Hayes & Adams (2017) Mathematica Notebook 1

About this notebook

This document is a PDF created from a Wolfram *Mathematica* notebook file prepared by Mark A. Hayes during December 2016 following the general approach for matrix population analysis outlined in Ellner and Guckenheimer (2006) and used in Hayes (2011). This code and output analyzes the population matrices used in the Hayes and Adams 2017 PLOS ONE manuscript “Simulated bat populations erode when exposed to climate change projections for western North America”. This notebook is used to calculate eigenvalues and other characteristics of the matrix model used, such as sensitivity of the matrix elements to small changes in a given matrix element. The “elasticity 01022017.xlsx” spreadsheet shows sensitivity and elasticity calculations, given these eigenvalues; this notebook also shows step by step sensitivity calculations. The sensitivity and elasticity matrix plots at the end of this notebook use information from this notebook and the elasticity calculations from the spreadsheet. If you would like a copy of the original *Mathematica* notebook, please contact MAH at hayesm@usgs.gov or hayes.a.mark@gmail.com.

Mark A. Hayes
January 2, 2017

```
SetDirectory[NotebookDirectory[]]
```

```
\\IGSKBACBFS2\groups\bts\t\mah\manuscripts\2016\Hayes & Adams 2016 - Bat pop
  modeling - PLOS ONE\revision - fall winter 2016\Plos One - Data package
```

Definiting the parameters, matrix model, and dominant eigenvalue

```
SA = 0.79;
SF = SA * 0.64;
adultBirthRate = 0.425;

FA = SA * adultBirthRate;
F0 = 0.90 * adultBirthRate * SF;

m = {{F0, FA, FA, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
MatrixForm[m]
Lambda = Eigenvalues[m, 1]
```

$$\begin{pmatrix} 0.193392 & 0.33575 & 0.33575 & 0.33575 \\ 0.5056 & 0 & 0 & 0 \\ 0 & 0.79 & 0 & 0 \\ 0 & 0 & 0.79 & 0.79 \end{pmatrix}$$

```
{1.00036}
```

```
OriginalLambda = Lambda
```

```
{1.00036}
```

```
MatrixForm[m]
```

$$\begin{pmatrix} 0.193392 & 0.33575 & 0.33575 & 0.33575 \\ 0.5056 & 0 & 0 & 0 \\ 0 & 0.79 & 0 & 0 \\ 0 & 0 & 0.79 & 0.79 \end{pmatrix}$$

Sensitivity of the matrix elements

Using the Ellner and Guckenheimer (2006) approach, where s is sensitivity for a given matrix element, and $\partial\lambda$ is the change in lambda (λ) given a small change in the matrix element (∂a_{ij}). In this case we reduced each matrix element in turn by 10%, and calculated the resulting λ (dominant eigenvalue) for each change, while keeping all other elements at the original value. Thus sensitivity is the original eigenvalue minus the new eigenvalue ($\partial\lambda$), divided by the change in the matrix element (∂a_{ij}):

$s_{ij} = \frac{\partial\lambda}{\partial a_{ij}}$

Reducing each vital rate, in turn, by 10% (Vital rate * 0.90):

Sensitivity of F0

Decreasing the matrix element by 0.10

```
0.193 * 0.90
```

0.1737

```
mf0 = {{0.1737, FA, FA, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[mf0, 1]
```

{0.996351 + 0. i}

```
Lambdaf0 = 0.996351
```

0.996351

```
Sensitivityf0 = (OriginalLambda - Lambdaf0) / (0.193 - 0.1737)
```

{0.207792}

Sensitivity of F1

```
0.336 * 0.9
```

0.3024

```
mf1 = {{F0, 0.3024, FA, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[mf1, 1]
```

{0.99691 + 0. i}

```
Lambdaf1 = 0.99691
```

0.99691

```
Sensitivityf1 = (OriginalLambda - Lambdaf1) / (0.336 - 0.3024)
```

{0.10272}

Sensitivity of F2

```
0.336 * 0.90
```

0.3024

```
mf2 = {{F0, FA, 0.3024, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[mf2, 1]
```

{0.997622 + 0. i}

```
Lambdaf2 = 0.997622
```

0.997622

```
Sensitivityf2 = (OriginalLambda - Lambdaf2) / (0.336 - 0.3024)
```

{0.0815294}

Sensitivity of F3+

```
0.336 * 0.90
```

```
0.3024
```

```
mf3  = {{F0, FA, FA, 0.3024}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[mf3, 1]
```

```
{0.989689 + 0. i}
```

```
Lambdaf3 = 0.989689
```

```
0.989689
```

```
Sensitivityf3 = (OriginalLambda - Lambdaf3) / (0.336 - 0.3024)
```

```
{0.317631}
```

Sensitivity of S0

```
0.506 * 0.90
```

```
0.4554
```

```
ms0  = {{F0, FA, FA, FA}, {0.4554, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[ms0, 1]
```

```
{0.983515}
```

```
LambdaS0 = 0.983515
```

```
0.983515
```

```
SensitivityS0 = (OriginalLambda - LambdaS0) / (0.506 - 0.4554)
```

```
{0.332933}
```

Sensitivity of S1

```
0.790 * 0.90
```

```
0.711
```

```
ms1  = {{F0, FA, FA, FA}, {SF, 0, 0, 0}, {0, 0.711, 0, 0}, {0, 0, SA, SA}};
```

```
Eigenvalues[ms1, 1]
```

```
{0.986823}
```

```
LambdaS1 = 0.986826
```

```
0.986826
```

```
SensitivityS1 = (OriginalLambda - LambdaS1) / (0.790 - 0.711)
```

```
{0.171334}
```

Sensitivity of S2

```
0.79 * 0.90
```

```
0.711
```

```
ms2 = {{F0, FA, FA, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, 0.711, SA}};
```

```
Eigenvalues[ms2, 1]
```

```
{0.989614 + 0. i}
```

```
LambdaS2 = 0.989614
```

```
0.989614
```

```
SensitivityS2 = (OriginalLambda - LambdaS2) / (0.79 - 0.711)
```

```
{0.136043}
```

Sensitivity of S3

```
0.79 * 0.90
```

```
0.711
```

```
ms3 = {{F0, FA, FA, FA}, {SF, 0, 0, 0}, {0, SA, 0, 0}, {0, 0, SA, 0.711}};
```

```
Eigenvalues[ms3, 1]
```

```
{0.964097 + 0. i}
```

```
LambdaS3 = 0.964097
```

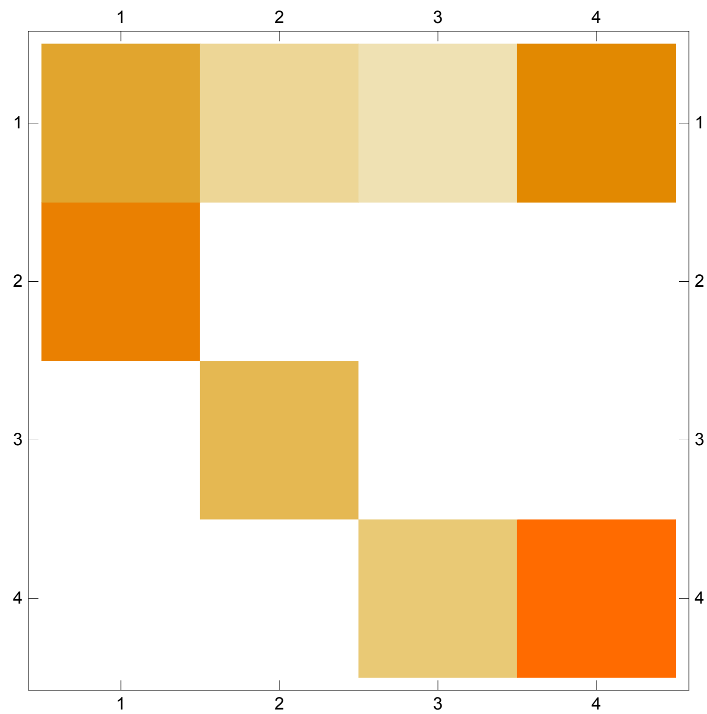
```
0.964097
```

```
SensitivityS3 = (OriginalLambda - LambdaS3) / (0.79 - 0.711)
```

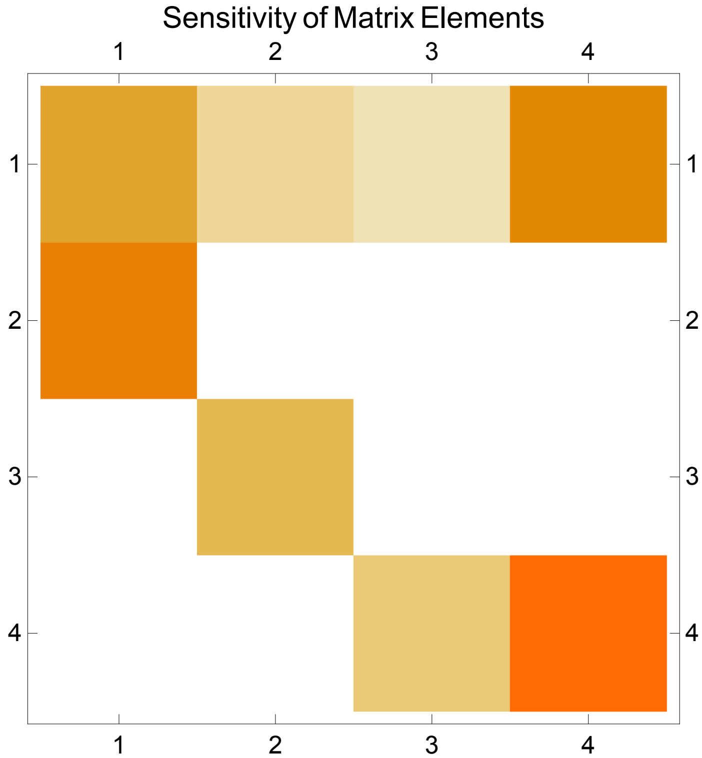
```
{0.459043}
```

Sensitivity Results, shown in matrix form

```
MatrixPlot[{{0.20779, 0.1027, 0.0815, 0.318},
  {0.3329, 0, 0, 0}, {0, 0.1713, 0, 0}, {0, 0, 0.1360, 0.4590 }}]
```



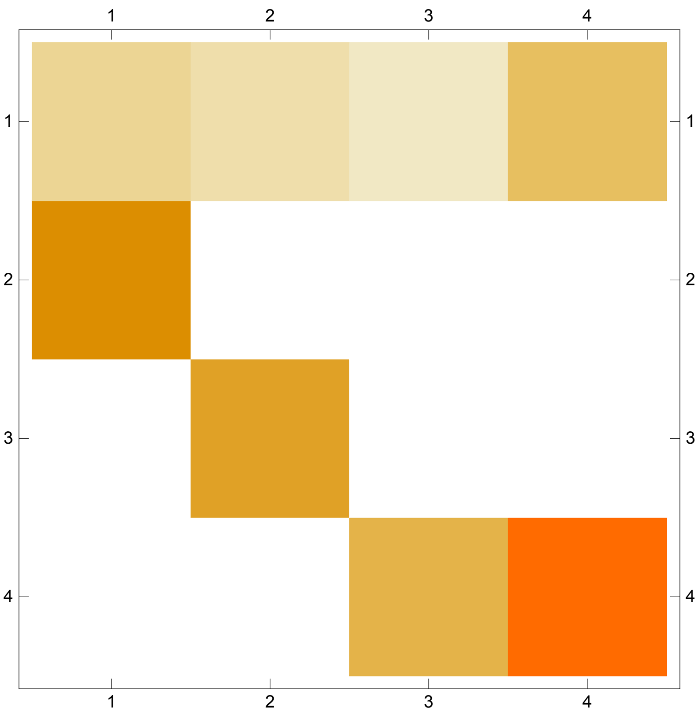
```
Show[%61, PlotLabel → HoldForm[Sensitivity of Matrix Elements],
 LabelStyle → {13, GrayLevel[0]}]
```



Elasticity matrix

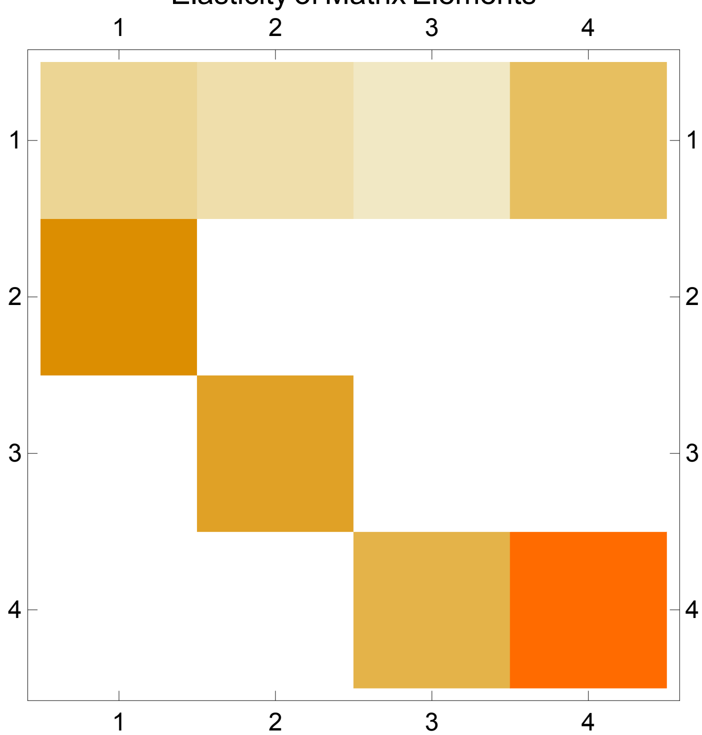
See calculations in “elasticity 01022017.xlsx” excel spreadsheet

```
MatrixPlot[{{0.040075, 0.0344875, 0.02737, 0.1066716},
  {0.16838, 0, 0, 0}, {0, 0.13529, 0, 0}, {0, 0, 0.10742, 0.3624995 }}]
```




```
Show[%17, PlotLabel → HoldForm[Elasticity of Matrix Elements],
 LabelStyle → {13, GrayLevel[0]}]
```

Elasticity of Matrix Elements



Hayes & Adams (2017) Mathematica Notebook 2

About this notebook

This document is a PDF created from a Wolfram *Mathematica* notebook file prepared by Mark A. Hayes during December, 2016, following the general approach for age structured population analysis discussed in Hayes (2011). This code and output analyzes the stable stochastic population model used in the Hayes and Adams 2017 PLOS ONE manuscript. This notebook is used to demonstrate that the stochastic population model results in an average ending population of about 2,000 females. The vital rates used in this notebook match the vital rates used in Notebook 1, which was used for sensitivity and elasticity analysis of the model. In the matrix model below, the first row of the matrix model can be confusing. This row shows (1) the probability of a bat surviving the year and then (2) giving birth to a female pup, and is thus survival for the age class times the birth rate for the age class. If you would like a copy of the original *Mathematica* notebook, please contact MAH at hayesm@usgs.gov or hayes.a.mark@gmail.com.

