HINKLEY POINT C PERMIT VARIATION

EPR/HP3228XT/V004

Technical Brief: TB013

HPC Entrapment Predictions – Uncertainty Analysis Report.

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National Fisheries Services, Environment Agency.

NNB HRA Team, Environment Agency.

Operations Catchment Services, Environment Agency.

Marine Contractor, APEM LTD.

2020 (DRAFT-04)

Note (to be removed prior signoff):

The results for European Eel have not yet been included. This is due to elements of the quantities impact assessment for this species currently being consulted on with teams from the wider business (EA & Defra).

CONTENTS

INTRODUCTION

A full uncertainty analysis of the quantitative impingement and entrainment assessment of HPC has been undertaken, for the permit variation application to amend or remove conditions relating to the design and operation of the Acoustic Fish Deterrent (AFD) system. This has been done for each of the species assessed and considered as representative of the fish assemblage of the Severn Estuary and inner Bristol Channel.

The quantitative aspects of the impingement and entrainment assessment conclude with a calculation of the annual proportional loss to the spawning stock biomass (SSB), fishery or spawning adult population for each species. This approach allows the numbers of fish impinged and entrained to be contextualised with a consistent measure, and the implications of the fish losses to species populations and the wider assemblage to be better assessed and understood.

Methodology

Uncertainty analysis

Estimates of annual proportional loss to the SSB, fishery or spawning adult population for each species, as the end output of the uncertainty analysis, are calculated using the following equation:

Eq.1 $$Annual\ proportional\ loss = \frac{\left(\left(N_{imp} \cdot F \cdot A \cdot V \cdot M_{imp} \cdot EAV_{imp}\right) + \left(N_{add} \cdot M_{add} \cdot EAV_{add}\right) + \left(N_{ent} \cdot M_{ent} \cdot EAV_{ent}\right)\right) \cdot W}{P}$$

Where:

N_{imp} *Number of biota impinged calculated from the CIMP data*

N_{add} *Number of additionally impinged biota due to the 10mm to 5mm screen size change*

N_{ent} *Number of entrained biota*

F *Scaling factor between HPB and HPC impingement*

A *Scaling factor for intake tidal intercept area between HPB and HPC*

V *Scaling factor for intake velocity cap effect between HPB and HPC*

M_{imp} *Mortality of the impinged fish calculated from the CIMP data*

EAV_{imp} *EAV of the impinged fish calculated from the CIMP data*

M_{add} *Mortality of the additionally impinged biota due to the 10mm to 5mm screen size change*

EAV_{add} *EAV of the additionally impinged biota due to the 10mm to 5mm screen size change*

M_{ent} *Mortality of the entrained biota*

EAV_{ent} *EAV of the entrained biota*

W *Mean weight of fish within the spawning stock*

P *Total weight or number of fish within the spawning stock (or captured within the fishery)*

Where P is quantified as a number of fish, rather than a weight of fish, then the W term is omitted from the equation.

Estimates of annual proportional loss to the species population or fishery are calculated using a Monte Carlo simulation method, resampling each parameter within the equation 100,000 times to generate 100,000 modelled outcomes and thus a probability distribution of the annual proportional loss.

To allow the re-sampling to generate a distribution of outcomes, each parameter is assigned its own probability distribution. For some parameters, fixed single values are used, or parameters are distributed using either uniform, normal or log-normal probability distributions.

Detail on the derivation of the values and distributions used within the uncertainty analysis for each parameter is available in a series of technical briefs, as described in Table 1, and a full set of the data used in the analysis is presented in Appendix 1. The uncertainty analysis has been undertaken in R (version 3.6.0) and validated using the Oracle Crystal Ball extension of Microsoft Excel.

Table 1 Technical briefs containing detail of the derivation of parameter values

Uncertainty analysis parameter	Technical brief containing parameter value detail
N_{imp}	TB001 Technical Brief: Vertical Audit and Raw Data Quality Assurance summary report.
N_{add}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
N_{ent}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
F	TB003 Technical Brief: The relationship between number of fish impinged and abstraction volume for Power Stations cooling water intakes.
A	TB006 Technical Brief: Low Velocity Side Entry Intake Design; effect of intake intercept area.
V	TB007 Technical Brief: Low Velocity Side Entry Intake Design; effect of intake velocity cap.
M_{imp}	TB008 Technical Brief: Fish Recovery and Return System Mortality Rates.
EAV_{imp}	TB010 Technical Brief: Converting impingement and entrainment numbers to Equivalent Adult Values and Spawning Production Foregone.
M_{add}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
EAV_{add}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
M_{ent}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
EAV_{ent}	TB004 Technical Brief: Accounting for entrainment losses and difference in drum screen size.
W	Unchanged from TR456
P	TB011 Technical Brief: Scale of assessment areas for marine fishes and assessment method comparing Sprat losses with Spawning Stock Biomass. TB012 Technical Brief: Predicting adult sea trout populations in the Severn Estuary.

The uncertainty analysis method generates a probability distribution of potential annual proportional losses for each species assessed, which could occur in any given year (see discussion on correlation below). This approach accounts for the potential for low impingement but high SSB and high impingement but low SSB, as well as the potential for variability within population structure (via the EAV parameter), mortality rates (via the FRR parameter), and the uncertainty within the performance of the HPC intake relative to the HPB intake (via the intake volume, intercept area and velocity cap scaling factors).

From the probability distributions generated by the analysis, estimates of annual proportional losses can be made with associated quantitative confidence levels (e.g. we can be X% confident that the annual proportional loss will not exceed Y% in any given year). A variety of confidence levels have been presented within the results, as required by the Environment Agency for the determination of the permit.

Sensitivity testing

The results of the uncertainty analysis for each species has been sensitivity tested, to identify the parameters that are having the greatest relative influence on the probability distribution generated. This has been done by fixing each of the parameters at the upper and lower limits of their 95% confidence interval (2.5th percentile and 97.5th percentile), and re-running the model with individual fixed parameters.

The mean of the baseline model run and the mean of the model run with a parameter fixed at the limit of its 95% confidence interval is then compared and the change in the mean identified. A single parameter at a time is fixed at either the upper or lower limit of its 95% confidence interval to identify the change in the mean for each parameter, and thus the relative sensitivity of the model to that parameter.

Independent testing of the method

To verify the accuracy of the outputs generated by the uncertainty analysis conducted in R, the model has been separately tested and validated using the Oracle Crystal Ball extension of Microsoft Excel.

Correlations

The potential for correlation between the parameters of the model has been reviewed, to ensure that the model is not selecting unrealistic combinations of parameters in determining the resulting probability distribution of proportional losses.

The analysis makes the underlying assumption that the assessment of proportional loss in 2009/10 is representative for other years of operation, as the data available for other years is of lower quality. As identified in TR456, there is some variability between years but 2009/10 was not considered to be a particularly extreme (low or high impact) year and therefore use of this year as a representative year is appropriate.

On their own, the impingement numbers are not representative of other years, the length-distribution and thus EAV is not representative of other years and the population size is not representative of other years. However, when combining them all into a proportional loss relating impingement numbers and EAVs to population size in a given year, the conceptual assumption for other years holds due to the correlations between these factors, as discussed in Table 2. For example, if the population size increases then the impingement numbers would in theory increase, and the proportional loss would remain similar. If the juvenile recruitment in a given year is very strong and impingement increases, but spawning population size has not subsequently increased, the EAV value will decrease which will mean the proportional loss will remain similar. This again is shown in TR456, with the proportional losses varying but remaining within the same order of magnitude.

Table 2 Identification of potential correlation between parameters and approach to ensuring this does not result in unrealistic combinations of parameters within the uncertainty analysis.

Parameter	Parameter notation	Review of potential for correlation
Annual HPB impingement length-frequency distribution	NA – not used within the model but an implicit aspect of the EAV parameters.	This parameter is closely correlated to the EAV factors. Currently, the annual impingement numbers and length-frequency distribution is taken from the 2009/10 CIMP dataset. The EAV factor is then calculated using the length-frequency distribution of the fish impinged, and so is a 2009/10 specific EAV. All uncertainty to be programmed within the impingement number and EAV factor parameters will be to account for the uncertainty in setting these parameters for the 2009/10 year. Therefore, all combinations of these two parameters will be realistic if it is assumed that the length-frequency distribution will remain unchanged as impingement numbers increase or decrease. As we are assessing only the uncertainty within the 2009/10 impingement, then it is proposed not to programme any uncertainty into the length-frequency distribution of the impinged fish for 2009/10. This avoids the potential for unrealistic combinations of impingement numbers and EAV factors being used within the simulations.

Parameter	Parameter notation	Review of potential for correlation
		If the length-frequency distribution changes in other years, the EAV factor will also change. For example, a year of particularly high recruitment for a species could result in an increase in impingement numbers but comprising a large proportion of small juvenile fish. This would result in the EAV factor reducing. For different years of impingement, the length-frequency distribution and EAV parameters would be positively correlated (i.e. as length increases, EAV increases), and the impingement number and EAV parameters would be negatively correlated (i.e. as impingement number increases, EAV decreases). This negative correlation will mean that the overall proportional loss is likely to remain similar to as calculated for the 2009/10 year, for different combinations of impingement numbers and EAVs (and population sizes - see parameter below).
Number of biota impinged calculated from the CIMP data	N_{imp}	The impingement numbers that will be used for the uncertainty analysis are derived from the re-run of the bootstrapping process following the vertical audit and adjustment to sampling period. This bootstrapping process only takes account of the variability within the impingement numbers for the CIMP year (i.e. 2009/10). Impingement numbers will be correlated with population size (P) as well as potentially with the EAV factor through the length-frequency changes as discussed in that parameter. However, as the uncertainty analysis uses the data from the 2009/10 year and no variability within the length-frequency dataset, then the possible combinations are all expected to be realistic.
Number of additionally impinged biota due to the 10mm to 5mm screen size change / Number of entrained biota	N_{ent} / N_{add}	No uncertainty within these parameters is included and therefore no further consideration has been given to potential correlations.
Scaling factor between HPB and HPC impingement	F	This factor determines the likely change in fish density between the water drawn into HPB and to be drawn into HPC. At present, this factor uses a linear and proportional relationship to scale between HPB and HPC. The linear and proportional approach assumes that there is no change in fish density within the water drawn into HPB and to be drawn into HPC. Therefore, the assumption is also made that the length-distribution of fish does not change between HPB and HPC.

Parameter	Parameter notation	Review of potential for correlation
		If this linear and proportional relationship is deviated from, and the conclusion reached that there may be a change in fish density between the water drawn into HPB and to be drawn into HPC, then there may be a requirement to evaluate whether the length-distribution of the fish drawn in may also change. If it can be concluded that there is no likely change in the length-distribution, then there is no correlation between this factor and other factors. If it is concluded that the length-distribution may change, then this will influence the EAV factor.
Scaling factor for intake tidal intercept area between HPB and HPC	A	This factor determines the change in horizontal area of the water column sampled between the HPB and HPC intakes. There is no correlation between this factor and other factors.
Scaling factor for intake velocity cap effect between HPB and HPC	V	This factor determines the change in vertical area of the water column sampled between the HPB and HPC intakes. There is no correlation between this factor and other factors.
Mortality of the impinged fish calculated from the CIMP data	M_{imp}	This factor determines the proportion of fish entering the intake which do not return to the sea alive. Survival of individual species may be length-specific and therefore be related to the EAV factor (EAV), and may also be influenced by impingement numbers (I) (and associated fish density within the drum screen buckets). However, these influences are not currently incorporated within the FRR mortality rates and therefore there is no correlation between this factor and other factors.
Mortality of the additionally impinged biota due to the 10mm to 5mm screen size change / Mortality of the entrained biota	M_{add} / M_{ent}	No uncertainty within these parameters is included and therefore no further consideration has been given to potential correlations.
EAV of the impinged fish calculated from the CIMP data	EAV_{imp}	As discussed for the length-frequency parameter above, the EAV factor will be correlated with the length of the fish impinged, and changing impingement numbers between years may change the EAV factor. However, this is dealt with by using 2009/10 data only and fixing the length-frequency distribution for that year.
EAV of the additionally impinged	EAV_{add} / EAV_{ent}	See above - independent EAV estimates are derived for this step using length-frequency distributions of entrained and impinged fish from the 10mm to 5mm screen size change.

Parameter	Parameter notation	Review of potential for correlation
biota due to the 10mm to 5mm screen size change / EAV of the entrained biota		
Mean weight of fish within the spawning stock	W	This parameter uses data from 2009/10 where possible on the mean adult weight in the stock, or where year-specific data does not exist, uses more general representative estimates. There may be a correlation between this parameter and the population size (P) but as 2009/10 data is used in both estimates then each possible value from the distributions are reasonable combinations and there is not expected to be a correlation between the factors.
Total weight or number of fish within the spawning stock (or captured within the fishery)	P	A correlation may exist between this parameter and the impingement numbers (M_{imp}) as the impingement numbers in any given year may be influenced by the population size that year due to the influence of the population size on recruitment strength. The base values for this parameter are set using the available data on the number or biomass of spawning adults for 2009/10, plus associated uncertainty around this within-year estimate. As the impingement numbers are also set for 2009/10 from the CIMP (plus associated uncertainty in within-year estimation of the 2009/10 numbers), then each possible value from the two parameters are reasonable combinations and there is no correlation between the factors.

Results

The results of the Monte Carlo simulation for each species is presented in Table 3.

Graphical outputs of the Monte Carlo simulation for each species, and the sensitivity testing of the model, is provided in Appendix 2. For each species assessed, Appendix 2 provides a probability distribution of the modelled annual proportional loss from the Monte Carlo simulation. This indicates the range of annual proportional losses that could occur in a given year, and the probability of each occurring. The calculated estimate values used in the deterministic quantitative assessment are provided on each of the probability distributions. A boxplot of the modelled annual proportional loss from the Monte Carlo simulation is also provided, which indicates the spread of the annual proportional losses. Finally, a cumulative quantiles chart is provided, which tracks the mean and 95% confidence interval from 1 iteration to 100,000 iterations within the Monte Carlo simulation. The cumulative quantiles chart is interrogated following the model run. This is to ensure that the probability distribution for that species from the Monte Carlo simulation is stable and would not be likely to vary should further iterations of the model be run.

For each species assessed, Appendix 2 also provides a tornado plot showing the outcomes of the sensitivity testing process. Each bar indicates the change in the mean annual proportional loss when that individual parameter is fixed at either the upper or lower limit of the 95% confidence interval of the parameter's distribution. These plots provide a relative measure of the influence of each parameter on the probability distribution.

The results of the Oracle Crystal Ball validation testing are presented in Appendix 3.

The models allow the annual proportional loss for each species to be presented as the mean, and the 95% confidence interval around the mean, which is also provided in Table 3. No assessment is provided for allis shad within the River Usk as there is no evidence of a population of the species present within the river.

There are a number of species whose annual losses exceed 100% at the upper end of the modelled probability distributions. The current method for calculating the annual losses, as used in TR456 and expanded here to account for entrainment, does not mathematically constrain impacts to ≤100%. An adjustment to the model would be required to achieve this, for example by calculating a daily loss and applying this over a year as the population is depleted.

Therefore, combinations of parameters could be chosen within the model which result in impacts of above 100%. This phenomenon is largely constrained to the species of Atlantic cod and whiting, and the parameters of Nimp and P, as the others for this species serve to reduce the Nimp value. As discussed in Section 3: Correlations above, the uncertainty within the Nimp and P parameters are drawn from independent uncertainty estimates, via bootstrapping for Nimp and via ICES expert judgement estimates for P. The parameter distributions also represent the uncertainty in the value specific to the 2009/10 year. Therefore, the selection of individual values from each distribution (such as a high impingement value and low SSB) do not represent unrealistic combinations of parameters for the 2009/10 year as the impingement could have been high and the SSB could have been low.

Instead, the uncertainty within the assessment that is likely to be causing this phenomenon is the extent to which the impingement numbers comprise entirely fish from the population unit used for the population scaling. As set out within TB011, there is likely to be an unknown degree of mixing between the fish within the selected population unit, and fish moving into the Bristol Channel from other population units. This would mean that only a proportion of Nimp would be from the P value. It is recognised that the potential for a loss of >100% is not possible, and in these situations losses would be on the local population and the wider population. For other species, such as Atlantic herring, it is further acknowledged that the population unit used may be wider than the actual local population at risk of impingement.

Table 3 Results of the uncertainty analysis Monte Carlo simulation – R model.

Species	Species estuarine use guild	Species population size measure	Annual Percentage (%) Loss									
			Mean	SD	1st %ile	2.5th %ile	5th %ile	50th %ile	90th %ile	95th %ile	97.5th %ile	99th %ile
European sprat	MM	SSB (t)	0.72	0.14	0.47	0.50	0.52	0.70	0.90	0.98	1.04	1.13
Whiting	MM	SSB (t)	12.48	5.77	3.94	4.65	5.36	11.38	20.03	23.37	26.74	31.12
Dover sole	MM	SSB (t)	5.20	2.96	1.21	1.47	1.75	4.54	9.02	10.83	12.72	15.14
Atlantic cod	MM	SSB (t)	16.53	10.15	3.58	4.43	5.35	14.11	29.41	35.90	42.67	51.52
Atlantic herring	*MM*	*Fishery (t)*	4.41	0.91	2.90	3.05	3.20	4.27	5.61	6.09	6.57	7.16
European seabass	MM	SSB (t)	3.02	0.98	1.34	1.46	1.58	2.96	4.36	4.71	5.02	5.39
European plaice	MM	SSB (t)	0.14	0.08	0.02	0.03	0.04	0.13	0.26	0.30	0.34	0.40
Thornback ray	*MM*	*Fishery (t)*	3.21	0.80	1.76	1.92	2.07	3.11	4.27	4.66	5.04	5.50
Blue whiting	MA	SSB (t)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European eel - Severn Estuary	CA	Spawning escapement (t)										
Twaite shad - Severn Estuary	CA	Adult spawning run (number of adults)	0.21	0.21	0.04	0.05	0.06	0.13	0.45	0.65	0.86	1.11
Allis shad - Severn Estuary	CA	Adult spawning run (number of adults)	1.49	1.58	0.27	0.32	0.37	0.93	3.26	4.74	6.21	8.14
Sea lamprey - Severn Estuary	CA	Adult spawning run (number of adults)	0.69	0.30	0.24	0.28	0.32	0.63	1.07	1.25	1.42	1.63
River lamprey - Severn Estuary	CA	Adult spawning run (number of adults)	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04
Atlantic salmon - Severn Estuary	CA	Adult spawning run (number of adults)	0.11	0.50	0.00	0.00	0.00	0.02	0.23	0.45	0.80	1.55
Sea trout - Severn Estuary	CA	Adult spawning run (number of adults)	0.12	0.08	0.02	0.03	0.03	0.10	0.21	0.26	0.32	0.40
Twaite shad - River Wye	CA	Adult spawning run (number of adults)	0.42	0.43	0.08	0.10	0.11	0.26	0.90	1.31	1.71	2.20
Twaite shad - River Usk	CA	Adult spawning run (number of adults)	0.83	0.86	0.17	0.19	0.22	0.52	1.82	2.62	3.43	4.43
Allis shad - River Wye	CA	Adult spawning run (number of adults)	3.72	3.95	0.68	0.80	0.92	2.32	8.10	11.74	15.42	20.29
Allis shad - River Usk	CA	Adult spawning run (number of adults)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Atlantic salmon - River Wye	CA	Adult spawning run (number of adults)	0.31	1.66	0.00	0.00	0.00	0.06	0.62	1.19	2.06	3.95
Atlantic salmon - River Usk	CA	Adult spawning run (number of adults)	0.35	1.34	0.00	0.00	0.00	0.07	0.71	1.34	2.36	4.63
Twaite shad – River Severn	CA	Adult spawning run (number of adults)	0.83	0.86	0.17	0.19	0.22	0.52	1.79	2.60	3.43	4.44
Allis shad – River Severn	CA	Adult spawning run (number of adults)	2.48	2.65	0.45	0.53	0.61	1.55	5.40	7.84	10.40	13.60
Atlantic salmon – River Severn	CA	Adult spawning run (number of adults)	0.58	2.46	0.00	0.00	0.01	0.12	1.18	2.27	3.93	7.56

Commented [MAP1]: Currently still under review

Appendix 1: Uncertainty analysis parameter data

Species	Parameter values and distributions																				
	N_{imp}	N_{imp}	N_{imp}	N_{add}	N_{add}	N_{add}	N_{ent}	N_{ent}	N_{ent}	F	F	F	A	A	A	V	V	V	M_{imp}	M_{imp}	M_{imp}
European sprat	13.868	0.272	log-normal	3557152	3557152	fixed value	3557152	3557152	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.955	1.000	uniform
Whiting	13.250	0.137	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.408	1.000	uniform
Dover sole	11.881	0.255	log-normal	1191823	1191823	fixed value	1106693	1106693	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.054	0.200	uniform
Atlantic cod	11.497	0.353	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.181	0.563	uniform
Atlantic herring	10.307	0.295	log-normal	221128	221128	fixed value	193487	193487	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.900	1.000	uniform
European seabass	8.871	0.116	log-normal	21590633	21590633	fixed value	20391153	20391153	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.301	0.953	uniform
European plaice	7.190	0.277	log-normal	2022534	2022534	fixed value	1300201	1300201	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.018	0.200	uniform
Thornback ray	6.676	0.211	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.409	0.545	uniform
Blue whiting	7.623	0.276	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.560	0.661	uniform
European eel - Severn Estuary	5.744	0.188	log-normal	0.000	0.000	fixed value	1581697	1581697	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.109	0.200	uniform
Twaite shad - Severn Estuary	6.410	0.269	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.955	1.000	uniform
Allis shad - Severn Estuary	2.905	0.326	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	1.000	1.000	uniform
Sea lamprey - Severn Estuary	3.833	0.363	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.340	0.407	uniform
River lamprey - Severn Estuary	2.905	0.326	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	1.000	1.000	fixed value	0.109	0.200	uniform
Atlantic salmon - Severn Estuary	4.109	0.584	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.970	1.000	uniform
Sea trout - Severn Estuary	1.884	0.581	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	1.000	1.000	uniform
Twaite shad - River Wye	6.410	0.269	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.955	1.000	uniform
Twaite shad - River Usk	6.410	0.269	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.955	1.000	uniform
Allis shad - River Wye	2.905	0.326	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	1.000	1.000	uniform
Allis shad - River Usk	2.905	0.326	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	1.000	1.000	uniform
Atlantic salmon - River Wye	4.081	0.659	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.970	1.000	uniform
Atlantic salmon - River Usk	4.081	0.659	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.970	1.000	uniform
Twaite shad – River Severn	6.410	0.269	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.9552	1.000	uniform
Allis shad – River Severn	2.905	0.326	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	1.000	1.000	fixed value
Atlantic salmon – River Severn	4.109	0.584	log-normal	0.000	0.000	fixed value	0.000	0.000	fixed value	3.913	3.913	fixed value	1.240	1.591	uniform	0.180	0.280	uniform	0.9697	1.000	uniform

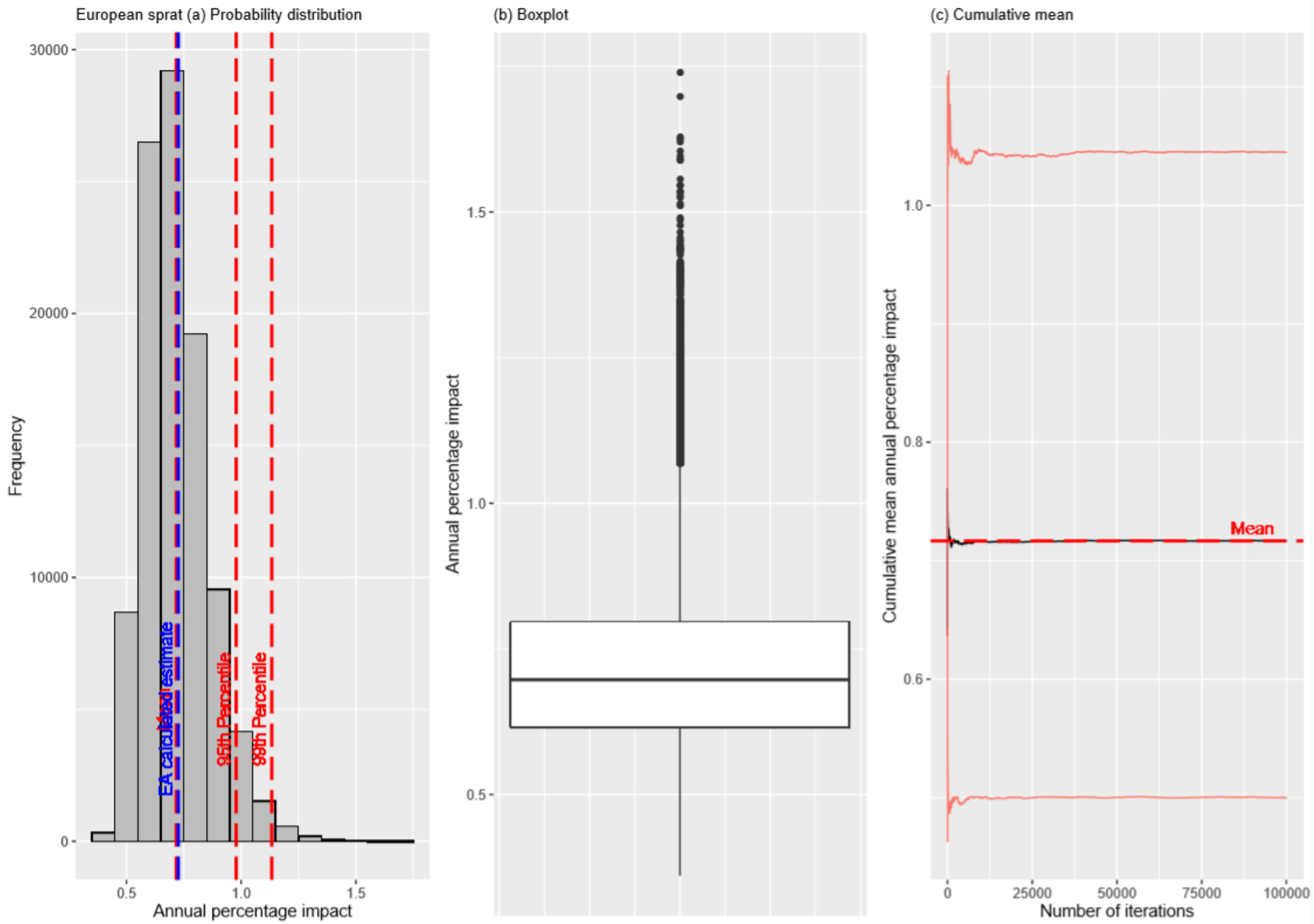
Species	EAV_{imp}	EAV_{imp}	EAV_{imp}	M_{add}	M_{add}	M_{add}	EAV_{add}	EAV_{add}	EAV_{add}	M_{ent}	M_{ent}	M_{ent}	EAV_{ent}	EAV_{ent}	EAV_{ent}	W	W	W	P	P	P
European sprat	1.586	0.002	normal	0.955	1.000	uniform	0.369	0.005	normal	1.000	1.000	fixed value	0.032	0.001	normal	0.00002	0.00002	fixed value	7062.000	8346.000	uniform
Whiting	0.338	0.439	uniform	0.408	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	0.0003	0.0003	fixed value	7.687	0.326	log-normal
Dover sole	1.070	1.070	fixed value	0.054	0.200	uniform	0.005	0.005	fixed value	1.000	1.000	fixed value	0.000	0.000	fixed value	0.0004	0.0004	fixed value	6.695	0.326	log-normal
Atlantic cod	0.171	0.171	fixed value	0.181	0.563	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	0.005	0.005	fixed value	7.019	0.326	log-normal
Atlantic herring	1.711	0.006	normal	0.900	1.000	uniform	0.198	0.006	normal	1.000	1.000	fixed value	0.001	0.000	normal	0.00007	0.00007	fixed value	156.750	156.750	fixed value
European seabass	0.582	0.582	fixed value	0.301	0.953	uniform	0.000	0.000	fixed value	0.300	0.300	fixed value	0.000	0.000	fixed value	0.001	0.001	fixed value	6.337	0.064	log-normal
European plaice	0.564	0.004	normal	0.018	0.200	uniform	0.024	0.002	normal	1.000	1.000	fixed value	0.000	0.000	normal	0.0003	0.0003	fixed value	7.194	0.326	log-normal
Thornback ray	0.556	0.034	normal	0.409	0.545	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	0.003	0.003	fixed value	121.774	121.774	fixed value
Blue whiting	0.338	0.439	uniform	0.560	0.661	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	0.0001	0.0001	fixed value	13.150	0.326	log-normal
European eel - Severn Estuary	1.000	1.000	fixed value	0.109	0.200	uniform	1.000	1.000	fixed value	0.218	0.340	fixed value	0.084	0.084	fixed value	0.00024	0.00024	fixed value			
Twaite shad - Severn Estuary	0.153	0.008	normal	0.955	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	10276	173204	uniform
Allis shad - Severn Estuary	0.410	0.466	uniform	1.000	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	128.000	2165	uniform
Sea lamprey - Severn Estuary	1.000	1.000	fixed value	0.340	0.407	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	10687.000	19851.000	uniform
River lamprey - Severn Estuary	1.000	1.000	fixed value	0.109	0.200	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	78069.000	154149.000	uniform
Atlantic salmon - Severn Estuary	-2.844	1.636	log-normal	0.970	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	9738.000	28385.000	uniform
Sea trout - Severn Estuary	1.000	1.000	fixed value	1.000	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	6500.000	11000.000	uniform
Twaite shad - River Wye	0.153	0.008	normal	0.955	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	5138.000	86602.000	uniform
Twaite shad - River Usk	0.153	0.008	normal	0.955	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	2569.000	43301.000	uniform
Allis shad - River Wye	0.410	0.466	uniform	1.000	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	51.000	866.000	uniform
Allis shad - River Usk	0.410	0.466	uniform	1.000	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	0.000	0.000	uniform
Atlantic salmon - River Wye	-2.844	1.636	log-normal	0.970	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	2519.000	13001.000	uniform
Atlantic salmon - River Usk	-2.844	1.636	log-normal	0.970	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	3403.000	8966.000	uniform
Twaite shad – River Severn	0.153	0.008	normal	0.9552	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	2569.000	43301.000	uniform
Allis shad – River Severn	0.410	0.466	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	77.000	1299.000	uniform
Atlantic salmon – River Severn	-2.844	1.636	log-normal	0.9697	1.000	uniform	1.000	1.000	fixed value	1.000	1.000	fixed value	1.000	1.000	fixed value	NA	NA	NA	1832.000	5698.000	uniform

