# Estimated Impacts of Mortality Reductions on Loggerhead Sea Turtle Population Dynamics

## Preliminary Results


**NOAA Fisheries**

**Southeast Fisheries Science Center**

**Miami, FL**

## Management Question:

**What is the effect of management actions that would decrease annual anthropogenic mortality rates of benthic loggerhead sea turtles on expected benthic female population size and trajectory ?**

**Loggerhead Life History: Stages in Straight Carapace Length (SCL)**

**pelagic/oceanic (birth to 63cm SCL)**
**small juvenile (41cm to 82cm SCL)**
**large juvenile (63cm to 100cm SCL)**
**adult (>82cm SCL)**

All **benthic** stages are vulnerable to GOM reef fish fishery bottom longlines

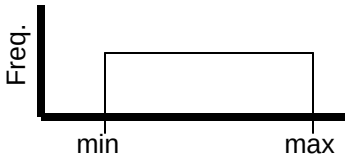
# The stage/age demographic model (structure based on NMFS SEFSC 2001*)

## 1) Updated parameters (minimum, nominal, maximum)

Mortality by stage
Stage duration (years in a stage)
Fecundity parameters
- Eggs per nest
- Nests per nesting female
- Hatchling emergence success
- Sex ratio (proportion female)
- Remigration interval (years between nesting for an adult female)

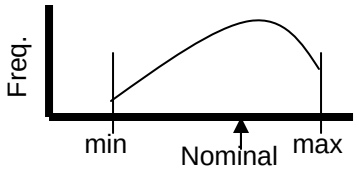
## 2) Described parameter uncertainty

uniform →




Note: when using uniform the nominal is effectively in the middle of the distribution.

"other distributions" →




## 3) Examined 5 management units (nesting assemblages)

(and allowed movement between units)

- Peninsular Florida
- "Northern"
- Dry Tortugas
- Northern Gulf of Mexico
- Greater Caribbean

* NMFS SEFSC 2001. Stock assessments of Loggerhead and leatherback sea turtles and an assessment of the impact of the pelagic longline fishery on the loggerhead and leatherback sea turtles of the western North Atlantic. NMFS-SEFSC-455.

**This presentation describes a model to**:

Estimate current female loggerhead population sizes for the western North Atlantic, and for Management Units of interest to the US.

Predict future population trajectories given management designed to reduce anthropogenic mortality of benthic loggerhead sea turtles

Predictions are in: number of benthic females, adults and juveniles
population growth rate

Show examples of model runs demonstrating a range of population predictions of loggerhead sea turtles in the western North Atlantic.

Examine uncertainty in the model due to changes in some parameters

Stochastic runs of the model represent our uncertainty in stock assessment based on all factors: parameter uncertainty due to sampling variation, environmental variation in demographic parameters, and variation in anthropogenic impacts

*NOTE: the model and all results are of females only. To estimate total population sizes, multiply results by a hypothesized loggerhead sex ratio (e.g. 2x for 1:1, etc)*

# Frequency distribution of conservatively predicted western North Atlantic adult female loggerhead population sizes 2004-2008

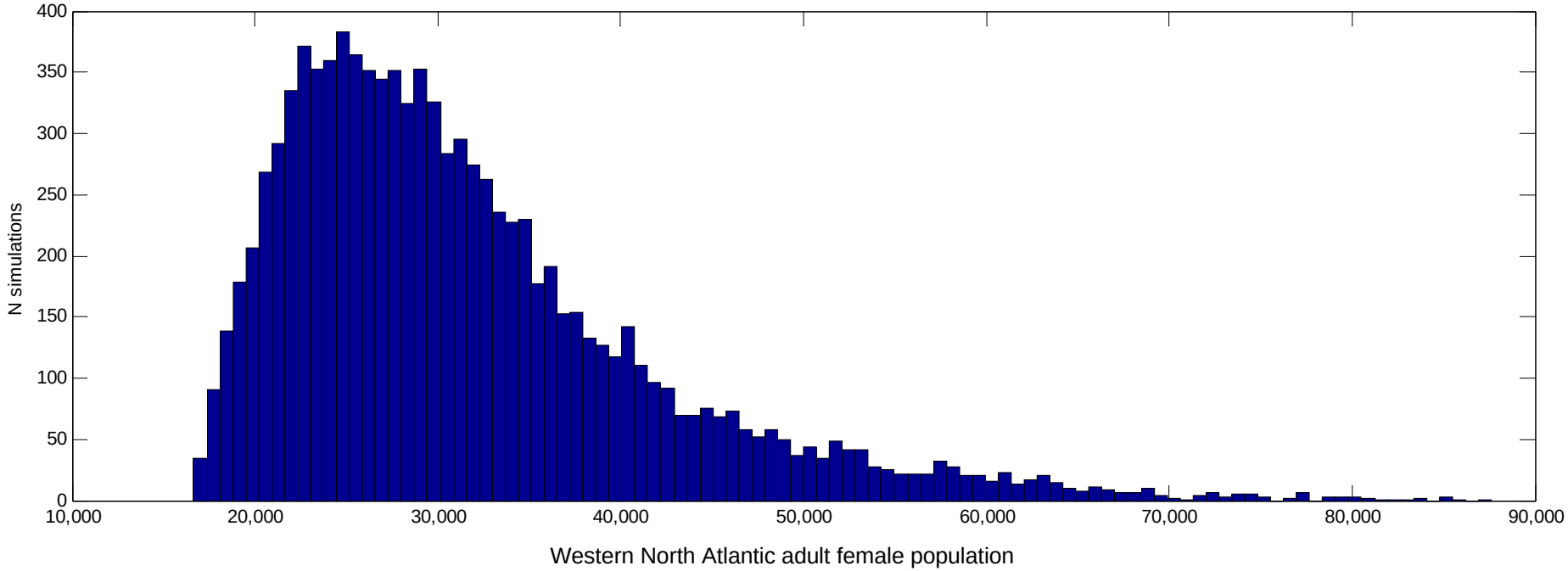
Derived from 10,000 simulated model populations:

Total Females = (nests/(nests per female)) * remigration interval

Nests = minimum nest count (2004-2008) = 48,252 nests

Remigration interval selected randomly (uniform) from range of 2.74 to 3.65 years

