dynamics given the Availability of Catch–at-Age Data

Introduction

This Appendix intends to provide an **illustration** of how the availability of catch-at-age data may lead to improved estimation of the effect of an environmental factor (or factors in combination) on whale population dynamics. Specifically the magnitude (*G*) of the trend in an enhancement of recruitment success is estimated without and with the availability of catch-at-age data, and estimation performance contrasted in terms of bias, variance and root mean square error.

The situation modelled is loosely based on the O stock of North Pacific common minke whales, and is developed from the model of Kitakado and Maeda (2016), and as refined further in Adjunct 3. Details of the methods applied are set out in Appendix A. The data available to the estimator are the results of six-yearly sightings surveys of 1+ abundance, and annual catch-at-age information with an effective (i.e. "independent") sample size of either 0 or 80.

Estimation performance for the environmental effect (*G*) parameter is compared after 20 and after 50 years for the two different sample sizes for catch-at-age data.

Results and discussion

Table 1 summarises the results for 20, and 50 year projections given 0 and 80[3] age samples each year, while Figures 1 plots the results.

The bottom row of Figure 1 in particular makes visually evident that there is an improvement in precision of the estimated trajectory of female births when the age data are also available to the estimator.

The extent of this improvement is best quantified by the statistics in Table 1 which relate to estimation performance for *G*. After 20 years there is appreciable negative bias in the absence of age data and variances are large, but the RMSE is appreciably less when age data are available. After 50 years bias and variance are substantially reduced, and the RMSE (which still remains less if age data are provided) is reduced in that last case to a level where a result is obtained which is almost statistically significant at the 5% level.

References

Kitakado, T and Maeda H. 2016. Fitting to catch-at-age data for North Pacific common minke whales in the Pacific side of Japan. Paper SC/F16/JR43 presented to the Expert Panel of the final review on the western North Pacific Japanese Special Permit programme (JARPN II) (unpublished) 12pp.

[3] As in Adjunct 3, the actual annual catch here is 107, but after allowing for over-dispersion, the effective "independent" sample size is 80.

Table 1: Mean, standard deviation, CV and root mean square error (RMSE) for the estimated environmental effect on recruitment parameter *G* (the true value of *G* is 0.005) after periods of 20 and 50 years, and given either an effective *n*=0 or *n*=80 age samples each year

	20yrs		50yrs	
	n=0	n=80	n=0	n=80
mean	0.01393	0.00634	0.00662	0.00598
stdev	0.03106	0.01127	0.00387	0.00251
CV	2.22993	1.77744	0.58345	0.41898
RMSE	0.03217	0.01129	0.00417	0.00268

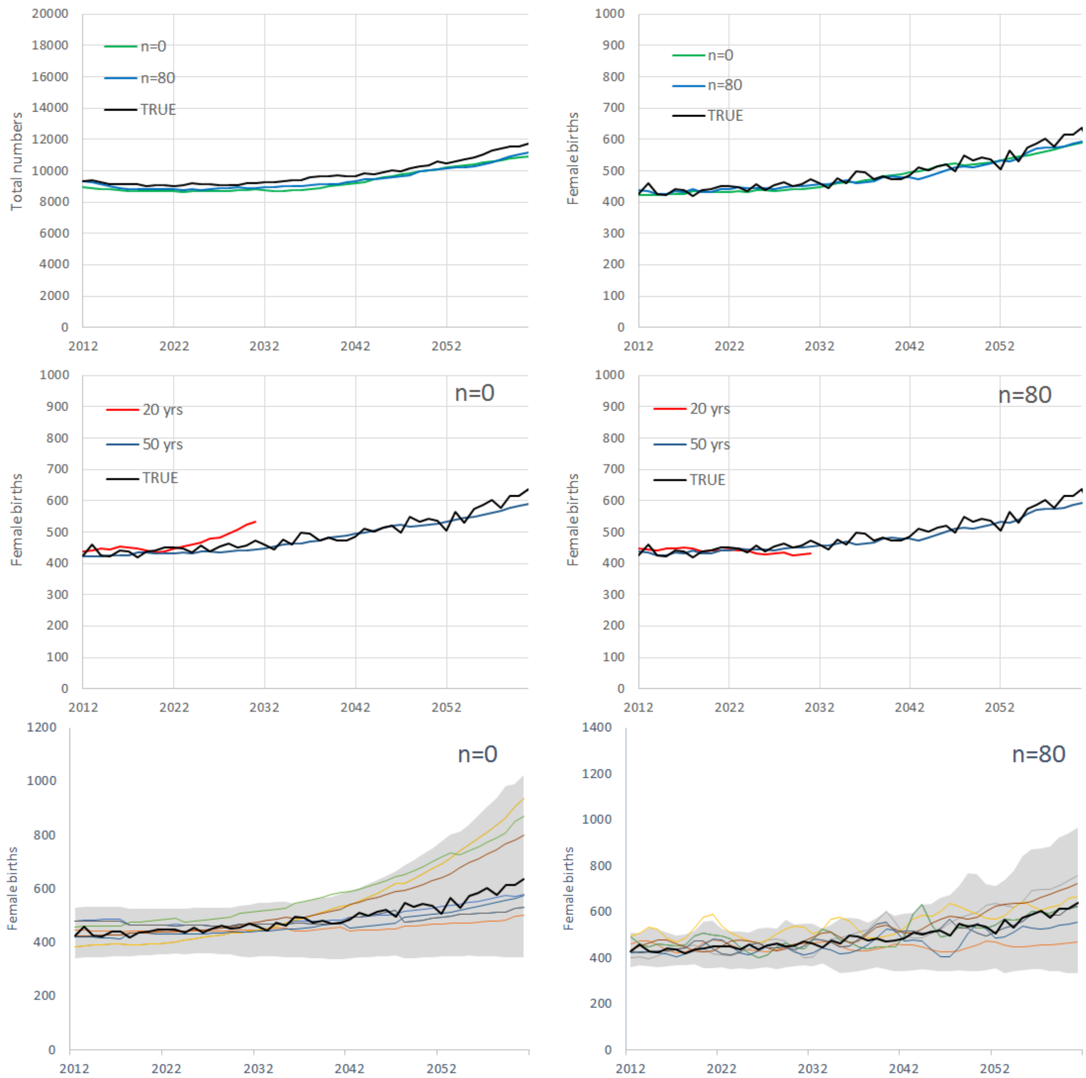

Figure 1: Top row: Medians for "true" and estimated total numbers and female births for sample sizes of 0 and 80 after 50 years. Second row: Medians for "true" and estimated female births for a sample size of 0 (LHS) and 80 (RHS), estimated after 20 and 50 years. Third row: Estimated 95%iles, some individual trajectories estimated and "true" female births for a sample size of 0 (LHS) and 80 (RHS) after 50 years.

Appendix A – Methodology

The text following sets out the equations and other general specifications of the SCAA estimation approach followed by details of the contributions to the log-likelihood function from the different sources of data available. Quasi-Newton minimization is then applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder$^{\mathrm{TM}}$ (Fournier *et al*. 2012) is used for this purpose).

A.1. Population dynamics

A.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,a}^{g} = \begin{cases} 0.5 b_{y+1}^{i} & \text{if } a = 0 \\ \left(N_{y,a-1}^{g} - C_{y,a-1}^{g}\right) S_{a-1} & \text{if } 1 \leq a < m \\ \left(N_{y,m-1}^{g} - C_{y,m-1}^{g}\right) S_{m-1} + \left(N_{y,m}^{g} - C_{m}^{g}\right) S_{m} & \text{if } a = m \end{cases} \quad \text{(A1)}$$

where

$N_{y,a}^{g}$ is the number of whales of gender g and age a at the start of year *y*,

$C_{y,a}^{g}$ is the catch (in number) of whales of gender g and age a during year *y*,

b_{y}^{i} is the number of calves born at the start of year *y*,

S_a is the survival rate e^{-M_a} where M_a is the instantaneous rate of natural mortality (assumed to be independent of gender),

$m = 50$ is the maximum age (treated as a plus-group).

A.1.2. Births

Density-dependence is assumed to act on the female component of the mature population.

$$b_y = B N_y^f \left\{1 + A\left[1 - \left(N_y^f / K^f\right)^z\right]\right\} \quad \text{(A2)}$$

where

B is the average number of births (of both genders) per year for a mature female in the pristine population,

A is the resilience parameter,

z is the degree of compensation,

$N_y^f = \sum_{a_m} f_a^f N_{y,a}^f$ is the number of mature females at the start of year *y*,

a_m is the earliest age-at-first parturition;

f_a^f is the proportion of females of age a which have reached the age at first parturition (ogive with parameters given in Table A.1), and

K^f is the number of mature females in the pristine population.

A.1.3. Total catch and catches-at-age

The catch-at-age is given by:

$$C_{y,a}^{g} = F_{y}^{g} v_{y,a}^{g} N_{y,a}^{g} \quad \text{(A3)}$$

where

$C_{y,a}^{g}$ is the catch-at-age, i.e. the number of animal of gender g and age a caught during year y,

$v_{y,a}^{g}$ is the commercial selectivity of an animal of gender g and age a for year y; when $v_{y,a}^{g} = 1$, the age-class a is said to be fully selected, and

$F_{y}^{g} = \frac{C_{y}^{g}}{\sum_{a} v_{y,a}^{g} N_{y,a}^{g}}$ is the proportion of a fully selected age class that is caught.

A.1.4. Initial conditions

For the first year (y_0) considered in the model, the numbers-at-age are taken to be at unexploited equilibrium, i.e.:

$$N_{y_0,a}^{g} = \begin{cases} 0.5BK^{f} & \text{if } a = 0 \\ N_{y_0,a-1}^{g} S_{a-1} & \text{if } 1 \leq a < m \\ N_{y_0,m-1}^{g} S_{m-1}/(1 - S_{m}) & \text{if } a = m \end{cases} \quad \text{(A4)}$$

Input values for the model parameters and data were selected to give a typical population trajectory, which is at about 50% of carrying capacity in the year the projections start (see Tables A1 and A2).

A.2. Projections

For each simulation i, the population is projected forward using equation A1 and a constant catch of 107 animals per year.

Future recruitments include residuals and an environmental effect G = 0.005 which reflects a 0.5% increase per annum in recruitment (density dependent effects aside):

$$b_{y}^{i} = \left(1 + G(y - 2011)\right) B N_{y}^{f,i} \left\{1 + A\left[1 - \left(N_{y}^{f,i}/K^{f}\right)^{z}\right]\right\} e^{\varphi_{y}^{i}} \quad \text{(A5)}$$

φ_{y}^{i} generated from $N(0, (\sigma_R)^2)$ with $\sigma_R = 0.25$.

Future observed abundance indices are computed as:

$$I_{y}^{i} = \sum_{a=1}^{m} N_{y,a}^{f,i} e^{\varepsilon_{y}^{i}} \quad \text{(A6)}$$

ε_{y}^{i} are generated from $N(0, (\sigma_I)^2)$ with $\sigma_I = 0.25$

Future catch-at-age data are generated under the assumption of a multinomial error distribution:

$$O_{y,a}^{g,i} = \sum_{a'} F_{y}^{g,i} v_{y,a'}^{g} r_{a'}^{g} N_{y,a'}^{g,i} E_{a,a'} \quad \text{(A7)}$$

where

$O_{y,a}^{g,i}$ is the observed number of whale of age *a* and gender *g* caught in year *y* for simulation *i*,

$E_{a,a}$ is the ageing error matrix (Table A3), and

r_a^g is the age readability at age *a* for gender *g* (Table A4).

The standardised residuals are computed as:

$$\omega_{y,a}^{g,i} = \frac{O_{y,a}^{g,i}/\Sigma_{a'} O_{y,a'}^{g,i} - \hat{O}_{y,a}^{g,i}/\Sigma_{a'} \hat{O}_{y,a'}^{g,i}}{\sigma_{y,a}^{g,i}} \quad \text{(A8)}$$

with

$$\sigma_{y,a}^{g,i} = \frac{O_{y,a}^{g,i} \frac{\hat{O}_{y,a}^{g,i}}{\Sigma_{a'} \hat{O}_{y,a'}^{g}} \left(1 - \frac{\hat{O}_{y,a}^{g,i}}{\Sigma_{a'} \hat{O}_{y,a'}^{g,i}}\right)}{\Sigma_{a'} O_{y,a'}^{g,i}} \quad \text{(A9)}$$

A.3. The likelihood function

The model is fitted to projected estimates of total (1+) numbers (from surveys every six years, starting in the first year of the projection) and annual catch-at-age data to estimate model parameters. Contributions by each of these to the negative of the log-likelihood ($-lnL$) are as follows.

A.3.1 Estimates of total (1+) numbers

$$-lnL^{abund} = \sum_y \left\{\frac{\left(\varepsilon_y^i\right)^2}{2\sigma^2}\right\} \quad \text{(A10)}$$

with

$$\varepsilon_y^i = ln\left(I_y^i\right) - ln\left(\sum_a f_a^{f,i} N_{y,a}^{f,i}\right) \quad \text{(A11)}$$

A.3.2. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of a multinomial error distribution is given by:

$$-lnL^{CAA} = \sum_{y,g,a} -O_{y,a}^{g,i} ln\left(\frac{\hat{O}_{y,a}^{g,i}}{\Sigma_{a'} \hat{O}_{y,a'}^{g,i}}\right) \quad \text{(A12)}$$

A.3.3. Female births

The following penalty added to the negative log-likelihood given the variability about the stock-recruitment relationship:

$$pen_{birth} = \sum_y \left\{\frac{\left(\varphi_y^i\right)^2}{2\sigma_R^2}\right\} \quad \text{(A13)}$$

The model assumes an unexploited equilibrium age structure in the starting year (1930). The estimable parameters of the model are *K*, the environmental effect *G*, and the annual recruitment residuals φ_y.

References

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., and Sibert, J. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

Table A1: Model parameter values assumed. Note that maturity and selectivity are logistic, with a_m referring to the earliest age at which first parturition can occur.

Parameter	Value
Carrying capacity, K^f	4160
Initial year, y_0	1930
Age at first parturition, a_m	5
Age-at-50% maturity	7
Steepness of the ascending limb of the maturity ogive	1.2
Age-at-50% selectivity	4
Steepness of the ascending limb of the selectivity ogive	1.2
Natural mortality, M_a:	
4-	0.085000
5	0.077500
6	0.072098
7	0.066696
8	0.061295
9	0.055893
10	0.050491
11	0.045089
12	0.039688
13	0.034286
14	0.028884
15	0.023482
16	0.018080
17	0.012679
18	0.007277
19	0.001875
20+	0.115000
MSYR(mat)	1%
Resilience parameter	0.12053
Degree of compensation	2.38475

Table A2: Historical male and female catches assumed.

