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Abbreviations and Acronyms

iPCoD	Interim Population Consequences of Disturbance
MS LOT	Marine Scotland Licensing Operations Team
OSP	Offshore Substation Platform
OTM	Offshore Transformer Module
OWF	Offshore Wind Farm
PTS	Permanent Threshold Shift
SMRU	Sea Mammal Research Unit

10A Assessment of Population Level Effects on Bottlenose Dolphins using iPCoD

10A.1 Introduction

1 As part of the piling impact assessment (see *Chapter 10: Marine Mammals, Sections 10.7.1, 10.8.1* and *10.11.1*), the potential impacts of pile driving noise on marine mammals (Permanent Threshold Shift (PTS) and displacement)) were explored at the population level for bottlenose dolphins in order to inform the Appropriate Assessment (AA). As agreed through consultation (see *Chapter 10, Section 10.2*), this (an assessment of population level effects) was not required for the other species.

10A.2 Modelling Approach

10A.2.1 Development only

2 The population level effects of the construction of the Inch Cape Wind Farm on bottlenose dolphins were modelled using version 3 of the interim Population Consequences of Disturbance framework (iPCoD v3; Plunkett *et al*., 2017; Booth, 2017), with the replacement of the "PCoDFunctionsFinal_ver3" file with a file of the same name provided to the Natural Power Consultants (Natural Power) by Sea Mammal Research Unit (SMRU) Consulting on 13/03/2018 to address a bug in the incorporation of demographic stochasticity into the model.

3 The exact piling schedules which will be used are not yet known; therefore indicative piling schedules were used for both the Development and other cumulative projects (see *Table 10A.1*). These (and the other input parameter values; see *Table 10A.2*) were agreed in consultation with Marine Scotland Licensing Operations Team (MS LOT). It is possible that piling for the Development will consist of a combination of single vessel operations (consecutive piling of individual piles within a day) and double vessel operations (simultaneous piling of two piles at a time within a day). Details of the Development piling scenarios are provided in *Chapter 10, Sections 10.5.1*. Simulations were run assuming either that all piling days are single vessel operations, representing a lower daily impact and a greater number of impact days (piling schedule 1; see *Table 10A.2*), or that all piling days are double vessel operations, representing a higher daily impact and fewer impact days (piling schedule 2; see *Table 10A.2*).

4 All models were run for predicted impacts from the installation of pin pile and monopile foundations, resulting in four modelling scenarios:

- Single vessel, pin piles;
- Simultaneous piling using two vessels, pin piles;
- Single vessel, monopiles; and
- Simultaneous piling using two vessels, monopiles.

5 The indicative piling schedules used in the modelling are presented in *Table 10A.1*. It was assumed that each day of piling would be followed by an additional day of works and that a day would be needed to move between sites. For pin-pile OSPs, two consecutive days of piling were assumed to take place (see descriptions of piling schedules used in *Table 10A.1*).

6 The number of individuals impacted per day (PTS and displacement) was calculated from the outputs of noise modelling carried out for the proposed piling operations, and agreed density surfaces for bottlenose dolphin (see *Section 10.6.6* of *Chapter 10*), incorporating a dose response curve for displacement (see *Section 10.7.1* of *Chapter 10*). The analysis suggested that the impact of PTS would be localised such that the use of an acoustic deterrent device (ADD) immediately prior to piling would rule out PTS damage to bottlenose dolphin under all scenarios. Therefore, only disturbance effects from displacement were included in the iPCoD modelling. The highest expected displacement scenarios were used representing a precautionary approach. iPCoD modelling was carried out for the worst case individual piling scenarios investigated (see *Chapter 10*). The model assumed one day of residual disturbance following each piling day, during which all displaced animals are disturbed. This is considered to be a conservative estimate as animals have been observed to return quickly following piling, for example at the Robin Rigg and Beatrice Offshore Wind Farms (OWFs) (Vallejo *et al*., 2017; Graham *et al*., 2017). Each simulation was run for 25 years starting in 2017 (as recommended by MS LOT) and 1000 simulations were carried out for each piling schedule, as recommended by the developers of iPCoD. Carrying capacity was set to 234 (the starting population size plus a 20 per cent increase, however, since there is no evidence of density dependence in the population (Cheney *et al*., 2018), this was not incorporated into the model. This is considered as a conservative approach, as not including density dependence has the effect of limiting the modelled population's ability to recover from any impact and return to undisturbed population levels. The models were run using the iPCoD recommended threshold for modelling the effects of demographic stochasticity of 500. Demographic parameters used were those suggested for bottlenose dolphin for the Coastal East Scotland management unit by Harwood and King (2017). The iPCoD sub-population option was not used because, although there is evidence of stratified movement in the inner Moray Firth (Wilson *et al*., 1997), individuals also exhibit long-range (from the inner Moray Firth to Fife) within-year movements (Wilson *et al*., 1997; Cheney *et al*., 2013) therefore the population cannot be subdivided into separate units based on area[1] (Cheney *et al*., 2013). In addition, the cumulative projects included within the models were outside of the Firth of Forth, and thus would be impacting animals present outside this component of the population's range. The complete list of parameters used for the model can be found in *Table 10A.2*.