Mark A. Hayes
January 2, 2017

```
SetDirectory[NotebookDirectory[]]
```

```
\\IGSKBACBFS2\groups\bts\t\mah\manuscripts\2016\Hayes & Adams 2016 - Bat pop
  modeling - PLOS ONE\revision - fall winter 2016\Plos One - Data package
```

Defining the model:

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

adultBirthRate = 0.425;

aReproAve = SAave * adultBirthRate;
aReproMin = aReproAve * 0.90;
aReproMax = aReproAve * 1.10;

jReproAve = 0.90 * adultBirthRate * SFave;
jReproMin = jReproAve * 0.90;
jReproMax = jReproAve * 1.10;

m = {{jReproAve, aReproAve, aReproAve, aReproAve},
   {SFave, 0, 0, 0}, {0, SAave, 0, 0}, {0, 0, SAave, SAave}};

runs = 10 000;
j = 0;

MatrixForm[m]
Eigenvalues[m, 1]
```

$$\begin{pmatrix} 0.193392 & 0.33575 & 0.33575 & 0.33575 \\ 0.5056 & 0 & 0 & 0 \\ 0 & 0.79 & 0 & 0 \\ 0 & 0 & 0.79 & 0.79 \end{pmatrix}$$

{1.00036}

Setting up the Monte Carlo simulation:

```
MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[TriangularDistribution[{jReproMin, jReproMax}]])) +
     (Nne * (RandomReal[TriangularDistribution[{aReproMin, aReproMax}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[{aReproMin, aReproMax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{aReproMin, aReproMax}]]));
   i = i + 1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
```

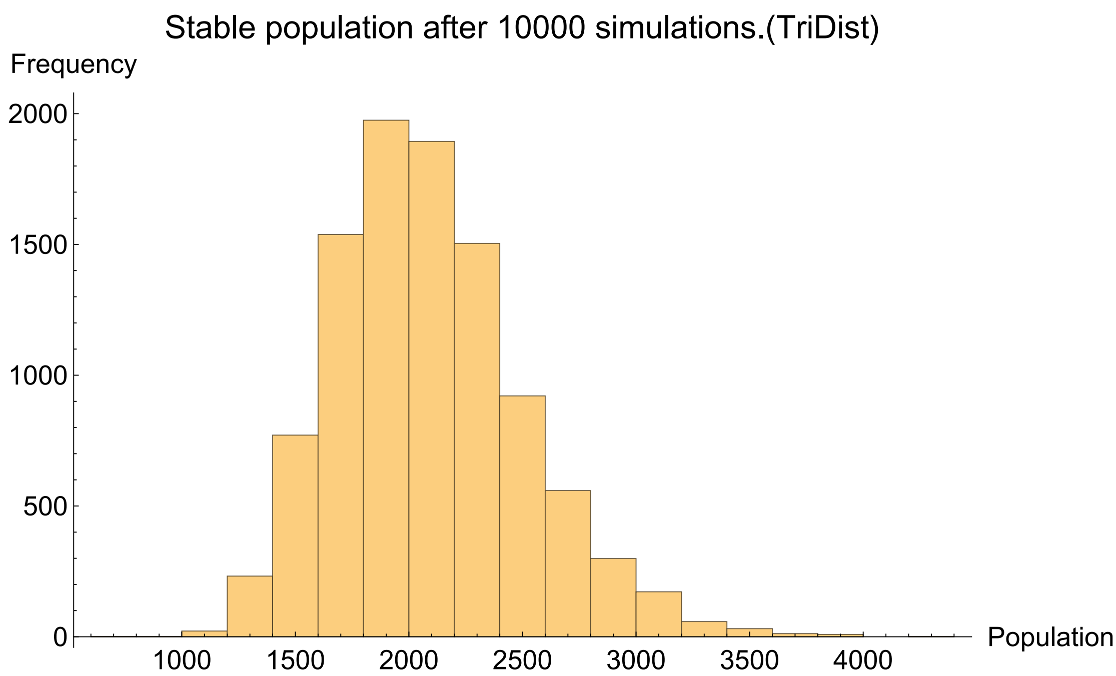
Calculating statistics and visualizing output:

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]

MatrixForm[m]
Lambda = Eigenvalues[m, 1]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize -> 14}, ImageSize → Large,
 PlotLabel → StringJoin["Stable population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
```

```
2063.92

414.594

756.

4201.
```

$$\begin{pmatrix} 0.193392 & 0.33575 & 0.33575 & 0.33575 \\ 0.5056 & 0 & 0 & 0 \\ 0 & 0.79 & 0 & 0 \\ 0 & 0 & 0.79 & 0.79 \end{pmatrix}$$

```
{1.00036}
```


Stable population after 10000 simulations.(TriDist)
Frequency
2000
1500
1000
500
0
1000
1500
2000
2500
3000
3500
4000
Population

Hayes & Adams (2017) *Mathematica* Notebook 3

Monte Carlos & Model Projections for the General Model

This document is a pdf created from a Wolfram *Mathematica* notebook file prepared by Mark A. Hayes during December 2016, following the general approach for logistic regression and Monte Carlo simulations outlined in Hayes (2011).This code and output supports the analysis described in Hayes, M. A. and R. A. Adams. 2017. Simulated bat populations collapse when exposed to conditions that mimic climate change projections for western North America. PLOS ONE. If you would like a copy of the original *Mathematica* notebook, please contact MAH at hayesm@usgs.gov or hayes.a.mark@gmail.-com.

Mark A. Hayes
January 2, 2017

Set the directory

```
SetDirectory[NotebookDirectory[]]
```

```
\\IGSKBACBFS2\groups\bts\t\mah\manuscripts\2016\Hayes & Adams 2016 - Bat pop
  modeling - PLOS ONE\revision - fall winter 2016\Plos One - Data package
```

Model projections and simulations are through the last full year average provided by the UCAR projections, which is 2086.

Average values for the triangular distribution are only added for the average repro rate. The average rate for all other vital rates will be equal to the average used in the default triangular distribution.

Deterministic repro rate = 0.85

```
DetRepro = {0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85};
```

RCP 2.6 Projections and Simulations

Model projections using RCP26 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP26 average values for years 2009-2086, using logistic regression.

```
ProbRCP26Ave =
  {0.800802411, 0.797752144, 0.803777931, 0.809706158, 0.812618484, 0.812618484,
   0.821149364, 0.823924642, 0.821149364, 0.823887791, 0.826629548, 0.829337462,
   0.832011676, 0.834652341, 0.832011676, 0.832011676, 0.839833667, 0.847358263,
   0.844882805, 0.839833667, 0.839833667, 0.84237467, 0.844849514, 0.847325408,
   0.852147944, 0.847292546, 0.847259679, 0.842273465, 0.844782915, 0.839731141,
   0.839731141, 0.842273465, 0.842273465, 0.842307206, 0.849703953, 0.847292546,
   0.842307206, 0.839731141, 0.844782915, 0.844816217, 0.849736387, 0.847325408,
   0.847325408, 0.839833667, 0.834652341, 0.839833667, 0.837259616, 0.837294222,
   0.837259616, 0.83986783, 0.834687392, 0.834687392, 0.826665946, 0.823887791,
   0.818302224, 0.821112058, 0.821112058, 0.821112058, 0.815496395, 0.815496395,
   0.809706158, 0.809706158, 0.812579805, 0.812579805, 0.815458175, 0.809667018,
   0.812541119, 0.815419948, 0.815458175, 0.815419948, 0.818264455, 0.815419948,
   0.821074745, 0.829301509, 0.832011676, 0.829337462, 0.826629548, 0.832011676};
Mean[ProbRCP26Ave]
```

0.830059

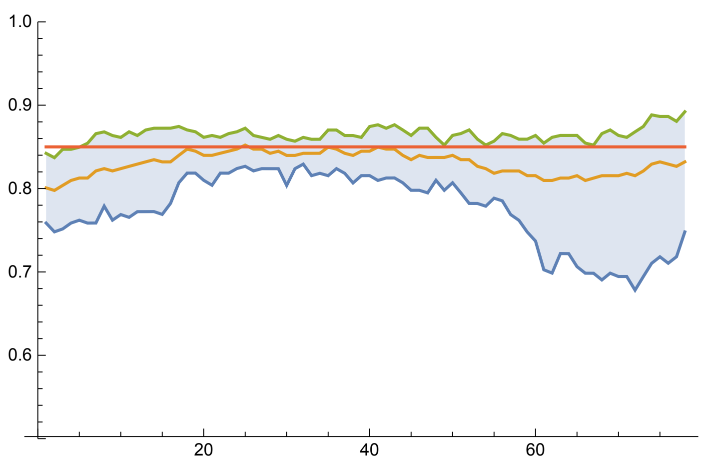
```
ProbRCP26Min = {0.758626494, 0.748076354, 0.751595161, 0.758626494, 0.762044813,
   0.75857998, 0.758673001, 0.778939335, 0.762090869, 0.768826177, 0.765475294,
   0.772277472, 0.772322139, 0.772366799, 0.769006704, 0.782239138, 0.80699681,
   0.818528708, 0.818528708, 0.809901765, 0.803978156, 0.818490976, 0.818453238,
   0.823998327, 0.826702339, 0.821186664, 0.823887791, 0.823850933,
   0.823850933, 0.803737867, 0.823850933, 0.829301509, 0.815496395,
   0.818302224, 0.815458175, 0.823887791, 0.818302224, 0.80671973, 0.815496395,
   0.815534609, 0.809745292, 0.812657158, 0.812734486, 0.806917675,
   0.79791602, 0.79791602, 0.794832878, 0.809901765, 0.79791602, 0.806917675,
   0.794832878, 0.782152592, 0.78210931, 0.778851848, 0.788435219, 0.785246361,
   0.76878103, 0.76190661, 0.747884832, 0.737027938, 0.702601106, 0.698613045,
   0.722024482, 0.721922512, 0.706347867, 0.698452579, 0.69839908, 0.690383755,
   0.698506073, 0.694486976, 0.694486976, 0.678116408, 0.694433081,
   0.710328291, 0.718141003, 0.710432807, 0.718243819, 0.747980605};
Mean[ProbRCP26Min]
```

0.773626

```
ProbRCP26Max = {0.842239719, 0.837051855, 0.847128151, 0.847095254, 0.849574156,
   0.854369478, 0.865833377, 0.867997618, 0.863609311, 0.861354281,
   0.868084901, 0.863639227, 0.870246951, 0.872350493, 0.872378774, 0.87240705,
   0.874508501, 0.870304302, 0.868113985, 0.861445256, 0.863669136,
   0.861414937, 0.865892378, 0.868113985, 0.872378774, 0.863669136,
   0.861384612, 0.8590988, 0.863639227, 0.859129544, 0.856812727, 0.861384612,
   0.8590988, 0.859129544, 0.870218267, 0.870218267, 0.863639227, 0.863609311,
   0.861354281, 0.87439696, 0.876497776, 0.872350493, 0.876525268, 0.870275629,
   0.863699041, 0.872435321, 0.872435321, 0.86147557, 0.852147944, 0.863758833,
   0.865980839, 0.870332969, 0.85922174, 0.852147944, 0.85687504, 0.865951357,
   0.86372894, 0.85922174, 0.85922174, 0.863699041, 0.854527423, 0.861445256,
   0.863699041, 0.863699041, 0.86372894, 0.854527423, 0.852115939, 0.865921871,
   0.870304302, 0.86372894, 0.861414937, 0.868055812, 0.874452741,
   0.888376199, 0.886476827, 0.886476827, 0.880635608, 0.892116135};
Mean[ProbRCP26Max]
```