	♂	♀		♂	♀
1930	3	3	1971	81	81
1931	4	4	1972	97	97
1932	5	5	1973	165	165
1933	6	6	1974	121	121
1934	9	9	1975	104	104
1935	9	9	1976	107	107
1936	6	6	1977	84	84
1937	15	15	1978	124	124
1938	17	17	1979	122	122
1939	19	19	1980	124	124
1940	20	20	1981	123	123
1941	16	16	1982	105	105
1942	19	19	1983	97	97
1943	26	26	1984	132	132
1944	20	20	1985	118	118
1945	18	18	1986	112	112
1946	29	29	1987	111	111
1947	36	36	1988	11	11
1948	43	43	1989	11	11
1949	42	42	1990	11	11
1950	58	58	1991	11	11
1951	64	64	1992	11	11
1952	82	82	1993	11	11
1953	63	63	1994	21	21
1954	77	77	1995	60	60
1955	101	101	1996	38	38
1956	124	124	1997	60	60
1957	101	101	1998	60	60
1958	150	150	1999	47	47
1959	78	78	2000	27	27
1960	73	73	2001	58	58
1961	94	94	2002	71	71
1962	71	71	2003	73	73
1963	63	63	2004	82	82
1964	80	80	2005	100	100
1965	94	94	2006	93	93
1966	102	102	2007	94	94
1967	86	86	2008	80	80
1968	72	72	2009	77	77
1969	71	71	2010	57	57
1970	97	97	2011	58	58

Table A3: Ageing error matrix.

True age	Expected age in observation																																																		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0.86	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.16	0.67	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.01	0.19	0.60	0.19	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0.01	0.21	0.55	0.21	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0.02	0.23	0.50	0.23	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0.03	0.24	0.47	0.24	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0.04	0.24	0.43	0.24	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0.05	0.24	0.40	0.24	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0.01	0.06	0.24	0.38	0.24	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0.01	0.07	0.24	0.36	0.24	0.07	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0.01	0.08	0.24	0.34	0.24	0.08	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0.02	0.09	0.23	0.32	0.23	0.09	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0.02	0.10	0.23	0.30	0.23	0.10	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0.03	0.10	0.22	0.29	0.22	0.10	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.11	0.22	0.28	0.22	0.11	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.11	0.21	0.26	0.21	0.11	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.11	0.21	0.25	0.21	0.11	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.05	0.12	0.20	0.24	0.20	0.12	0.05	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0.12	0.20	0.23	0.20	0.12	0.05	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0.12	0.19	0.22	0.19	0.12	0.05	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.12	0.19	0.22	0.19	0.12	0.06	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.12	0.18	0.21	0.18	0.12	0.06	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.06	0.12	0.18	0.20	0.18	0.12	0.06	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.20	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.19	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.18	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.07	0.12	0.16	0.18	0.16	0.12	0.07	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.07	0.12	0.16	0.17	0.16	0.12	0.07	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.17	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.16	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.16	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.05	0.08	0.11	0.14	0.16	0.14	0.11	0.08	0.05	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.05	0.08	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.14	0.14	0.14	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.13	0.14	0.13	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.14	0.13	0.11	0.08	0.05	0.03	0.02	0.01	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.13	0.13	0.11	0.08	0.05	0.03	0.02	0.01	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.06	0.08	0.11	0.12	0.13	0.12	0.11	0.08	0.06	0.03	0.02	0.01	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.06	0.08	0.10	0.12	0.13	0.12	0.10	0.08	0.06	0.03	0.02	0.01	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.13	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.03
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.12	0.13	0.12	0.11	0.09	0.07
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.13	0.13	0.11	0.09
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.14	0.14	0.12
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.14	0.16	0.16	0.16
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.05	0.08	0.11	0.14	0.17	0.18	0.19

Table A4: Age readability proportion for males and females.

Age	Males	Females
0	0.1981	0.1998
1	0.2047	0.2134
2	0.2764	0.2757
3	0.4232	0.3906
4	0.4874	0.4678
5	0.5042	0.4969
6	0.5091	0.5067
7	0.5109	0.5102
8	0.5117	0.5116
9	0.5121	0.5123
10	0.5123	0.5126
11	0.5125	0.5128
12	0.5125	0.5129
13	0.5126	0.5129
14	0.5126	0.5130
15	0.5127	0.5130
16	0.5127	0.5130
17	0.5127	0.5130
18	0.5127	0.5130
19	0.5127	0.5130
20+	0.5127	0.5130

ADJUNCT 3

Analyses underlying choice of sample size for Primary Objective I (common minke whale) for the Pacific side of Japan (sub-areas 7-9)

Introduction

This Adjunct provides the details of an **illustrative** example of the extent of improvement achievable for the assessment of the dynamics of the O stock of western North Pacific common minke whales in relation to the size of the sample taken to provide age data.

The approach followed is founded on the SCAA methodology applied to this stock by Kitakado and Maeda (2016), which is used to generate future data in a simulation testing context. The intent is to **illustrate** how well, using the SCAA methodology to analyse the future data generated, it is possible to detect changes in recruitment (strictly in the number of recruits per adult female) – specifically whether the sample sizes proposed do secure a meaningful improvement in this detectability.

Data and Methodology

The data used for these analyses are set out in Appendix A. Appendix B provides details of the SCAA assessment methodology. Note that this remains as in Kitakado and Maeda (2016), and has not been extended to incorporate some of the suggestions made by the 2016 JARPNII review panel, such as allowing for dome-shaped selectivity. The reason is that those extensions are not of particular pertinence to the issue under examination in the **illustrative** exercise here, and are considered to better await subsequent work when the NP minke RMP trials are re-conditioned on a basis that includes the use of age data, when they will likely also estimate rather than pre-fix natural mortality (note that estimates of natural mortality at age for larger ages and the extent of doming in the selectivity function are confounded).

Appendix C details how the population model of Appendix B is used to generate the future data required to test how well the SCAA approach can estimate future recruitments. These data comprise annual catches at age as well as six-yearly estimates of population abundance. Note that the effects of ageing error are incorporated in both the assessment (Appendix B) and in the projections (Appendix C). The age data are generated using a multinomial distribution, but analysis of existing data suggests some over-dispersion. Appendix D explains this and how it is taken into account.

Results

Results are presented to show first the dependence on (aged) sample size of the detectability of a 30% **decrease** in recruits per adult female. Changes of such a magnitude over a relatively short period are evident from the SCAA assessments of Antarctic minke whales (GOJ, 2015). For the scenario examined, this change is assumed to take place 10 years into the projection period (corresponding to 2022).

The second scenario considered includes instead a 30% **increase** in recruits per adult female, taking place 10 years into the projection period.

The third scenario considered is based on the recruitment variability evident for Antarctic minke (stocks I and P) as estimated in SCAA results for Antarctic minke whales reported to the 2016 annual meeting of the Scientific Committee. The 1970-2010 vector $\boldsymbol{X}$ of moving averages for recruitment variability (renormalized so that the 1970 value is 1, see Table 1 for I and P stocks) is used to project recruitment forward from 2011 (using the 1971 value) onwards, with the 2051 value taken to apply to all years from 2052 onwards. A three-year moving average is used to eliminate some of the estimation error around the real underlying trend; values prior to 1970 are not used as they reflect more model assumptions than being informed by the actual age data. Equation C8 (see Appendix C) for future births is modified:

$$b_y^i = B^j N_y^{f,j} X_y \qquad (1)$$

Results are shown for estimation of O-stock trajectories in terms of annual female births. They compare across different "multinomial" sample sizes (*n*) for the acquisition of age information (see Appendix D for how these "effective" sizes are related to actual sample sizes when allowance is made for over-dispersion). Figure 1 reports results for a scenario which considers a 30% drop in recruits per adult female after the 10th year of the projections for the A01_1 RMP trial (IWC, 2014) which sets MSYR(mature) equal to 1%. The results are shown for estimation after 20 and after 50 years, and include both medians and worm plots (for ten realisations/individual trajectories, and also showing the 90% probability envelopes shaded). Figure 2 shows similar results for this same situation except that recruits per adult female increase instead of decreasing by 30%. Figure 3 shows such results for the A01_1 trial for P stock MSYR(mature) 1% equivalent recruitment variations.

These **illustrative** results show clearly that the recruitment change is not detected in the absence of age data. Furthermore detectability improves with both an increasing age sample size and a longer period of data availability, and is meaningful for the sample size (*n*=80) proposed (even after 20 years). Note that after adjustment for over-dispersion as indicated in Appendix D, this effective sample size of *n*=80 is increased to an actual size of 107.

References

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Kitakado, T and Maeda H. 2016. Fitting to catch-at-age data for North Pacific common minke whales in the Pacific side of Japan. Paper SC/F16/JR43 presented to the Expert Panel of the final review on the western North Pacific Japanese Special Permit programme (JARPN II) (unpublished) 12pp.

Table 1: Moving averages of recruitment variability (renormalized so that the values for 1970 for Antarctic minke and for 2011 for the assumed projected values for the North Pacific O stock of minke whales are 1). The Antarctic values correspond to those reported for the I and P stocks of Antarctic minke whales for an MSYR of 1% in analyses presented by Kitakado to the 2016 meeting of the IWC Scientific Committee. The 1970-2010 values from the Antarctic are used in the projections for the 2011-2051 period for the North Pacific, with values being kept constant after 2051.

Year		I-stock (1%)	P-stock (1%)
Antarctic	North Pacific		
1970	2011	1.0000	1.0000
1971	2012	0.9126	0.9964
1972	2013	0.8973	0.9739
1973	2014	0.8204	0.9444
1974	2015	0.6548	0.8903
1975	2016	0.6164	0.7994
1976	2017	0.6395	0.7106
1977	2018	0.5629	0.6338
1978	2019	0.5564	0.5823
1979	2020	0.6362	0.5473
1980	2021	0.6759	0.5475
1981	2022	0.7580	0.6199
1982	2023	0.8806	0.6581
1983	2024	0.9840	0.6786
1984	2025	0.9714	0.6824
1985	2026	1.1005	0.6860
1986	2027	1.0904	0.6196
1987	2028	1.0511	0.5675
1988	2029	0.9935	0.5201
1989	2030	1.0772	0.5039
1990	2031	1.0321	0.4938
1991	2032	1.0715	0.4973
1992	2033	1.0963	0.5278
1993	2034	1.3100	0.5197
1994	2035	1.3289	0.5045
1995	2036	1.4931	0.5570
1996	2037	1.5884	0.6024
1997	2038	1.6565	0.6185
1998	2039	1.6914	0.7480
1999	2040	1.7960	0.8030
2000	2041	1.7229	0.8751
2001	2042	1.7694	0.8129
2002	2043	1.7485	0.7998
2003	2044	1.6526	0.6842
2004	2045	1.5270	0.6529
2005	2046	1.5480	0.5344
2006	2047	1.4261	0.6040
2007	2048	1.5137	0.6128
2008	2049	1.5242	0.6493
2009	2050	1.5664	0.7044
2010	2051+	1.5430	0.7387

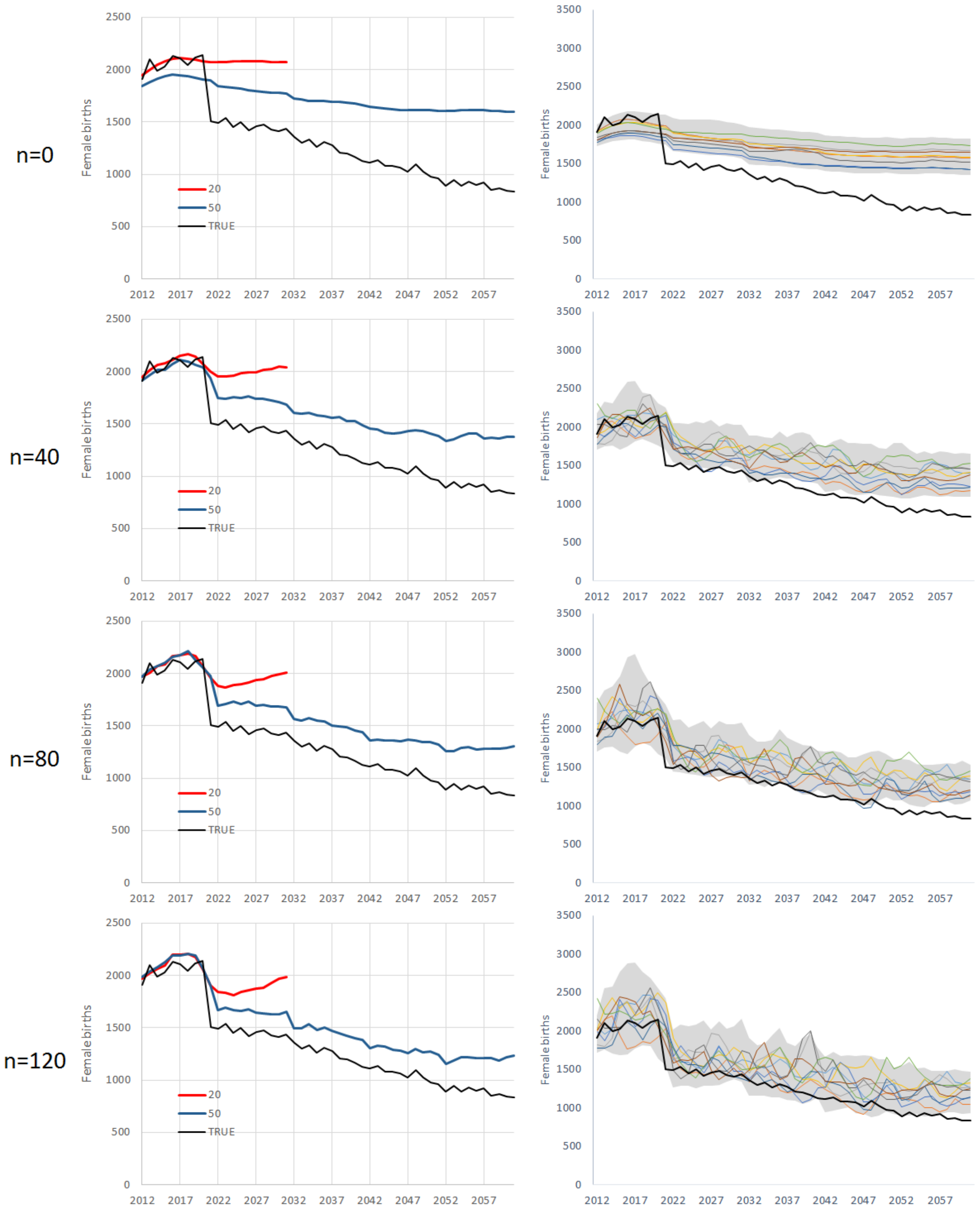

Figure 1: Estimates of female births for scenario **A01_1, with MSYR 1% recruitments, with a 30% drop in (per capita) recruitment after 10 years**. The left side plots compare medians of estimates after 20 and after 50 years with the true values. The right side plots show worms (individual realizations) after 50 years together with 90% probability envelopes (shaded). The rows reflect different effective (i.e. "independent") annual sample sizes for age, ranging from *n*=0 to *n*=120.