[1] Cheney *et al*. (2013) also report that results of genetic analyses show some but not complete isolation between animals found on the east and west coasts and elsewhere in Britain and Ireland and state that, together, these results confirm that the east coast population should continue to be considered as a single separate unit for management purposes.

Table 10A.1: Indicative piling schedules

Site (in order appears in models)	Number of days of piling schedule	Justification	Year	Start date	End date	Pattern of piling (OSP/OTMs assumed to be piled first)
Development - pin piles - single vessel	76	72 4-legged jackets (one day each) and 2 8-legged Offshore Substation Platforms (OSPs) (two consecutive days)	2021	13/03/2021	20/10/2021	(110110)100100100100…
Development - monopiles - single vessel	74	72 monopiles and 2 monopile OSPs	2021	12/03/2021	17/10/2021	100100100100100100…
Development - pin piles - double vessel	38	As above divided by two (no consecutive days)	2021	05/05/2021	24/08/2021	100100100100100100…
Development - monopiles - double vessel	37	As above divided by two	2021	05/05/2021	21/08/2021	100100100100100100…
Neart na Gaoithe	112	54 6-legged jackets (two days each) and 2 8-legged OSPs (two days each)	2021	08/04/2021	21/09/2021	110110110110110110…
Aberdeen Harbour Expansion Project	32	32 days of blasting	2018	19/04/2018	10/09/2018	000000011000000011…
Moray East	137	137 4-legged jackets (one day each)	2020-2021	21/03/2020 & 20/03/2021	08/10/2020 & 10/10/2021	100100100100100100…
Beatrice	88	84 4-legged jackets (one day each) and 2 8-legged Offshore Transformer Modules (OTMs) (two consecutive days each)	From 27/03/2017 to 31/10/2017	27/03/2017	29/10/2017	(110110)1001010010…

Table 10A.2: Input parameter values used[2]

Parameter description	Parameter name	Justification of parameters	Models run					
Folder name			IC_single_pin	IC_single_mono	IC_double_pin	IC_double_mono	Cum_single_pin	Cum_single_mono
Assessment type			Development only	Development only	Development only	Development only	Cumulative	Cumulative
Vessel number			One	One	Two	Two	One	One
Worst case or most likely			Worst case	Worst case	Worst case	Worst case	Most likely	Most likely
Monopile or pin pile			Pin pile	Monopile	Pin pile	Monopile	Pin pile	Monopile
Name for output files	run_ID	NA	_IC_single_pin	_IC_single_mono	_IC_double_pin	_IC_double_mono	_Cum_single_pin	_Cum_single_mono
Number of bootstraps	nboot	Recommended by developers of PCoD	1000	1000	1000	1000	1000	1000
Species	spec	Appropriate parameter for BND	BND	BND	BND	BND	BND	BND
Proportion of females	propfemale	Recommended by developers of PCoD	0.5	0.5	0.5	0.5	0.5	0.5
Population size	pmean	Cheney *et al*. (2013)[3]	195	195	195	195	195	195

[2] This information (input parameter values) is also available as an Excel spreadsheet if required.
[3] This estimate, rather than the most recent one of 189 individuals (Cheney *et al*., 2018), has been used following advice from Barbara Cheney of the University of Aberdeen. The Cheney *et al*. (2013) estimate was generated using the most comprehensive dataset from around the coast.

Parameter description	Parameter name	Justification of parameters	Models run					
Threshold for demographic stochasticity	threshold	Recommended by developers of PCoD	500	500	500	500	500	500
Calf/pup survival	Surv[1]	Harwood and King (2017)	0.9	0.9	0.9	0.9	0.9	0.9
Juvenile survival	Surv[7]	Harwood and King (2017)	0.94	0.94	0.94	0.94	0.94	0.94
Adult survival	Surv[13]	Harwood and King (2017)	0.945	0.945	0.945	0.945	0.945	0.945
Fecundity rate	Fertility	Harwood and King (2017)	0.3	0.3	0.3	0.3	0.3	0.3
Age at which calf/pup becomes independent	age1	Harwood and King (2017)	2	2	2	2	2	2
Age at which female gives birth to her first calf/pup	age2	Harwood and King (2017)	9	9	9	9	9	9
Number of years on which piling will occur	pile_years	Actually length of piling schedule	5	5	5	5	5	5
Proportion of animals in each vulnerable sub-population	vulnmean	Assuming no sub-populations	c(1)	c(1)	c(1)	c(1)	c(1)	c(1)