0.864842

```
aReproRCP26Ave = ProbRCP26Ave;

aReproRCP26Min = ProbRCP26Min;

aReproRCP26Max = ProbRCP26Max;

ListLinePlot[{aReproRCP26Min, aReproRCP26Ave, aReproRCP26Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```



RCP2.6 Monte Carlo simulation

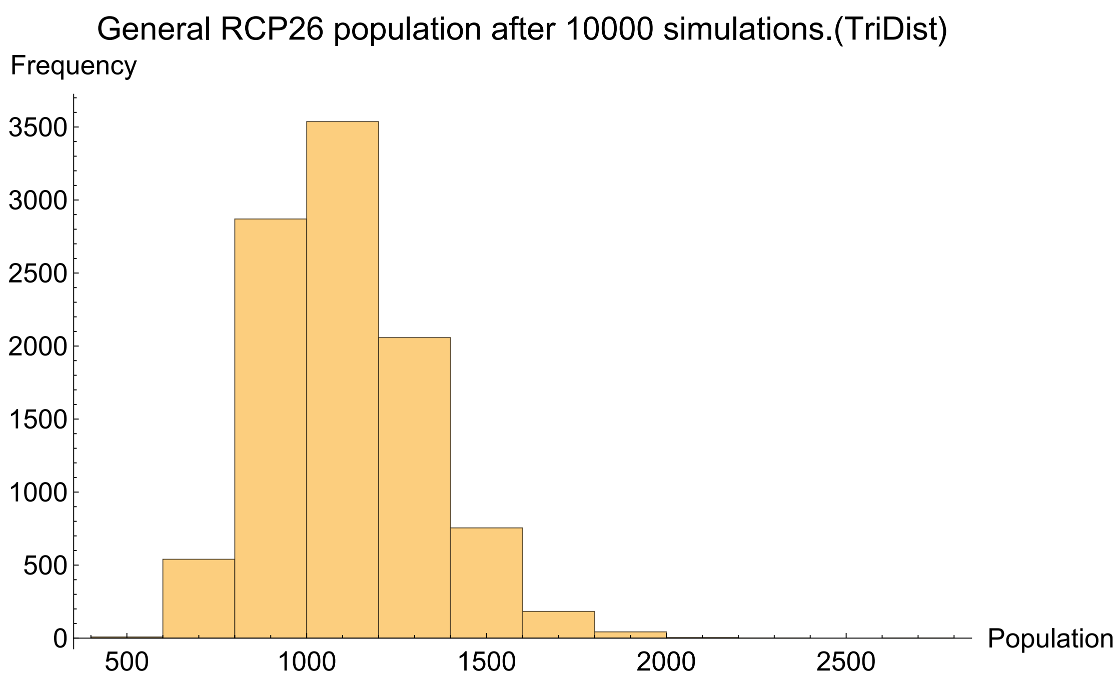
Environmental stochasticity added to reproductive rates.

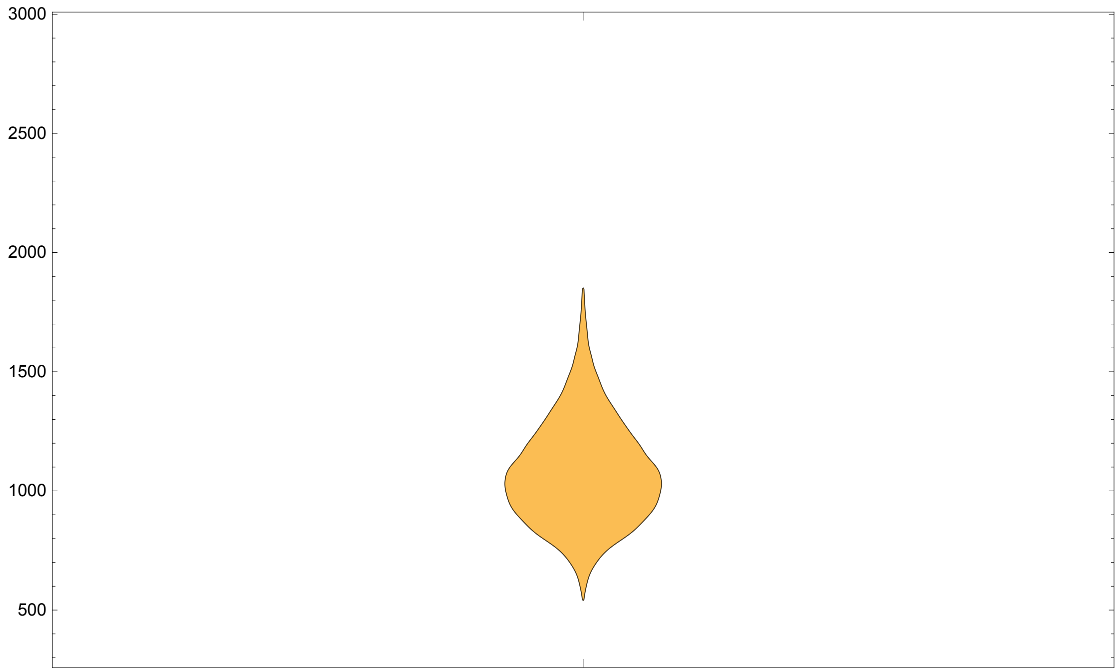
Monte Carlo RCP 26 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP26Ave / 2);
aReproMin = SAave * (aReproRCP26Min / 2);
aReproMax = SAave * (aReproRCP26Max / 2);

jReproAve = 0.90 * (aReproRCP26Ave / 2) * SFave;
jReproMin = 0.90 * (aReproRCP26Min / 2) * SFmin;
jReproMax = 0.90 * (aReproRCP26Max / 2) * SFmax;

runs = 10 000;
j = 0;

MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
   i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
    Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
      (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
    Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
    Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
    Npups = (Npups * (RandomReal[
           TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
      (Ntwo * (RandomReal[TriangularDistribution[
            {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
    i =
     i +
      1;];
   j = j + 1;
   Ntotal, {runs}]; k = 0;
```

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["General RCP26 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
1081.37

219.374

509.

2759.
```





RCP 4.5 Projections and Simulations

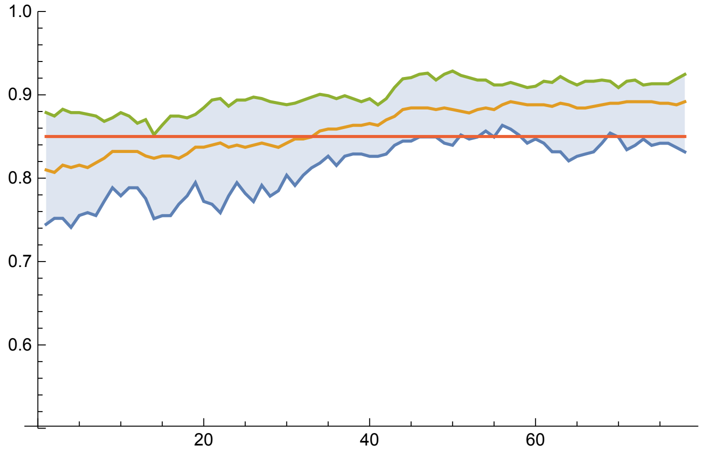
Model projections using RCP45 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP45 average values for years 2009-2086, using logistic regression.

```
ProbRCP45Ave =
  {0.809901765, 0.806917675, 0.815649216, 0.812773141, 0.81561102, 0.812734486,
   0.818415493, 0.823961488, 0.832082667, 0.832082667, 0.832082667, 0.832047175,
   0.826665946, 0.823887791, 0.826593143, 0.826593143, 0.823850933, 0.829265549,
   0.837190386, 0.837190386, 0.839731141, 0.842273465, 0.837155762, 0.839662762,
   0.837051855, 0.839628563, 0.842138444, 0.839594358, 0.836982554, 0.842104674,
   0.847062352, 0.847062352, 0.849509223, 0.856625654, 0.858944999, 0.858914222,
   0.86117218, 0.863429702, 0.863399748, 0.865597152, 0.863369788, 0.869931134,
   0.874173622, 0.882329996, 0.884289693, 0.884289693, 0.884289693, 0.882329996,
   0.884289693, 0.882329996, 0.880314841, 0.878269937, 0.882277243, 0.884237703,
   0.882277243, 0.888073589, 0.891773411, 0.889924683, 0.888048339, 0.888073589,
   0.888048339, 0.886144104, 0.889924683, 0.888023084, 0.884185694, 0.884159681,
   0.88609284, 0.887997825, 0.88987491, 0.88987491, 0.891724372, 0.891748894,
   0.891724372, 0.891724372, 0.88987491, 0.88987491, 0.887997825, 0.891724372};
```

```
ProbRCP45Min =
  {0.744669555, 0.751832194, 0.751832194, 0.740988952, 0.7553157, 0.758673001,
   0.755174845, 0.772277472, 0.788519943, 0.778851848, 0.788519943, 0.788477584,
   0.775515447, 0.751452869, 0.755033934, 0.75508091, 0.768826177, 0.778764337,
   0.794667146, 0.772143435, 0.768735877, 0.75853346, 0.778720572, 0.794584242,
   0.781806162, 0.771919917, 0.791379696, 0.778457853, 0.784903497, 0.803537456,
   0.791295814, 0.80357755, 0.812425025, 0.818113319, 0.82641103, 0.815228724,
   0.826374589, 0.829049667, 0.829013665, 0.826228765, 0.826228765, 0.828905625,
   0.839423246, 0.844482927, 0.844516282, 0.849476748, 0.849509223, 0.849444267,
   0.842037116, 0.839491709, 0.851859694, 0.846963611, 0.849379288, 0.856532041,
   0.849411781, 0.863399748, 0.858852651, 0.851827638, 0.842003328, 0.847029444,
   0.842003328, 0.831691924, 0.831656366, 0.82073866, 0.826228765, 0.828941644,
   0.831549656, 0.841935735, 0.85411647, 0.849314286, 0.834161001, 0.83935476,
   0.846897754, 0.83935476, 0.84190193, 0.84190193, 0.836774508, 0.831514074};

ProbRCP45Max = {0.87870376, 0.87456424, 0.882672389, 0.878676685, 0.878676685,
   0.876662653, 0.874592102, 0.868172136, 0.872463587, 0.878649605, 0.874536374,
   0.865921871, 0.870246951, 0.852179943, 0.86372894, 0.874508501, 0.874480624,
   0.872378774, 0.876552756, 0.884471496, 0.893787856, 0.895579315, 0.886374541,
   0.893739622, 0.893739622, 0.897273813, 0.895508034, 0.89187143, 0.889999305,
   0.888149309, 0.890024169, 0.893643094, 0.897180127, 0.900612613,
   0.898943916, 0.895412925, 0.89892084, 0.895389136, 0.891773411, 0.895365342,
   0.888048339, 0.895365342, 0.908782664, 0.919231577, 0.920631991, 0.92466565,
   0.92597943, 0.917789498, 0.924683341, 0.928543941, 0.923312498, 0.920557721,
   0.917731985, 0.917731985, 0.911845451, 0.911845451, 0.914854619, 0.911825031,
   0.908740543, 0.910305108, 0.916304537, 0.914834831, 0.921937094,
   0.916285055, 0.911804608, 0.916285055, 0.916285055, 0.917731985,
   0.916304537, 0.908698405, 0.916285055, 0.917712806, 0.911763747,
   0.913261309, 0.913261309, 0.913241186, 0.919061691, 0.92452398};

aReproRCP45Ave = ProbRCP45Ave;

aReproRCP45Min = ProbRCP45Min;

aReproRCP45Max = ProbRCP45Max;
```

```
ListLinePlot[{aReproRCP45Min, aReproRCP45Ave, aReproRCP45Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

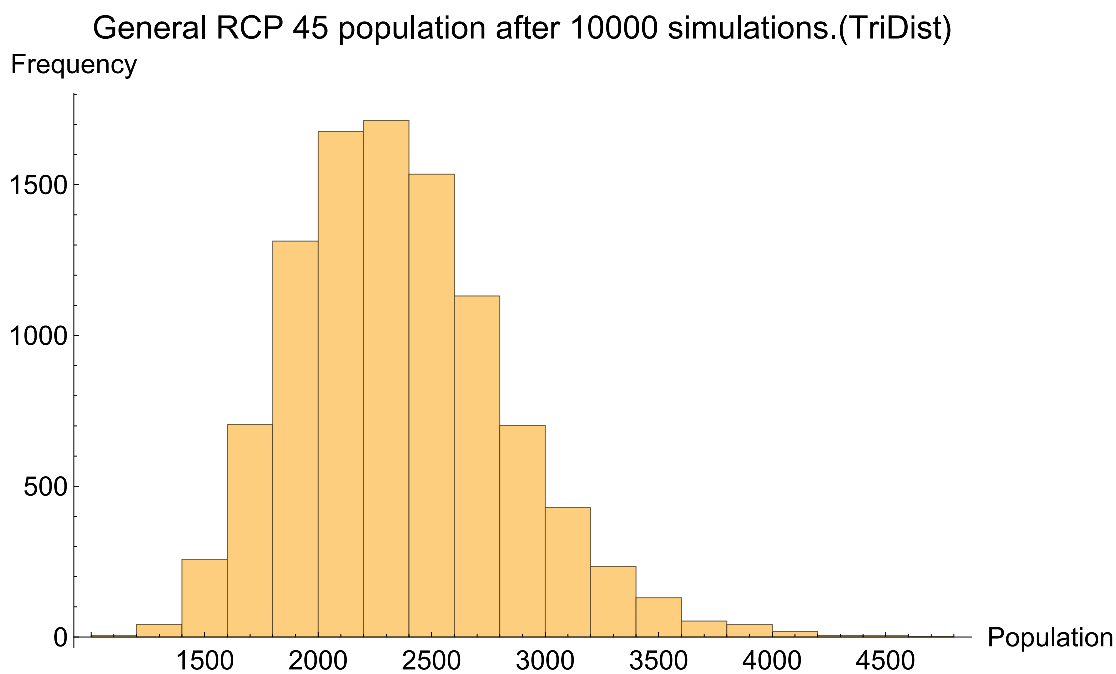


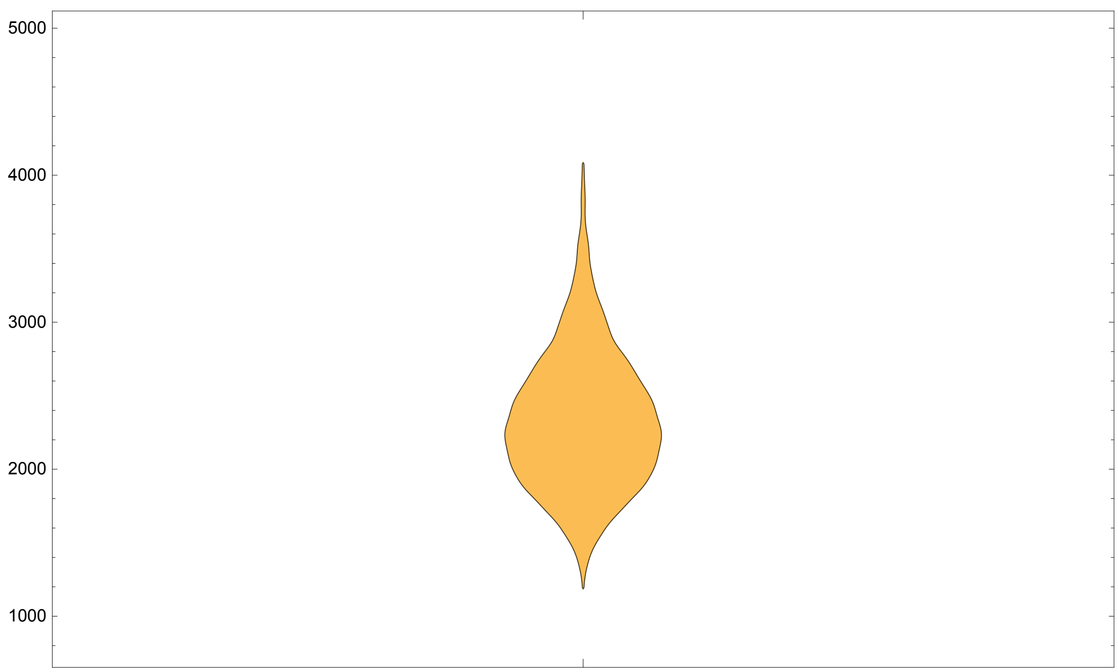
Monte Carlo RCP 45 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP45Ave / 2);
aReproMin = SAave * (aReproRCP45Min / 2);
aReproMax = SAave * (aReproRCP45Max / 2);

jReproAve = 0.90 * (aReproRCP45Ave / 2) * SFave;
jReproMin = 0.90 * (aReproRCP45Min / 2) * SFmin;
jReproMax = 0.90 * (aReproRCP45Max / 2) * SFmax;

runs = 10 000;
j = 0;
```

```
MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
           {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["General RCP 45 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
2333.06

468.773

1058.