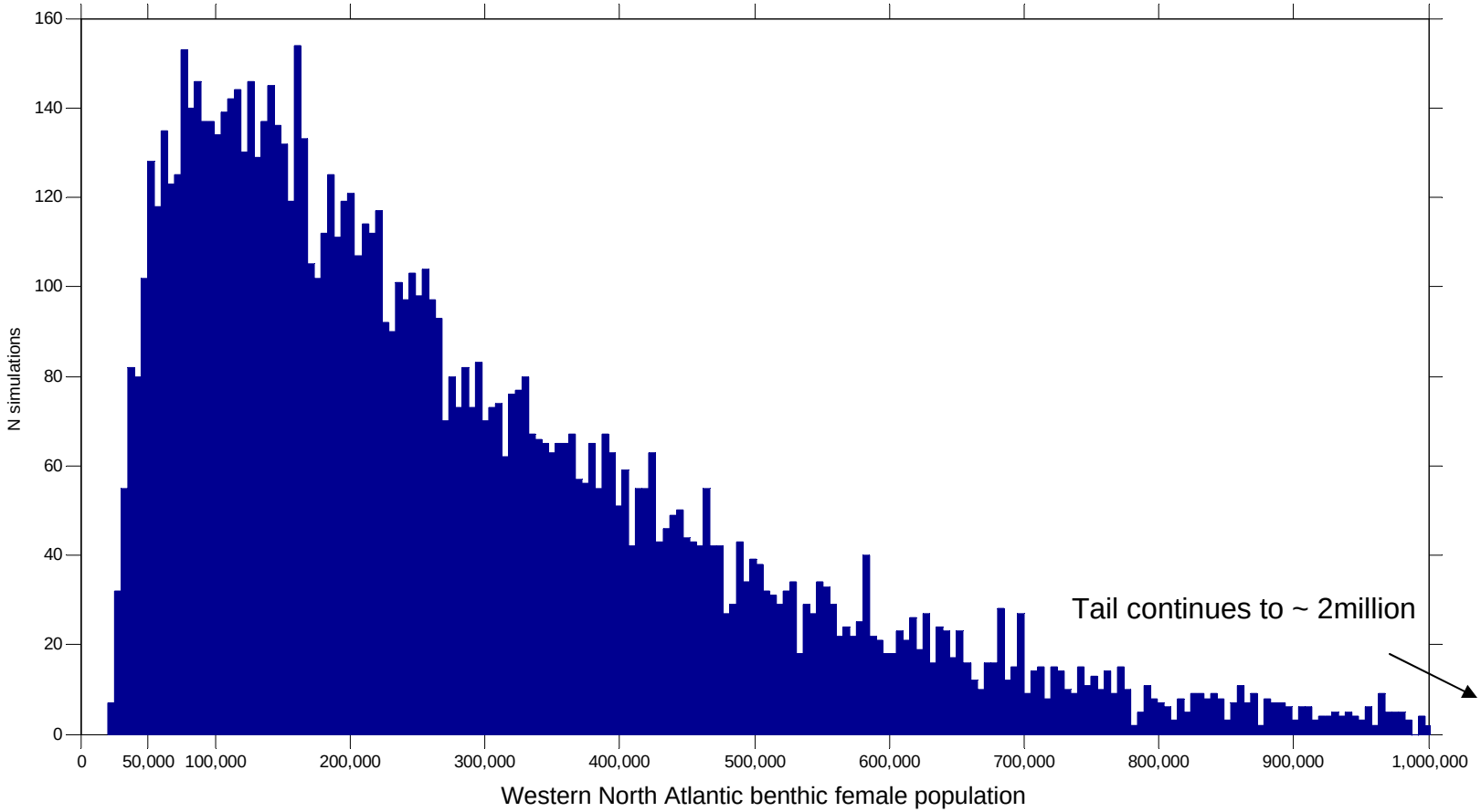
Nests per female selected randomly (truncated normal) from nominal = 5, CV~25%, [2-8]




This distribution suggests that the current adult female population is likely to be between ~20,000 and ~40,000, and not very likely to be >70,000.

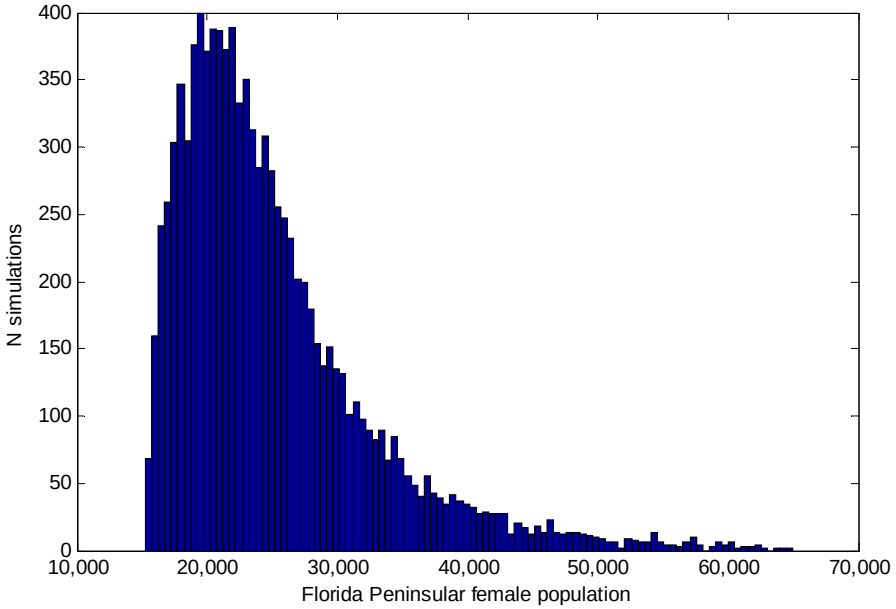
## Frequency distribution of predicted western North Atlantic female benthic loggerhead population sizes 2004-2008

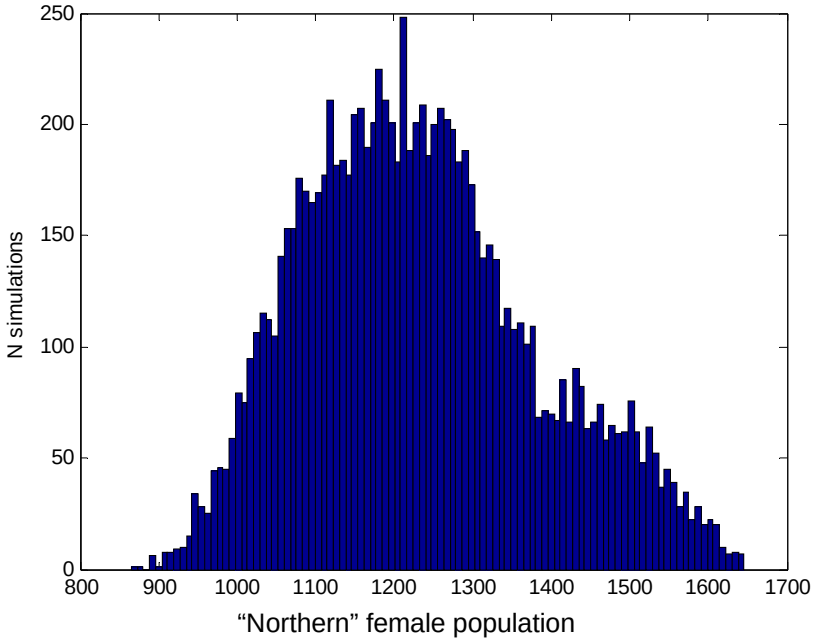
Uses the same methods as the adult female population but assumes a stable age/stage distribution to estimate benthic juvenile population, which is highly dependent upon all the other input parameters.

