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Ongoing work towards an In-Depth Assessment of western North Pacific Minke whales

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ABSTRACT
This document summarises the progress made on the In-Depth assessment of western North Pacific minke whales, including the new data received and changes made since SC68c. The decisions required to continue the assessment and complete the conditioning are outlined. In addition, examples of the diagnostic plots for Hypothesis B are provided.

Proposed changes at SC68c

The following changes to the specifications were proposed and agreed upon by the Scientific Committee at SC68c (section 8.1.3 of IWC 2022):

1. Estimates of abundance based on less than 70% coverage should be treated as 'minimum abundance estimates' (except in sub-areas where there are no other estimates). Implemented. The coverages for sub-areas for which there are no other estimates (and thus not used as minima) are as follows:

10W	59.9%
7E	57.1%
8	62-65%
9N	67.8%

2. The approach used to generate abundance estimates for estimates of abundance that are not 'minima' should be applied to 'minimum' estimates of abundance. Implemented.
3. The maximum size for each survey estimate for sub-areas 5 and 6W should be based on scaling the minimum sizes upwards by the inverse of the proportion of area surveyed, and the minimum and maximum abundance estimates should be included in the objective function using a method that allows for the uncertainty of the estimates. Implemented.
4. The model expectation for an abundance estimate based on a survey conducted during multiple months should be based on weighting the model predictions using the proportion of the months during which the survey occurred. Not implemented as exact dates are not available for several surveys. Instead, if less than 20% of the number of days of the survey occurred during a given month, that month was not used as part of the survey-time-period in the likelihood equation.
5. The zero abundance estimates should be included in the objective function under the assumption of an overdispersed Poisson distribution, with the extent of overdispersion specified as detailed in Appendix A. Implemented.
6. The effort in the fisheries that lead to bycatch off Japan should be based on the numbers of large-scale set nets (where the nets with unknown locations are assigned to sub-area in the same proportion as the data for set nets with known locations). Implemented.
7. The effort in the net fisheries that lead to bycatch off Korea should be based on the number of nets rather than licenses. Implemented.
8. Projections of set net numbers beyond the years with data (2018 for Japan; 2009 for Korea) should be set to the average of the last five years with data. Implemented.

Changes to data since SC68c

- Table of Abundance Estimates (Table 6, Appendix A):

Japan supplied information to revise entries and fill some gaps in the abundance table, particularly regarding exact survey dates, area, coverage, no. of whales/schools sighted, effective search width and the percentage of survey track realised.

\- The following estimates have been recalculated:

1. Abundance estimates for sub-area 10E in 2002, 2003, 2005 and 2007 have been revised to use the exact size of the sub-area calculated using GIS (there was an error in the area size used in earlier calculations).
2. The abundance estimate for sub-area 12SW in 1990 has been recalculated as the previous value was calculated before the sub-area was redefined (see IWC 2012, pp. 420-21).
3. Abundance estimates for sub-area 12NE in 1990 and 1992 have been recalculated as the previous values were calculated before the sub-area was redefined (see IWC 2012, pp420-21).

4. The abundance estimate for sub-area 9 in 1990 was recalculated, following examination of an inconsistency between the estimate for the agreed total abundance in the NW Pacific of 5,841 (Buckland et al 1992), which was split between sub-areas 7, 8 and 9.

These were accepted intersessionally by the Steering Group for use in conditioning.

- The Steering Group additionally agreed that three estimates of abundance agreed previously, but not used in conditioning the 2013 trials, should be added to the data set used for conditioning:

1. Estimates of abundance for sub-areas 6 and 10 in 1992 were agreed for use in conditioning the 2003 trials (both of which were used as minima because only the eastern portions of the sub-areas were surveyed). However, they were not included in the estimates used to condition the 2013 trials, although no explanation was provided as to why they were dropped. The estimate of abundance for sub-area 6E is the only value available for abundance in August-September in that sub-area and in sub-area 10E there is only one other estimate in September.
2. An estimate of abundance for sub-area 10E in 2007 was only used in the 2013 trials in a sensitivity trial (after extrapolating the value from 80% coverage to 100%) – it is unclear why this estimate was not suggested for use in these trials.

- Some estimates of coverage were also updated. As noted above, estimates with <70% coverage are used as minima (except in sub-areas 10W, 7E, 8 and 9N where there are no other estimates).

- SC68a suggested that the ASI Standing Working Group should conduct an intersessional review of the abundance estimates that have yet to be accepted to date to enable the conditioning process to be finalised. The Steering Group reviewed the above changes intersessionally and the changes will be presented to the ASI Standing Working Group during SC68d.

- Updates to the numbers of nets and bycatches were received from Japan during SC68c and have been incorporated into the trials.

Changes to model since SC68c

The current version of the specifications is provided in Appendix A.

1. In years for which actual bycatch estimates are available, these are removed from the population rather than model-predicted bycatches.
2. The mixing matrices have been updated to improve the fit to the stock mixing proportions.
3. Following a review of initial conditioning results by the Steering Group, the population sizes in sub-areas 2C, 2R, 3 and 4 were seen to be unrealistically large. To allay this, a penalty has been added to the likelihood function to constrain the abundance in all months in 2009 in sub-area 2C to be less than 300 individuals.
4. A penalty has also been added to the likelihood to constrain the abundance in August and September of 2009 in sub-area 2R to less than 500 individuals.
5. Previously, the model-estimated proportion of **recruited** individuals by stock was fitted to the observed stock proportions (equation F.5a of Appendix A). In sub-areas where the observed stock proportions are based on genetic samples from bycatch data, the model estimated proportions are now calculated using the 1+ population. In sub-areas where the observed stock proportions are based on genetic samples from special permit data or a combination of bycatch and special permit data, the model-estimated proportion is still calculated from the recruited population.
6. In line with the agreed item (5) above from SC68c, replicates are now generated from an over-dispersed Poisson distribution using the abundance estimates by fitting the actual data as the mean (not the observed zero abundance), together with the adjusted CV of the survey estimate for that sub-area, $\hat{\alpha}^k$ (Table 8 of Appendix A).
7. At SC68c, the Scientific Committee proposed that the approach for implementing minimum estimates should be refined as the penalty was too weak to prevent the population size in sub-areas 5 and 6W from being estimated to be lower than the minima. The model-estimated abundances are now either above or within the confidence intervals of the minimum estimates.

Hypotheses A and B

The models have been conditioned to fit to the 'best' values for the abundance and stock proportion estimates. Initially, this resulted in some poor fits to the abundance estimates, particularly in sub-areas 7CS and 9 and to some of the proportion data. The mixing matrices were revised (see yellow highlights in Appendix A) to achieve improved fits to the data. Once the fits to these 'best' estimates have been accepted, runs to condition the 100 replicates will begin.

Hypothesis E

Promising fits to the data were initially obtained for this hypothesis during the intersessional period. However, the population sizes in sub-areas 2C, 2R, 3 and 4 were unrealistically large for this hypothesis, as was the case for the A and B hypotheses. Since then, work has focused on revising the A and B hypotheses first, as detailed above, to ensure acceptable fits to the data could be found for these models before returning to the E hypothesis.

Example output

Appendix B includes an example set of figures showing results from a fit to the 'best' estimates of abundance and stock proportions for the baseline B hypothesis with MSYR of 1%. These include several new diagnostic plots. The figures shown are ordered as follows:

- The numbers of mature females and 1+ population by stock.
- The 1+ population by sub-area in May-June (red) and Aug-Sep (blue), including available estimates (x), minima (∇), maxima (Δ) and zero abundances (▲), to give an overview of sub-areas for which there are/not abundance estimates and an overview comparison of population distribution between the sub-areas.
- The model fits to the J- and O-stock proportions from genetic samples. Proportions are calculated from the 1+ population if samples were from bycatches and the recruited population if samples were from special permit catches or a combination of both bycatches and special permit catches. The solid line denote predictions based on recruited population sizes and the dashed lines those based on 1+ population sizes. The aggregated data to which the model is conditioned are shown with thick 90% CIs, while the annual data are shown with thin grey 90% CIs (excluding cases of 0%:100%) for information purposes. (See Appendix A, Table 7a for the data.)
- The model fits to the J-stock proportions based on mtDNA and microsatellite samples in sub-area 6W. (See Appendix A, Table 7b for the data.)
- The model-predicted bycatches compared to those observed.
- The number and percentage of individuals by age group/sex for each month and sub-area.
- The 10-year average percentage by age group, sub-area and month.
- The monthly age/sex distribution of minke whales by sub-area in 1930, 1960 and 2020. The area of the circles is proportional to the abundance in each sub-area.
- The monthly age/sex distribution of minke whales by sub-area in 1930 and 2020. The area of the circles is standardised for all sub-areas.

Decisions that need to be made

The following need to be agreed/advised particularly noting that this is no longer an *Implementation Review,* which might require more detailed and accurate analyses than an In-depth Assessment.

- The list of sensitivity trials.
- The number of replicates to be run for (a) the baseline trials and (b) the sensitivity tests. (100 replicates are used for both baseline and sensitivity tests in *Implementation Reviews,* but conditioning 100 replicates is a very time-consuming process.)
- What direct catches should be assumed in future years (e.g. a constant catch, catch limit set by Japan or other)?
- Given (e) under 'Changes made since SC68c', and that genetic samples for sub-area 11 were obtained from both bycatch and special permit catches, it may be more reasonable to calculate stock proportions separately. See Appendix C for alternative example fits.
- Should the mixing matrices be adjusted to allow for P-stock individuals (males, females and/or juveniles) in sub-area 11 during October-December to accommodate all the bycatches assigned to the P-stock?
- Estimates of dispersal rates between the J- and P-stocks and the P- and O-stocks need to be confirmed once updated results from Hypothesis E are available.
- Consider including parent-offspring data in the E Hypothesis (Wilburg 2019).

References

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International Whaling Commission. 2012. Report of the first RMP intersessional workshop for western North Pacific common minke whales. *J. Cetacean Res. Manage. (Suppl.)* 13:411-60.

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Wilburg, 2019 pers. comm.

Appendix A - Specifications for the *In-Depth Assessment* of western North Pacific Minke Whales

C. Allison, C.L. de Moor and A.E. Punt

DRAFT – the details of some of these specifications are still to be finalised

A. Basic concepts and stock structure

The objective of this *In-Depth Assessment* of western North Pacific minke whales is to review the current status of the stocks and to examine the effect of future catches, for example as set by the Revised Management Procedure (RMP). This assessment has been developed from the *Implementation Simulation Trials* previously used to test the performance of the RMP in scenarios that relate to the actual problem of managing a likely fishery for minke whales in the North Pacific (IWC, 2014b)[1]. The trials attempt to bound the range of plausible hypotheses regarding the number of minke whale stocks in the North Pacific, how they feed (by sex, age and month) and recruit and how surveys index them. The underlying dynamics model is age- and sex-structured and allows for multiple stocks.

The region to be managed (the western North Pacific) is divided into 22 sub-areas (see Fig. 1). Future surveys are unlikely to cover sub-areas 1, 2, 3, 4 and 13 (see Table 3) so these sub-areas are taken to be *Residual Areas* in the current trials (although allowance is made for future bycatches from some of these sub-areas – see section D). The term 'stock' refers to a group of whales from the same breeding ground.

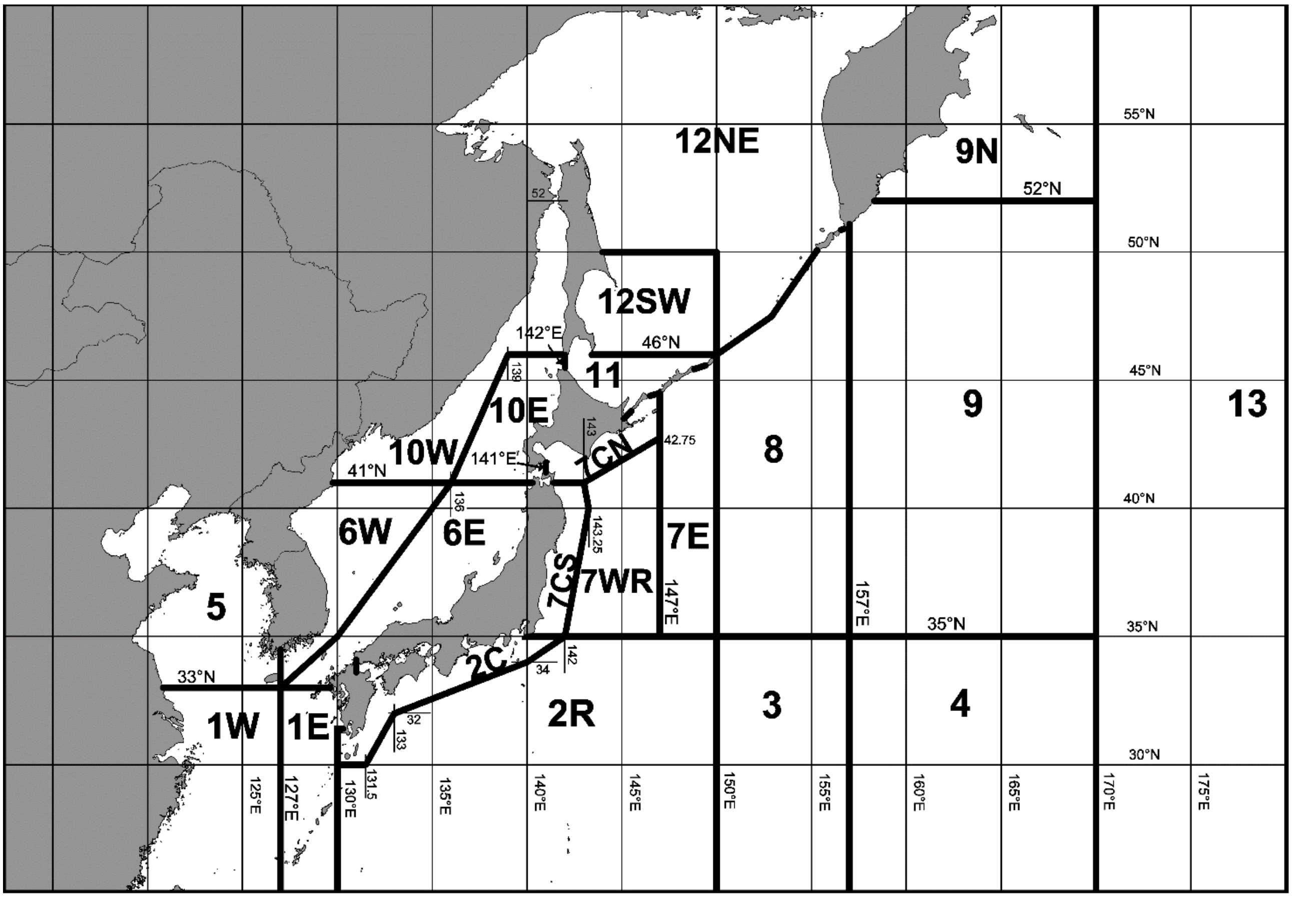

Fig. 1. The 22 sub-areas used in the *In-Depth Assessment* for North Pacific minke whales

[1] Since this *Implementation Assessment* is developed from the *Implementation Simulation Trials* framework, we continue to use the testing nomenclature from the trials (e.g. conditioning rather than fitting).

Three fundamental hypotheses are considered to account for patterns observed in the results from the genetic analyses[2]:

(i) there is a single J-stock distributed to the west of Japan (sub-areas 1W, 1E, 5, 6W, 6E, 10W and 10E) and the Pacific coast of Japan (sub-areas 2C, 7CS, 7CN, 11 and 12SW) and a single O-stock in sub-areas to the east and north of Japan (2C, 2R, 3, 4, 7CS, 7CN, 7WR, 7E, 8, 9, 9N, 10E, 11, 12SW and 12NE) (referred to as hypothesis A);

(ii) as for hypothesis A, but there is a third stock (Y) that resides around the Korean peninsula (sub-areas 1W, 5 and 6W) and overlaps with J-stock in the southern part of sub-area 6W (referred to as hypothesis B); and

(iii) there are four stocks, referred to Y, J, P, and O, two of which (Y and J) occur to the west of Japan, and three of which (J, P, and O) are found to the east of Japan and in the Okhotsk Sea (referred to as hypothesis E). Stock P is a coastal stock.

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Sensitivity tests in which there is a C-stock are also conducted based on stock structure hypotheses A and E. The C-stock is found in sub-areas 9 and 9N for the sensitivity test based on stock structure hypothesis A and in these sub-areas as well as sub-area 12NE for the sensitivity test based on stock structure hypothesis E. There is uncertainty regarding whether C-stock is found in sub-area 12NE because of the lack of genetic data for this sub-area.

B. Basic dynamics

Further details of the underlying age-structured model and its parameters can be found in IWC (1991, p.112), except that the model has been extended to take sex-structure into account. The dynamics of the animals in stock j are governed by Equations B.1(a) except for hypothesis E, which allows for dispersal (permanent movement between stocks) as given by Equations B.1(b).

$$N_{t+1,a}^{g,j} = \begin{cases} 0.5\, b_{t+1}^{j} & \text{if } a=0 \\ (N_{t,a-1}^{g,j} - C_{t,a-1}^{g,j})\tilde{S}_{a-1} & \text{if } 1 \le a < x \\ (N_{t,x}^{g,j} - C_{t,x}^{g,j})\tilde{S}_{x} + (N_{t,x-1}^{g,j} - C_{t,x-1}^{g,j})\tilde{S}_{x-1} & \text{if } a = x \end{cases} \tag{B.1a}$$

$$N_{t+1,a}^{g,j} = \begin{cases} 0.5\, b_{t+1}^{j} & \text{if } a=0 \\ \sum_{j \ne j'} [\left(1-D^{j,j'}\right)(N_{t,a-1}^{g,j} - C_{t,a-1}^{g,j})\tilde{S}_{a-1} + D^{j',j}(N_{t,a-1}^{g,j'} - C_{t,a-1}^{g,j'})\tilde{S}_{a-1}] & \text{if } 1 \le a < x \\ \sum_{j \ne j'} [\left(1-D^{j,j'}\right)\left((N_{t,x}^{g,j} - C_{t,x}^{g,j})\tilde{S}_{x} + (N_{t,x-1}^{g,j} - C_{t,x-1}^{g,j})\tilde{S}_{x-1}\right) & \\ \quad + D^{j',j}\left((N_{t,x}^{g,j'} - C_{t,x}^{g,j'})\tilde{S}_{x} + (N_{t,x-1}^{g,j'} - C_{t,x-1}^{g,j'})\tilde{S}_{x-1}\right)] & \text{if } a = x \end{cases} \tag{B.1b}$$

where $N_{t,a}^{g,j}$ is the number of animals of gender g and age a in stock j at the start of year t;

$C_{t,a}^{g,j}$ is the catch (in number) of animals of gender g and age a in stock j during year t (whaling is assumed to take place in a pulse at the start of each year);

b_t^j is the number of calves born to females from stock j at the start of year t;

$\tilde{S}_a$ is the survival rate = e^{-M_a} where M_a is the instantaneous rate of natural mortality (assumed to be independent of stock and sex); and

x is the maximum age (treated as a plus-group); and

$D^{j,j'}$ is the dispersal rate (i.e. the probability of an animal moving permanently) from stock j to j'. It is assumed that the numbers dispersing from the j-stock to the j'-stock are the same as from the j'-stock to the j-stock at unexploited equilibrium and that the proportion of calves dispersing from the j-stock to the j'-stock at equilibrium is the same as that from the j'-stock to the j-stock.

Note that projections start in year t=2021.

For computational ease, the numbers-at-age by sex are updated at the end of each year only, even though catching is assumed to occur from March to October. This simplification is unlikely to affect the results substantially for two reasons: (1) catches are at most only a few percent of the number of animals selected to the fisheries; and (2) sightings survey estimates are subject to high variability so that the resultant slight positive bias in abundance estimates is almost certainly inconsequential.

[2] See IWC, 2020 pp376-381 for details of the data and analyses used in the development of these hypotheses.

C. Births

Density-dependence is assumed to act on the female component of the mature population. The convention of referring to the mature population is used here, although this actually refers to animals that have reached the age of first parturition.

$$b_t^j = B^j N_t^{\mathrm{f},j}\{1+A^j(1-(N_t^{\mathrm{f},j}/K^{\mathrm{f},j})^{z^j})\} \tag{C.1}$$

where B^j is the average number of births (of both sexes) per year for a mature female in stock *j* in the pristine population;

A^j is the resilience parameter for stock *j*;

z^j is the degree of compensation for stock *j*;

$N_t^{\mathrm{f},j}$ is the number of 'mature' females in stock *j* at the start of year *t*:

$$N_t^{\mathrm{f},j} = \sum_{a=a_m}^{x} N_{t,a}^{\mathrm{f},j} \tag{C.2}$$

a_m is the age-at-first-parturition; and

$K^{\mathrm{f},j}$ is the number of mature females in stock *j* in the pristine (pre-exploitation, written as *t*=-∞) population:

$$K^{\mathrm{f},j} = \sum_{a=a_m}^{x} N_{-\infty,a}^{\mathrm{f},j} \tag{C.3}$$

The values of the parameters A^j and z^j for each stock are calculated from the values for $MSYL^j$ and $MSYR^j$ (Punt, 1999). Their calculation assumes harvesting equal proportions of males and females.

D. Catches

The operating model considers two sources of non-natural mortality: direct catches and bycatches (which are also referred to as incidental catches). In future (*t* > 2020), the direct catches are set externally (e.g. by the RMP or specified as a time-series of fixed removals by sub-area), while the bycatches are a function of abundance and future fishery effort.

In cases in which the total catch limit (e.g. as set by the RMP) is less than the level of incidental catch, the total removals are taken to be the incidental catch only whereas if this total catch limit exceeds the incidental catch (if any), the level of the commercial removals is taken to be the difference between the total catch limit and the best estimate of the incidental catch (see 'Future incidental catches' below).

D.1 Direct catches

The direct historical (pre-2021) catch series used are listed in Appendix A1 and include both commercial and special permit catches. Details of the sources of the catch data are given in Allison (2011). The baseline trials use the 'best' direct catch series, and an alternative 'high' catch series is used in Trial 4. Trials 8 and 9 test the effect of the method used to allocate historical catches between sub-areas 5 and 6W. If catch limits are set by the RMP, it will use the 'best' series in all cases; i.e. it will use what are in effect incorrect catches for Trials 4, 8 and 9 to examine the implications of uncertainty about historical catches. Catch limits are set by *Small Area*. (Catches are always reported by *Small Area*).

Catches and bycatches are removed month by month from each sub-area. It is assumed that whales are homogeneously distributed across a sub-area (excepting in sub-areas 7CS and 7CN in the future), so historical catches and the future catch limits for a sub-area are allocated to stocks by sex and age relative to their true density within that sub-area, and a catch mixing matrix *V* that depends on sex, age and time of the year (and may also depend on year), i.e.

$$C_{t,a}^{g,j} = \sum_k \sum_q F_t^{g,k,q}\, V_{t,a}^{g,j,k,q} S_a^g \tilde{N}_{t,q,a}^{g,j} \tag{D.1}$$

$$F_t^{g,k,q} = \frac{C_t^{g,k,q}}{\sum_{j'}\sum_{a'} V_{t,a'}^{g,j',k,q} S_{a'}^g \tilde{N}_{t,q,a'}^{g,j'}} \tag{D.2}$$

where $F_t^{g,k,q}$ is the exploitation rate in sub-area k on fully recruited ($S_a^g \to 1$) animals of gender g during month q of year *t*;

S_a^g is the selectivity on animals of gender g and age a:

$$S_a^g = (1+e^{-(a-a_{50}^g)/\delta^g})^{-1} \tag{D.3}$$

$\tilde{N}^{g,j}_{t,q,a}$ is the number of animals of gender g and age a in stock j at the start of month q in year t after removal of catches in earlier months and after removal of any bycatches in month q;

a^g_{50}, δ^g are the parameters of the (logistic) selectivity ogive for gender g; and

$C^{g,k,q}_t$ is the catch of animals of gender g in sub-area k during month q of year t (see Appendix A1 for the historical catches).

Each entry in the catch mixing matrix, $V^{g,j,k,q}_{t,a}$, is the fraction of males/females of age a from stock j that are found in sub-area k during month q of year t. The catch mixing matrix is different for each month to reflect the effects of migration between the breeding and the feeding grounds and back. Appendix A2 lists the catch mixing matrices considered. The matrices are based on the presence/absence matrices developed at the First Intersessional Workshop (see IWC, 2020) and represent the relative fraction of an age-class in each of the sub-areas during the months March-October. Once the values of the parameters related to mixing rates (the γs – see section F) are specified (these are estimated separately for each trial and each replicate during the conditioning process), the catch mixing matrices can be converted to fractions of each age-class in each sub-area. The values for the γ parameters are selected to mimic available data (see Section F).

Catch mixing matrices are specified for ages 4 and 10 (these being three years below and above the assumed age-at-50%-maturity). Few animals of age 4 are mature while most of age 10 are. The catch mixing matrices for ages 0-3 are assumed to be the same as that for age 4, and those for ages 11+ the same as that for age 10. The catch mixing matrices for ages 5-9 are set by interpolating linearly between those for ages 4 and 10.

The trials model whale movements for the eight months from March to October. To account for historical direct and incidental catches outside these months, all catches in January-March are modelled as being taken in March and the catches after October are assumed to have been taken in October. The historical direct catches by sex, sub-area, month and year are given in Appendix A1.

The trials are conducted assuming that the sub-areas for which future catch limits might be set are:

sub-area	7CS and 7CN	April to October (coastal/pelagic whaling outside a specified distance[3])
	7WR and 7E	April to October (pelagic whaling)
	8 and 9	April to October (pelagic whaling)
	11	April to October (coastal and pelagic whaling)
	12	April to October (coastal and pelagic whaling)

Future (t > 2020) commercial catches are allocated to sex, sub-area, month and year using the equation:

$$C^{g,k,q}_t = C^k_t \, Q^{g,k,q} \tag{D.4}$$

$Q^{g,k,q}$ is the fraction of the commercial catch in sub-area k of gender g that is taken during month q, the values of which are given in Table 1a; and

C^k_t is the commercial catch limit for sub-area k and year t (t > 2020). Note that C^k_t is equal to the total catch limit (eg as set by the RMP) less any reported incidental catch (constrained to be non-negative).

Entries in the Q matrix are determined by the options related to the sub-areas for which catch limits might be set; the non-zero entries (see Table 1a) reflect the historical breakdown of catches over the last 10 years of commercial whaling (1978-87) within each sub-area. In sub-areas for which there was no catch between 1978-87 (7E, 8 and 9), the entries in the *Q* matrix are set using the entire historical commercial and scientific catch in these sub-areas. In some instances where regulations limited the commercial whaling season, the matrix entries have been adjusted using the special permit data.

Future commercial catches are allocated to stock as described above (Equations D.1 and D.2) except in sub-areas 7CS and 7CN where the genetic data show differences between nearshore and offshore catches. It is assumed future catches will be taken offshore and are allocated to a stock based on the mixing proportions set using genetic data from special permit samples only (Table 2a). The process of allocating removals to stock within sub-areas 7CS and 7CN involves first denoting the modelled mixing proportion used when conditioning, $R^{k,q}$, as:

$$R^{k,q} = \sum_{t=1996}^{2016} P^{J/JE,k,q}_{1+,t} \Big/ \sum_j \sum_{t=1996}^{2016} P^{j,k,q}_{1+,t}$$

where $P^{j,k,q}_{1+,t}$ is the average number of 1+ animals from stock j in sub-area k in month q of year t.

[3]Operations preliminarily being considered would be limited 'to outside a certain distance from the coast to minimise catch of J-stock whales' (see IWC, 2020 p387). The 2013 trials were conducted assuming whaling would be outside 10 n.miles.

The mixing proportions obtained from the offshore samples, $\tilde{R}^{k,q}$, are given in Table 2a. The proportion of J-stock animals in some future year would normally be $P_{1+,t}^{J,k,q} \big/ (P_{1+,t}^{J,k,q} + P_{1+,t}^{P,k,q} + P_{1+,t}^{O,k,q})$. For sub-areas 7CS and 7CN in future this equation is adjusted to:

$$\left(\tilde{R}^{k,q} \neq R^{k,q}\right) \;:\; \alpha^{k,q} P_{1+,t}^{J,k,q} \big/ (\alpha^{k,q} P_{1+,t}^{J,k,q} + P_{1+,t}^{P,k,q} + P_{1+,t}^{O,k,q}) \quad \text{where} \quad \alpha^{k,q} = \frac{(1-R^{k,q})\tilde{R}^{k,q}}{(1-\tilde{R}^{k,q})R^{k,q}} \tag{D.4a}$$

The $\alpha^{k,q}$ factor is then applied to the recruited population from J-stock in sub-area k and month q when setting the commercial catch by stock using Equations D.1 and D.2.

To comply with RMP specifications regarding the sex ratio in catches (IWC, 1999), if the proportion, P_f, of females in the total directed catch (i.e. commercial and/or special permit) taken from a *Small Area* in the five years prior to the catch limit calculation exceeds 50%, the catch limits are adjusted downwards by the ratio 0.5/P_f.

Table 1a

The Q matrix used to allocate future commercial catches for a sub-area to sex and month. The entries give the percentage of the catch in sub-area k that is taken by sex and month for sub-areas other than *Residual Areas*. Dashes indicate sub-areas/months for which catch limits are defined to be zero. See text for a description of how the entries are set. Values are set using catches taken up to and including 2018.

Sub-area	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct
				Males								**Females**				
7CS	-	24.3	21.5	10.1	4.8	0.8	0.3	-	-	21.7	12.6	2.8	0.7	0.3	-	-
7CN	-	-	0.8	8.2	15.5	15.3	23.9	11.9	-	0.1	0.4	4.9	6.9	3.5	5.3	3.1
7WR	-	0.9	45.0	30.3	2.8	0.9	6.4	-	-	-	8.3	2.8	2.8	-	-	-
7E	-	-	32.9	19.3	1.9	7.2	12.6	1.0	-	-	3.9	1.9	5.3	5.3	8.7	-
8	-	-	12.8	33.6	31.9	4.4	3.0	2.0	-	-	2.7	2.0	3.4	2.0	0.7	1.7
9	-	-	5.4	13.6	30.4	36.3	2.9	-	-	-	1.5	1.8	2.7	4.9	0.5	-
11	-	1.3	5.5	9.6	9.6	4.0	3.0	0.6	0.1	10.6	19.3	18.5	10.7	4.5	2.3	0.4

Table 1b

QB matrix: the percentage of the incidental catch in sub-area k that is taken by sex and month. The values are set using all available bycatches known by sub-area, sex and month, up to and including 2016 (Japan) and 2017 (Korea). There are no known incidental catches in other sub-areas.