Commented [MAP2]: Currently still under review

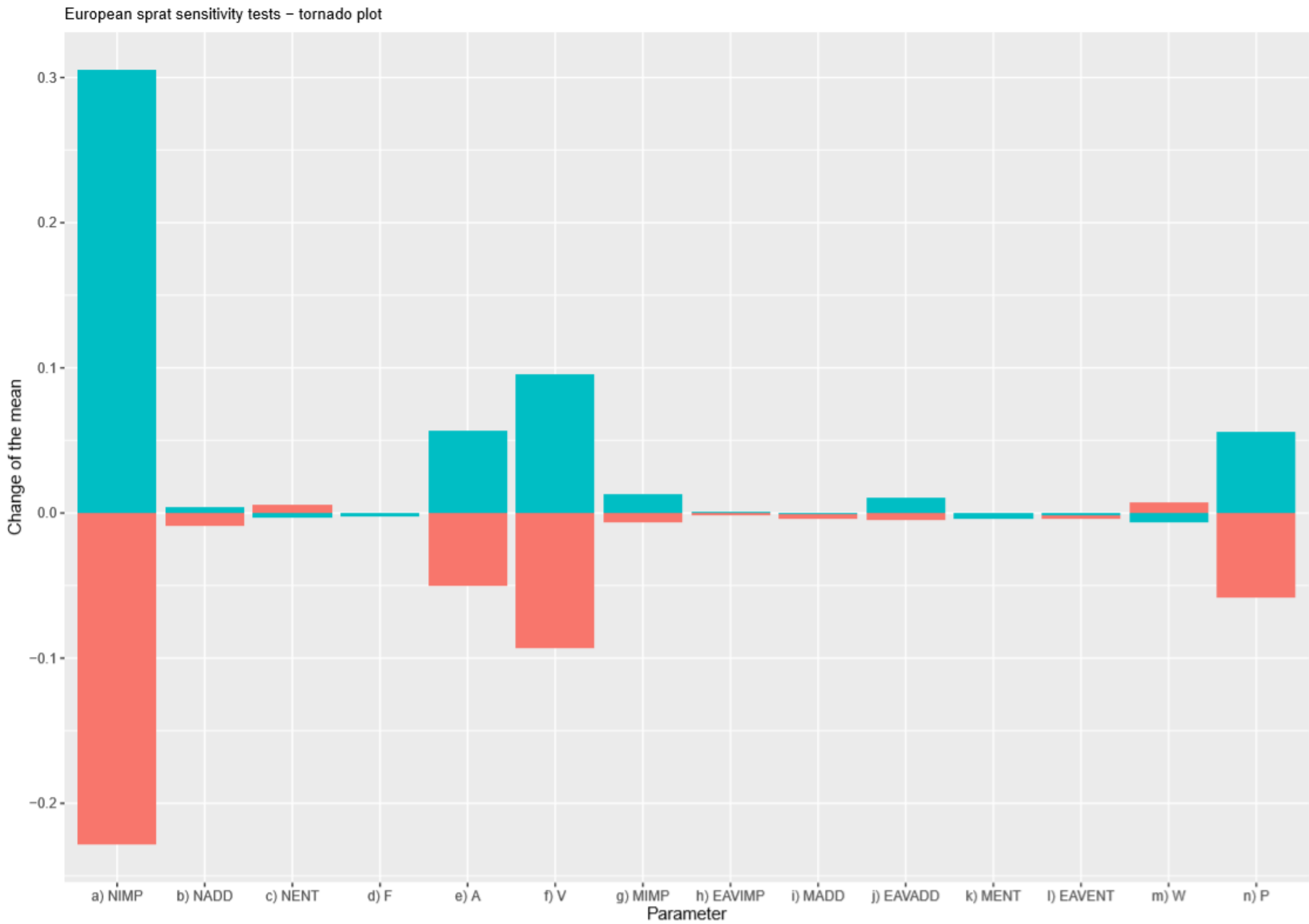
Data notes

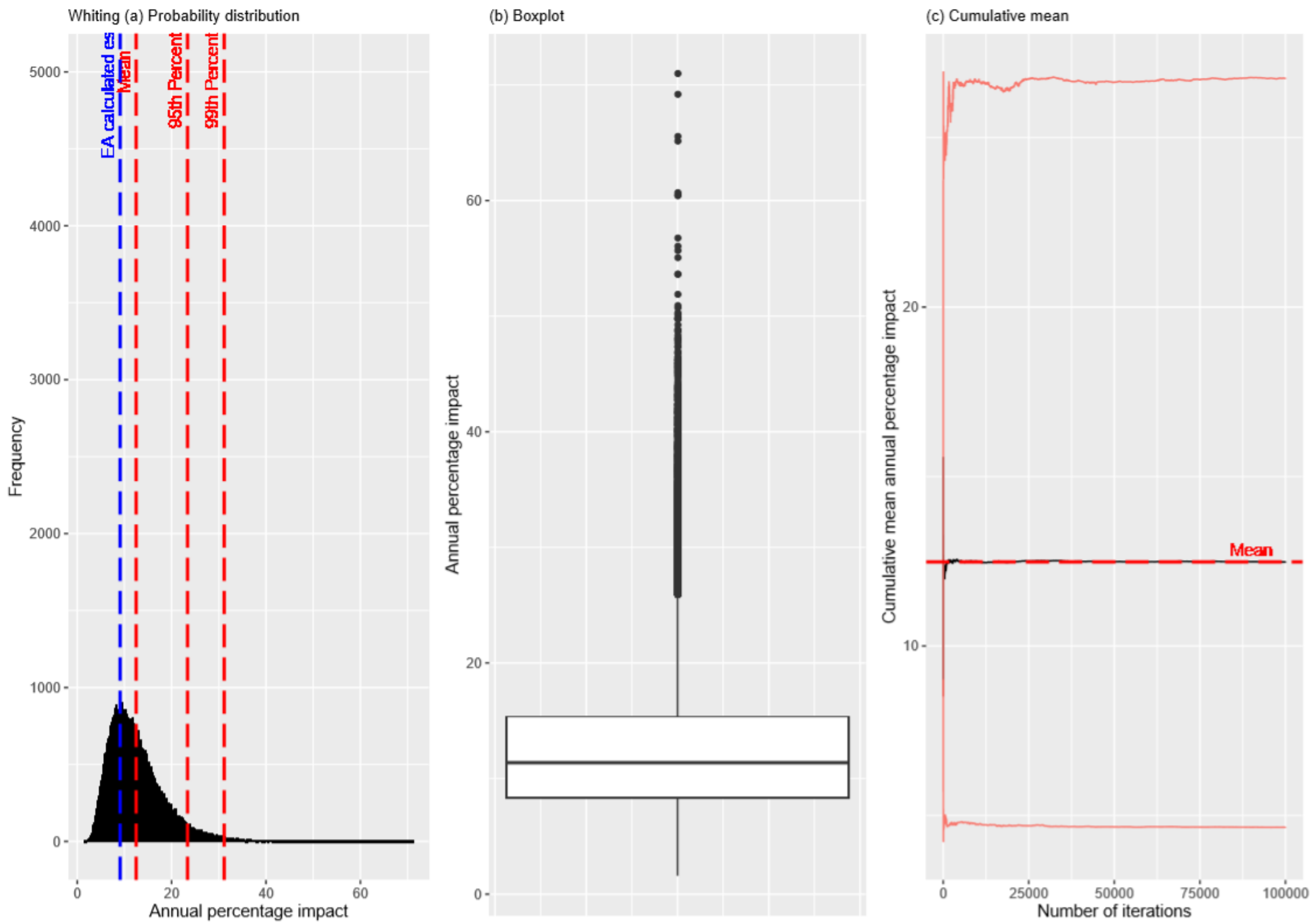
- Where log-normal distributions are used, the parameter values presented in the table are meanlog and sdlog for use in R. These have been converted from the raw mean and standard deviation estimates provided.
- Where uniform distributions are used, the parameter values are the minimum and maximums of the distribution.
- Where normal distributions are used, the parameter estimates are the mean and standard deviation of the distribution.
- Where fixed values are used, the parameter values are the minimum and maximums of the distribution but both are assigned the same value. When applied within R, this generates the same value each time.
- For the entrainment and additional impingement estimates, where there are zeroes this may be an outstanding uncertainty for this parameter that cannot be quantified at present as no entrainment estimates were provided at the DCO stage.
- Where an EAV has not been calculated for a species (see ***EAV Evidence Report***, ***Entrainment and Screen Size Evidence Report, Twaite shad and allis shad EAV Evidence Report***), a value of 1 has been used within the models.
- Where weight is assigned NA, the assessment is made against numbers of adults rather than weight of adults.
- Atlantic herring and thornback ray are both assessed against the size of the fishery, as full population size estimates for these species are not available for the population ranges selected.

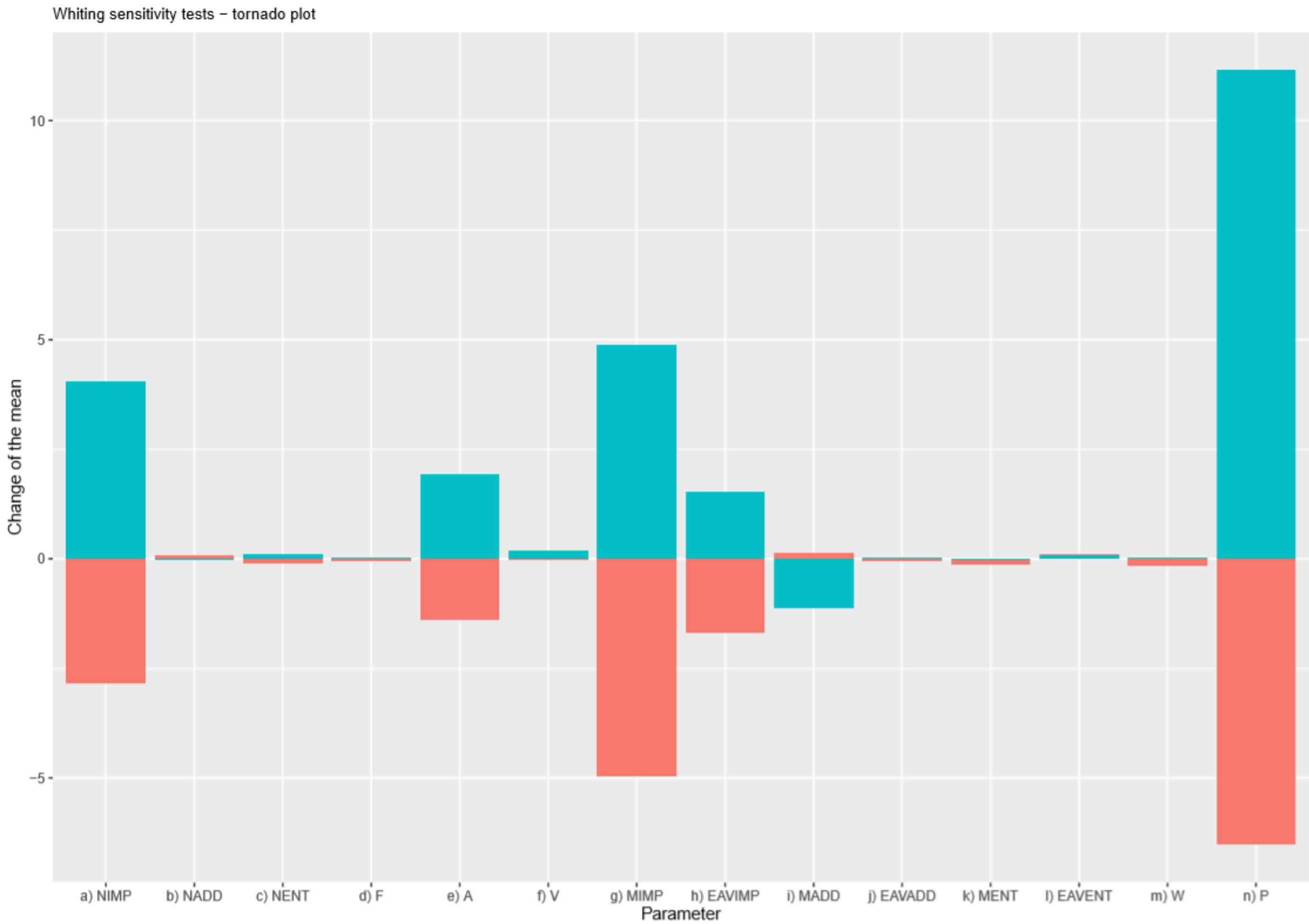
Appendix 2: Uncertainty analysis results and sensitivity testing graphical outputs

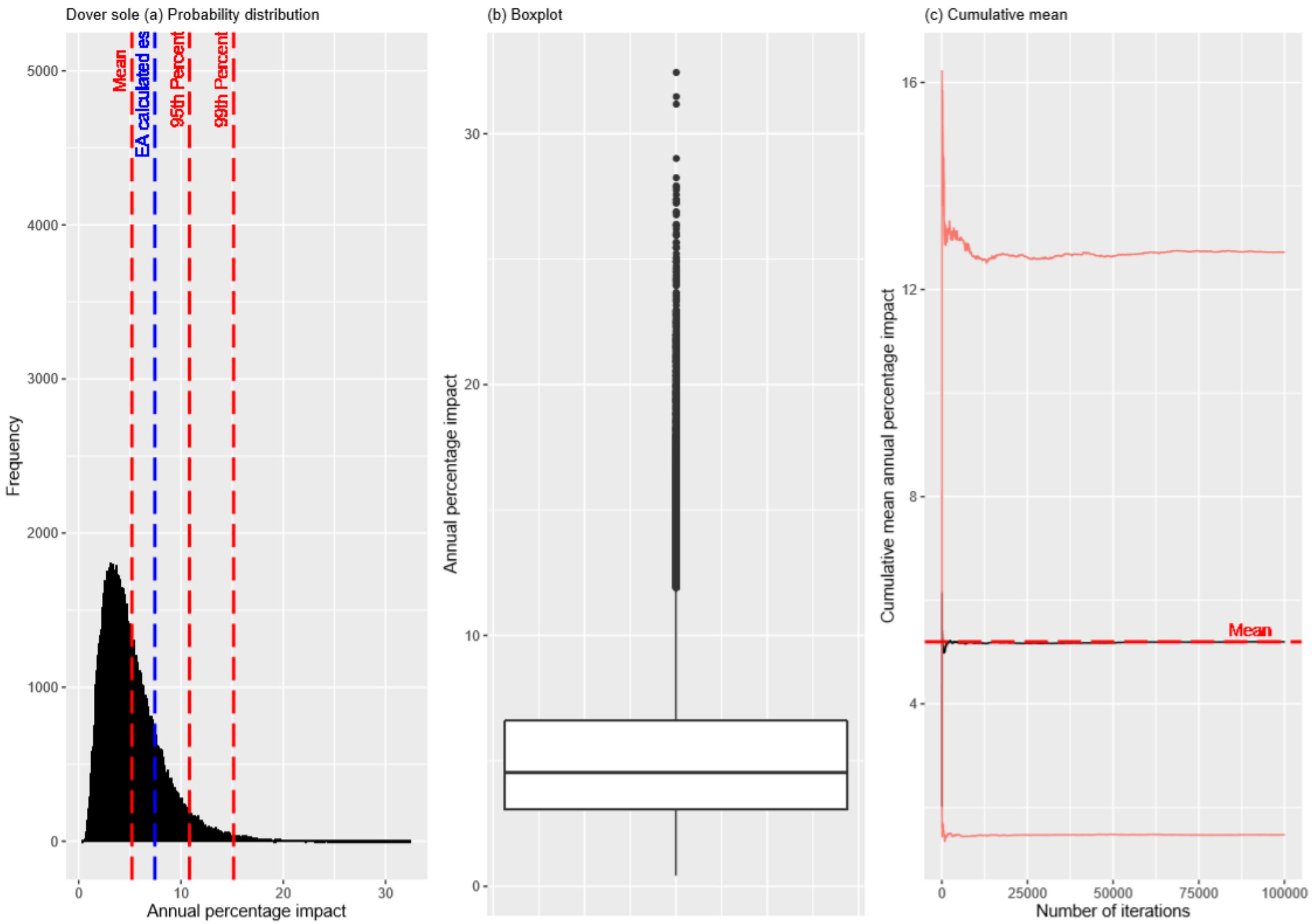


European sprat (a) Probability distribution
(b) Boxplot
(c) Cumulative mean
Frequency
Annual percentage impact
EA calculated estimate
Mean
95th Percentile
99th Percentile
Cumulative mean annual percentage impact
Number of iterations

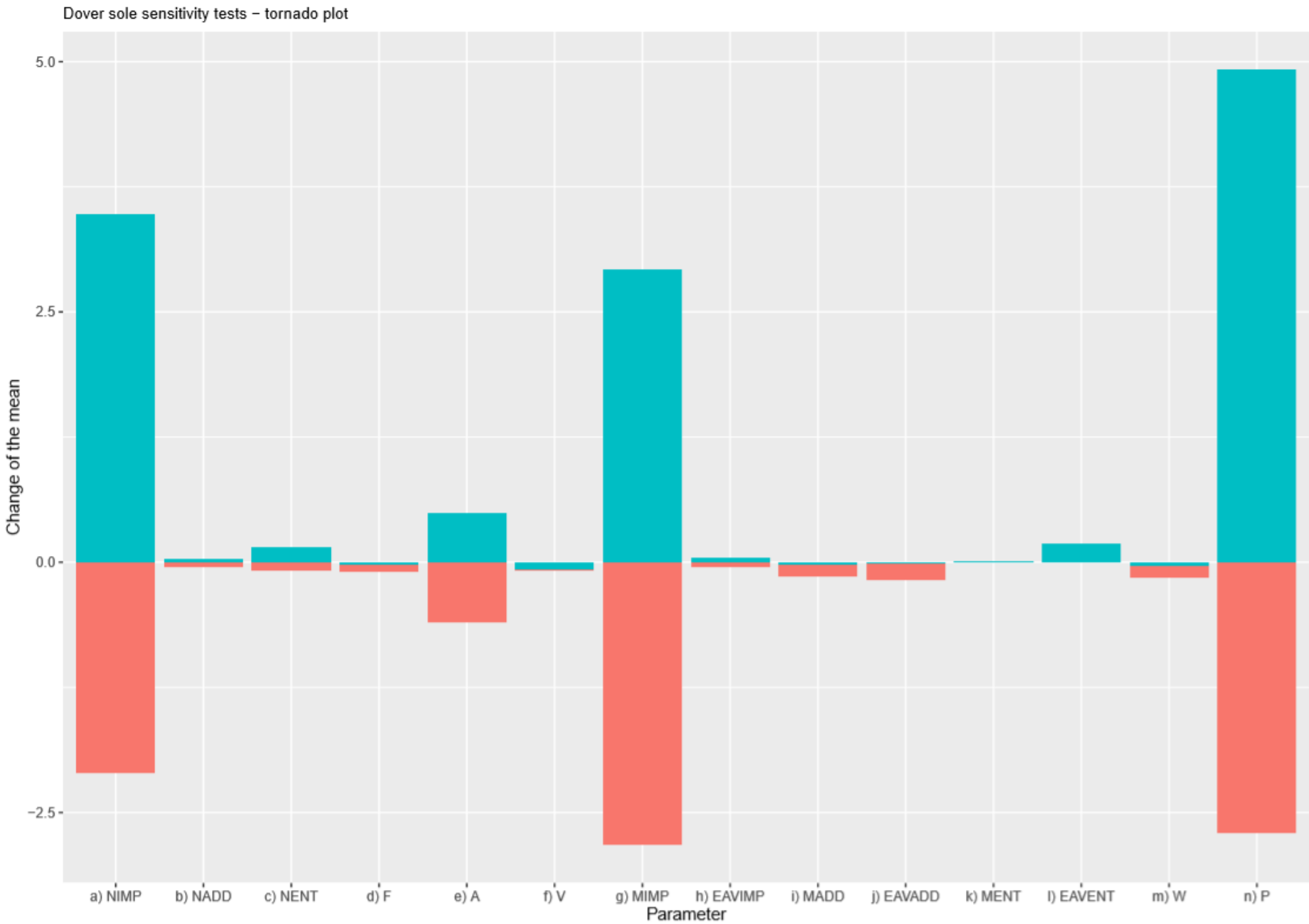

European sprat sensitivity tests – tornado plot
Change of the mean
0.3
0.2
0.1
0.0
−0.1
−0.2
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter


Whiting (a) Probability distribution
EA calculated es
Mean
95th Percent
99th Percent
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Mean
Cumulative mean annual percentage impact
Number of iterations

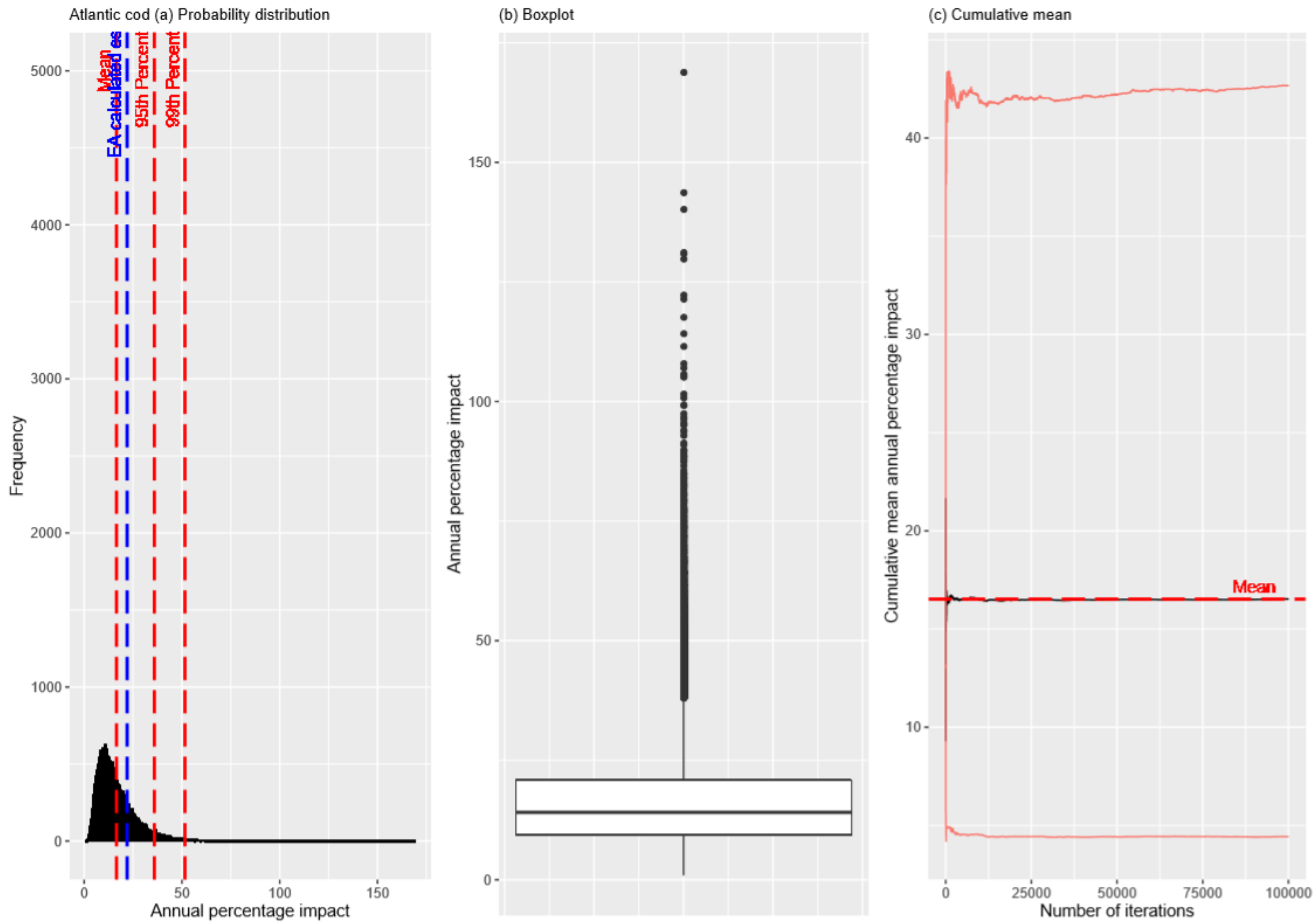

Whiting sensitivity tests – tornado plot
Change of the mean
10
5
0
−5
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

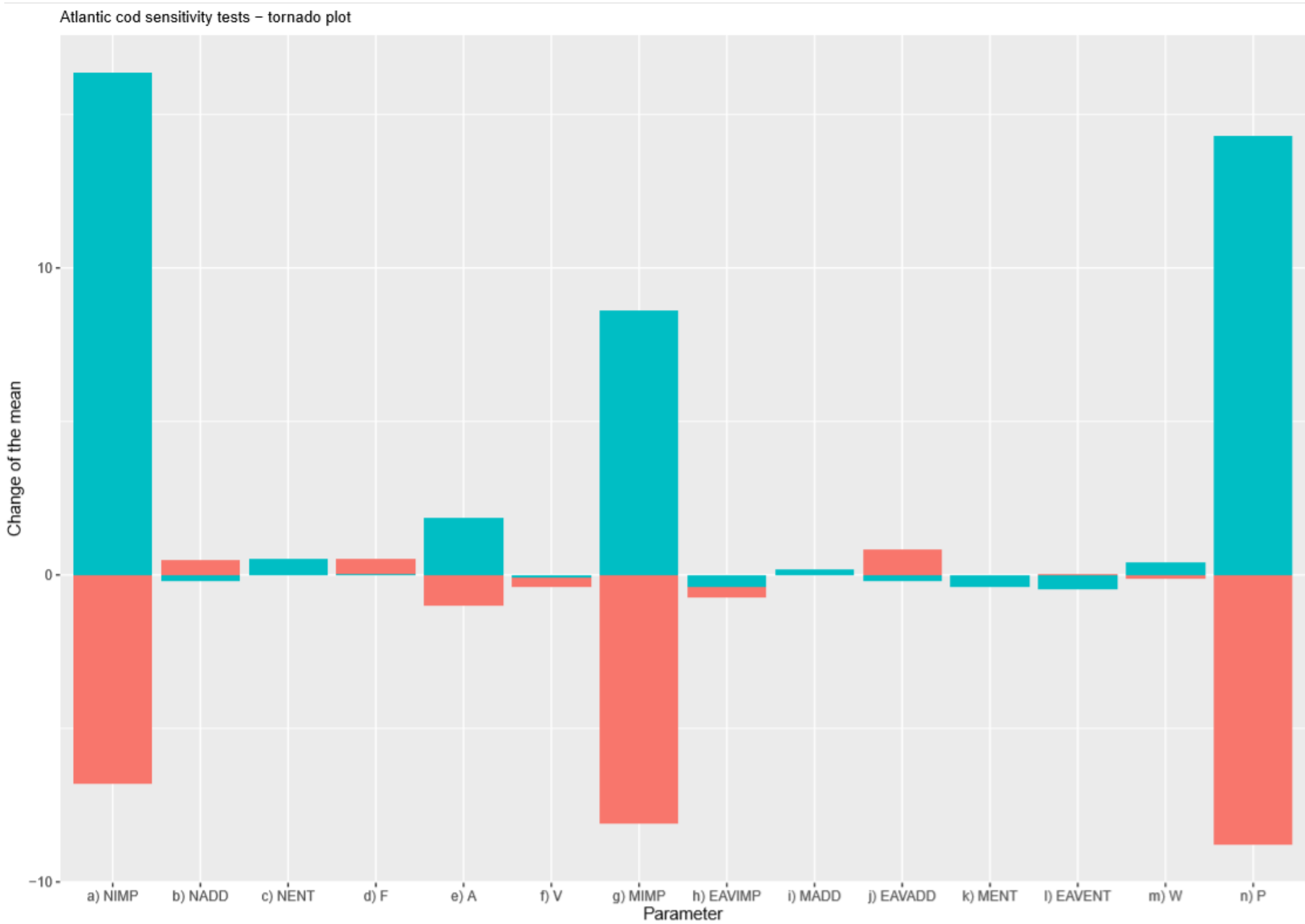


Dover sole (a) Probability distribution
Mean
EA calculated es
95th Percent
99th Percent
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations

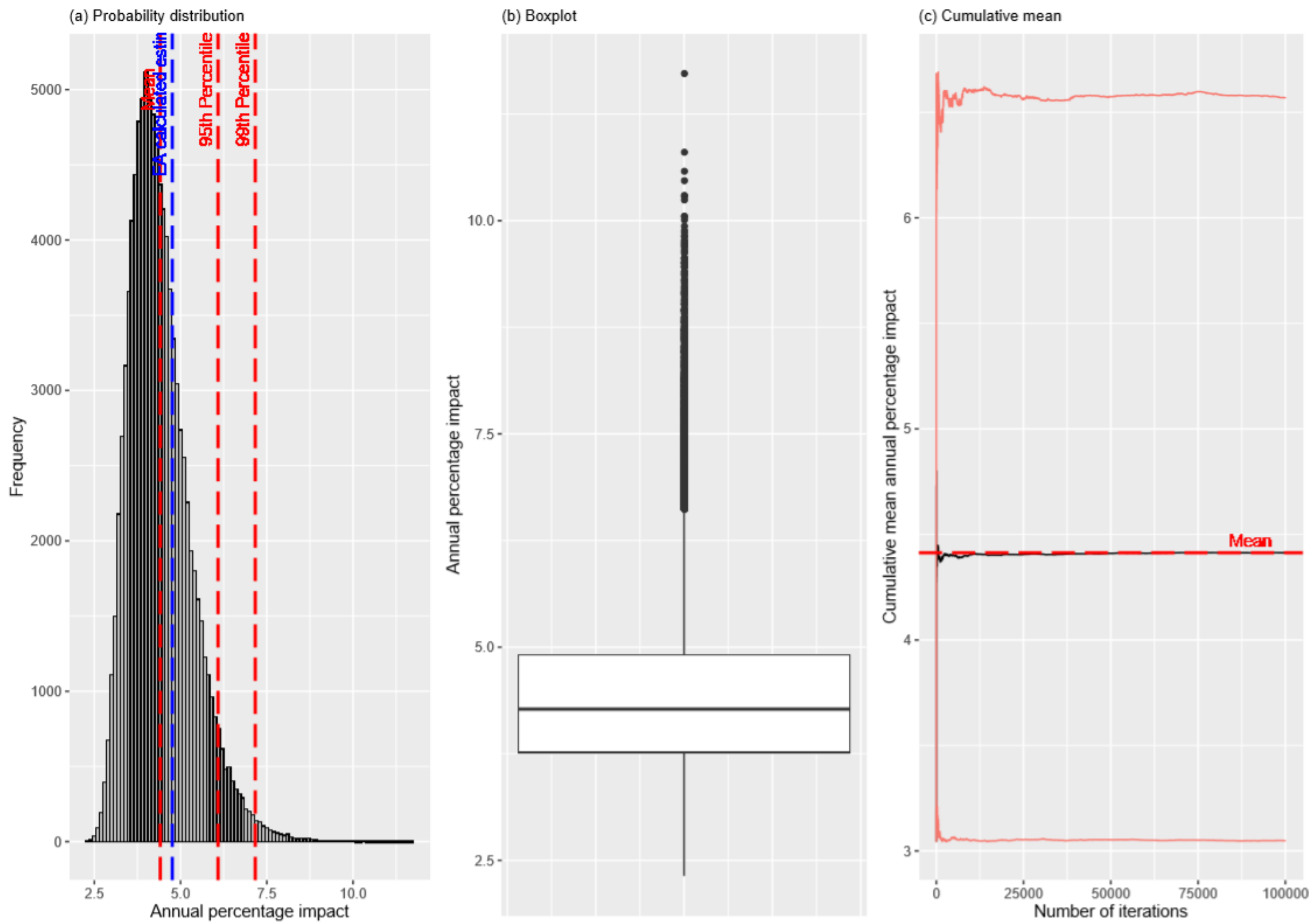


Dover sole sensitivity tests – tornado plot
5.0
2.5
0.0
−2.5
Change of the mean
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

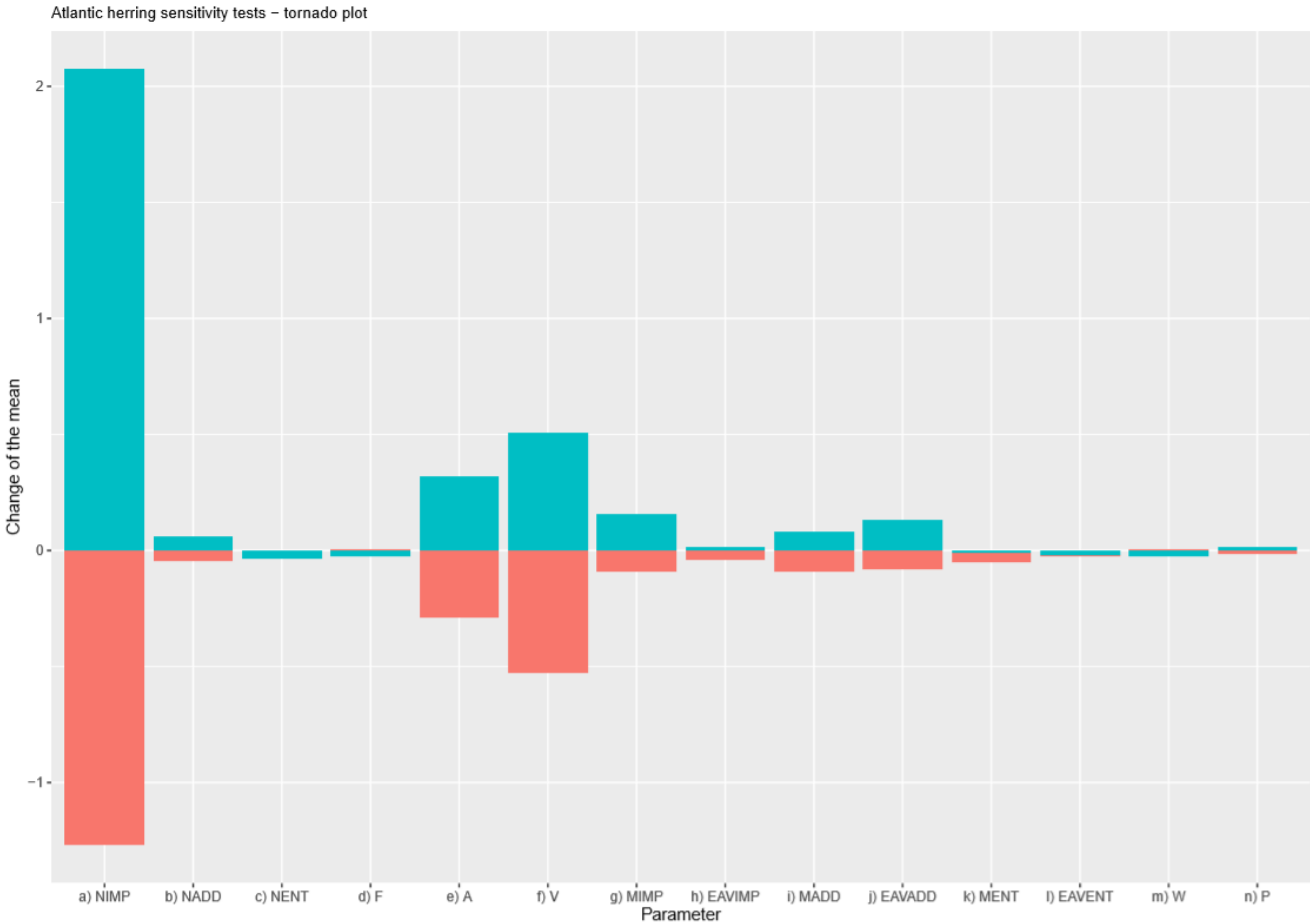

Atlantic cod (a) Probability distribution
Mean
EA calculated es
95th Percent
99th Percent
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations

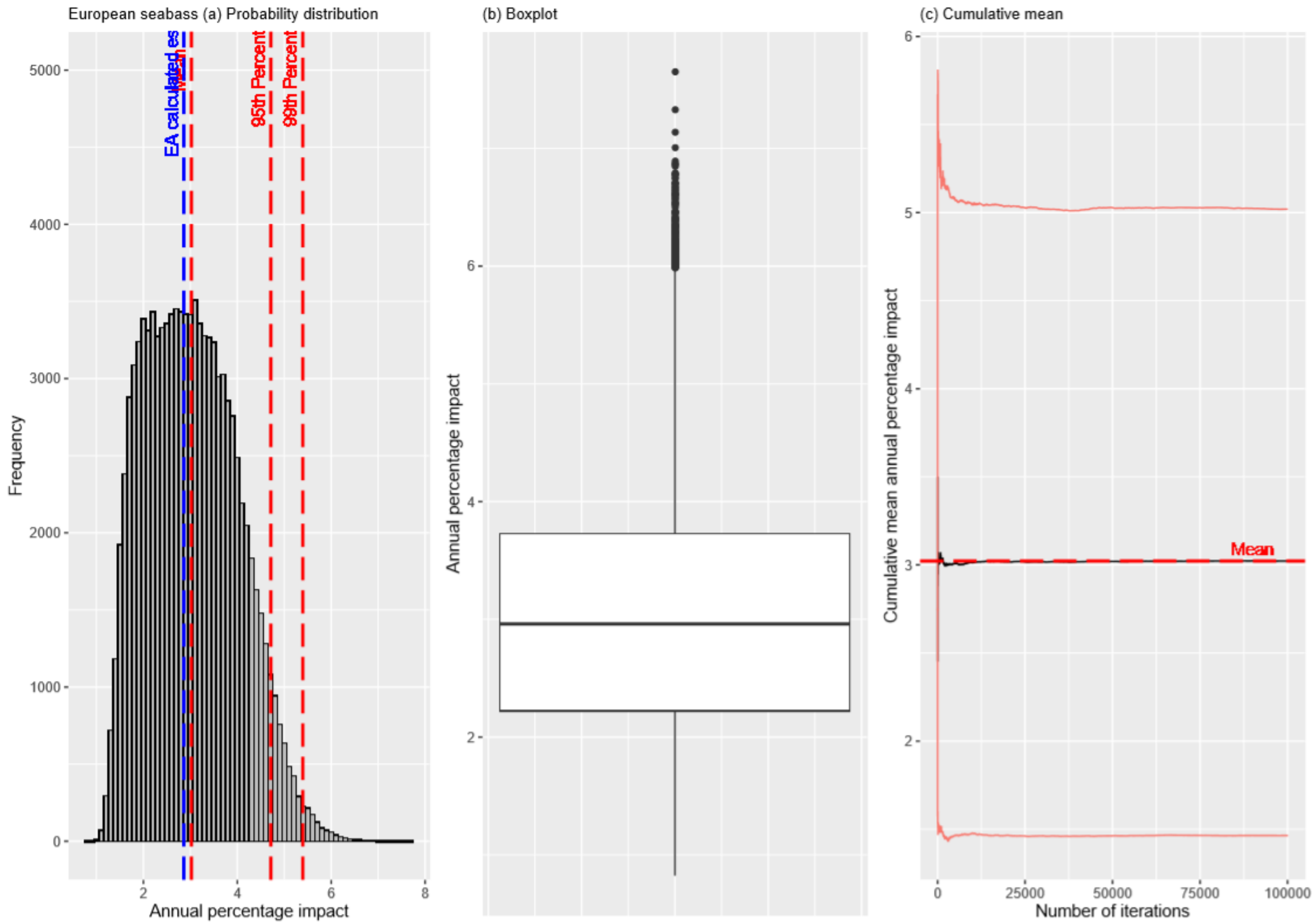


Atlantic cod sensitivity tests − tornado plot
Change of the mean
10
0
−10
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

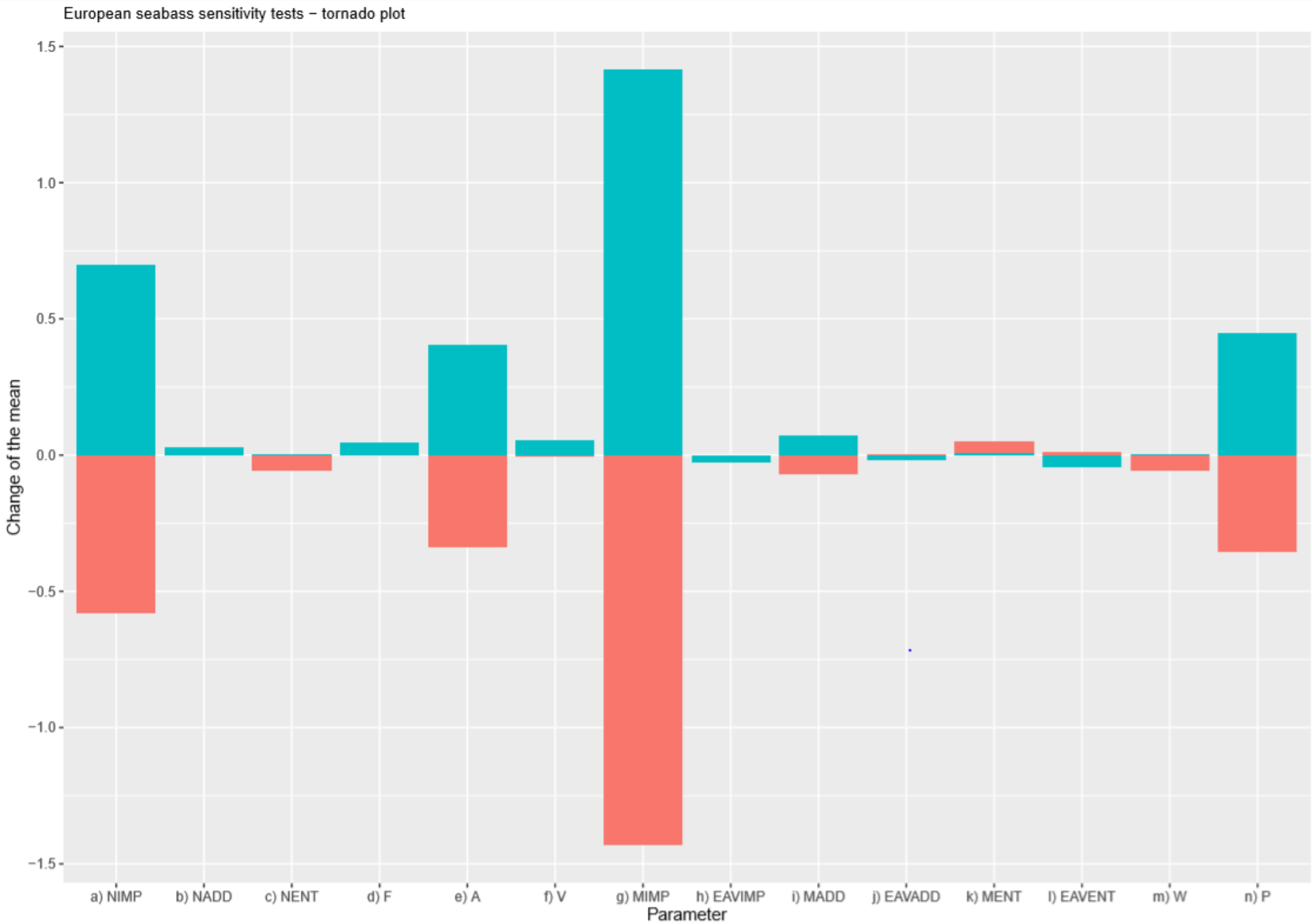


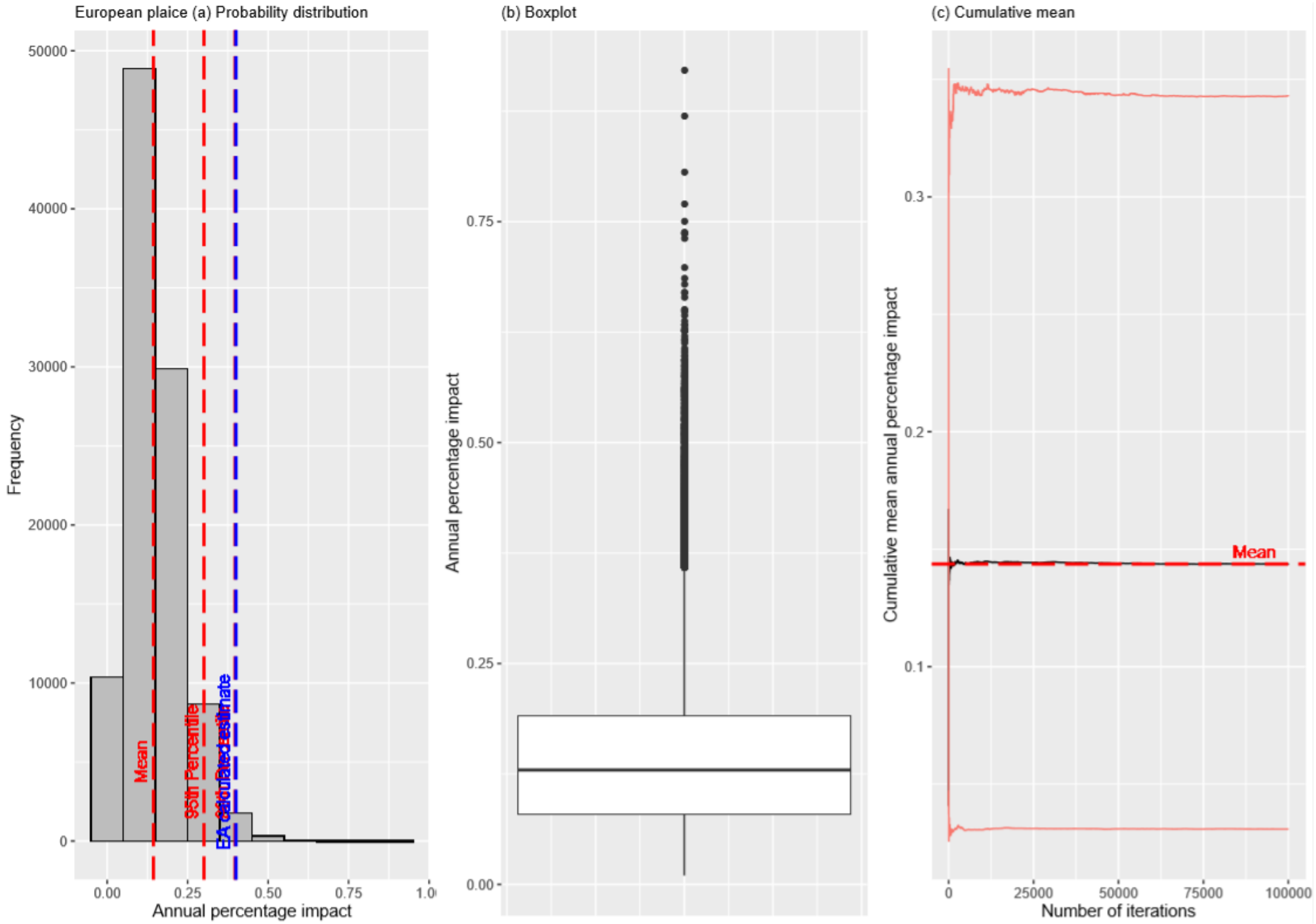
(a) Probability distribution
Mean
EA calculated estim
95th Percentile
99th Percentile
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations


Atlantic herring sensitivity tests – tornado plot
Change of the mean
2
1
0
−1
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

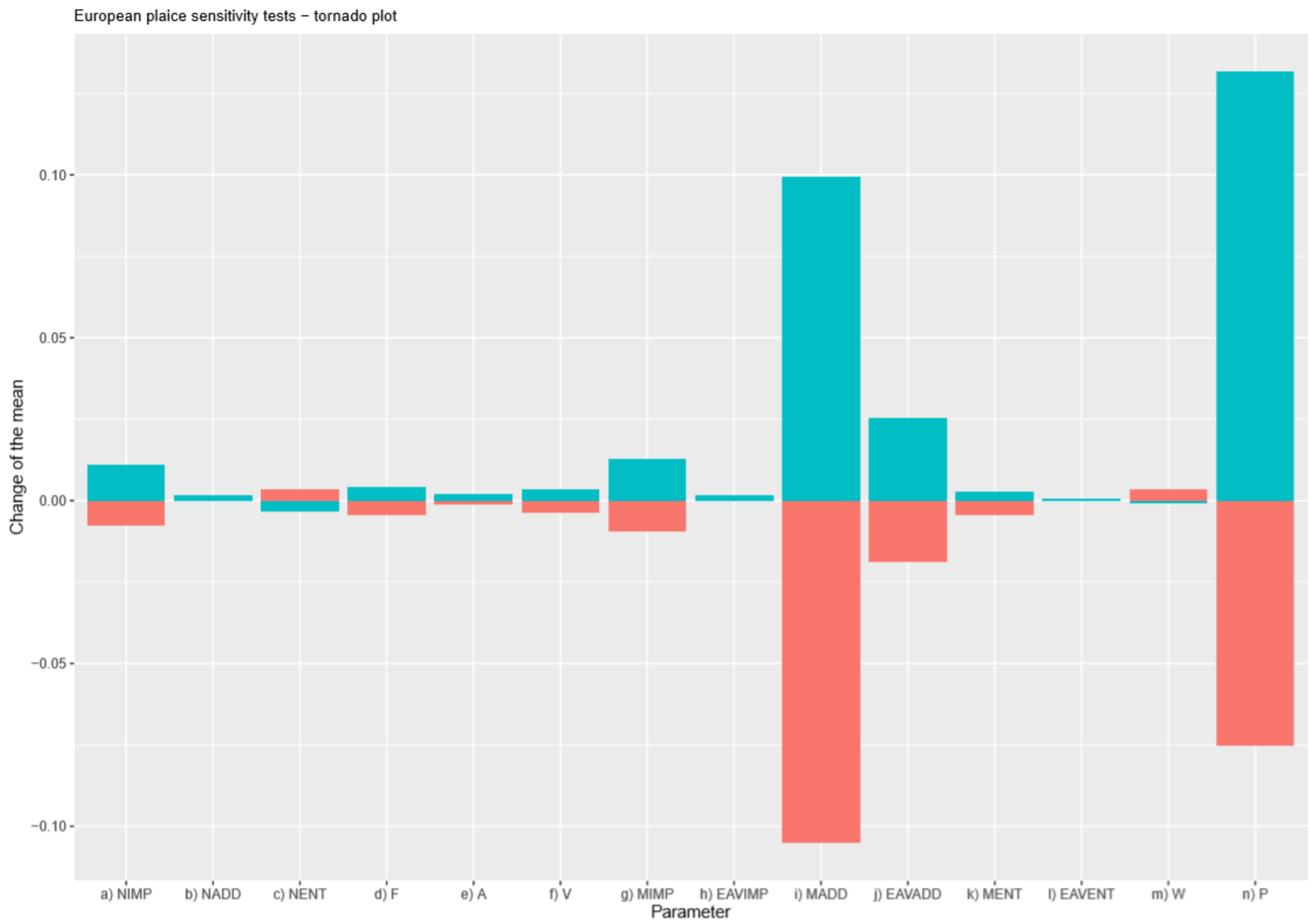


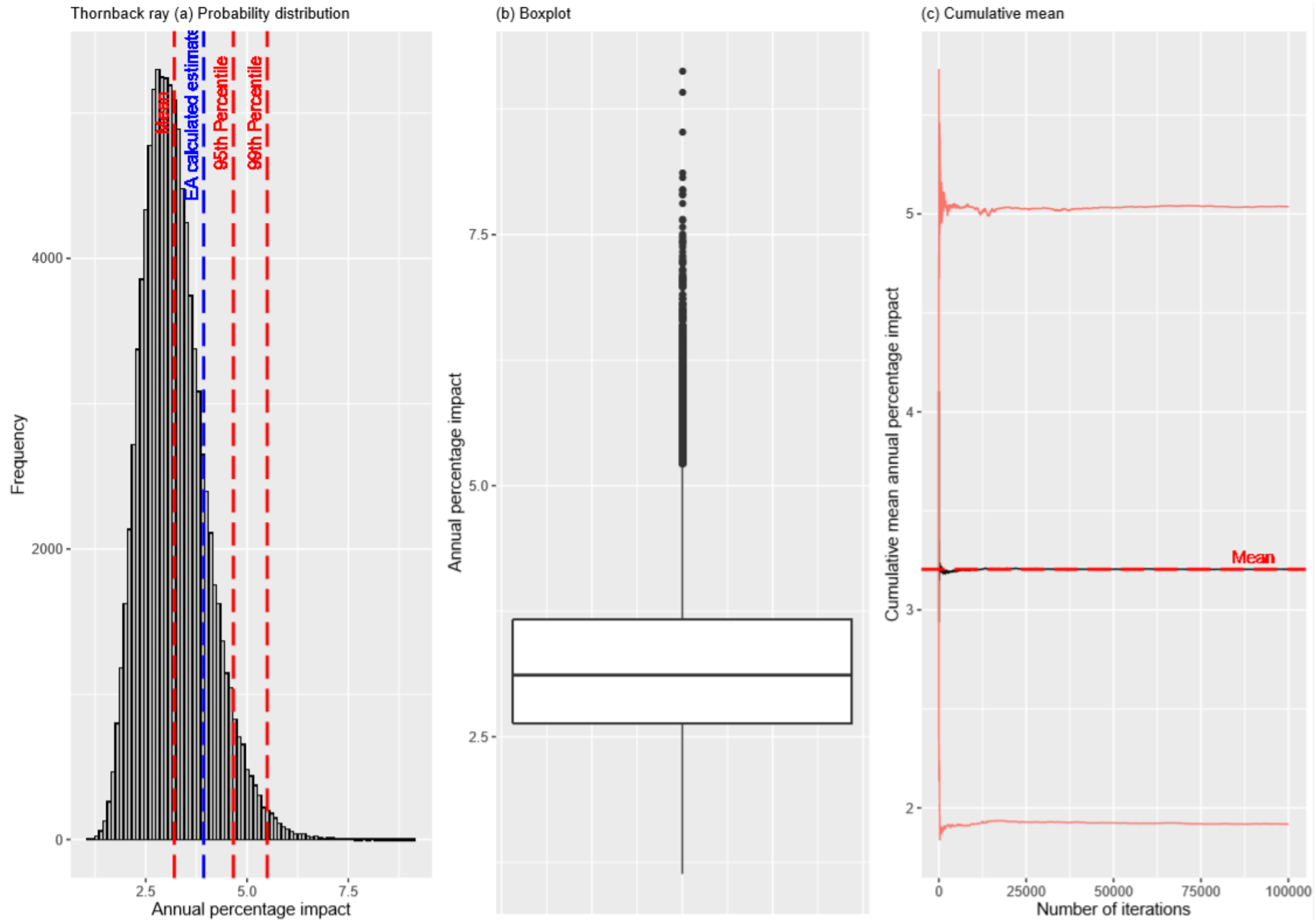
European seabass (a) Probability distribution
EA calculated es
Mean
95th Percent
99th Percent
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Mean
Cumulative mean annual percentage impact
Number of iterations


European seabass sensitivity tests – tornado plot
Change of the mean
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

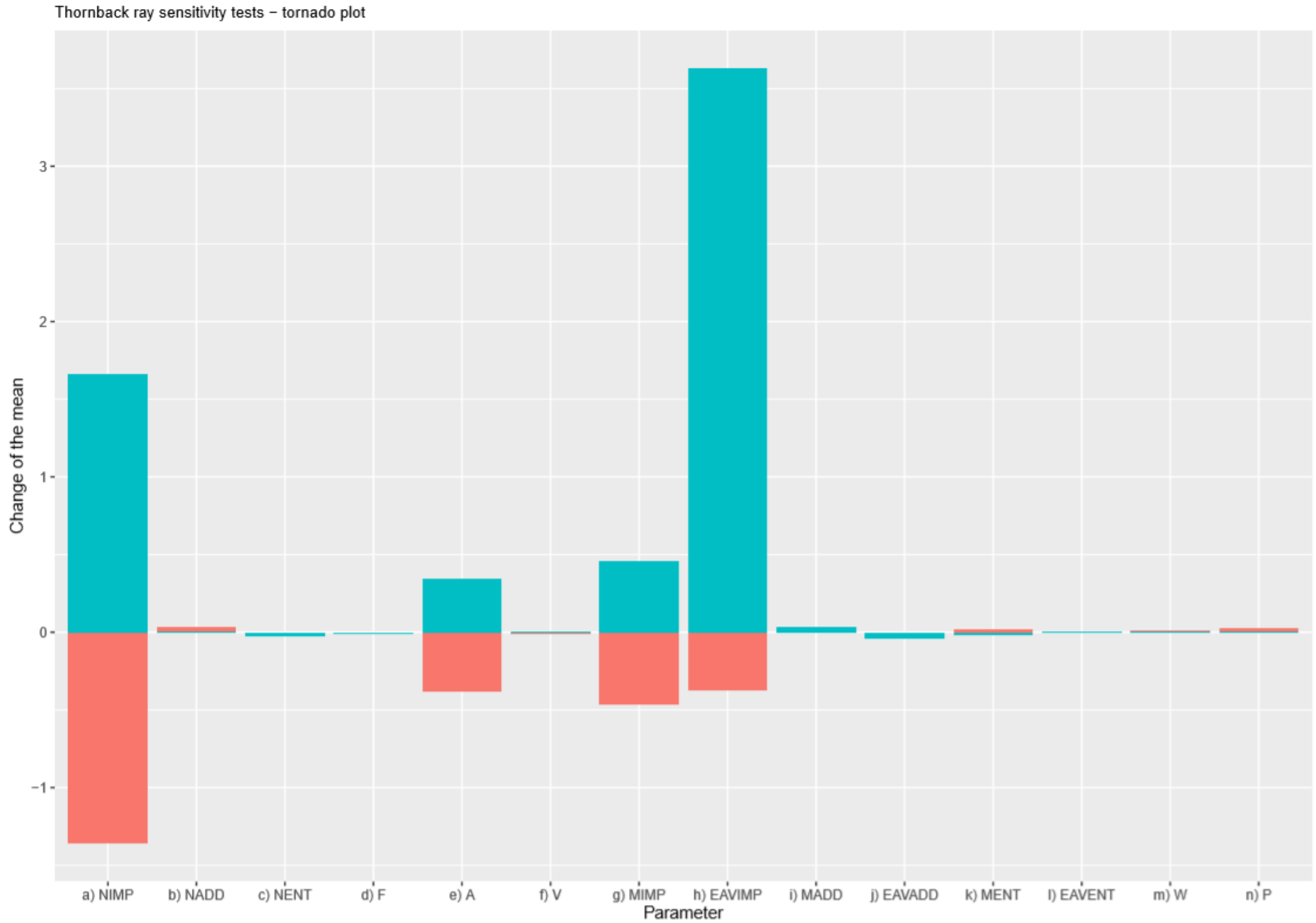


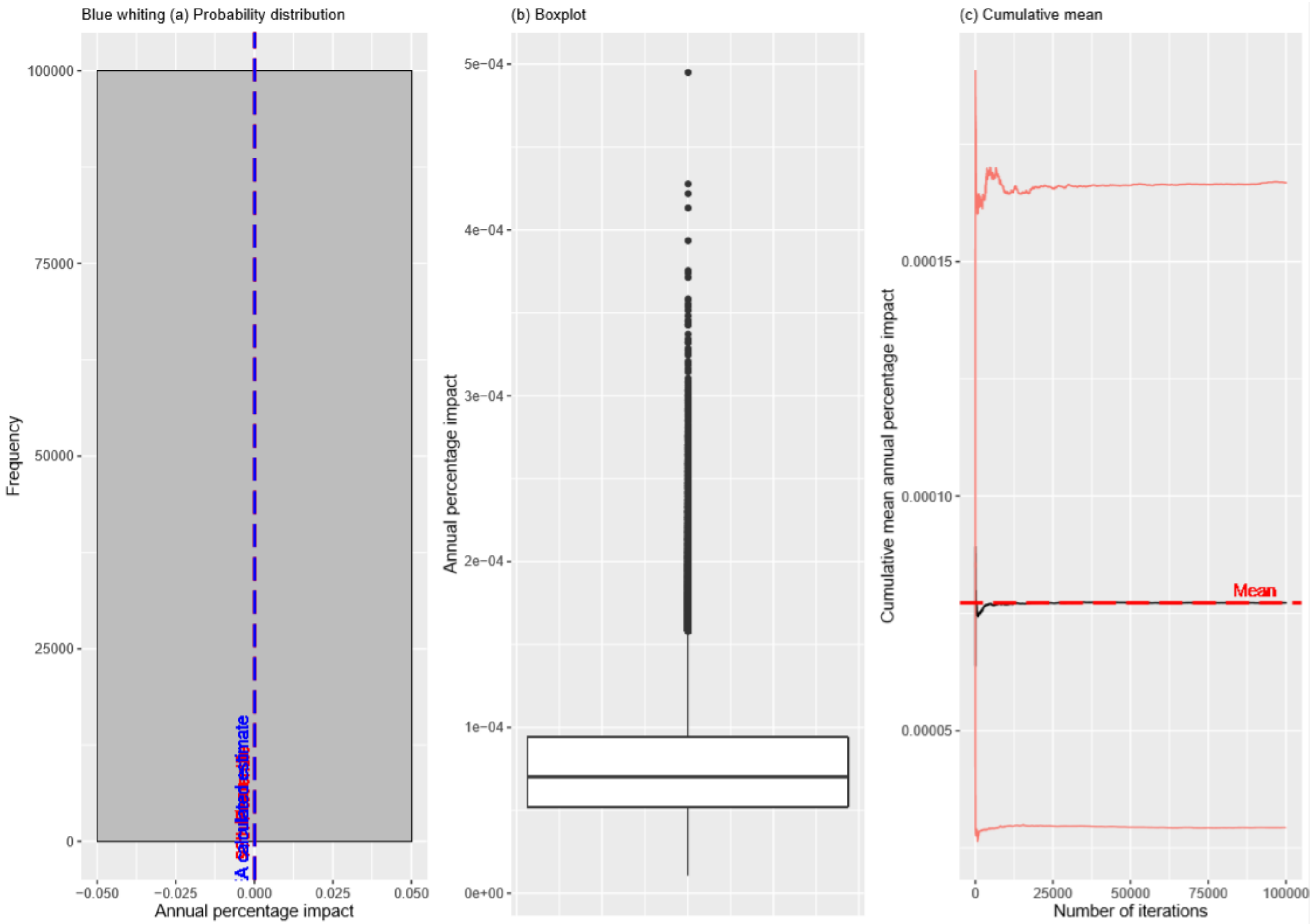
European plaice (a) Probability distribution
Frequency
Annual percentage impact
Mean
95th Percentile
EA calculated estimate
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean


European plaice sensitivity tests – tornado plot
Change of the mean
0.10
0.05
0.00
−0.05
−0.10
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

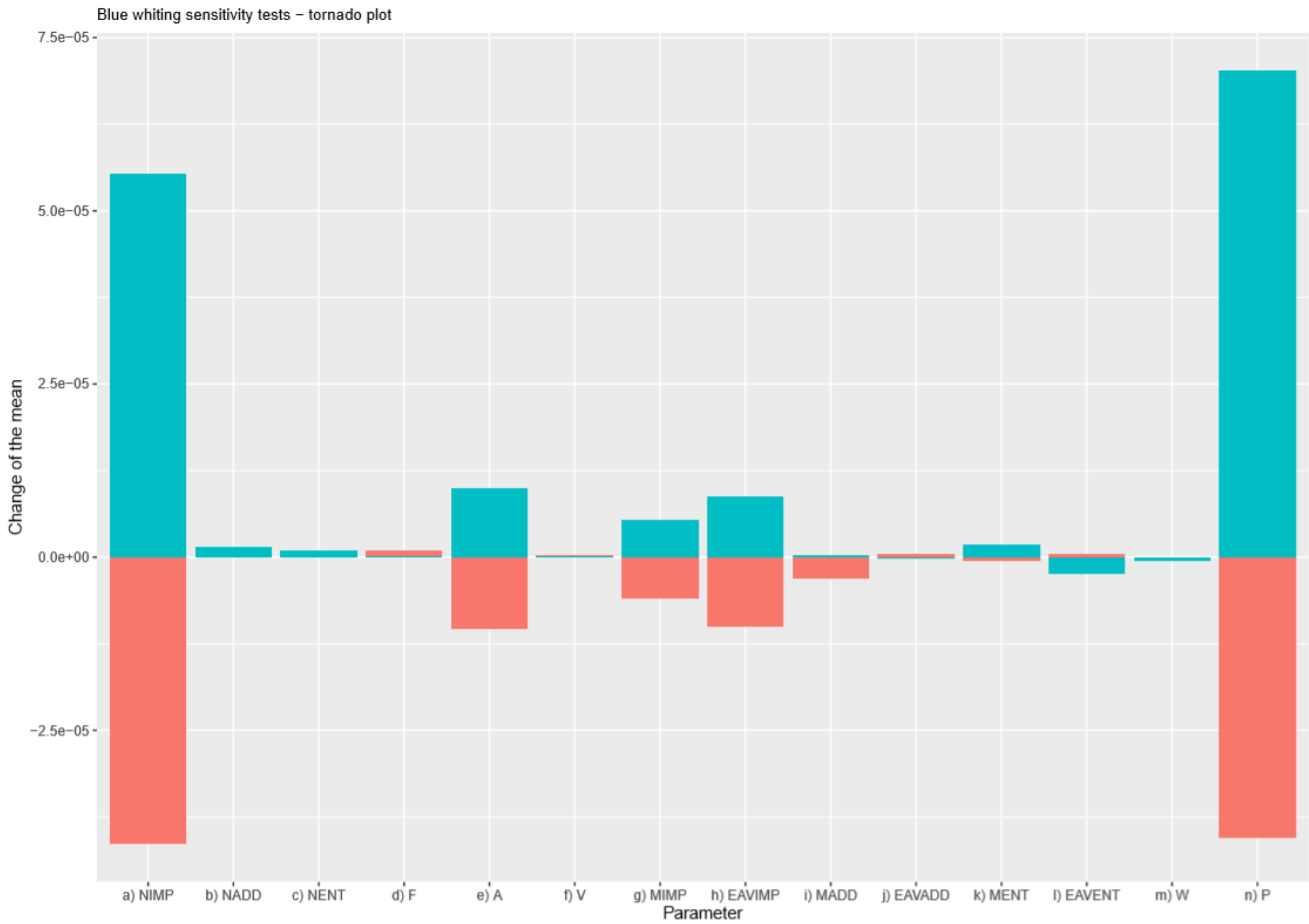


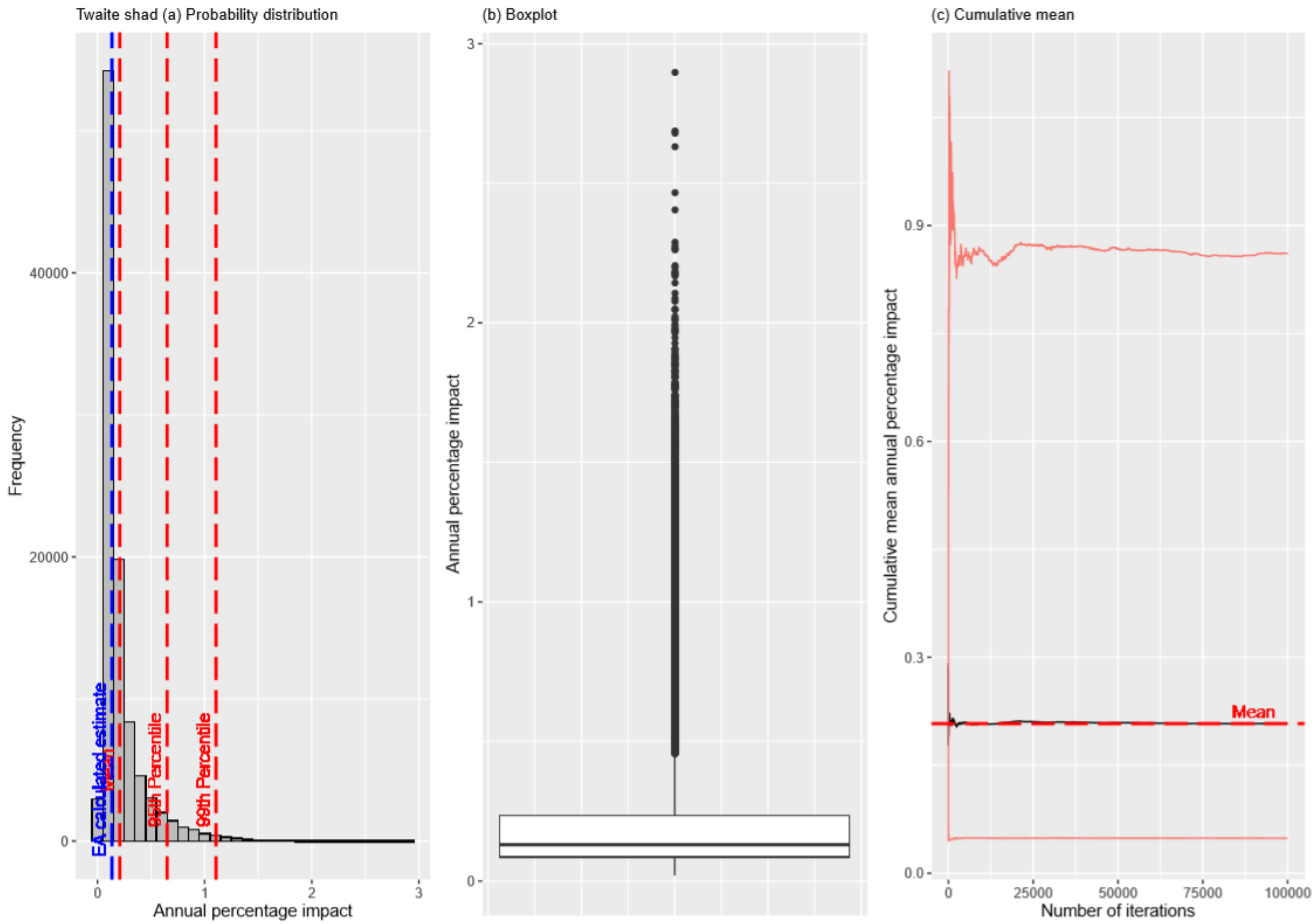
Thornback ray (a) Probability distribution
Mean
EA calculated estimate
95th Percentile
99th Percentile
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Mean
Cumulative mean annual percentage impact
Number of iterations

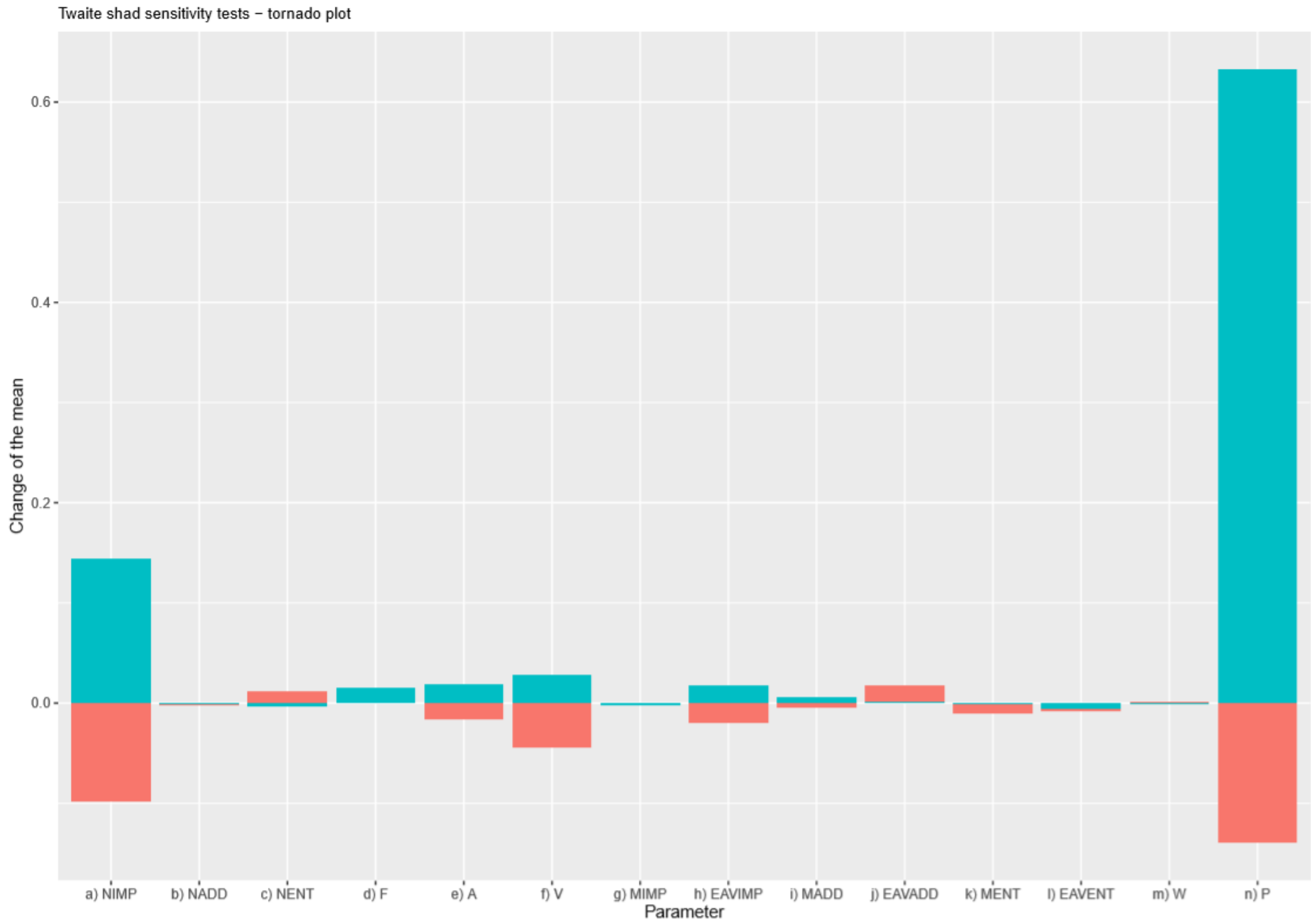

Thornback ray sensitivity tests – tornado plot
Change of the mean
3
2
1
0
−1
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter



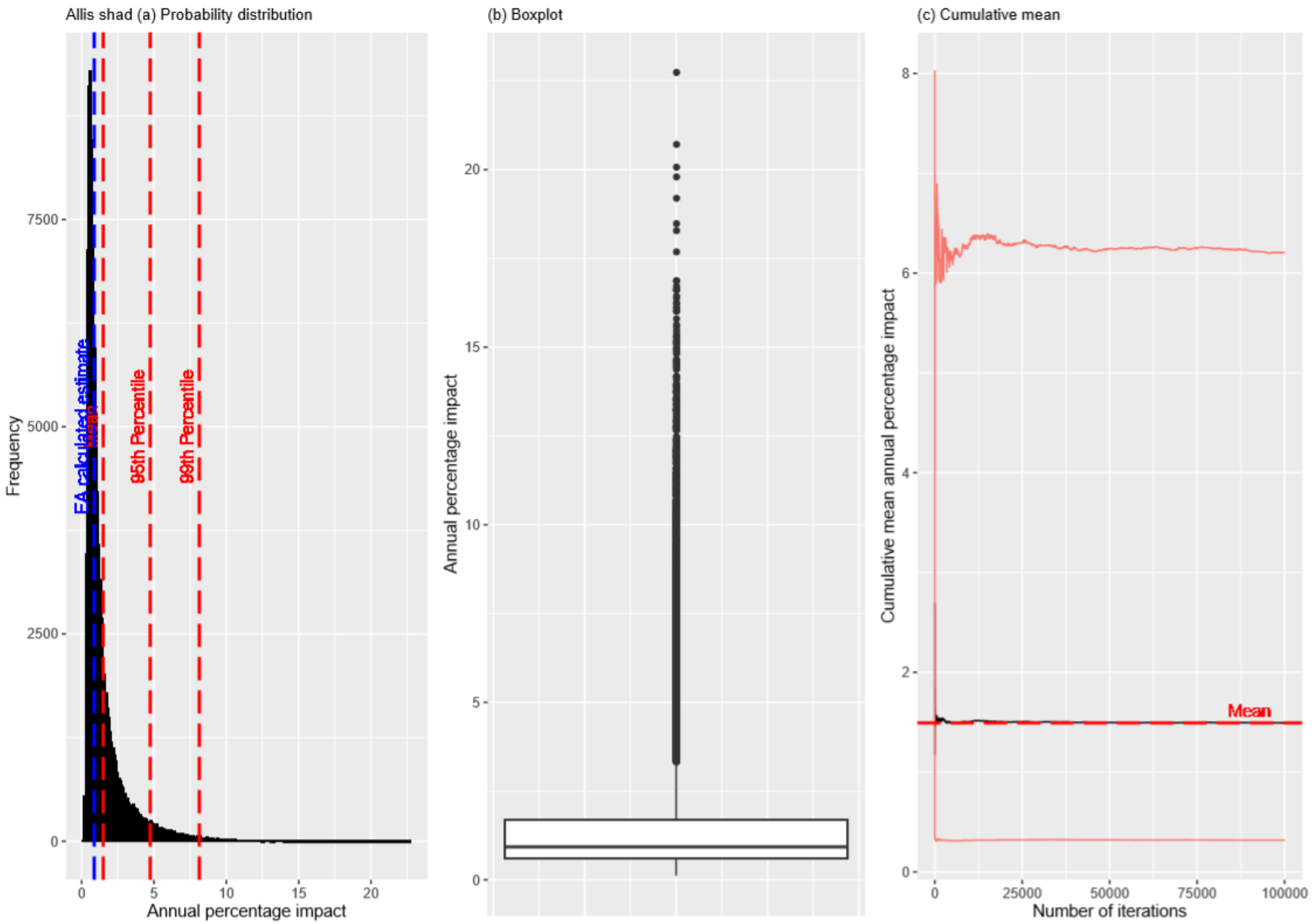
Blue whiting (a) Probability distribution
Frequency
Annual percentage impact
A calculated estimate
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations

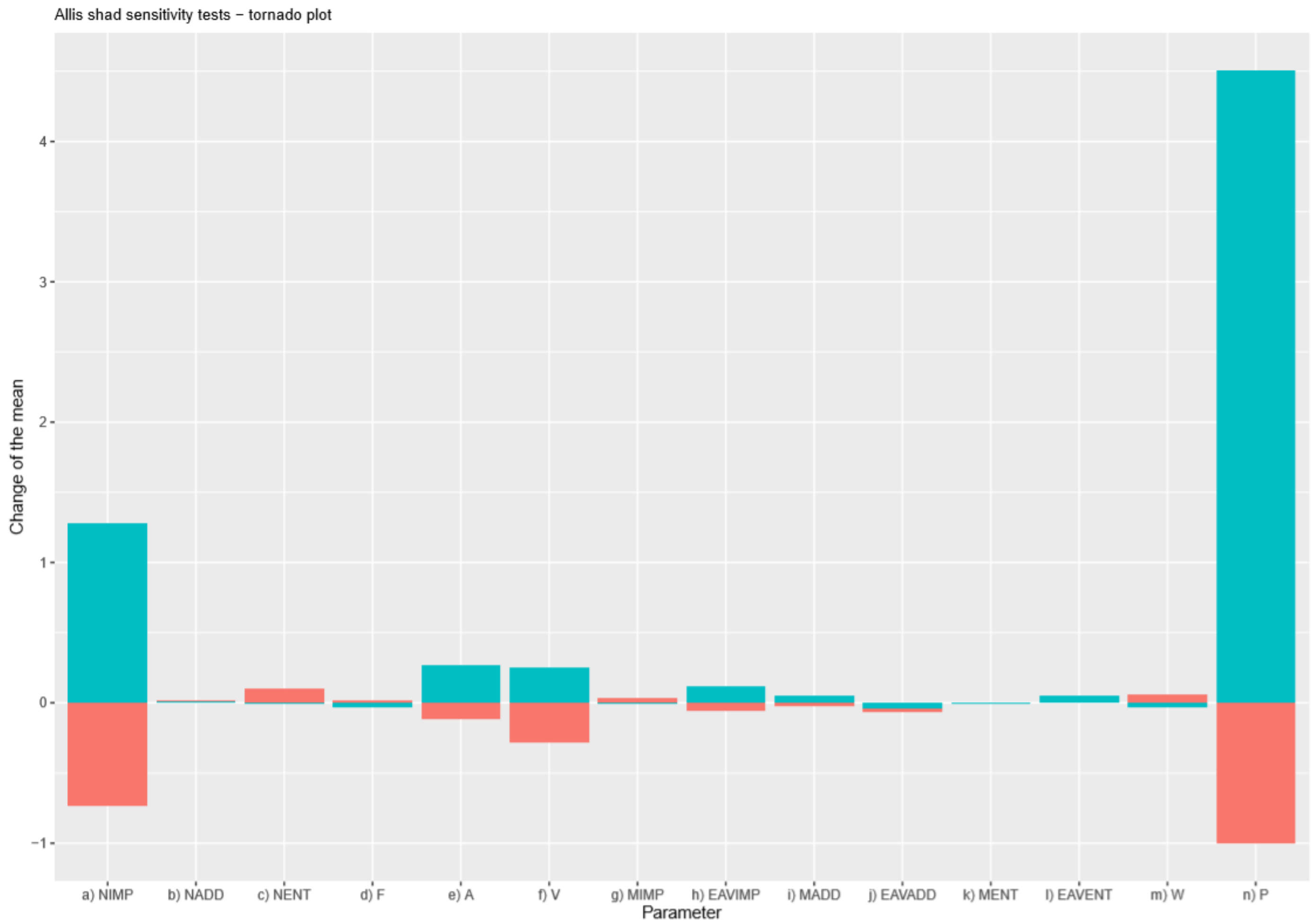

Blue whiting sensitivity tests – tornado plot
7.5e−05
5.0e−05
2.5e−05
0.0e+00
−2.5e−05
Change of the mean
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

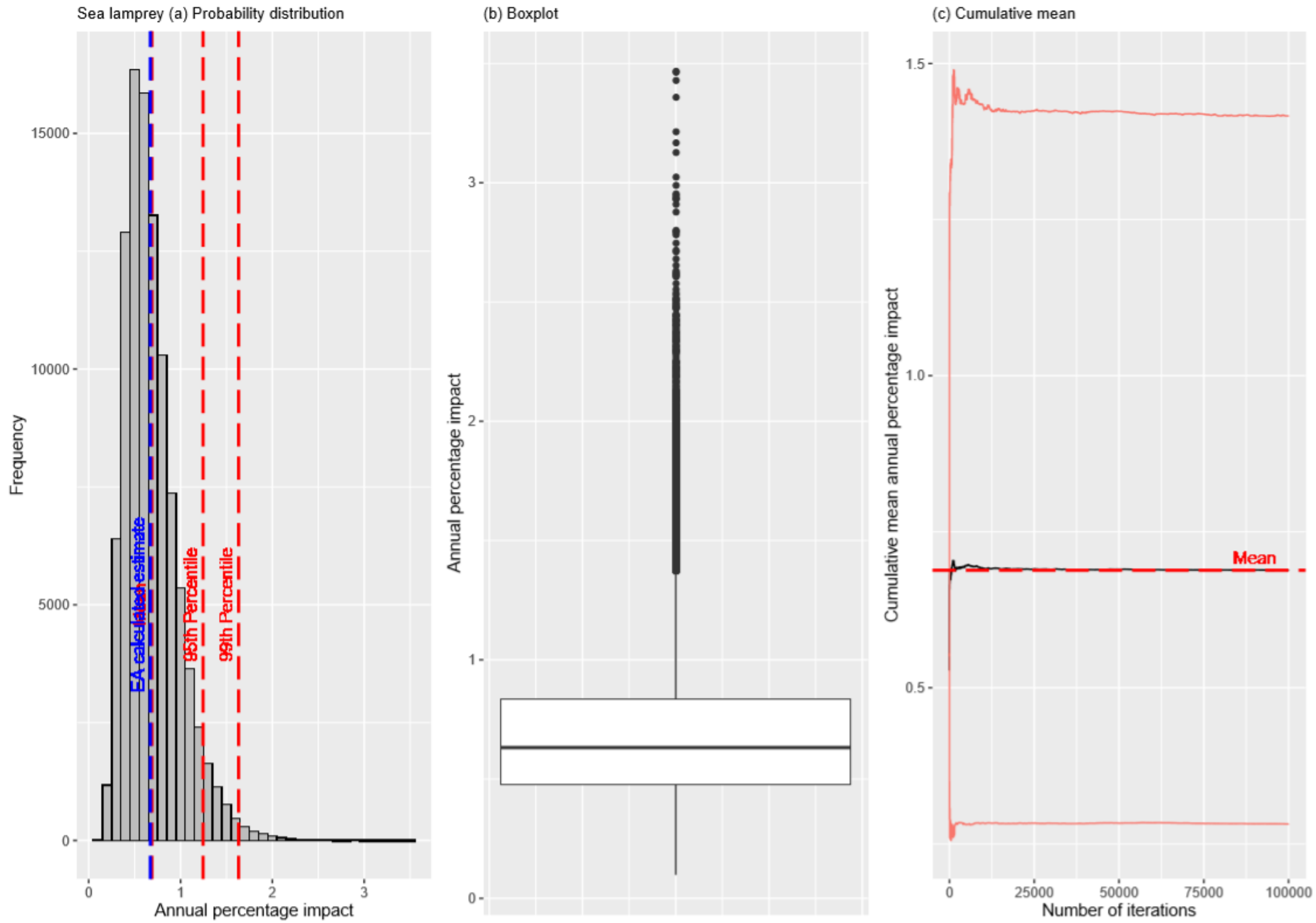

Twaite shad (a) Probability distribution
Frequency
Annual percentage impact
EA calculated estimate
Mean
95th Percentile
99th Percentile
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

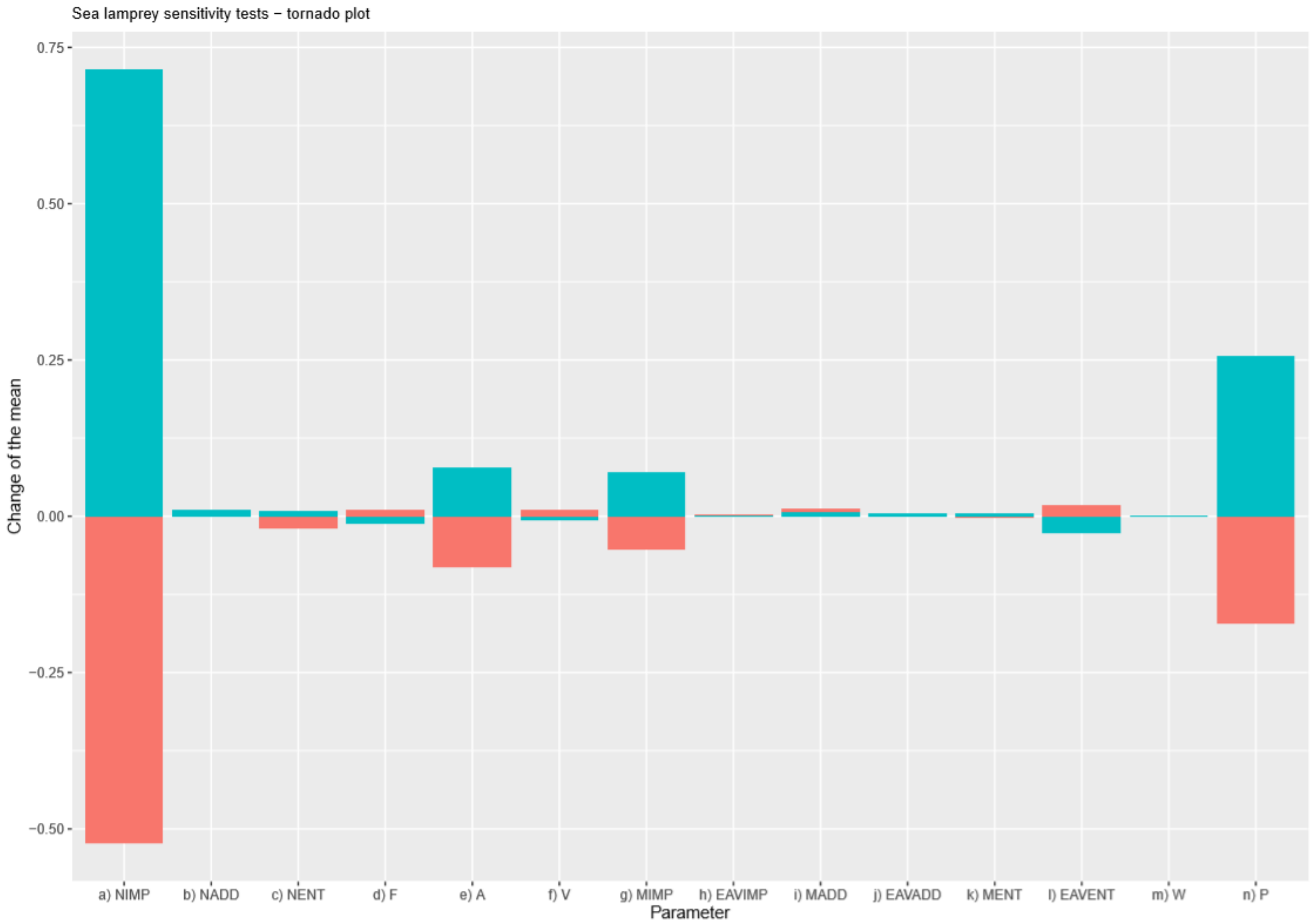


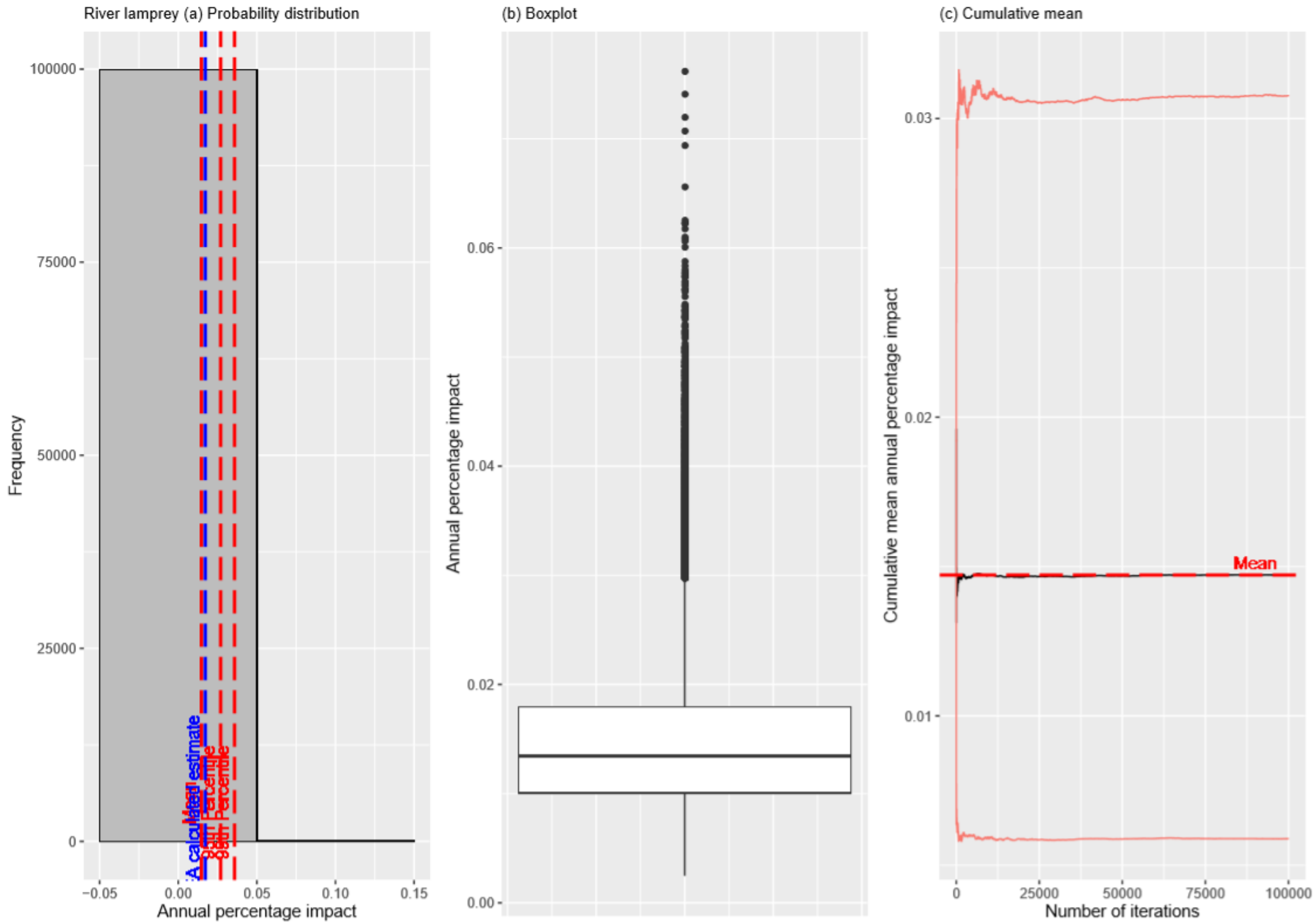
Twaite shad sensitivity tests – tornado plot
Change of the mean
0.6
0.4
0.2
0.0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