Parameter description	Parameter name	Justification of parameters	Models run					
File which contains the piling schedule	piling.file	NA	"IC_single_pin.csv"	"IC_single_mono.csv"	"IC_double_pin.csv"	"IC_double_mono.csv"	"Cum_single_pin.csv"	"Cum_single_mono.csv"
Number of piling operations (i.e. sites)	pilesx1	Number of operations considered	1	1	1	1	5	5
Which operations affect which sub-populations (one line per sub-population)	vulnpile[1,]	Assuming no sub-populations	c(1)	c(1)	c(1)	c(1)	c(1, 1, 1, 1, 1)	c(1, 1, 1, 1, 1)
Number of animals displaced	numDT	Displacement per operation	c(5)	c(7)	c(6)	c(8)	c(4, 2, 53, 17, 19)	c(5, 2, 53, 17, 19)
Number of animals experiencing PTS	numPT	No PTS predicted for any site	c(0)	c(0)	c(0)	c(0)	c(0, 0, 0, 0, 0)	c(0, 0, 0, 0, 0)
Residual days of disturbance (e.g. a 1 here means 1 day of piling gives rise to 2 days of disturbance. This can be decimal)	days	Precautionary based on rapid return rate at e.g. Robin Rigg and Beatrice	1	1	1	1	1	1
Proportion of disturbed animals experiencing the residual disturbance	prop_days_dist	Precautionary	1	1	1	1	1	1

Parameter description	Parameter name	Justification of parameters	Models run					
How many days of residual disturbance the other animals experience	other_days	NULL due to parameter above	0	0	0	0	0	0
Disturbed animals avoid ALL operations	Avoid	Disturbed animals avoid ALL operations	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Number of years to project forwards	years	Recommended by MS LOT	25	25	25	25	25	25
Number of collisions e.g. with tidal arrays	NCollisions	NA	0	0	0	0	0	0
Exponent for density dependence relationship. If 0, no density dependence	z	No data on density dependence	0	0	0	0	0	0
Carrying capacity	K	Starting population plus 20% as recommended by MS LOT	234	234	234	234	234	234
Maximum fertility value	Fert_0	Default	0.95	0.95	0.95	0.95	0.95	0.95

7 For each model run, the median predicted population size at each year of simulation was plotted with 95 per cent confidence intervals for the unimpacted and impacted populations. It is important to note that this is presented to facilitate comparisons among the scenarios rather than to make quantitative predictions regarding the likely bottlenose dolphin population size at any time. Several metrics requested by MS LOT were also tabulated. These included:

1. The median of the ratio of the impacted to unimpacted annual growth rate: This was calculated using the final population sizes for each simulation to derive the average population growth rate over the 25 year simulation. It is expected that growth rate should be lower for the impacted population therefore this parameter would be expected to be less than one. A value of one would indicate that, on average, the disturbance levels experienced by the population have no impact on population growth over the 25 year period. The derived value in brackets represents the median difference in the impacted and unimpacted growth rates. This is the least sensitive metric of metrics one to three presented here (Jitlal *et al*., 2017[4]).
2. The median of the ratio of the impacted to unimpacted population size: This was calculated using the final population sizes for each simulation. Again, since it is expected that end population size should be lower for the impacted population, this parameter would also be expected to be less than one. A value of one would indicate that, on average, the disturbance levels experienced by the population have no impact on population size over the 25 year period. The derived value in brackets represents the median difference in the impacted and unimpacted population size.
3. The centile for the unimpacted population that matches the 50th centile for the impacted population: This was calculated based on the final population sizes after 25 years. Since the end population size of the impacted population is expected to be less than that of the unimpacted population, this value is expected to be less than 0.5. A value of 0.5 would indicate no impact on population size over the 25 year period. This is the most sensitive metric of metrics one to three presented here (Jitlal *et al*., 2017[3]). The distributions of population sizes for both the impacted and unimpacted populations were also plotted as histograms.
4. The predicted median end population size is also presented for each scenario.