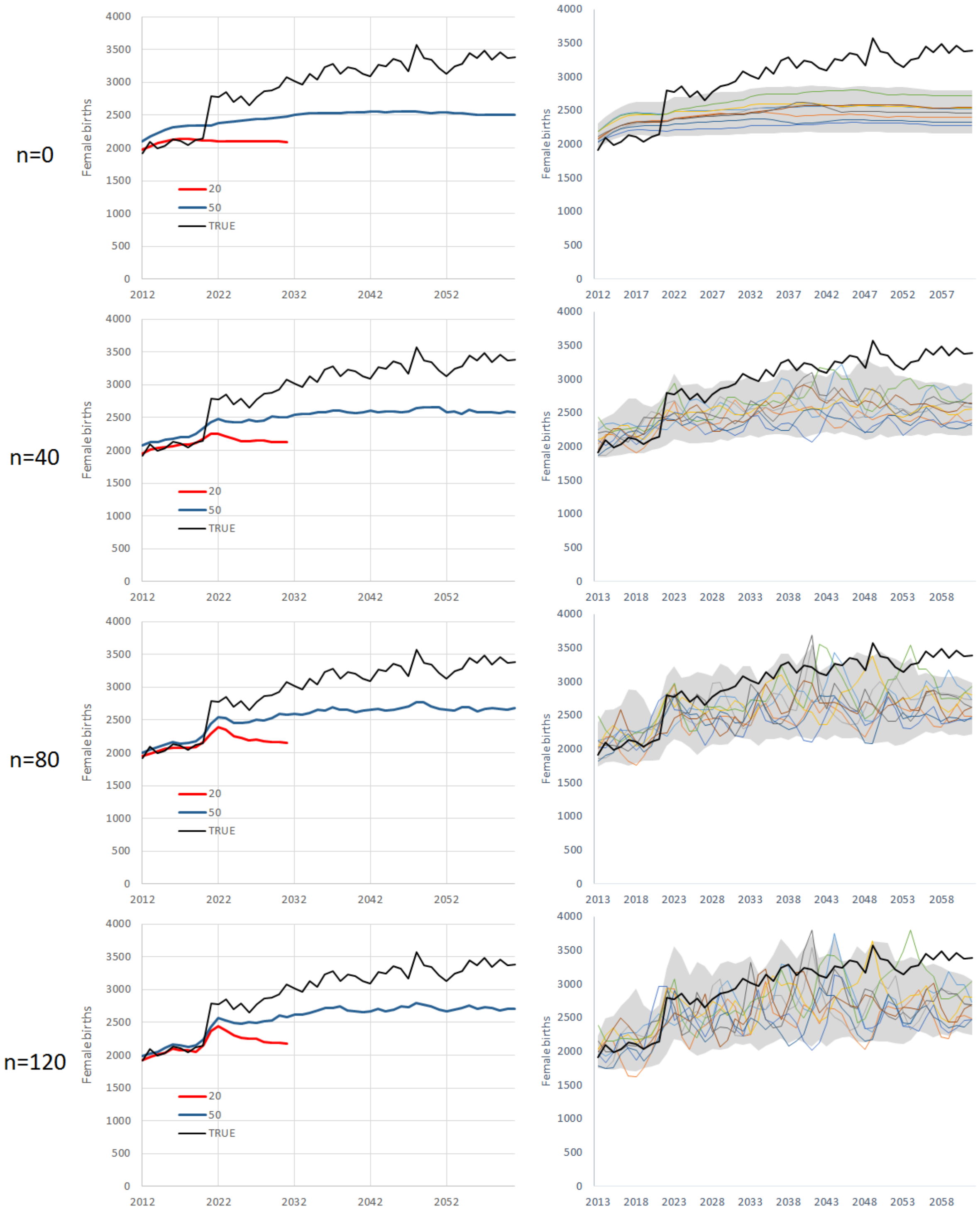

Figure 2: Estimates of female births for scenario **A01_1, with MSYR 1% recruitments, with a 30% increase in (per capita) recruitment after 10 years**. The left side plots compare medians of estimates after 20 and after 50 years with the true values. The right side plots show worms (individual realizations) after 50 years together with 90% probability envelopes (shaded). The rows reflect different effective (i.e. "independent") annual sample sizes for age, ranging from *n*=0 to *n*=120.

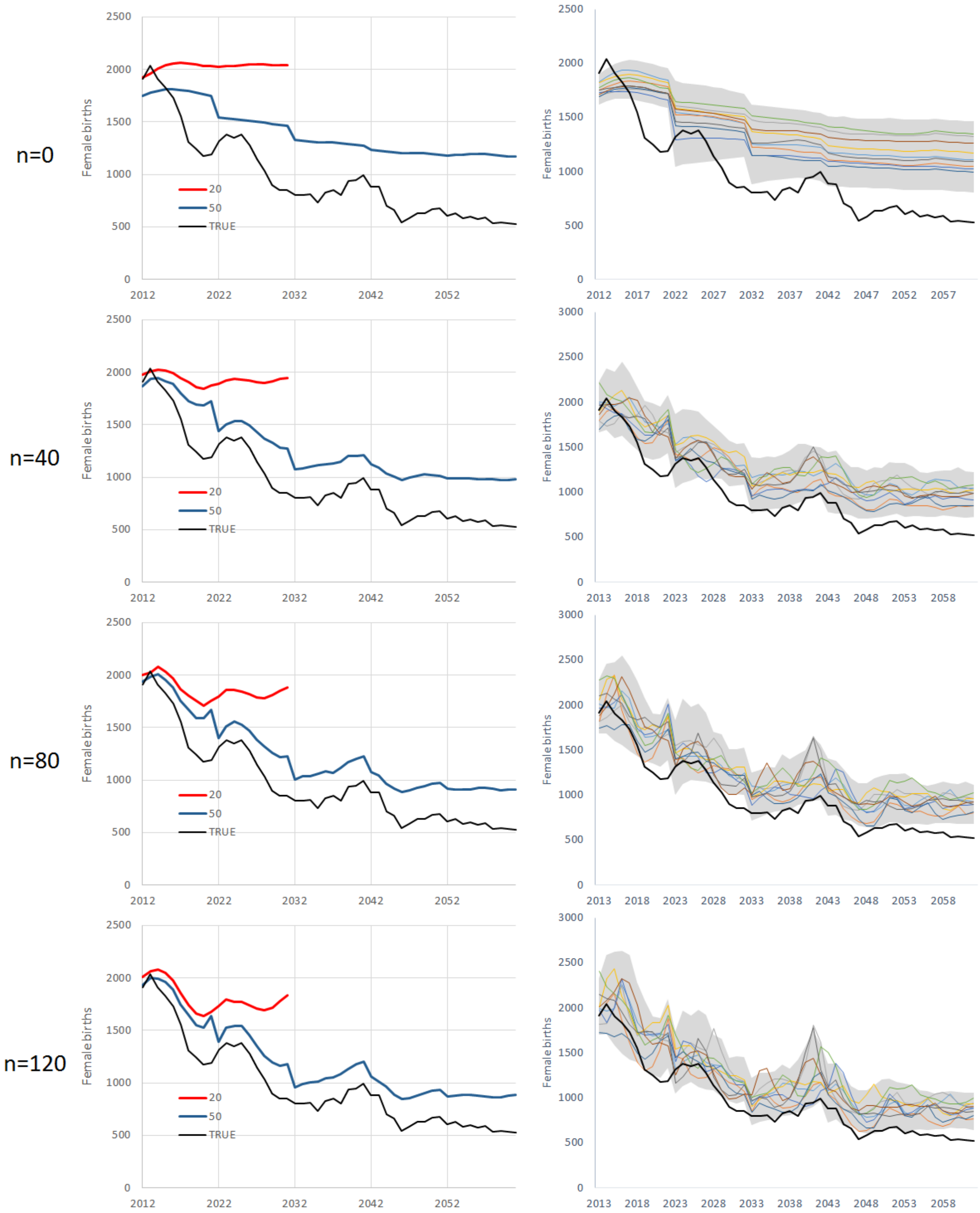

Figure 3: Estimates of female births for scenario **A01_1,** for **P stock MSYR 1% equivalent recruitment variations**. The left side plots compare medians of estimates after 20 and after 50 years with the true values. The right side plots show worms (individual realizations) after 50 years together with 90% probability envelopes (shaded). The rows reflect different effective (i.e. "independent") annual sample sizes for age, ranging from *n*=0 to *n*=120.

Appendix A - The data

The catches assumed by regions/stocks for males and females separately are given in Table A1 (Cherry Allison, pers. commn). These catches are median outputs from trials A01_1/4 which are detailed in IWC (2014). For the one stock hypotheses, the catches for males and females have been split by region corresponding to OW and OE (see details given below), assuming the same OW:OE proportions as those in the corresponding C01_1 and C01_4 trials.

The numbers assumed for mature females in 2000 are provided in Table A2. They correspond to deterministic values for the associated trials, kindly provided by Cherry Allison.

Table A3 gives the males and females catches-at-age from JARPN surveys for the regions corresponding to OW and OE. Catches in sub-areas 8, 9 and 7E have been assigned to region/stock OE. Catches in sub-areas 11, 7CN and 7CS have been assigned to region/stock OW. Catches in sub-area 7WR have been assumed to belong to region/stock OE if taken east of 145E and OW otherwise.

Table A4 lists the life history parameters used (IWC, 2014).

The ageing error matrix is given in Table A5 and is taken to be the same for males and females, across regions. The sex-specific age readability vectors are listed in Table A6. The assumed proportion of the total sample of males and females in each region, based on averages over the 2000-2010 period for JARPN and JARPNII is shown in Table A7.

Table A1: Historical male and female minke catches assumed (see text above for source).

A01_1									
	Regions corresponding to:					Regions corresponding to:			
	OW		OE			OW		OE	
	♂	♀	♂	♀		♂	♀	♂	♀
1930	4	2	0	0	1971	58	55	23	26
1931	4	2	0	1	1972	39	69	35	50
1932	6	4	0	0	1973	75	85	81	89
1933	6	5	0	0	1974	66	67	47	62
1934	10	6	0	1	1975	68	70	32	38
1935	10	6	0	1	1976	45	59	47	63
1936	7	4	0	1	1977	66	39	32	31
1937	18	11	0	0	1978	122	80	10	36
1938	20	13	1	0	1979	136	56	8	44
1939	22	13	1	2	1980	99	66	22	61
1940	25	15	0	0	1981	120	65	17	44
1941	19	10	1	1	1982	99	70	4	37
1942	21	13	1	2	1983	85	78	3	28
1943	32	18	0	1	1984	100	79	30	55
1944	25	14	0	1	1985	108	60	20	48
1945	21	13	0	1	1986	100	70	12	41
1946	30	18	2	7	1987	110	64	11	36
1947	35	22	3	11	1988	9	11	0	2
1948	33	23	8	21	1989	9	11	0	2
1949	36	26	5	16	1990	9	11	0	2
1950	54	33	9	20	1991	9	11	0	2
1951	54	33	7	33	1992	9	11	0	2
1952	52	55	9	48	1993	9	11	0	2
1953	42	42	14	27	1994	7	10	19	5
1954	34	34	26	59	1995	6	10	93	11
1955	66	59	17	59	1996	27	12	27	9
1956	92	70	29	56	1997	7	10	88	15
1957	64	68	13	56	1998	14	10	83	13
1958	83	95	38	83	1999	42	17	19	15
1959	47	53	18	38	2000	21	15	16	1
1960	41	49	18	38	2001	29	11	67	8
1961	54	63	23	47	2002	65	37	36	3
1962	35	41	21	44	2003	28	30	80	8
1963	36	42	16	31	2004	57	22	74	10
1964	51	61	14	33	2005	77	53	57	13
1965	39	73	29	46	2006	63	46	68	8
1966	57	79	30	37	2007	100	65	21	2
1967	42	59	25	46	2008	48	51	52	8
1968	40	61	10	33	2009	61	56	28	8
1969	25	32	23	62	2010	49	49	12	4
1970	66	65	24	39	2011	33	30	34	18

A01_4									
	Regions corresponding to:					Regions corresponding to:			
	OW		OE			OW		OE	
	♂	♀	♂	♀		♂	♀	♂	♀
1930	4	3	0	0	1971	60	57	26	29
1931	4	2	0	1	1972	39	72	38	55
1932	7	5	0	0	1973	76	88	87	94
1933	7	5	0	0	1974	68	69	51	65
1934	11	6	0	1	1975	71	73	36	40
1935	10	6	1	1	1976	46	61	51	68
1936	8	4	0	1	1977	69	39	36	33
1937	20	12	0	0	1978	135	85	11	38
1938	23	14	1	0	1979	150	58	10	46
1939	24	14	2	2	1980	107	68	25	65
1940	28	16	0	0	1981	131	66	20	48
1941	20	12	2	1	1982	110	74	4	39
1942	23	14	2	2	1983	93	83	4	29
1943	36	20	0	1	1984	108	82	33	58
1944	28	16	0	1	1985	117	60	22	51
1945	24	14	0	1	1986	109	71	13	43
1946	32	19	2	7	1987	119	66	12	37
1947	37	23	4	11	1988	8	10	0	2
1948	35	22	10	23	1989	9	11	0	2
1949	38	26	6	17	1990	8	10	0	2
1950	59	33	11	22	1991	8	11	0	1
1951	58	32	8	36	1992	8	11	0	1
1952	56	56	10	52	1993	8	10	0	2
1953	44	43	17	30	1994	7	10	20	5
1954	34	32	29	63	1995	6	9	93	12
1955	70	59	21	65	1996	27	12	27	9
1956	98	72	34	60	1997	7	10	88	15
1957	69	69	15	61	1998	14	10	83	13
1958	86	96	44	91	1999	43	17	18	14
1959	49	53	21	42	2000	21	15	16	1
1960	43	50	20	41	2001	29	11	67	8
1961	56	64	27	52	2002	64	37	36	3
1962	36	41	23	47	2003	28	31	80	8
1963	37	41	18	35	2004	56	22	74	10
1964	53	64	17	37	2005	77	53	56	13
1965	39	75	32	51	2006	63	46	67	7
1966	59	82	33	42	2007	98	64	21	2
1967	42	58	28	50	2008	47	51	51	8
1968	42	63	11	36	2009	60	55	27	8
1969	24	31	25	65	2010	47	48	12	4
1970	69	67	27	43	2011	63	45	1	2

Table A2: Number of mature females in 2000 (from NP minke *IST*s – see text above - Cherry Allisson, pers. commn). Only the A01_1 scenario is considered here.