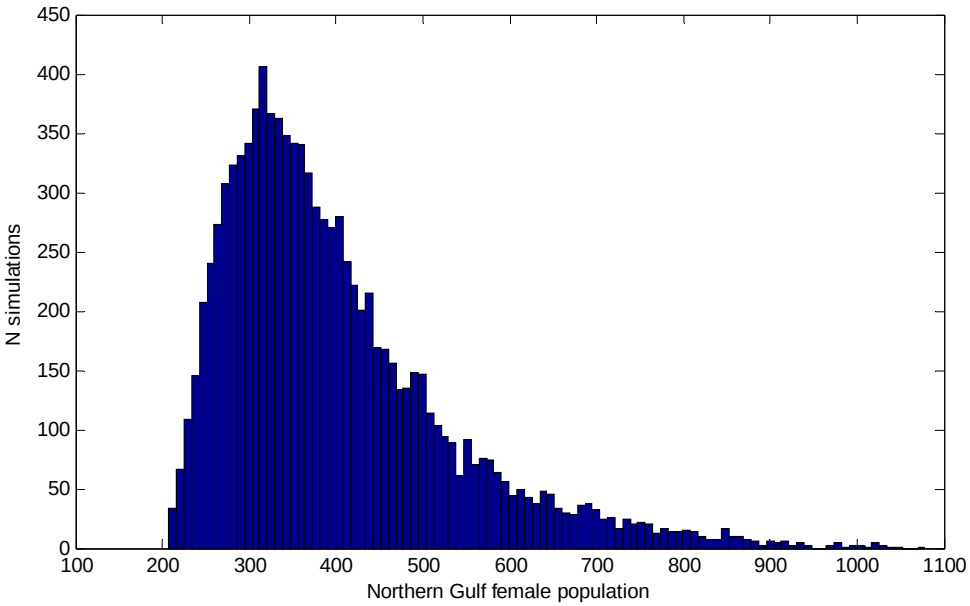


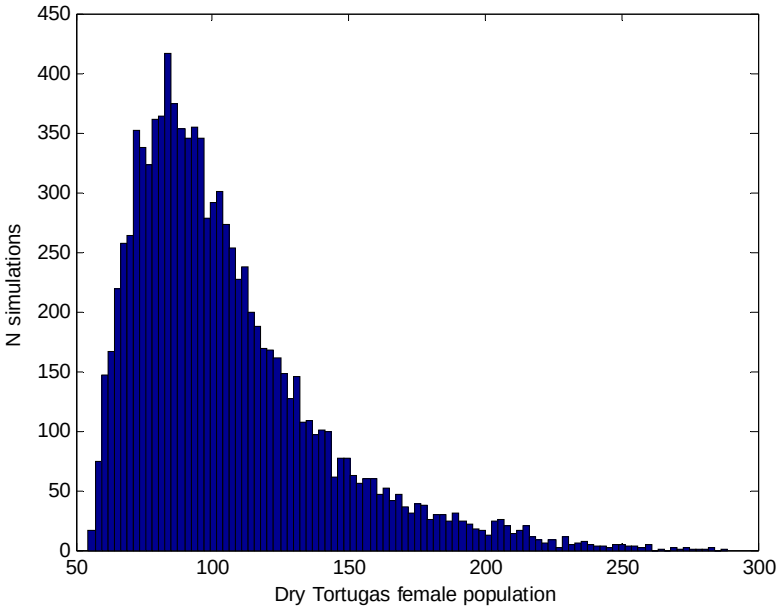

This distribution suggests that the current benthic female population is likely to be between ~30,000 and ~300,000 and not very likely to be > 1 million.