10A.2.2 Cumulative assessment

8 For the cumulative scenarios, four additional developments were included in the quantitative assessment (Neart na Gaoithe, Moray East and Beatrice OWFs and the Aberdeen Harbour Expansion Project; see *Chapter 10, Section 10.7.1*). Parameters used are presented in *Table 10A.2* and a description of the impact (piling) schedules used is provided in *Table 10A.1*. Where there was a choice, numbers from the single vessel most likely scenarios (e.g. scenario 1 for the Wind Farm) were used in the modelling. Analyses were carried out separately for pin pile foundations and monopile foundations.

[4] Cited in the Scoping Opinion (Marine Mammals Addendum) when it was an unpublished Marine Scotland Science-commissioned report.

10A.3 Results

10A.3.1 Development only

9 For each of the four Development only scenarios, it is very difficult to differentiate between predicted bottlenose dolphin population growth with no displacement (undisturbed population) and with displacement (disturbed population; see *Figure 10A.1, Figure 10A.3, Figure 10A.5* and *Figure 10A.7*). This suggests that displacement from piling is unlikely to affect population growth.

10 The median ratio of disturbed to undisturbed growth rate, and disturbed to undisturbed population size, was equal to one for each of the four Development only scenarios (see *Table 10A.3, Table 10A.4, Table 10A.5* and *Table 10A.6*). This indicates that, on average, the disturbance levels experienced by the population have no impact on population size over the 25 year period modelled. Furthermore, the end population size of the disturbed population is the same as, or just one or two individuals less than, that of the undisturbed population (see *Figure 10A.2, Figure 10A.4, Figure 10A.6* and *Figure 10A.8*). This also indicates no impact on population size over the 25 year period modelled.

11 In conclusion, displacement from pile driving at the Development is unlikely to affect the size or growth of the bottlenose dolphin population off the east coast of Scotland (for any of the four scenarios).

Development only pin piles one vessel (Scenario A)

Figure 10A.1: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with piling pin piles (disturbed population) at the Development using a single vessel

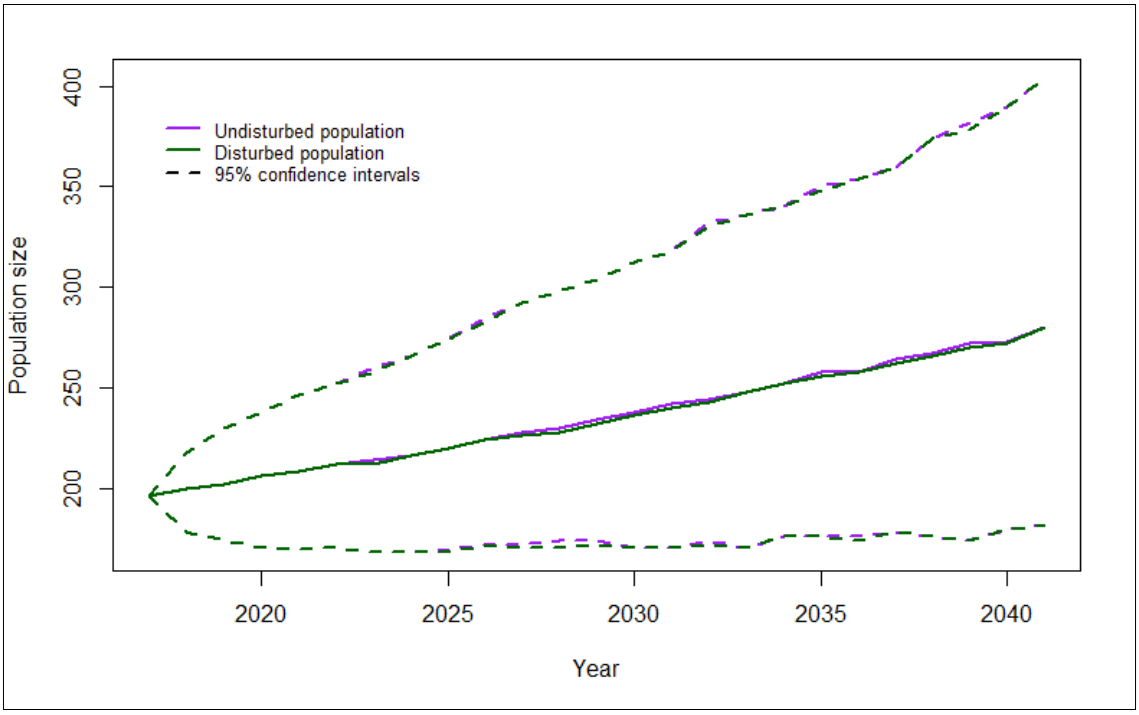

Figure 10A.2: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with piling pin piles (disturbed population) at the Development using a single vessel