		Year	Number of mature females
A01_1:	O	2000	9562
A01_4:	O	2000	9581
C01_1:	OW	2000	2000
	OE	2000	8119
C01_4:	OW	2000	1894
	OE	2000	8071

Table A3: Catch-at-age data from JARPN and JARPN II surveys for regions corresponding to OW and OE.

Region OW, males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1996	0	0	2	0	0	1	2	0	1	2	0	1	3	3	0	0	0	0	0	1	2
1999	0	0	0	0	1	1	3	0	1	2	2	3	2	1	4	0	1	1	0	0	5
2000	0	0	0	2	1	1	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0
2001	0	0	0	2	0	1	0	0	0	0	2	1	1	1	1	0	0	0	1	1	4
2002	0	1	2	1	3	0	0	1	1	0	0	1	3	0	3	0	2	2	4	0	6
2003	0	1	2	2	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	1	0
2004	0	2	0	1	2	1	2	4	0	2	2	2	2	2	1	1	6	0	0	1	0
2005	0	2	2	4	7	3	0	4	1	1	2	3	1	1	0	6	0	3	1	2	3
2006	0	4	5	4	4	3	1	0	2	3	2	1	1	0	2	0	2	2	2	0	5
2007	0	2	2	4	6	6	4	0	2	4	1	3	4	0	0	2	3	4	2	2	5
2008	0	2	5	3	4	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	1
2009	0	5	2	3	4	3	1	1	1	0	2	0	1	1	1	1	1	0	0	0	6
2010	0	2	2	2	2	1	1	1	0	0	2	1	1	0	1	2	0	0	1	0	2
2011	0	1	1	3	4	4	3	2	5	4	0	1	1	4	2	0	1	0	0	2	3

Region OW, females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	2
1999	0	0	0	0	0	0	0	0	0	0	1	1	2	3	1	2	1	0	0	1	1
2000	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1
2001	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	1	2	1	0	1	0	2	1	0	0	0	1	0	1	0	0	0	0	2
2003	0	2	2	2	1	2	0	2	0	0	1	1	1	0	0	0	0	0	0	0	1
2004	0	3	1	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2005	0	4	5	4	2	0	2	4	0	1	1	2	1	1	0	2	1	0	1	0	1
2006	0	2	0	6	3	4	0	3	0	0	1	0	0	1	0	0	0	0	1	0	1
2007	0	5	5	5	2	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1
2008	0	3	3	3	5	0	1	0	1	1	0	1	1	1	0	2	0	0	0	1	1
2009	0	6	4	1	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2010	0	6	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2011	0	2	4	0	1	5	4	0	2	1	0	0	1	1	0	0	0	1	0	0	2

Region OE, males

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1994	0	0	0	0	0	0	1	0	1	1	1	0	0	0	1	0	2	0	0	2	2
1995	0	0	1	0	0	0	2	1	3	2	3	3	3	0	1	0	2	3	2	3	5
1996	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	1	0	0	1	3
1997	0	0	0	2	4	0	1	2	3	0	4	3	2	5	3	2	2	1	1	0	6
1998	0	0	1	2	1	0	1	0	1	0	3	2	3	2	2	1	1	3	0	1	10
1999	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1
2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2001	0	0	0	0	0	0	0	1	1	1	1	0	1	0	0	0	1	4	0	1	12
2002	0	0	0	0	0	0	0	0	1	0	2	0	0	0	2	0	2	1	3	2	8
2003	0	0	1	1	2	1	1	2	3	0	1	0	2	2	5	2	2	1	0	0	18
2004	0	0	0	0	1	1	0	0	1	0	3	1	0	1	3	4	1	0	1	3	11
2005	0	0	1	1	0	2	1	2	0	1	0	1	1	1	1	1	1	1	2	2	8
2006	0	0	0	0	3	0	0	1	3	1	3	1	1	0	0	0	2	1	0	0	8
2007	0	0	1	1	0	1	0	0	1	2	1	1	0	0	0	0	0	0	1	1	7
2008	0	0	0	0	0	1	3	2	0	0	1	1	1	0	2	3	1	1	1	2	7
2009	0	0	0	0	0	0	1	0	0	0	2	0	1	0	1	0	0	0	0	0	4
2010	0	0	2	0	1	1	0	0	0	0	0	1	0	1	0	2	1	0	0	0	0

Region OE, females

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1995	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4
1996	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2001	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2004	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
2005	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2008	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2
2009	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2010	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A4: Life history parameter values (as defined for the *IST*s detailed in IWC (2014)). The maturity ogive is logistic, with a_m the earliest age at which first parturition can occur.

Parameter	Value	
Age at first parturition	5	
Age-at-50% maturity	7	
Steepness of the ascending limb of the maturity ogive	1.2	
Natural mortality:		
4-	0.085000	
5	0.077500	
6	0.072098	
7	0.066696	
8	0.061295	
9	0.055893	
10	0.050491	
11	0.045089	
12	0.039688	
13	0.034286	
14	0.028884	
15	0.023482	
16	0.018080	
17	0.012679	
18	0.007277	
19	0.001875	
20+	0.115000	
	MSYR=1%	MSYR=4%
Resilience parameter	0.12053	0.48523
Degree of compensation	2.38475	2.37389

Table A5: Ageing error matrix.

	Expected age in observation																																																		
True age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0.86	0.14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.16	0.67	0.16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0.01	0.19	0.60	0.19	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0.01	0.21	0.55	0.21	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0.02	0.23	0.50	0.23	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0.03	0.24	0.47	0.24	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0.04	0.24	0.43	0.24	0.04	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0.05	0.24	0.40	0.24	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0.01	0.06	0.24	0.38	0.24	0.06	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0.01	0.07	0.24	0.36	0.24	0.07	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0.01	0.08	0.24	0.34	0.24	0.08	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0.02	0.09	0.23	0.32	0.23	0.09	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0.02	0.10	0.23	0.30	0.23	0.10	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0.03	0.10	0.22	0.29	0.22	0.10	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.11	0.22	0.28	0.22	0.11	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.11	0.21	0.26	0.21	0.11	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.11	0.21	0.25	0.21	0.11	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.05	0.12	0.20	0.24	0.20	0.12	0.05	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0.12	0.20	0.23	0.20	0.12	0.05	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0.05	0.12	0.19	0.22	0.19	0.12	0.05	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.12	0.19	0.22	0.19	0.12	0.06	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.06	0.12	0.18	0.21	0.18	0.12	0.06	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.06	0.12	0.18	0.20	0.18	0.12	0.06	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.20	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.19	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.03	0.07	0.12	0.17	0.18	0.17	0.12	0.07	0.03	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04	0.07	0.12	0.16	0.18	0.16	0.12	0.07	0.04	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.07	0.12	0.16	0.17	0.16	0.12	0.07	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.17	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.16	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.04	0.08	0.12	0.15	0.16	0.15	0.12	0.08	0.04	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.05	0.08	0.11	0.14	0.16	0.14	0.11	0.08	0.05	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.05	0.08	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.14	0.14	0.14	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.05	0.08	0.11	0.13	0.14	0.13	0.11	0.08	0.05	0.03	0.01	0.01	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.14	0.13	0.11	0.08	0.05	0.03	0.02	0.01	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.13	0.13	0.11	0.08	0.05	0.03	0.02	0.01	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.06	0.08	0.11	0.12	0.13	0.12	0.11	0.08	0.06	0.03	0.02	0.01	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.06	0.08	0.10	0.12	0.13	0.12	0.10	0.08	0.06	0.03	0.02	0.01	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.13	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01	0.01
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.02	0.01
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.03	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04	0.03
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.12	0.12	0.12	0.10	0.08	0.06	0.04
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.12	0.13	0.12	0.11	0.09	0.07
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.03	0.05	0.07	0.09	0.11	0.13	0.13	0.13	0.11	0.09
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.14	0.14	0.12
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.02	0.03	0.05	0.07	0.09	0.12	0.14	0.16	0.16	0.16
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.04	0.05	0.08	0.11	0.14	0.17	0.18	0.19

Table A6: Age readability proportion for males and females. These values were obtained by fitting logistic curves to the data available.

Age	Males	Females
0	0.1981	0.1998
1	0.2047	0.2134
2	0.2764	0.2757
3	0.4232	0.3906
4	0.4874	0.4678
5	0.5042	0.4969
6	0.5091	0.5067
7	0.5109	0.5102
8	0.5117	0.5116
9	0.5121	0.5123
10	0.5123	0.5126
11	0.5125	0.5128
12	0.5125	0.5129
13	0.5126	0.5129
14	0.5126	0.5130
15	0.5127	0.5130
16	0.5127	0.5130
17	0.5127	0.5130
18	0.5127	0.5130
19	0.5127	0.5130
20+	0.5127	0.5130

Table A7: Assumed proportion of the total sample of males and females in each region, based on averages over the 2000-2010 period for JARPN and JARPNII.

	Males	Females
OW	0.471	0.279
OE	0.200	0.050

Appendix B - The Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the SCAA followed by details of the contributions to the log-likelihood function from the different sources of data available. Quasi-Newton minimization is then applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder™ (Fournier *et al*., 2012) is used for this purpose).

B.1. Population dynamics

B.1.1 NUMBERS-AT-AGE

The resource dynamics are modelled by the following set of population dynamics equations:

$$N^g_{y+1,a} = \begin{cases} 0.5b_{y+1} & \text{if } a = 0 \\ \left(N^g_{y,a-1} - C^g_{y,a-1}\right)S_{a-1} & \text{if } 1 \le a < m \\ \left(N^g_{y,m-1} - C^g_{y,m-1}\right)S_{m-1} + \left(N^g_{y,m} - C^g_{m}\right)S_m & \text{if } a = m \end{cases} \quad \text{(B1)}$$

where

$N^g_{y,a}$ is the number of animal of gender g and age a at the start of year y,

$C^g_{y,a}$ is the catch (in number) of animal of gender g and age a during year y,

b_y is the number of calves born to females at the start of year y,

S_a is the survival rate e^{-M_a} where M_a is the instantaneous rate of natural mortality (assumed to be independent of gender),

$m = 50$ is the maximum age (treated as a plus-group).

B.1.2. BIRTHS

Density-dependence is assumed to act on the female component of the mature population.

$$b_y = BN^f_y\left\{1 + A\left[1 - \left(N^f_y/K^f\right)^z\right]\right\}e^{\varepsilon_y} \quad \text{(B2)}$$

where

B is the average number of births (of both genders) per year for a mature female in the pristine population,

A is the resilience parameter (see Table A4),

z is the degree of compensation (see Table A4),

$N^f_y = \sum_{a_m} f^f_a N^f_{y,a}$ is the number of mature' females at the start of year y,

a_m is the earliest age-at-first parturition (see Table A4);

f_a^f is the proportion of mature female of age a,

K^f is the number of mature females in the pristine population, and

ε_y from $N(0,(\sigma_R)^2)$ with $\sigma_R = 0.25$.

B.1.3. TOTAL CATCH AND CATCHES-AT-AGE

The catch-at-age is given by:

$$C_{y,a}^{k,g} = F_y^{k,g} v_{y,a}^{k,g} N_{y,a}^{g} \tag{B3}$$

where

$C_{y,a}^{k,g}$ is the catch-at-age, i.e. the number of animal of gender *g* and age *a* caught during year *y* in region *k* (where *k* refers to inshore/offshore),

$v_{y,a}^{k,g}$ is the commercial selectivity of an animal of gender *g* and age *a* for year *y* in region *k*; when $v_{y,a}^{g} = 1$, the age-class a is said to be fully selected, and

$F_y^{k,g} = \frac{C_y^{k,g}}{\sum_a v_{y,a}^{k,g} N_{y,a}^{g}}$ is the proportion of a fully selected age class that is caught in region *k*.

B.1.4. INITIAL CONDITIONS

For the first year (y_0) considered in the model (here 1930), the numbers-at-age are taken to be at unexploited equilibrium, i.e.:

$$N_{y_0,a}^{g} = \begin{cases} 0.5BK^f & \text{if } a = 0 \\ N_{y_0,a-1}^{g} S_{a-1} & \text{if } 1 \leq a < m \\ N_{y_0,m-1}^{g} S_{m-1}/(1-S_m) & \text{if } a = m \end{cases} \tag{B4}$$

B.2. The likelihood function

The model is fitted to estimates of mature female numbers and catch-at-age data to estimate model parameters.

Contributions by each of these to the negative of the (penalised) log-likelihood ($-lnL$) are as follows.

Mature female numbers

$$-lnL^{abund} = \sum_j \left\{ \frac{(\varepsilon_y)^2}{2\sigma_y^2} \right\} \tag{B5}$$

with

$$\varepsilon_y = ln(I_y) - ln(\sum_a f_a^f N_{y,a}^f) \quad \text{(B6)}$$

where

I_y is the estimate of mature female numbers in year *y*, and

$$\sigma_y = \begin{cases} 0.01 & \text{for } y = 2000 \text{ (i.e. sufficiently low to force and exact fit to } I_{2000}) \\ 0.25 & y \geq 2012 \end{cases}$$

Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of a multinomial error distribution is given by:

$$-lnL^{CAA} = \sum_{k,y,g,a} -O_{y,a}^{k,g} ln\left(\frac{\hat{O}_{y,a}^{k,g}}{\sum_{a'} \hat{O}_{y,a'}^{k,g}}\right) \quad \text{(B7)}$$

where

$O_{y,a}^{k,g}$ is the observed number of whale of age *a* and gender *g* caught in year *y* in region *k*,

$\hat{O}_{y,a}^{k,g}$ is the model-predicted number of whale of age *a* and gender *g* caught in year *y*in region *k*,

where

$$\hat{O}_{y,a}^{k,g} = \sum_{a'} F_y^{k,g} v_{y,a'}^{k,g} r_{a'}^g N_{y,a'}^g E_{a,a'} \quad \text{(B8)}$$

with

$E_{a,a}$ being the ageing error matrix (Table A5), and

r_a^g being the age readability at age *a* for gender *g* (Table A6).