4711.
```





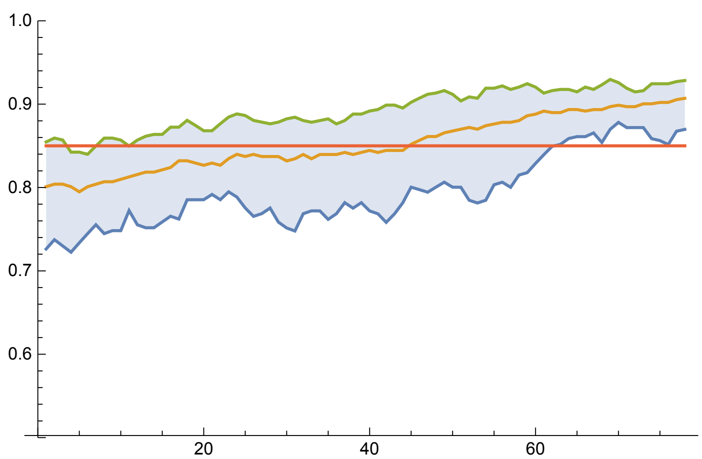
RCP 6.0

Model projections using RCP60 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP60 average values for years 2009-2086, using logistic regression.

```
ProbRCP60Ave =
  {0.801004922, 0.804018183, 0.804018183, 0.800964432, 0.794832878, 0.800923936,
   0.803978156, 0.806917675, 0.806917675, 0.809823541, 0.812734486, 0.81561102,
   0.818453238, 0.818453238, 0.821223958, 0.823998327, 0.832082667, 0.832082667,
   0.82937341, 0.826665946, 0.82937341, 0.826665946, 0.834652341, 0.839833667,
   0.837225004, 0.839765323, 0.837155762, 0.837155762, 0.837155762, 0.831905146,
   0.834512078, 0.839662762, 0.834476997, 0.839628563, 0.839628563, 0.839594358,
   0.842104674, 0.839560148, 0.842070898, 0.844549632, 0.842037116, 0.844516282,
   0.844482927, 0.844482927, 0.851827638, 0.856563251, 0.86117218, 0.86114181,
   0.865597152, 0.867793765, 0.869931134, 0.872067383, 0.869931134, 0.87414568,
   0.876195008, 0.878242779, 0.878215616, 0.880234533, 0.88609284, 0.887997825,
   0.891699846, 0.889850016, 0.88987491, 0.893522327, 0.893522327, 0.891675314,
   0.893473986, 0.893449808, 0.897015994, 0.898736058, 0.896992528, 0.896969057,
   0.900407807, 0.900407807, 0.902077404, 0.902077404, 0.905385408, 0.907001606};

ProbRCP60Min = {0.726228523, 0.737421586, 0.72994233, 0.722381194, 0.73367387,
   0.744669555, 0.75536264, 0.744669555, 0.748267779, 0.748219932, 0.772366799,
   0.755268754, 0.751737399, 0.751737399, 0.758719502, 0.765566479, 0.762136918,
   0.785332015, 0.785332015, 0.785374833, 0.791714976, 0.785374833, 0.794832878,
   0.788562296, 0.775515447, 0.765384084, 0.768690717, 0.775382761, 0.758486934,
   0.751452869, 0.747836937, 0.768645552, 0.772009343, 0.771964633,
   0.761814444, 0.76860038, 0.781849487, 0.77525002, 0.781806162, 0.771919917,
   0.768510018, 0.758161083, 0.768419631, 0.781676148, 0.800437503,
   0.797465123, 0.794376875, 0.800478073, 0.806402697, 0.800396926,
   0.800315755, 0.784731916, 0.781459334, 0.784689006, 0.80333689, 0.806323377,
   0.800234559, 0.814960752, 0.817810754, 0.828869599, 0.83935476, 0.849379288,
   0.851731435, 0.858791058, 0.861020276, 0.861020276, 0.865478908,
   0.854021498, 0.869787364, 0.878134094, 0.871868888, 0.87189726, 0.871868888,
   0.858575304, 0.856282158, 0.851538873, 0.867560464, 0.869729819};
```

```
ProbRCP60Max = {0.854685226, 0.859313886, 0.856999597, 0.84244211, 0.84244211,
   0.83986783, 0.849833657, 0.859252461, 0.859252461, 0.85693733, 0.84980124,
   0.856906188, 0.861505879, 0.86372894, 0.863669136, 0.872378774, 0.872378774,
   0.880608906, 0.874508501, 0.868084901, 0.868113985, 0.876525268,
   0.884497448, 0.888300613, 0.886374541, 0.880502046, 0.878459899,
   0.876387752, 0.87840565, 0.882382728, 0.88431568, 0.8803416, 0.87829709,
   0.880314841, 0.882329996, 0.876277645, 0.8803416, 0.888098834, 0.888048339,
   0.891773411, 0.89354649, 0.898851582, 0.898851582, 0.895341543, 0.902256752,
   0.90719425, 0.911845451, 0.913361859, 0.916304537, 0.911825031, 0.903876594,
   0.908698405, 0.907108675, 0.919137236, 0.919099472, 0.921882236,
   0.917655244, 0.920464795, 0.92452398, 0.920464795, 0.913241186, 0.916207088,
   0.917655244, 0.917655244, 0.914755639, 0.920483388, 0.917655244,
   0.923204519, 0.929662465, 0.925840033, 0.919023894, 0.91467638, 0.916129055,
   0.924488524, 0.924470791, 0.924470791, 0.927083454, 0.928375228};

aReproRCP60Ave = ProbRCP60Ave;

aReproRCP60Min = ProbRCP60Min;

aReproRCP60Max = ProbRCP60Max;

ListLinePlot[{aReproRCP60Min, aReproRCP60Ave, aReproRCP60Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

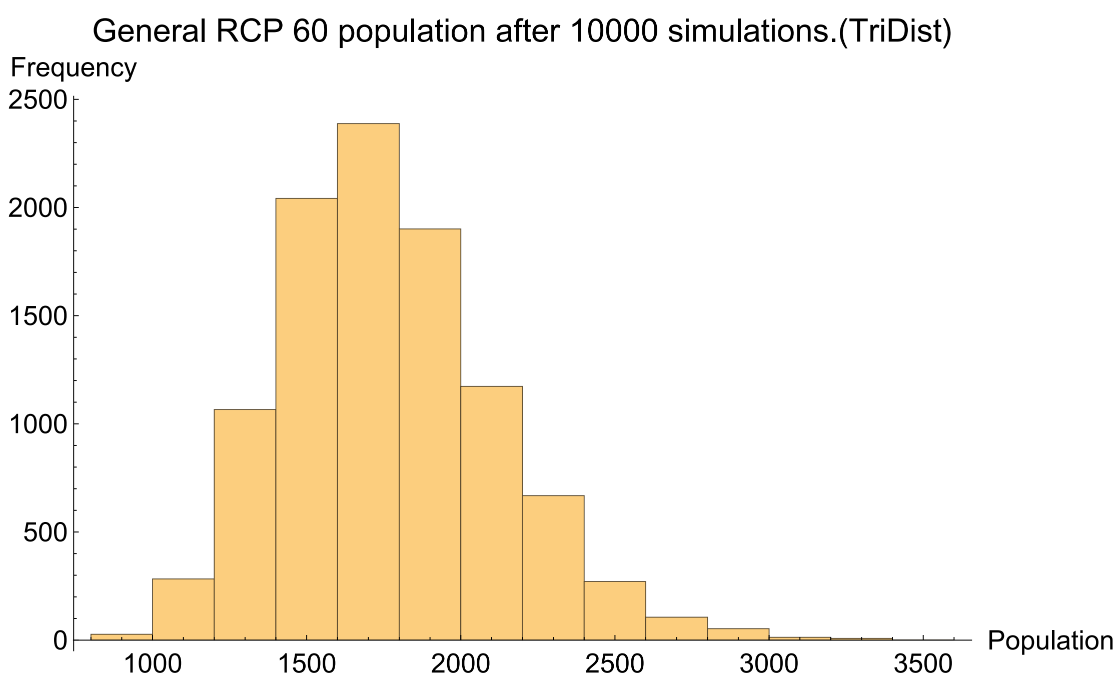


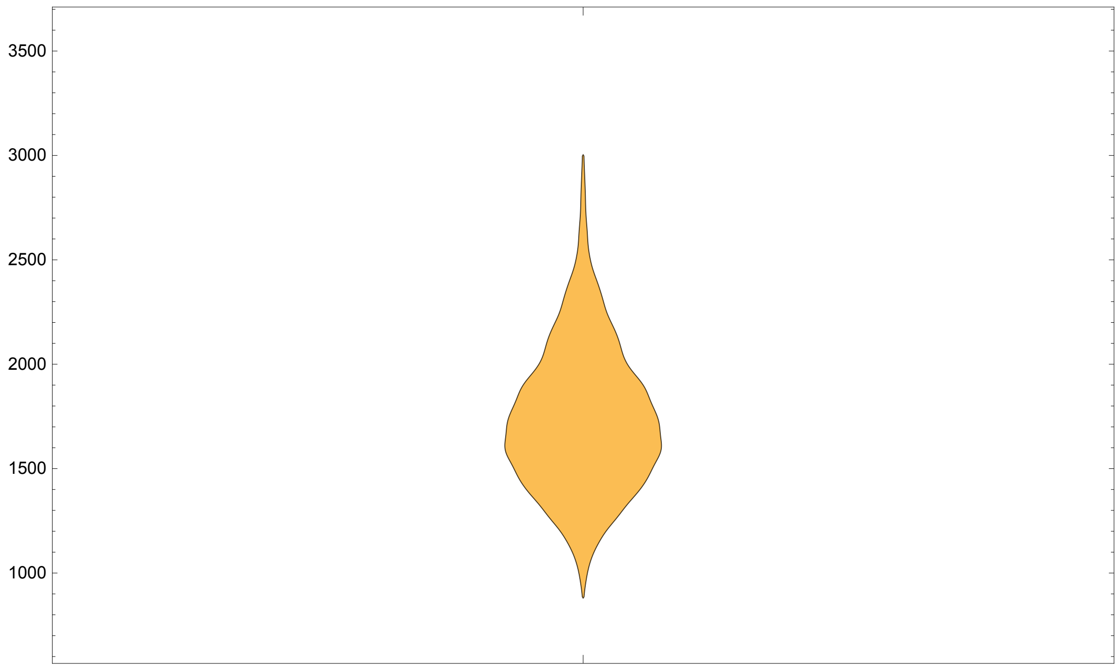
Monte Carlo RCP 60 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP60Ave / 2);
aReproMin = SAave * (aReproRCP60Min / 2);
aReproMax = SAave * (aReproRCP60Max / 2);

jReproAve = 0.90 * (aReproRCP60Ave / 2) * SFave;
jReproMin = 0.90 * (aReproRCP60Min / 2) * SFmin;
jReproMax = 0.90 * (aReproRCP60Max / 2) * SFmax;

runs = 10 000;
j = 0;

MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
           {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
```

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["General RCP 60 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
1739.14

346.884

853.

3425.
```