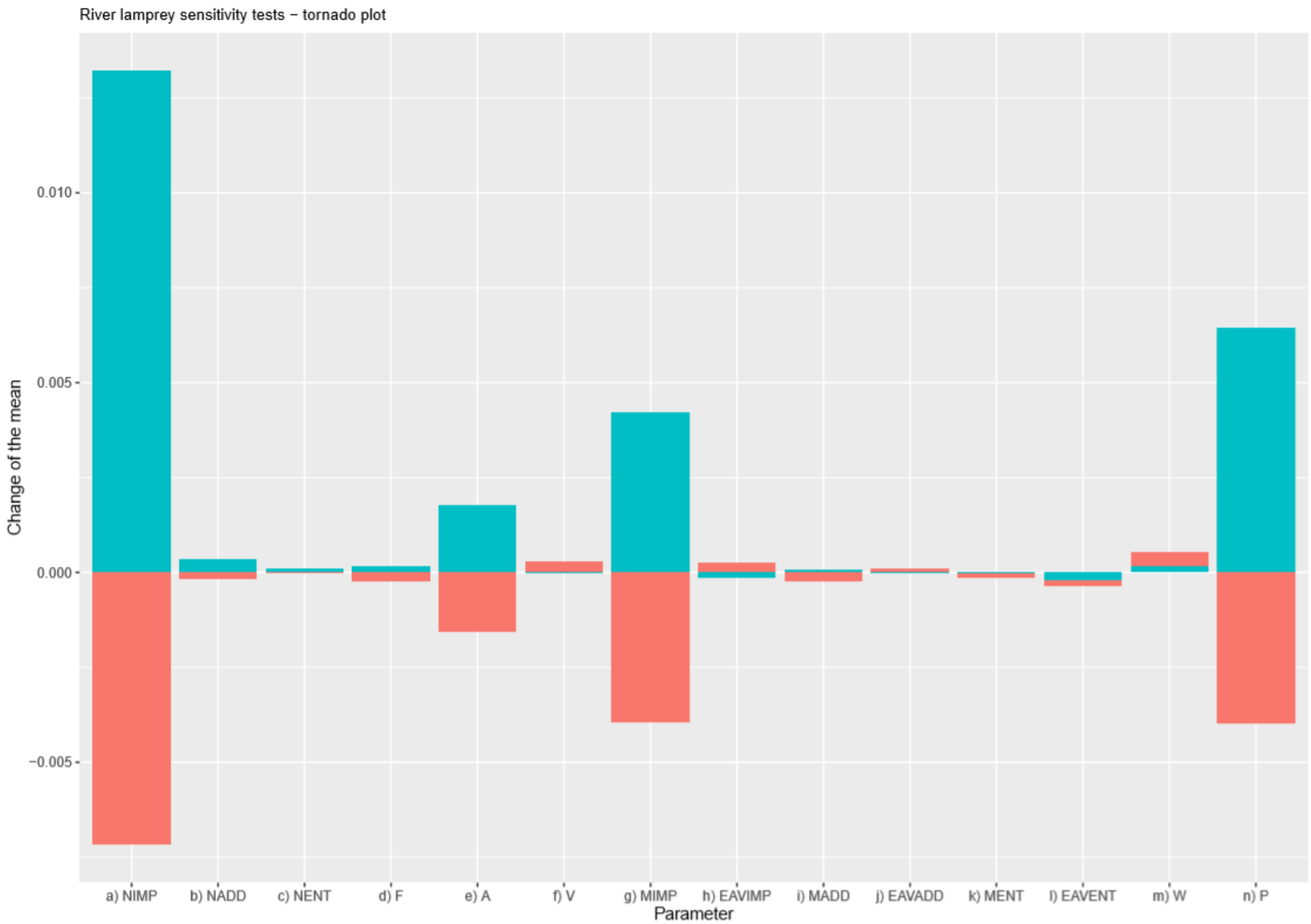

Allis shad (a) Probability distribution
(b) Boxplot
(c) Cumulative mean
Frequency
Annual percentage impact
EA calculated estimate
Mean
95th Percentile
99th Percentile
Cumulative mean annual percentage impact
Number of iterations

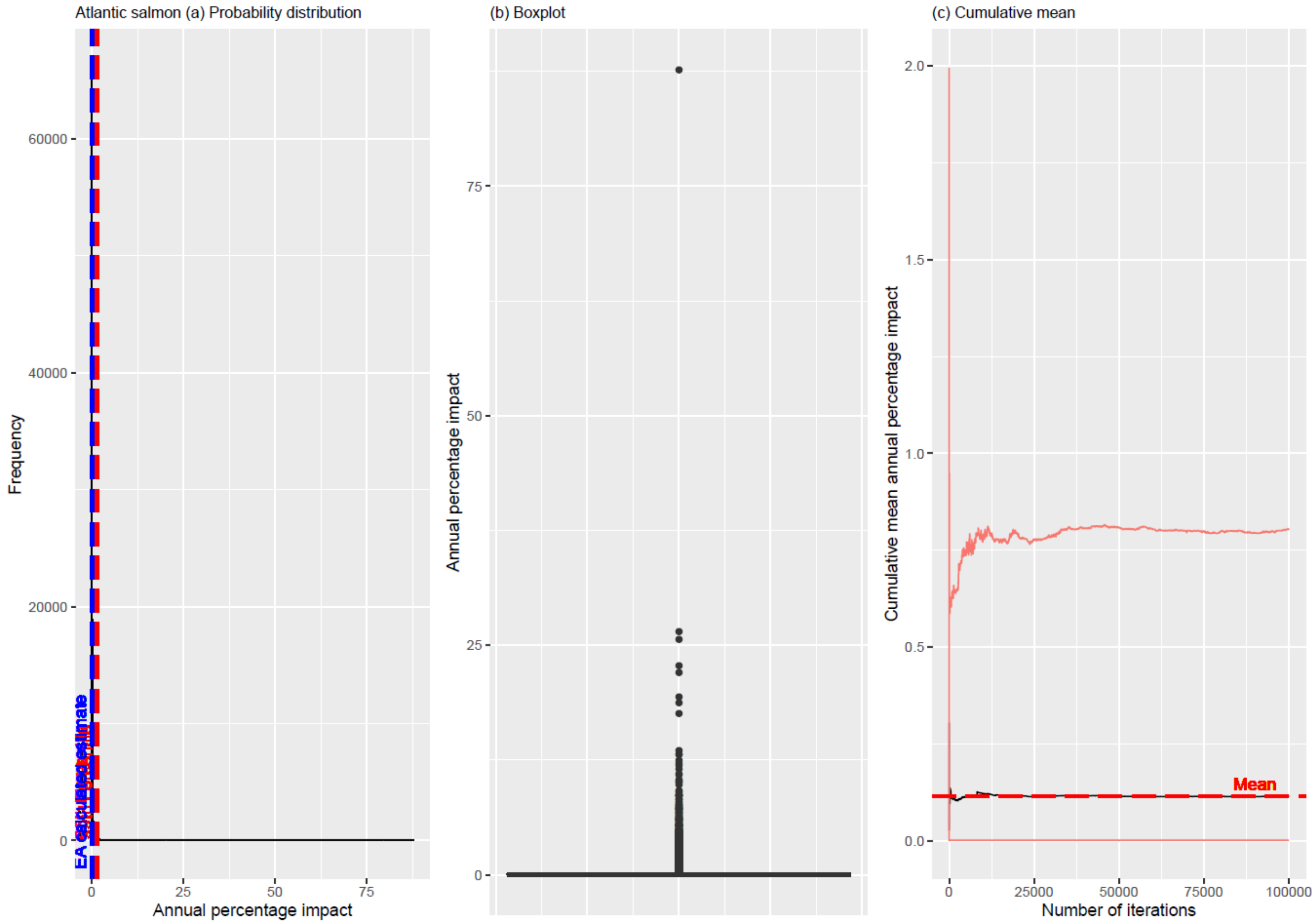

Allis shad sensitivity tests – tornado plot
Change of the mean
4
3
2
1
0
−1
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter


Sea lamprey (a) Probability distribution
Frequency
Annual percentage impact
EA calculated estimate
95th Percentile
99th Percentile
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

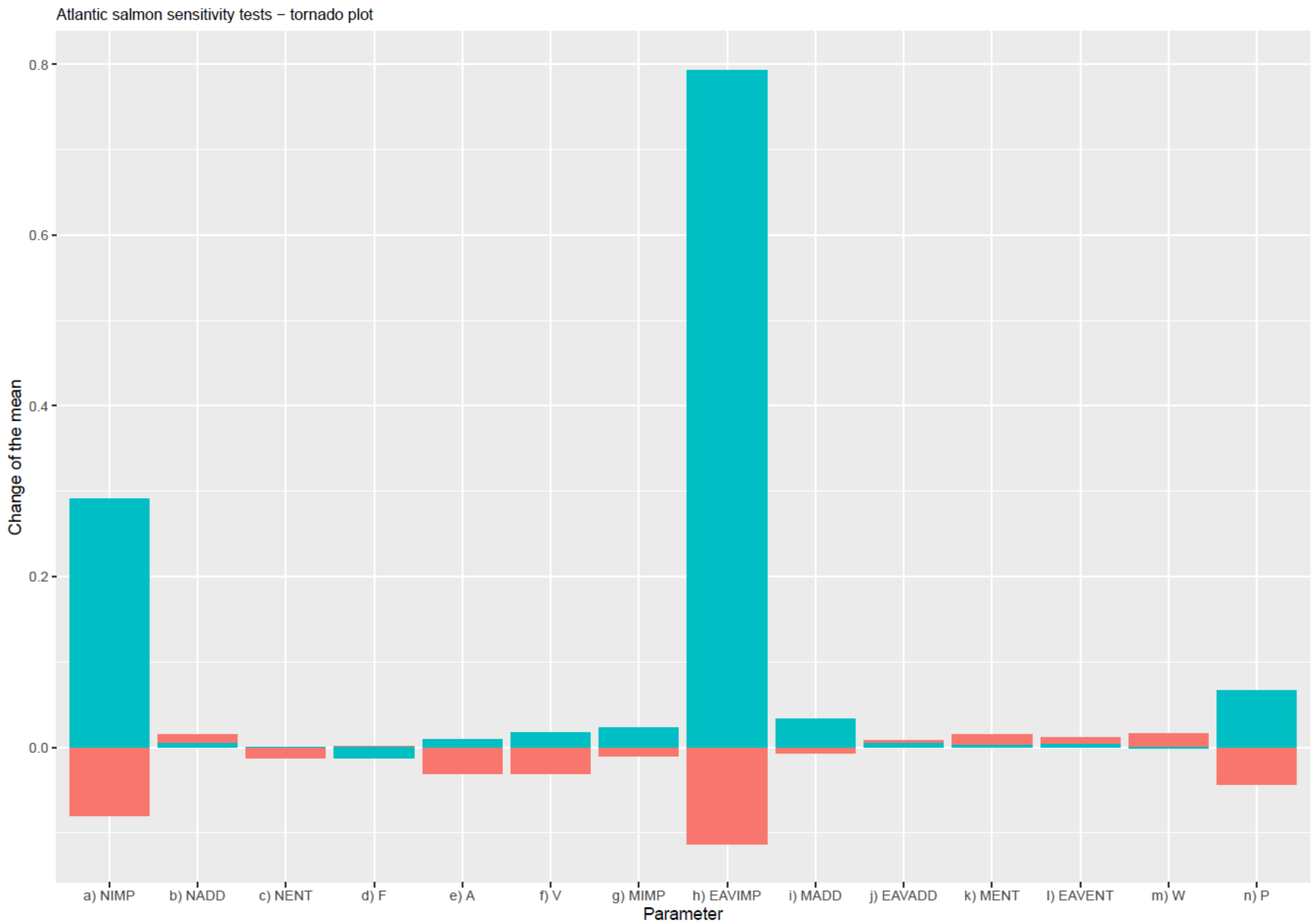

Sea lamprey sensitivity tests – tornado plot
Change of the mean
0.75
0.50
0.25
0.00
−0.25
−0.50
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

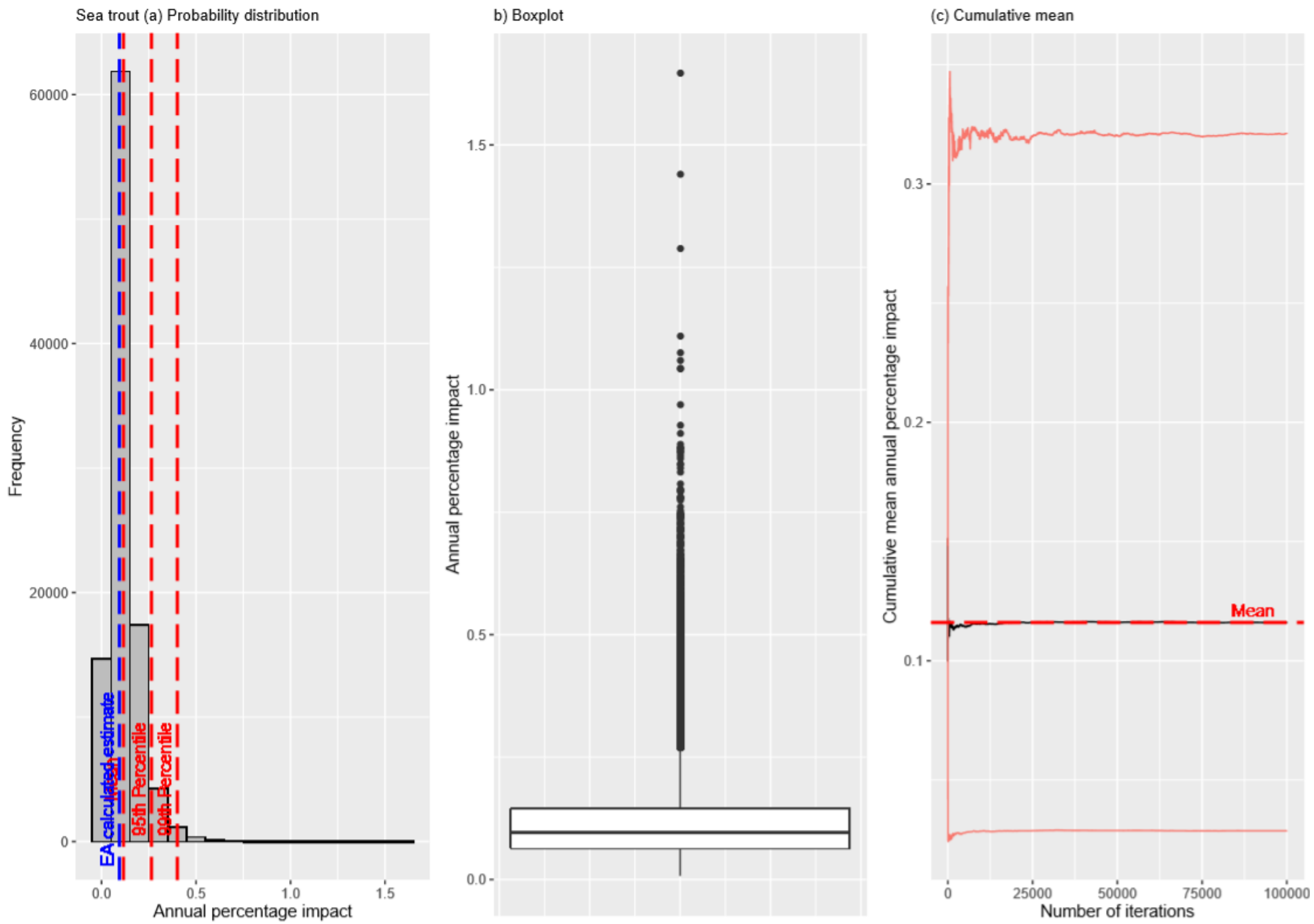

River lamprey (a) Probability distribution
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

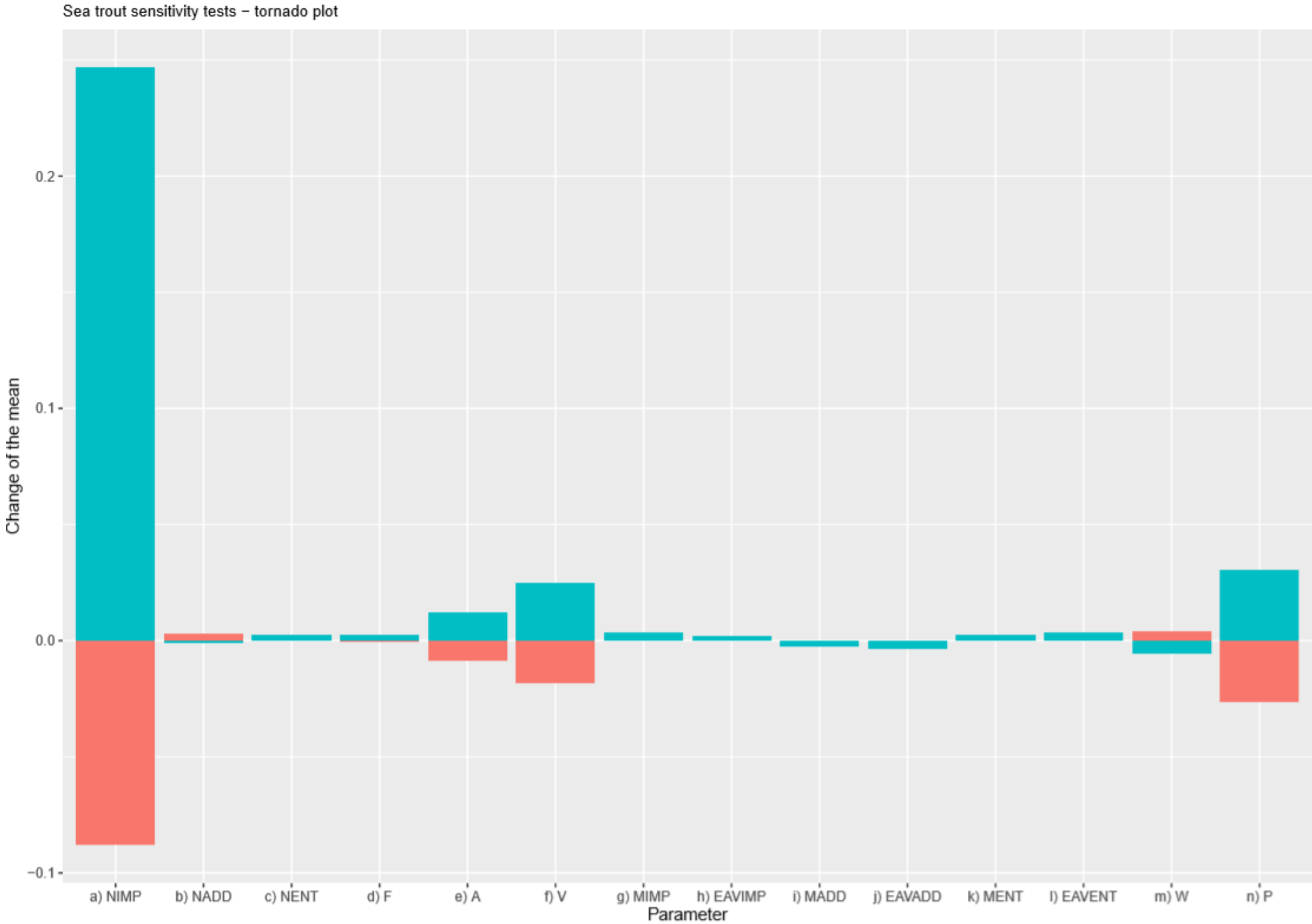

River lamprey sensitivity tests − tornado plot
Change of the mean
0.010
0.005
0.000
−0.005
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

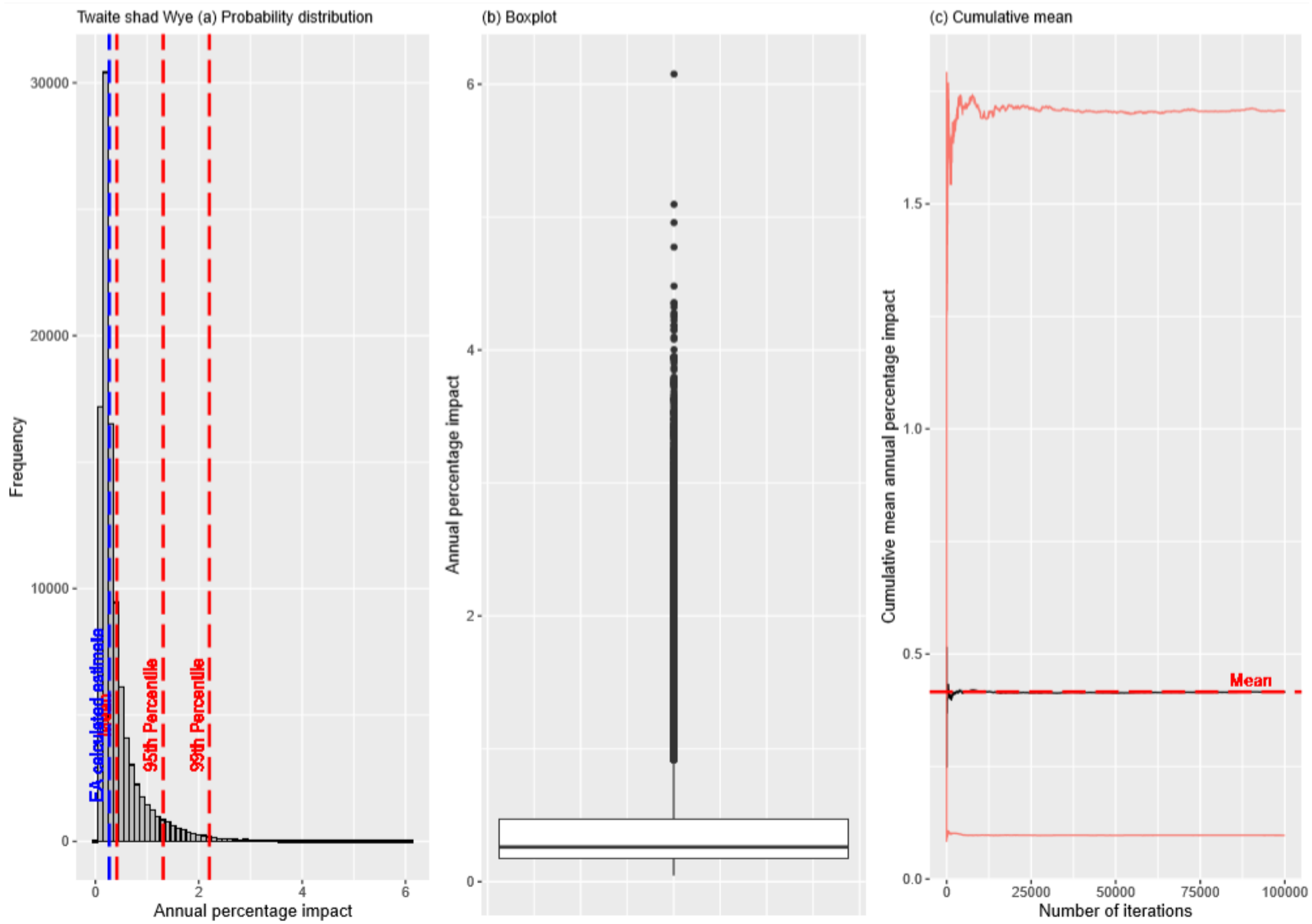


Atlantic salmon (a) Probability distribution
Frequency
60000
40000
20000
0
0
25
50
75
Annual percentage impact
(b) Boxplot
Annual percentage impact
75
50
25
0
(c) Cumulative mean
Cumulative mean annual percentage impact
2.0
1.5
1.0
0.5
0.0
Mean
0
25000
50000
75000
100000
Number of iterations

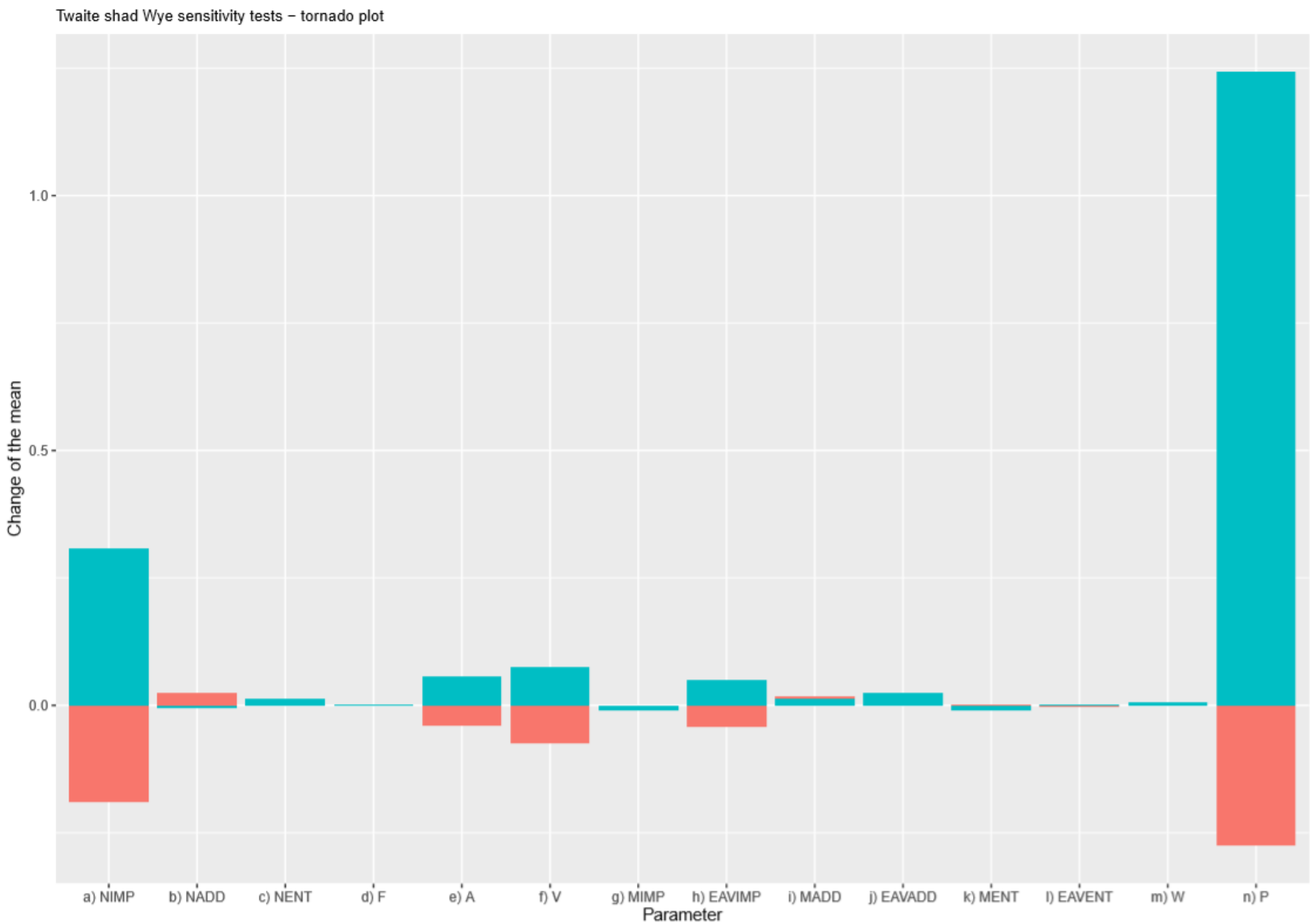

Atlantic salmon sensitivity tests − tornado plot
Change of the mean
0.8
0.6
0.4
0.2
0.0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