The standardised residuals are computed as:

$$\varepsilon_{y,a}^{k,g} = \frac{O_{y,a}^{k,g,k}/\Sigma_{a'} O_{y,a'}^{g} - \hat{O}_{y,a}^{g}/\Sigma_{a'} \hat{O}_{y,a'}^{g}}{\sigma_{y,a}^{g,j}} \quad \text{(B9)}$$

with

$$\sigma_{y,a}^{k,g} = \frac{pO_{y,a}^{k,g} \frac{\hat{O}_{y,a}^{k,g}}{\Sigma_{a'} \hat{O}_{y,a'}^{k,g}} \left(1 - \frac{\hat{O}_{y,a}^{k,g}}{\Sigma_{a'} \hat{O}_{y,a'}^{k,g}}\right)}{\Sigma_{a'} O_{y,a'}^{k,g}} \quad \text{(B10)}$$

Female births (recruitment) residuals are defined by:

$$b_y = BN_y^f \left\{1 + A\left[1 - \left(N_y^f/K^f\right)^Z\right]\right\} e^{\varphi_y} \quad \text{(B11)}$$

where φ_y from $N(0, (\sigma_R)^2)$ with $\sigma_R = 0.25$

with the following penalty added to the negative log-likelihood:

$$pen_{birth} = \Sigma_y \left\{\frac{(\varphi_y)^2}{2\sigma_R^2}\right\} \quad \text{(B12)}$$

The standard deviations for total numbers are computed as follows, taking account of the estimation bias:

$$\sigma_y^{N_{tot}} = \sqrt{\Sigma_n \left(\hat{N}_y^{tot} - \beta_y - N_y^{tot}\right)^2/n} \quad \text{(B13)}$$

with the bias computed as:

$$\beta_y = \left(\hat{N}_y^{tot} - N_y^{tot}\right)/n \quad \text{(B14)}$$

and similarly for the female births.

To allow for a better fit, carrying capacity K is allowed to change (by a limited amount) every 10 projected years, starting in 2012, but staying constant during each of these 10 year periods:

$$K_y = \begin{cases} K_y = K & \text{for } y \leq 2011 \\ K_{y-1}e^{\varepsilon_y} & \text{for } y = 2012, 2022, 2032 \ldots \\ K_{y-1} & \text{for } y \neq 2012, 2022, 2032 \ldots \end{cases}$$

(B15)

with the following penalty added to the negative log-likelihood:

$$pen_K = \sum_y \left\{ \frac{(\varepsilon_y)^2}{2\sigma_K^2} \right\} \quad \text{(B16)}$$

with $\sigma_K = 0.1$.

Thus, aside from selectivity-related parameters, the estimable parameters of the model are *K*, and the 10-yearly ε_y together with the annual recruitment residuals φ_y.

B.3. Harvesting selectivity

Fishing selectivities-at-age in each region *k* are estimated using a logistic form:

$$v_{y,a}^{k,g} = \left(1 + e^{\left(\Delta_{y,a}^{k,g} - a\right)/\delta_{y,a}^{k,g}}\right)^{-1} \quad \text{(B17)}$$

Pre-1988, the selectivities are taken to be the same for males and females, with the parameters fixed: $\Delta = 4$ and $\delta = 1.2$ (i.e. as for the trials detailed in IWC (2014)).

Post-1988, the selectivities are estimated separately for males and females. Furthermore, ρ is estimated for the female selectivity, so that:

$$v_{y,a}^{f} \to \rho v_{y,a}^{f} \quad \text{(B18)}$$

Reference

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., and Sibert, J. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. *Optim. Methods Softw*. 27:233-249.

Appendix C – Projection methodology

Projections into the future and their evaluation are developed using the following steps.

Step 1: Begin-year numbers-at-age

The components of the numbers-at-age vector for each gender g and at the start of 2012 ($N^g_{2012,a}$) are obtained from the MLE of an assessment.

Error is included for all ages, i.e.: $N^g_{2012,a} \rightarrow N^g_{2012,a} e^{\varepsilon_a}$

ε_a from $N(0, (\sigma_N)^2)$ (C1)

where

σ_N is taken to be 0.2 (independent of age).

Step 2: Catch

These numbers-at-age are projected one year forward at a time given a catch for the year concerned C_y .

This requires specification of how the catch is disaggregated by gender and age and region to obtain $C^{k,g}_{y,a}$, and how future births are generated.

Step 3: Catch-at-age by region, gender and age

Catch by region:

A 60:40 ratio is assumed for the future catches in the inshore:offshore regions.

Catch by gender:

The male/female fishing mortality ratio is taken to stay constant at the 2007-2011 average estimated in the assessment:

$$\rho = \frac{1}{5}\sum_{y=2007}^{2011} F^{k,m}_y / F^{k,f}_y \qquad \text{(C2)}$$

so that:

$$F^{k,f}_y = \frac{C^k_y}{\sum_a v^{k,f}_{y,a} N^f_{y,a} + r \sum_a v^{k,m}_{y,a} N^m_{y,a}} \qquad \text{(C3)}$$

and

$$F^{k,m}_y = \rho F^{k,f}_y \qquad \text{(C4)}$$

The catch by gender is computed by:

$$C^{k,g}_y = F^{k,f}_y \sum_a v^{k,g}_{y,a} r^g_a N^g_{y,a} \qquad \text{(C5)}$$

Catch by age

$C^{k,g}_{y,a}$ is obtained by assuming that the commercial selectivity of an animal of gender g and age a for year y ($v^{k,g}_{y,a}$) stays constant in the future as estimated in the assessment.

$$C^{k,g}_{y,a} = F^{k,f}_y v^{k,g}_{y,a} r^g_a N^g_{y,a} \qquad \text{(C6)}$$

The numbers-at-age can then be computed for the beginning of the following year (*y*+1):

$$N^g_{y+1,a} = \begin{cases} 0.5b_{y+1} & \text{if } a = 0 \\ \left(N^g_{y,a-1} - \sum_k C^{k,g}_{y,a-1}\right)S_{a-1} & \text{if } 1 \leq a < m \\ \left(N^g_{y,m-1} - \sum_k C^{k,g}_{y,m-1}\right)S_{m-1} + \left(N^g_{y,m} - \sum_k C^{k,g}_{m}\right)S_m & \text{if } a = m \end{cases} \quad \text{(C7)}$$

Step 4: Births

Future births are obtained assuming a density-dependence acting on the female component of the mature population.

$$b_y = BN^f_y \left\{1 + A\left[1 - \left(N^f_y/K^f\right)^z\right]\right\} e^{\varepsilon_y} \quad \text{(C8)}$$

Step 5: Generate data

The information obtained in Steps 1 to 4 is used to generate NEWREP-NP catch-at-age data. These data are generated assuming the same multinomial error structure as in the past. The multinomial parameters are the probabilities for each age and the sample size. The probabilities are the expected proportions-at-age for gender g:

$$\hat{O}^{k,g}_{y,a} = \frac{\sum_{a'} v^{k,g}_{y,a'} r^g_{a'} N^g_{y,a'} E_{a,a'}}{\sum_{a*,a'} v^{k,g}_{y,a'} r^g_{a'} N^g_{y,a'} E_{a*,a'}} \quad \text{(C9)}$$

while the sample size for the corresponding gender is a fixed proportion of the total sample size:

$$n^g = \gamma^g n \quad \text{(C10)}$$

with

γ^g given in Table A7.

Note that because the purpose of the exercise is to compare estimation performance for different sample sizes for age data, it is desirable that the true numbers-at-age trajectories are the same though these sample sizes differ. This has been done by computing the dynamics using the largest sample size considered (160 in this case), and then scaling down the age-readability vectors to reflect the actual sample size.

In addition, survey estimates of abundance are generated every six years, commencing in year 2012, as follows:

$$I_y = \sum_a f^f_a N^f_{y,a} e^{\varepsilon_y} \quad \text{(C11)}$$

ε_y from $N(0, (\sigma)^2)$ with $= 0.25$.

Step 6: Conduct updated assessment using generated data

The updated assessments follow the procedures set out in Appendix B, incorporating all those historical data in $-lnL$. For the generated data, the catch-at-age data is included as for the historical data. The generated survey estimates of abundance are included using equation B5, with $\sigma_y = 0.25$, i.e. the assessment assumes the same value as used in generating these data.

Appendix D – Over-dispersion in catch-at-age data

Over-dispersion in the catch-at-age data has been estimated from the fit of the baseline population model to the A01_1 scenario, using the following equation:

$$D = \frac{\sum_{y,A}\left(\sum_{a\in A}(n_{y,a}p_{y,a}) - \sum_{a\in A}(n_{y,a}\hat{p}_{y,a})\right)^2}{\sum_{y,A}\left[\sum_{a\in A}(n_{y,a}\hat{p}_{y,a})(1-\sum_{a\in A}\hat{p}_{y,a})\right]} \qquad \text{(D1)}$$

where the ratio of summations over years rather than the average of yearly ratios was used in the interests of more robust estimation in the face of differing annual sample sizes.

The result of the calculation yielded D = 1.34, i.e. an increase of about one third.

The original intention was to generate future catch-at-age data from an over-dispersed multinomial distribution with this value of 1.34 for the over-dispersion parameter. However for the small samples sizes typical for most of the ages considered here, standard Dirichlet–multinomial generation procedures exhibit large small sample bias, precluding their use.

In these circumstances the assumption has been made that effective sample size scales inversely with variance. Hence, given that the value D = 1.34 reflects an increase of about one third, for an actual intended sample size of N, the sample size used when generating catch-at-age data from a multinomial has been set at $n = 0.75N$.

ADJUNCT 4

The selection of sample size North of Hokkaido (sub area 11)

There is limited information on mixing proportion of J stock in sub area 11 (see Annex 7). An examination of the required sample size to estimate the **annual** mixing proportion in this sub area with sufficient precision (e.g. SE (*p*) is less than 0.1).

In the formula below *p* is the proportion of J stock in the sub-area and *n* is the number of the samples in the sub area. Standard error of *p*, SE($\hat{p}$) is:

$$SE(\hat{p}) = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \quad (1)$$

Considering overdispersion ϕ (>1), equation (1) becomes:

$$SE(\hat{p}) = \sqrt{\frac{\hat{p}(1-\hat{p})\phi}{n}} \quad (1)'$$

SE($\hat{p}$) is a maximum when *p*=0.5 for fixed *n*. Therefore for this calculation *p*=0.5 is assumed, without loss of generality. It is desirable to obtain the proportion of the J stock in sub-area 11 with sufficient precision (e.g. SE($\hat{p}$) is less than 0.1). To fulfil this condition:

$$\frac{0.5\sqrt{\phi}}{\sqrt{n}} > 0.1$$
$$n > 25\phi \quad (2)$$

Considering that the ratio of unassigned samples is 9% in sub-areas 7CS and 7CN (data from the JARPNII coastal component), the required sample size should satisfy the following condition:

$$n > \frac{25\phi}{(1-0.09)} \quad (3)$$

The overdispersion parameter was estimated by using the samples in sub-area 7CN, assuming a quasi-binomial error in conducting Generalized Linear Model GLM):

$$p = \frac{\exp\{-(a_1 + a_2 y)\}}{1-\exp\{-(a_1 + a_2 y)\}} \quad (4)$$

where a_1 and a_2 are coefficients to be estimated and *y* indicates year. The overdispersion parameter ϕ was estimated as 1.689. Substituting the formula (3) for the estimated parameter the resulting sample size is 47.

It should be noted that this estimate is preliminary, and only applies for the first six years of NEWREP-NP. More detailed estimates of sample sizes for the objective of studying yearly trend in the J stock proportion will be made once new data are accumulated after the first six surveys.

ANNEX 16

Estimates of sample size for Primary Objective II (sei whale)

Introduction

This annex introduces an approach to estimate the proposed sample size for the North Pacific sei whales to meet the Primary Objectives II, especially the Secondary Objective II (ii). The approach followed is based on the age- and sex-structured model applied to this stock for conditioning and generating future data in a simulation. The target is to estimate the natural mortality rate, *M*, by using the SCAA methodology.

Materials and methods

Data for conditioning

The data used for the conditioning are as follows:

i) Catch series since 1906 (aggregated over ages and sexes) (Figure 1).
ii) Sex-specific catch-at-age data for commercial period (1966-1973) and those from JARPNII (2002-2013) (Figures 2 and 3).
iii) An abundance estimate of the sei whales, 34,718 (CV=21.4%) in the whole North Pacific area (Hakamada and Matsuoka, 2015; 2016). Note that this estimate adds the contributions from the IWC-POWER and JARPNII cruises which covered non-overlapping areas

Model assumed for conditioning

The population dynamics assumed for the conditioning is the same as the model shown in Annex 14 except for the recruitment as

$$R_t = f \ \tilde{P}_t^F \exp\left[A \left\{ 1 - \left(\frac{P_{t,1+}}{K} \right)^z \right\} \right]$$

The plus group age is set at *m*=40, and in the maturity ogive, age at 50% maturity is fixed at 7.5 with scale parameter 1.2. The natural mortality is assumed to be age-independent as *M*=0.04 and 0.05 (/year) (the reasons for these choices are explained below), and the MSYR(1+) is set at 1 and 2.5%. These values are used not only for conditioning but also for generating future data in the simulation context to assess the estimation performance of the natural mortality coefficient.

For the estimation process, given the single abundance estimate available, a procedure like 'Hitter' was applied, which means the standard deviation of abundance estimate was intentionally set at a tiny value (here at 0.01) while naive multinomial distributions were assumed for the catch-at-age data. Unknown parameters to be estimated in the model fitting process) are the carrying capacity, sex- and fleet- (same as period-) specific selectivity parameters given the values of *M* and as well as MSYR (equivalently given A). The fecundity is solved internally assuming that population in the start year 1906 is at equilibrium.

Conditioning gave rise to some problems because the historical catch-at-age data for the commercial period show substantial variability and are in fact made available only as ages rounded to odd integers. The likelihoods obtained did, however, indicate a preference for *M* values close to the 0.04 to 0.05 range.

Model assumed for simulation

Based on the conditioned models, projections were conducted to generate future abundance estimates and catch-at-age data. Given the somewhat questionable nature of the historical age data from commercial whaling, it was decided not to use these when fitting the model given additional data generated in the future; furthermore commercial and research selectivities (the same for the past and the future) were fixed at their values estimated for the MSYR/*M* scenario concerned. For 12 years research period, it was assumed that an abundance estimate is available twice though not for the whole area of the North Pacific but only the survey area covered under NEWREP-NP. These abundance estimates are subject to the process error due to inter-annual variations in spatial distribution, and therefore it was assumed that the abundance estimates generated when inflated to the whole area for use in the simulations have a larger CV (30%) than CV=21.4% for the actual survey to take additional variance into consideration.