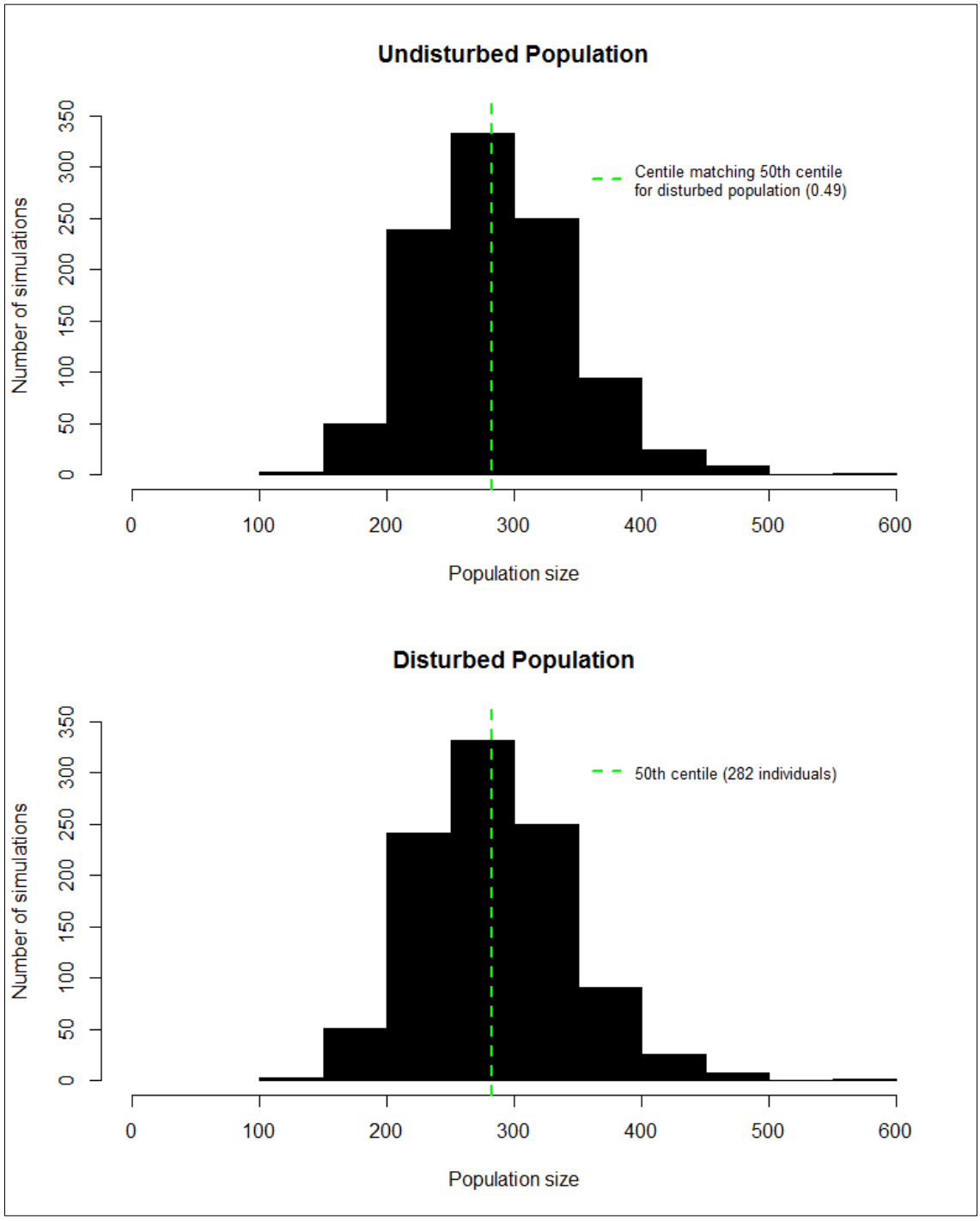

Table 10A.3: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated with piling pin piles at the Development using a single vessel. Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	284
IC pin pile single vessel	1.00 (0.00)	1.00 (0.00)	0.49	282

Development only pin piles two vessels (Scenario B)

Figure 10A.3: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with piling pin piles (disturbed population) at the Development with simultaneous piling using two vessels