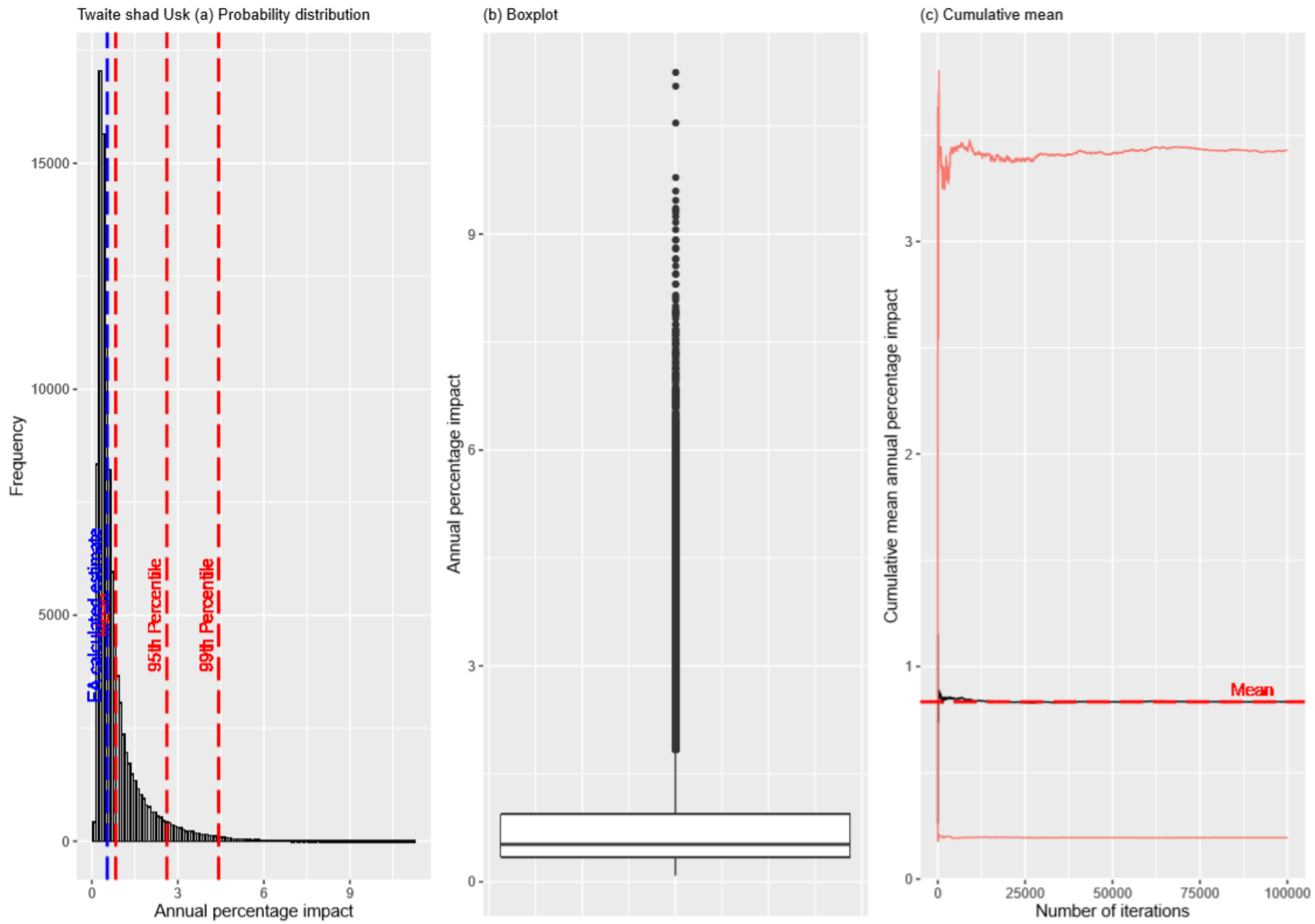

Sea trout (a) Probability distribution
b) Boxplot
(c) Cumulative mean
Frequency
Annual percentage impact
Cumulative mean annual percentage impact
Number of iterations
EA calculated estimate
Mean
95th Percentile
99th Percentile
0
20000
40000
60000
0.0
0.5
1.0
1.5
0.1
0.2
0.3
25000
50000
75000
100000


Sea trout sensitivity tests – tornado plot
Change of the mean
0.2
0.1
0.0
−0.1
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

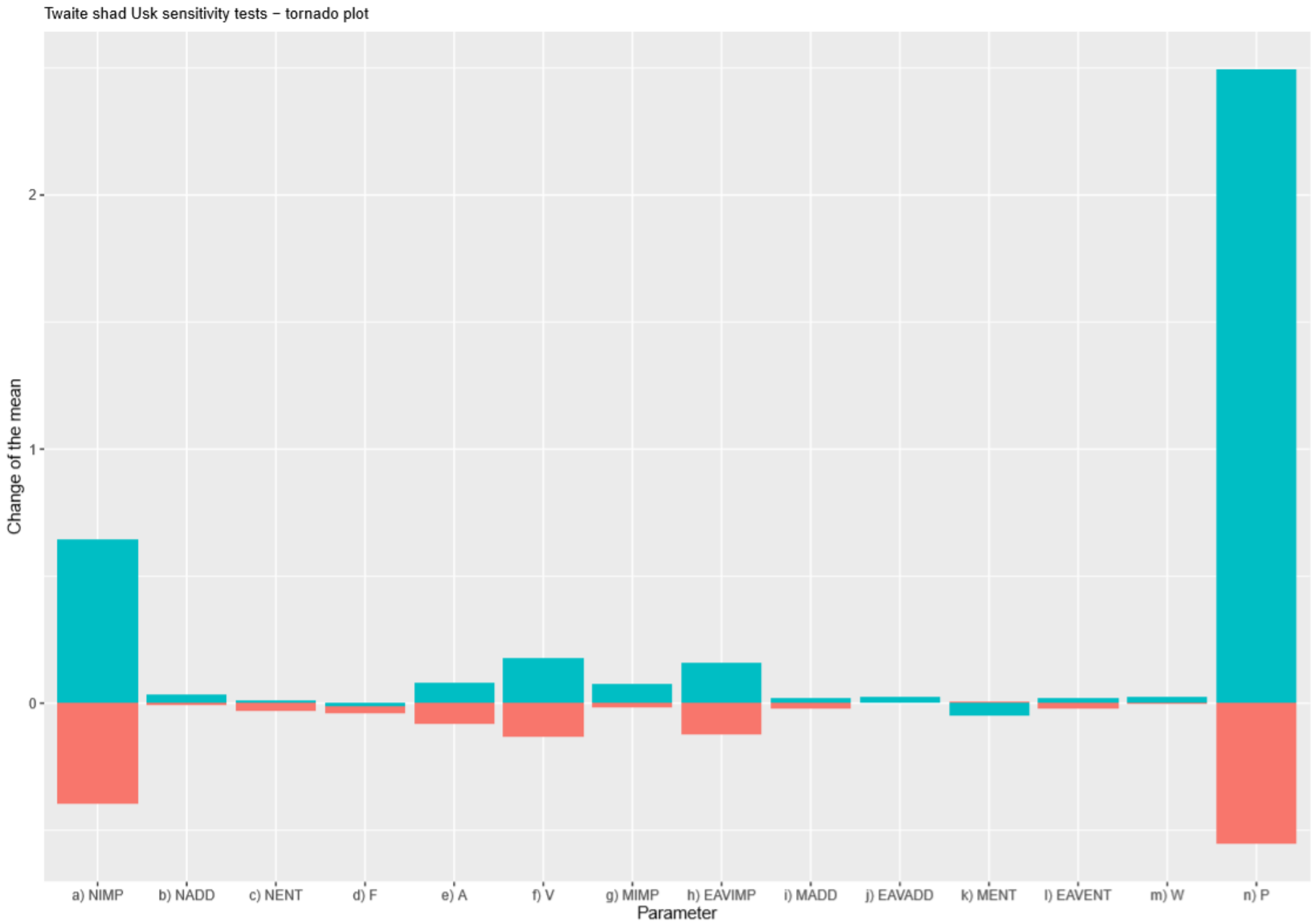


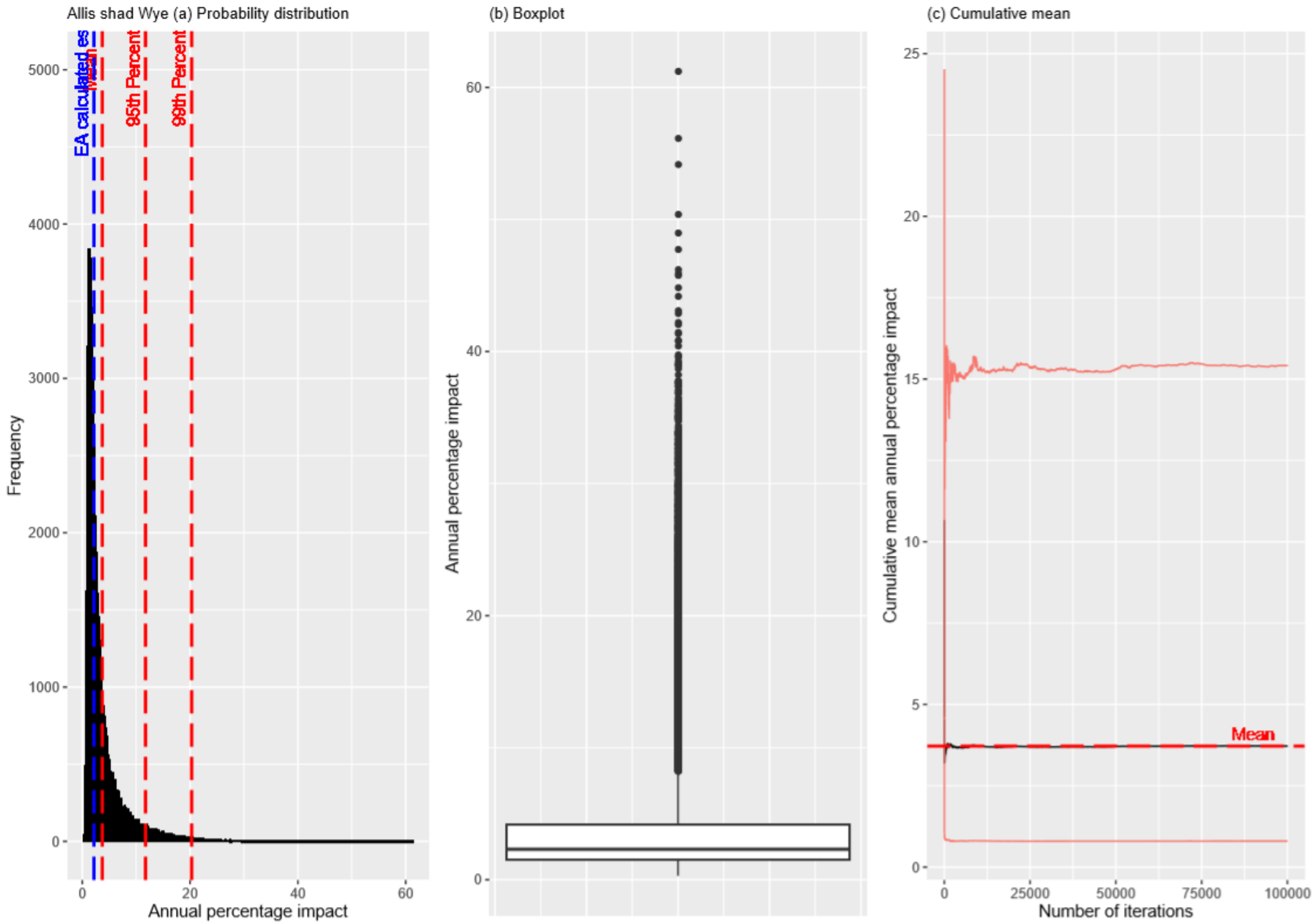
Twaite shad Wye (a) Probability distribution
Frequency
Annual percentage impact
EA calculated estimate
Mean
95th Percentile
99th Percentile
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean


Twaite shad Wye sensitivity tests – tornado plot
Change of the mean
1.0
0.5
0.0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

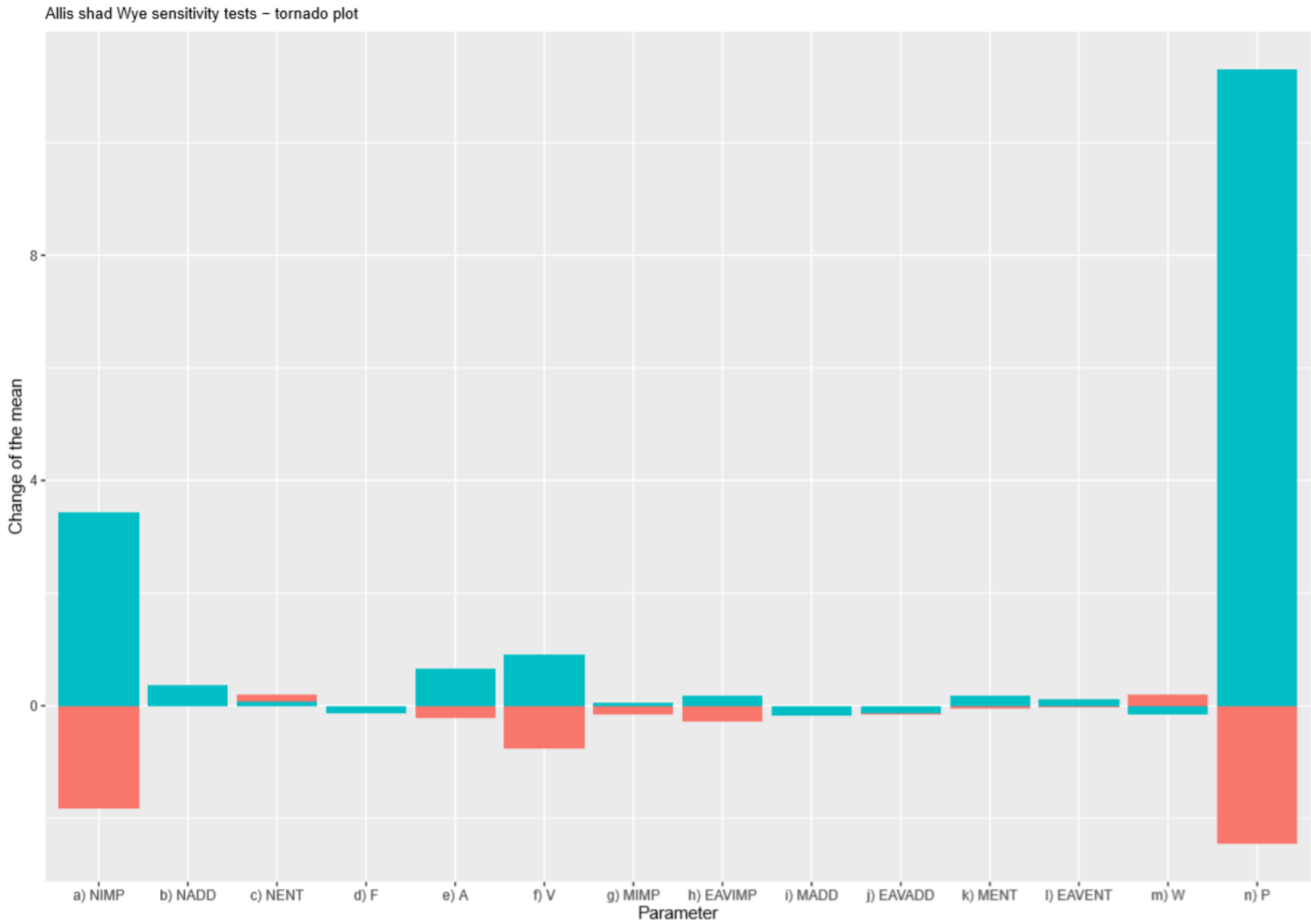


Twaite shad Usk (a) Probability distribution
Frequency
Annual percentage impact
EA calculated estimate
95th Percentile
99th Percentile
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

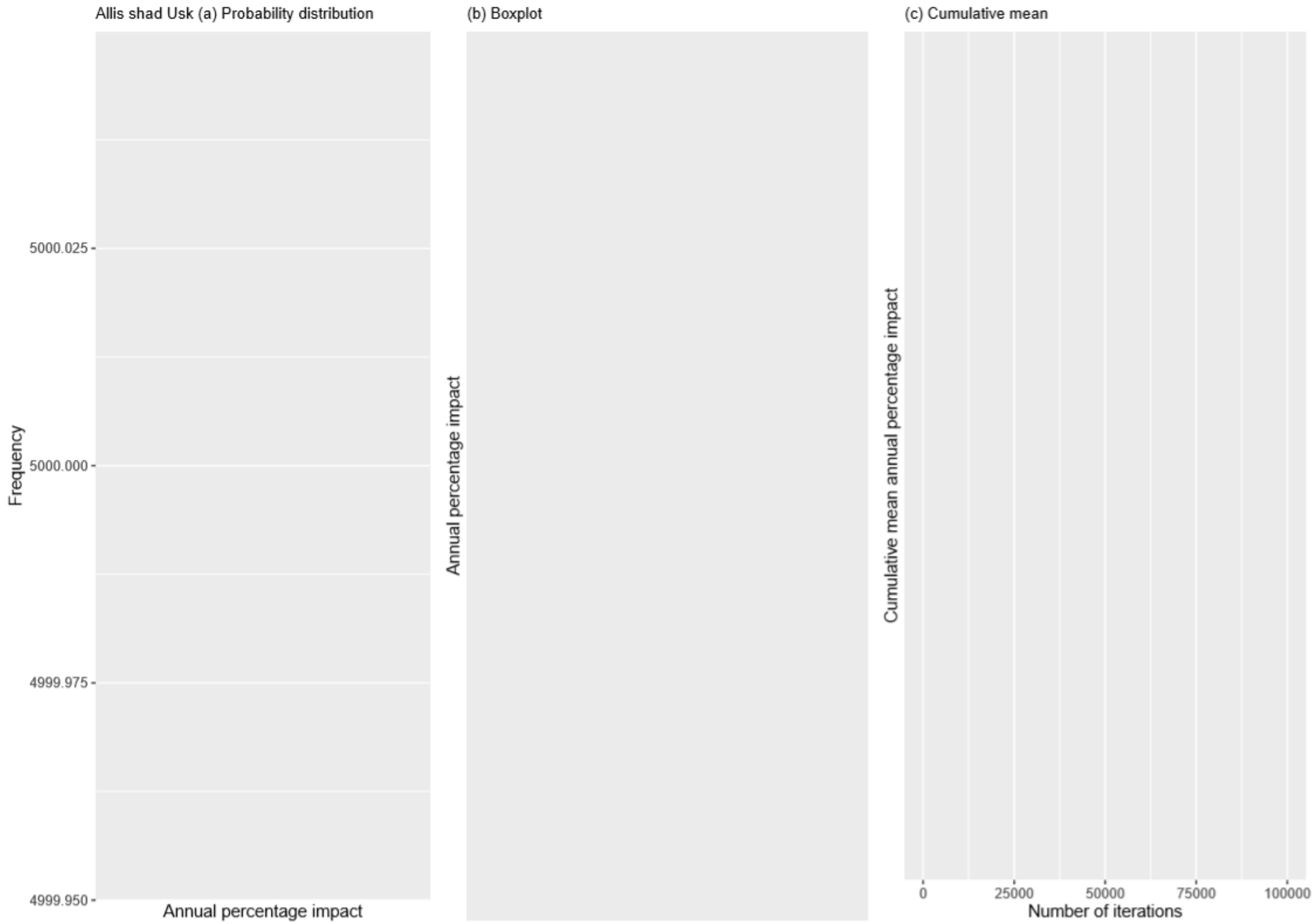

Twaite shad Usk sensitivity tests – tornado plot
Change of the mean
2
1
0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

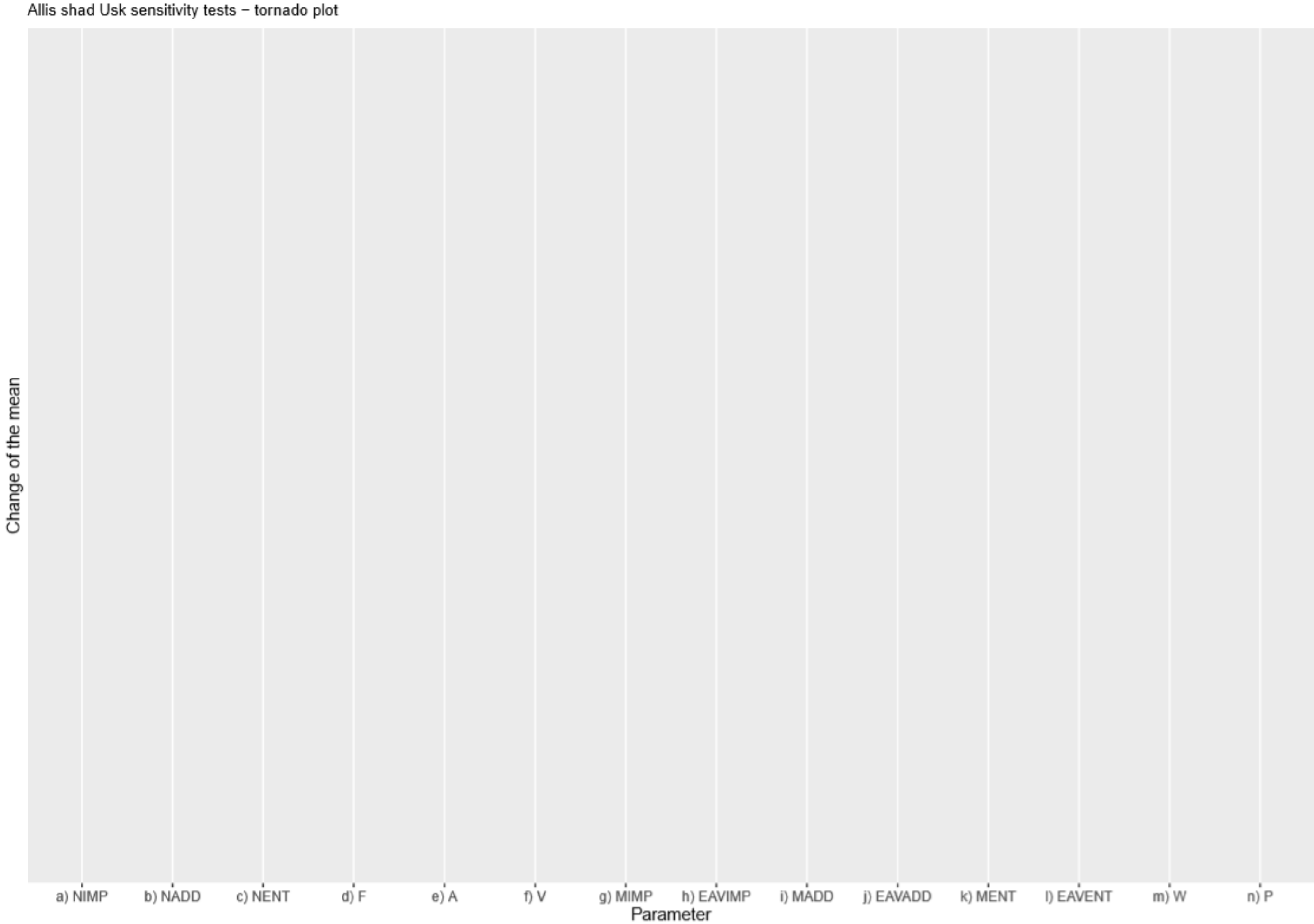


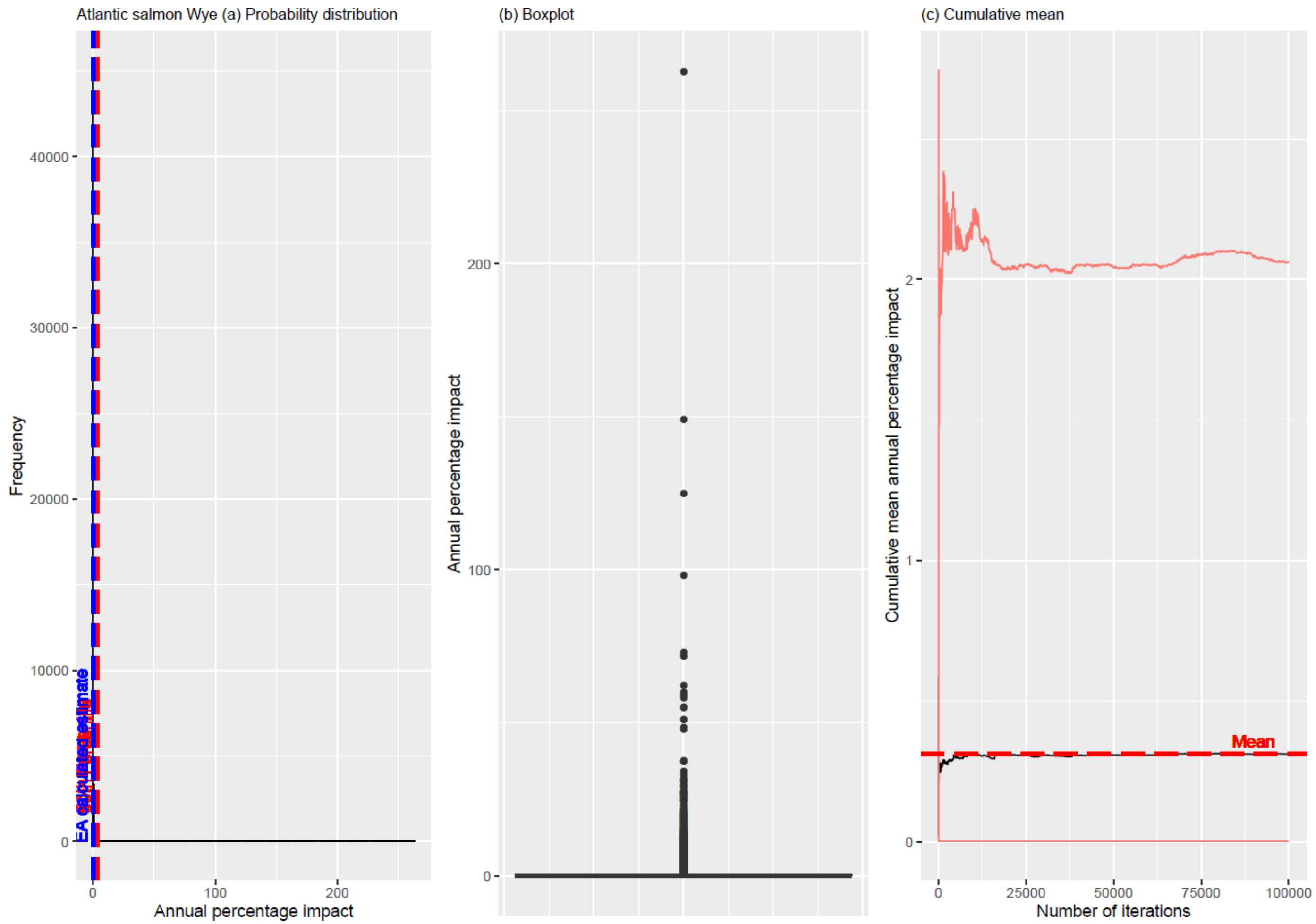
Allis shad Wye (a) Probability distribution
EA calculated es
Mean
95th Percent
99th Percent
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations



Allis shad Wye sensitivity tests − tornado plot
Change of the mean
8
4
0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

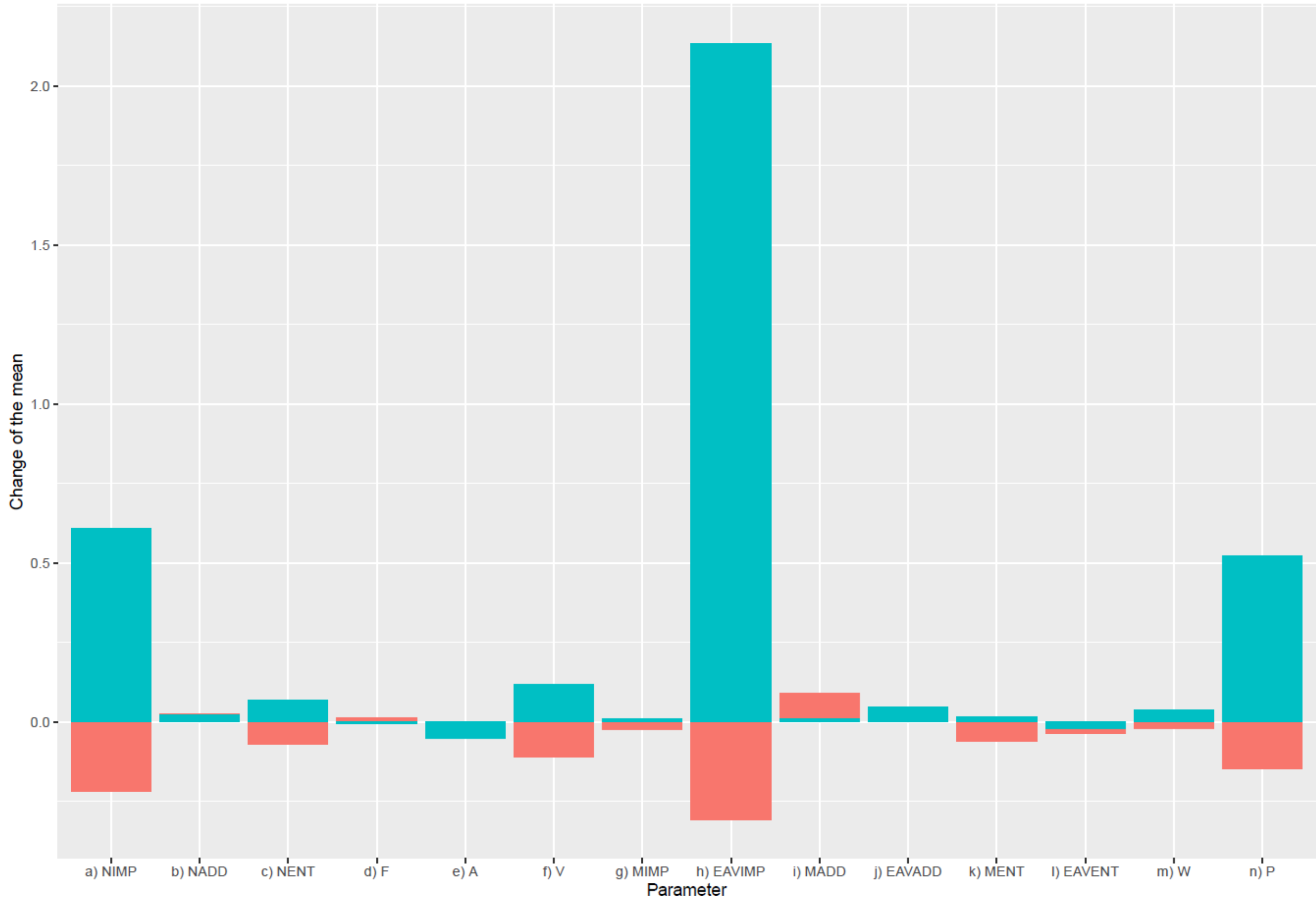

Allis shad Usk (a) Probability distribution
(b) Boxplot
(c) Cumulative mean
Frequency
5000.025
5000.000
4999.975
4999.950
Annual percentage impact
Annual percentage impact
Cumulative mean annual percentage impact
0
25000
50000
75000
100000
Number of iterations