In the projection and generation of future data, log-normal deviations are incorporated into the recruitment although these recruitment deviations were turned off in the estimation process. The projection starts from 2014 because the model was conditioned data up to 2013. In the 3-year gap, the actual catch was allocated to age composition using estimated selectivity and numbers-at-age. For future catch-at-age data, multinomial distributions were used without assuming any overdispersion and age-reading error. Age-readability was assumed to be 70% across all the ages based on a coarse analysis. The various annual sample sizes for the 12 years of the research program generated for the evaluation were 40, 60, 80, 100, 120 and 140. For each sample size, data generation and estimation were repeated 100 times (i.e. n=100 for the measures defined below). Estimation assumed the true selectivities, so that only carrying capacity K and natural mortality M were estimated estimated. The existing JARPNII age data were not included in the likelihood for these fits because of 'double usage' concerns since they had been used to fix the research selectivity; including them would not have a large effect on results as they total only 100, which is small compared to the sample numbers to be accumulated over the research period.

Performance measures

The parameter of interest is the natural mortality (M), and therefore the following three measures are used for evaluation of estimation performance by sample size.

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{M}_i - M\right)^2}$$

$$\text{CV} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\hat{M}_i - \bar{M}\right)^2} \,/\, M$$

$$\text{Relative Bias} = 100\left[\frac{1}{n}\sum_{i=1}^{n}\hat{M}_i - M\right] / M$$

Results and conclusion

Figure 4 shows the performance measures for the four scenarios (true *M*.MSYR combinations) considered. Robust results across these scenarios are that for an annual sample size n of 100 or above, bias reduces to close to zero, and RMSE stabilises at about 0.005. Figure 5 illustrates how the variance of the distribution of *M* estimates narrows considerably as the sample size is increased from 40 to 100.

This value makes no allowance for possible over-dispersion in the age data, and the sample sizes available are too small to estimate this reliably. Consequently the assumption has been made that this is the same as for minke whales, corresponding to a need to increase the sample size by a multiplicative factor of 1.34 (see Appendix D of Adjunct 3 of Annex 11).

Consequently the proposed annual sample size for sei whales is 134.

References

Hakamada, T. and Matsuoka, K. 2015. Abundance estimate for sei whales in the North Pacific based on sighting data obtained during IWC-POWER surveys in 2010-2012. Paper SC/66a/IA12 presented to IWC Scientific Committee, May 2015 (unpublished). 11pp.

Hakamada, T. and Matsuoka, K. 2016. The number of western North Pacific common minke, Bryde's and sei whales distributed in JARPNII Offshore survey area. Paper SC/F16/JR12 presented to the Expert Panel of the final review on the western North Pacific Japanese Special Permit programme (JARPN II), Tokyo, February 2016 (unpublished). 13pp.

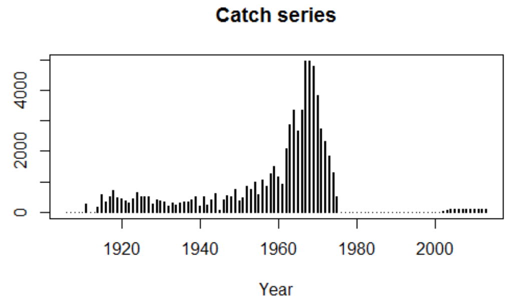

Figure 1. Catch series for the North Pacific sei whales.

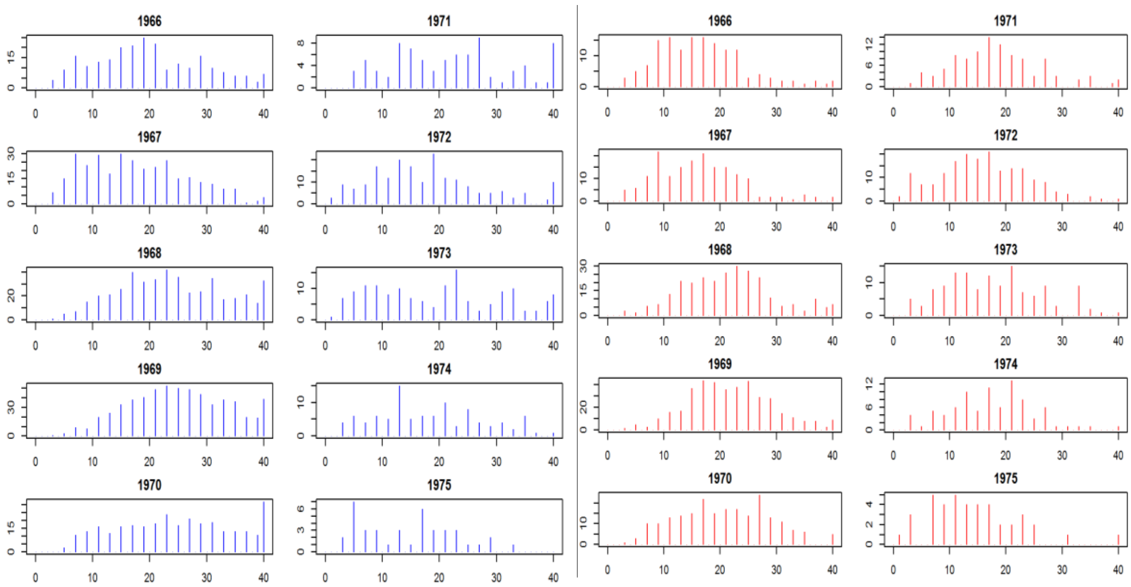

Figure 2. Catch-at-age data for male (left) and female (right) in commercial period (1966-1975)

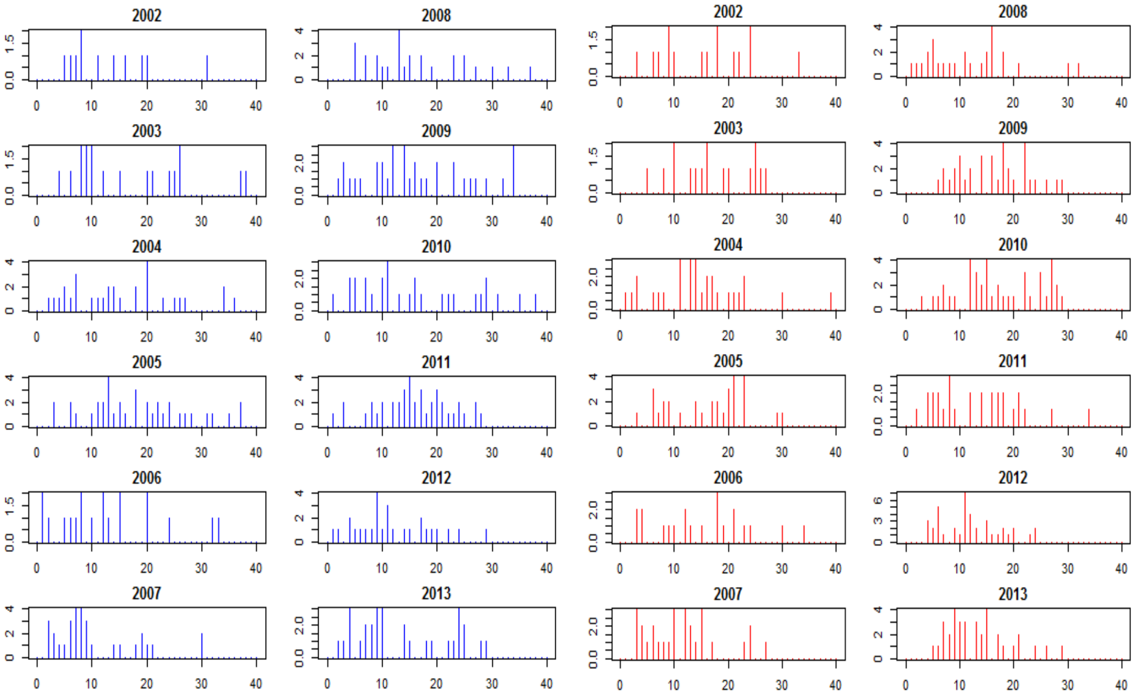

Figure 3. Catch-at-age data for male (left) and female (right) in JARPN-II period (2002-2013).

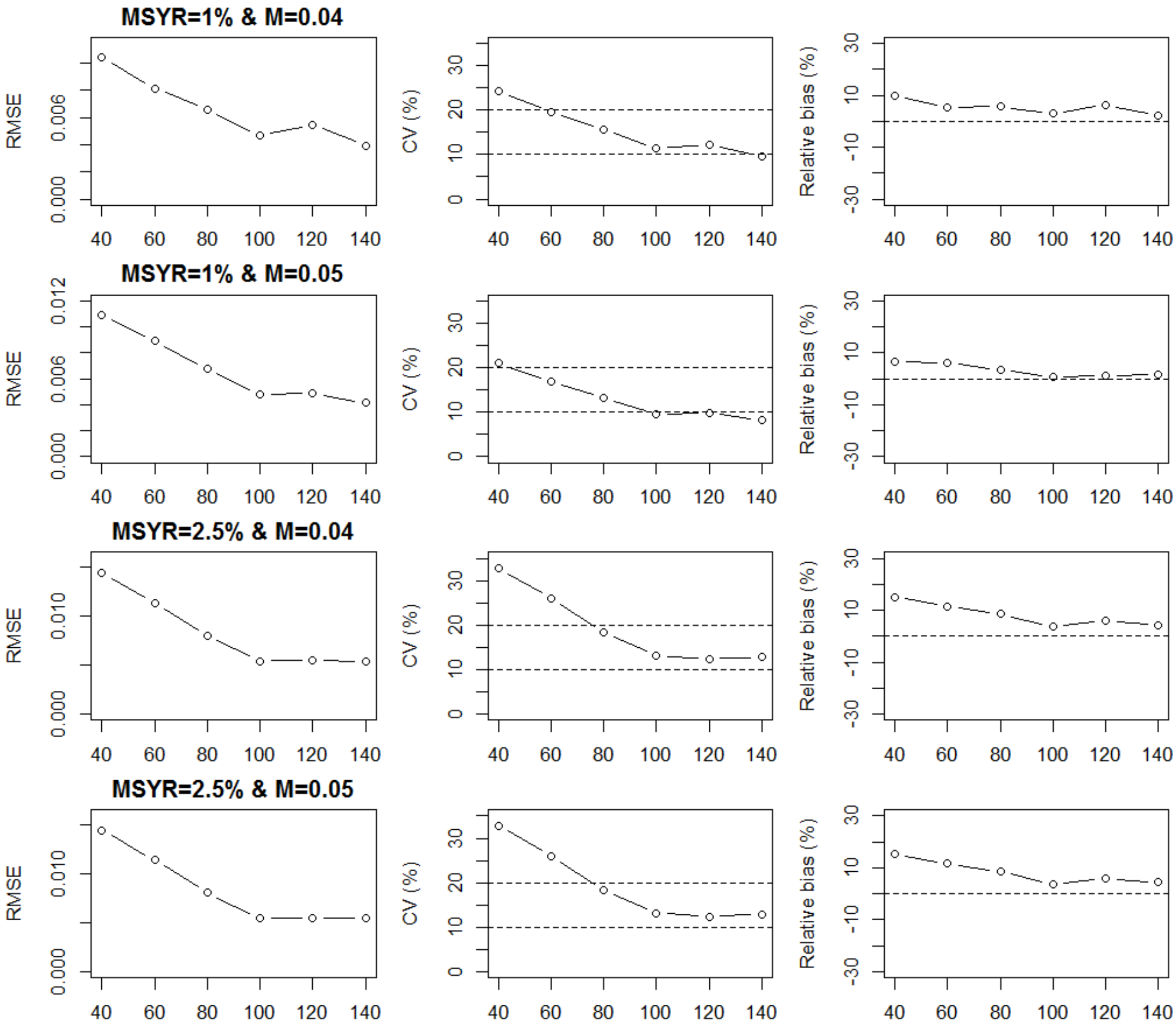

Figure 4. Summary of estimation performance for the true values of *M* at 0.04 and 0.05 under MSYR(1+)=1.0 and 2.5%.

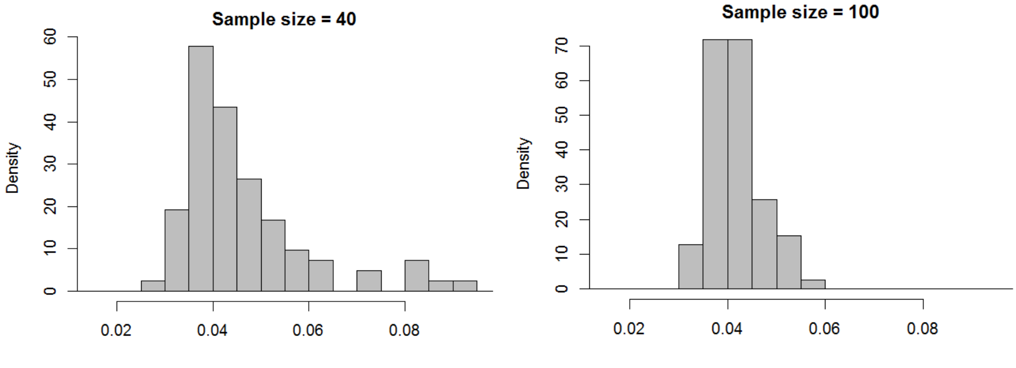

Figure 5. Histogram of estimates of *M* for the sample sizes 40 and 100 under *M*= 0.04 and MSYR= 2.5%

SECTION 4

Assessment of Potential Effect of Catches[4]

Primary Objective I (common minke whale)

Three stock structure hypotheses were used in that *Implementation Review* (IWC, 2013b) (see the Introduction section of the revised proposal for more details of these hypotheses). In essence:

Hypothesis A	J and O stocks
Hypothesis B	Y, J and O stocks
Hypothesis C	Y, Jw, Je, Ow and Oe stocks

The baseline trials for those hypotheses developed in that *Implementation Review* have been used here to assess the effect of catches, except that:

a) Hypothesis B has not been considered, as the hypothesized Y stock to the west of Korea is not impacted by the catches under consideration.

b) Those trials (*IST*s) considered the lowest plausible MSYR value to be MSYR(mat) = 1%. The Scientific Committee has subsequently agreed that this minimum be increased to MSYR(1+) = 1% [IWC, 2014b], so that the deterministic versions of the trials in question have been reconditioned with MSYR(1+) values of 1%, 2%, 3% and 4% (only the value of MSYR was changed in these reconditionings).