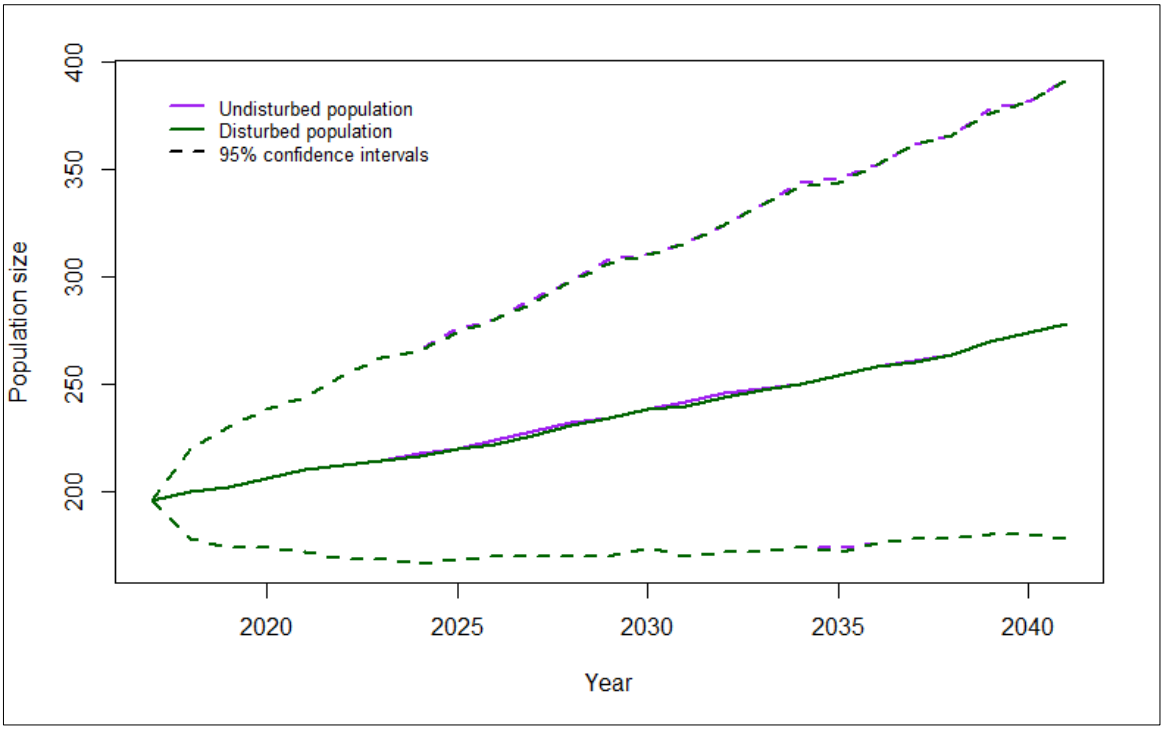

Figure 10A.4: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with piling pin piles (disturbed population) at the Development with simultaneous piling using two vessels