Sub-area	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Sample size
				Males								**Females**					
1E	17.1	9.21	1.32	9.21	1.32	0	0	3.95	18.4	6.58	10.5	7.89	6.58	2.63	0	5.26	76
2C	15.1	4.3	2.42	0.81	1.08	0.54	0	14.2	24.7	1.88	3.76	2.42	2.69	1.61	0.27	24.2	372
5	5.17	3.45	10.3	19.8	1.72	2.59	1.72	12.1	9.48	4.31	7.76	7.76	3.45	0	1.72	8.62	116
6W	13.3	5.91	6.6	4.75	2.67	3.01	4.17	14.6	13.2	4.98	4.63	6.14	1.16	1.51	1.74	11.6	863
6E	15.5	9.88	6.79	2	2.5	2.5	1.2	9.08	16.7	9.28	6.29	2.69	1.7	2.1	1.1	10.8	1002
7CS	7.89	5.02	10.4	7.17	2.51	1.08	0.36	11.5	10	8.96	9.32	8.6	2.15	1.43	1.08	12.5	279
7CN	4.19	4.79	3.59	8.38	7.19	1.8	1.2	9.58	2.99	8.98	12	9.58	6.59	2.99	1.8	14.4	167
10E	0	0	0	0	0	5.56	0	55.6	0	0	0	5.56	0	0	0	33.3	18
11	0	0	0	4.08	0	0	6.12	24.5	0	0	18.4	18.4	4.08	0	2.04	22.4	49

Table 2a

Time-invariant fixed proportions by stock to be used in removing **future commercial catches** from sub-areas 7CS and 7CN for each stock hypothesis, based on the number of sampled whales that were assigned to each stock using the genetic data[4] limited to special permit samples only [in the 2013 trials this was limited to >10nm]. The values are set using data from 1996-to 2016.

			Sample size		Proportion	
Hypothesis	Sub-Area	Months	J-Stock	O-Stock	J-Stock	O-Stock
A & B	7CS	Apr	48	138	0.258	0.742
A & B	7CS	May	89	255	0.259	0.741
A & B	7CS	Jun-Sep	4	75	0.051	0.949
A & B	7CN	Apr-Jun	12	139	0.079	0.921
A & B	7CN	Jul-Dec	169	645	0.208	0.792

			Sample size			Proportion		
Hypothesis	Sub-Area	Months	J-Stock	P-Stock	O-Stock	J-Stock	P-Stock	O-Stock
E	7CS	Apr	0	188	0	0.000	1.000	0.000
E	7CS	May	0	303	24	0.000	0.927	0.073
E	7CS	Jun-Sep	0	5	73	0.000	0.064	0.936
E	7CN	Apr-Jun	2	28	109	0.014	0.201	0.784
E	7CN	Jul-Dec	10	574	225	0.012	0.710	0.278

[4] From the data file "Data_NPM_190226_v3.csv", based on "stock90" for Hypotheses A&B and "geneland.stock2" for Hypothesis E, using special permit data only. The months are based on the same month-split used in 2013 for commercial catches. There were no special permit catches in sub-areas 7CN & 7CS in Jan-Mar or in sub-area 7CS in Oct-Dec.

Table 2b

Time-invariant fixed proportions by stock to be used in removing **bycatch** from sub-areas 7CS and 7CN for each for stock hypothesis, based on the number of sampled whales that were assigned to each stock using genetic data[5] limited to bycatch only, using data from 2001-2016.

			Sample size		Proportion	
Hypothesis	Sub-Area	Months	J-Stock	O-Stock	J-Stock	O-Stock
A & B	7CS	Jan-Apr	43	34	0.558	0.442
A & B	7CS	May	16	31	0.340	0.660
A & B	7CS	Jun-Dec	86	34	0.717	0.283
A & B	7CN	Jan-Jun	38	44	0.463	0.537
A & B	7CN	Jul-Dec	51	15	0.773	0.227

			Sample size			Proportion		
Hypothesis	Sub-Area	Months	J-Stock	P-Stock	O-Stock	J-Stock	P-Stock	O-Stock
E	7CS	Jan-Apr	0	73	1	0.000	0.986	0.014
E	7CS	May	0	49	2	0.000	0.961	0.039
E	7CS	Jun-Dec	0	118	1	0.000	0.992	0.008
E	7CN	Jan-Jun	12	69	0	0.148	0.852	0.000
E	7CN	Jul-Dec	13	59	0	0.181	0.819	0.000

D.2 Incidental catches (also known as bycatches)

Incidental catches of minke whales are known to occur off Japan (in sub-areas 1E, 2C, 6E, 7CS, 7CN, 10E and 11 and small numbers in 6W) and the Republic of Korea (sub-areas 5 and 6W and small numbers in 1W).

Japan: The bycatch numbers for Japan are considered to be reliable since 2001, when it became obligatory to report them. Earlier bycatches are believed to be under-reported based on the sudden increase in reported bycatches in 2001. In view of this, the relationship between bycatch and set-net effort is integrated into the conditioning process, with the advantage that the method is independent of the reporting rate before 2001. The reporting rate since 2001 is assumed to be constant at 100% (except in Trial 4 – see below).

Almost all of the reported bycatch off Japan occurred in set-net fisheries. Three types of set nets are used off Japan: large-scale (excluding salmon nets), salmon nets and small-scale. For fishing gears other than set-nets, incidental catch, retention and marketing of whales are prohibited by the 2001 regulation and a diagnostic DNA registry is used to deter the illegal distribution of whales caught. Ideally, the catch by each gear type should be modelled separately to allow the historical (pre-2001) bycatch to be predicted. However, information on the numbers of catches by net type is not available. Therefore, in the 2013 Implementation, the historical bycatches for each sub-area were set using the total number of incidental catches and the combined number of large-scale and salmon nets in each sub-area. The numbers of salmon nets since 2006 are not available and the numbers caught in salmon nets are small in comparison to those from large-scale nets (see Appendix A1). In the current trials, the historical bycatches are extrapolated using the total number of incidental catches and the number of large-scale nets only in each sub-area over the period 2002-2018. For the best effort series, the number of nets from Japan is extrapolated from 1946 to 1969 assuming a linear relationship from 0 in 1935 to the known number in 1970 (Tobayama *et al.*, 1992). Incidental catches before 1946 are ignored because although some set-nets were in operation before 1946 (Brownell, pers. comm.) the numbers are highly uncertain and are sufficiently small that they are unlikely to affect the conditioning process.

The year 2001 is excluded from the fitting because the catch data are incomplete, as the new regulations date from June 2001. A sensitivity test using a different series of nets from Hakamada may be added. A high effort series is also generated, for use in Trial 4, in which the number of nets is double the best-case values from 1946 to 1969, up to a maximum equal to the number of nets in 1969. In Trial 4 all bycatches are assumed to be under-reported and are adjusted upward by a factor of 2.

Korea. The same method is used as for Japan above except the incidental catch numbers from 1996-2009 (sub-area 6W) and 2000-2009 (sub-area 5) are used to extrapolate backwards and the incidental catch numbers are adjusted to allow for underreporting. The bycatches in sub-area 6W (the East Sea) are adjusted upward by a factor of 2. The factor 2 is based on DNA profiling and a capture-recapture analysis of market products that estimated a total of 887 whales going through Korean markets from 1999 to 2003, in comparison to the reported catch of 458 whales (Baker *et al.*, 2007). The baseline trials assume that the bycatches in the Yellow Sea (sub-area 5) are fully reported as there is no evidence of under-reporting. The 'high' effort series for sub-area 5 used in Trial 4 will apply the same estimate of under-reporting as for sub-area 6W (i.e. a factor of 2) and the number of nets is set to the maximum of either double the base-case values or the number of nets in 1969.

To account for bycatch prior to 1996, the average for the *adjusted* takes are used to extrapolate backwards to 1946 based on fisheries effort using the same approach as for Japan. Incidental catches before 1946 are ignored as for Japan.

[5] From the data file "Data_NPM_190226_v3.csv", based on "stock90" for Hypotheses A&B and "geneland.stock2" for stock hypothesis E, using bycatch data only. The months are based on the same month-split used in 2013 for bycatches.

China. There are no data on incidental catches off China, although they are known to occur. The trials, therefore, consider two (essentially arbitrary) scenarios: (i) the incidental catch by China is twice that reported by Korea in sub-area 5); and (ii) incidental catches off China are ignored. The first option forms part of the baseline specifications and the second is included in a sensitivity test (Trial 12) to determine the effects of the base case assumptions.

Allocation to sex and month. Bycatches by sex, sub-area~~,~~ month and year, $C_{B,t}^{g,k,q}$, are set using the equation:

$$C_{B,t}^{g,k,q} = C_{B,t}^{k} Q_{B}^{g,k,q} \qquad \text{(D.5)}$$

$Q_{B}^{g,k,q}$ is the fraction of the bycatch of gender g in sub-area k which is taken during month q and, the values of which are given in Table 1b; and

$C_{B,t}^{k}$ is the bycatch in sub-area k and year t (as estimated by the model).

To avoid a proliferation of sub-areas and to avoid the need for finer time-steps than month, incidental catches in sub-areas other than 7CS and 7CN are apportioned to stock and age class in the same way as for the commercial catches in Equations D.1 and D.2, but assuming that the bycatch is taken uniformly from all age classes (i.e. selectivity=1). Thus

$$C_{B,t}^{g,j} = \sum_{k}\sum_{q} F_{B,t}^{g,k,q} \; V_{t,a}^{g,j,k,q} \ddot{N}_{t,q,a}^{g,j}$$

$F_{B,t}^{g,k,q}$ is the bycatch removal rate for gender g in sub-area k (all sub-areas except 7CS and 7CN) during month q of year t

$$F_{B,t}^{g,k,q} = \frac{C_{B,t}^{g,k,q}}{\sum_{j'}\sum_{a'} V_{t,a'}^{g,j',k,q} \ddot{N}_{t,q,a}^{g,j'}}$$

In sub-areas 7CS and 7CN, (where the genetic data show differences between nearshore and offshore catches) bycatches are taken nearshore and so are allocated to stock using mixing proportions calculated from the number of sampled whales that were assigned to each stock using genetic data from bycatches only (Table 2b).

$$\tilde{N}_{t,q,a}^{g,j} = \ddot{N}_{t,q,a}^{g,j}\left(1 - V_{t,a}^{g,j,k,q} F_{B,t}^{g,k,q}\right) \qquad \text{for all sub-areas except 7CS and 7CN and}$$

$$\tilde{N}_{t,q,a}^{g,j} = \ddot{N}_{t,q,a}^{g,j}\left(1 - F_{B,t}^{g,k,q,j}\right) \qquad \text{for sub-areas 7CS and 7CN,}$$

$F_{B,t}^{g,k,q,j}$ is the removal rate due to bycatch of gender g and stock j in sub-area k (sub-areas 7CS and 7CN) during month q of year t.

$$F_{B,t}^{g,k,q,j} = \frac{p_{B}^{k,q,j} C_{B,t}^{g,k,q}}{\sum_{a'} \ddot{N}_{t,q,a}^{g,j}}$$ where $p_{B}^{k,q,j}$ is given by Table 2b; and

$C_{B,t}^{g,k,q}$ is the bycatch of animals of gender g in sub-area k during month q of year t (given by Equation D.5).

The historical bycatch model: The historical bycatch $C_{B,t}^{k}$ in sub-area k in year t is given by:

$$C_{B,t}^{k} = A^{k} P_{t}^{k} E_{t}^{k} \qquad \text{(D.6)}$$

where A^{k} is the bycatch constant, E_{t}^{k} is the number of nets in sub-area k during year t and P_{t}^{k} is the total population size (including calves) in sub-area k in year t averaged over all 8 time periods. In Trial 17, the abundance P_{t}^{k} in Equation D.6 is replaced by $\sqrt{\left(P_{t}^{k}\right)}$ to test an alternative assumption for the relationship between bycatch and abundance and the impact of possible saturation effects. The values of the bycatch constants are set by fitting during the conditioning process (see section F). In years where actual numbers of bycatches are known, these are the values removed from the population rather than the model estimated values.

The recent bycatches and the numbers of set-nets by type, year and area are listed in Appendix A1. Further details are given in Annex H of IWC (2012a).

Future bycatches: Future bycatches by sub-area (except in sub-areas 7CS and 7CN) are generated assuming that the exploitation rate due to bycatch in the future equals that estimated for the trial in question for the most recent five years of data used in the conditioning process, i.e.:

$$C^k_{B,t} = \overline{F}^k \, P^k_t \tag{D.7}$$

where $C^k_{B,t}$ is the bycatch in sub-area k in year t, P^k_t is the total population (including calves) in sub-area k during year t averaged over all 8 time periods (March-October), and $\overline{F}^k$ is the average exploitation rate (sum over years of the known bycatch divided by the sum over years of P^k_t) over the last five years of the period used for conditioning (2016-20 for sub-areas off Japan and 2015-19 for those off Korea), i.e. F is reset for each of the 100 simulations within a trial. Thus, the future bycatch by sex, month and sub-area is given by:

$$C^{g,k,q}_{B,t} = Q^{g,k,q}_B \overline{F}^k \, P^k_t \tag{D.7a}$$

For Trial 17, the abundance P^k_t in Equation D.7a is replaced by $\sqrt{\left(P^k_t\right)}$.

To avoid possible dis-proportionate bycatches of J- to O-stock whales, Equation (D.7a) is replaced with (D.7b) in sub-areas 7CS and 7CN.

$$C^{g,k,q}_{B,t} = \tilde{P}^k_t \overline{F}^k \, Q^{g,k,q}_B \tag{D.7b}$$

where $\tilde{P}^{k,q}_t$ is the availability-weighted population size in sub-area k during month q:

$$\tilde{P}^{k,q}_t = (P^{k,q,J}_t + \lambda^{k,q} P^{k,q,O}_t) \frac{\overline{P}^{k,q,J} + \overline{P}^{k,q,O}}{\overline{P}^{k,q,J} + \lambda^{k,q} \overline{P}^{k,q,O}} \tag{D.8}$$

where $\overline{P}^{k,q,j}$ is the average number (including calves) of stock j animals in sub-area k during month q over the last five years of the period used for conditioning;

$P^{k,q,j}_t$ is the total population size (including calves) of stock j in sub-area k during month q of year t;

$\lambda^{k,q}$ is a relative availability factor for J whales relative to O whales:

$$\lambda^{k,q} = \frac{(1-\ddot{P}^{k,q})}{\ddot{P}^{k,q}} \frac{\overline{P}^{k,q,J}}{\overline{P}^{k,q,O}} \tag{D.9}$$

$\ddot{P}^{k,q}$ is the weighted mean proportion of J-stock in sub-area k during month q (as given in Table 2b).

This bycatch is allocated to stock as follows:

$$C^{g,k,q,J}_{B,t} = \frac{P^{g,k,q,J}_t}{\lambda^{k,q} P^{g,k,q,O}_t + P^{g,k,q,J}_t} C^{g,k,q}_{B,t} \tag{D.10a}$$

$$C^{g,k,q,O}_{B,t} = \frac{\lambda^{k,q} P^{g,k,q,O}_t}{\lambda^{k,q} P^{g,k,q,O}_t + P^{g,k,q,J}_t} C^{g,k,q}_{B,t} \tag{D.10b}$$

where $P^{g,k,q,j}_t$ is the total population size (including calves) of animals of gender g from stock j in sub-area k during month q of year t.

Reported bycatches

A single series of historical bycatches will be used for all of the trials when applying the RMP (i.e. for calculating catch limits), irrespective of the true values of the bycatches, which differ both among trials and simulations within trials. The estimate of the historical bycatches used by the CLA will be set to the averages of the predicted bycatches based on the fit to the actual data[6] of the operating model for the six baseline trials (i.e. using the 'best fit' simulation (0)). The series will be generated after conditioning is complete (see Appendix A1).

The future bycatches used when applying the RMP are the true bycatches in all sub-areas[7], except for Trial 4 (in which the estimated bycatches are in error to reflect the under-estimation of bycatch inherent in these trials) and Trial 12 (in which the bycatch by China is taken to be zero).

[6] In the case of sub-area 6W the actual data is the *adjusted* bycatch data.

[7] Including sub-area 6W since the best estimate of bycatches in this area is the adjusted figure.

E. Generation of data

In 2013, the *Implementation Simulation Trials* (IWC, 2014b) used to test the performance of the RMP required estimates of future abundance to be generated. This is retained in the control program and so is documented below, although it is unnecessary for the current assessment.

The plan for future sightings surveys is listed in Table 3a. Surveys will be conducted by Japan in sub-areas 7CS, 7CN, 7WR, 7E, 8, 9, 11, 12SW and 12N. Additional surveys will be conducted by Japan in sub-areas 6E, 10W, 10E and by Korea in sub-areas 5 and 6W (see IWC, 2020 p382), but they are not listed here as they are not required for setting future catch limits and so are not modelled in the trials. Table 3b shows how surveys will be combined for areas that are combinations of sub-areas.

The estimates of absolute abundance (and their associated CVs) that are provided to the *CLA* for the years prior to management are given in Table 4. Estimates of abundance are generated for any surveys which have already been conducted but for which the results are not yet available.

The sightings mixing matrix for a year in which a survey takes place is the average of the catch mixing matrices over the two survey months in that year (April-May for surveys to the west of Japan or August-September for the remainder). The values for the parameters of the various distributions have been selected to achieve CVs for *Small Areas* comparable to those for the surveys in Table 6. The future estimates of abundance for a *Small Area* (say *Small Area E*) are generated using the formula:

$$\hat{P} = P\,Y\,w/\mu = P^*\,\beta^2\,Y\,w \tag{E.1}$$

Y is a lognormal random variable $Y = e^{\varepsilon}$ where $\varepsilon \sim N\left[0,\sigma^2\right]$ and $\sigma^2 = Ln(\alpha^2+1)$;

w is Poisson random variable with $E(w) = \mathrm{var}(w) = \mu = (P/P^*)/\beta^2$; ($Y$ and w are independent);

P is the average current total (1+) population size in the *Small Area* (*E*) over the survey period:

$$P = P_t^E = \frac{1}{2}\sum_{k\in F}\ \sum_{q\in SurveyPeriod}\ \sum_j\sum_g\sum_{a=1}^{x}\left(V_{t,a}^{g,j,k,q}N_{t,a}^{g,j}\right) \tag{E.2}$$

P^* is the reference population level, and is equal to the mean total (1+) population size in the *Small Area* prior to the commencement of exploitation in the area being surveyed; and

F is the set of sub-areas making up *Small Area E*.

Note that under the approximation $CV^2(ab) \cong CV^2(a) + CV^2(b)$: $E(\hat{P}) \cong P$ and $CV^2(\hat{P}) \cong \alpha^2 + \beta^2 P^*/P$

For consistency with the first stage screening trials for a single stock (IWC, 1991, p.109; 1994, pp.85-86), the ratio $\alpha^2 : \beta^2 = 0.12 : 0.025$, so that:

$$CV(\hat{P}) = \tau(0.12 + 0.025P^*/P)^{1/2} \tag{E.3}$$

and the CV of a survey estimate prior to the commencement of exploitation in the area being surveyed would be:

$$\sqrt{(\alpha^2+\beta^2)} = 0.38\tau \tag{E.4}$$

The values of τ applicable to each sub-area are calculated separately for each replicate once the conditioning has been accomplished by substituting the true value of the CV for each abundance estimate used in conditioning (Table 6)[8] and the corresponding model depletion level into Equation E.3. If more than one abundance estimate exists for a particular sub-area, the value assumed for τ is calculated by taking the true CV to be the root mean square of the values obtained from the abundance estimates for that sub-area, and the depletion to be the mean value over the corresponding years.

An estimate of the *CV*, X_t is also generated for each sightings estimate, $\hat{P}_t$:

$$X_t = \sqrt{(\sigma_t^2\,\chi^2/n)} \tag{E.5}$$

where $\sigma_t^2 = Ln(1+\alpha^2+\beta^2 P^*/\hat{P}_t)$, and χ^2 is a random number from a Chi-square distribution with n=10 degrees of freedom. The value 10 is chosen to roughly indicate the number of trackline segments in a sightings survey in a *Small Area*.

The trials will be based on the use of two alternative values for *g(0)* in the conditioning process: *g(0)* = 0.798 (the base case value) and *g(0)*=1 (Trial 3) (IWC, 2012a, p.417; Okamura *et al.*, 2010). When *g(0)* = 0.798 the values of the operating model abundances are multiplied by this factor when setting the future survey estimates of abundance.

[8] Excluding zero, minimum and maximum estimates and those assumed to apply to adjacent areas.

Table 3a Requires checking if used in future

Past and planned future Japanese surveys to the North and East of Japan. The survey coverage is given in parentheses. Future coverage in sub-areas 7CN, 7WR and 7E is expected to be similar to the values below (because of territorial issues). Coverage in sub-areas 8 and 9 assumes that future surveys include the Russian EEZ. Future coverage in sub-areas 11 and 12SW (of 30.1% and 48.9% respectively) excludes areas in the Russian EEZ that cannot be surveyed until the resolution of territorial issues with Japan. Future coverage in sub-area 12NE (of 46.4) reflects the area which cannot be surveyed in the North and East because of Russian restrictions. * Estimate=0; [#] surveys covered different parts of sub-area 12NE each year.

	7CS	7CN	7WR	7E	8	9	11	12SW	12NE
1990	-	-	-	-	Aug (62%)	Aug (61%)	Aug-Sep(100%)	Aug-Sep(100%)	Aug-Sep(100%)
1991	Aug-Sep*(100%)	Aug-Sep(100%)	Aug-Sep(100%)	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	Aug-Sep (100%)
1999	-	-	-	-	-	-	Aug-Sep(100%)	-	Aug-Sep (64%)
2000	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	Jun-Jul*(65%)	-	-	-	-
2003	-	-	May-Jun (27%)	-	-	Jul-Sep (33%)	Aug-Sep (34%)	Aug-Sep(100%)	Aug-Sep (41%)
2004	May (37%)	-	May-Jun (89%)	My-Jun (57%)	Jun (41%)	-	-	-	-
2005	-	-	-	-	May-Jul (65%)	-	-	-	-
2006	Jun-Jul (100%)	-	-	My-Jun (57%)	May-Jul (65%)	-	-	-	-
2007	-	-	Jun-Jul (89%)	Jun-Jul* (57%)*	Jun-Jul (65%)	-	Aug-Sep (20%)	-	-
2008	Aug* (100%)	Aug* (75%)	Aug* (89%)	Aug* (57%)	Jul-Aug*(65%)	Jul-Aug (87%)	-	-	-
2009	May-Jun (100%)	May-Jun (75%)	May-Jun (89%)	May-Jun (57%)	May-Jun (65%)	May-Jun (63%)	-	-	-
2010	-	-	-	-	-	-	-	-	-
2011	-	-	-	-	May (65%)	May (87%)	-	-	-
2012	May-Jun (100%)	May-Jun (67%) Sep (67%)	Jun (89%)	Jun*(57%)	-	-	-	-	-
2013	-	-	May-Jun (89%)	Jun*(57%)	May-Jun (65%)	-	-	-	-
2014	-	Sep (75%)	-	-	-	-	Aug (35%)	-	-
2015	-	-	-	-	-	May (87%)	-	-	Aug-Sep[#](17%)
2016	Aug-Sep*(100%)	Jul-Aug (67%)	Jul-Aug (89%)	Aug-Sep*(100%)	-	-	-	-	Aug-Sep[#](28%)
2017	May-Jun(100%)	May-Jun (75%)	-	-	-	-	-	-	Aug[#] (14%)
2018	May-Jun(100%)	May-Jun (75%)	-	-	-	-	May-Jun (22%)	-	Aug[#] (11%)
2019	-	-	May-Jun (89%)	May-Jun (57%)	-	-	-	-	Aug-Sep[#](16%)
2020	-	-	-	-	-	-	Aug-Sep	Aug-Sep	Aug-Sep
2021	-	-	Aug-Sep	Aug-Sep	Aug-Sep	Aug-Sep	-	-	-
2022	Aug-Sep	Aug-Sep	-	-	-	-	-	-	-
2023	-	-	-	-	-	-	-	-	-
2024	-	-	-	-	-	-	Aug-Sep	Aug-Sep	Aug-Sep
2025	-	-	Aug-Sep	Aug-Sep	Aug-Sep	Aug-Sep	-	-	-
2026	Aug-Sep	Aug-Sep	-	-	-	-	-	-	-
2027	-	-	-	-	-	-	-	-	-

Continue in future in the same pattern.

Table 3b

Component survey estimates to include in estimates for areas that are combinations of sub-areas. Requires updating if used in future.

	C4 = 7,8	C5 = 7WR,7E,8	C6 = 7,8,9,11	C7 = 7,8,9,11,12
1991	Yes[a]: 1990-91	Yes[a]: 1990-91	Yes[a]: 1990-91	Yes[a]: 1990-92
2003	Yes: 2002-04	Yes: 2002-04	Yes: 1999-04	Yes: 1999-04
2006	Yes[b]: 2005-07	Yes[b]: 2005-07	- (see[c])	- (see[c])
2013	Yes: 2012-3	Yes: 2013	Yes: 2012-14	Yes: 2012-14
2016	-	-	-	-
2017	Yes: 2016-17	Yes: 2017	Yes: 2016-18	Yes: 2016-18
2018	-	-	-	-
2019	-	-	-	-
2020	-	-	-	-
2021	Yes: 2020-21	Yes: 2021	Yes: 2020-22	Yes: 2020-22
2022	-	-	-	-
2023	-	-	-	-

Continue in future in the same pattern.

a) The abundance estimates set for the combined sub-areas in 1990-92 assume a zero contribution from sub-area 7E as there is no available estimate for sub-area 7E to include.

b) The abundance estimates set for combined areas C4 and C5 in 2005-07 assume a zero contribution from sub-area 7CN as there is no sub-area 7CN estimate to include.

c) There are no 2005-2011 abundance estimates for sub-areas 9 and 12 to include in combination estimates C6 and C7; no C6 or C7 estimates are generated in this period.

Table 4

List of historical abundance estimates agreed in 2013 for use by the *CLA;* requires updating if they are to be used in future. Further details are given in IWC, 2014a, pp.126-9. All estimates are calculated assuming a value of 1.0 for g(0) but the trials (except Trial 3) assume that g(0) = 0.798. *: zero abundance estimate is replaced by a value that depends on what the population estimates would have been for recent surveys in the areas had there been only one minke whale sighting made.

Year	SubA	Period	Est.	CV	Year	SubA	Period	Est.	CV	Year	SubA	Period	Est.	CV
1991	7CS	Aug-Sep	42*	0.603	1990	8	Aug-Sep	1,057	0.705	1990	11	Aug-Sep	2,120	0.449
2004	7CS	May	504	0.291	2002	8	Jun-Jul	63.6*	0.603	1999	11	Aug-Sep	1,456	0.565
2006	7CS	Jun-Jul	3,690	1.199	2004	8	Jun	1,093	0.576	2003	11	Aug-Sep	882	0.820
2012	7CS	May-Jun	890	0.393	2005	8	May-Jul	132	1.047	2007	11	Aug-Sep	377	0.389
1991	7CN	Aug-Sep	853	0.23	2006	8	May-Jul	309	0.677	1990	12SW	Aug-Sep	5,244	0.806
2012	7CN	Sept	398	0.507	2007	8	Jun-Jul	391	1.013	2003	12SW	Aug-Sep	3,401	0.409
1991	7WR	Aug-Sep	311	0.23	1990	9	Aug-Sep	8,264	0.396	1990	12NE	Aug-Sep	10,397	0.364
2003	7WR	May-Jun	267	0.700	2003	9	Jul-Sep	2,546	0.276	1992	12NE	Aug-Sep	11,544	0.380
2004	7WR	May-Jun	863	0.648						1999	12NE	Aug-Sep	5,088	0.377
2007	7WR	Jun-Jul	546	0.953						2003	12NE	Aug-Sep	13,067	0.287
2004	7E	May-Jun	440	0.779										
2006	7E	May-Jun	247	0.892										
2007	7E	Jun-Jul	52.6*	0.603										

The trials assume that it takes two years for the results of a sighting survey to become available to be used by a management procedure, i.e. a survey conducted in 2019 would first be used for setting the catch limit in 2021. Tables 3a and 3b list the pattern for future surveys and also show how results of surveys from different sub-areas are combined for use in variants in which *Small Areas* are comprised of more than one sub-areas. If a *Small Area* is comprised of sub-areas that are surveyed in different years, the combination abundance estimate is taken to be a summation of the estimates of abundance in the sub-areas over the years and taken to refer to the mean year (where the mean year is defined as the centre year in the set, or the later of two if this yields a half-integral year) (IWC, 1999). In cases in which the combined survey used more than one abundance estimate from the same sub-area, the abundance estimates are pooled using inverse variance weighting.

F. Parameter values and Conditioning

The biological parameters (natural mortality, age-at-maturity) and the technological parameters (selectivity) will be the same as for the previous Implementations (IWC, 1992a, p.160; IWC, 2014a, pp.133-180) (based on those for N Atlantic minke whales, IWC, 1992b, p.249)[9] i.e.:

Table 5

The values for the biological and technological parameters that are fixed

Parameter	Value
Plus group age, *x*	20 yrs
Age-at-first-parturition, a_m	$m_{50} = 7$; $\sigma_m = 1.2$; first age at which a female can be mature is three,
Selectivity: Males and Females	$r_{50} = 4$; $\sigma_r = 1.2$
Maximum Sustainable Yield Level, *MSYL*	0.6 in terms of mature female component of the population

Natural mortality is age-dependent, and identical to that for the North Atlantic minke trials:

$$M_a = \begin{cases} 0.085 & \text{if } a \le 4 \\ 0.0775 + 0.001875a & \text{if } 4 < a < 20 \\ 0.115 & \text{if } a \ge 20 \end{cases}$$

The MSYR scenarios are specified in Section G.

The 'free' parameters of the above model are the initial (pre-exploitation) sizes of each of the stocks, the values that determine the mixing matrices (i.e. the γ parameters), the bycatch constants (A_k). The process used to select the 'free' parameters is known as conditioning. The conditioning process involves first generating 100 sets of 'target' data as detailed in steps (a) and (b) below, and then fitting the population model to each (in the spirit of a bootstrap). The number of animals in sub-area k at the start of year t is calculated starting with guessed values of the initial population sizes and projecting the operating model forward to 2020 to obtain values of abundance etc. for comparison with the

[9] The values are consistent with the results from JARPN. Japanese scientists advised that the above approach is appropriate given the well-known practical difficulties in using earplugs for age determination of North Pacific common minke whales. However, they also noted that technical advances mean that it may be possible to obtain age estimates in the future (IWC, 2014b, p.492).

generated data[10]. When performing the projections, the direct catches and known bycatches from each sub-area are set to their historical values – Appendix A1 and the bycatches are set as detailed below).

The information used in the conditioning process is as follows.

(a) Abundance estimates

The target values for the historical abundance by sub-area (except for the maximum and zero estimates – see below) are generated using the formula:

$$P_t^k = O_t^k \exp[\mu_t^k - (\sigma_t^k)^2 / 2] \qquad \mu_t^k \sim N[0;(\sigma_t^k)^2] \tag{F.1}$$

P_t^k is the abundance for sub-area k in year t

O_t^k is the actual survey estimate for sub-area k in year t (see Table 6); and

σ_t^k is the CV of O_t^k .

The trials are based on the two alternative values for *g(0)* in the conditioning process: *g(0)*=0.798 (the base case value) and *g(0)*=1 (Trial 3) (IWC, 2012a, p.417; Okamura *et al.*, 2010). When *g(0)*=0.798 the values of the operating model abundances (P_t^k) are multiplied by this factor for comparison with the conditioning targets.

Minimum abundance estimates:

Table 6 includes several survey estimates that are assumed to be minima[11]. Target values for these are similarly generated using Equation (F.1).

Maximum abundance estimates.