RCP 8.5

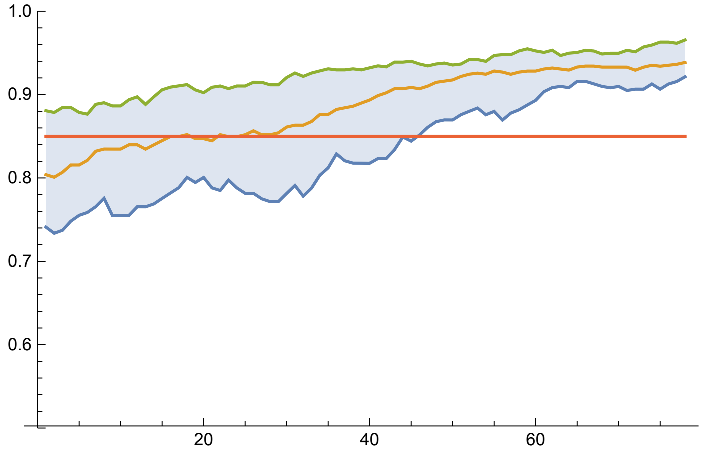
Model projections using RCP85 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP85 average values for years 2009-2086, using logistic regression.

```
ProbRCP85Ave =
  {0.803898085, 0.800842926, 0.806838516, 0.815534609, 0.815534609, 0.821149364,
   0.832047175, 0.834652341, 0.834617284, 0.834617284, 0.839765323, 0.839765323,
   0.834547152, 0.839696954, 0.844749606, 0.849639066, 0.849606614, 0.851987862,
   0.847128151, 0.847095254, 0.844582975, 0.851891745, 0.849476748, 0.849444267,
   0.851827638, 0.856532041, 0.851763508, 0.851763508, 0.85411647, 0.861050668,
   0.863309852, 0.863279876, 0.867677158, 0.876167453, 0.876139891, 0.882171676,
   0.884133664, 0.886041556, 0.889825117, 0.893473986, 0.898759172, 0.902144694,
   0.907044447, 0.907023029, 0.908592984, 0.907001606, 0.910139057, 0.91467638,
   0.916129055, 0.917559227, 0.921754096, 0.924435312, 0.925735327, 0.924399819,
   0.92825691, 0.926980365, 0.924346549, 0.926945972, 0.928189219, 0.928189219,
   0.930666513, 0.931867227, 0.930633726, 0.929379586, 0.933016902, 0.934179791,
   0.934164172, 0.932969264, 0.932953378, 0.932953378, 0.932921595, 0.929246103,
   0.932873894, 0.93520086, 0.93403909, 0.935185466, 0.936313277, 0.938528871};
```

```
ProbRCP85Min = {0.741037698, 0.73367387, 0.737274012, 0.748172079, 0.755174845,
   0.758626494, 0.765520889, 0.775603873, 0.75512788, 0.75508091, 0.75508091,
   0.765429692, 0.765384084, 0.768826177, 0.775426996, 0.781892807, 0.788265695,
   0.800640292, 0.794542781, 0.800599746, 0.788096072, 0.784946377, 0.797465123,
   0.788053651, 0.781589441, 0.781546078, 0.774984371, 0.771606731,
   0.771517194, 0.781415952, 0.791002031, 0.778107214, 0.787798993, 0.80325662,
   0.812076411, 0.828833568, 0.820589131, 0.817735052, 0.817697192,
   0.817621453, 0.823223426, 0.823186459, 0.833950069, 0.849086597,
   0.844149053, 0.85147464, 0.860776939, 0.867443683, 0.869614663, 0.869557053,
   0.87586399, 0.879939672, 0.883847135, 0.875808747, 0.879832294, 0.869384092,
   0.877753038, 0.881748588, 0.887516942, 0.893086563, 0.903478628,
   0.908318377, 0.909847802, 0.908276064, 0.915874992, 0.915874992,
   0.912878254, 0.909785279, 0.908170205, 0.90976443, 0.904927494, 0.906507662,
   0.906486133, 0.91271651, 0.9064646, 0.912696273, 0.915639852, 0.921331711};

ProbRCP85Max = {0.880608906, 0.878568333, 0.884523394, 0.884549336, 0.878595429,
   0.876525268, 0.888325813, 0.890198082, 0.88640012, 0.88640012, 0.893811966,
   0.897344028, 0.888250198, 0.897344028, 0.905754652, 0.908929947, 0.910450175,
   0.911947484, 0.905602767, 0.902279149, 0.908761606, 0.910305108, 0.907151472,
   0.910305108, 0.910284366, 0.914795243, 0.91473583, 0.911743311, 0.91172287,
   0.920464795, 0.925857471, 0.921827342, 0.925840033, 0.928409, 0.930879276,
   0.92962924, 0.92962924, 0.930862931, 0.929645854, 0.932092654, 0.934444799,
   0.933254621, 0.938937902, 0.938923338, 0.939990281, 0.936705945, 0.934413673,
   0.936690884, 0.937794242, 0.935508029, 0.936645682, 0.94203041, 0.942016538,
   0.939889908, 0.946970622, 0.947904787, 0.947892243, 0.952381212,
   0.954891327, 0.952369692, 0.950602867, 0.953190785, 0.946868487,
   0.949653831, 0.950555137, 0.953156775, 0.952288974, 0.948687546,
   0.949593076, 0.949605232, 0.953100038, 0.951358922, 0.957150227,
   0.959429553, 0.962954383, 0.962945321, 0.961554959, 0.965531671};

aReproRCP85Ave = ProbRCP85Ave;

aReproRCP85Min = ProbRCP85Min;

aReproRCP85Max = ProbRCP85Max;
```

```
ListLinePlot[{aReproRCP85Min, aReproRCP85Ave, aReproRCP85Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

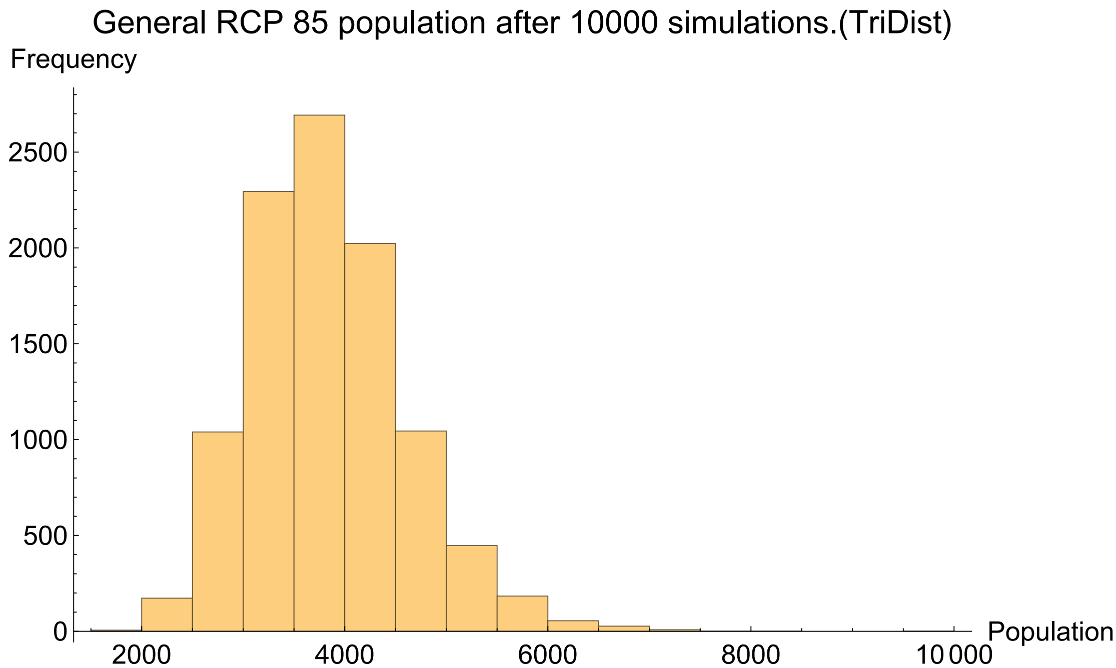


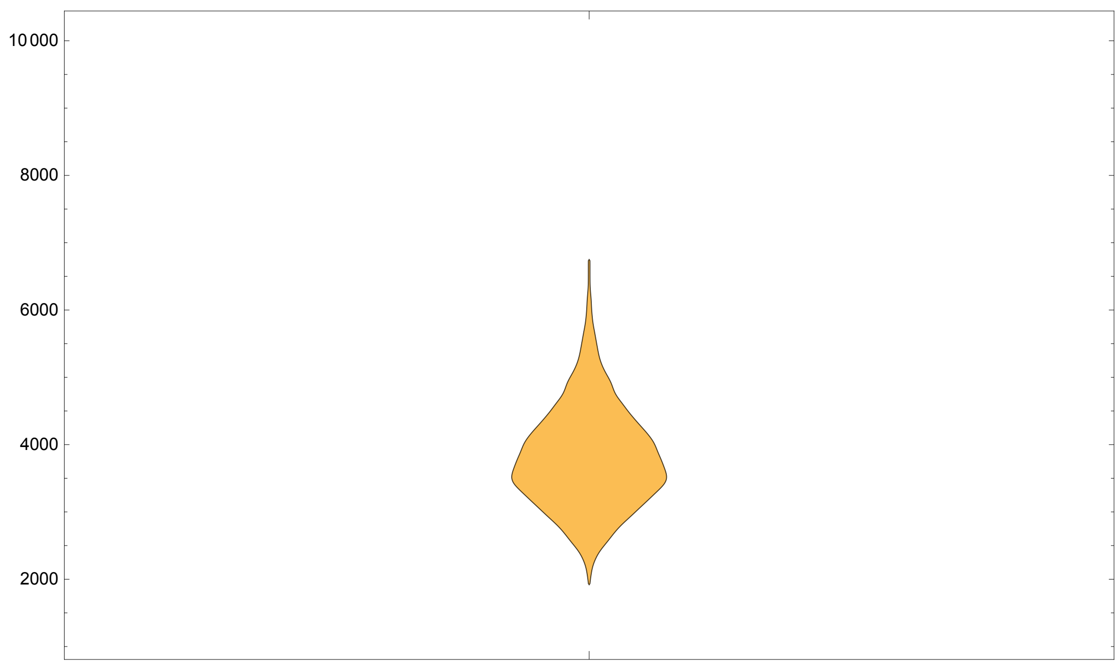
Monte Carlo RCP 85 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP85Ave / 2);
aReproMin = SAave * (aReproRCP85Min / 2);
aReproMax = SAave * (aReproRCP85Max / 2);

jReproAve = 0.90 * (aReproRCP85Ave / 2) * SFave;
jReproMin = 0.90 * (aReproRCP85Min / 2) * SFmin;
jReproMax = 0.90 * (aReproRCP85Max / 2) * SFmax;

runs = 10 000;
j = 0;
```

```
MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
           {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["General RCP 85 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
3813.23

760.83

1684.

9567.
```


General RCP 85 population after 10000 simulations.(TriDist)
Frequency
2500
2000
1500
1000
500
0
2000
4000
6000
8000
10 000
Population


10 000
8000
6000
4000
2000

Hayes & Adams (2017) *Mathematica* Notebook 4

Monte Carlos & Model Projections for the MYTH Model

This document is a pdf created from a Wolfram *Mathematica* notebook prepared by Mark A. Hayes during December 2016, following the general approach for logistic regression and Monte Carlo simulations outlined in Hayes (2011). This code and output supports the analysis described in Hayes, M. A. and R. A. Adams. 2017. Simulated bat populations collapse when exposed to conditions that mimic climate change projections for western North America. PLOS ONE. If you would like a copy of the original *Mathematica* notebook, please contact MAH at hayesm@usgs.gov or hayes.a.mark@gmail.com.

Mark A. Hayes
January 2, 2017

Set the directory

```
SetDirectory[NotebookDirectory[]]
```

```
\\IGSKBACBFS2\groups\bts\t\mah\manuscripts\2016\Hayes & Adams 2016 - Bat pop
  modeling - PLOS ONE\revision - fall winter 2016\Plos One - Data package
```

Deterministic repro rate = 0.85

```
DetRepro = {0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85,
   0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85, 0.85};
```

RCP 2.6 Projections and Simulations

Model projections using RCP26 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP26 average values for years 2009-2086, using logistic regressiion.

```
ProbRCP26Ave =
  {0.825683368, 0.824206052, 0.823650142, 0.826602317, 0.828063697, 0.828063697,
   0.83238927, 0.833811684, 0.83238927, 0.830418197, 0.831853959, 0.833280005,
   0.834696361, 0.836103051, 0.834696361, 0.834696361, 0.838887536, 0.842992436,
   0.841633676, 0.838887536, 0.838887536, 0.840265386, 0.838368949, 0.839750386,
   0.839234043, 0.836454379, 0.833104053, 0.830239839, 0.831676805, 0.828793131,
   0.828793131, 0.830239839, 0.830239839, 0.833636181, 0.834521606, 0.836454379,
   0.833636181, 0.828793131, 0.831676805, 0.835050109, 0.837849014, 0.839750386,
   0.839750386, 0.838887536, 0.836103051, 0.838887536, 0.8375001, 0.840779044,
   0.8375001, 0.842143761, 0.839404779, 0.839404779, 0.835224416, 0.830418197,
   0.827517432, 0.828972696, 0.828972696, 0.828972696, 0.8295153, 0.8295153,
   0.826602317, 0.826602317, 0.824577531, 0.824577531, 0.826052385, 0.823092851,
   0.821035958, 0.822534178, 0.826052385, 0.822534178, 0.824022545, 0.822534178,
   0.825501077, 0.829877876, 0.834696361, 0.833280005, 0.831853959, 0.834696361};
Mean[ProbRCP26Ave]
```

```
0.832308
```

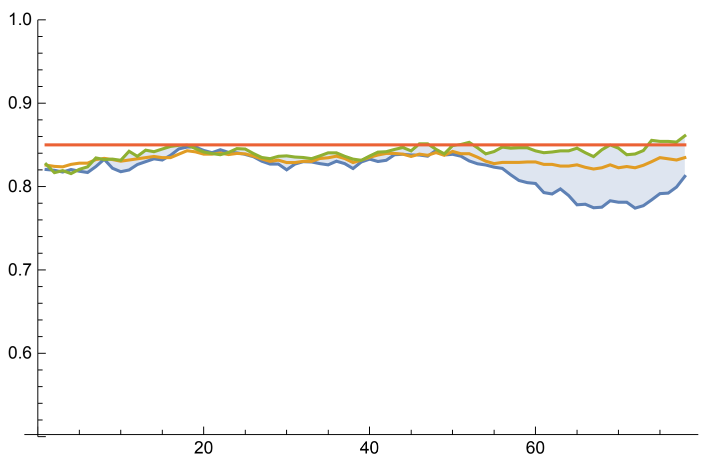
```
ProbRCP26Min = {0.820467198, 0.819522835, 0.81743364, 0.820467198, 0.818386512,
   0.816861072, 0.824017615, 0.832742231, 0.821969148, 0.817816267, 0.819902048,
   0.826415907, 0.829873076, 0.833275282, 0.831849203, 0.837495473,
   0.845176275, 0.847339637, 0.847339637, 0.843327271, 0.840604937,
   0.844170759, 0.84094845, 0.840435234, 0.838540426, 0.835751116, 0.830418197,
   0.826969796, 0.826969796, 0.82009393, 0.826969796, 0.829877876, 0.8295153,
   0.827517432, 0.826052385, 0.830418197, 0.827517432, 0.821598323, 0.8295153,
   0.83292322, 0.830056536, 0.831494739, 0.838192713, 0.838711757, 0.837844395,
   0.837844395, 0.836449728, 0.843327271, 0.837844395, 0.838711757,
   0.836449728, 0.830774464, 0.827331801, 0.825865509, 0.823277119,
   0.821783811, 0.814168954, 0.80730268, 0.804702719, 0.803695273, 0.792781524,
   0.791095916, 0.797159043, 0.789189692, 0.778135873, 0.778796726,
   0.774583559, 0.775251937, 0.782953213, 0.781209721, 0.781209721, 0.77413521,
   0.777029354, 0.784038504, 0.791519664, 0.7921513, 0.79942332, 0.812225159};
Mean[ProbRCP26Min]
```

```
0.819451
```

```
ProbRCP26Max = {0.826788568, 0.816676694, 0.819153073, 0.815526486, 0.820663613,
   0.82365508, 0.834346704, 0.832394014, 0.832927952, 0.831499503, 0.842316503,
   0.836281118, 0.843670493, 0.841806871, 0.845014995, 0.848169792, 0.849482502,
   0.849971813, 0.845516188, 0.841464862, 0.839579947, 0.838197324,
   0.840952998, 0.845516188, 0.845014995, 0.839579947, 0.834875655,
   0.833460529, 0.836281118, 0.836805101, 0.83540325, 0.834875655, 0.833460529,
   0.836805101, 0.840439794, 0.840439794, 0.836281118, 0.832927952,
   0.831499503, 0.836632139, 0.841295903, 0.841806871, 0.844512474,
   0.846847698, 0.8428248, 0.851271675, 0.851271675, 0.844678642, 0.839234043,
   0.849154114, 0.850459814, 0.85304326, 0.8465146, 0.839234043, 0.841975389,
   0.847344035, 0.846016056, 0.8465146, 0.8465146, 0.8428248, 0.840609492,
   0.841464862, 0.8428248, 0.8428248, 0.846016056, 0.840609492, 0.835929491,
   0.844175232, 0.849971813, 0.846016056, 0.838197324, 0.839063161,
   0.843164422, 0.85543316, 0.854163438, 0.854163438, 0.853364643, 0.86087997};
Mean[ProbRCP26Max]
```