# Predicted frequency distributions of adult female population sizes

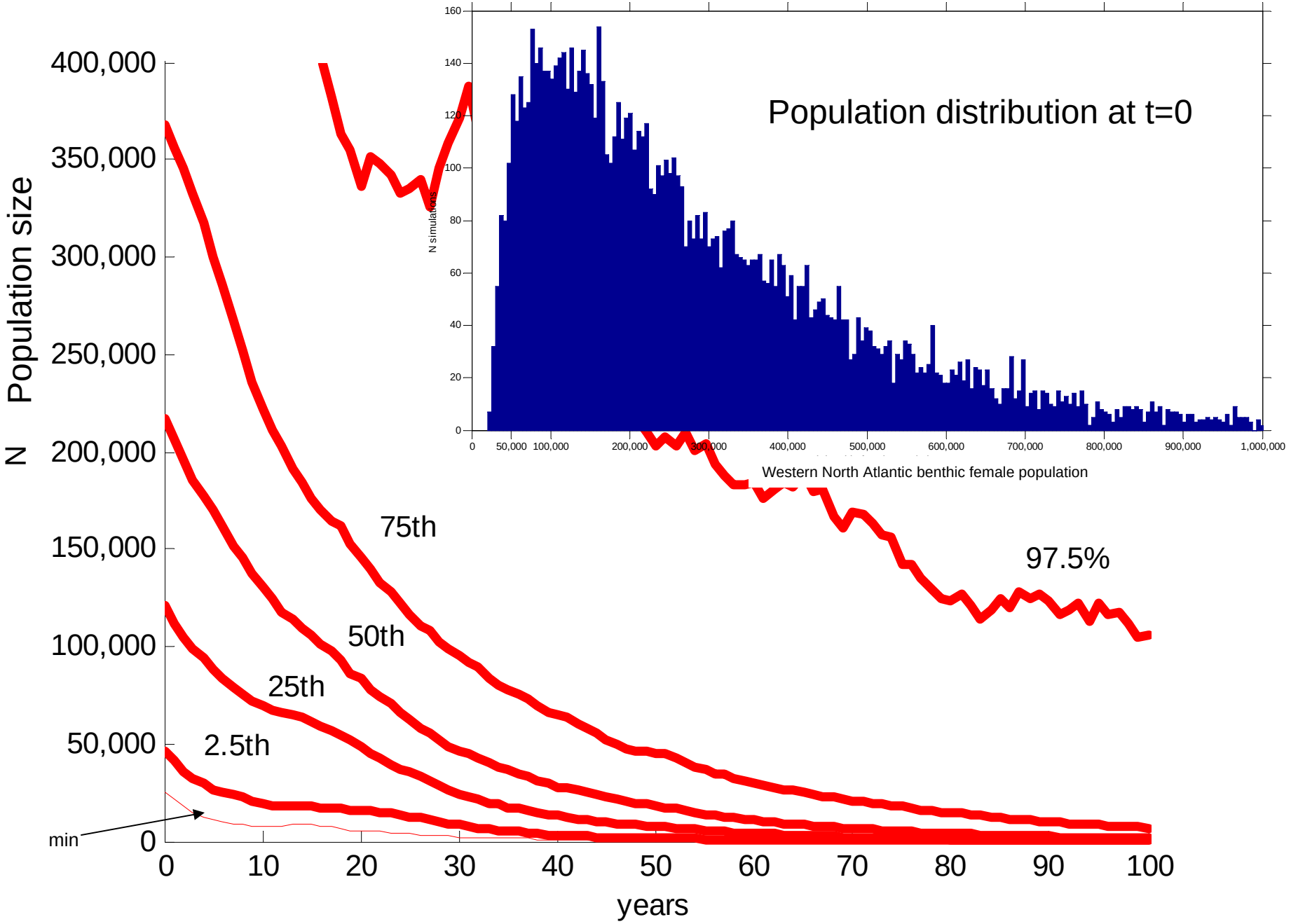


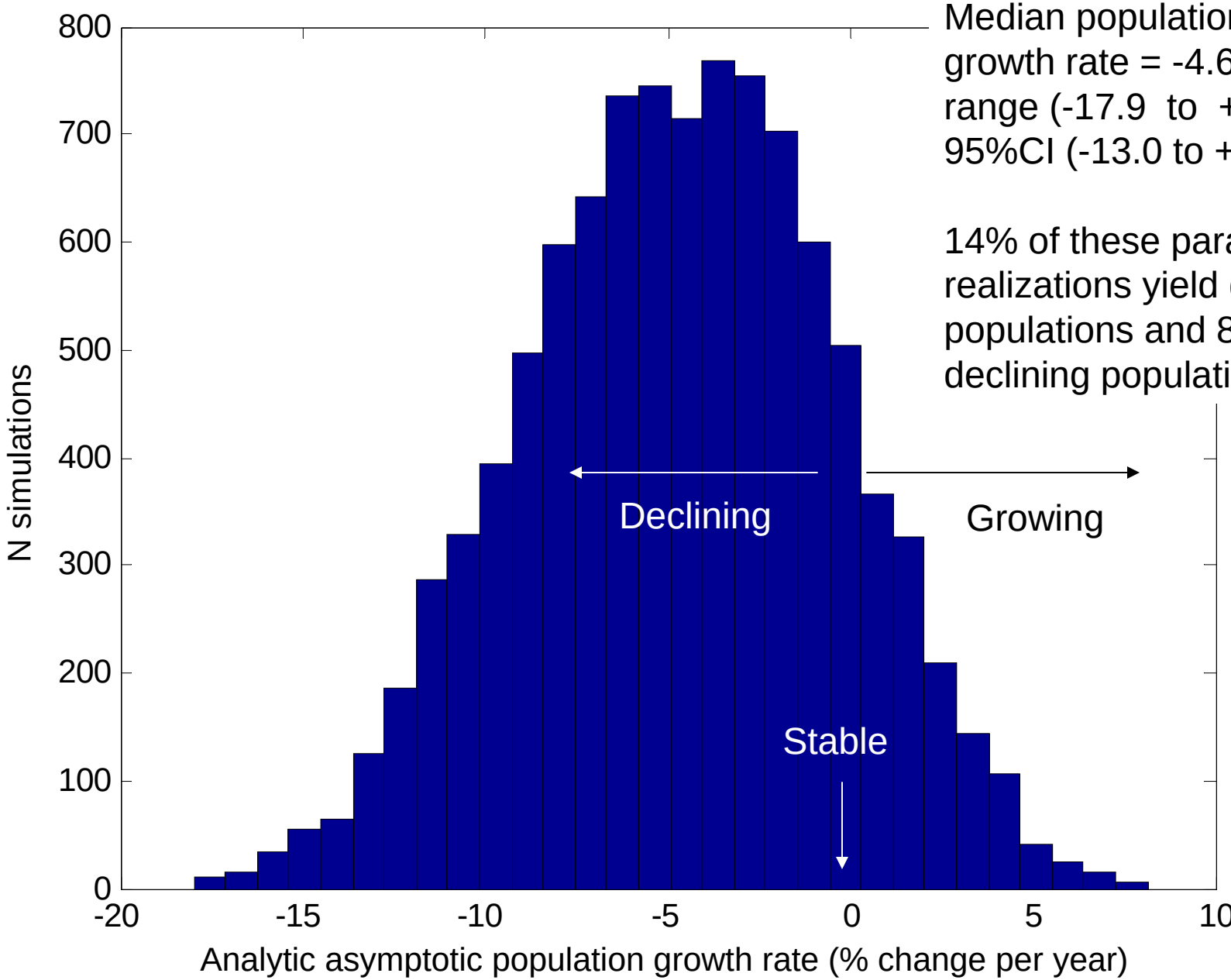



# Base example: predicted distribution of population trajectories for benthic females



Distribution of analytically derived asymptotic population growth rates at t=0




Median population growth rate = -4.68%
range (-17.9 to +8.1%)
95%CI (-13.0 to + 3.4%)