Bounds need to be placed on the maximum size of populations in sub-areas 5 and 6W as there is insufficient information to estimate the abundance in sub-areas 5 and 6W, given that the only estimates available for these sub-areas have very low survey coverage. Target values were generated as $P_t^k = Z_t^k / \vartheta_t^k$, where Z_t^k is the minimum estimate for the survey in the same year and period and ϑ_t^k is the proportion of the sub-area that was covered by the survey.

Following a review of initial conditioning results, the population sizes in sub-areas 2C, 2R, 3 and 4 were seen to be unrealistically large. To allay this, two penalties have been added to the likelihood function i) to constrain the abundance in all months in 2009 in sub-area 2C to be less than 300 individuals and ii) to constrain the abundance in August and September in 2009 in sub-area 2R to be less than 500 individuals.

Zero abundance estimates:

Table 6 includes several survey estimates of zero abundance. The target values for the historical abundance are generated using an overdispersed Poisson distribution.

(b) Proportion estimates

Estimates of the number of genetic samples assigned by stock in sub-areas 2C, 6W, 7CS, 7CN, 7WR, 10E and 11 are generated from a multinomial distribution that corresponds to the observed data (see Table 7a). Some of the mixing proportions are based on data from several years so the model estimates to which these proportions are fitted during conditioning are sample size-weighted year-specific proportions.

Estimates of the proportion of recruited J-stock whales in sub-areas 6W (see Appendix A3 for how these proportions are estimated) are generated from appropriately truncated normal distributions that correspond to the observed data and are based on mtDNA and other genetic information (see Table 7b). Some of the mixing proportions are based on data from several years so year-specific proportions weighted by sample size are fitted during conditioning. A minimum standard error for the mixing proportions of 0.05 was imposed to prevent a few of the mixing proportions from dominating the conditioning processes – see IWC (2012c, p.106).

(c) Fixed stock proportion in sub-area 12SW

The data for sub-area 12SW are limited and so the proportion of J-stock in sub-area 12SW in June is fixed at 20% in the baseline trials. This value reflects a rough average of the J-stock mixing proportions for sub-area 11 (J-stock animals in sub-area 12SW need to pass through sub-area 11). Since the proportions for sub-area 11 are calculated from the 1984-1999 data, the 20% is taken as an average over these same years. Sensitivity trials test different levels of the sub-area 12SW proportion. In Trial 10 the proportion is 10 % (with 0% J-stock in sub-area 12NE as for the base case) and in Trial 11 the proportion is 30% (with 10% J-stock in sub-area 12NE in the same months/years; the mixing matrix is adjusted accordingly). In Trial 21 the proportion of J-stock in sub-area 12NE in May-July is fixed at 10%.

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[10] In order to check that the conditioning exercise has been successfully achieved, plots such as those shown in IWC (2003, pp.473-80) will be examined, together with time-trajectories of the fraction of each stock in each sub-area.

[11] Survey estimates based on less than 70% coverage are treated as 'minima' (except in sub-areas where there are no other estimates). A sensitivity trial may be added that uses a different criteria to define minimum estimates.

Table 6

Abundance data used to condition the trials**. All estimates were calculated assuming g(0)=1 whereas the conditioning process assumes g(0) = 0.798 (excepting Trial 3). See IWC, 2014a, pp. 126-9 for details of estimates used in the 2013 implementation.

Sub-area	Year	Season[a]	STD estimate[b]	CV[c]	Mode[d]	% Areal coverage	Use for Conditioning?[e]	Source
5	2001	Apr-May	1,534	0.523	NC	13	Min & Max[f]	An *et al*, 2010
5	2004	Apr-May	799	0.321	NC	13	Min & Max[f]	An *et al*, 2010
5	2008	Apr-May	680	0.372	NC	13	Min & Max[f]	An *et al*, 2010
5	2011	Apr-May	587	0.405	NC	13	Min & Max[f]	Park *et al*, 2012
6W	2000	May	549	0.419	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2002	May-Jun	391	0.614	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2003	Apr-May	485	0.343	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2005	Apr-May	336	0.317	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2006	Apr-May	459	0.516	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2007	Apr-May	574	0.437	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2009	Apr-May	884	0.286	NC	14.3	Min & Max[f]	An *et al*, 2010
6W	2010	Apr-May	1,014	0.387	NC	23.6	Min & Max[f]	An *et al*, 2011
6E	1992	Aug-Sep	893	0.67		56.8	Yes	Miyashita & Shimada, 1994
6E	2002	May-Jun	891	0.608	NC	79.1	Yes	Miyashita *et al*, 2009
6E	2003	May-Jun	935	0.357	NC	79.1	Yes	Miyashita *et al*, 2009
6E	2004	May-Jun	727	0.372	NC	79.1	Yes	Miyashita *et al*, 2009
10W	2006	May-Jun	2,476	0.312	IO-PS	59.9	Yes	Miyashita & Okamura 2011
10E	1992	Aug-Sep	707	0.57		30.0	Yes	Miyashita & Shimada, 1994
10E	2002	May-Jun	1,192	0.658	NC	100	Yes	Miyashita *et al*, 2009
10E	2003	May-Jun	591	0.566	NC	100	Yes	Miyashita *et al*, 2009
10E	2005	May-Jun	875	0.441	NC	64	Min	IWC, 2014a, pp.126-9
10E	2007	Jun	672	0.327	IO-PS	80.1	Yes	Miyashita *et al*, 2009
10E	2014	Sep	872	0.585		100	Yes	Miyashita, 2019
10E	2018	May-Jun	620	0.478		100	Yes	Hakamada *et al*, 2019
7CS	2004	May	504	0.291	NC	36.7	Min	IWC, 2014a, pp.126-9, 181
7CS	2006	Jul	3,690	1.199	NC	100	Yes	Hakamada & Kitakado, 2010
7CS	2012	May-Jun	537	0.346		100	Yes	Hakamada *et al*, 2016
7CS	2016	Aug	0	-		100	Yes	Hakamada *et al*, 2019
7CS	2017	May	284	0.497		100	Yes	Hakamada *et al*, 2019
7CS	2018	May-Jun	245	0.828		100	Yes	Hakamada *et al*, 2019
7CN	2012	May	542	0.601		66.7	Min	Hakamada & Kitakado, 2010
7CN	2012	Sep	599	0.525		66.7	Min	Hakamada *et al*, 2016
7CN	2014	Sep	244	0.454		75	Yes	Hakamada *et al*, 2016
7CN	2016	Aug	185	0.423		66.7	Min	Miyashita, 2019
7CN	2017	May	179	0.377		75	Yes	Hakamada *et al*, 2019
7CN	2018	May	212	0.784		75	Yes	Hakamada *et al*, 2019
7WR	2003	May-Jun	267	0.7	NC	26.7	Min	IWC, 2014a, pp.126-9
7WR	2004	May-Jun	863	0.648	NC	88.8	Yes	Hakamada & Kitakado, 2010
7WR	2007	Jun-Jul	546	0.953		88.8	Yes	Hakamada & Kitakado, 2010
7WR	2012	Jun	378	0.79		88.8	Yes	Hakamada & Matsuoka 2016
7WR	2013	May-Jun	65	1.007		89	Yes	Hakamada *et al*, 2019
7WR	2016	Aug	75	1.062		89	Yes	Hakamada *et al*, 2019
7W: 7CS+ 7CN+7WR	1991	Aug-Sep	1,164	0.183			Yes	Butterworth & Miyashita, 2014
7E	2004	Jun	440	0.779	NC	57.1	Yes	Hakamada & Kitakado, 2010
7E	2006	May-Jun	247	0.892	NC	57.1	Yes	Hakamada & Kitakado, 2010
7E	2007	Jun-Jul	0	-		57.1	Yes	Hakamada & Kitakado, 2010
7E	2012	Jun	0	-		57.1	Yes	Hakamada & Matsuoka 2016
7E	2013	Jun	0	-		57.1	Yes	Hakamada *et al*, 2019
7E	2016	Aug	0	-		57.1	Yes	Hakamada *et al*, 2019
8	1990	Aug	1,057	0.706	NC	62.2	Yes	Buckland *et al*, 1992; Miyashita pers com 2021
8	2002	Jun-Jul	0	-	NC	65	Yes	Hakamada & Kitakado, 2010
8	2004	Jun	1,093	0.576	NC	40.5	Min	Hakamada & Kitakado, 2010
8	2005	May-Jul	132	1.047	NC	65	Yes	Hakamada & Kitakado, 2010
8	2006	May-Jul	309	0.677	NC	65	Yes	Hakamada & Kitakado, 2010
8	2007	Jun-Jul	391	1.013		65	Yes	
8	2008	Jul-Aug	0	-		65	Yes	Hakamada & Matsuoka 2016
8	2009	May-Jun	602	0.725		65	Yes	Hakamada & Matsuoka 2016
8	2011	May	121	0.966		65	Yes	Hakamada & Matsuoka 2016
8	2013	May-Jun	413	0.586		65	Yes	Hakamada *et al*, 2019
9	1990	Aug	3,287	0.819	NC	61.4	Min	Buckland *et al*, 1992; Miyashita pers com 2021
9	2003	Jul-Sep	2,546	0.276	NC	33.2	Min	Hakamada & Kitakado, 2010
9	2008	Jul-Aug	2,458	0.664		87	Yes	Hakamada *et al*, 2016
9	2009	May-Jun	2,079	0.688		63	Min	Hakamada *et al*, 2016
9	2011	May	115	1.025		87	Yes	Hakamada *et al*, 2016
9	2015	May	140	0.963		87	Yes	Hakamada *et al*, 2019
9N	2005	Aug-Sep	420	0.969	IO-PS	67.8	Yes	Miyashita & Okamura 2011
9N	2011	May-Jun			115	1.05	Yes	Hakamada et al, 2016

Table 6 continued

Sub-area	Year	Season[a]	STD estimate[b]	CV[c]	Mode[d]	% Areal coverage	Use for Conditioning?[e]	Source
11	1990	Aug-Sep	2,120	0.449	NC	100	Yes	Buckland et al, 1992. IWC, 2004, p.124
11	1999	Aug-Sep	1,456	0.565	IO	100	Yes	IWC, 2004, p.124
11	2003	Aug-Sep	882	0.826	IO-AC	33.9	Min	Miyashita & Okamura, 2011
11	2007	Aug-Sep	377	0.389	IO-PS	20.2	Min	Miyashita & Okamura, 2011
11	2014	Aug	306	0.679		35	Min	Miyashita, 2019
11	2018	May	235	0.481		21.7	Min	Hakamada *et al*, 2019
12SW	1990	Aug-Sep	4,774	0.508	NC	100	Yes	Buckland et al, 1992. cv recalculated (Miyashita pers. comm 2021).
12SW	2003	Aug-Sep	3,401	0.409	IO-AC	100	Yes	Miyashita & Okamura, 2011
12NE	1990	Aug-Sep	11,805	0.377	NC	100	Yes	Buckland et al, 1992. Recalculated Miyashita pers. comm Nov 2021
12NE	1992	Aug-Sep	11,051	0.705	NC	[100]	Yes	Miyashita & Shimada, 1994; Recalculated Miyashita pers. comm Nov 2021
12NE	1999	Aug-Sep	5,088	0.377	NC	63.8	Min	IWC, 2014a, pp.126-9
12NE	2003	Aug-Sep	13,067	0.287	IO-AC	41	Min	Miyashita & Okamura, 2011

** The above table lists estimates used in conditioning, including corrections received from Japan. The Secretariat maintains a full list of estimates including details of other estimates and the reason they were not included in the above table.

[a] Season: if a survey took place in less than 20% of a month, that month was not used as part of the survey-time-period in the likelihood calculation.

[b] Standard (STD) estimate based on 'Top and Upper bridge' assuming g(0)=1, but subsequently corrected by estimate of g(0) for the combined platform 'Top and Upper bridge'.

[c] CV does not consider any process errors.

[d] Mode: NC=Normal-closing, IO-PS=Passing with IO mode, IO-AC=Abeam-closing with IO mode. (STD estimates by different modes, NC, IO-AC, IO-NC, are considered comparable.)

[e] Survey estimates based on less than 70% coverage are treated as 'minima' (except in sub-areas where there are no other estimates).

[f] Maximum values are calculated as the best estimate/coverage.

(d) Fixed stock proportion in sub-area 9 and 9N

The data for sub-area 9 are also limited. For Trials 2 and 23, which assume a C-stock that mixes with the O-stock in sub-area 9 and 9N, the proportion of O-stock is assumed to be 0.5 during August and September in 1995. This is based on the ratio assumed in 9W in 2003. For hypothesis E, Trial 2 the same proportion is also assumed in 12NE in August and September 1995 (but not in Trial 23).

Table 7a ** In future consider splitting Jan-Mar (11) &Apr-May (89) to assist estimation of different gammas

The number of sampled whales that were assigned to each stock using the genetic assignment data based on STRUCTURE (Hypothesis A & B) and Geneland (Hypothesis E) using a 90% probability of assignment, except for Trial 5 where a 70% probability of assignment is used. In sub-areas 7CS and 7CN, the baseline and Trial 5 proportion of whales assigned to each stock is weighted by 5/60 of the bycatch proportion and 55/60 of the special permit proportion. The number assigned by stock is then taken as this proportion multiplied by the total number of assigned animals. In Trial 6 the proportion of whales assigned to each stock is weighted by 2/60 of the bycatch proportion and 58/60 of the special permit proportion, while in Trial 7 10/60 of the bycatch proportion and 50/60 of the special permit proportion are used. These data are used to condition the trials.

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	Bycatch Samples		Special Permit Samples		Weighted Total	
							J-Stock	O-Stock	J-Stock	O-Stock	J-Stock	O-Stock
A & B	Baseline	2C	2002-16	Jan-Apr	M+F	155	127	28			127	28
A & B	Baseline	2C	2001-16	May-Sep	M+F	56	46	10			46	10
A & B	Baseline	2C	2001-16	Oct-Dec	M+F	134	122	12			122	12
A & B	Baseline	7CS	2002-16	Jan-Apr	M+F	263	43	34	48	138	74	189
A & B	Baseline	7CS	2001-16	May	M+F	391	16	31	89	255	104	287
A & B	Baseline	7CS	1999-2016	Jun-Dec	M+F	199	86	34	4	75	21	178
A & B	Baseline	7CN	2002-16	Jan-May	M+F	100**	27	29	6	38	17	83
A & B	Baseline	7CN	1999-2016	Jun	M+F	133	11	15	6	101	12	121
A & B	Baseline	7CN	1996-2016	Jul-Sep	M+F	610	16	13	103	478	127	483
A & B	Baseline	7CN	2001-16	Oct-Dec	M+F	270	35	2	66	167	91	179
A & B	Baseline	10E	2001-16	Jun-Dec	M+F	15	14	1			14	1
A & B	Baseline	11	1996-2012	May-Dec	M	57					28	29
A & B	Baseline	11	1996-2015	May-Dec	F	58					28	30

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk
E	Baseline	2C	2002-16	Jan-Apr	M+F	138	107	31					107	31	-
E	Baseline	2C	2001-16	May-Sep	M+F	49	32	17					32	17	-
E	Baseline	2C	2001-16	Oct-Dec	M+F	122	105	17					105	17	-
E	Baseline	7CS	2002-16	Jan-Apr	M+F	262	-	73	1	-	188	-	-	262	0
E	Baseline	7CS	2001-16	May	M+F	378	-	49	2	-	303	24	-	351	27
E	Baseline	7CS	1999-2016	Jun-Dec	M+F	197	-	118	1	-	5	73	-	28	169
E	Baseline	7CN	1999-2016	Jan-Jun	M+F	220	12	69	-	2	28	109	6	56	158
E	Baseline	7CN	1996-2016	Jul-Dec	M+F	881	13	59	-	10	574	225	23	633	225
E	Baseline	11	1996-2012	May-Nov	M	59							13	45	1
E	Baseline	11	1996-2015	May-Nov	F	63							18	41	4

* Samples in October and November were assigned to the J-stock only. Hypotheses A and B assume only J-stock individuals in sub-area 11 in October-December.

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	Bycatch Samples		Special Permit Samples		Weighted Total	
							J-Stock	O-Stock	J-Stock	O-Stock	J-Stock	O-Stock
A & B	5	2C	2002-16	Jan-Apr	M+F	170	138	32			138	32
A & B	5	2C	2001-16	May-Sep	M+F	57	47	10			47	10
A & B	5	2C	2001-16	Oct-Dec	M+F	141	129	12			129	12
A & B	5	7CS	2002-16	Jan-Apr	M+F	291	48	41	51	151	80	211
A & B	5	7CS	2001-16	May	M+F	431	17	37	100	277	116	315
A & B	5	7CS	1999-2016	Jun-Dec	M+F	212	92	36	4	80	22	190
A & B	5	7CN	2002-16	Jan-May	M+F	105	28	30	7	40	19	86
A & B	5	7CN	1999-2016	Jun	M+F	139	12	16	8	103	14	125
A & B	5	7CN	1996-2016	Jul-Sep	M+F	660	20	14	109	517	138	522
A & B	5	7CN	2001-16	Oct-Dec	M+F	283	38	2	67	176	94	189
A & B	5	7WR+7E	1996-2006	May	M+F	87					3	84
A & B	5	7WR+7E	1996-2012	Jun-Aug	M+F	49					0	49
A & B	5	8	1998-2012	May-Jun	M+F	139					1	138
A & B	5	8	1996-2009	Jul-Sep	M+F	106					1	105
A & B	5	9	1995-2011	May-Jun	M+F	125					1	124
A & B	5	9	1994-2010	Jul	M+F	190					4	186
A & B	5	9	1994-2013	Aug-Sep	M+F	212					0	212
A & B	5	10E	2001-16	Jun-Dec	M+F	16					15	1
A & B	5	11	1996-2012	May-Dec	M	64					30	34
A & B	5	11	1996-2015	May-Dec	F	63					30	33
A & B	6	7CS	2002-16	Jan-Apr	M+F	263	43	34	48	138	71	192
A & B	6	7CS	2001-16	May	M+F	391	16	31	89	255	102	289
A & B	6	7CS	1999-2016	Jun-Dec	M+F	199	86	34	4	75	14	185
A & B	6	7CN	2002-16	Jan-May	M+F	100**	27	29	6	38	15	85
A & B	6	7CN	1999-2016	Jun	M+F	133	11	15	6	101	9	124
A & B	6	7CN	1996-2016	Jul-Sep	M+F	610	16	13	103	478	116	494
A & B	6	7CN	2001-16	Oct-Dec	M+F	270	35	2	66	167	82	188
A & B	7	7CS	2002-16	Jan-Apr	M+F	263	43	34	48	138	81	182
A & B	7	7CS	2001-16	May	M+F	391	16	31	89	255	106	285
A & B	7	7CS	1999-2016	Jun-Dec	M+F	199	86	34	4	75	32	167
A & B	7	7CN	2002-16	Jan-May	M+F	100**	27	29	6	38	19	81
A & B	7	7CN	1999-2016	Jun	M+F	133	11	15	6	101	16	117
A & B	7	7CN	1996-2016	Jul-Sep	M+F	610	16	13	103	478	146	462
A & B	7	7CN	2001-16	Oct-Dec	M+F	270	35	2	66	167	106	144

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk
E	5	2C	2002-16	Jan-Apr	M+F	150							116	33	1
E	5	2C	2001-16	May-Sep	M+F	54							36	18	0
E	5	2C	2001-16	Oct-Dec	M+F	125							108	17	0
E	5	7CS	2002-16	Jan-Apr	M+F	282	2	79	3	2	196	0	3	278	1
E	5	7CS	2001-16	May	M+F	411	0	51	2	1	326	31	1	376	34
E	5	7CS	1999-2016	Jun-Dec	M+F	211	1	127	2	0	8	73	0	36	175
E	5	7CN	1999-2016	Jan-Jun	M+F	237	13	70	-	2	30	122	6	59	172
E	5	7CN	1996-2016	Jul-Dec	M+F	915	15	59	-	11	582	248	27	641	247
E	5	11	1996-2012	May-Dec	M	63							14	48	1
E	5	11	1996-2015	May-Dec	F	64							18	42	4
E	6	7CS	2002-16	Jan-Apr	M+F	262	-	73	1	-	188	-	-	262	0
E	6	7CS	2001-16	May	M+F	378	-	49	2	-	303	24	-	351	27
E	6	7CS	1999-2016	Jun-Dec	M+F	197	-	118	1	-	5	73	-	19	178
E	6	7CN	1999-2016	Jan-Jun	M+F	220	12	69	-	2	28	109	4	49	167
E	6	7CN	1996-2016	Jul-Dec	M+F	881	13	59	-	10	574	225	16	628	237
E	7	7CS	2002-16	Jan-Apr	M+F	262	-	73	1	-	188	-	-	261	1
E	7	7CS	2001-16	May	M+F	378	-	49	2	-	303	24	-	352	26
E	7	7CS	1999-2016	Jun-Dec	M+F	197	-	118	1	-	5	73	-	43	154
E	7	7CN	1999-2016	Jan-Jun	M+F	220	12	69	-	2	28	109	8	68	144
E	7	7CN	1996-2016	Jul-Dec	M+F	881	13	59	-	10	574	225	36	641	204

Table 7b

Estimates of the proportion of recruited 'J'-whales used to condition the trials based on mtDNA and Allele samples.

Hypothesis	Area	Years	Months	Sex	Ratio	CV[12]	Data Type	Stock	
B and E	6W	1999-2007	Jan-Mar	M+F	0.584	0.131	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Jan-Mar	M+F	0.672	0.05	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Apr-Jun	M+F	0.496	0.126	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Apr-Jun	M+F	0.812	0.05	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Jul-Aug	M+F	1.000	0.05	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Jul-Aug	M+F	0.749	0.077	Allelle	J:Total	Bycatch samples
B and E	6W	1999-2007	Sep-Dec	M+F	0.593	0.123	mtDNA	J:Total	Bycatch samples
B and E	6W	1999-2007	Sep-Dec	M+F	0.761	0.05	Allelle	J:Total	Bycatch samples

(f) Calculation of likelihood

The objective function consists of three components: Objective Function = -(L_1+L_2+L_3) Equations F.4-6 list the negative of the logarithm of the objective function for each of the three components:

Abundance estimates

$$L_{1a} = 0.5\sum_n \frac{1}{(\sigma_t^k)^2}\left(\ln\left(P_n^k / \hat{P}_n^k\right)\right)^2 \tag{F.4a}$$

where $\hat{P}_n^k$ is the model estimate of the abundance in the same year, period and sub-area as the *n*th estimate of abundance P_n^k.

Minimum abundance estimates

$$L_{1b} = \sum_n \left\{ln\sigma_t^k + \frac{1}{2(\sigma_t^k)^2} ln\left(P_n^k/\hat{P}_n^k\right)^2\right\}\left\{\frac{exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} + ln\sigma_t^k\left\{\frac{1}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} \tag{F.4b}$$

where Δ is a "large" number (here 30).

Maximum abundance estimates

$$L_{1c} = \sum_n \left\{ln\sigma_t^k + \frac{1}{2(\sigma_t^k)^2} ln\left(P_n^k/\hat{P}_n^k\right)^2\right\}\left\{\frac{1}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} + ln\sigma_t^k\left\{\frac{exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}{1+exp\left(\Delta\left(P_n^k-\hat{P}_n^k\right)\right)}\right\} \tag{F.4c}$$

Zero abundance estimates

$$L_{1d} = -\sum_n \left[n_n^k ln\left(\beta_n^k \hat{P}_n^k\right) - \beta_n^k \hat{P}_n^k\right]/\hat{\alpha}_n^k \tag{F.4d}$$

where n_n^k is the number of animals seen during the *n*th survey in sub-area k , β_n^k is the realised track length for the *n*th survey in sub-area k multiplied by the average effective search half width, and divided by the sub-area size (Table 8), $\hat{P}_n^k$ is the model-estimate corresponding to the *n*th survey in sub-area *k* and $\hat{\alpha}^k$ is the adjusted coefficient of variation of the survey estimate P_n^k, $\hat{\alpha}^k = \frac{\sum_m (n_m^k)^2 CV^2(P_m^k)}{\sum_m n_m^k}$, constrained to $\hat{\alpha}^k \geq 1$, where m denotes the number of (non-minima) survey estimates within sub-area k for which the number of animals seen and the CV of the survey estimate are available. See Appendix A4 for the derivation of this equation.

Table 8 (based on abundance data made available by 28/10/2021).

The realised track length, average effective search half-width and sub-area size corresponding to the zero abundance estimates. The effective search half-width is taken to be the average from other surveys (excluding those considered minimum estimates) in the same sub-area used in conditioning, for which effective search half-width is available.

Year	Sub-Area	Realised track length	Average effective search half width [No. of surveys used]	Sub-area size	$\hat{\alpha}^k$
2016	7CS	754	0.3955 [4]	26826	22.83
2007	7E	360	0.4225 [2]	84427	1.73
2012	7E	302	0.4225 [2]	84427	1.73
2013	7E	599	0.4225 [2]	84427	1.73
2016	7E	472	0.4225 [2]	84427	1.73
2008	7	887	0.374 [1]	217678	1.00[13]
2002	8	1184	0.5283 [7]	250291	1.50
2008	8	1194	0.5283 [7]	250445	1.50

[12] In cases when the sample size used to generate the proportion estimates is small and the se's are small (which will overweight such results), the standard error is set to 0.05.

[13] Due to constraint of $\hat{\alpha}^k \geq 1$

Stock proportions

For sub-areas 2C, 7CN, 7CS, 10E and 11:

$$L_2 = -\sum_j \sum_n N_{j,n}^k ln(\hat{p}_{j,n}^k / p_{j,n}^{obs,k}) \quad \text{(F.5a)}$$

where $\hat{p}_{j,n}^k$ is the model estimate of the proportion of *j*-stock whales in the same year, period, sub-area and gender as the *n*th set of data and $p_{j,n}^{obs,k}$ is the corresponding observed value, with $N_{j,n}^k$ denoting the observed number of samples of *j*-stock whales in the *n*th set of data. The model estimated proportion is calculated from the 1+ population when the data were generated from samples obtained from bycatches, and from the recruited population when the data were generated from samples obtained from special permit data. In sub-areas 7CN and 7CS the model estimated proportion is calculated from the recruited population due to the higher number of samples from special permit compared to bycatch data.

For sub-area 6W in Hypotheses B and E only:

$$L_2 = 0.5\sum_n \frac{1}{(\sigma_n^k)^2}\left(p_n^k - \hat{p}_n^k\right)^2 \quad \text{(F.5b)}$$

where $\hat{p}_n^k$ is the model estimate of the proportion of whales in the same year, period and sub-area as the *n*th proportion estimate p_n^k.

Bycatch estimates

$$L_3 = 0.5\sum_n \left(B_n^k - \hat{B}_n^k\right)^2 / 10 \quad \text{(F.6)}$$

where $\hat{B}_n^k$ is the model estimate of the total bycatch in sub-area k over the years being fitted and B_n^k is the observed bycatch in the same area and period.

G. Trials

The factors to be considered based on the previous trials are listed in Table 9 and the set of trials in Table 10. The sensitivity trials are variants of the base-case trials A01-1 etc. (see section A).

H. Management options

Future direct catch options will be specified later.

I. Output statistics

Population-size and continuing catch statistics are produced for each stock, and catch-related statistics for each sub-area. Catch-related statistics are produced both for the total catches (commercial and incidental) and for the commercial catches alone.

(1) Total catch (TC) distribution: (a) median; (b) 5th value; (c) 95th value.

(2) Initial mature female population size (P_{1930}) distribution: (a) median; (b) 5th value; (c) 95th value.

(3) Final mature female population size (P_{2120}) distribution: (a) median; (b) 5th value; (c) 95th value.

(4) Lowest mature female population size over 100 years (P_{low}) distribution: (a) median; (b) 5th value; (c) 95th value.

(5) Average catch over the last 10 years of the 100-year management period: (a) median; (b) 5th value; (c) 95th value.

(6) Catch by sub-area, stock and catch-type (incidental or commercial): (a) median; (b) 5th value; (c) 95th value.

(7) The median percentage of mature J-stock females being in sub-area 12 in June-August 1973-75.

(8) The median annual rate of decline in the number of whales assumed recruited to the Korean fishery over the period 1973-1986.

(9) The median 1+ population size for animals in sub-areas 6 and 10 in August-September in 1992 and in 2000 (corresponding to Sea of Japan surveys).

(10) Proportion Mature: compare the numbers of mature animals by sub-area and time period with the (approximate) proportion mature in the available observation data.

(11) The mean proportion of J whales in the total (scientific, commercial and incidental) catch taken by Japan from 1993-98 is output in trials, for comparison with results obtained from market samples.

Table 9
Proposed factors to be considered in the Trials.

Factor
Stock structure hypothesis
Stock structure hypotheses A, B and E
MSYR
$1\%_{1+}$; $4\%_{mat}$
g(0)
0.798; 1.00 (Trial 3)
Other stock structure issues
With a C-stock, i.e. from a putative 'Central' North Pacific population (Trial 2)
Alternative basis for mixing rates (Trial 5)
10% J-stock in sub-area 12SW in June (Trial 10)
30% J-stock in sub-area 12SW in June (Trial 11)
No C-stock (i.e. from a putative 'Central' North Pacific population) in sub-area 12NE (Trial 23)
10% J-stock in sub-area 12NE in May-July (Trial 21)
Catches and bycatches
High direct catches (Baseline total = 39,299; high total = 40,879) + alternative Korean & Japanese bycatch level (Trial 4)
Different allocation of the Korean catches between sub-areas 5 and 6W. (Trials 8 and 9)
Chinese incidental catch = 0 (Trial 12) (Baseline value = 2* Korean bycatch in sub-area 5)
Number of bycaught animals is proportional to square root of abundance (Trial 17)
Mixing and dispersion
Mixing proportion in sub-areas 7CS and 7CN calculated using alternative weighting for bycatch: 2/60 weight (Trial 6) and 10/60 weight (Trial 7)
A substantially larger fraction of whales aged 1-4 from O-stock are found in sub-areas 2R, 3 and 4 year round (Trial 18)
Set the proportion of O-stock animals of ages 1-4 in sub-areas 9 and 9N to zero (Trial 19)
Time-varying mixing matrix for the bycatch (Trial 22) (requires specification)
Abundance estimates
The 2013 implementation considered Alternative abundance estimates for sub-areas 6E and 10E. To be decided later.
The number of 1+ whales in 2009 in sub-area 2C in any month < 200 (Trial 20)

Table 10
The list of trials (MSYR 1% is defined in terms of the total (1+) component and 4% on the mature female component of the population).