0.840879

```
aReproRCP26Ave = ProbRCP26Ave;

aReproRCP26Min = ProbRCP26Min;

aReproRCP26Max = ProbRCP26Max;

ListLinePlot[{aReproRCP26Min, aReproRCP26Ave, aReproRCP26Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

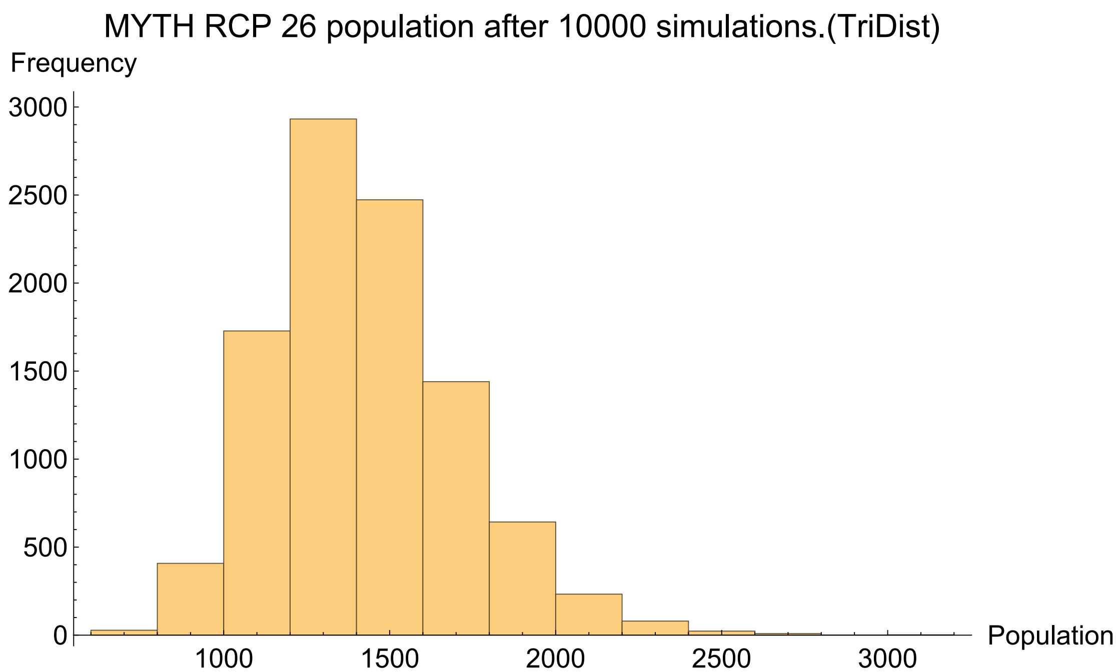


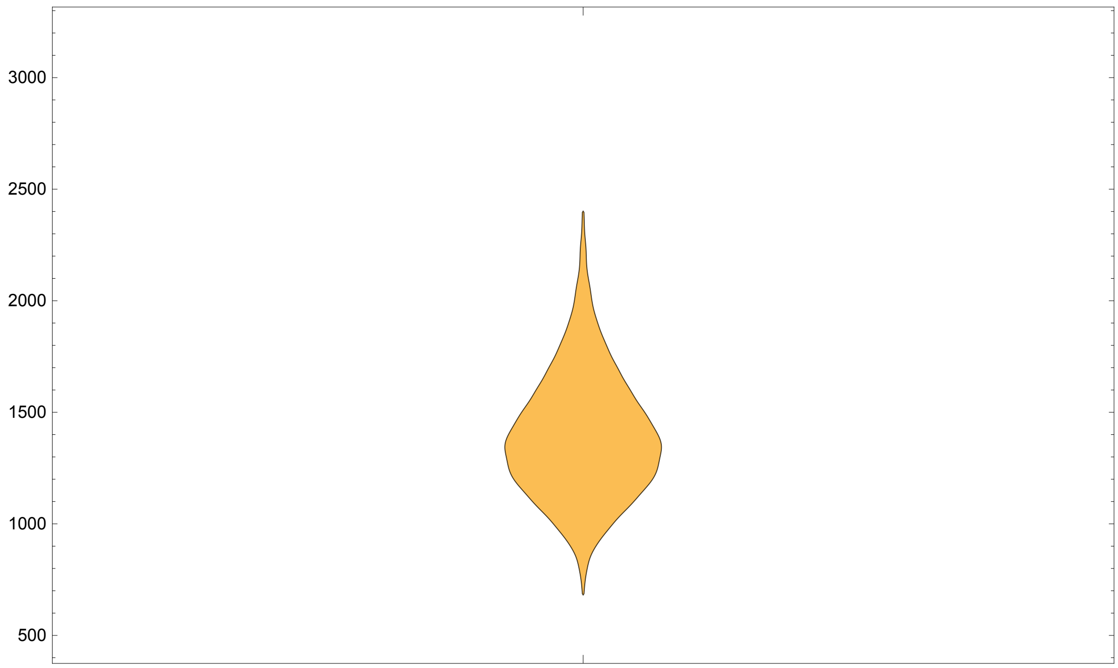
Monte Carlo RCP 26 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP26Ave / 2);
aReproMin = aReproAve * 0.90;
aReproMax = aReproAve * 1.10;

jReproAve = 0.90 * (aReproRCP26Ave / 2) * SFave;
jReproMin = 0.90 * jReproAve;
jReproMax = 1.10 * jReproAve;

runs = 10 000;
j = 0;

MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
          {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
```

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["MYTH RCP 26 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
1399.05

284.24

642.

3049.
```





RCP 4.5 Projections and Simulations

Model projections using RCP45 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP45 average values for years 2009-2086, using logistic regression.

```
ProbRCP45Ave =
  {0.843327271, 0.838711757, 0.842820296, 0.841460327, 0.839575368, 0.838192713,
   0.837672321, 0.837150582, 0.841291363, 0.841291363, 0.841291363, 0.838020937,
   0.835224416, 0.830418197, 0.828428721, 0.828428721, 0.826969796, 0.826420785,
   0.830779244, 0.830779244, 0.828793131, 0.830239839, 0.827336658, 0.821788791,
   0.816676694, 0.818203328, 0.816102286, 0.814562007, 0.809290715, 0.81242853,
   0.811843878, 0.811843878, 0.813401563, 0.814370701, 0.81591221, 0.81223553,
   0.810081527, 0.811650416, 0.807908657, 0.80571689, 0.804110504, 0.805116336,
   0.808306566, 0.818208386, 0.81972508, 0.81972508, 0.81972508, 0.818208386,
   0.81972508, 0.818208386, 0.813016952, 0.807712107, 0.810869826, 0.812433711,
   0.810869826, 0.815531601, 0.814954418, 0.813406723, 0.811849072, 0.815531601,
   0.811849072, 0.81028145, 0.813406723, 0.808110326, 0.804917619, 0.801074887,
   0.802700058, 0.804315195, 0.805920307, 0.805920307, 0.807515404, 0.811263034,
   0.807515404, 0.807515404, 0.805920307, 0.805920307, 0.804315195, 0.807515404};
Mean[ProbRCP45Ave]
```

```
0.818357
```

```
ProbRCP45Min = {0.832026212, 0.83486628, 0.83486628, 0.827146012, 0.832918489,
   0.824017615, 0.822529215, 0.826415907, 0.830235047, 0.825865509, 0.830235047,
   0.826783698, 0.820844861, 0.806305418, 0.81164002, 0.81532571, 0.817816267,
   0.818767586, 0.822718903, 0.815711759, 0.810465545, 0.813199004, 0.815135013,
   0.815521371, 0.801674016, 0.796749319, 0.806508367, 0.792156898, 0.791525275,
   0.801472654, 0.798813634, 0.805309569, 0.810076296, 0.809486032,
   0.810470768, 0.804105149, 0.806711154, 0.80450903, 0.800660243, 0.791107153,
   0.791107153, 0.788773802, 0.79551092, 0.798819099, 0.802694674, 0.809686435,
   0.813401563, 0.805914989, 0.80491228, 0.803300866, 0.807510119, 0.800458108,
   0.798202564, 0.803100751, 0.802087073, 0.807908657, 0.804713405,
   0.803706001, 0.801069469, 0.808105054, 0.801069469, 0.802287965,
   0.798406408, 0.79173971, 0.791107153, 0.792792694, 0.786421422, 0.793213901,
   0.793634474, 0.790263425, 0.784050018, 0.787494079, 0.792584648,
   0.787494079, 0.789201005, 0.789201005, 0.785777083, 0.782312887};
Mean[ProbRCP45Min]
```

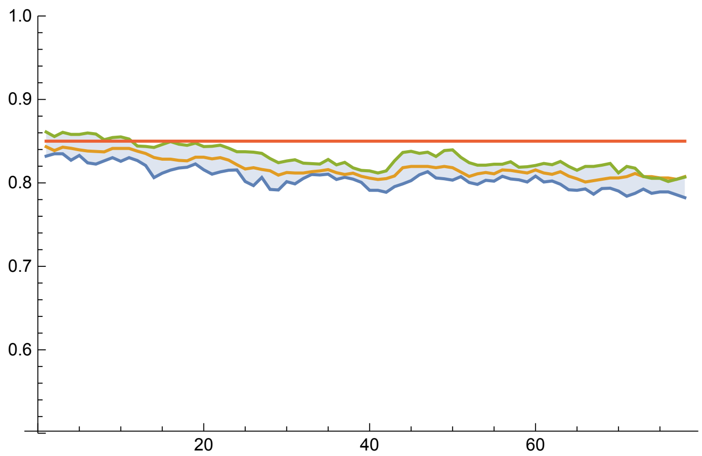
0.805804

```
ProbRCP45Max = {0.861031524, 0.855589652, 0.860572367, 0.858099262, 0.858099262,
   0.859802914, 0.858565225, 0.851756185, 0.854321071, 0.85511554, 0.852562228,
   0.844175232, 0.843670493, 0.84248458, 0.846016056, 0.849482502, 0.846350039,
   0.845014995, 0.847675657, 0.843503446, 0.843841874, 0.845185172, 0.841638208,
   0.837332363, 0.837332363, 0.836809744, 0.835407925, 0.829161743, 0.824215904,
   0.826243984, 0.827707754, 0.823660018, 0.823102752, 0.822544104, 0.828073378,
   0.82160829, 0.824587367, 0.818020001, 0.814954418, 0.814375841, 0.811849072,
   0.814375841, 0.826430539, 0.836463681, 0.837858253, 0.8354126, 0.836814387,
   0.831686324, 0.838725555, 0.839589106, 0.830610757, 0.82422083, 0.821236878,
   0.821236878, 0.822359237, 0.822359237, 0.825328439, 0.818782721,
   0.819350609, 0.820859861, 0.823291959, 0.821798749, 0.825698049,
   0.819730105, 0.815150383, 0.819730105, 0.819730105, 0.821236878,
   0.823291959, 0.812047566, 0.819730105, 0.817642775, 0.807717388,
   0.805523963, 0.805523963, 0.801690233, 0.804320546, 0.806924375};
Mean[ProbRCP45Max]
```

0.830975

```
aReproRCP45Ave = ProbRCP45Ave;

aReproRCP45Min = ProbRCP45Min;

aReproRCP45Max = ProbRCP45Max;
```

```
ListLinePlot[{aReproRCP45Min, aReproRCP45Ave, aReproRCP45Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