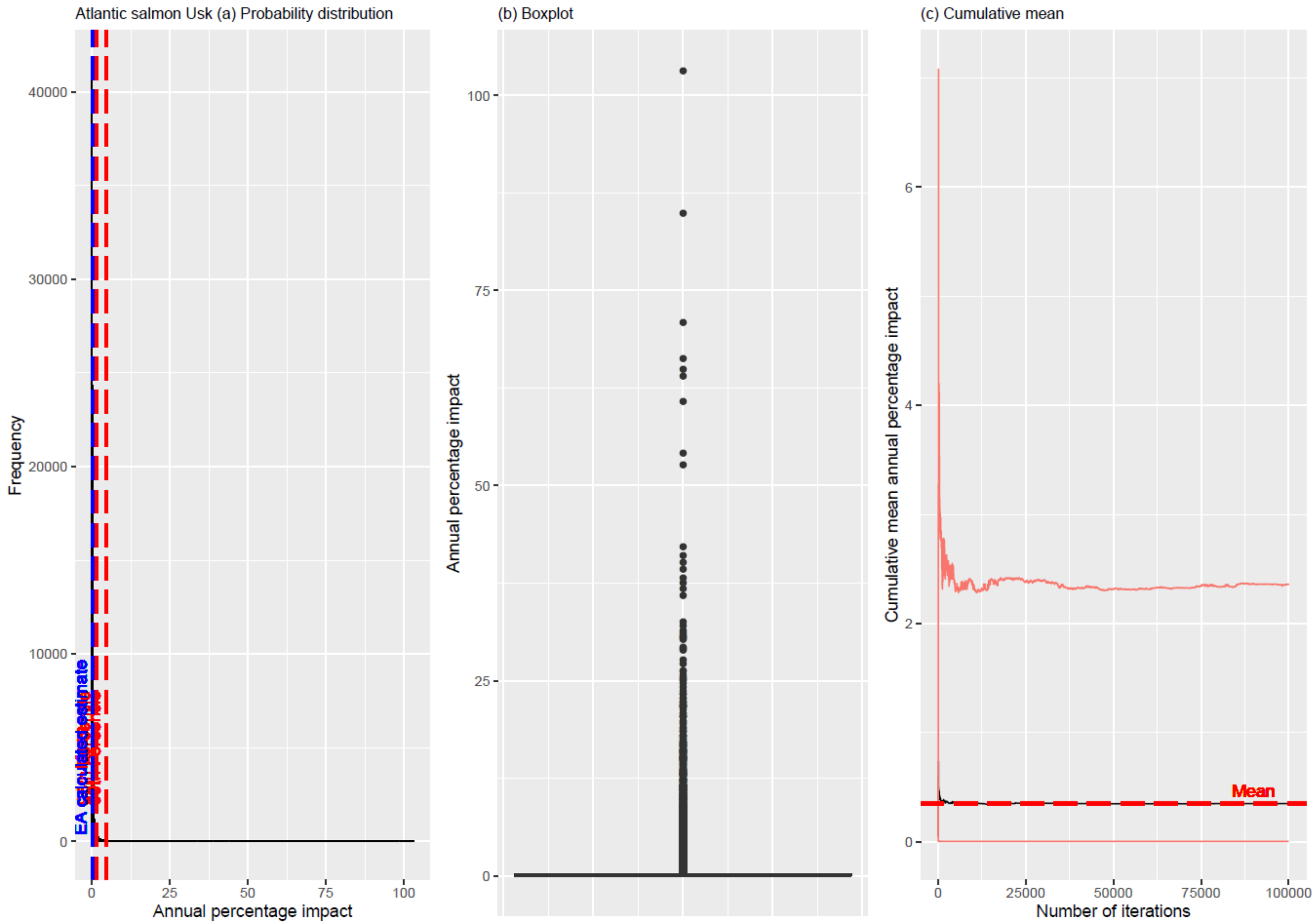

Allis shad Usk sensitivity tests – tornado plot
Change of the mean
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

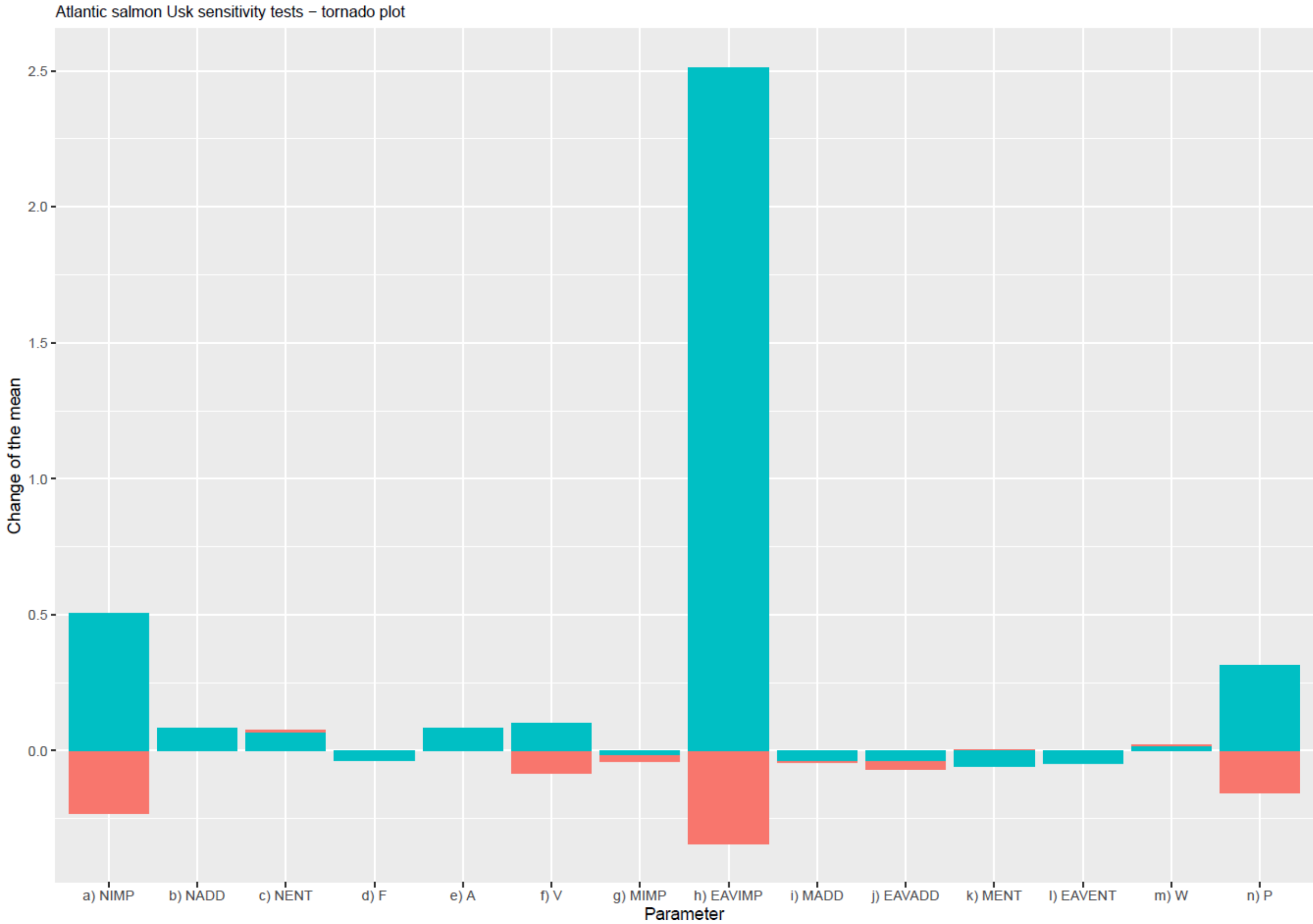


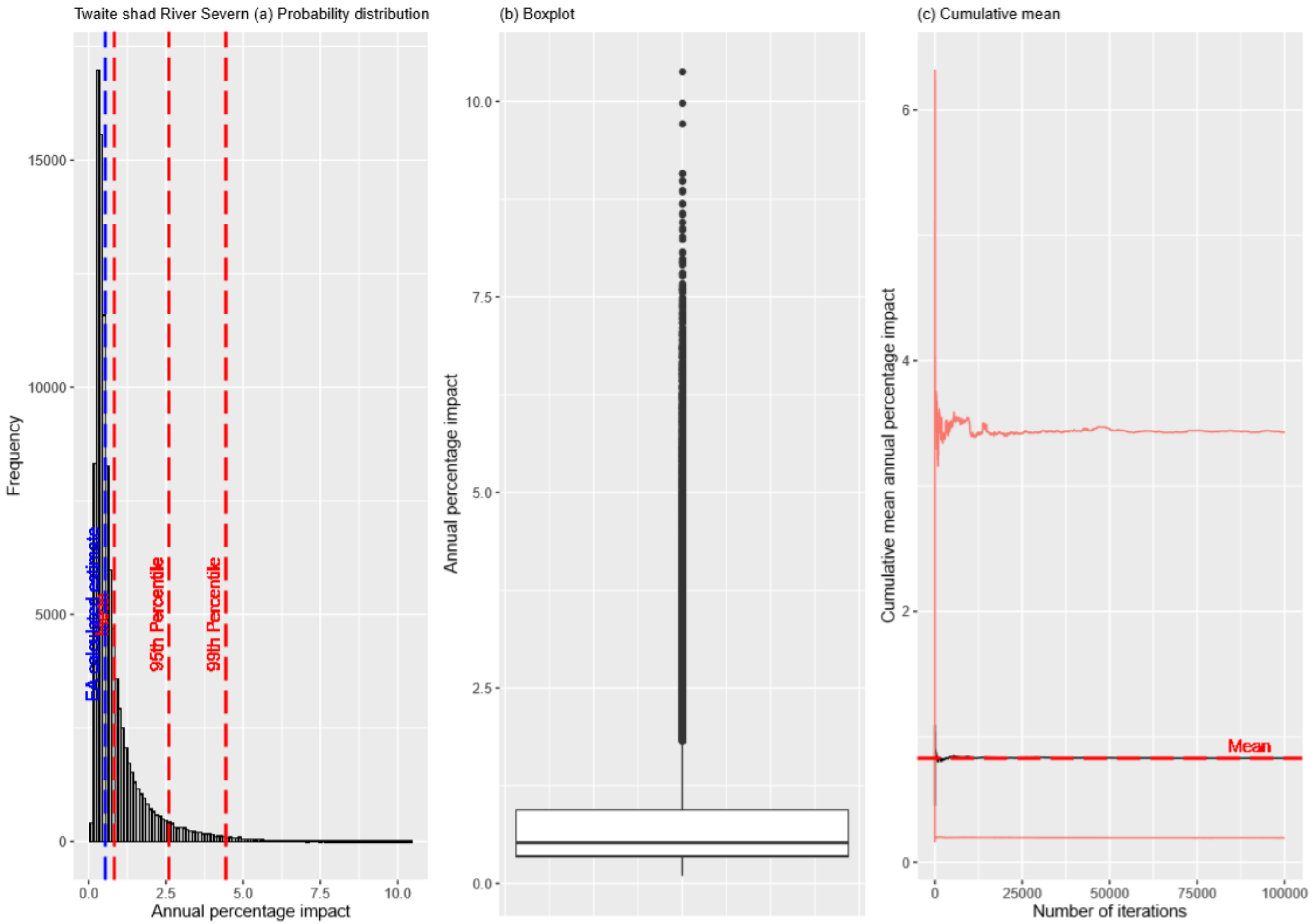
Atlantic salmon Wye (a) Probability distribution
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

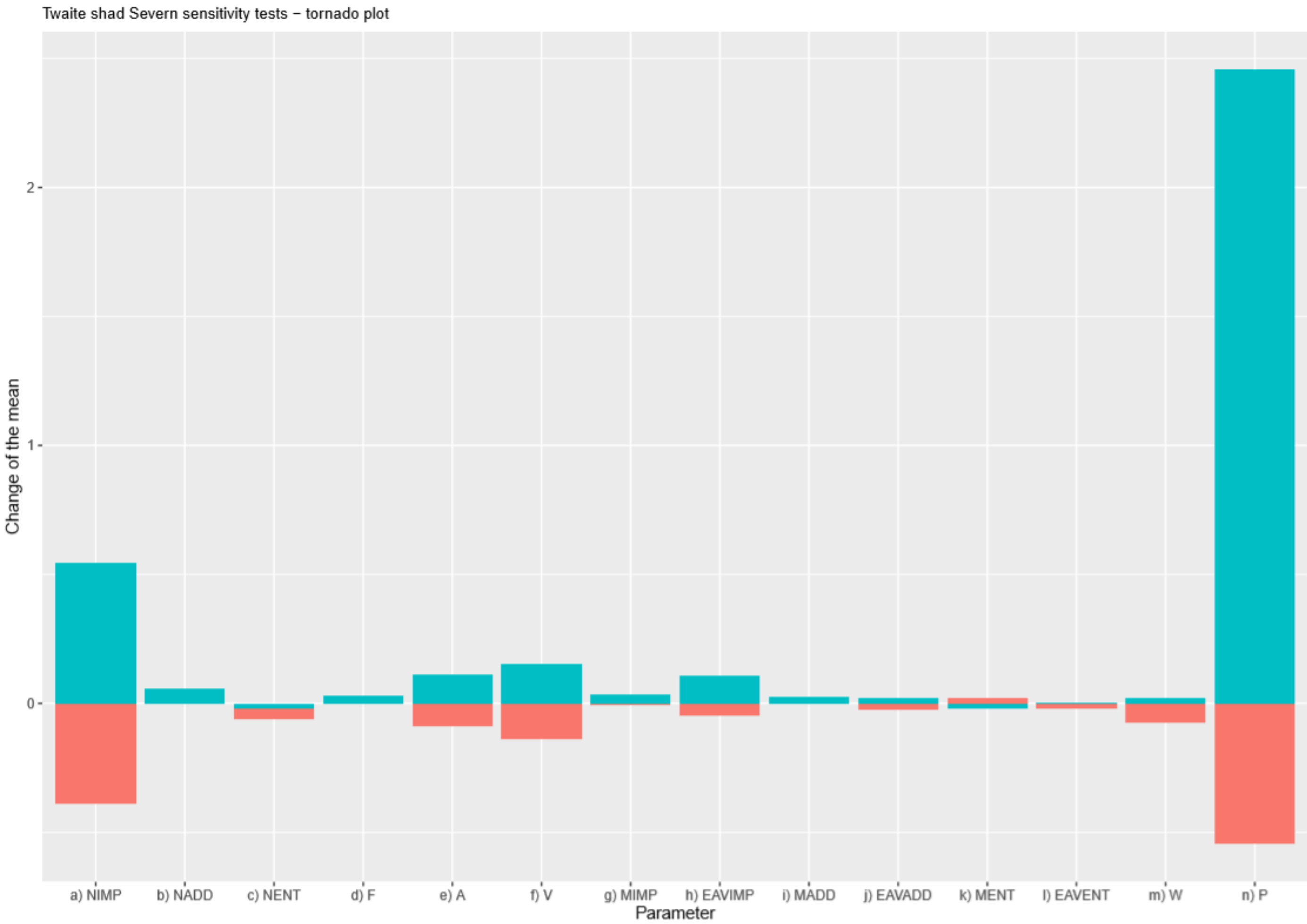
Atlantic salmon Wye sensitivity tests – tornado plot



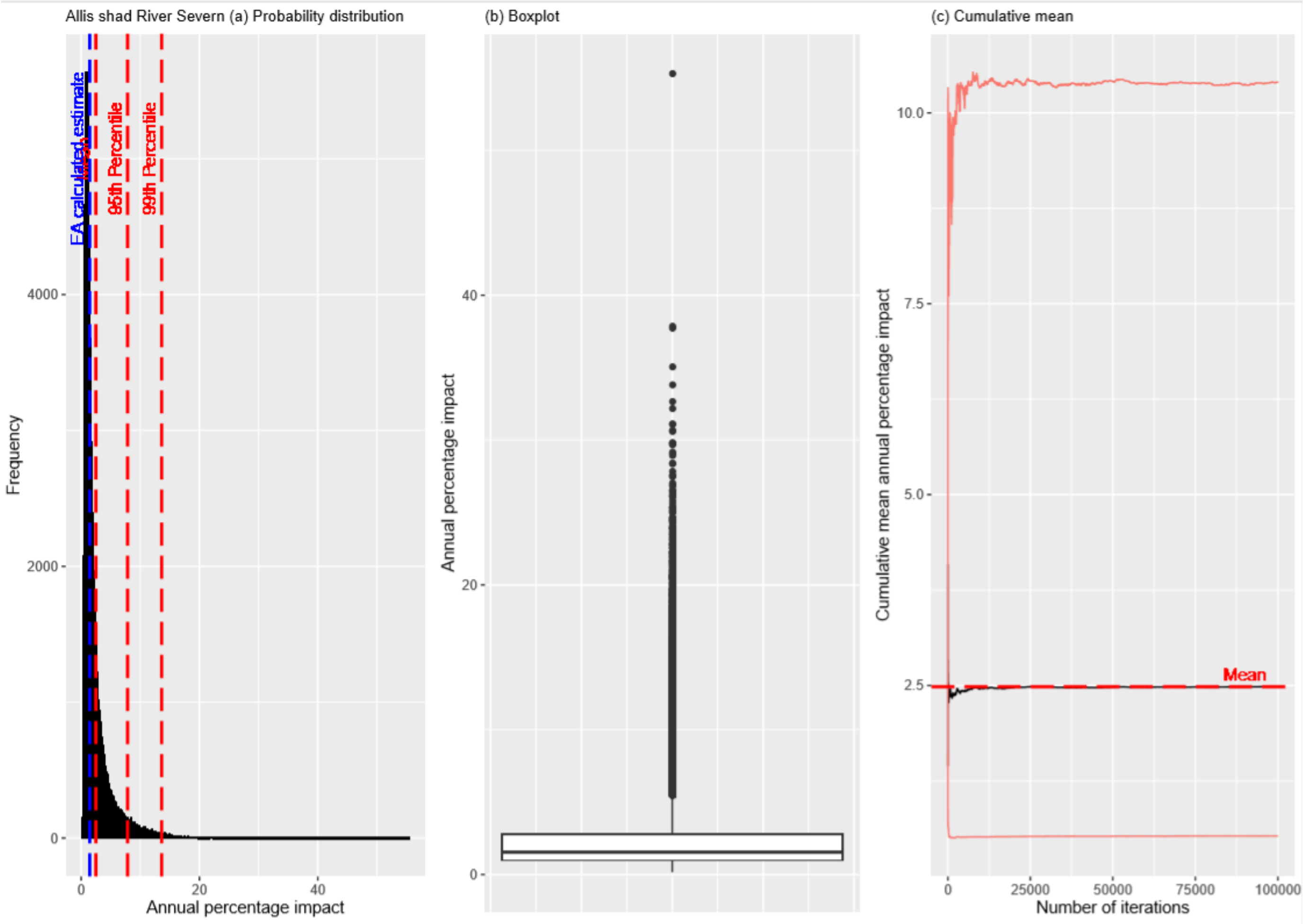

Atlantic salmon Usk (a) Probability distribution
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations


Atlantic salmon Usk sensitivity tests – tornado plot
Change of the mean
2.5
2.0
1.5
1.0
0.5
0.0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

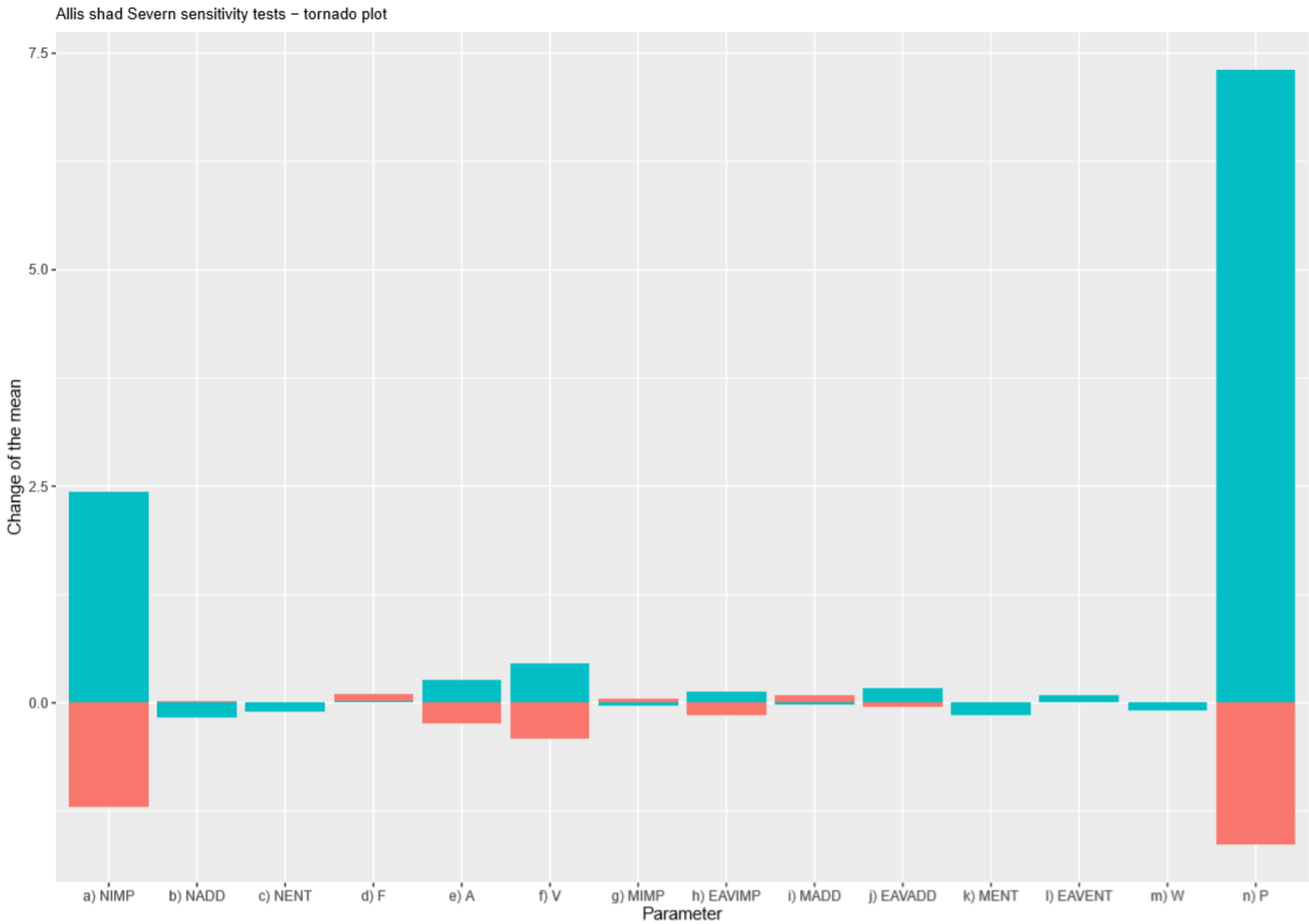

Twaite shad River Severn (a) Probability distribution
Frequency
Annual percentage impact
EA calculated estimate
95th Percentile
99th Percentile
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Number of iterations
Mean

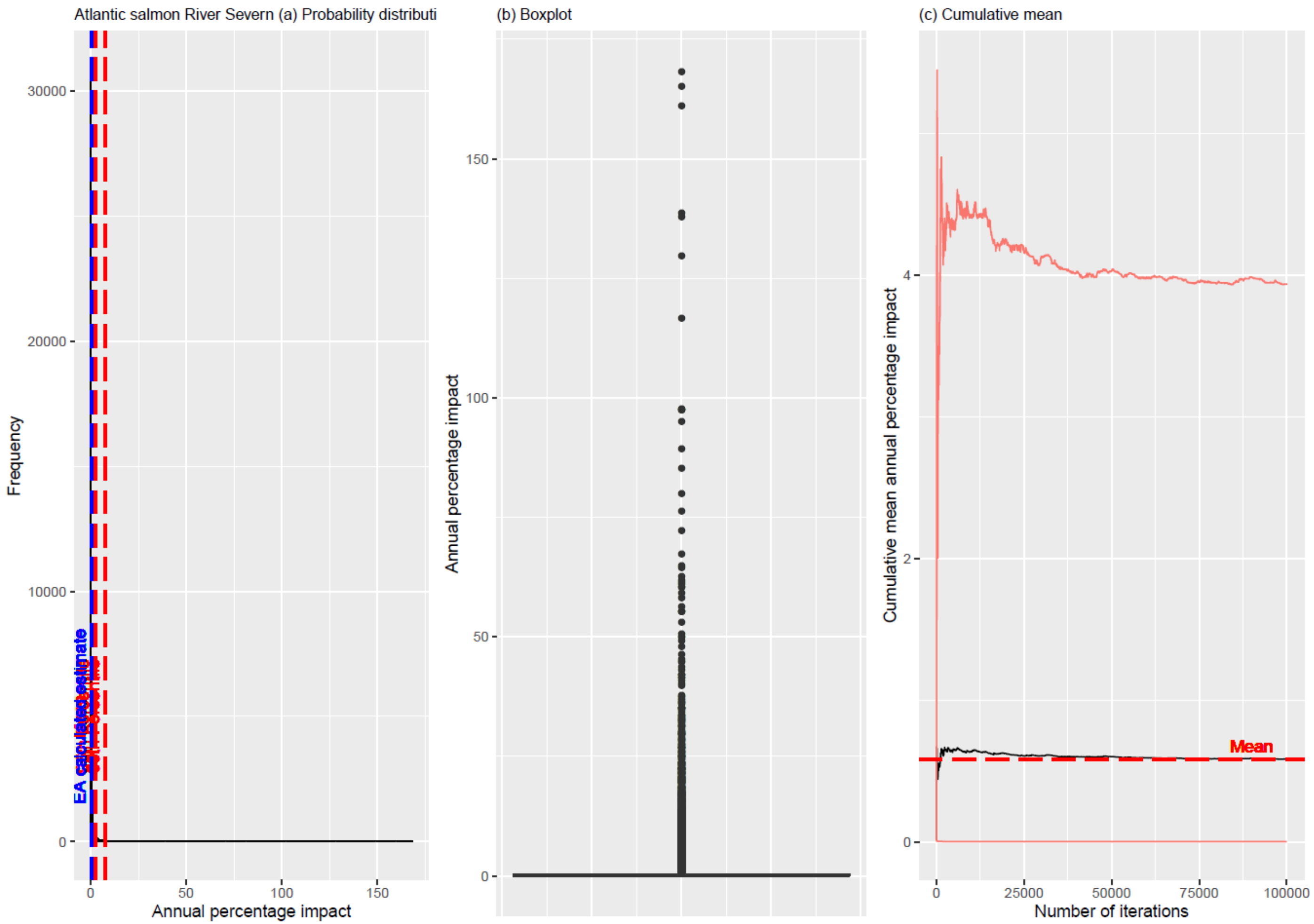


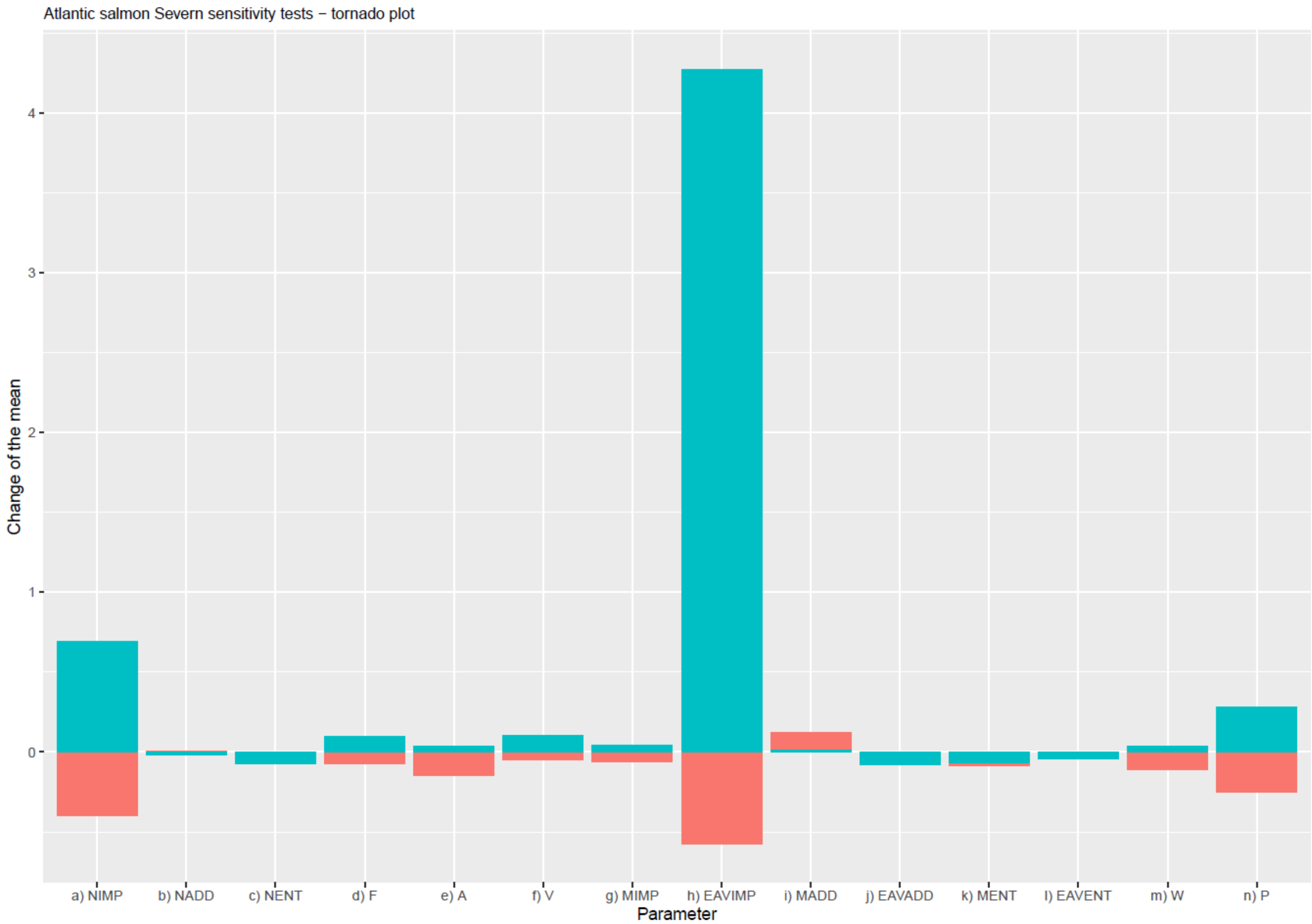
Twaite shad Severn sensitivity tests – tornado plot
Change of the mean
2
1
0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter



Allis shad River Severn (a) Probability distribution
EA calculated estimate
95th Percentile
99th Percentile
Frequency
Annual percentage impact
(b) Boxplot
Annual percentage impact
(c) Cumulative mean
Cumulative mean annual percentage impact
Mean
Number of iterations


Allis shad Severn sensitivity tests − tornado plot
7.5
5.0
2.5
0.0
Change of the mean
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

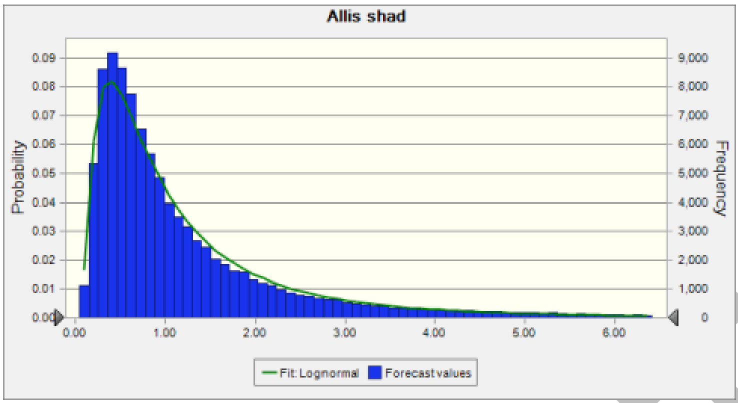

Atlantic salmon River Severn (a) Probability distributi
Frequency
30000
20000
10000
0
EA calculated estimate
0
50
100
150
Annual percentage impact
(b) Boxplot
Annual percentage impact
150
100
50
0
(c) Cumulative mean
Cumulative mean annual percentage impact
4
2
0
Mean
0
25000
50000
75000
100000
Number of iterations

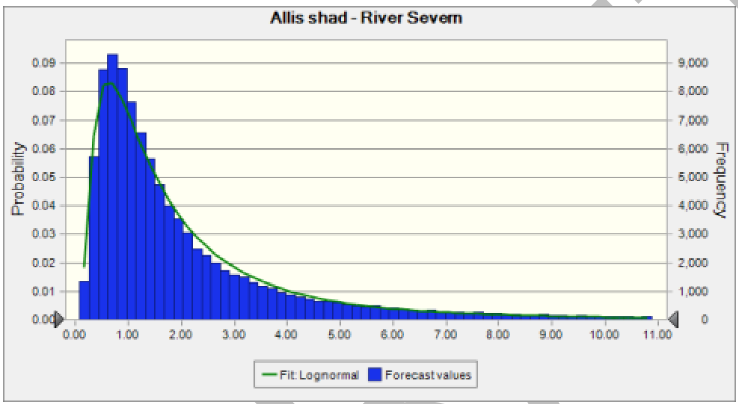

Atlantic salmon Severn sensitivity tests − tornado plot
Change of the mean
4
3
2
1
0
a) NIMP
b) NADD
c) NENT
d) F
e) A
f) V
g) MIMP
h) EAVIMP
i) MADD
j) EAVADD
k) MENT
l) EAVENT
m) W
n) P
Parameter

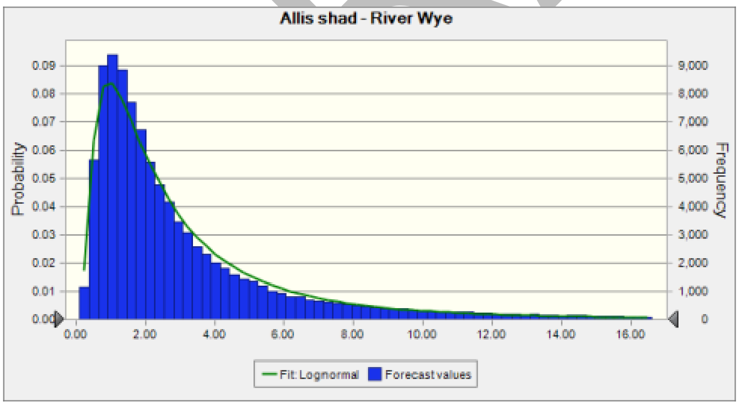
Appendix 3: Oracle Crystal Ball validation results

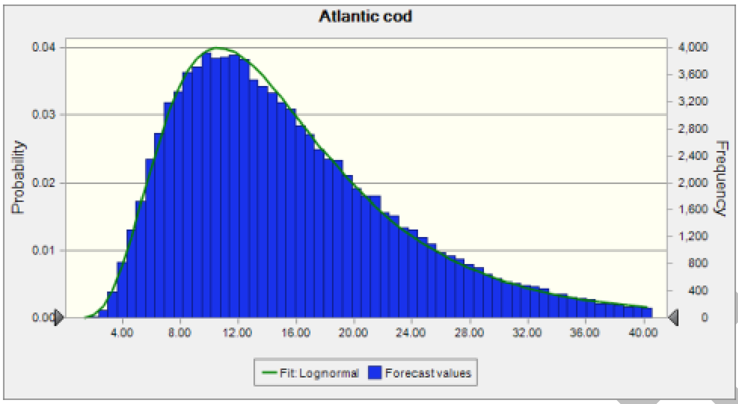
Species	Percentage (%) Loss - R				Percentage (%) Loss – Crystal Ball			
	Mean	**SD**	**Median**	**90th %ile**	**Mean**	**SD**	**Median**	**90th %ile**
European sprat	0.72	0.14	0.70	0.90	0.70	0.15	0.68	0.90
Whiting	12.48	5.77	11.38	20.03	12.78	5.48	11.78	20.01
Dover sole	5.20	2.96	4.54	9.02	5.18	2.79	4.61	8.86
Atlantic cod	16.53	10.15	14.11	29.41	15.98	8.77	14.06	27.30
Atlantic herring	4.41	0.91	4.27	5.61	*4.30*	*0.89*	*4.17*	*5.47*
European seabass	3.02	0.98	2.96	4.36	3.00	0.98	2.93	4.33
European plaice	0.14	0.08	0.13	0.26	0.15	0.08	0.14	0.26
Thornback ray	3.21	0.80	3.11	4.27	*3.14*	*0.86*	*3.03*	*4.28*
Blue whiting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
European eel - Severn Estuary								
Twaite shad - Severn Estuary	0.21	0.21	0.13	0.45	0.20	0.21	0.13	0.44
Allis shad - Severn Estuary	1.49	1.58	0.93	3.26	1.41	1.79	0.82	3.07
Sea lamprey - Severn Estuary	0.69	0.30	0.63	1.07	0.65	0.33	0.57	1.07
River lamprey - Severn Estuary	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.03
Atlantic salmon - Severn Estuary	0.11	0.50	0.02	0.23	0.09	0.23	0.04	0.21
Sea trout - Severn Estuary	0.12	0.08	0.10	0.21	0.10	0.59	0.02	0.19
Twaite shad - River Wye	0.42	0.43	0.26	0.90	0.40	0.41	0.25	0.87
Twaite shad - River Usk	0.83	0.86	0.52	1.82	0.80	0.84	0.50	1.75
Allis shad - River Wye	3.72	3.95	2.32	8.10	3.57	4.65	2.07	7.83
Allis shad - River Usk	NA	NA	NA	NA	NA	NA	NA	NA
Atlantic salmon - River Wye	0.31	1.66	0.06	0.62	0.26	0.70	0.09	0.59
Atlantic salmon - River Usk	0.35	1.34	0.07	0.71	0.29	0.67	0.11	0.66
Twaite shad – River Severn	0.83	0.86	0.52	1.79	0.80	0.83	0.50	1.75
Allis shad – River Severn	2.48	2.65	1.55	5.40	2.36	3.04	1.37	5.19
Atlantic salmon – River Severn	0.58	2.46	0.12	1.18	0.49	1.19	0.19	1.13

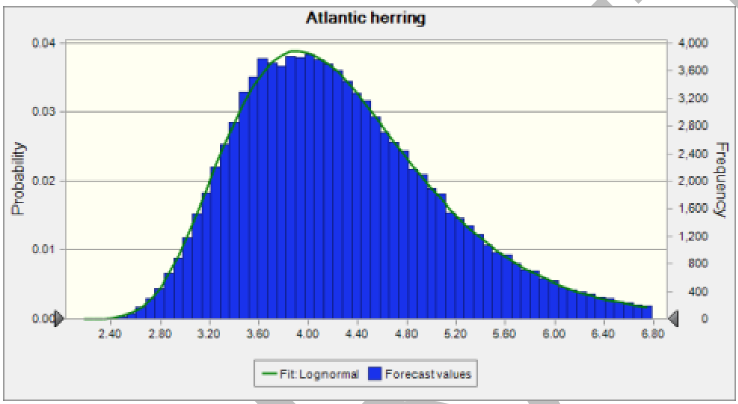
Commented [MAP3]: Currently still under review

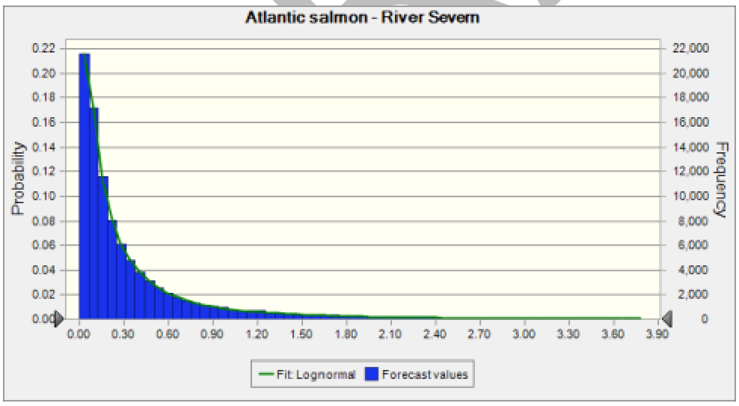

Allis shad
Probability
Frequency
Fit: Lognormal
Forecast values

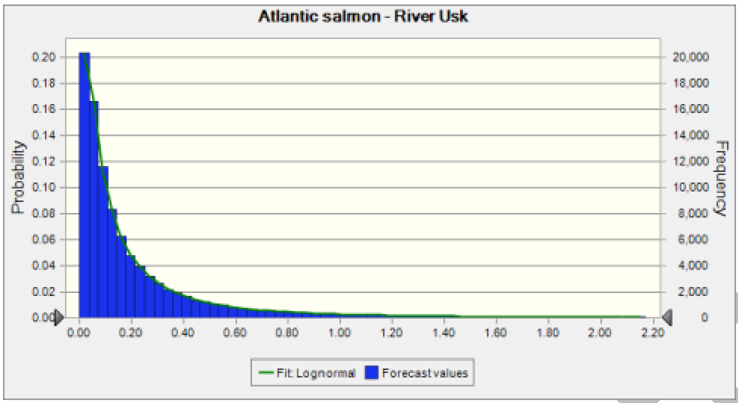

Allis shad - River Severn
Probability
Frequency
Fit: Lognormal
Forecast values

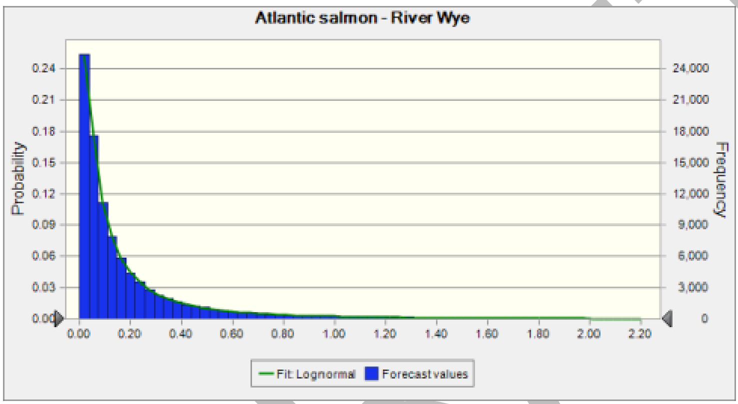

Allis shad - River Wye
Probability
Frequency
Fit: Lognormal
Forecast values

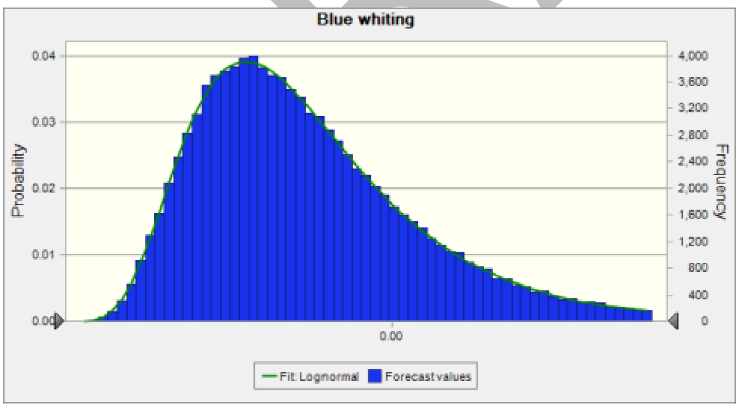

Atlantic cod
Probability
Frequency
0.04
0.03
0.02
0.01
0.00
4,000
3,600
3,200
2,800
2,400
2,000
1,600
1,200
800
400
0
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
Fit: Lognormal
Forecast values

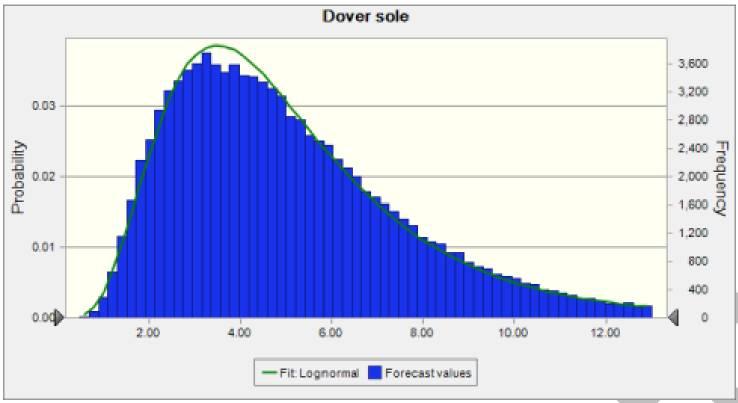

Atlantic herring
Probability
Frequency
0.04
0.03
0.02
0.01
0.00
4,000
3,600
3,200
2,800
2,400
2,000
1,600
1,200
800
400
0
2.40
2.80
3.20
3.60
4.00
4.40
4.80
5.20
5.60
6.00
6.40
6.80
Fit: Lognormal
Forecast values

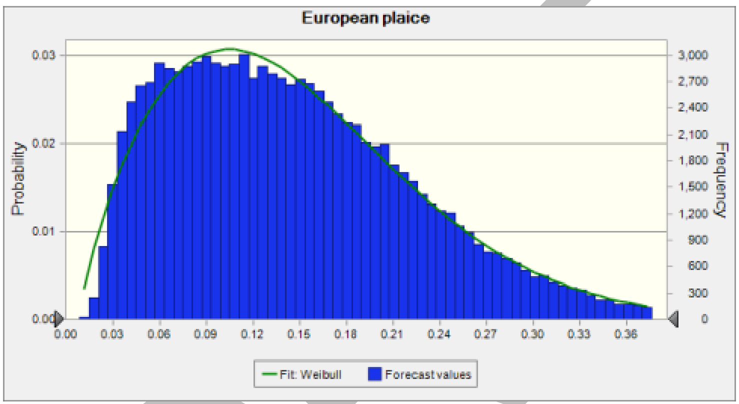

Atlantic salmon - River Severn
Probability
Frequency
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
0.00
0.30
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
3.30
3.60
3.90
Fit: Lognormal
Forecast values

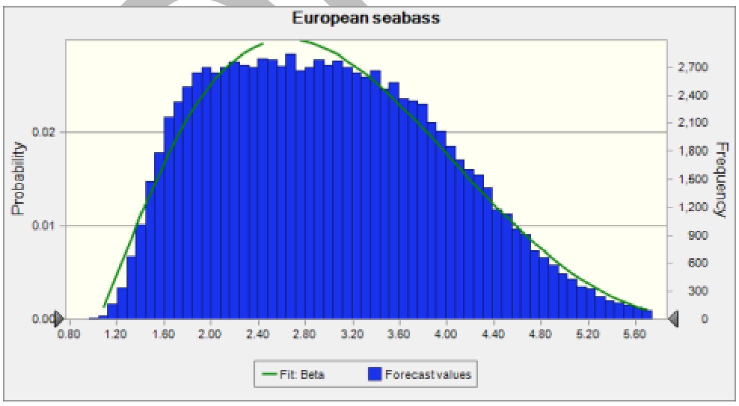

Atlantic salmon - River Usk
Probability
Frequency
Fit: Lognormal
Forecast values

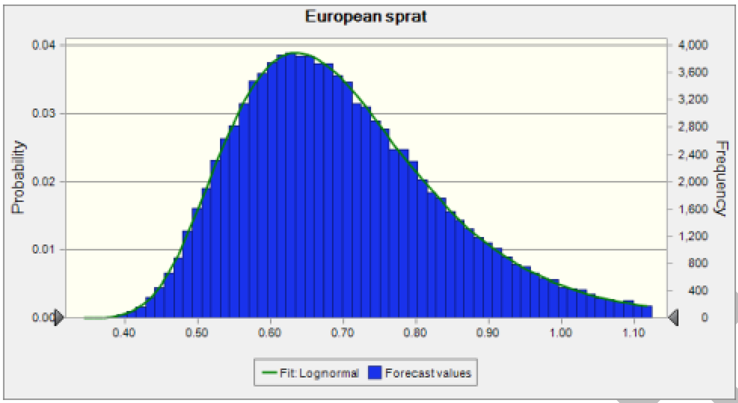

Atlantic salmon - River Wye
Probability
Frequency
Fit: Lognormal
Forecast values

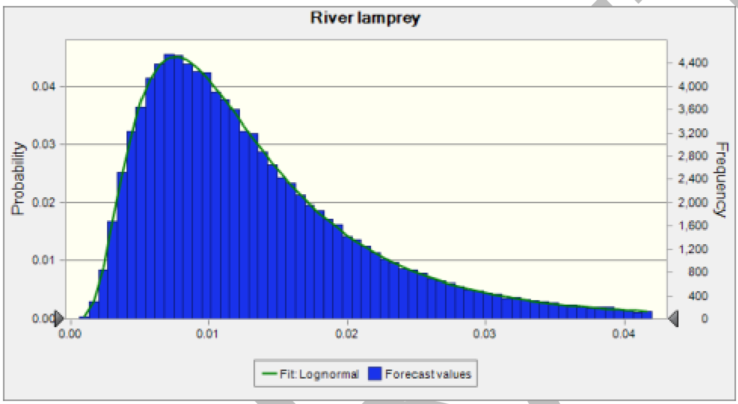

Blue whiting
Probability
Frequency
Fit: Lognormal
Forecast values

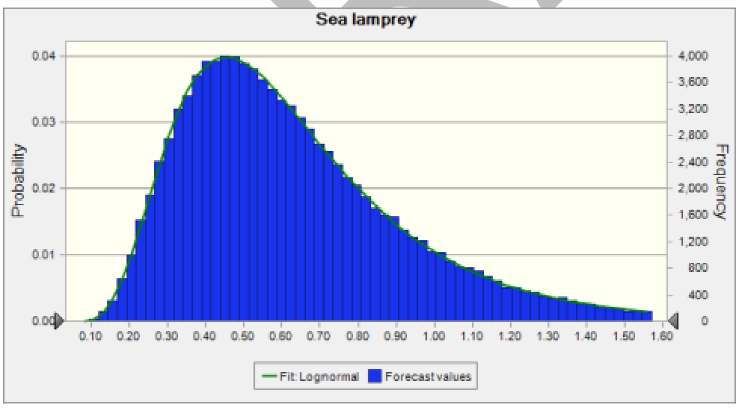

Dover sole
Probability
Frequency
Fit: Lognormal
Forecast values

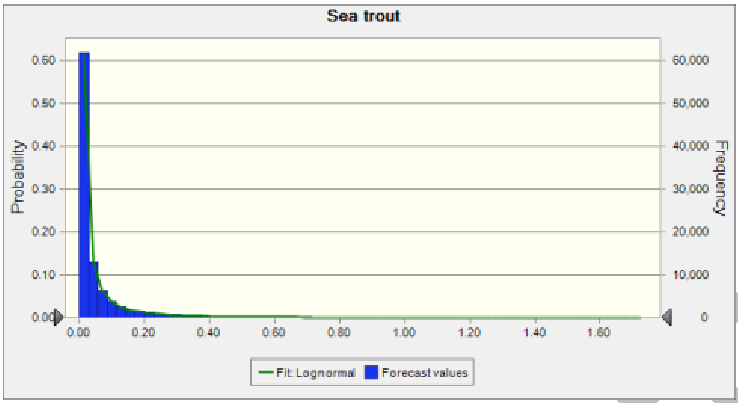

European plaice
Probability
Frequency
Fit: Weibull
Forecast values

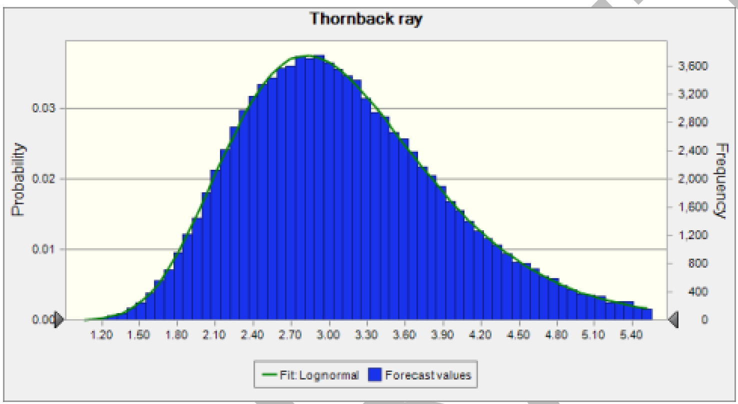

European seabass
Probability
Frequency
Fit: Beta
Forecast values

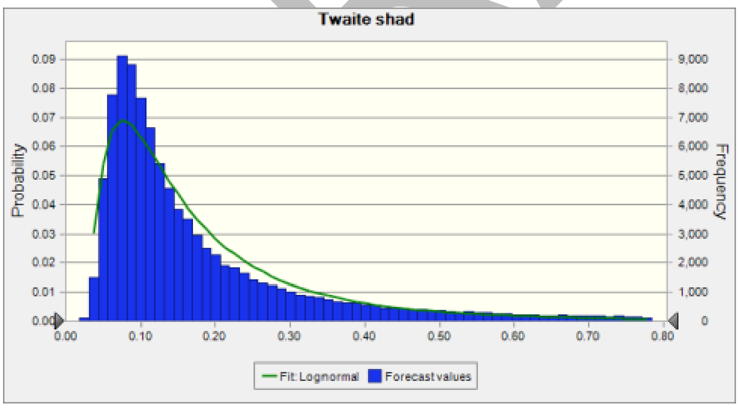

European sprat
Probability
Frequency
Fit: Lognormal
Forecast values

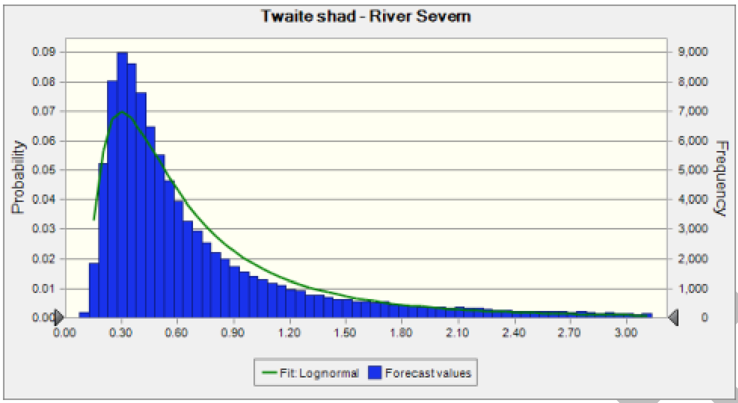

River lamprey
Probability
Frequency
Fit: Lognormal
Forecast values

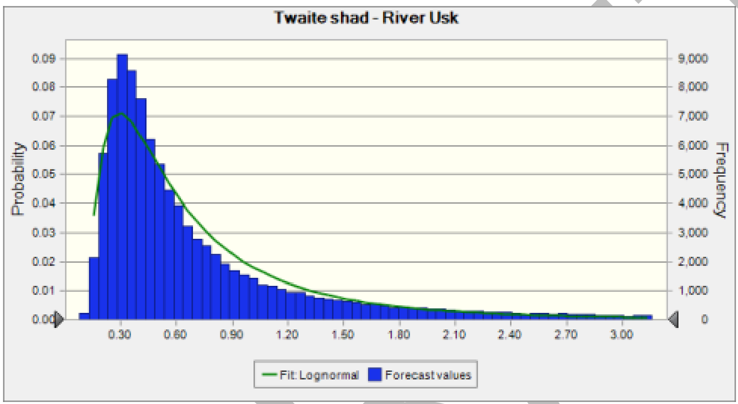

Sea lamprey
Probability
Frequency
Fit: Lognormal
Forecast values

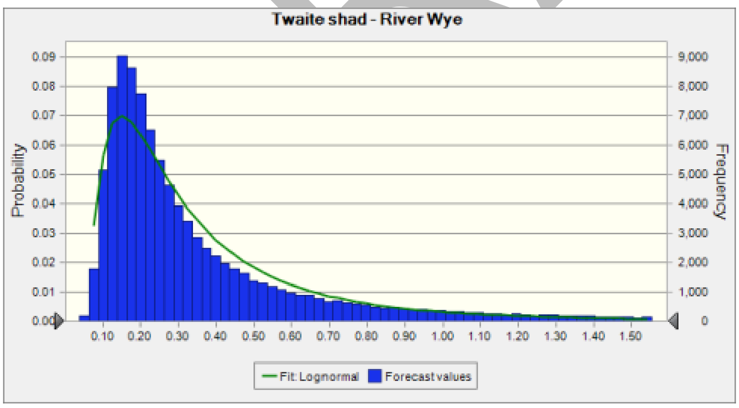

Sea trout
Probability
Frequency
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0
10,000
20,000
30,000
40,000
50,000
60,000
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60
Fit: Lognormal
Forecast values

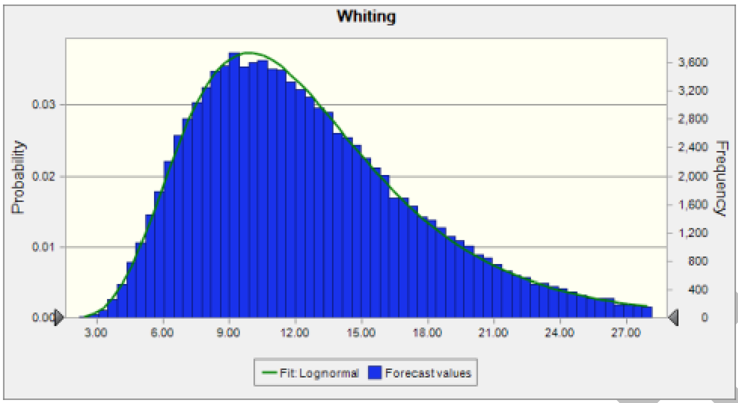

Thornback ray
Probability
Frequency
0.00
0.01
0.02
0.03
0
400
800
1,200
1,600
2,000
2,400
2,800
3,200
3,600
1.20 1.50 1.80 2.10 2.40 2.70 3.00 3.30 3.60 3.90 4.20 4.50 4.80 5.10 5.40
Fit: Lognormal
Forecast values


Twaite shad
Probability
Frequency
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80
Fit: Lognormal
Forecast values


Twaite shad - River Severn
Probability
Frequency
0.00
0.30
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
Fit: Lognormal
Forecast values


Twaite shad - River Usk
Probability
Frequency
0.30
0.60
0.90
1.20
1.50
1.80
2.10
2.40
2.70
3.00
Fit: Lognormal
Forecast values


Twaite shad - River Wye
Probability
Frequency
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
Fit: Lognormal
Forecast values


Whiting
Probability
Frequency
0.03
0.02
0.01
0.00
3,600
3,200
2,800
2,400
2,000
1,600
1,200
800
400
0
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
27.00
Fit: Lognormal
Forecast values