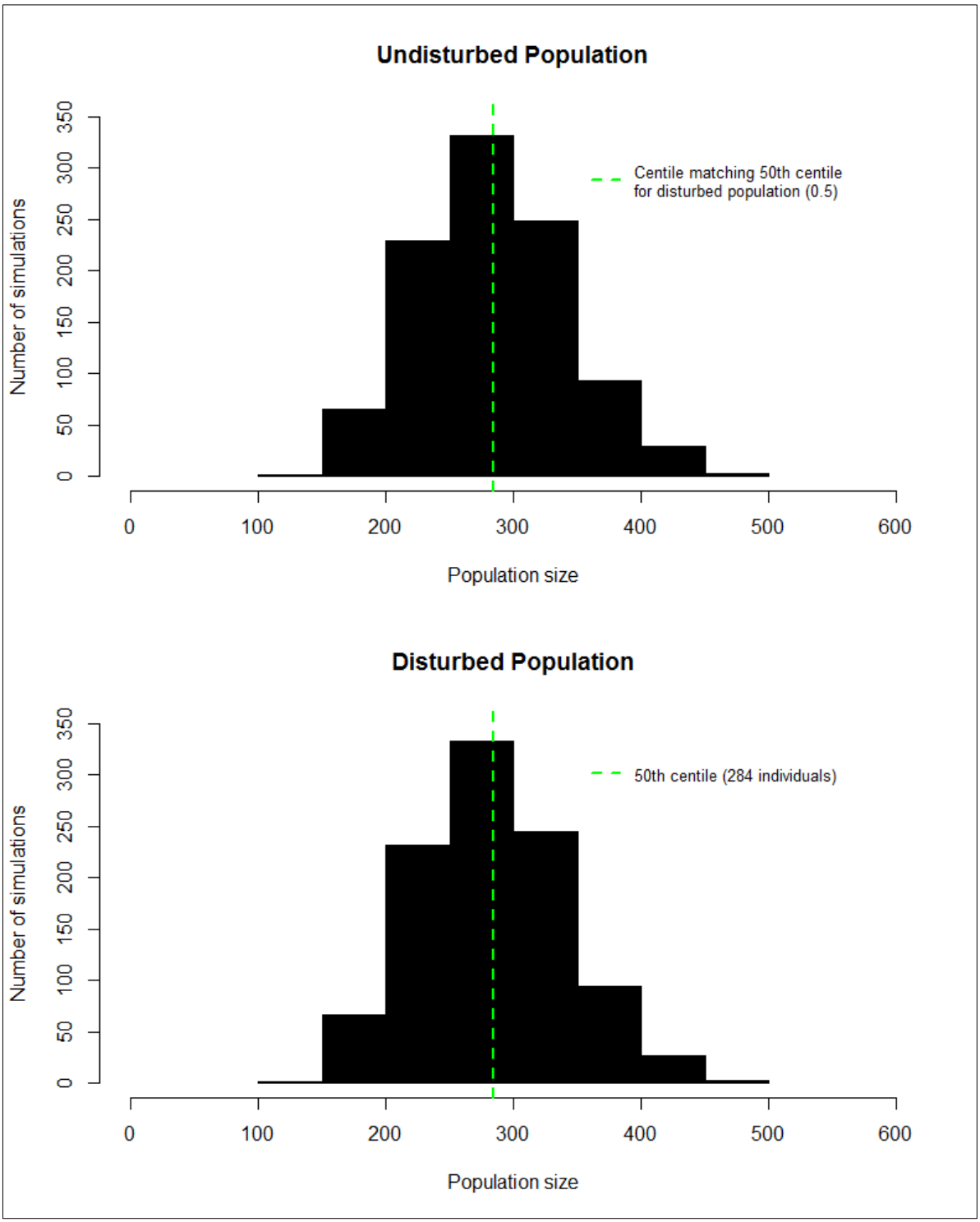

Table 10A.4: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated with piling pin piles at the Development with simultaneous piling using two vessels. Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	284
IC pin pile two vessels	1.00 (0.00)	1.00 (0.00)	0.50	284

Development only monopiles single vessel (Scenario C)

Figure 10A.5: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with piling monopiles (disturbed population) at the Development using a single vessel

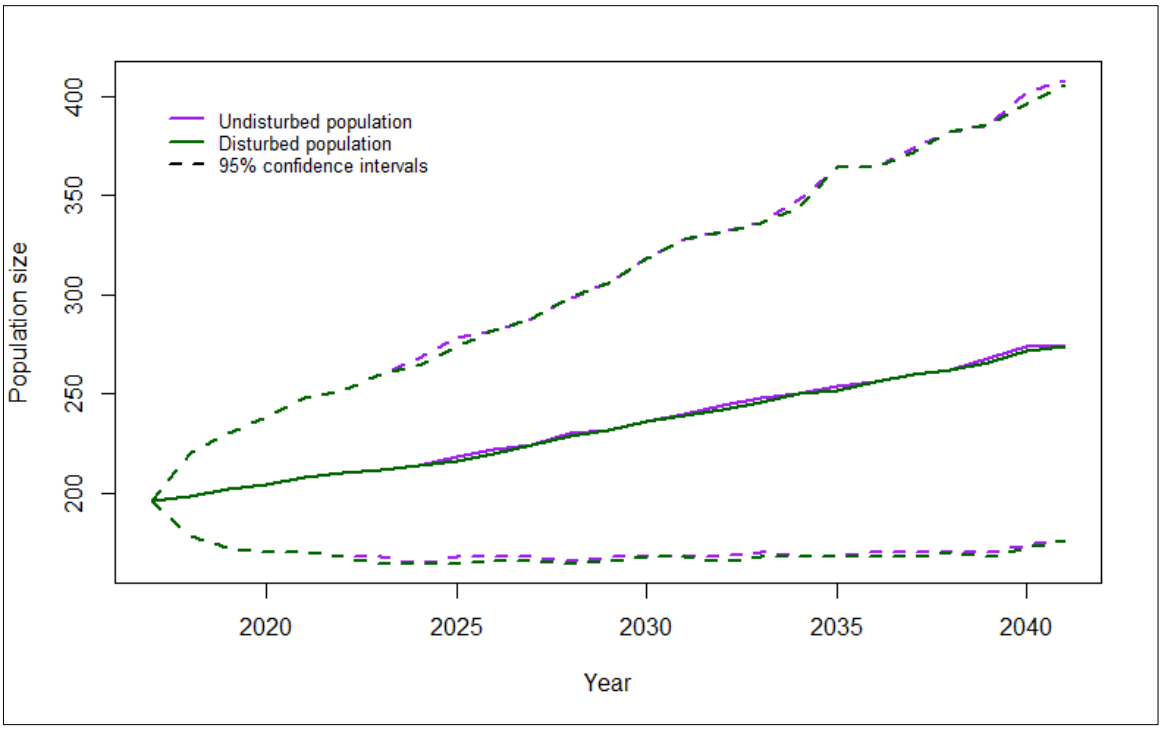

Figure 10A.6: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with piling monopiles (disturbed population) at the Development using a single vessel