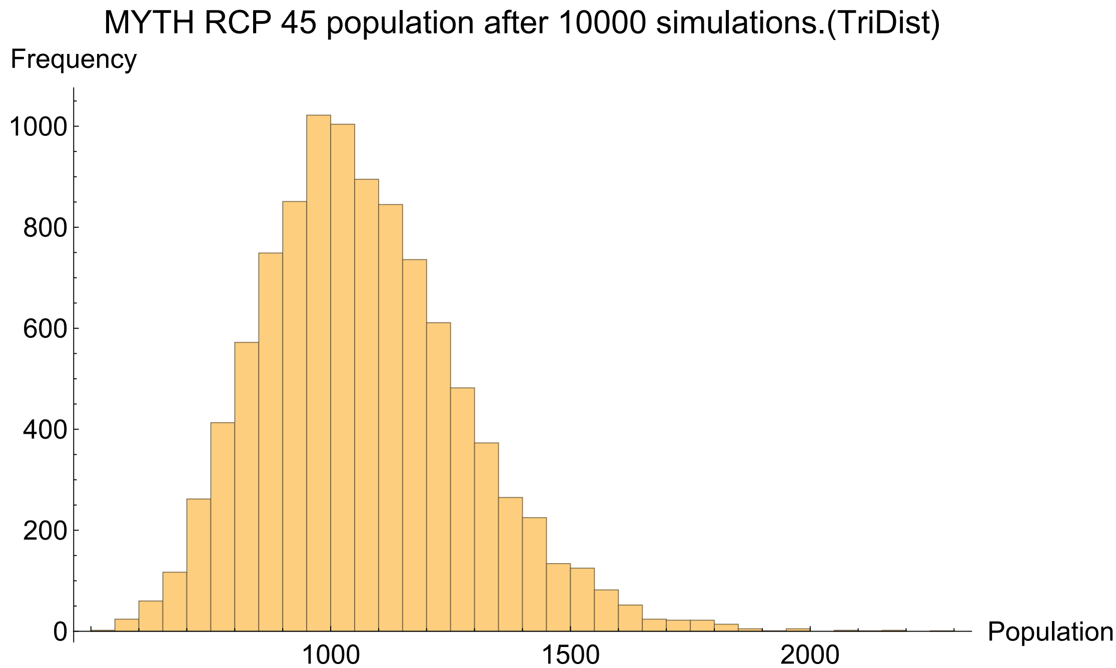


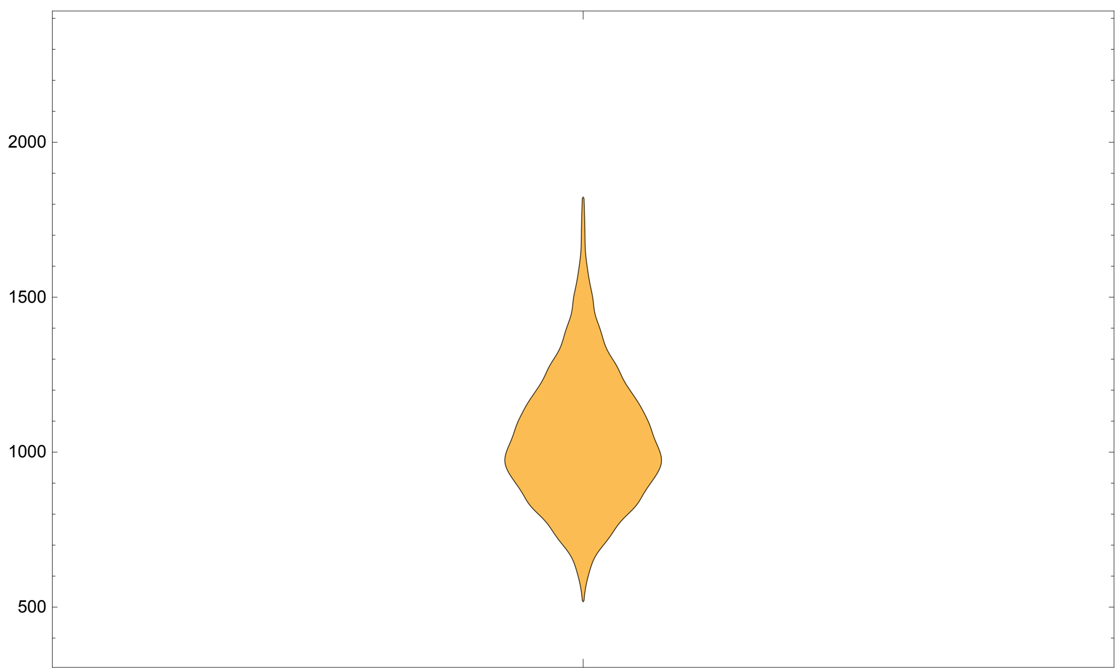
Monte Carlo RCP 45 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP45Ave / 2);
aReproMin = aReproAve * 0.90;
aReproMax = aReproAve * 1.10;

jReproAve = 0.90 * (aReproRCP45Ave / 2) * SFave;
jReproMin = 0.90 * jReproAve;
jReproMax = 1.10 * jReproAve;

runs = 10 000;
j = 0;
```

```
MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
           {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["MYTH RCP 45 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
1043.14

212.954

498.

2231.
```





RCP 6.0

Model projections using RCP60 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP60 average values for years 2009-2086, using logistic regression:

Average RCP60 values for years 2009-2086 (from 1995, substract 15):

```
ProbRCP60Ave =
  {0.842480068, 0.843832913, 0.843832913, 0.839229456, 0.836449728, 0.835924828,
   0.840604937, 0.838711757, 0.838711757, 0.836800457, 0.838192713, 0.839575368,
   0.84094845, 0.84094845, 0.83905857, 0.840435234, 0.841291363, 0.841291363,
   0.836627492, 0.835224416, 0.836627492, 0.835224416, 0.836103051, 0.838887536,
   0.83416695, 0.832212567, 0.827336658, 0.827336658, 0.827336658, 0.82439433,
   0.822349303, 0.821788791, 0.818772631, 0.818203328, 0.818203328, 0.814562007,
   0.81242853, 0.810864611, 0.808698585, 0.806513673, 0.80491228, 0.802694674,
   0.798819099, 0.798819099, 0.803706001, 0.80691378, 0.810081527, 0.806316037,
   0.80571689, 0.807313258, 0.805116336, 0.806716456, 0.805116336, 0.804514377,
   0.802293358, 0.803911011, 0.800053377, 0.801684827, 0.802700058, 0.804315195,
   0.803711365, 0.80209247, 0.805920307, 0.805320231, 0.805320231, 0.79985078,
   0.797590107, 0.793640042, 0.796970763, 0.79468591, 0.793011748, 0.788995973,
   0.78835731, 0.78835731, 0.786001551, 0.786001551, 0.789422848, 0.791118391};
Mean[ProbRCP60Ave]
```

0.816157

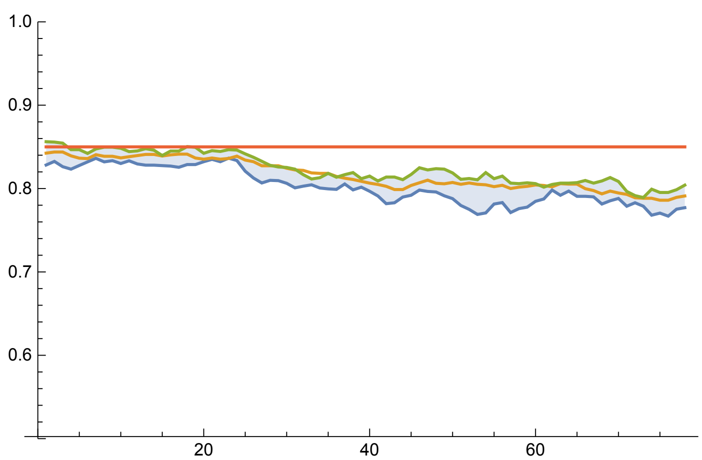
```
ProbRCP60Min = {0.828239031, 0.832561086, 0.82622934, 0.823272172, 0.827693208,
   0.832026212, 0.836271808, 0.832026212, 0.83345109, 0.83005174, 0.833275282,
   0.829510492, 0.828058856, 0.828058856, 0.82751258, 0.82696493, 0.82549618,
   0.828788307, 0.828788307, 0.83220782, 0.835045426, 0.83220782, 0.836449728,
   0.833631465, 0.820844861, 0.8126162, 0.806705853, 0.809876207, 0.809480788,
   0.806305418, 0.800856801, 0.80288972, 0.804503682, 0.800654816, 0.799631688,
   0.799017017, 0.805507984, 0.798400935, 0.801674016, 0.796749319, 0.791101535,
   0.781869783, 0.78295899, 0.789832157, 0.791948381, 0.798197087, 0.796544226,
   0.795922501, 0.791316291, 0.787917493, 0.779685403, 0.775037205, 0.768961049,
   0.770773507, 0.781437644, 0.783179824, 0.771226558, 0.775930729,
   0.777704318, 0.784698129, 0.787494079, 0.798202564, 0.791953983,
   0.796965261, 0.790688415, 0.790688415, 0.790053512, 0.781443451,
   0.785350559, 0.788140324, 0.778814297, 0.782970546, 0.778814297,
   0.768060154, 0.770555763, 0.766918436, 0.775269708, 0.777047026};
Mean[ProbRCP60Min]
```

0.802298

```
ProbRCP60Max = {0.8562184, 0.855746004, 0.854478562, 0.846679016, 0.846679016,
   0.842143761, 0.847507723, 0.849644304, 0.849644304, 0.848332753, 0.844341693,
   0.845180724, 0.847839053, 0.846016056, 0.839579947, 0.845014995, 0.845014995,
   0.850298735, 0.849482502, 0.842316503, 0.845516188, 0.844512474, 0.84668343,
   0.846185334, 0.841638208, 0.837504728, 0.832751702, 0.827888221, 0.825875288,
   0.825323538, 0.823287012, 0.816681784, 0.811456801, 0.813016952, 0.818208386,
   0.813598795, 0.816681784, 0.819158109, 0.811849072, 0.814954418, 0.809100496,
   0.813795868, 0.813795868, 0.810675596, 0.816876331, 0.824958212, 0.822359237,
   0.823848756, 0.823291959, 0.818782721, 0.811069113, 0.812047566,
   0.810481213, 0.819163146, 0.811854265, 0.814959545, 0.806524284,
   0.805925625, 0.806924375, 0.805925625, 0.801690233, 0.804922958,
   0.806524284, 0.806524284, 0.807121538, 0.809696913, 0.806524284,
   0.809105748, 0.813219662, 0.80851318, 0.796560756, 0.791542106, 0.789212318,
   0.799242068, 0.795315968, 0.795315968, 0.798626502, 0.804121215};
Mean[ProbRCP45Max]
```

```
0.830975
```

```
aReproRCP60Ave = ProbRCP60Ave;

aReproRCP60Min = ProbRCP60Min;

aReproRCP60Max = ProbRCP60Max;

ListLinePlot[{aReproRCP60Min, aReproRCP60Ave, aReproRCP60Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

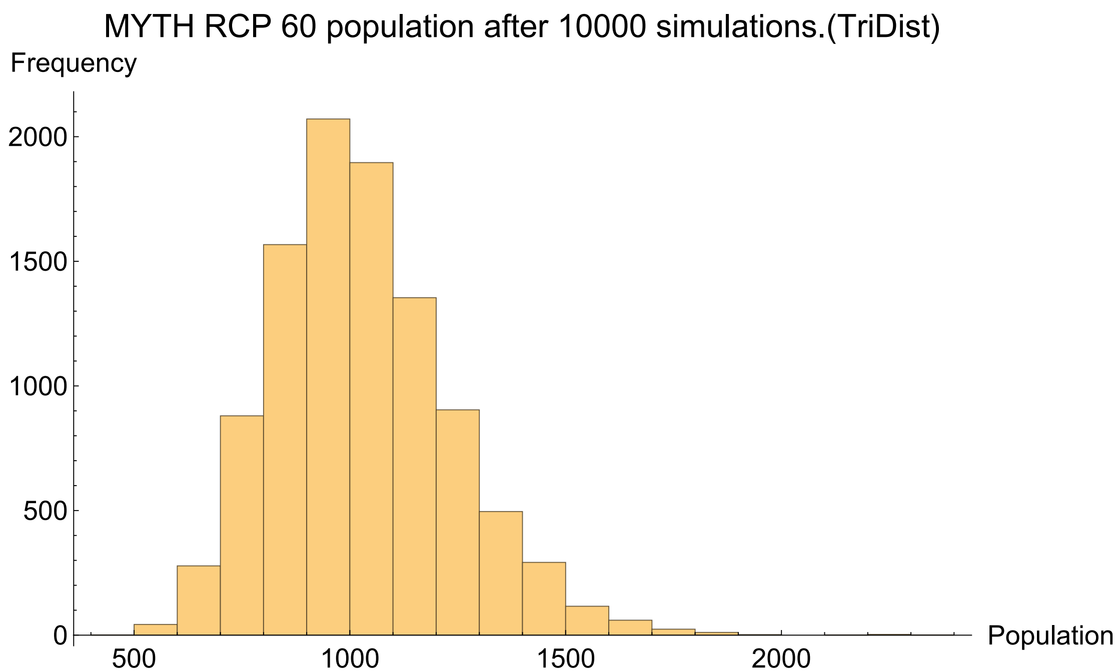


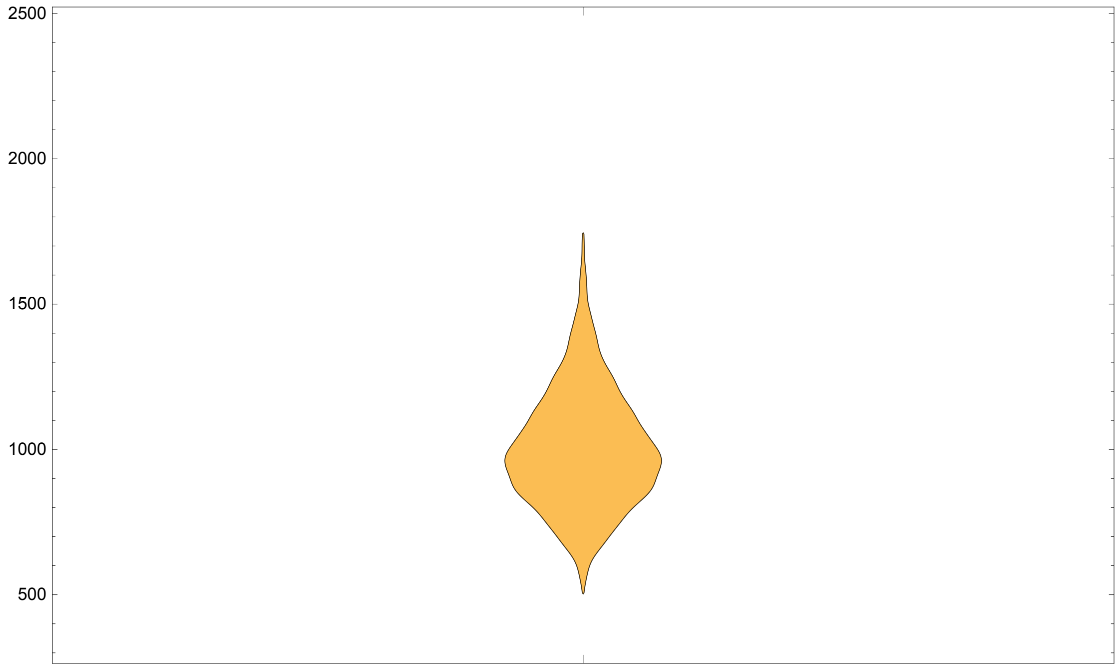
Monte Carlo RCP 60 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP60Ave / 2);
aReproMin = aReproAve * 0.90;
aReproMax = aReproAve * 1.10;

jReproAve = 0.90 * (aReproRCP60Ave / 2) * SFave;
jReproMin = 0.90 * jReproAve;
jReproMax = 1.10 * jReproAve;

runs = 10 000;
j = 0;

MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
          TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
           {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
        (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
```

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["MYTH RCP 60 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
1004.54

205.875

469.

2317.
```





RCP 8.5

Model projections using RCP85 2009-2086 average values

Predicted probability of an adult female being reproductively active in a given year, given RCP85 average values for years 2009-2086, using logistic regression:
Average RCP85 values for years 2009-2086 (from 1995, substract 15):

```
ProbRCP85Ave =
  {0.833987039, 0.829152111, 0.832030963, 0.83292322, 0.83292322, 0.83238927,
   0.838020937, 0.836103051, 0.832746967, 0.832746967, 0.832212567, 0.832212567,
   0.825870398, 0.825318636, 0.828248704, 0.827702906, 0.824210978, 0.822164276,
   0.819153073, 0.815526486, 0.810276224, 0.811257828, 0.809686435, 0.805914989,
   0.803706001, 0.803100751, 0.795928023, 0.795928023, 0.793634474, 0.794680362,
   0.796344493, 0.792376448, 0.791745317, 0.79841188, 0.79447372, 0.795516451,
   0.797175535, 0.794892393, 0.79820804, 0.797590107, 0.798621034, 0.798004046,
   0.799033396, 0.795104262, 0.792803865, 0.791118391, 0.790484446, 0.791542106,
   0.789212318, 0.786863503, 0.787934538, 0.787293528, 0.784929158, 0.77904401,
   0.775948462, 0.774164933, 0.766244928, 0.765557864, 0.758604153, 0.758604153,
   0.757901727, 0.755312189, 0.748875892, 0.742328051, 0.743549943, 0.740859382,
   0.736168424, 0.729408968, 0.724587789, 0.724587789, 0.714787341, 0.703447296,
   0.699700904, 0.69889511, 0.696737931, 0.693758519, 0.690762827, 0.689943677};
Mean[ProbRCP85Ave]
```

0.78499

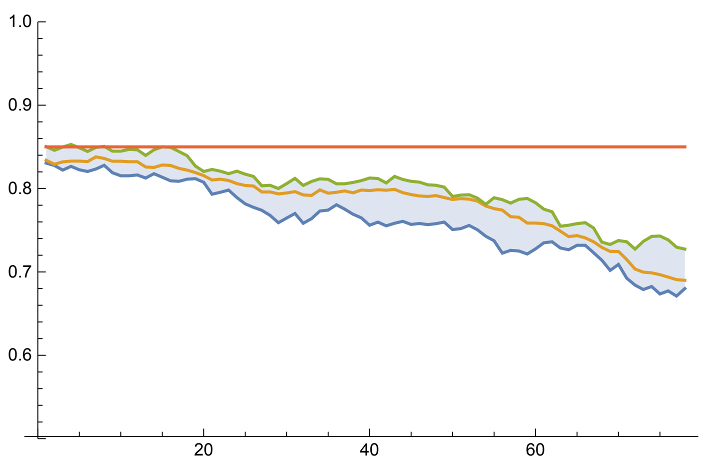
```
ProbRCP85Min = {0.830591621, 0.827693208, 0.822154334, 0.826597443, 0.822529215,
   0.820467198, 0.823461236, 0.827878531, 0.818955368, 0.81532571, 0.81532571,
   0.816287112, 0.8126162, 0.817816267, 0.813588483, 0.809285467, 0.808693325,
   0.811252621, 0.811838685, 0.807504834, 0.793208324, 0.795505389,
   0.798197087, 0.789195349, 0.781653791, 0.777479492, 0.773919722,
   0.767822425, 0.759048865, 0.764617166, 0.770095761, 0.75834732, 0.763926792,
   0.77302649, 0.774147099, 0.780565693, 0.775263785, 0.769191926, 0.764851056,
   0.756000894, 0.759755223, 0.755293337, 0.758353551, 0.760690704, 0.756946317,
   0.758121476, 0.756713325, 0.75788925, 0.759761429, 0.750782128, 0.751977326,
   0.755773564, 0.750545174, 0.742805571, 0.737396026, 0.722527971,
   0.725849208, 0.725086011, 0.721504758, 0.727629358, 0.734917276, 0.73616182,
   0.728645253, 0.72661784, 0.731920437, 0.731920437, 0.72304892, 0.71399854,
   0.701838911, 0.709012325, 0.692390291, 0.684161717, 0.678889266,
   0.682503314, 0.673570793, 0.677216239, 0.671038105, 0.680007006};
Mean[ProbRCP85Min]
```

0.762297

```
ProbRCP85Max = {0.850298735, 0.845851058, 0.849810302, 0.852884482, 0.848991878,
   0.844512474, 0.849320557, 0.85062507, 0.844849121, 0.844849121, 0.847016228,
   0.846519017, 0.839754961, 0.846519017, 0.849976149, 0.849486849, 0.844516939,
   0.839413945, 0.826979526, 0.820482222, 0.822918341, 0.820859861, 0.817831464,
   0.820859861, 0.817259865, 0.814572279, 0.803311611, 0.803916371, 0.800058816,
   0.805925625, 0.8122459, 0.803716728, 0.80851318, 0.811660811, 0.811074323,
   0.805727534, 0.805727534, 0.807323836, 0.809501761, 0.812636908, 0.812052756,
   0.806727059, 0.814577414, 0.810880254, 0.808714365, 0.807722668, 0.804525071,
   0.80392173, 0.801695638, 0.790490077, 0.792179289, 0.792601416, 0.788579803,
   0.781022333, 0.789007294, 0.786656812, 0.782551552, 0.787087141,
   0.788157355, 0.782987878, 0.775287479, 0.772154695, 0.754843933,
   0.756025981, 0.757907966, 0.759079955, 0.752710318, 0.735676354,
   0.732932857, 0.737660843, 0.736175028, 0.727391867, 0.736673098,
   0.742583132, 0.743073326, 0.738408294, 0.729672181, 0.727398609};
Mean[ProbRCP85Max]
```

0.800719

```
aReproRCP85Ave = ProbRCP85Ave;

aReproRCP85Min = ProbRCP85Min;

aReproRCP85Max = ProbRCP85Max;

ListLinePlot[{aReproRCP85Min, aReproRCP85Ave, aReproRCP85Max, DetRepro},
 PlotRange → {0.5, 1}, Filling → {1 → {3}}]
```

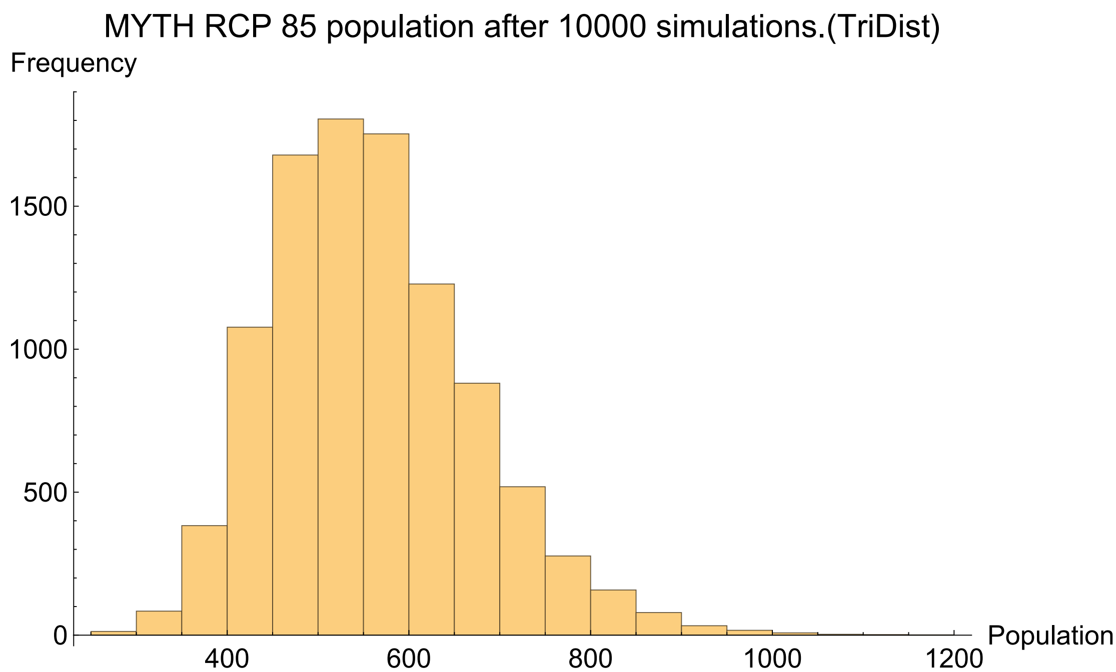


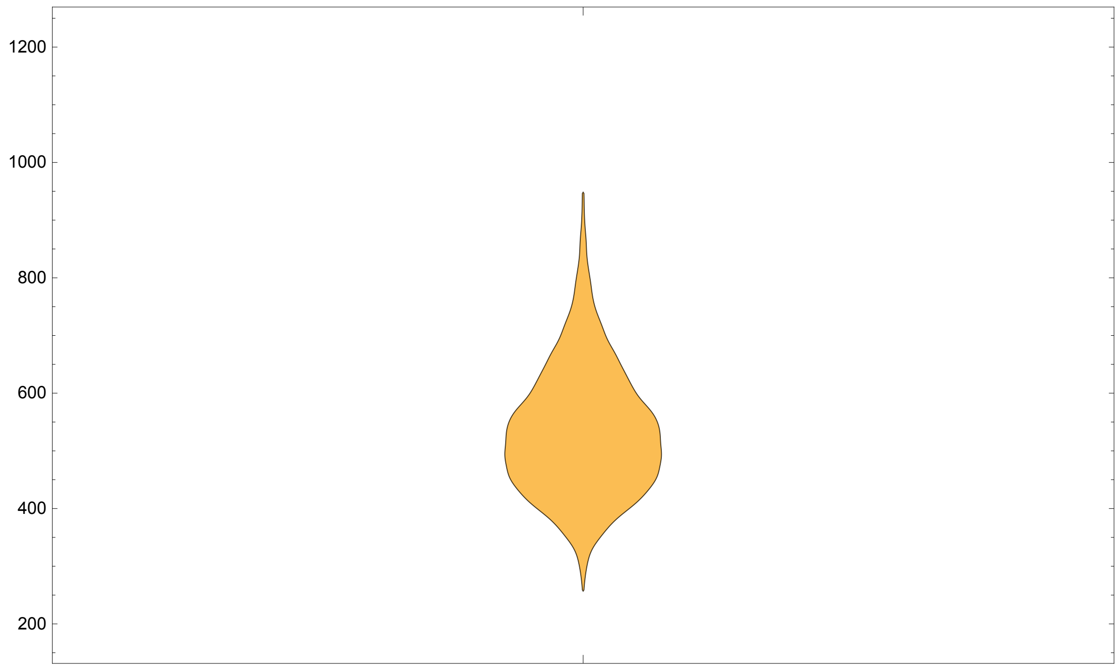
Monte Carlo RCP 85 simulation

```
SAave = 0.79;
SAmin = SAave * 0.90;
SAmax = SAave * 1.10;

SFave = SAave * 0.64;
SFmin = SFave * 0.90;
SFmax = SFave * 1.10;

aReproAve = SAave * (aReproRCP85Ave / 2);
aReproMin = aReproAve * 0.90;
aReproMax = aReproAve * 1.10;

jReproAve = 0.90 * (aReproRCP85Ave / 2) * SFave;
jReproMin = 0.90 * jReproAve;
jReproMax = 1.10 * jReproAve;

runs = 10 000;
j = 0;

MonteCarlo = Table[Npups = 600; Nne = 290; Ntwo = 230; Nthree = 880;
  i = 1; While[i < 77, Ntotal = Npups + Nne + Ntwo + Nthree;
   Nthree = (Ntwo * (RandomReal[TriangularDistribution[{SAmin, SAmax}]])) +
     (Nthree * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Ntwo = (Nne * (RandomReal[TriangularDistribution[{SAmin, SAmax}]]));
   Nne = (Npups * (RandomReal[TriangularDistribution[{SFmin, SFmax}]]));
   Npups = (Npups * (RandomReal[
         TriangularDistribution[{jReproMin[[i]], jReproMax[[i]]}]])) + (Nne *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]])) +
     (Ntwo * (RandomReal[TriangularDistribution[
          {aReproMin[[i]], aReproMax[[i]]}]])) + (Nthree *
       (RandomReal[TriangularDistribution[{aReproMin[[i]], aReproMax[[i]]}]]));
   i =
    i +
     1;];
  j = j + 1;
  Ntotal, {runs}]; k = 0;
```

```
N[Mean[Round[MonteCarlo]]]
N[StandardDeviation[Round[MonteCarlo]]]
N[Min[Round[MonteCarlo]]]
N[Max[Round[MonteCarlo]]]
Hist = Round[MonteCarlo, 50];
Histogram[Hist, BaseStyle → {FontSize → 14}, ImageSize → Large,
 PlotLabel → StringJoin["MYTH RCP 85 population after ", ToString[runs],
   " simulations.", "(TriDist)"], AxesLabel → {"Population", "Frequency"}]
DistributionChart[Round[MonteCarlo]]
```

```
534.991

111.725

235.

1166.
```




1200
1000
800
600
400
200