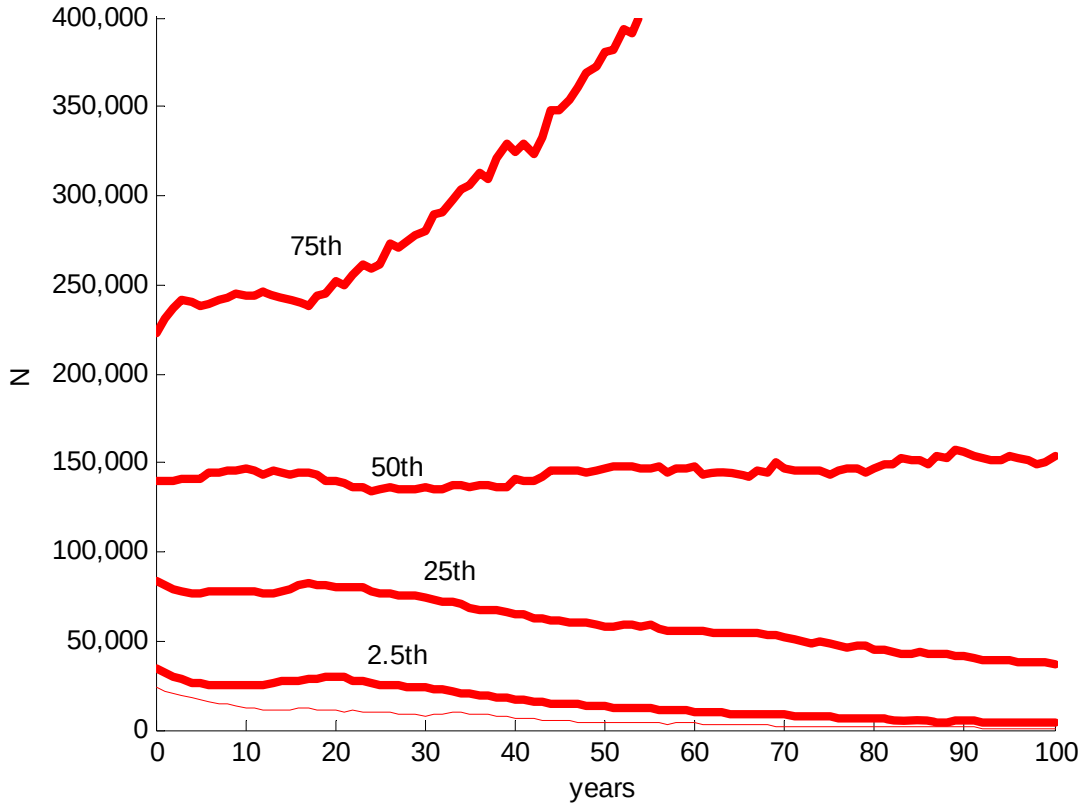
14% of these parameter realizations yield growing populations and 86% yield declining populations.

# Is it possible to get larger proportion of positive growth rates from the nominal model for western North Atlantic loggerheads by reducing mortality of benthic stages?

Nominal model mortality rates (% dead per year) by stage:

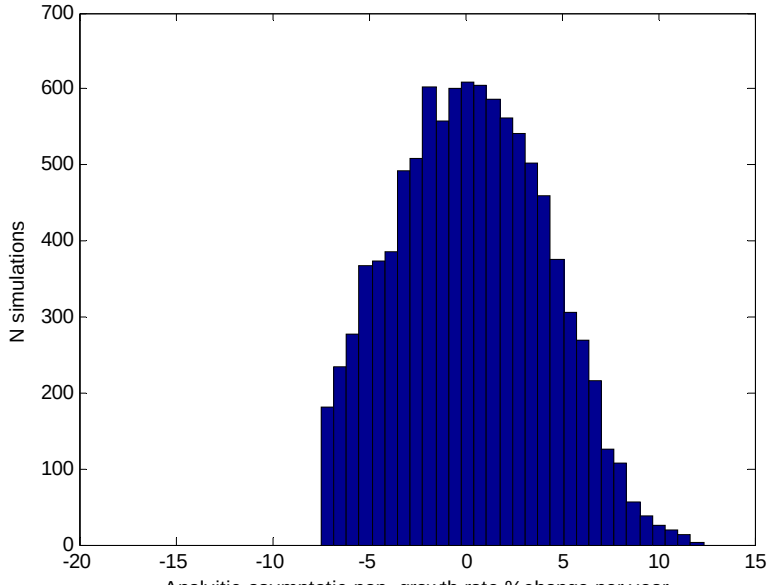
| | |
|---|---|
| small juvenile | nominal 17% (range 11-26%) |
| large juvenile | nominal 15% (range 7.5-23%) |
| adult | nominal 15% (range 7.5-23%) |

What happens if we set benthic mortalities at their minimum estimates (not limits of natural mortality)?



→Reduction in benthic mortality moves the distribution to the right compared to nominal model; The model is very sensitive to changes in benthic survival.

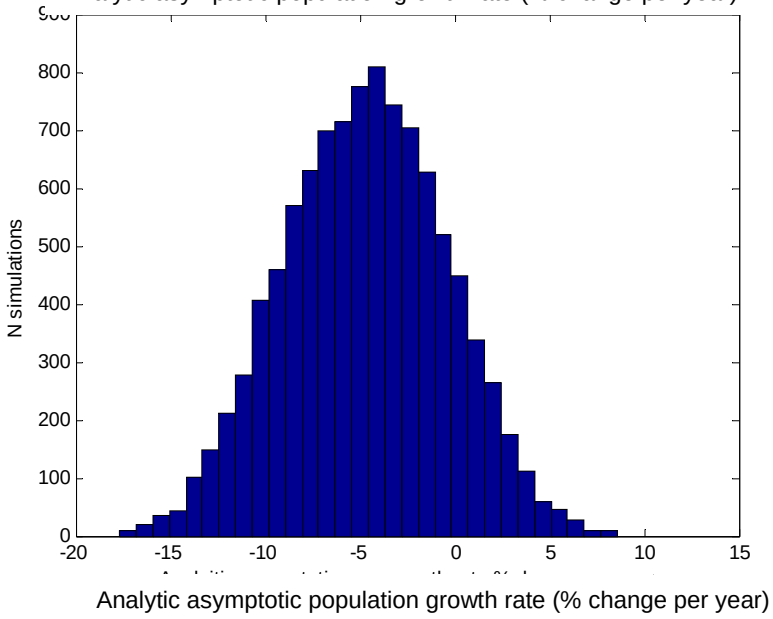
Reduction in benthic mortality to minimum nominal values




Median long term population growth rate = +0.26%
range (-7.5 to +12.3%)
95%CI (-6.6 to + 7.8%)

54% of these parameter realizations yield growing populations and 46% yield declining populations.

Nominal values for all parameters




Median long term population growth rate = -4.68%
range (-17.9 to +8.1%)
95%CI (-13.0 to + 3.4%)

14% of these parameter realizations yield growing populations and 86% yield declining populations.