The constant future annual research catches considered when projecting under the proposed annual take of 170 minke whales is divided amongst sub areas as set out in Table 4.1.1, which corresponds to the temporal and spatial allocation proposed.

Table 4.1.1: Distribution of future J and O whale research catches amongst sub areas. Catches take place in the months of April-October

Sub area	7CS	7CN	7WR	7E	8	9	11
Annual catch	40	40	5	5	10	23	47

Projections under these catches for MSYR(1+) values of 1% and 2% are shown in Figure 4.1.1 for Hypothesis A for the J and O stocks, and in Figure 4.1.2 for Hypothesis C for the Jw, Je, Ow and Oe stocks. Note that these projections assume that current levels of bycatch continue unchanged. To ease

[4] To aid the reader, the text below contains some repetition of text in the main body of the program proposal.

understanding, projections are also shown for the case of these bycatches only, with no research catch[5].

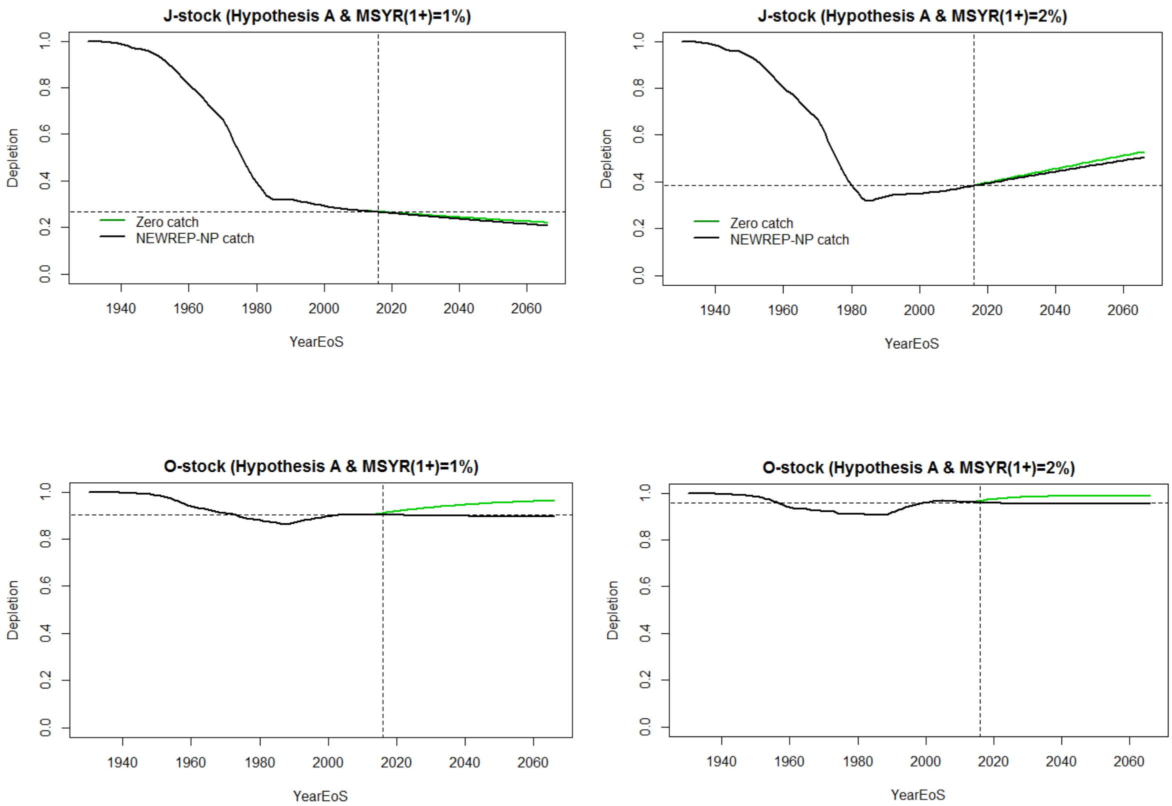

Figure 4.1.1. Projections under the proposed catches for MSYR(1+) values of 1% and 2% for Hypothesis A for the J and O stocks. Depletion refers to the mature female component. Note that the zero catch results refer to the situation of no commercial or research catch, but bycatch continuing as in the immediate past.

[5] The projections here have used the IWC code which allows only for a fixed catch each year following the last year of the assessment, i.e. projections here start in 2013. Thus the proposed scientific catches have been taken to apply starting in 2013, rather than in 2017. Strictly the actual catches made over 2013-2016 should be input, but the resultant differences to the projections will be very small and of no consequence to the key conclusions..

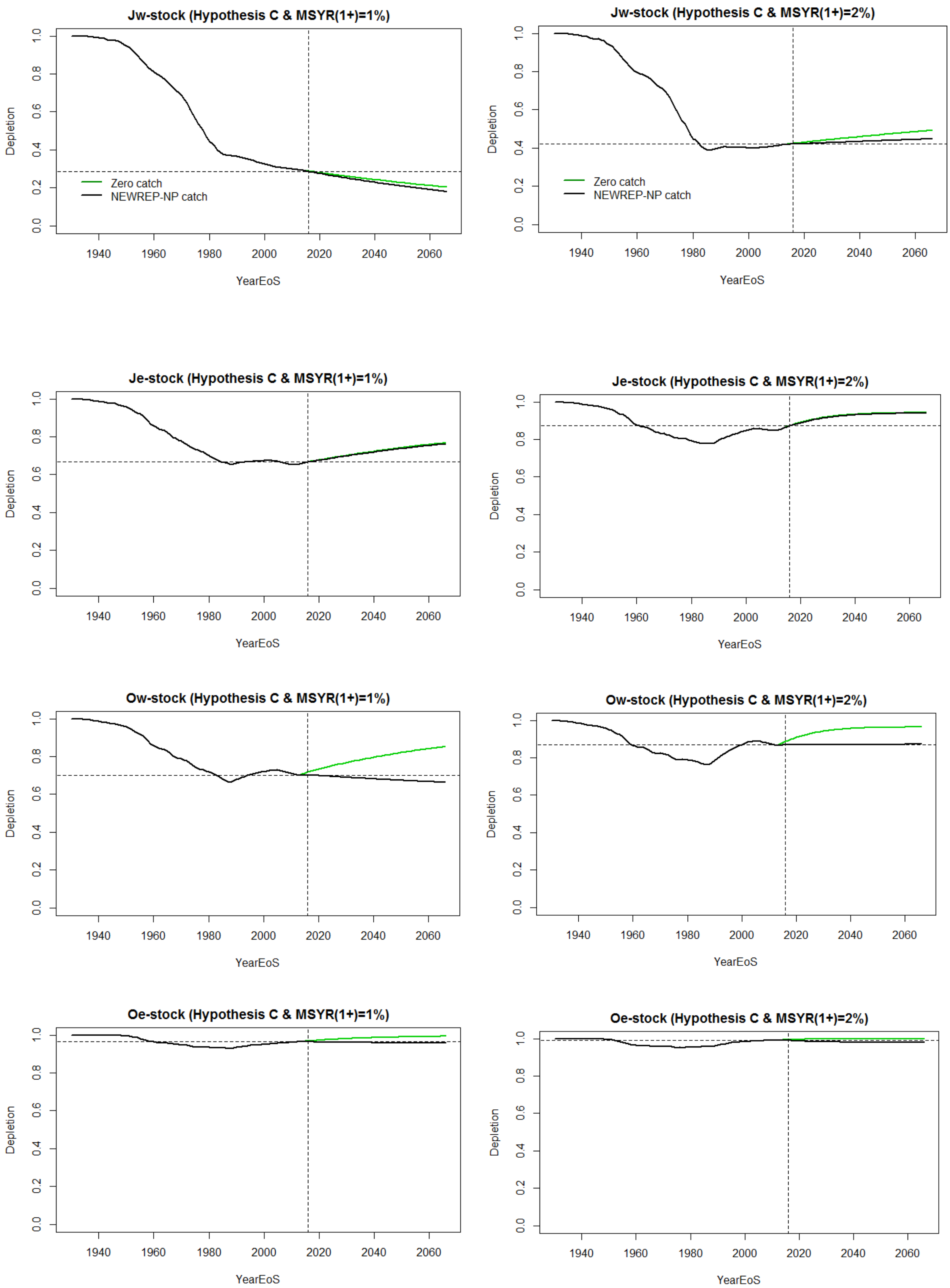

Figure 4.1.2. Projections under the proposed catches for MSYR(1+) values of 1% and 2% for Hypothesis C for the Jw, Je, Ow and Oe stocks. Depletion refers to the mature female component.

Note that the zero catch results refer to the situation of no commercial or research catch, but bycatch continuing as in the immediate past.

For MSYR(1+) = 2%, all stocks show increases and/or are well above 54% of their pre-exploitation levels under the research catches proposed, so there are no population conservation concerns.

For MSYR(1+) = 1%, under Hypothesis A the J stock is currently less than 54% of its pre-exploitation level and is projected to continue to decline, while under Hypothesis C the same applies for the Jw stock (though this is a consequence of the bycatches only, as no research take from sub areas where this stock is present is planned), and the Ow stock, currently at 70.2% of its pre-exploitation level, decreases slowly to reach 66.3% by 2066. However, while these instances might be considered by some to be population conservation concerns, the proponents consider that issue to be negligible, as recent information/analyses have shown the associated stock structure/MSYR combinations to be clearly implausible, for the reasons set out below.

In summary, the results provided therefore show that the research catches proposed will not adversely impact the stocks, so that no population conservation concern arises.

The assumption of an MSYR(1+) value for 1% for the J stock in Hypothesis A

The conditioning of the North Pacific common minke whale *IST*s includes a component in the objective function which secures trends in whale abundance that are consistent with by-catch per unit effort in fixed set nets, including those off Japan (see equation F.6 in IWC 2014c).

However this conditioning does not take account of further information that is available on the J:O split of these bycatches which indicates an increasing proportion of J whales, contrary to what might be expected if the J stock was heavily depleted and continuing to decline under the current bycatches as indicated for MSYR(1+) = 1% in Figure 4.1.1 above. Figure 4.1.3 compares this historical observed trend with the annual values for the proportion of J whales in the J+O total for different values of MSYR(1+) as predicted, and is suggestive that this further J:O bycatch ratio information may be able to discriminate amongst different MSYR(1+) values. Note that the explanation for the recent increase in the J stock proportion in the overall population as MSYR increases is that the O stock is hardly depleted so that its numbers hardly change, whereas the J stock has been more substantially reduced in the past, and has recently been changing at a fairly large rate that increases with MSYR.

Figure 4.1.4 compares the estimate of annual trend provided by log-linear regression of the J proportion of the bycatch (with the associated 95% CI) with the point estimates of the trends from the Hypothesis A model abundances for different MSYR(1+) values. This suggests an MSYR(1+) value of 2.8% with a lower 95% confidence limit of 1.6%.

Deterministically such a log-linear relationship is the more justified for the J:O bycatch ratio compared to the J proportion, but precision decreases because of the greater variance in ratio data. Such an analysis does, however, suggest a larger value for the lower 95% confidence limit for MSYR(1+) of 2.8%.

These bycatch data are thus strongly suggestive of a MSYR(1+) value of 2% or more, for which the results discussed above indicate no conservation concern for the J stock under the research catches proposed.

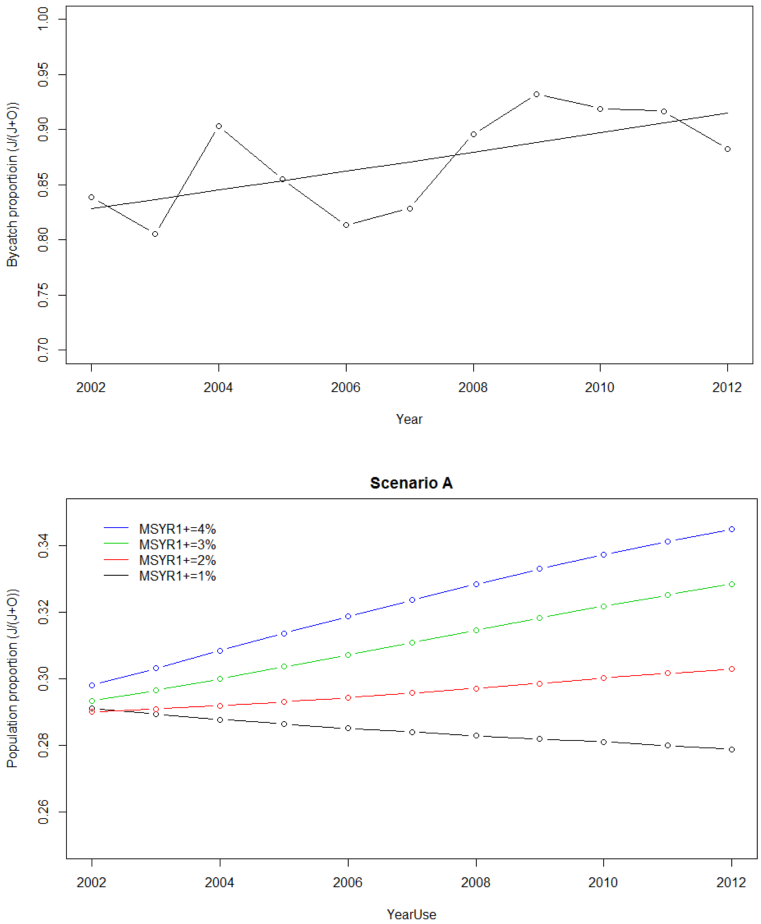

Figure 4.1.3. Comparison of historical observed trend in the proportion of bycatch of J whales in the J+O total with the trend in the proportion of J whales in the J+O total for different values of MSYR(1+) as predicted under Hypothesis A.

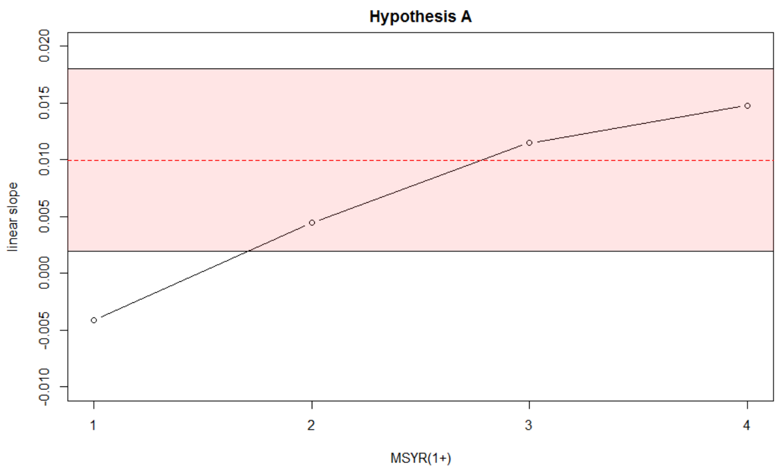

Figure 4.1.4. Comparison of the estimate of annual trend provided by log-linear regression of the observed bycatch (with the associated 95% CI) with the point estimates of the trends from the Hypothesis A model abundances for different MSYR(1+) values.