Stock hypothesis	Trial no.	MSYR	Mix matrix:	Description
A	A01-1 & A01-4	1%/ 4%	Baseline	Baseline A: 2 stocks (J- and O-); g(0) = 0.798; including Chinese bycatch
B	B01-1 & B01-4	1%/ 4%	Baseline	Baseline B: 3 stocks (J-, O,- and Y-); g(0) = 0.798; including Chinese bycatch
E	E01-1 & E01-4	1%/ 4%	Baseline	Baseline E: 5 stocks (J-, P-, O-, and Y-); g(0) = 0.798; including Chinese bycatch
AE	A02-1 etc	1% / 4%	Trial 2	With a C- ('Central' North Pacific) stock
ABE	A03-1 etc	1% / 4%	Baseline	Assume g(0) = 1
ABE	A04-1 etc	1% / 4%	Baseline	High direct catches + alternative Korean & Japanese bycatch levels
ABE	A05-1 etc	1% / 4%	Trial 5	Alternative (70% probability) thresholds for assignment of stock proportions
ABE	A06-1 etc	1% / 4%	Baseline	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN calculated using 2/60 weight for bycatch
ABE	A07-1 etc	1% / 4%	Baseline	No. of genetic samples assigned to stock in sub-areas 7CS and 7CN calculated using 10/60 weight for bycatch
ABE	A08-1 etc	1% / 4%	Baseline	More Korean catches in sub-area 5 (and fewer in sub-area 6W). Rationale: the baseline uses the best split. Trials 8 and 9 test alternatives in both directions.
ABE	A09-1 etc	1% / 4%	Baseline	More Korean catches in sub-area 6W (and fewer in 5)
ABE	A10-1 etc	1% / 4%	Baseline	10% J -stock in sub-area 12SW in June (base case value = 20%). See section F(c).
ABE	A11-1 etc	1% / 4%	Trial 11	30% J -stock in sub-area 12SW in June (base case value = 20%) with 10% J-stock in 12NE in May-June. See section F(c).
ABE	A12-1 etc	1% / 4%	Baseline	Chinese incidental catch = 0 (the base case value = twice that of Korea in sub-area 5)
ABE	A13-1 etc	1% / 4%	Baseline	Alternative abundance estimates in sub-area 6E (see table 6)
ABE	A14-1 etc	1% / 4%	Baseline	Additional abundance estimate in sub-area 10E in 2007 (see table 6)
AE	A17-1 etc	1% / 4%	Baseline	The number of bycaught animals is proportional to the square-root of abundance rather than to abundance (in order to examine the impact of possible saturation effects)
ABE	A18-1 etc	1% / 4%	Trial 18	A substantially larger fraction of whales ages 1-4 from O-stock are found in sub-areas 2R, 3 and 4 year-round (so the proportion of 1-4 whales in sub-area 9 is closer to expectations given the length-frequencies of catches from sub-area 9). The mixing matrices are adjusted such that the numbers of age 1-4 of O-stock animals in sub-areas 9 and 9N are no more than half the base case numbers; juveniles are allowed into sub-areas 2R, 3 and 4 in the corresponding months.
ABE	A19-1 etc	1% / 4%	Trial 19	Set the proportion of O animals of ages 1-4 in sub-areas 9 and 9N to zero and allow the abundance in sub-areas 7CS and 7CN to exceed the abundance estimates for these sub-areas. Projections for these sub-areas will need to account for the implied survey bias
ABE	A20-1 etc	1% / 4%	Trial 20	The number of 1+ whales in 2009 in sub-area 2C in any month < 200 (if large numbers of whales were found in 2C, the historical catch would be expected to be much greater).
ABE	A21-1 etc	1% / 4%	Trial 21	10% J-stock in sub-area 12NE in May-July. See section F(c).
ABE	A22-1 etc	1% / 4%	Trial 22	Time-varying mixing matrix for the bycatch [details to be specified]
E	E23-1 & 4	1% / 4%	Trial 23	With a putative C ('Central North' Pacific) stock, but no C animals in sub-area 12NE
				Use 60% coverage for minima estimates
				Fit to Korea net licence numbers from 1996-2017 instead of net numbers from 1996-2009

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Appendix A1 The Historical Catch Series

See Published version in IWC 2022 (in press)

Appendix A2

Using the Genetic Stock Assignment by Sub-Area to Inform the Mixing Matrices of the North Pacific Minke Whale *Implementation Simulation Trials*

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This appendix details the stock assignment by sub-area and sex used to develop the data used to estimate mixing matrices for the North Pacific minke whale *Implementation Simulation Trials*. The baseline mixing matrices for Hypothesis E were newly developed for these *Implementation Simulation Trials*, largely informed by the genetic assignment tables below. The baseline mixing matrices for Hypotheses A and B were only changed from those used during the 2013 *Implementation Simulation Trials* where the genetic assignment tables below strongly supported such changes.

Baseline Trials, Hypotheses A and B

For the baseline trials, the stock assignment for Hypotheses A and B is based on the "stock90" assignment by STRUCTURE in *Data_NPM_190226_v3.csv*. The number of samples assigned to stock by sub-area is as follows. Table 7a of specifications details the assigned numbers by stock, sub-area, period and sex used to condition the trials.

Males	**10E**	**11**	**1E**	**2C**	**6E**	**7CN**	**7CS**	**7E**	**7WR**	**8**	**9**
J-stock	8	28	29	107	453	158	135	0	0	0	1
O-stock	1	29	1	26	1	580	281	41	74	207	442
Unassigned	2	7	2	10	41	80	61	3	6	22	44
Females											
J-stock	6	28	42	188	471	112	151	0	1	0	0
O-stock	0	30	0	24	3	263	286	4	8	17	49
Unassigned	1	7	2	17	33	23	49	1	0	6	5

Grey highlight: stock **has** been assigned to a sub-area, but is not modelled in that sub-area in the mixing matrices

- The singleton assignment of a J-stock female to sub-area 7WR is ignored for the baseline trials, but in Trial 5 J-stock animals are assumed to be found in both sub-areas 7E and 7WR.
- The singleton assignment of an O-stock male to sub-area 1E is ignored for modelling purposes
- The singleton assignment of a J-stock male to sub-area 9 is small compared to the total sample size, and is therefore ignored for the baseline, but in Trial 5 J-stock animals are assumed to be found in sub-areas 8 and 9
- The assignment of O-stock animals to sub-area 6E are very small compared to the total sample size, and O-stock animals are therefore not modelled to be found in sub-area 6E.

Pink highlight: females of a stock **have not** been assigned to a sub-area, but are modelled in that sub-area in the mixing matrices

- The sample sizes in sub-area 10E are low and one cannot therefore discount the presence of O-stock females in sub-area 10E.

J-Stock Baseline A (Matrix J-A) Green indicates changes since Nov 21

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D	2	2	2				γ_{25}	γ_{25}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D	4	4	1				γ_{25}	γ_{25}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	$2\gamma_2$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug	0	0	1				γ_{25}	γ_{25}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep	2	2	1				γ_{25}	$2\gamma_{25}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D	4	4	1				γ_{25}	γ_{25}		γ_3	γ_5										

J-Stock Baseline B (Matrix J-B) Green indicates changes since Nov 21 Note: The J-Stock Mixing Matrix Hypothesis E now differs from this one

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_2$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D		2	2					γ_{33}	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_1$	$2\gamma_4$						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_1$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May		0	1					γ_{33}	$2\gamma_{29}$	$4\gamma_2$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D		4	1					γ_{33}		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_1	γ_4						γ_6	γ_7			
	Apr		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_1$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May		0	1					γ_{33}	$2\gamma_{29}$	$2\gamma_2$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug		0	1					γ_{33}	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep		2	1					$2\gamma_{33}$	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D		4	1					γ_{33}		γ_3	γ_5										

O-Stock Baseline A (Matrix O-AB) **Blue indicates changes since 2013 *ISTs*. Yellow indicates changes since May 2021.**

Age/ Sex	Mon	Sub - Area 1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M			γ_{13}	4	4	4				$4\gamma_{31}$	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				$8\gamma_{31}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	0		$2\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	May			γ_{14}	2	2	2				$8\gamma_{31}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	γ_{21}		$2\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	Jun			γ_{14}	2	2	2				$4\gamma_{31}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	Jul			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	Aug			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	Sep			γ_{15}	2	2	2				$4\gamma_{32}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}		$4\gamma_{30}$	γ_{22}	γ_{23}	γ_{24}
	O-D			γ_{15}	4	4	4				$4\gamma_{32}$	$2\gamma_{16}$	0	0	0	0	0		$2\gamma_{30}$	0	0	0
Ad.M	J-M			γ_{13}	4	4	4				γ_{31}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				$2\gamma_{31}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	0		$2\gamma_{30}$	γ_{22}	γ_{23}	$3\gamma_{24}$
	May			0	0	0	0				$2\gamma_{31}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	$2\gamma_{21}$		$2\gamma_{30}$	γ_{22}	γ_{23}	$6\gamma_{24}$
	Jun			0	0	0	0				$2\gamma_{31}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	γ_{22}	γ_{23}	$6\gamma_{24}$
	Jul			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	γ_{22}	γ_{23}	$6\gamma_{24}$
	Aug			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$		$4\gamma_{30}$	γ_{22}	γ_{23}	$6\gamma_{24}$
	Sep			0	0	0	0				$2\gamma_{32}$	$4\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	γ_{21}		$4\gamma_{30}$	γ_{22}	γ_{23}	$3\gamma_{24}$
	O-D			γ_{15}	4	4	4				γ_{32}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0
Ad.F	J-M			γ_{13}	4	4	4				γ_{31}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0
	Apr			γ_{14}	2	2	2				γ_{31}	γ_{16}	$2\gamma_{17}$	$2\gamma_{18}$	$2\gamma_{19}$	γ_{20}	0		γ_{30}	γ_{22}	γ_{23}	$3\gamma_{24}$
	May			0	0	0	0				γ_{31}	γ_{16}	γ_{17}	γ_{18}	γ_{19}	γ_{20}	$4\gamma_{21}$		γ_{30}	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jun			0	0	0	0				γ_{31}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jul			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Aug			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Sep			0	0	0	0				γ_{32}	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$2\gamma_{21}$		$2\gamma_{30}$	$2\gamma_{22}$	$2\gamma_{23}$	$3\gamma_{24}$
	O-D			γ_{15}	4	4	4				γ_{32}	γ_{16}	0	0	0	0	0		γ_{30}	0	0	0

Y-Stock Baseline B (Matrix Y-B) **Note: The Y-Stock Mixing Matrix Hypothesis E now differs from this one**

Age/ Sex	Mon	Sub - Area 1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdM	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdF	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{27}													
	Aug	1						4	γ_{27}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													

Baseline Trials, Hypothesis E

For the baseline trials, stock assignment for Hypothesis E is based on the "geneland.stock2" assignment by GENELAND in *Data_NPM_190226_v3.csv*. The number of samples assigned to stock by sub-area is as follows. Table 7a of specifications details the assigned numbers by stock, sub-area, period and sex used to condition the trials.

Males	**10E**	**11**	**1E**	**2C**	**6E**	**7CN**	**7CS**	**7E**	**7WR**	**8**	**9**
J-stock	8	13	31	88	492	20	0	0	0	0	0
P-stock	0	39	0	10	0	384	217	0	0	0	0
O-stock	0	1	0	0	0	280	83	41	70	207	464
Unassigned	0	6	0	19	0	55	105	0	0	0	0
Females											
J-stock	7	18	44	156	500	17	0	0	0	0	0
P-stock	0	24	0	10	0	216	296	0	0	0	0
O-stock	0	4	0	0	0	54	18	5	7	22	49
Unassigned	0	17	0	26	0	75	118	0	0	0	0

Pink highlight: animals of a stock **have not** been assigned to a sub-area, but are modelled in that sub-area in the mixing matrices

- It is assumed the J-stock occurs distributed in sub-area 7CS given they have been assigned to sub-areas 7CN and 2C to the east of Japan as well as sub-areas 6E and 10E to the west of Japan.

J-Stock Baseline E (Matrix J-BE) Yellow indicates changes since May 2021.

Age/ Sex	Mon	Sub - Area																				
		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M		2	6					2	$4\gamma_{29}$	$2\gamma_{27}$	$2\gamma_4$						γ_6	γ_7			
	Apr		2	6					2	$4\gamma_{29}$	$2\gamma_{27}$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	May		2	2					2	$4\gamma_{29}$	$2\gamma_{27}$	$2\gamma_4$						γ_6	γ_7	$2\gamma_8$	$2\gamma_8$	
	Jun		2	2					2	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_4$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Jul		2	2					2	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Aug		2	2					2	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	Sep		2	2					2	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$	$2\gamma_9$	
	O-D		2	6					2	$4\gamma_{29}$	$2\gamma_3$	$2\gamma_5$						γ_6	γ_7	$2\gamma_9$		
Ad.M	J-M		2	3					4	$4\gamma_{29}$	$2\gamma_{27}$	$2\gamma_4$						γ_6	γ_7			
	Apr		0	3					2	$2\gamma_{29}$	$4\gamma_{27}$	$2\gamma_4$						γ_6	$2\gamma_7$	γ_8	γ_8	
	May		0	1					2	$2\gamma_{29}$	$4\gamma_{27}$	$2\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_8	$2\gamma_8$	
	Jun		0	1					2	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_4$						$2\gamma_6$	$2\gamma_7$	γ_9	$2\gamma_9$	
	Jul		0	1					2	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Aug		0	1					2	$2\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7	γ_9	$2\gamma_9$	
	Sep		2	1					4	$4\gamma_{29}$	$2\gamma_3$	$4\gamma_5$						γ_6	γ_7			
	O-D		4	3					2		$2\gamma_3$	$2\gamma_5$										
Ad.F	J-M		2	3					4	$4\gamma_{29}$	$1\gamma_{27}$	γ_4						γ_6	γ_7			
	Apr		0	3					2	$2\gamma_{29}$	$2\gamma_{27}$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{10}	γ_{10}	
	May		0	1					2	$2\gamma_{29}$	$2\gamma_{27}$	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{11}	$2\gamma_{11}$	
	Jun		0	1					2	$2\gamma_{29}$	γ_3	γ_4						$2\gamma_6$	$2\gamma_7$	γ_{12}	$2\gamma_{12}$	
	Jul		0	1					2	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Aug		0	1					2	$2\gamma_{29}$	γ_3	γ_5						γ_6	γ_7	γ_{12}	$2\gamma_{12}$	
	Sep		2	1					4	$4\gamma_{29}$	γ_3	γ_5						γ_6	γ_7			
	O-D		4	3					2		γ_3	γ_5										

P-Stock Baseline E (Matrix P-E) **Yellow indicates changes since May 2021.**

Age/	Mon										Sub -	Area										
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M			γ_{13}							$4\gamma_{31}$	γ_{30}										
	Apr			γ_{14}							$8\gamma_{31}$	$2\gamma_{30}$								γ_{22}		
	May			γ_{14}							$8\gamma_{31}$	$2\gamma_{30}$								γ_{22}		
	Jun			γ_{14}							$4\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Jul			γ_{15}							$4\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Aug			γ_{15}							$4\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Sep			γ_{15}							$4\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	O-D			γ_{15}							$4\gamma_{32}$	$2\gamma_{30}$										
Ad.M	J-M			γ_{13}							γ_{31}	γ_{30}										
	Apr			γ_{14}							$2\gamma_{31}$	$2\gamma_{30}$								γ_{22}		
	May										$2\gamma_{31}$	$2\gamma_{30}$								γ_{22}		
	Jun										$2\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Jul										$2\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Aug										$2\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	Sep										$2\gamma_{32}$	$4\gamma_{30}$								γ_{22}		
	O-D			γ_{15}							γ_{32}	γ_{30}										
Ad.F	J-M			γ_{13}							γ_{31}	γ_{30}										
	Apr			γ_{14}							γ_{31}	γ_{30}								γ_{22}		
	May										γ_{31}	γ_{30}								$2\gamma_{22}$		
	Jun										γ_{32}	$2\gamma_{30}$								$2\gamma_{22}$		
	Jul										γ_{32}	$2\gamma_{30}$								$2\gamma_{22}$		
	Aug										γ_{32}	$2\gamma_{30}$								$2\gamma_{22}$		
	Sep										γ_{32}	$2\gamma_{30}$								$2\gamma_{22}$		
	O-D			γ_{15}							γ_{32}	γ_{30}										

O-Stock Baseline E (Matrix O-E) **Yellow indicates changes since May 2021. .** **Note: now differs from Hyp B matrix**

Age/	Mon										Sub -	Area										
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M				4	4	4				$2\gamma_{1}$	$2\gamma_{16}$										
	Apr				2	2	2				$2\gamma_{1}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}				γ_{22}	γ_{23}	γ_{24}
	May				2	2	2				$4\gamma_{1}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	γ_{20}	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Jun				2	2	2				$4\gamma_{2}$	$4\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Jul				2	2	2				$4\gamma_{2}$	γ_{16}	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Aug				2	2	2				$4\gamma_{2}$	γ_{16}	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	Sep				2	2	2				$4\gamma_{2}$	γ_{16}	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	γ_{24}
	O-D				4	4	4				$2\gamma_{2}$	$2\gamma_{16}$										
Ad.M	J-M				4	4	4				γ_{1}	γ_{16}										
	Apr				2	2	2				γ_{1}	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$				γ_{22}	γ_{23}	$3\gamma_{24}$
	May										$2\gamma_{1}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$2\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	$6\gamma_{24}$
	Jun										$2\gamma_{2}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Jul										$2\gamma_{2}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Aug										$2\gamma_{2}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	$2\gamma_{21}$			γ_{22}	γ_{23}	$6\gamma_{24}$
	Sep										$2\gamma_{2}$	$2\gamma_{16}$	$4\gamma_{17}$	$4\gamma_{18}$	$4\gamma_{19}$	$5\gamma_{20}$	γ_{21}			γ_{22}	γ_{23}	$3\gamma_{24}$
	O-D				4	4	4				γ_{2}	γ_{16}										
Ad.F	J-M				4	4	4				γ_{1}	γ_{16}										
	Apr				2	2	2				γ_{1}	γ_{16}	$2\gamma_{17}$	$2\gamma_{18}$	$2\gamma_{19}$	γ_{20}				γ_{22}	γ_{23}	$3\gamma_{24}$
	May										$2\gamma_{1}$	γ_{16}	γ_{17}	γ_{18}	γ_{19}	γ_{20}	γ_{21}			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jun										$2\gamma_{2}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Jul										$2\gamma_{2}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Aug										$2\gamma_{2}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$4\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$9\gamma_{24}$
	Sep										$2\gamma_{2}$	$2\gamma_{16}$	γ_{17}	γ_{18}	γ_{19}	$3\gamma_{20}$	$2\gamma_{21}$			$2\gamma_{22}$	$2\gamma_{23}$	$3\gamma_{24}$
	O-D				4	4	4				γ_{2}	γ_{16}										

Y-Stock Baseline E (Matrix Y-BE) Yellow indicates changes since May 2021. Note: now differs from Hyp B matrix

Age/	Mon	Sub - Area																				
Sex		1W	1E	2C	2R	3	4	5	6W	6E	7CS	7CN	7WR	7E	8	9	9N	10W	10E	11	12SW	12NE
Juv	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{26}													
	Aug	1						4	γ_{26}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdM	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{26}													
	Aug	1						4	γ_{26}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													
AdF	J-M	4						4	γ_{25}													
	Apr	1						4	γ_{26}													
	May	1						4	γ_{26}													
	Jun	1						4	γ_{26}													
	Jul	1						4	γ_{26}													
	Aug	1						4	γ_{26}													
	Sep	2						4	γ_{28}													
	O-D	4						4	γ_{28}													

Appendix A3

Calculation of stock mixing proportions, including correction for "missing alleles":

Unpooled results for sub-area 6W

C.L. de Moor

This appendix is based on de Moor (2011, 2014) and details the calculation of the stock mixing proportions by month and sex used for conditioning the 2013 *Implementation Simulation Trials* of western North Pacific common minke whales (Allison *et al*, 2014).

In calculating the mixing proportions in sub-area 6W, samples representative of 'pure' Y-stock and J-stock animals were taken as follows:

Stock	Location / months to define pure sample	Haplotypes Sample Size	Loci Sample Size
Y-stock	5 (all months)	58	58 58 58 58 58 58 56 58 58 58 54
J-stock	6E (all months)	392	392 392 392 392 392 392 392 392 392 392 392 (392 391 392 392 392)

Mixing proportions in sub-area 6W were calculated from 415 samples from bycatch data only.

Hyp B and E: Proportion of J mixing with Y		Sample Size	Proportion Haplotypes	SE	Sample Size (x11)	Proportion Loci	SE
Jan-Mar	Males	83	0.555	0.142	83 with 81 in 11th	0.745	0.050
Apr		37	0.449	0.253	37 with 36 in 1st	0.963	0.083
May		41	0.749	0.243	41 with 40 in 8th	0.926	0.062
Jun		43	0.534	0.245	43	0.787	0.080
Jul		21	0.830	0.38	21	0.788	0.089
Aug		16	1.000	0.004	16 with 15 in 11th	0.726	0.137
Sep		20	0.533	0.335	20 with 18 in 11th	0.475	0.107
Oct-Dec		97	0.629	0.140	97 with 96 in 7th and 94 in 11th	0.859	0.049
Jan-Mar	Females	13	0.730	0.314	13 with 12 in 6th	0.284	0.128
Apr		3	0.002	0.139	3	0.751	0.301
May		7	0.000	0.006	7	0.529	0.148
Jun		10	0.364	0.309	10	0.583	0.167
Jul		1	1.000	0.009	1	0.999	0.000
Aug		4	1.000	0.024	4	0.457	0.323
Sep		6	0.415	0.636	6 with 5 in 9th	0.773	0.143
Oct-Dec		13	0.409	0.455	13 with 12 in 11th	0.806	0.130
Summary: all data		415	0.625	0.069	415 with 414 in 1st, 6-9th and 406 in 11th	0.776	0.109
Pooled Data							
Jan-Mar	M F	96	0.584	0.131	96 with 95 in 6th, 94 in 11th	0.672	0.047
Apr-Jun	M F	141	0.496	0.126	141 with 140 in 1st , 8th	0.812	0.04
Jul-Aug	M F	42	1.000	0.004	42 with 41 in 11th	0.749	0.077
Sep-Dec	M F	136	0.593	0.123	136 with 135 in 7th, 9th, 130 in 11th	0.761	0.04

Notation:

In most cases samples are obtained from 16 loci. In sub-area 6W samples from the first 11 loci only were available to be used in the calculation of the mixing proportions, denoted by (x11) in the above table. In some cases there was a missing value in a sample at a particular loci. Thus, for example if the total sample size were 50, for one of the loci (the 10th) the sample size is 49. This is noted by saying e.g. "50 with 49 in 10th".

References

Allison, C., de Moor, C.L. and Punt, A.E. 2014. Report of the Scientific Committee. Annex D1. Report of the Working Group on the *Implementation Review* for Western North Pacific Common Minke Whales. Appendix 2. North Pacific minke whale *Implementation Simulation Trial* specifications. *J. Cetacean Res. Manage. (Suppl.)* 15:133-80.

de Moor, C.L. 2011. Calculation of stock mixing proportions, including correction for 'missing alleles': unpooled results. Paper SC/D11/NPM4rev presented to the First Intersessional Workshop for the *Implementation Review* of western North Pacific common minke whales, 12-16 December 2011, Tokyo, Japan (unpublished). [Paper available from the Office of this Journal].

de Moor, C.L. 2014. Report of the Scientific Committee. Annex D1. Report of the Working Group on the *Implementation Review* for Western North Pacific Common Minke Whales. Appendix 2. North Pacific minke whale *Implementation Simulation Trial* specifications. Adjunct 3. Calculation of stock mixing proportions, including correction for 'missing alleles': unpooled results. *J. Cetacean Res. Manage. (Suppl.)* 15:167-80.

Appendix A4

Method to derive the adjusted coefficient of variation for zero survey estimates

AE Punt

Simple case - the data are the number of observed whales and the sampling process is Poisson (for the case of one area):

$$LnL = \sum_y (n_y^{obs} \ell n(\beta_y P_y) - \beta_y P_y) \tag{1}$$

where n_y^{obs} is the observed number of animals during the survey in year y, P_y is the true population size in year y, and β_y is the proportion of the area occupied that was sampled. For $\beta_y = 1$ this collapses to the standard Poisson likelihood.

Now consider the situation in which there is over-dispersion (e.g. clumping), one can account for this by defining an over-dispersed distribution for the data, i.e.

$$LnL -> \sum_y (n_y^{obs} \ell n(\beta_y P_y) - \beta_y P_y) / \alpha \tag{2}$$

where α is a measure of overdispersion (and would be greater than 1 for over-dispersed sampling). Justin provided the following formula for α:

$$\alpha = \sum_{y'} CV(P_{y'}^{obs}) n_{y'}^{obs} / \sum_{y'} 1 \tag{3}$$

where the summation is over years for which there is a CV for the abundance estimate and a value for the number of sightings.

To derive 3, one estimator for α is:

$$\alpha = \sum_y \frac{\text{var}(\text{observed}_y)}{\text{var}(\text{expected}_y)} / \sum_y 1 \tag{4}$$

where $\text{var}(\text{observed}_y) = CV^2(P_y)(n_y^{obs})^2$ and $\text{var}(\text{expected}_y) = n_y^{obs}$ (under the Poisson assumption) so that

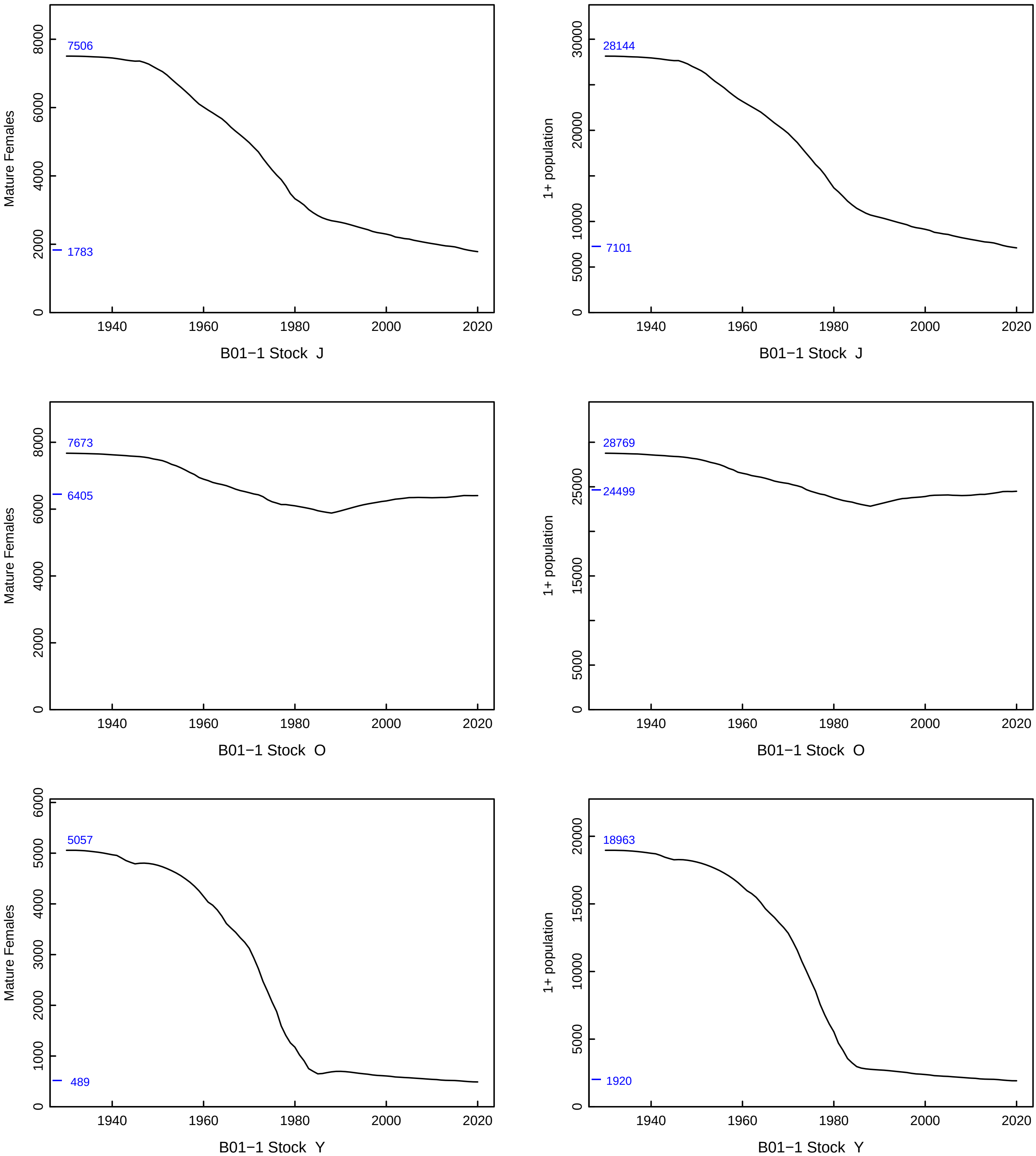
$$\frac{\text{var}(\text{observed}_y)}{\text{var}(\text{expected}_y)} \sim \frac{(n_y^{obs})^2 CV^2(n_y^{obs})}{E(n_y^{obs})} \cong \frac{(n_y^{obs})^2 CV^2(P_y)}{n_y^{obs}} = n_y^{obs} CV^2(P_y) \tag{5}$$

which is close to, but not identical to, 3. An alternative estimate for α would be:

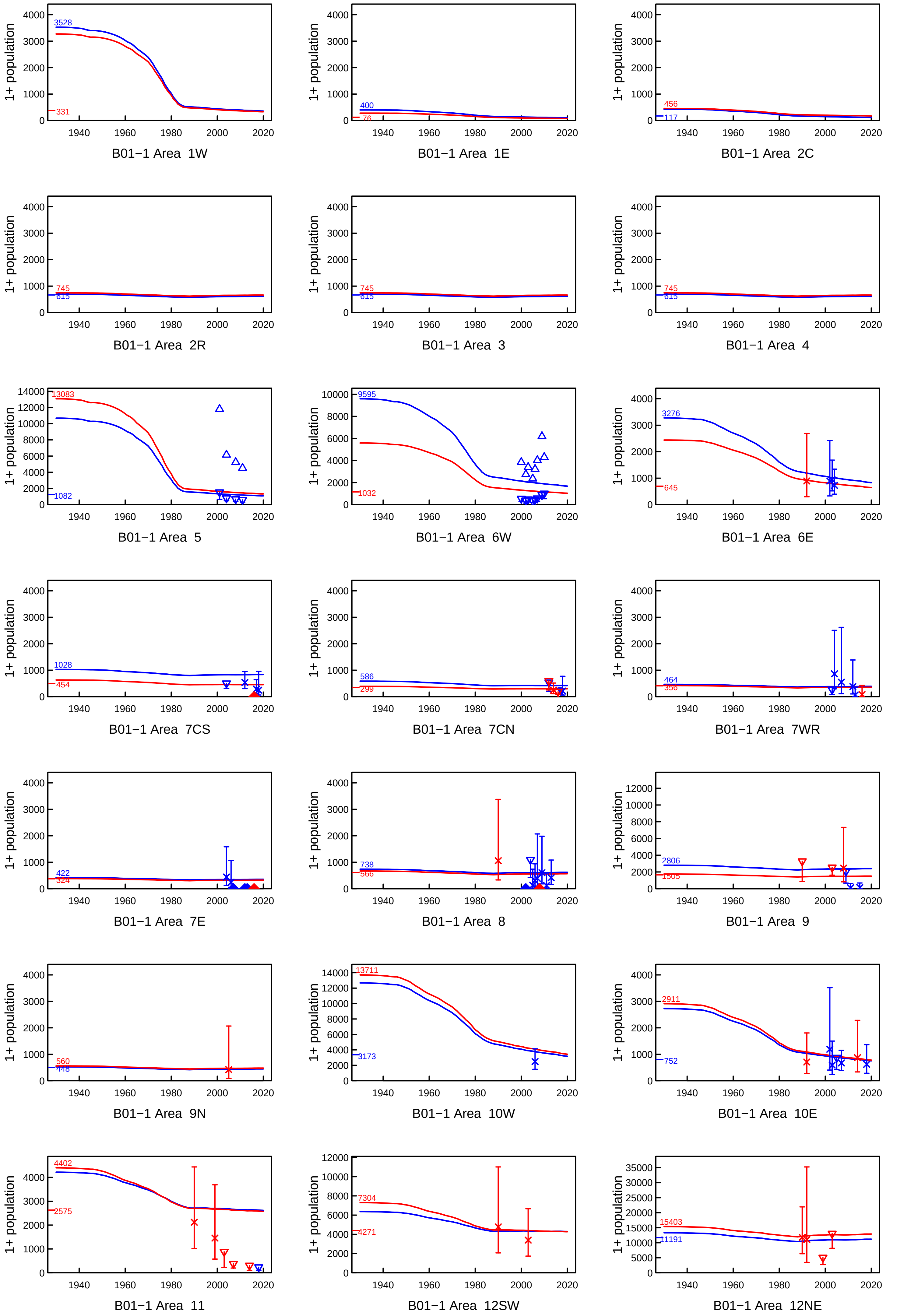
$$\alpha = \frac{\sum_y \text{var}(\text{observed}_y)}{\sum_y \text{var}(\text{expected}_y)} \cong \frac{\sum_y (n_y^{obs})^2 CV^2(P_y)}{\sum_y n_y^{obs}} \tag{6}$$

Equation 6 would (I suspect) be more robust to odd outlying estimates of CV.