## What happens if we change some other parameters?

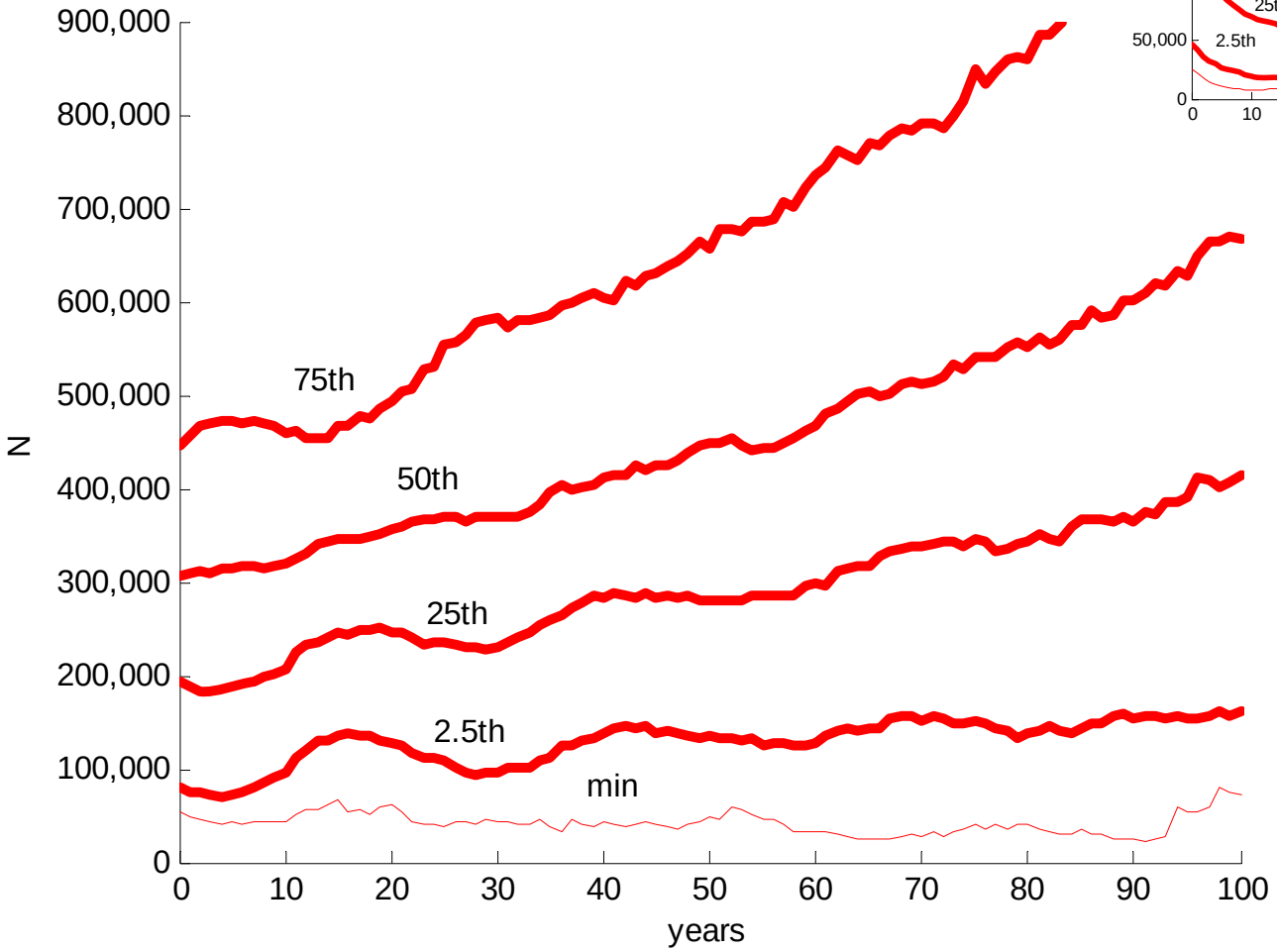
Another Example:

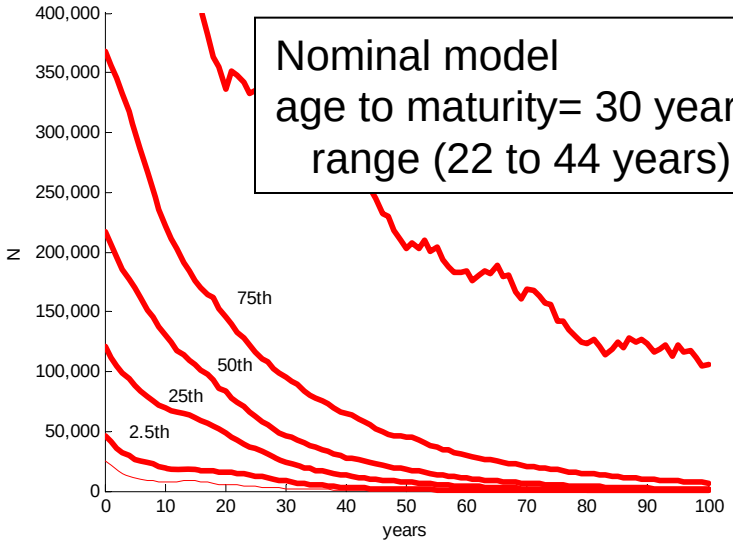
The nominal model used age to maturity = 30 years, range 22 to 44 years, and resulted in most model populations declining.

What happens if we change age to maturity to the minimum of 22 years with no uncertainty and all other parameters are at their nominal values and varying?

**Predicted population trajectories for benthic females:**

For example
Minimum age to maturity = 22 years




Nominal model
age to maturity= 30 years
range (22 to 44 years)

Model is very sensitive to changes in age to maturity

In other words:
Qualitative statements about population increase or decrease are very sensitive to age to maturity

Note: initial conditions are different due to parameters impact on stable age distribution.

- Parameters used were the estimated range (with few exceptions), not the expected or possible range

- Increasing or decreasing the min/max/nominal or entire range, or changing the shapes of parameter distributions can affect the model results

## Sensitivity analysis: What parameters have the biggest effect on population trajectory?

Parameters in order of relative importance from 10K runs of the stochastic model based on simple regression of each parameter on asymptotic population growth rate. Order determined by the magnitude of the adjusted $R^2$ of the significant regressions.

| Adj $R^2$ | Parameter |
|---|---|
| 0.673 | pelagic survival |
| 0.107 | pelagic stage duration |
| 0.066 | small benthic survival |
| 0.042 | emergence success |
| 0.038 | adult survival |
| 0.020 | large benthic survival |
| 0.019 | large benthic stage duration |
| 0.017 | nests per female |
| 0.004 | eggs per nest |
| 0.003 | proportion female |
| n.s. | small benthic stage duration |
| n.s. | mean remigration interval |

This result suggests a rank order of research priorities to help reduce our uncertainty in loggerhead population trajectories.

For example: Pelagic survival explains 67% of the variation in population growth rate, and small benthic survival explains about 6.6%.

**Rephrasing the question: "How much will it help population recovery of loggerhead sea turtles to reduce bycatch in the GOM reef fish fishery?".**

First question is: How much reduction is possible?

We assume non-compensatory additive mortality:
Current mortality = natural mortality + anthropogenic mortality.