A more formal investigation is possible through noting that the bycatch model used for the *IST*s (IWC 2014c) indicates that the expected value of the J stock bycatch proportion in each (pertinent) sub area for each year is equal to the corresponding proportion (appropriately averaged over months) of the number of whales in that sub area each year, specifically:

$$E[C^{k,s}_{B,t,m}] = A^k P^{k,s}_{t,m} E_t \ , \tag{4.1}$$

where $E[C^{k,s}_{B,t,m}]$ and $P^{k,s}_{t,m}$ are the expected bycatch and the number of whales in year *t* and month *m* for subarea *k* and stock s (J or O), respectively (these two quantities depends on the value of $MSYR_{1+}$); A^k is a sub-area effect; and E_t is an effort in year *t*.

Assuming catches are Poisson distributed, so that these J stock proportions are binomially distributed, leads to the following negative log likelihood as a function of the value of MSYR(1+):

$$NLL(MSYR_{1+}) \propto -\sum_{t,k}\left[C^{k,J}_{B,t} \log \phi^{k,J}_t + C^{k,O}_{B,t} \log \phi^{k,O}_t)\right], \tag{4.2}$$

where

$$\phi^{k,s}_t = \frac{\sum_m E[C^{k,s}_{B,t,m}]}{\sum_s\sum_m E[C^{k,s}_{B,t,m}]} = \frac{\sum_m A^k P^{k,s}_{t,m} E_t}{\sum_s\sum_m A^k P^{k,s}_{t,m} E} = \frac{\sum_m P^{k,s}_{t,m}}{\sum_s\sum_m P^{k,s}_{t,m}} = \frac{P^{k,s}_t}{\sum_s P^{k,s}_t} \qquad (s = \text{J/O}) \tag{4.3}$$

and

$$P^{k,s}_t = \sum_m P^{k,s}_{t,m} \ \ (s = \text{J/O}) \ .$$

Since $P^{k,s}_{t,m}$ depends on the value of MSYR(1+), the loglikelihood is a function of that value as specifically shown in (4.2).

The associated computations indicate strong support for an MSYR(1+) value of 4% or more. However there are systematic deviations from model predicted proportions for some sub areas, which are such as preclude these results from being used to provide reliable confidence bounds. This indicates a need to refine the current bycatch model in the next *Implementation Review* for these minke whales. In the meantime, however, this result does provide qualitative support for the conclusion above based on a simpler approach regarding the value of MSYR(1+).

While in general terms there might be reservations about the assumption of CPUE being proportional to abundance, these concerns are greatly reduced here because the effort in question relates to set nets in fixed locations over time, and the analysis assumes only that the ratio of the stocks present in the bycatches is given by the ratio of the populations of those stocks present in the sub area concerned.

The assumption of separate Ow/Oe and Jw/Je stocks for Hypothesis C

Tables 4.1.2 and 4.1.3 (duplicated from Taguchi *et al*., 2017) show the number of close-kin pairs observed by sub area pairings for O and J whales. They also show which sub area pairings should and should not evidence pairings in terms of the Hypothesis C mixing matrices for the assumed Ow/Oe and Jw/Je stocks.

Table 4.1.2. The number of Parent-Offspring pairs of O stock whales within and between sub-areas (duplicate from Taguchi *et al*., 2017). The blue color indicates those sub-area pairings that are not consistent with the Hypothesis C mixing matrices for the assumed Ow/Oe stocks; the orange color indicates those sub-areas that are not inconsistent with this hypothesis.

O stock

	1E	2C	6E	7CN	7CS	7WR	7E	8	9	11
1E				1						
2C				1						
6E										
7CN				1	7	1		3	7	1
7CS					5	1		1	6	
7WR										
7E									2	
8									2	
9									1	
11										

Table 4.1.3. The number of Parent-Offspring pairs of J stock whales within and between sub-areas (duplicate from Taguchi *et al*., 2017). The blue color indicates those sub-area pairings that are not consistent with the Hypothesis C mixing matrices for the assumed Jw/Je stocks; the orange color indicates those sub-areas that are not inconsistent with this hypothesis.

J stock

	2	6	7CN	7CS
2				
6		4		2
7CN			1	
7CS				2

Table 4.1.2 indicates 20 examples of close-kin pairs that are inconsistent with the Hypothesis C split of O whales into Ow and Oe stocks. This constitutes compelling evidence that this split is NOT supported by the data.

Table 4.1.3 indicates 2 examples of close-kin pairs that are inconsistent with the Hypothesis C split of J whales into Jw and Je stocks. This is not quite as strong evidence as in the Ow-Oe case above, given the lesser number of close-kin pairs observed which are inconsistent with the Hypothesis C assumptions. Nevertheless this result, taken together with the view of geneticists that the genetic evidence for a Jw-Je differentiation is in any case very weak (IWC 2013c), is sufficient to conclude that this differentiation within J whales in Hypothesis C is not plausible.

In summary, taking account of the close-kin evidence now available, Hypothesis C may no longer be considered plausible.

Primary Objective II (sei whale)

- Information on stock structure

The most comprehensive studies conducted so far with regard to the stock structure of the North Pacific sei whales were those presented at the mid-term JARPNII Review workshop in 2009 (Kanda *et al*. 2009) as well as those presented at more recent IWC SC meetings (Kanda *et al*. 2013). These studies used microsatellite DNA loci and mtDNA markers to examine sei whales samples collected from almost the entire range of North Pacific.

Kanda *et al*. (2009) analyzed genetic variation at 17 microsatellite DNA loci and 487bp of mitochondrial DNA (mtDNA) control region sequences in the JARPNII samples (n=489) from 2002 to 2007 in the area between 143°E and 170°E as well as in the commercial whaling samples (n=301) from 1972 and 1973 conducted in the area between 165°E and 139°W. The results indicated no evidence of significant genetic differences within as well as between the JARPNII and commercial whaling samples. Both females and males showed the same pattern of the stock structure. Sequencing and phylogenetic analysis of the mtDNA control region also showed no evidence of the genetic heterogeneity in the JARPNII samples as well as no spatially or temporally unique phylogenetic clusters.

Kanda *et al*. (2013) examined genetic variations at 14 microsatellite DNA loci in the North Pacific sei whale using biopsy samples obtained from the IWC-POWER surveys that covered the 173°E - 172°W area of the central North Pacific in 2010 (n=13), 170°W - 150°W area of the central North Pacific in 2011 (n=29), and 150°W - 135°W area of the eastern North Pacific in 2012 (n=35), and these obtained data were analyzed with those in Kanda *et al*. (2009). This study allowed the authors to examine temporal (40 years apart between the POWER and commercial whaling data) and spatial (143°E to 135°W area divided into western, central and eastern) genetic differences of the North Pacific sei whales. Similar to Kanda *et al*. (2009), the results showed no evidence of the temporal genetic differences between the recent POWER and past commercial whaling samples collected from the same area and no evidence of the spatial genetic differences among the western, central and eastern samples.

One drawback to these two studies was that there was no direct comparison among samples collected at the same time of the year from the different areas over the North Pacific. Considering that sei whales conduct seasonal migration from their breeding ground to feeding ground every year, development of stock structure hypothesis should test the genetic differentiation in the samples collected in the same year that eliminate temporal negative biases. If no genetic difference is found, this would hardly suggest a strong possibility of multiple stocks in the area. Kanda *et al*. (2015a) looked at genetic variation at the microsatellite DNA loci to analyze the JARPNII and POWER samples collected from the same time of years in 2010, 2011 and 2012, respectively. Again the study failed to demonstrate evidence of multiple stocks of sei whales in the North Pacific.

The *in-depth assessment* of North Pacific sei whale started at the 2015 IWC SC meeting. The IWC SC agreed to proceed with two initial alternative stock structure hypotheses: i) a single stock in the entire North Pacific as proposed by Kanda *et al*. (2015a;b), based on several pieces of evidence including genetics; and ii) a five-stock hypothesis proposed in Mizroch (2015), based mainly on the interpretation of mark-recapture data: Japan coastal; North Pacific pelagic; Aleutian Islands and Gulf of Alaska; eastern North Pacific migratory; and Southern North American coastal stock (coastal California) (IWC, 2015a). The IWC SC agreed that discriminating between these two hypotheses is difficult in the absence of genetic data from the potentially extirpated stocks, and thus both hypotheses are plausible (IWC, 2015a). The IWC SC agreed that the oceanic regions of the North Pacific are composed of a single stock (IWC, 2015a).

At the 2016 IWC SC meeting the Committee agreed that the genetic and mark-recapture data currently available are consistent with a single stock in the pelagic region of the North Pacific (IWC, 2016b).

Therefore the analyses conducted to evaluate the effect on the sei whale stocks of future NEWREP-NP catches are based on the hypothesis of a single stock in the pelagic regions of the North Pacific to which the catches to be made will be restricted.

- The estimated abundance of the species/stocks, including methods used and an assessment of uncertainty, with a note as to whether the estimates have previously been considered by the SC

Hakamada and Matsuoka (2015) estimated abundance estimate based on IWC-POWER data from the 2010-2012 surveys using the design based estimator and detection function with covariates following the previous IWC SC recommendations. Considering the discussion at the IWC SC in 2015, Akaike-weighted average of the estimate of 29,632 (CV=0.242) was endorsed for use in the in-depth assessment of the sei whales (IWC, 2016d).

Hakamada and Matsuoka (2016) estimated abundance of 5,086 (CV=0.378) in sub-areas 7, 8 and 9 in late season based on the 2008 JARPNII sighting data using the design based estimator and detection functions considering some covariates of detectability. The estimates were presented at the final JARPNII review workshop and the review workshop recommended that exploration of methods to account for sampling differences between areas and years to obtain measures of short and long-term variation and trends and estimates the extent of additional variance due to changes over time in spatial distribution (IWC 2016c). The additional variance has not been estimated yet and this would cause some underestimation of variances of abundance estimates.

Since the areas covered by these two surveys do not overlap, the abundance estimates from each have been added. Hence computations have been conducted for a population estimate of 34,718 in 2010 and its lower 5%-ile of 24,530.

- Provision of the results of a simulation study on the effects of the permit takes on the stock that takes into account uncertainty

Figure 8 shows projections of the cases considered for the NP sei whales. The calculation was conducted based on conditioned age-/sex-structured models (see Annexes 14 and 16). Regardless of parameters assumed, there is no serious difference in the median trajectory between the two catch scenarios (0 and 134 per year) over the 12 years research period, and therefore it is evident that the impact of an annual catch of 134 whales is very small in relative terms.

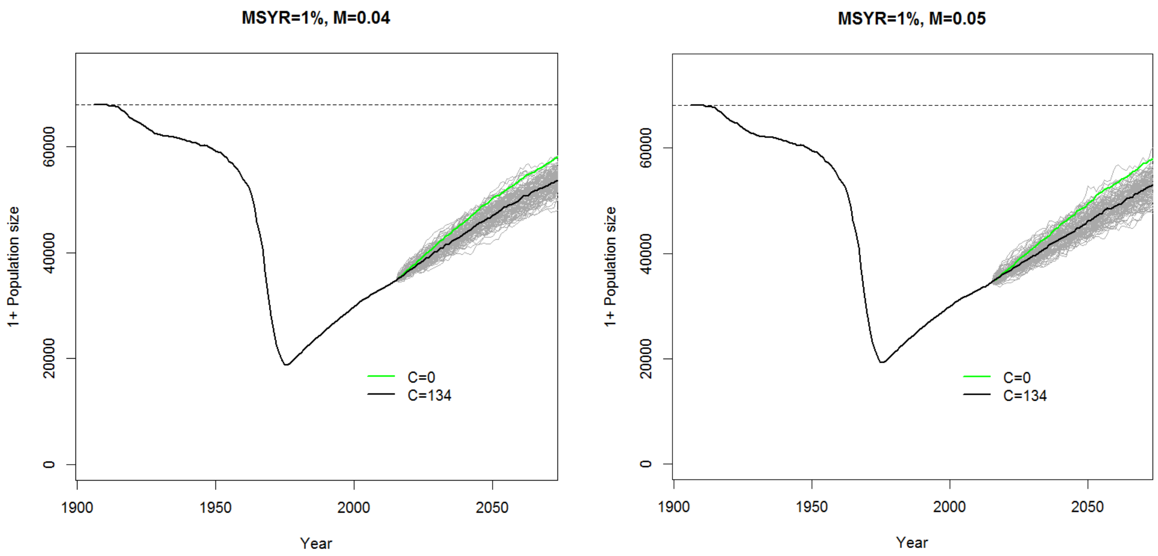

Figure 8. Population trajectory for the sei whales for 50 years under MSYR(1+)=1%. The black line shows the median trajectory with the proposed catch of 100 replicates (gray lines). The green line is the median for no catch. The horizontal dashed line shows the carrying capacity for the 1+ population.

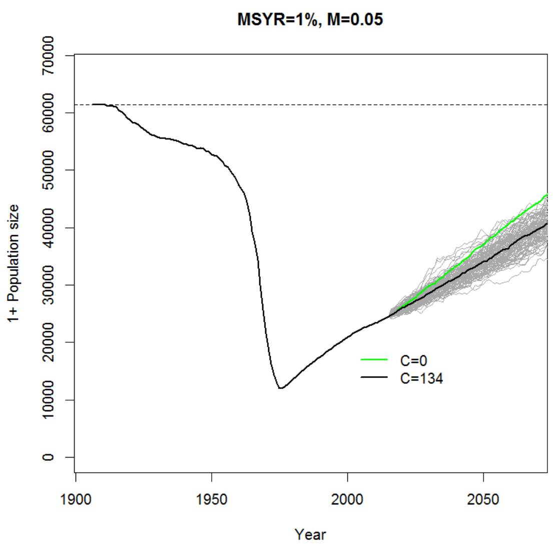

Figure 9. Precautionary evaluation of population trajectory for the sei whales by hitting the lower 5%-tile of abundance estimate in 2010.

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