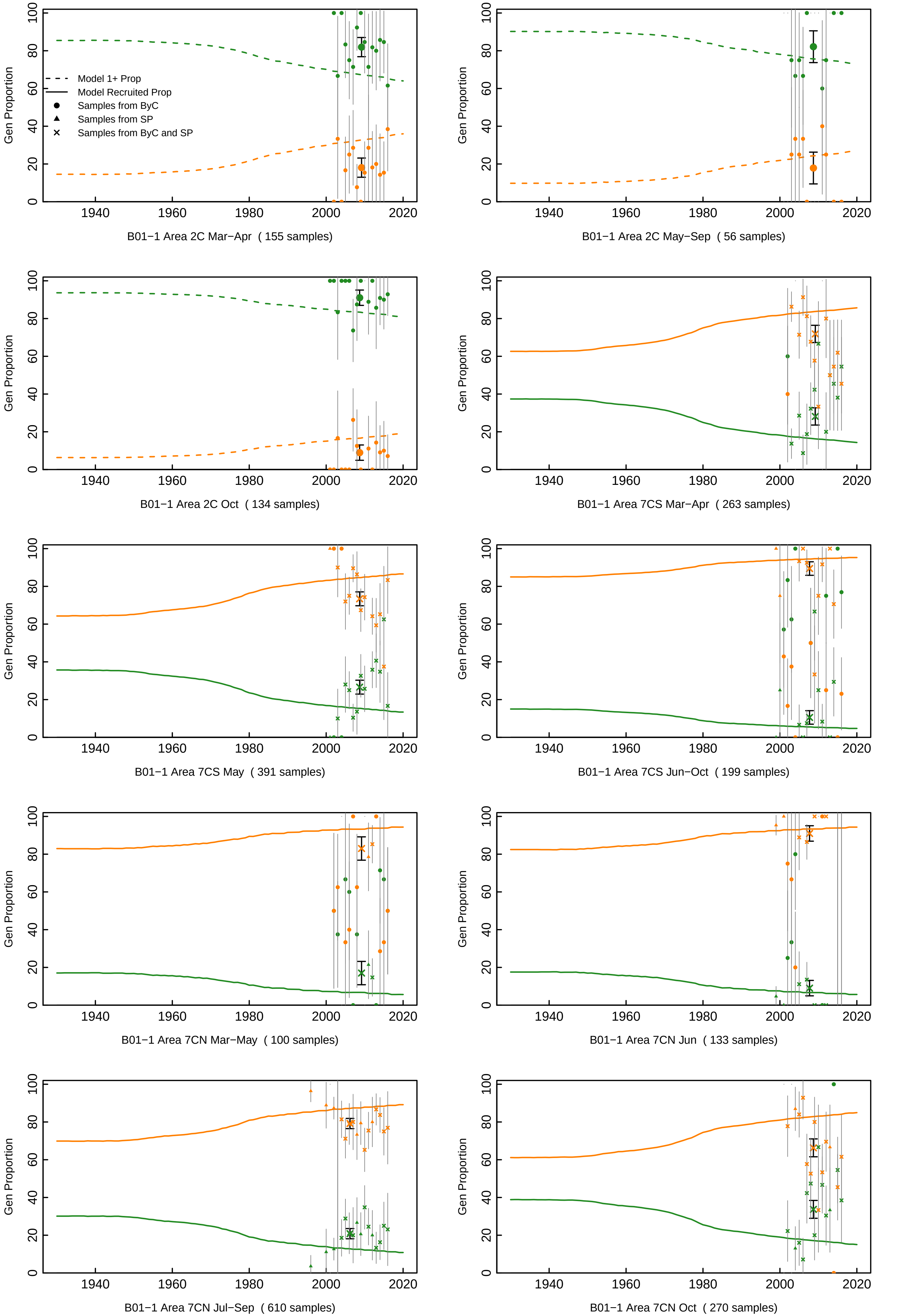
B01−1 Hyp. B 1% Baseline Conditioning Plot 1: 'Best fit' Stock Trajectories



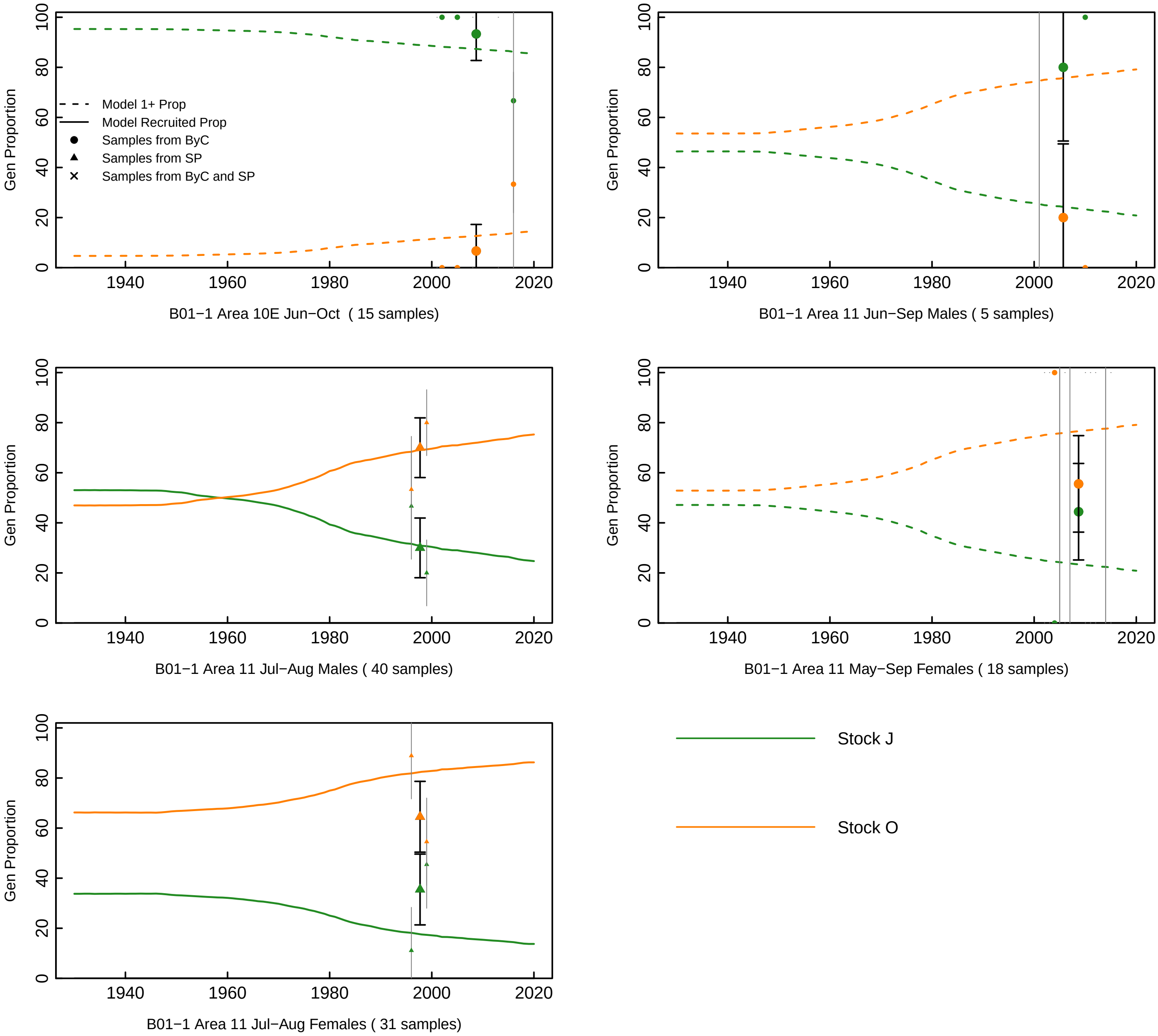
B01−1 Hyp. B 1% Baseline Conditioning Plot 2a: May/Jun (red) & Aug/Sep (blue)



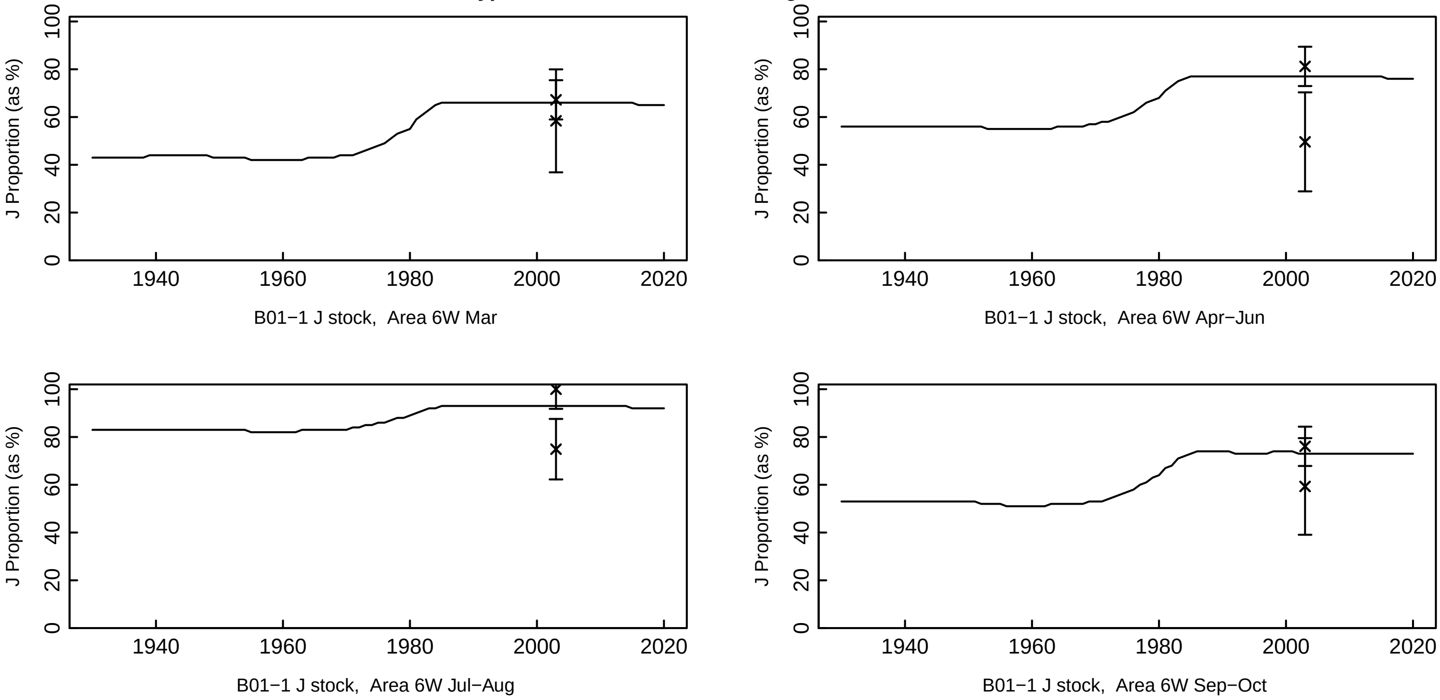
B01−1 Hyp. B 1% Baseline Conditioning Plot 4: 'Best Fit' Fits to Data



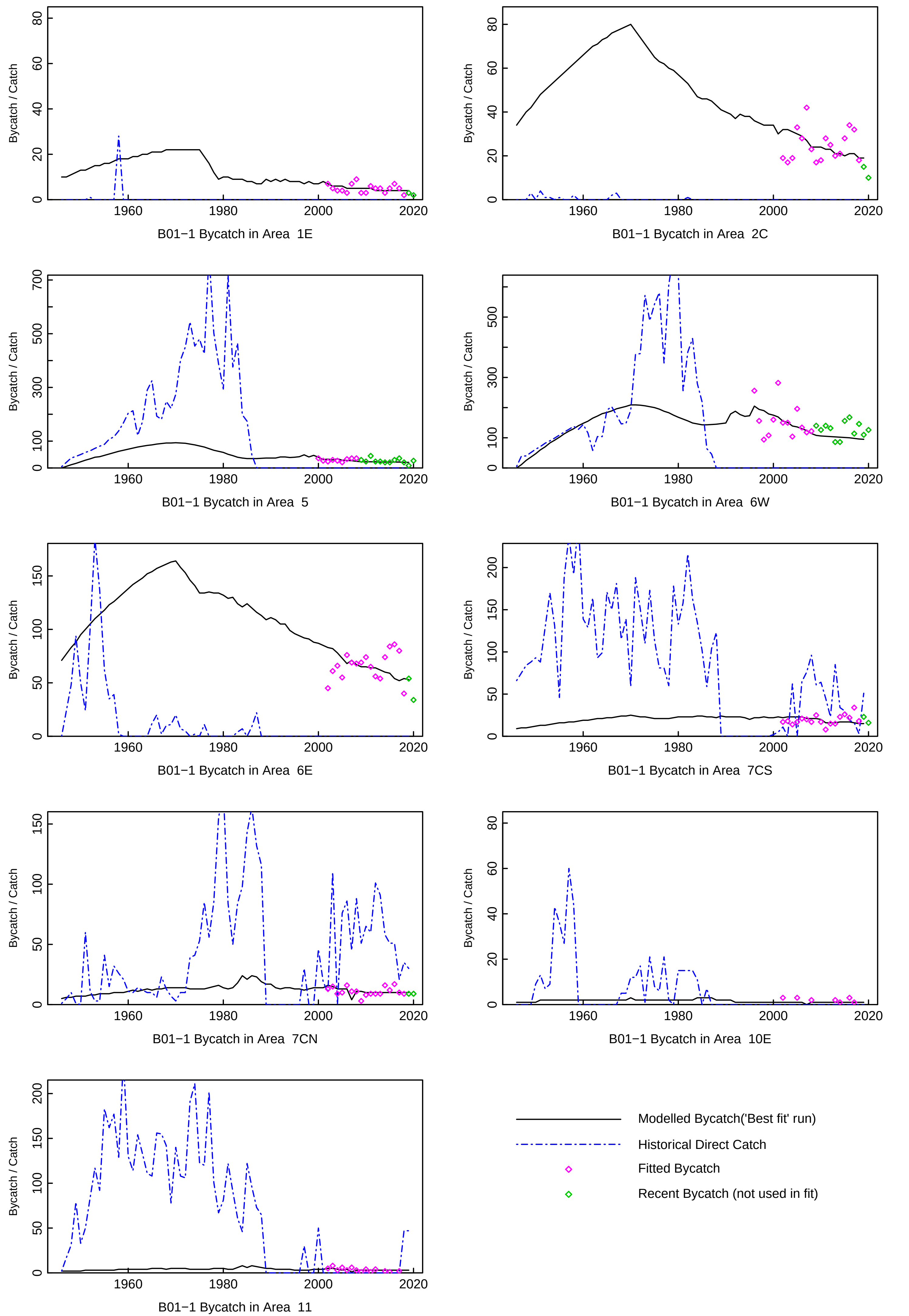
B01−1 Hyp. B 1% Baseline Conditioning Plot 4: 'Best Fit' Fits to Data



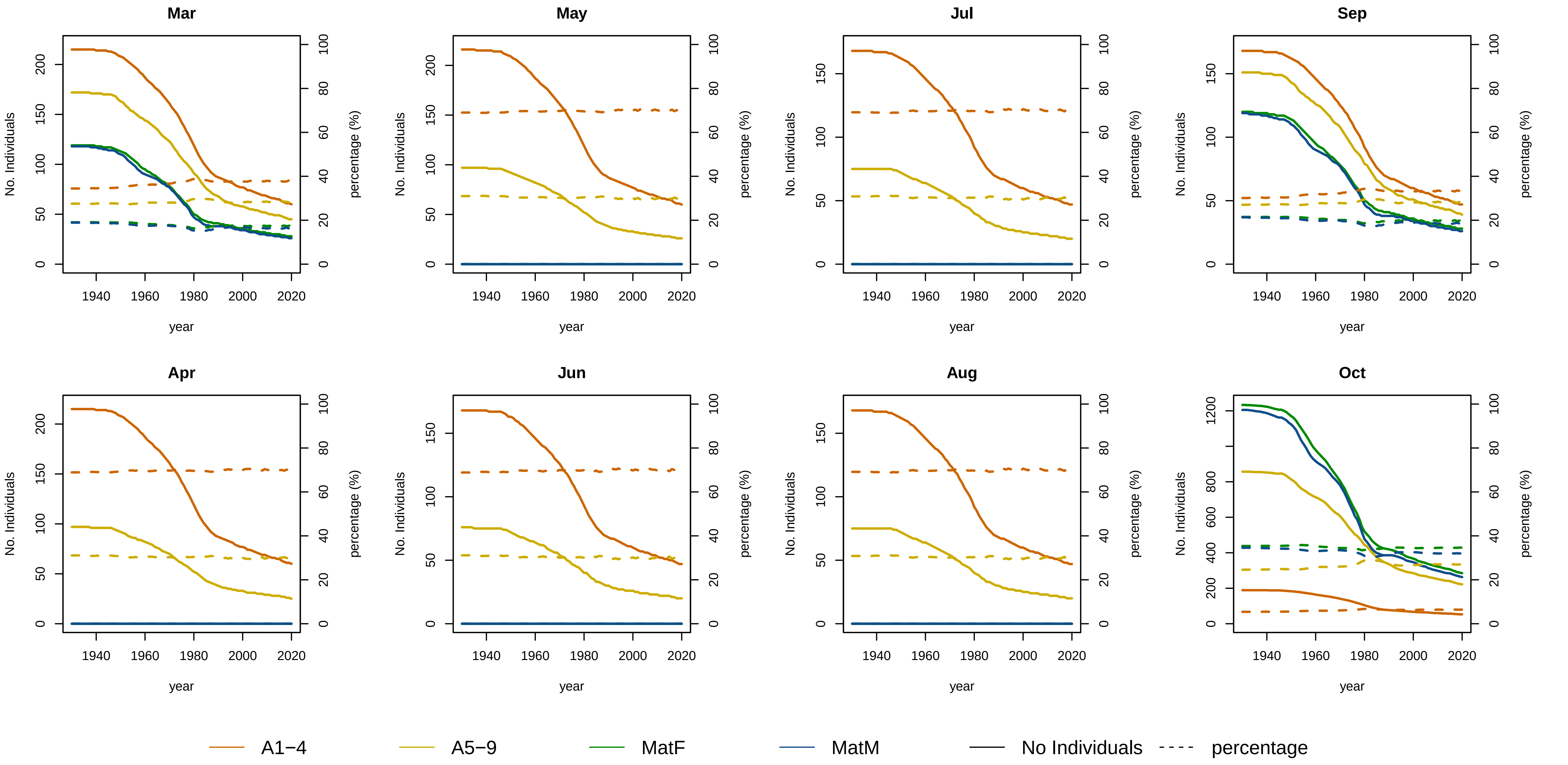
B01−1 Hyp. B 1% Baseline Conditioning Plot 4: 'Best Fit' Fits to Data

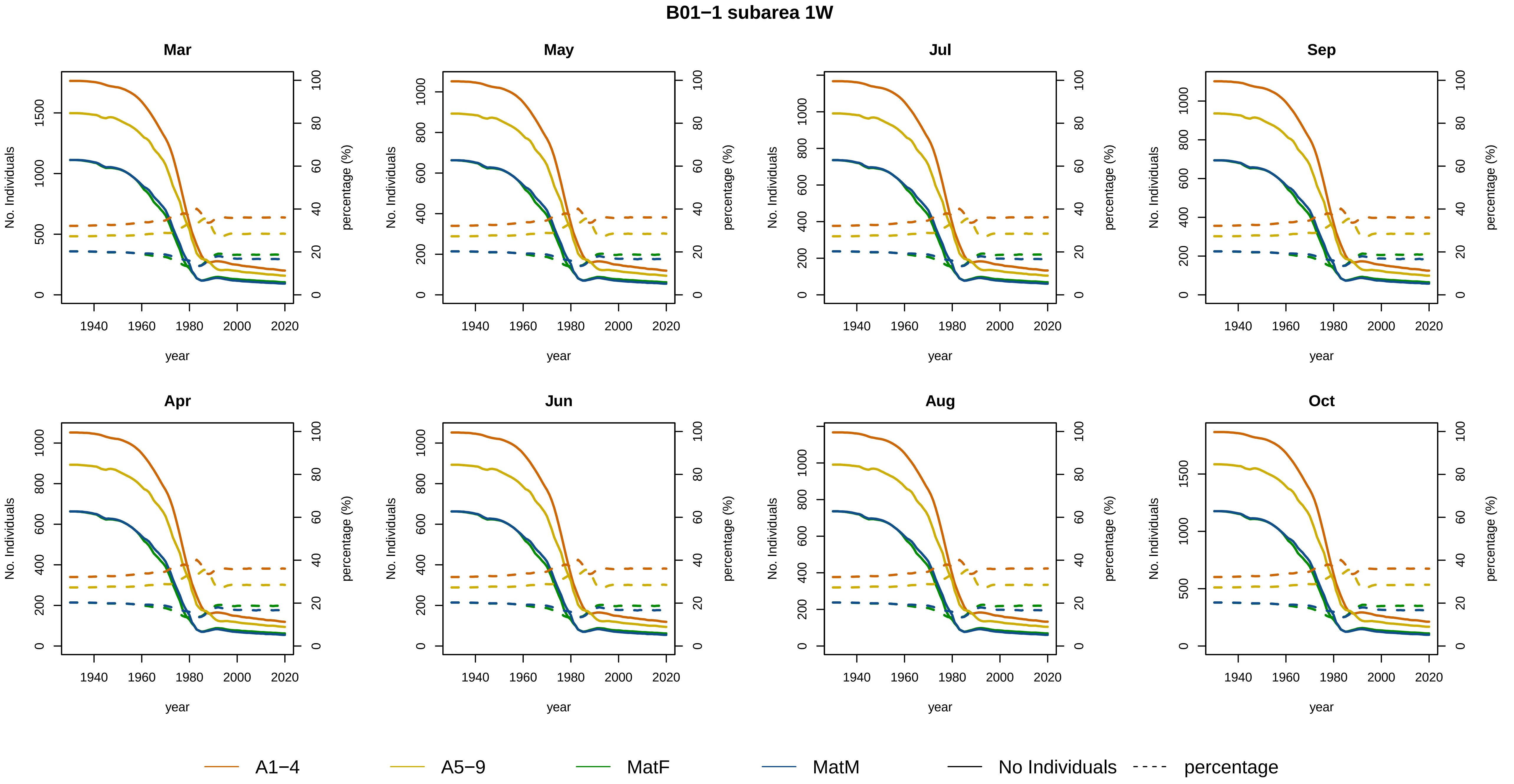


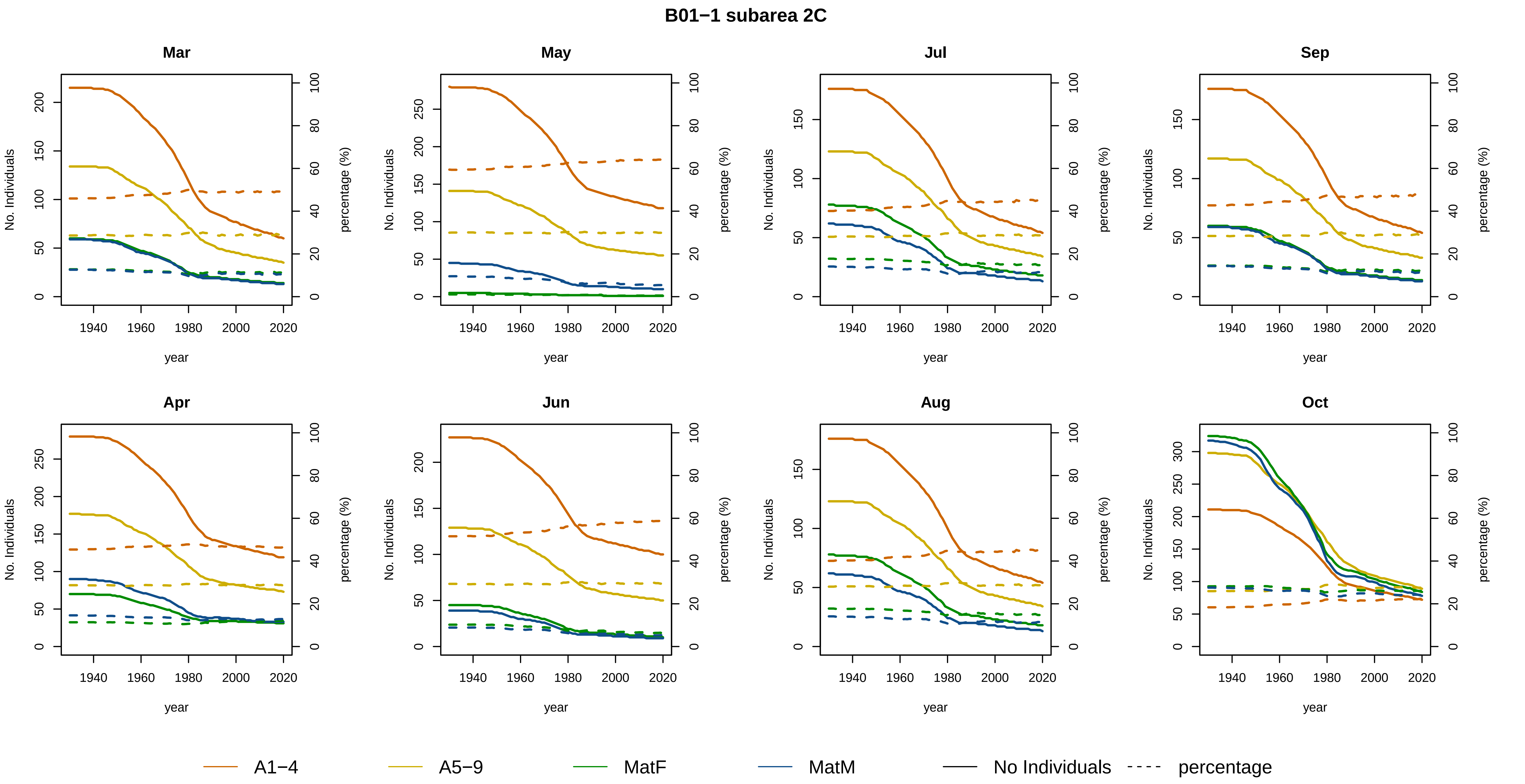
B01−1 Hyp. B 1% Baseline Conditioning Plot 3: 'Best Fit' Bycatches