Unfortunately we have no estimate of natural mortality, but if we assume it to be between 1% and 5% for all benthic stages (Note: it could be higher).

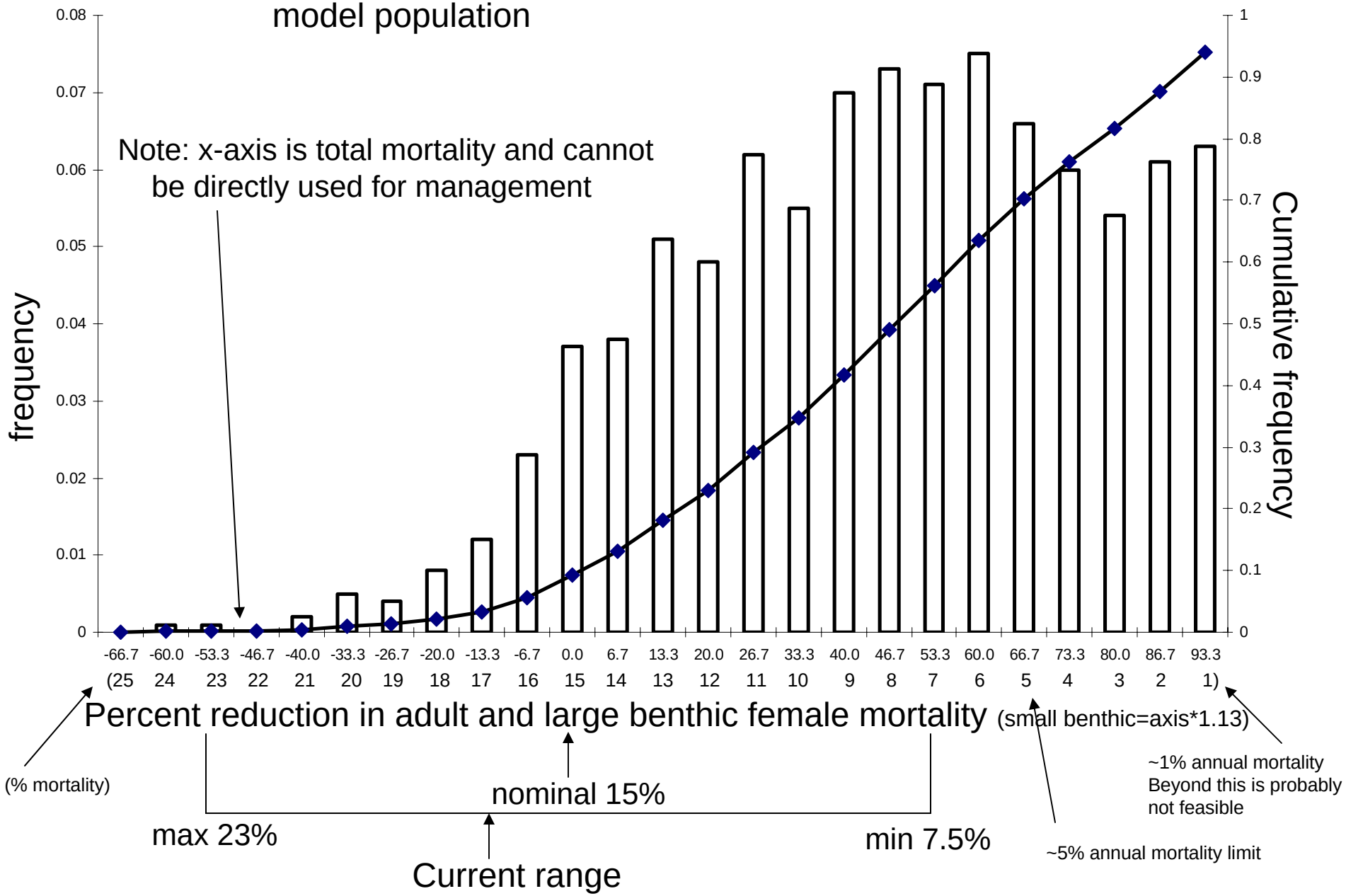
Recall:
Nominal model mortality rates (% dead per year) by stage:

| | |
|---|---|
| small juvenile | nominal 17% (range 11-26%) |
| large juvenile | nominal 15% (range 7.5-23%) |
| adult | nominal 15% (range 7.5-23%) |

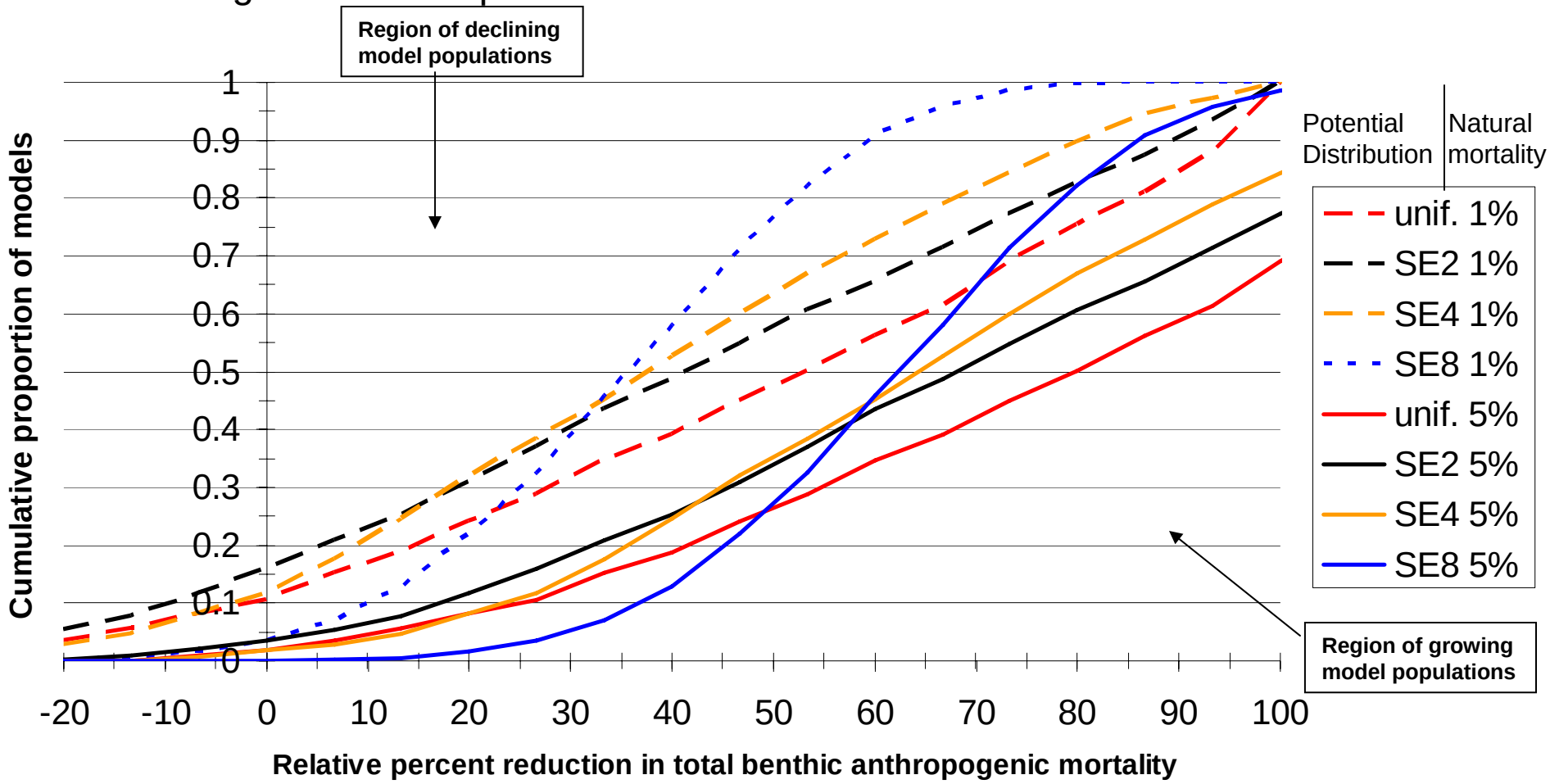
There is approximately between 93% (=(15-1%)/15%) and 67% (=(15-5%)/15%) reduction to the adult and large juvenile nominal mortality parameters available to management (and assume small juvenile = 1.13*[adult mortality]).