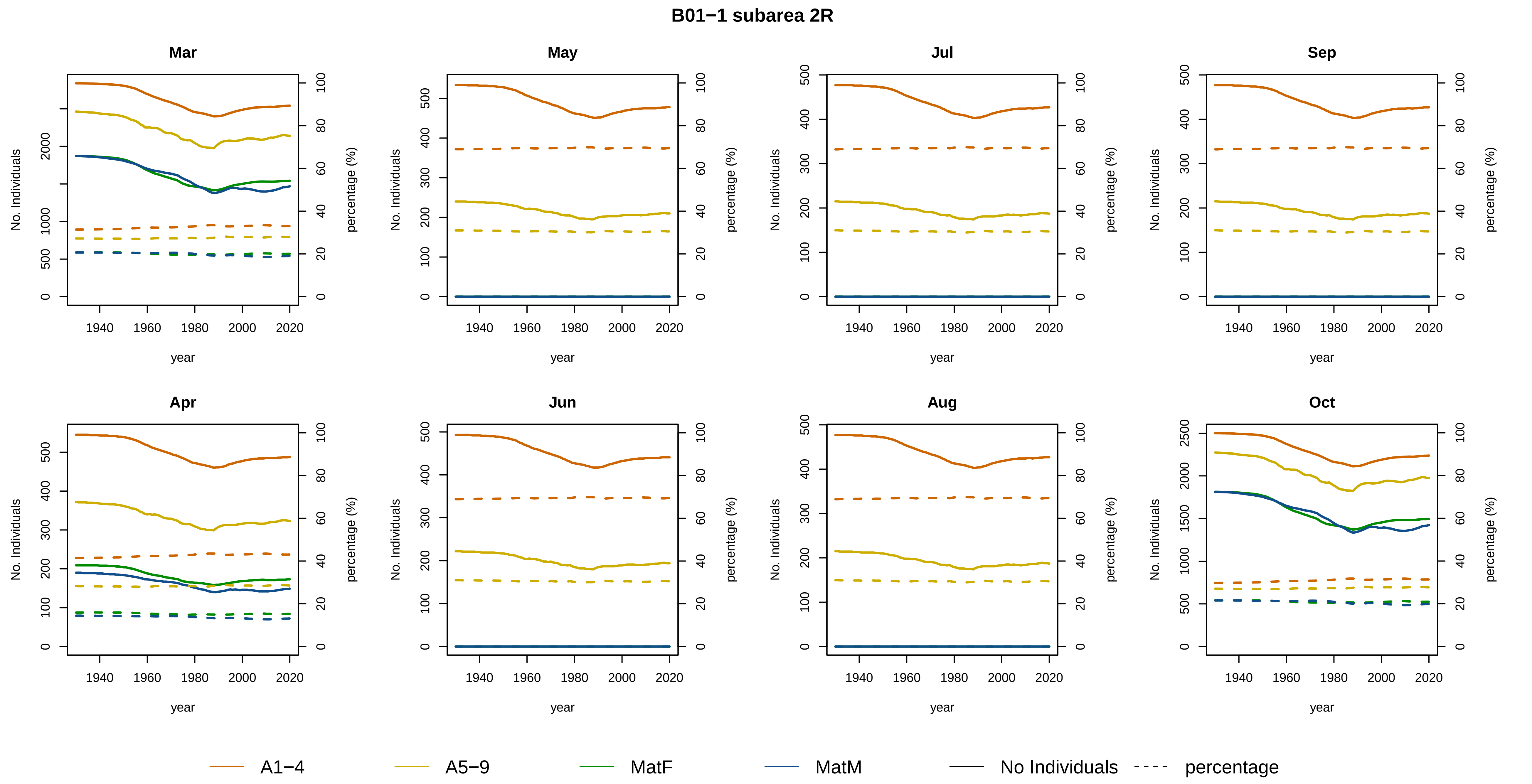


B01−1 subarea 1E




B01−1 subarea 1W
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 2C
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage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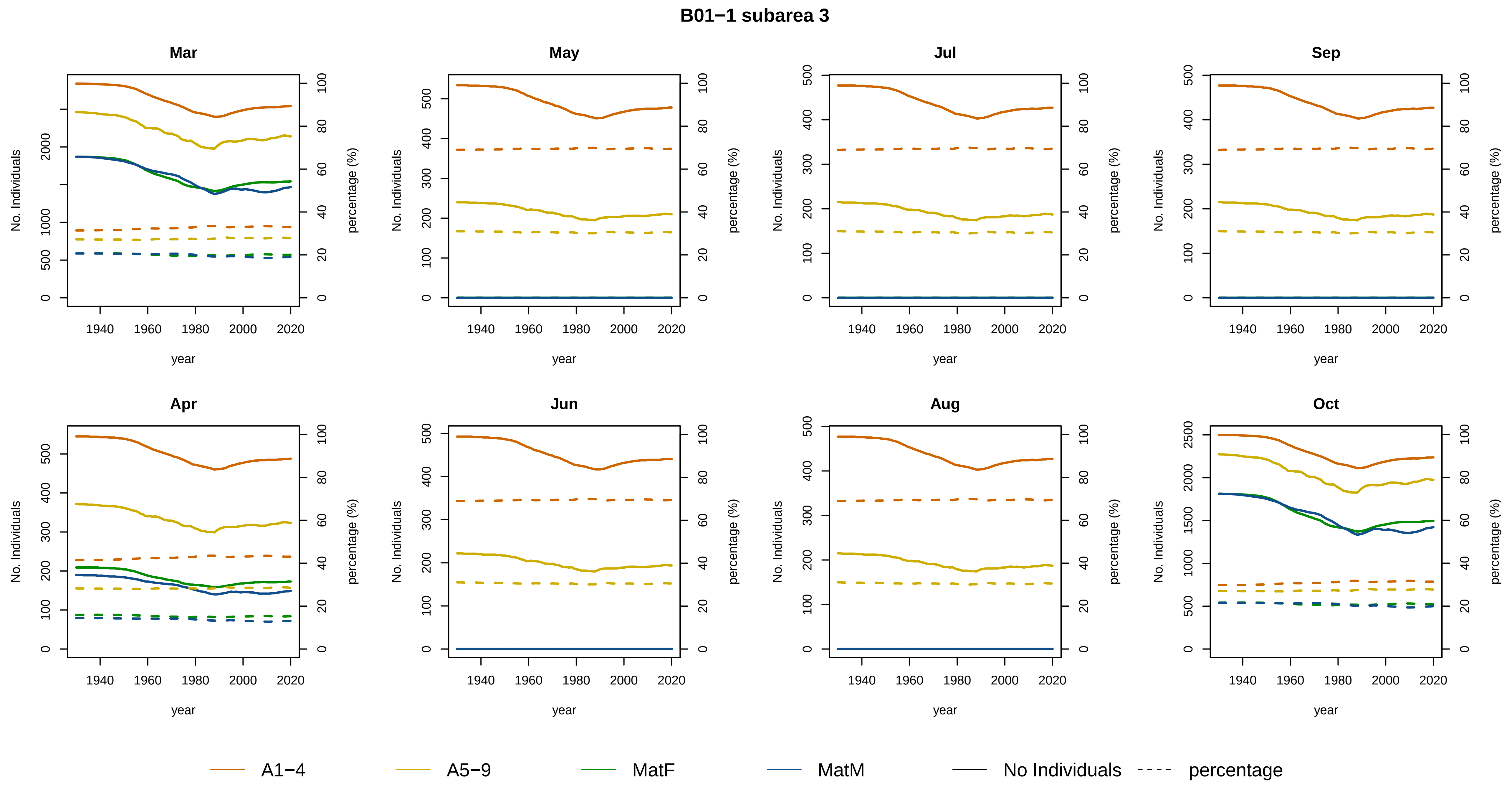
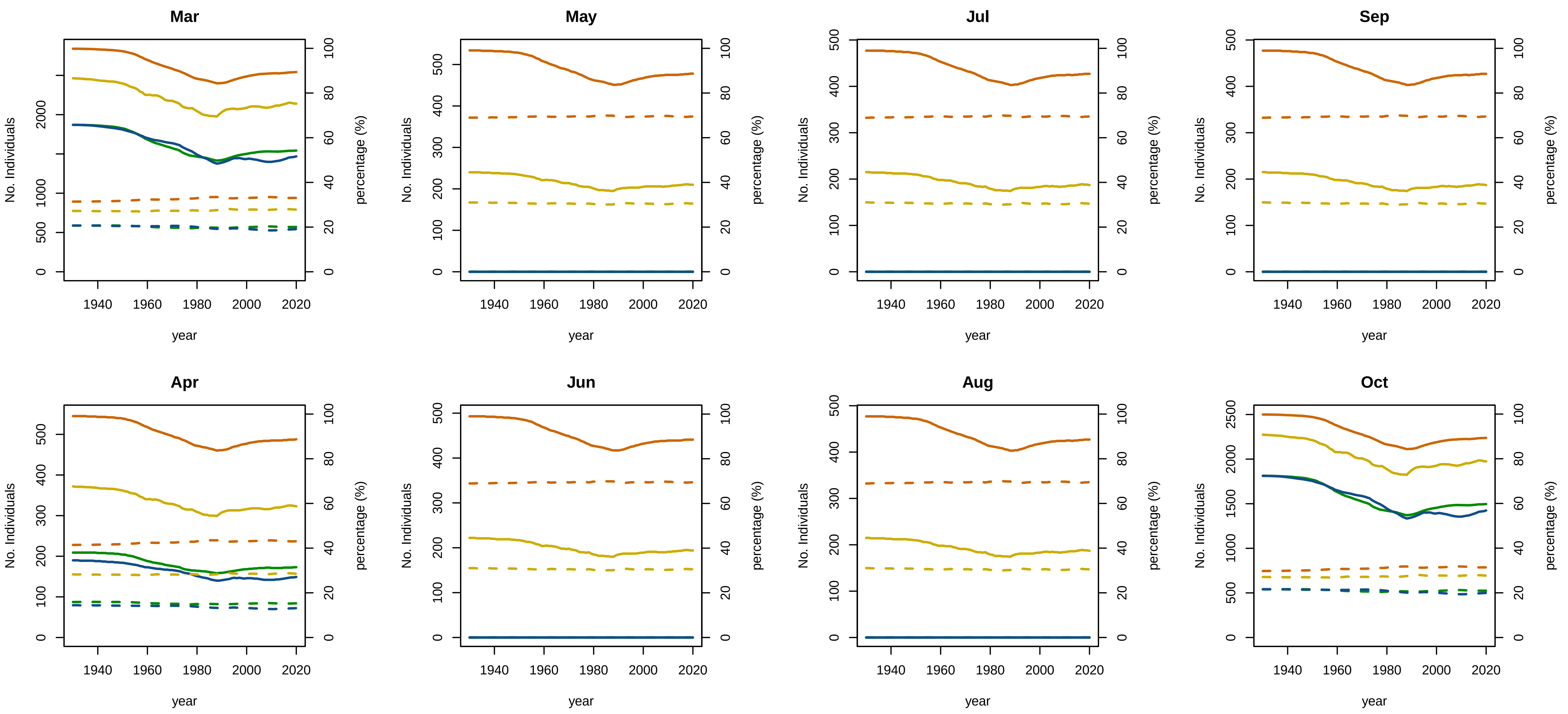
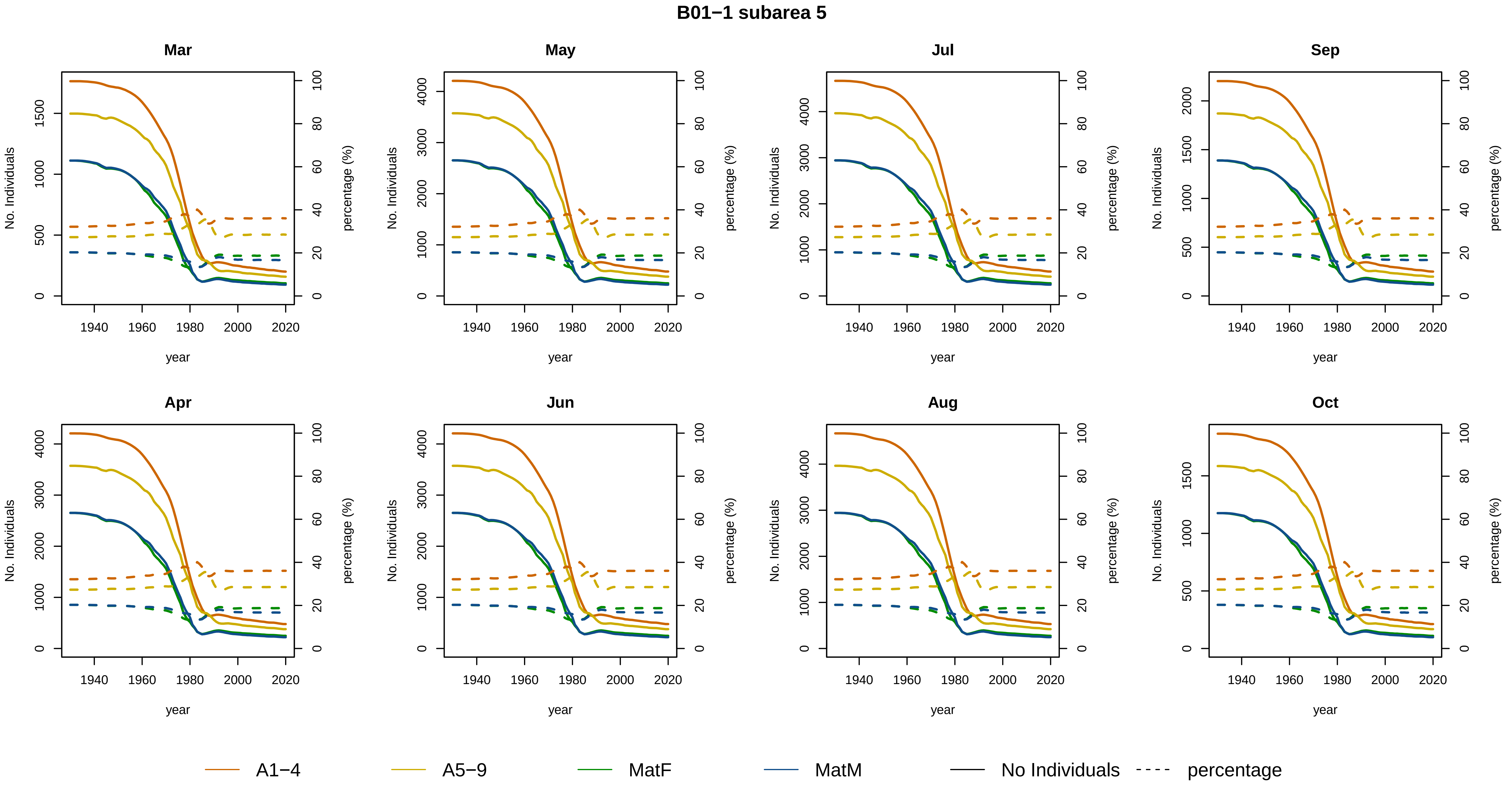
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

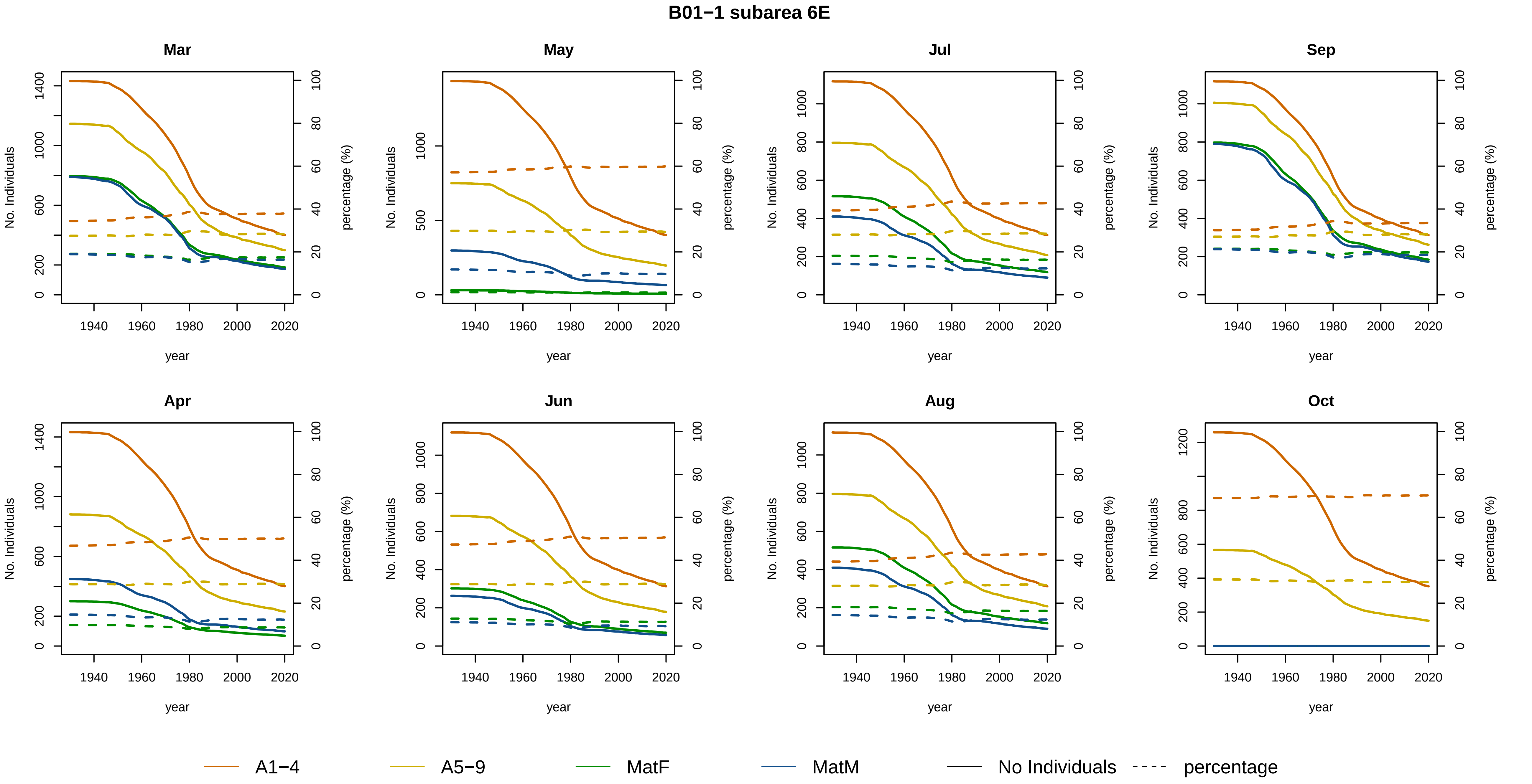

B01−1 subarea 3
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

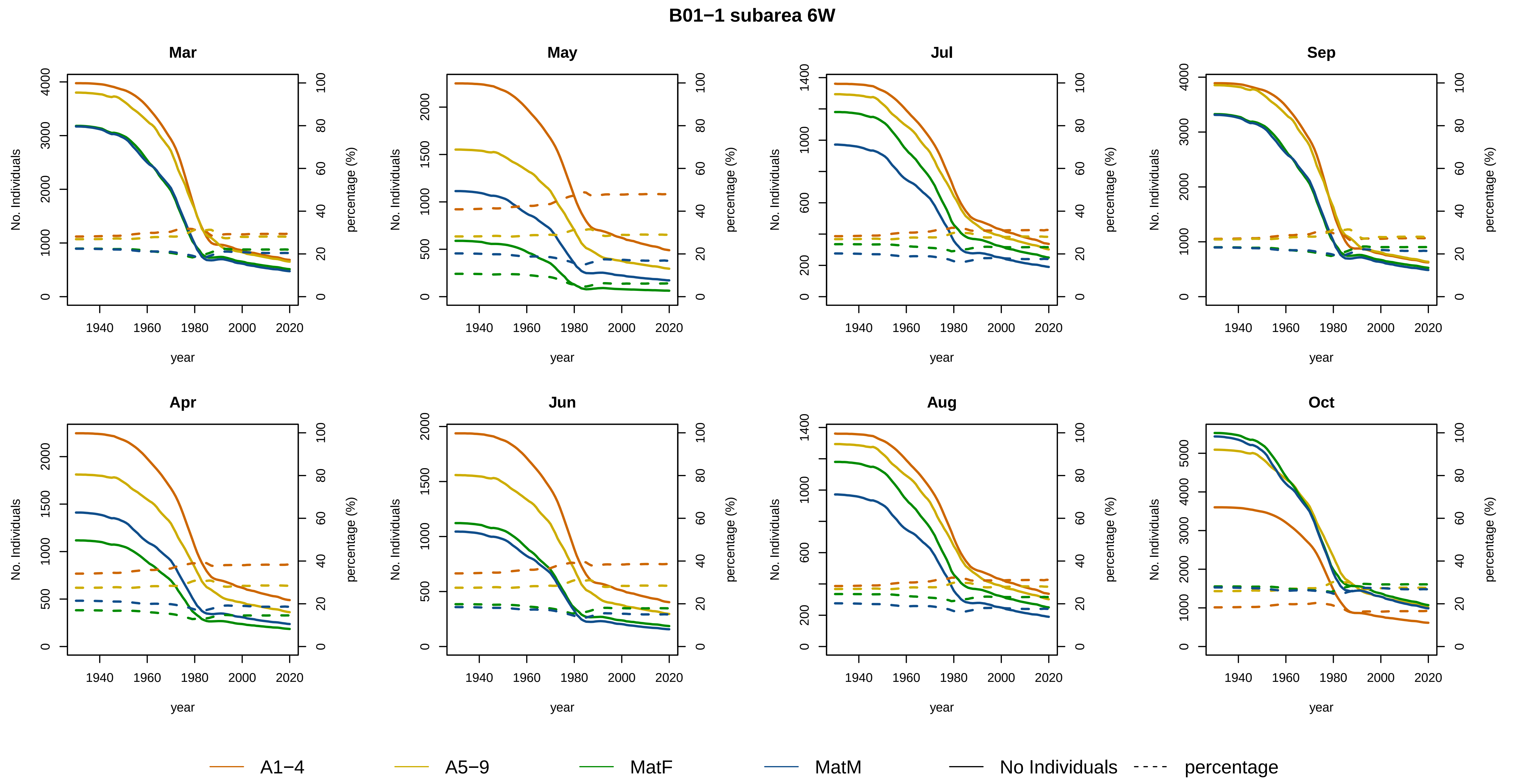
B01−1 subarea 4



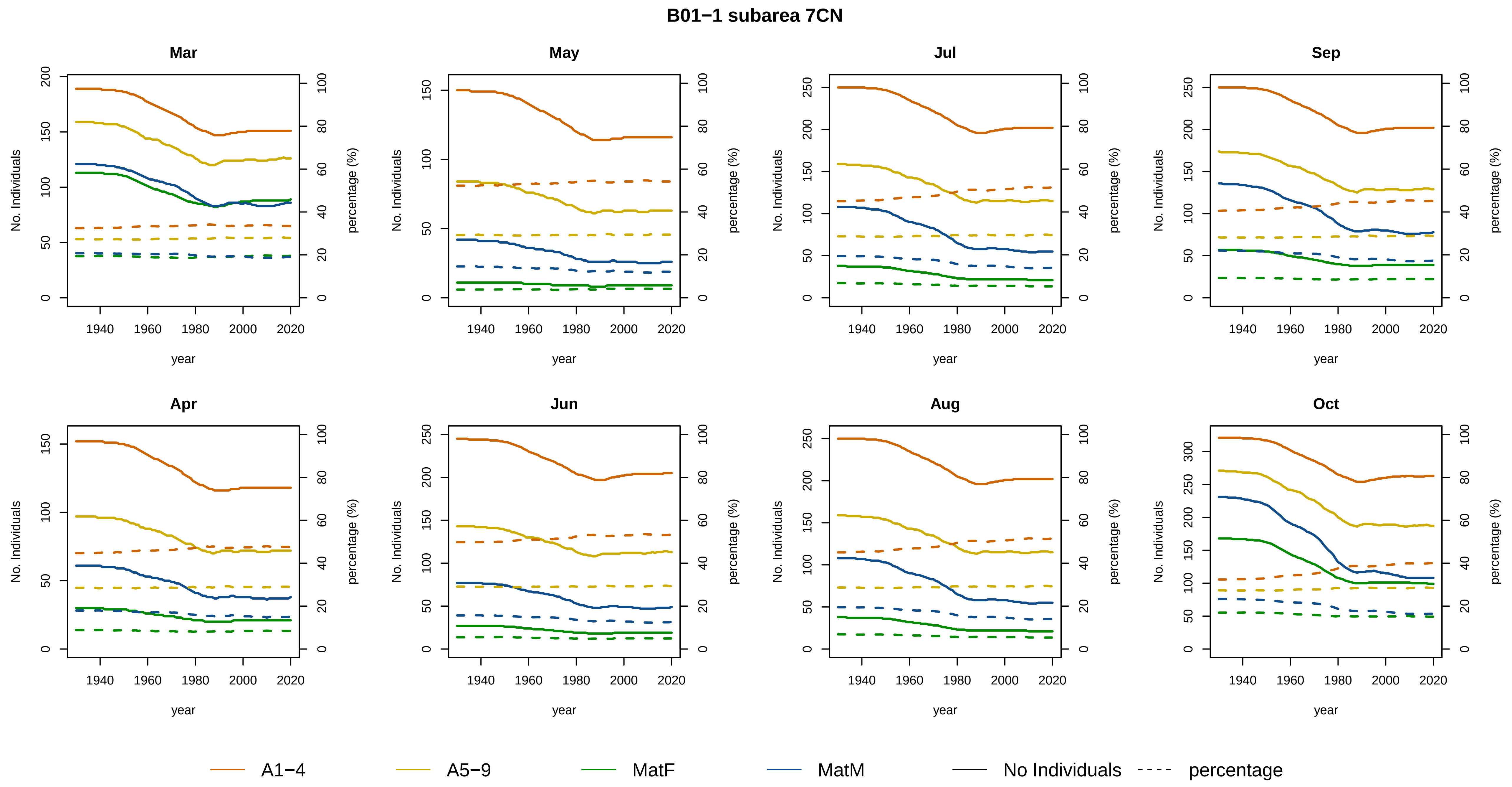
A1−4   A5−9   MatF   MatM   No Individuals   percentage

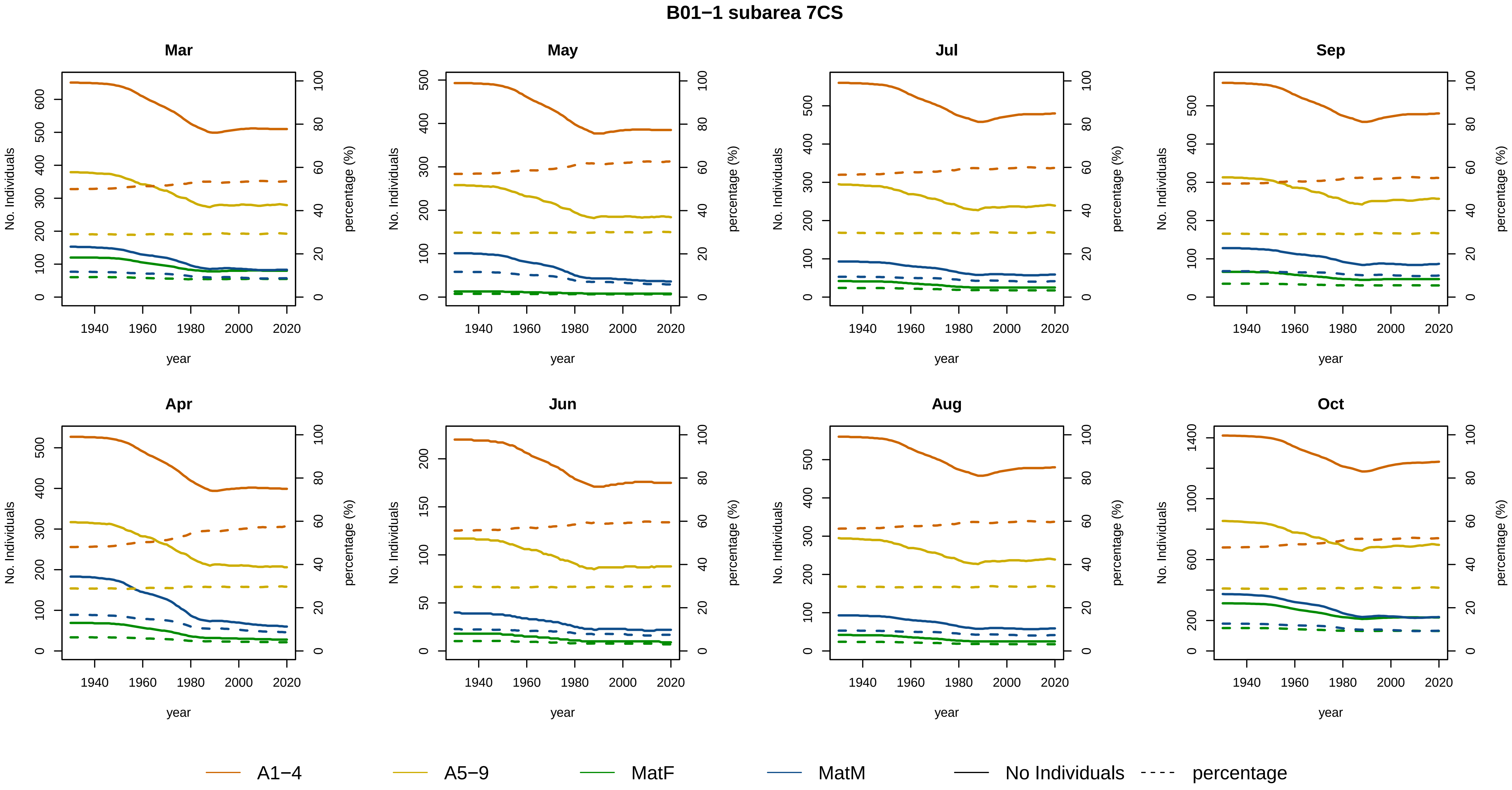

B01−1 subarea 5
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
1940
1960
1980
2000
2020
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 6E
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

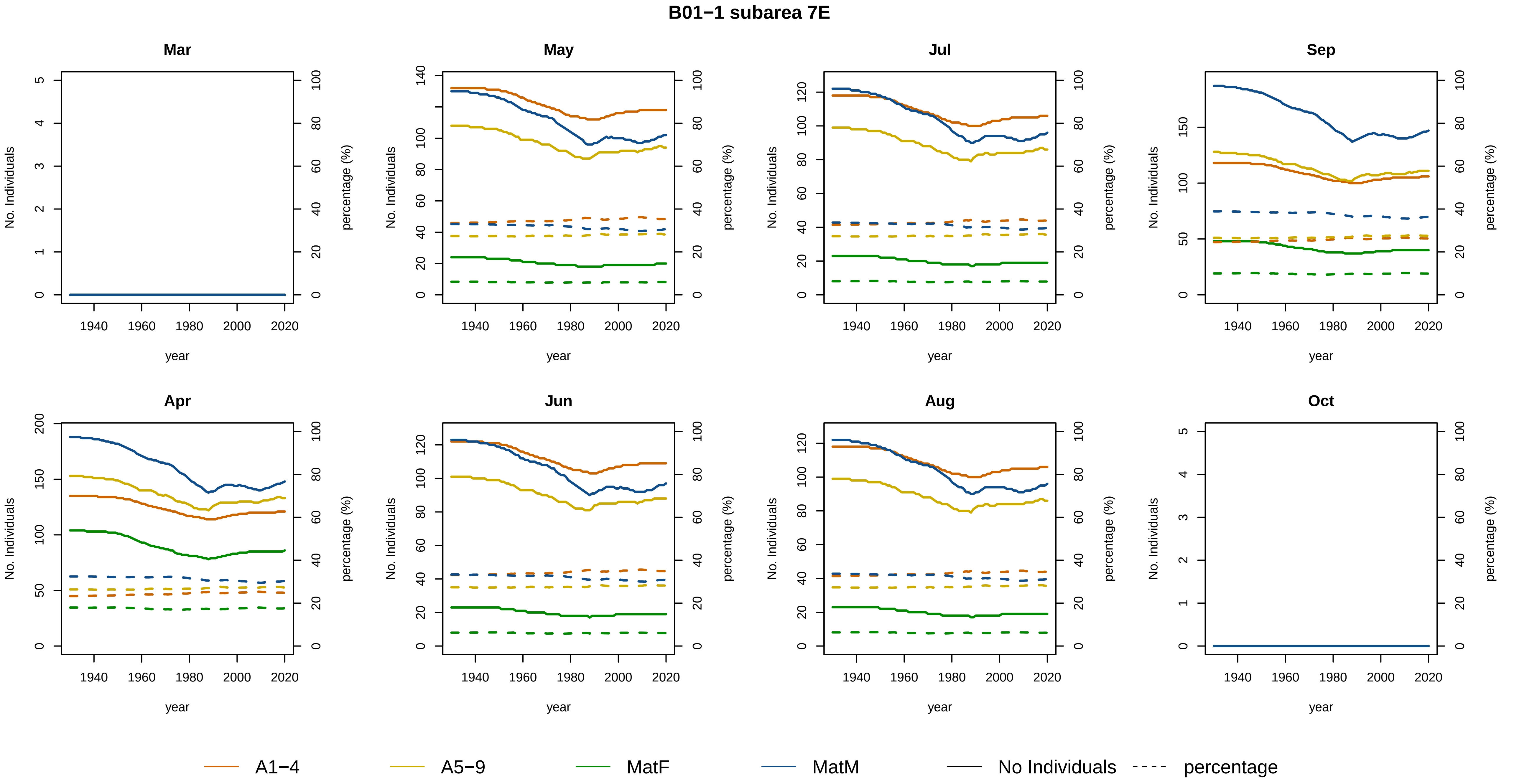


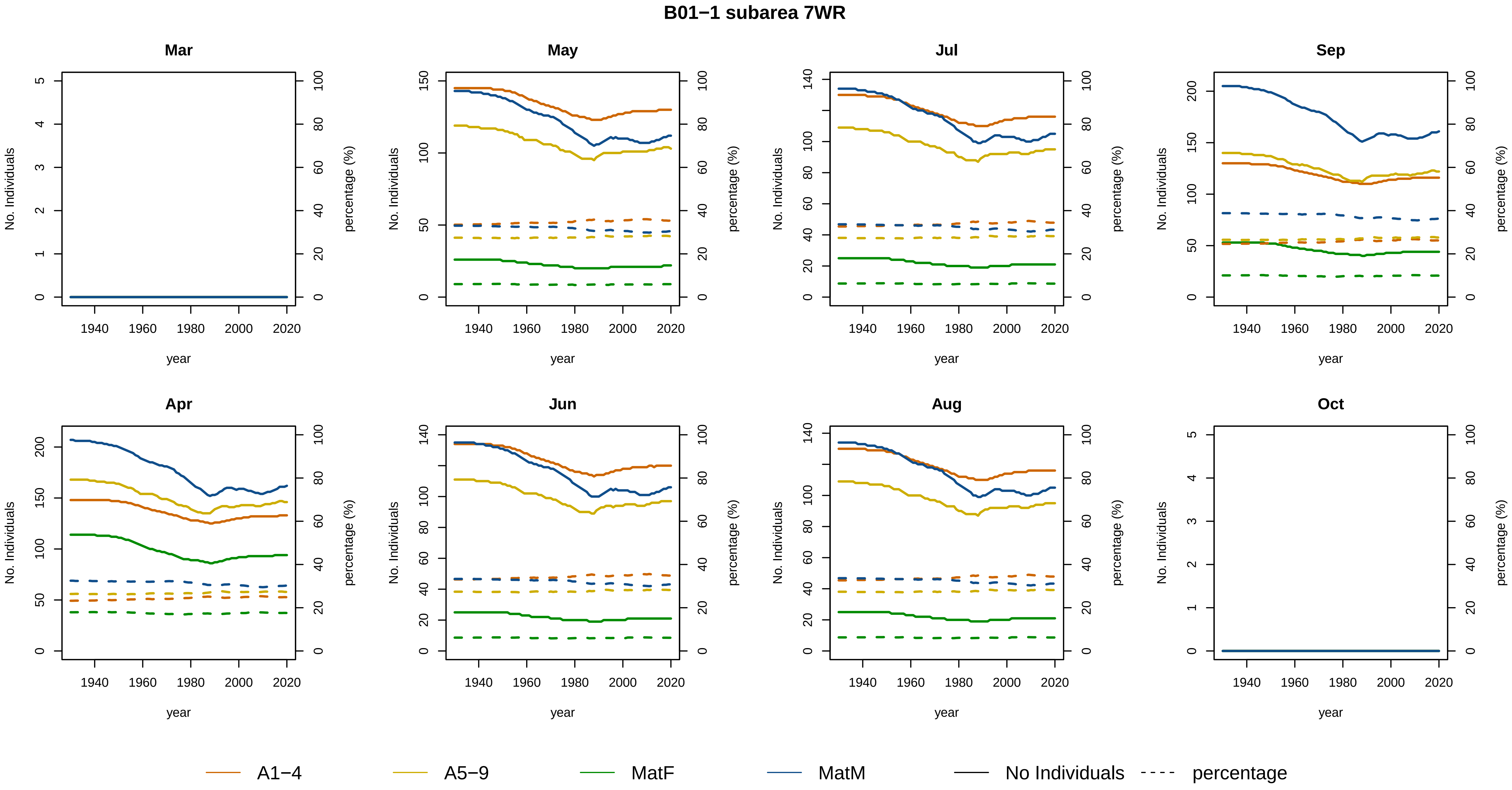
B01−1 subarea 6W
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 7CN
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

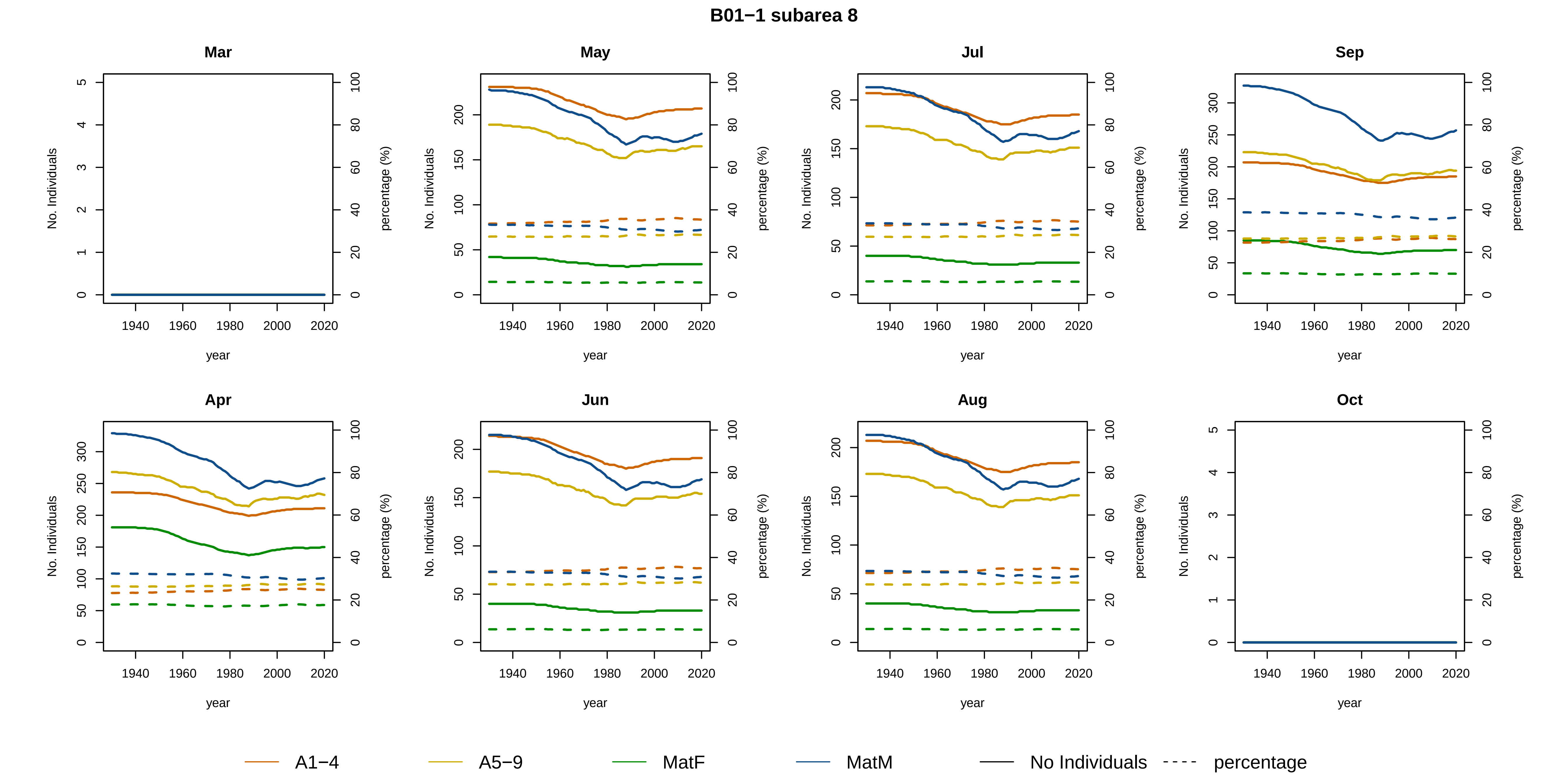


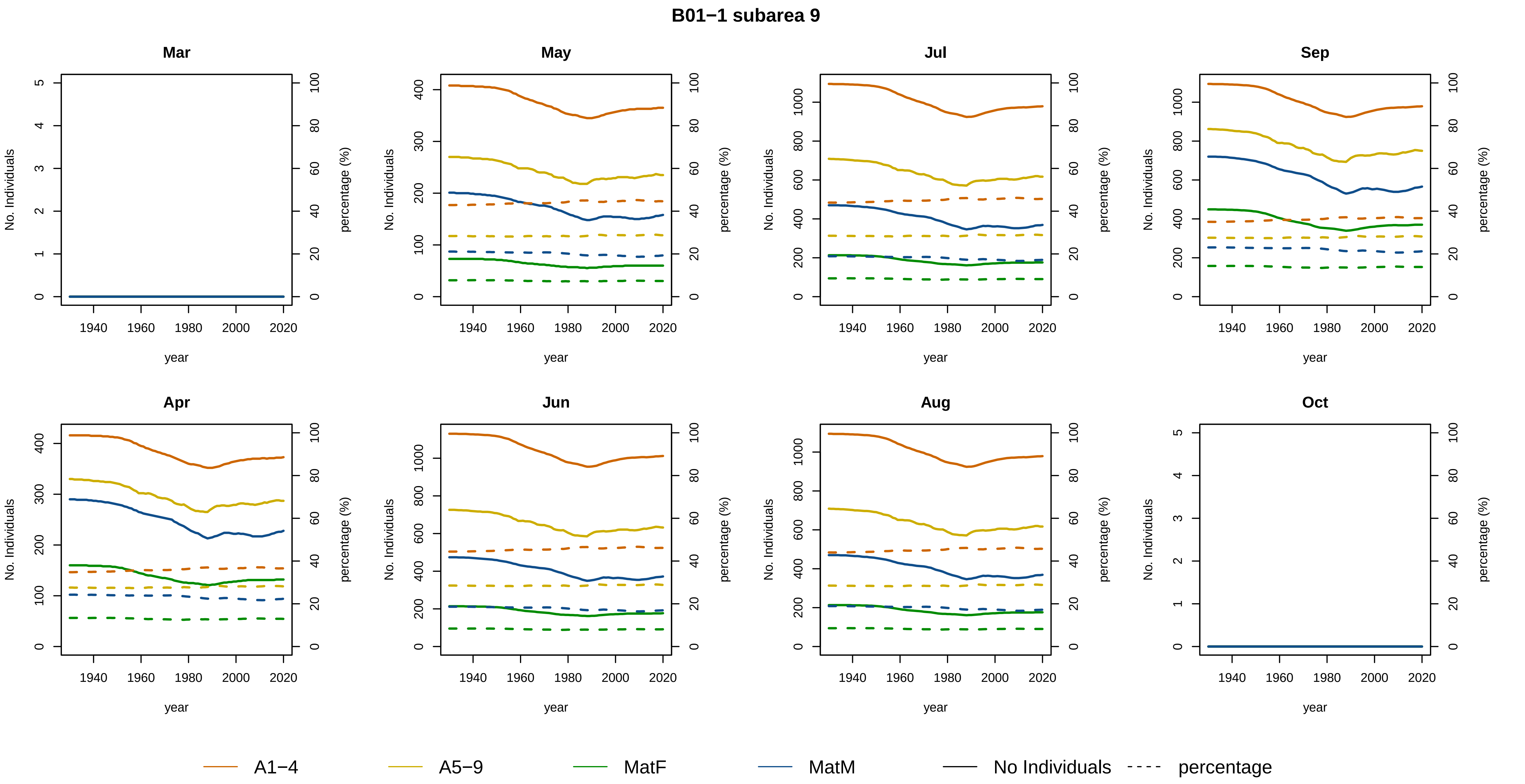
B01−1 subarea 7CS
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 7E
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

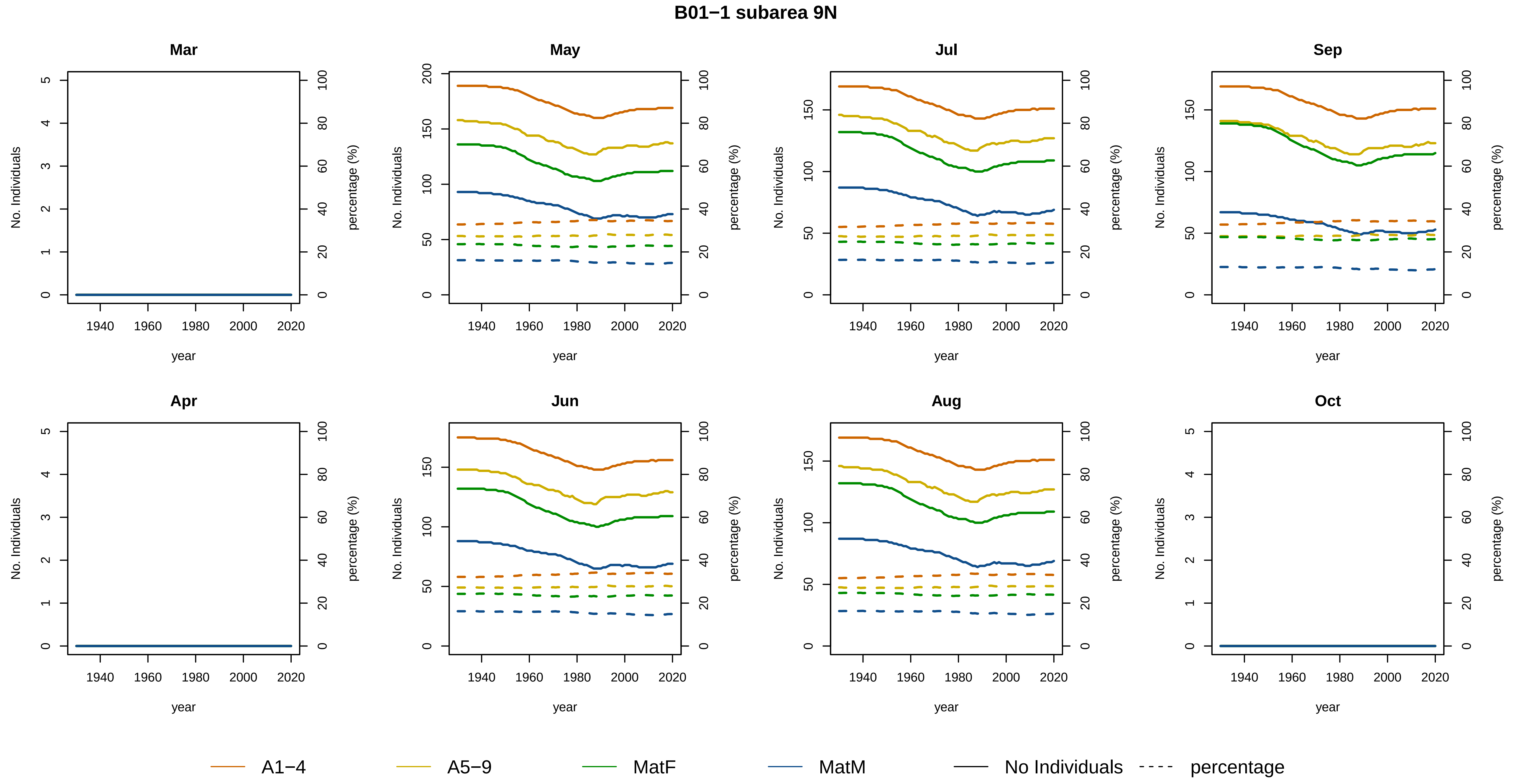


B01−1 subarea 7WR
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

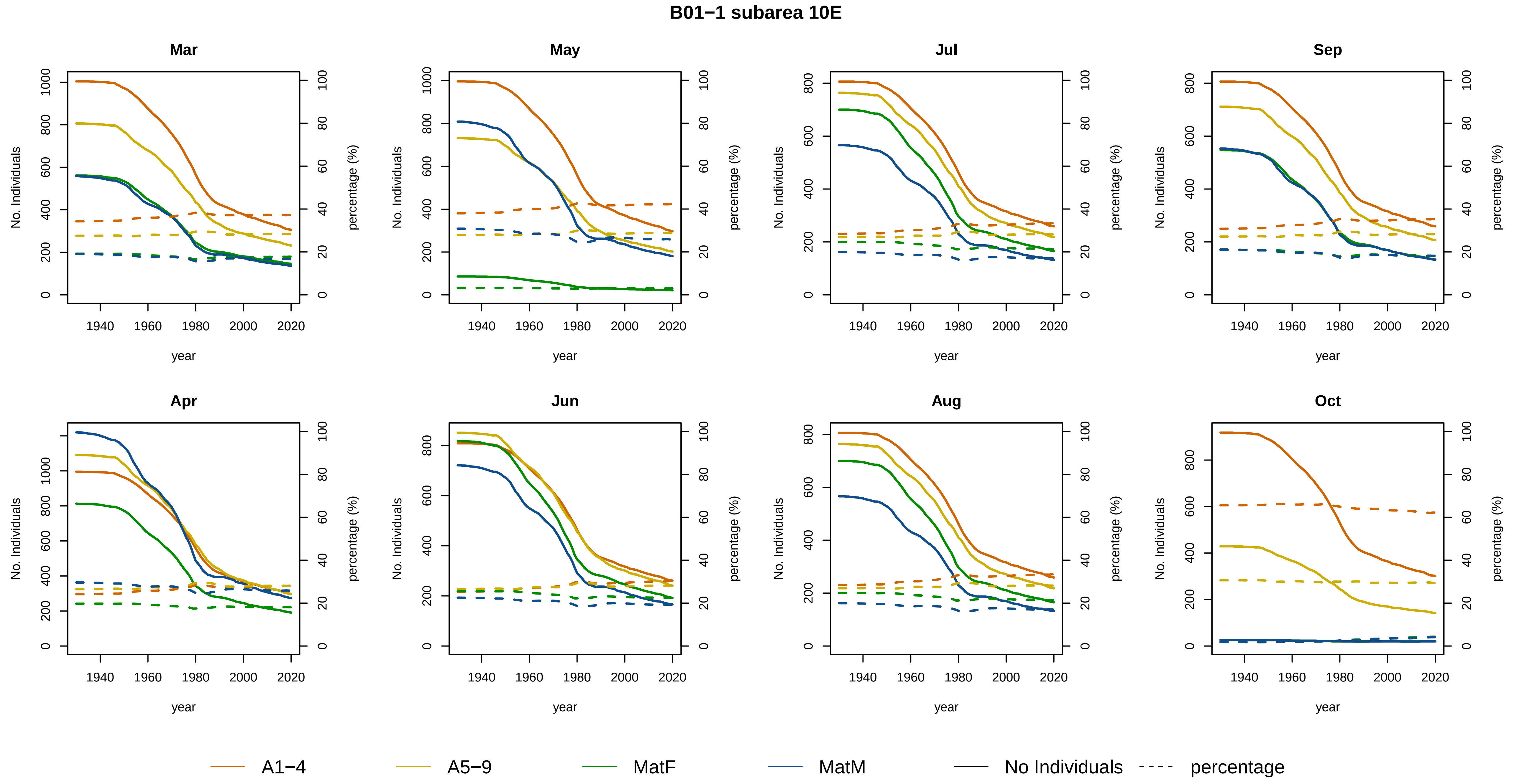

B01−1 subarea 8
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

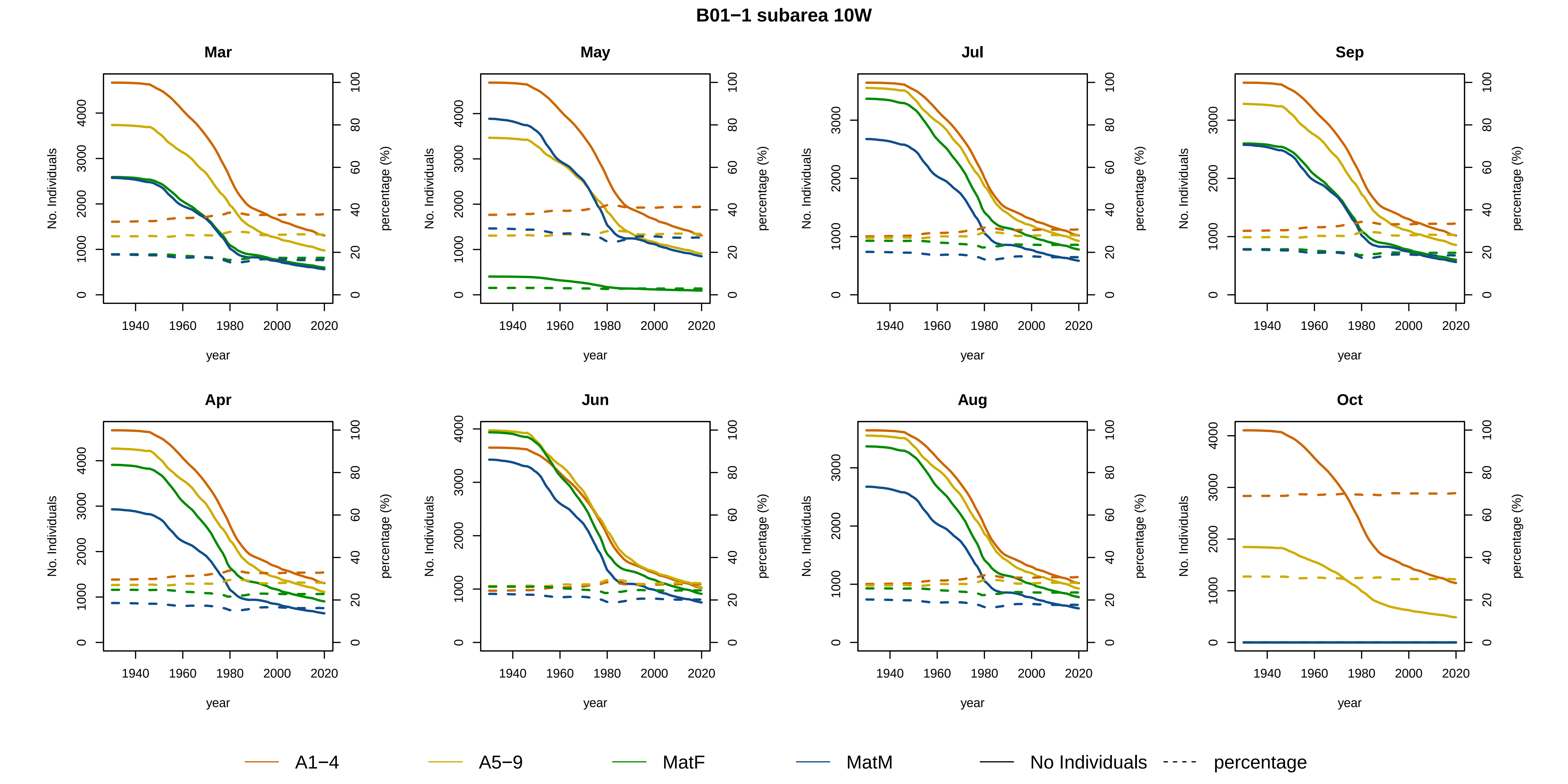


B01−1 subarea 9
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

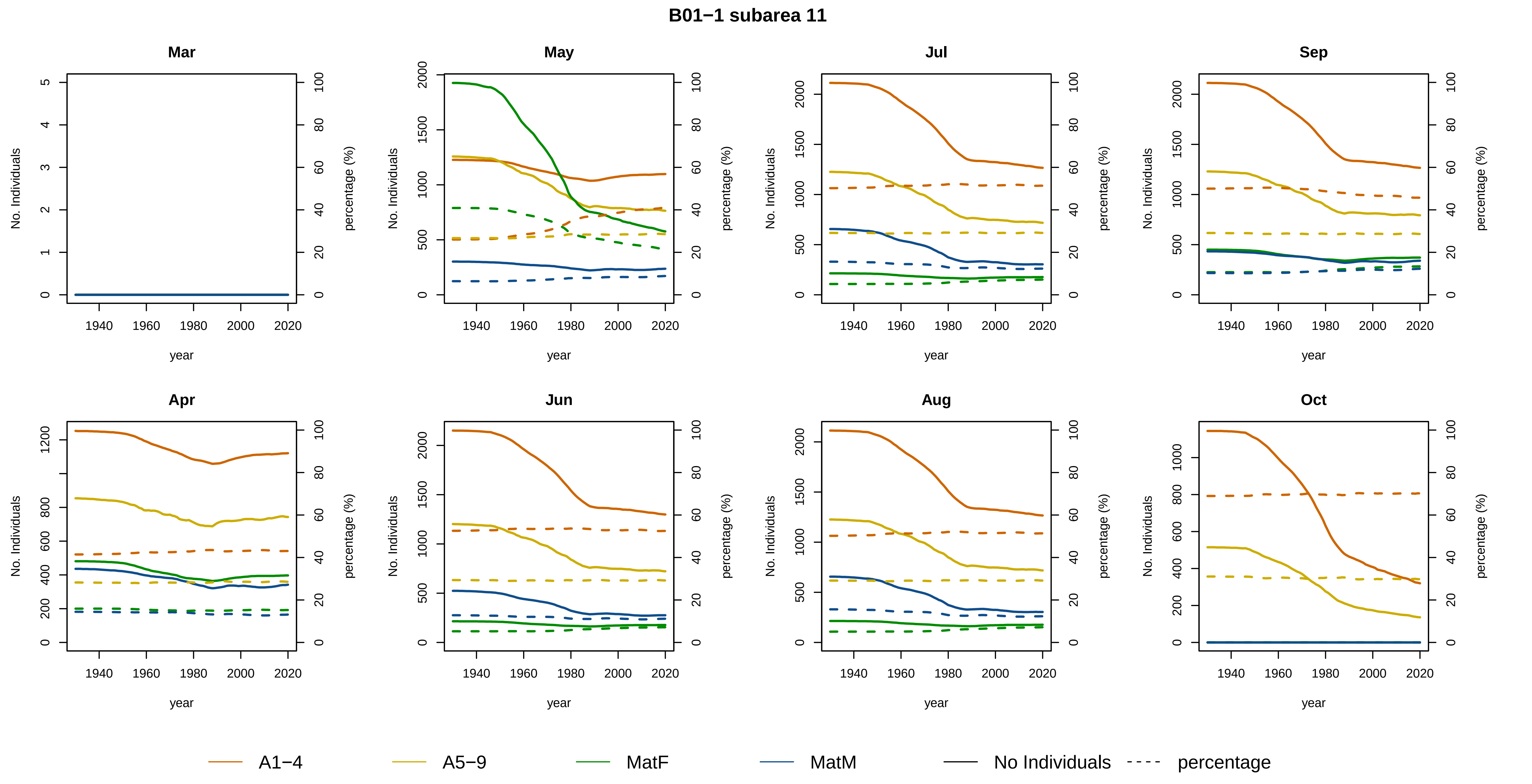


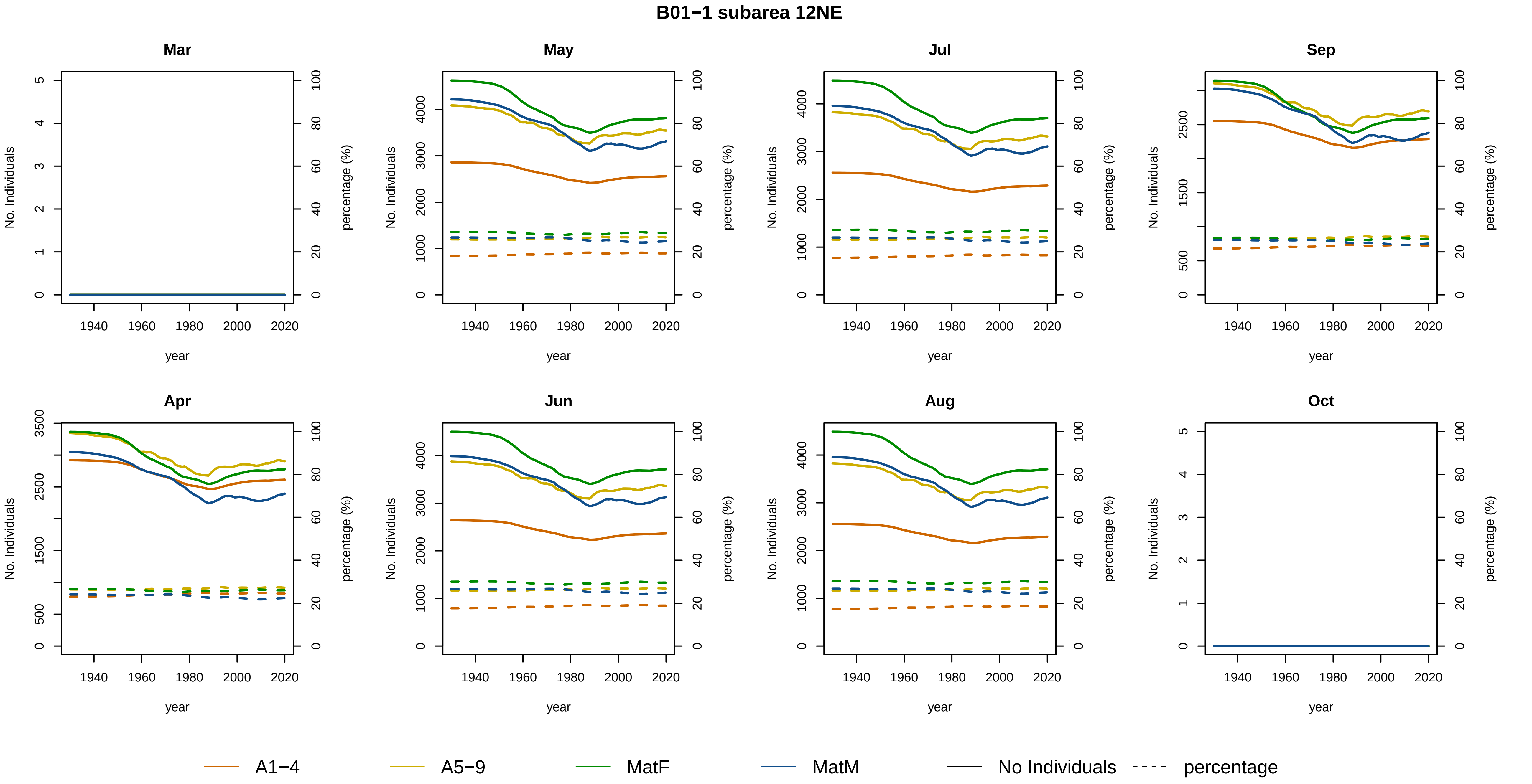
B01−1 subarea 9N
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 10E
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage

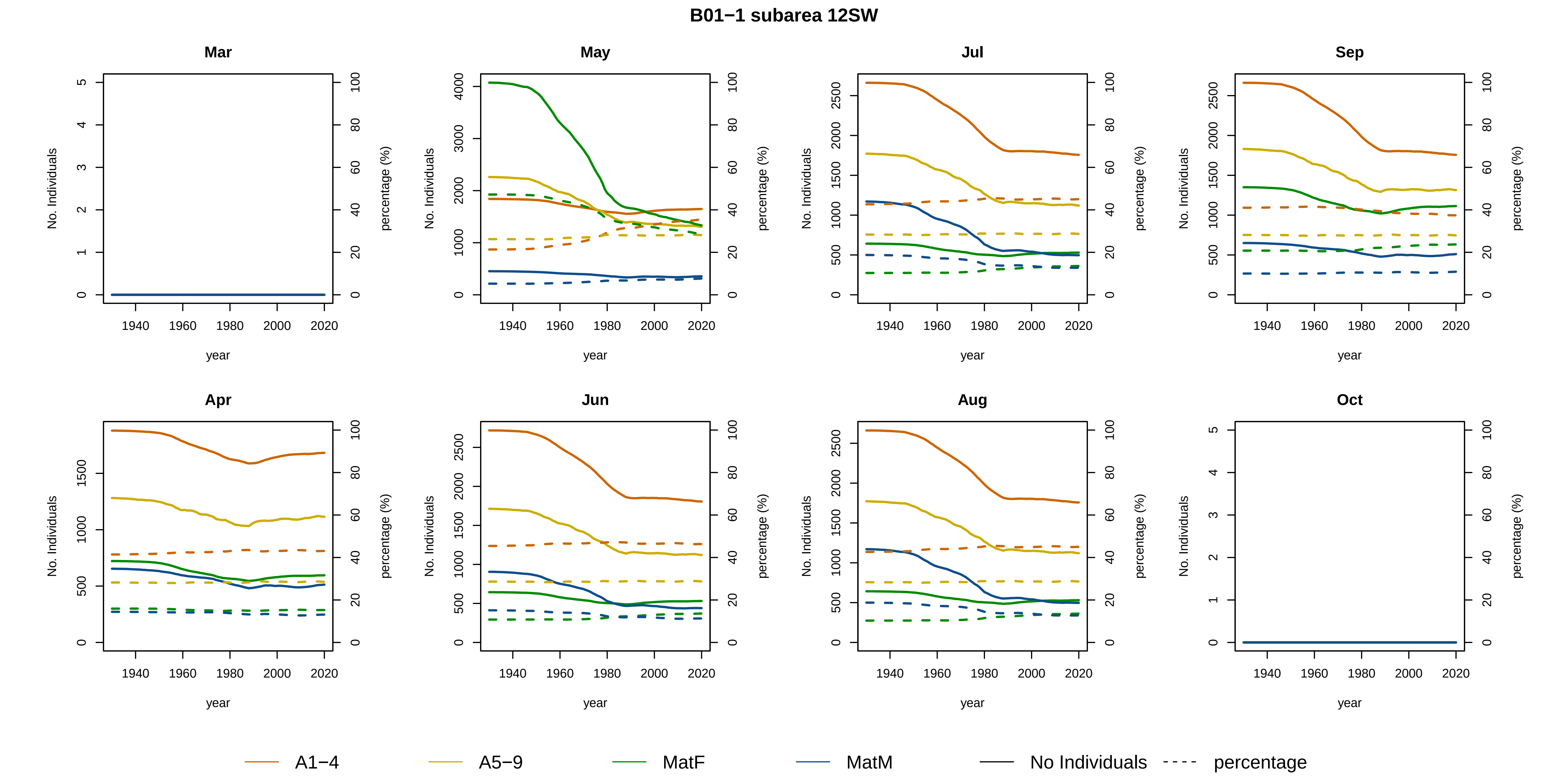


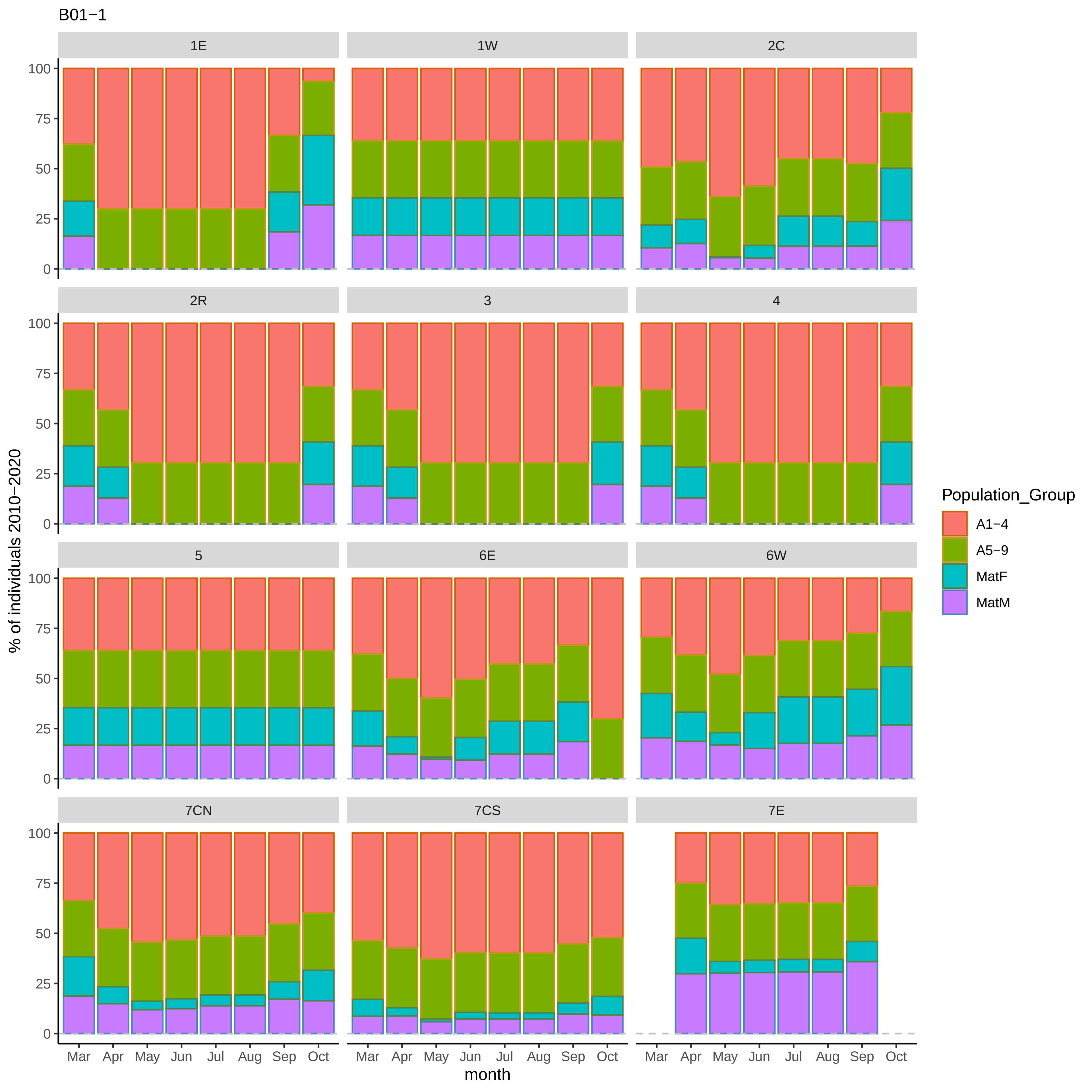
B01−1 subarea 10W
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 11
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
1940
1960
1980
2000
2020
A1−4
A5−9
MatF
MatM
No Individuals
percentage

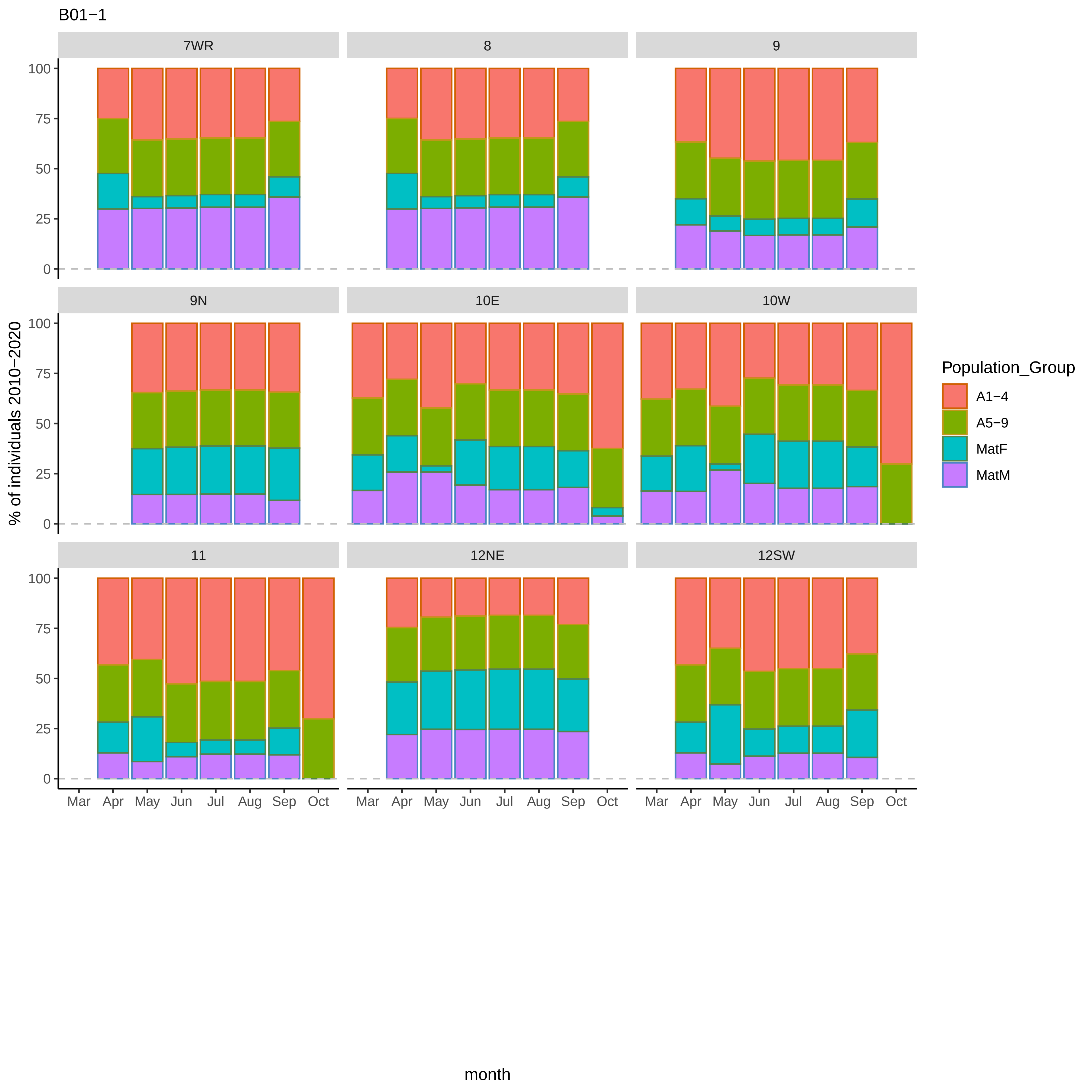


B01−1 subarea 12NE
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
1940
1960
1980
2000
2020
A1−4
A5−9
MatF
MatM
No Individuals
percentage


B01−1 subarea 12SW
Mar
May
Jul
Sep
Apr
Jun
Aug
Oct
No. Individuals
percentage (%)
year
A1−4
A5−9
MatF
MatM
No Individuals
percentage



B01−1
1E
1W
2C
2R
3
4
5
6E
6W
7CN
7CS
7E
100
75
50
25
0
% of individuals 2010−2020
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
month
Population_Group
A1−4
A5−9
MatF
MatM


B01−1
7WR
8
9
9N
10E
10W
11
12NE
12SW
% of individuals 2010−2020
100
75
50
25
0
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
month
Population_Group
A1−4
A5−9
MatF
MatM


Mar−1930
Pop estimate:75869
13812
8288
0
type
A1−4
A5−9
MatF
MatM
lat
long
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
120°E
130°E
140°E
150°E
160°E
170°E
Apr−1930
Pop estimate:75881
16575
8288
0
May−1930
Pop estimate:75877
16575
8288
0
Jun−1930
Pop estimate:75875
13812
8288
0
Jul−1930
Pop estimate:75876
13812
8288
0
Aug−1930
Pop estimate:75876
13812
8288
0
Sep−1930
Pop estimate:75875
13812
8288
0
Oct−1930
Pop estimate:75877
19338
11050
0
110°E

Mar−1960
Pop estimate:65969
11002
6602
0
type
A1−4
A5−9
MatF
MatM
lat
long
Apr−1960
Pop estimate:65971
13203
6602
0
May−1960
Pop estimate:65968
15404
6602
0
Jun−1960
Pop estimate:65970
13203
6602
0
Jul−1960
Pop estimate:65969
13203
6602
0
Aug−1960
Pop estimate:65969
13203
6602
0
Sep−1960
Pop estimate:65971
11002
6602
0
Oct−1960
Pop estimate:65970
15404
8802
0
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
110°E
120°E
130°E
140°E
150°E
160°E
170°E

Mar−2020
Pop estimate:33522
7632
3816
0
Apr−2020
Pop estimate:33519
11448
5724
0
May−2020
Pop estimate:33519
13356
5724
0
Jun−2020
Pop estimate:33519
13356
5724
0
Jul−2020
Pop estimate:33520
13356
5724
0
Aug−2020
Pop estimate:33520
13356
5724
0
Sep−2020
Pop estimate:33520
9540
5724
0
Oct−2020
Pop estimate:33520
7632
3816
0
type
A1−4
A5−9
MatF
MatM
lat
long


Mar−1930
Pop estimate:75869
Apr−1930
Pop estimate:75881
May−1930
Pop estimate:75877
Jun−1930
Pop estimate:75875
Jul−1930
Pop estimate:75876
Aug−1930
Pop estimate:75876
Sep−1930
Pop estimate:75875
Oct−1930
Pop estimate:75877
type
A1−4
A5−9
MatF
MatM
lat
long
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
120°E
130°E
140°E
150°E
160°E
170°E


Mar−2020
Pop estimate:33522
Apr−2020
Pop estimate:33519
May−2020
Pop estimate:33519
Jun−2020
Pop estimate:33519
Jul−2020
Pop estimate:33520
Aug−2020
Pop estimate:33520
Sep−2020
Pop estimate:33520
Oct−2020
Pop estimate:33520
type
A1−4
A5−9
MatF
MatM
lat
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
long
120°E
130°E
140°E
150°E
160°E
170°E

Appendix C – Plots of initial fits to alternative combinations of the genetic samples in sub-area 11

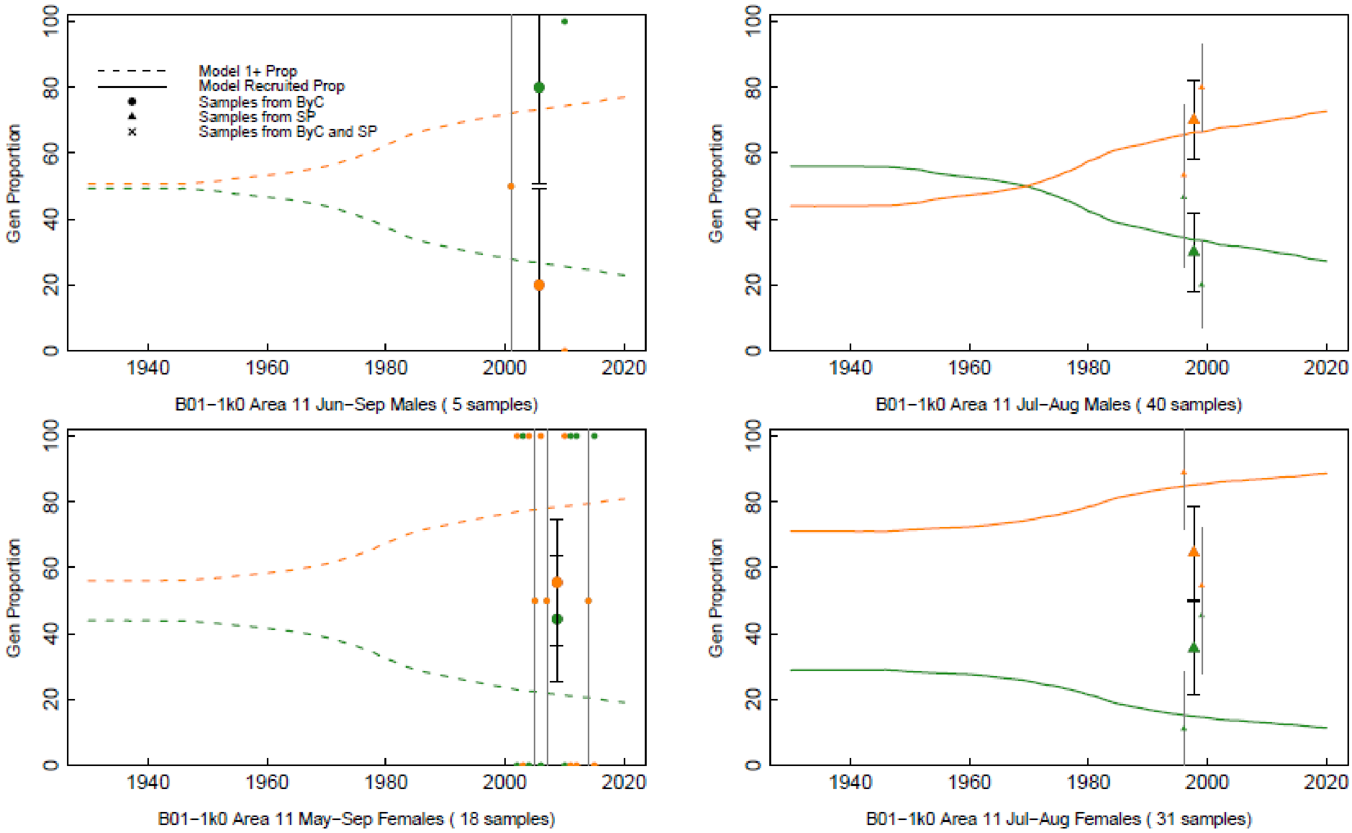
The number of sampled whales that were assigned to each stock using the genetic assignment data based on STRUCTURE (Hypothesis A & B) and Geneland (Hypothesis E) using a 90% probability of assignment. In sub-areas 7CS and 7CN the baseline and Trial 5 proportion of whales assigned to each stock is weighted by 5/60 of the bycatch proportion and 55/60 of the special permit proportion. The number assigned by stock is then taken as this proportion multiplied by the total number of assigned animals. In Trial 6 the proportion of whales assigned to each stock is weighted by 2/60 of the bycatch proportion and 58/60 of the special permit proportion, while in Trial 7 10/60 of the bycatch proportion and 50/60 of the special permit proportion are used. These data are used to condition the trials.

Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	Bycatch Samples		Special Permit Samples		Weighted Total	
							J-Stock	O-Stock	J-Stock	O-Stock	J-Stock	O-Stock
A & B	Baseline	11	1996-2012	May-Dec	M	57					28	29
A & B	Baseline	11	1996-2015	May-Dec	F	58					28	30
		Or Alternatively										
A & B	Baseline	11	2001-2010	Jun-Sep*	M	5	4	1				
A & B	Baseline	11	1996-1999	Jul-Aug	M	40			12	28		
A & B	Baseline	11	2002-2015	May-Sep	F	18	8	10				
A & B	Baseline	11	1996-1999	Jul-Aug	F	31			11	20		

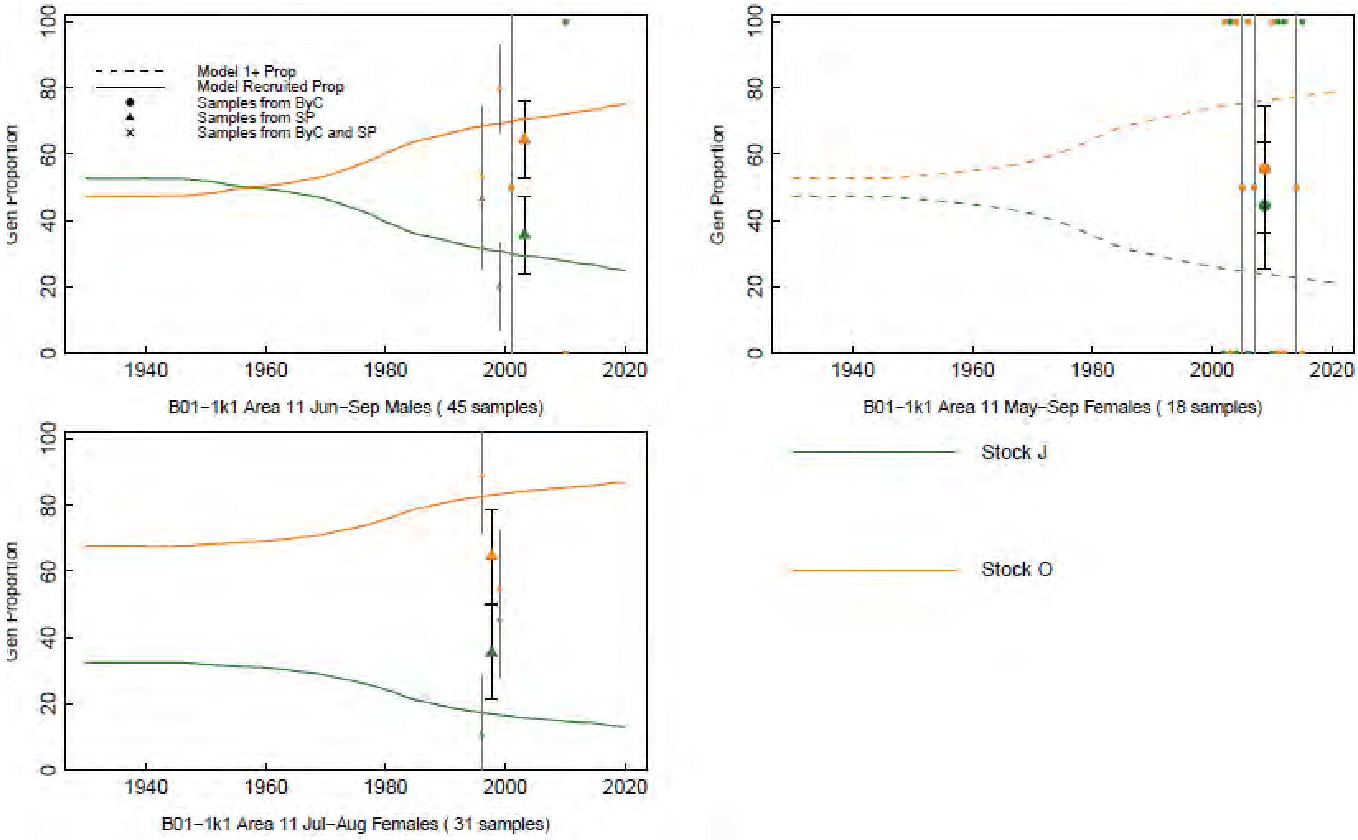
Hypothesis	Trial	Area	Years	Months	Sex	Total Sample	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk	J-Stk	P-Stk	O-Stk
E	Baseline	11	1996-2012	May-Dec	M	59							13	45	1
E	Baseline	11	1996-2015	May-Dec	F	63							18	41	4
		Or Alternatively													
E	Baseline	11	2001-2012	Jun-Nov	M	15	9	6	-						
E	Baseline	11	1996-1999	Jul-Aug	M	44				4	39	1			
E	Baseline	11	2002-2015	May-Nov	F	30	13	17	-						
E	Baseline	11	1996-1999	Jul-Aug	F	33				5	24	4			

* Samples in October and November were assigned to the J-stock only. Hypotheses A and B assume only J-stock individuals in sub-area 11 in October-December.

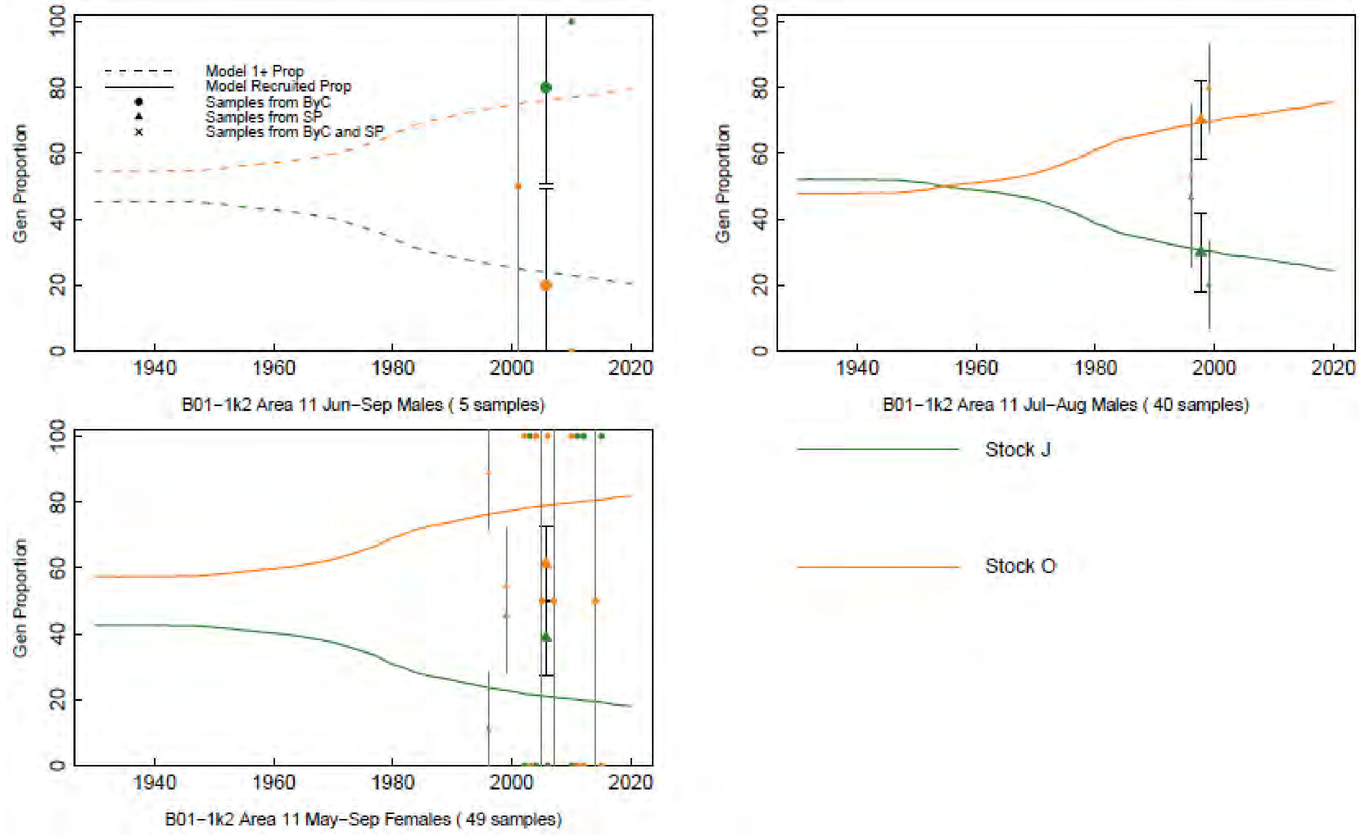
4 combinations (M bycatch, M special permits, F bycatch, F special permits)



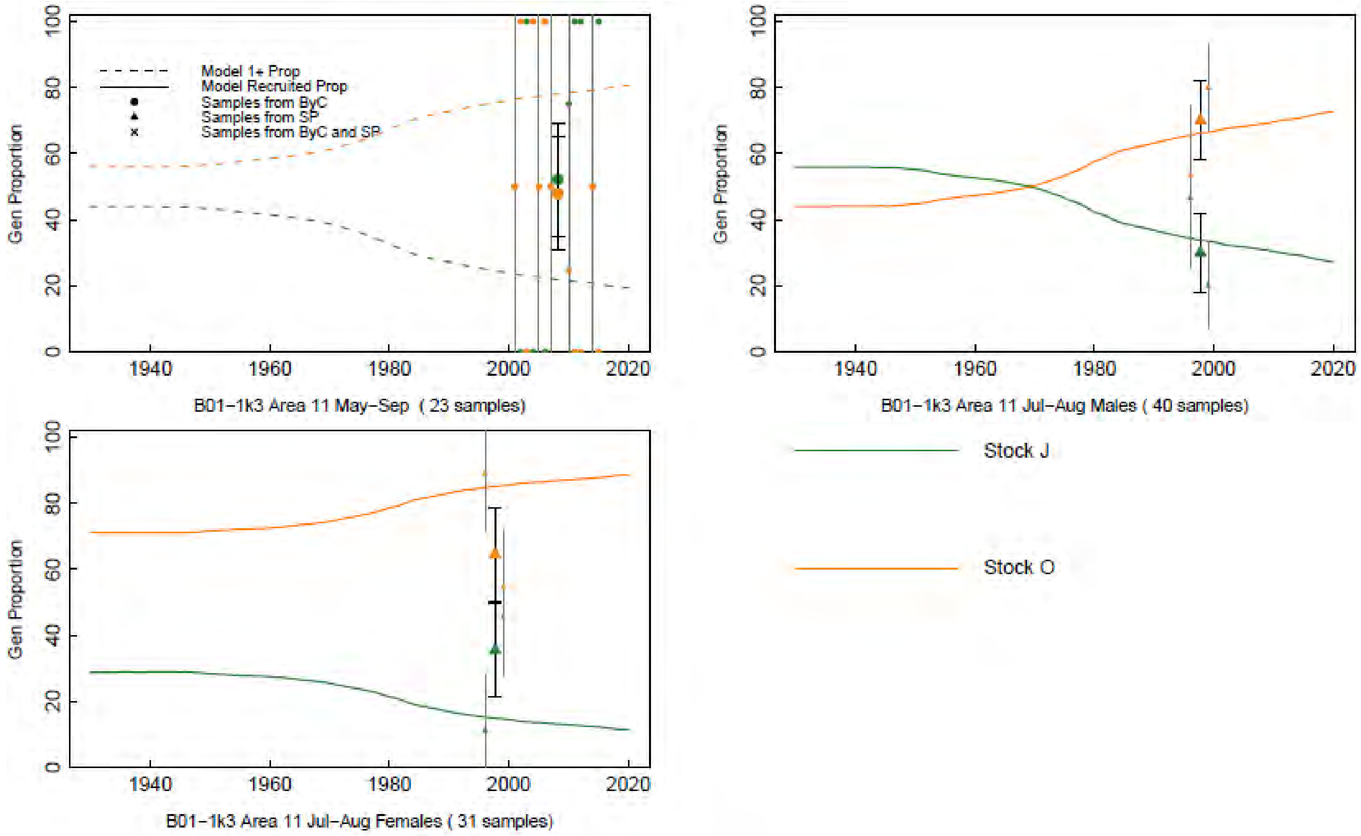
3 combinations (M bycatch & special permits, F bycatch, F special permits)



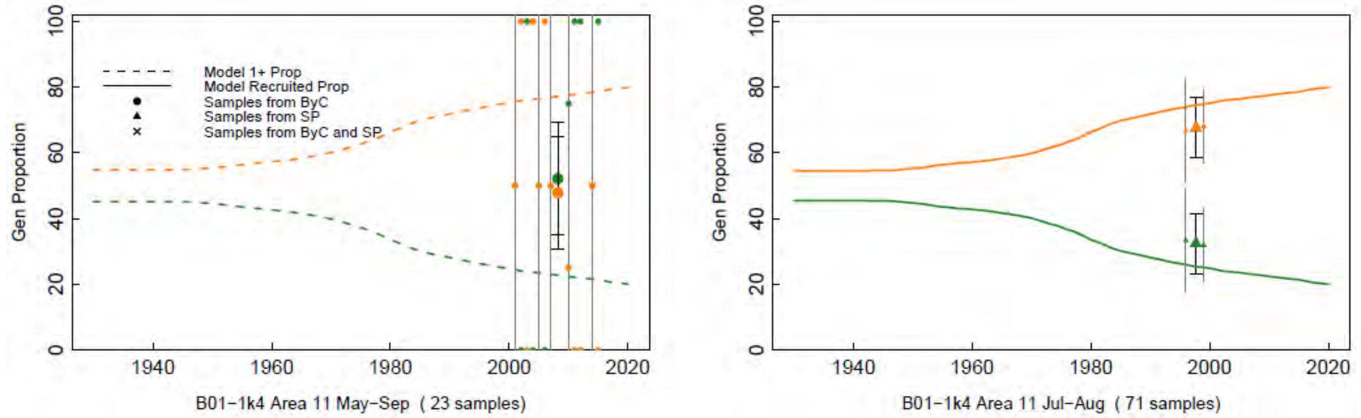
3 combinations (M bycatch, M special permits, F bycatch & special permits)



3 combinations (M+F bycatch, M special permits, F special permits)



2 combinations (M+F bycatch, M+F special permits)



2 combinations (M bycatch & special permits, F bycatch & special permits)