If the nominal model is close to correct then what would this mean? ……

ONE example of a frequency distribution and cumulative distribution of the percent change in total benthic mortality, relative to nominal, that could achieve a growing model population



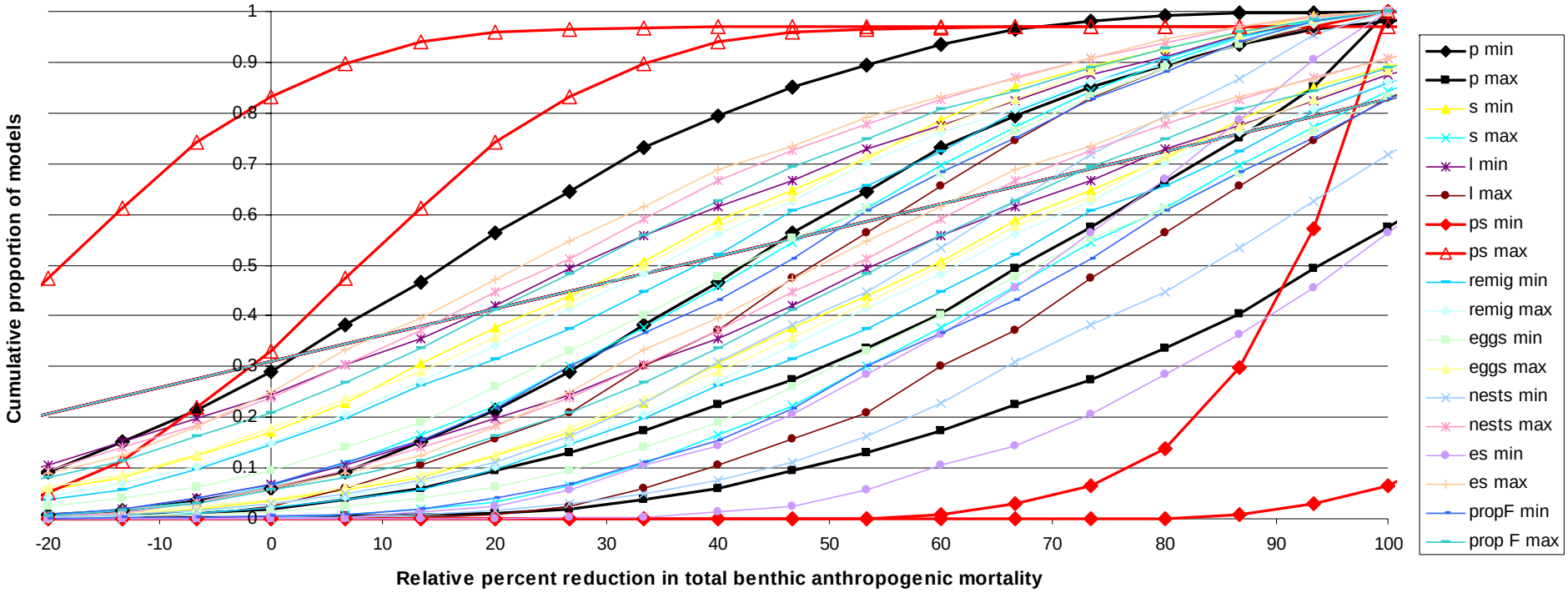
Cumulative proportions of models with population growth = 0 (not declining) for the nominal model showing the relative percent reduction in total anthropogenic mortality of benthic loggerheads with natural mortality assumed to be between 1% and 5%, under a range of nominal parameter distributions.




We are unable to quantify the relative likelihood of any of these lines.

What does the sensitivity analysis (individual parameter perturbations) do to these lines?

Sensitivity of the cumulative proportions of models with population growth = 0 (not declining) for the nominal model showing the relative percent reduction in total anthropogenic benthic mortality with natural mortality assumed to be either 1% and 5%, under the SE4 distribution. Each parameter is fixed at either minimum or maximum value while all other parameters' values vary.




The relative percent reduction in total anthropogenic mortality of benthic loggerheads needed to get model populations with long term growth = 0 is most sensitive to pelagic survivorship (red) when examining parameters individually. This result includes a number of assumptions and does not incorporate correlation in vital rates.

**The population model suggests that:**

1) The loggerhead benthic female population in the western North Atlantic is fairly large with a large range of uncertainty in total population size (30,000 to 300,000 or more).

2) Predicting future populations of loggerhead sea turtles is very uncertain due in part to large uncertainty in our knowledge of loggerhead life history.

3) Fine-scale questions such as impacts of individual fisheries (for example “How much will it help population recovery of loggerhead sea turtles to reduce bycatch in the GOM reef fish fishery?”) cannot be resolved by the model given the high degree of uncertainty in model parameters.

4) Any reductions in mortality will improve the long term outlook for loggerhead sea turtles, but even 100% reduction in anthropogenic benthic mortality may be insufficient to reverse a population decline if it exists.