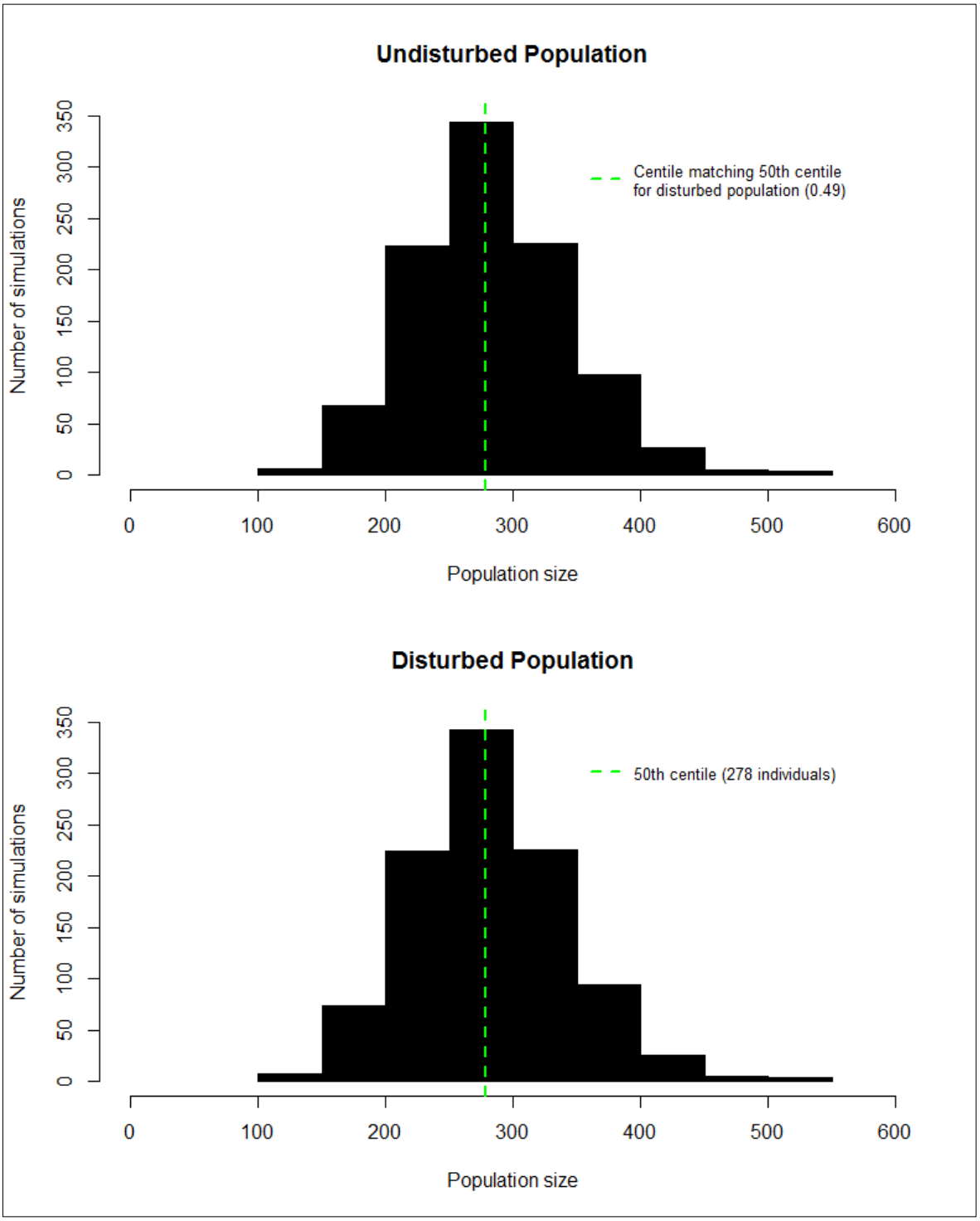

Table 10A.5: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated with piling monopiles at the Development using a single vessel. Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	280
IC monopile single vessel	1.00 (0.00)	1.00 (0.00)	0.49	278

Development only monopiles two vessels (Scenario D)

Figure 10A.7: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with piling monopiles (disturbed population) at the Development with simultaneous piling using two vessels

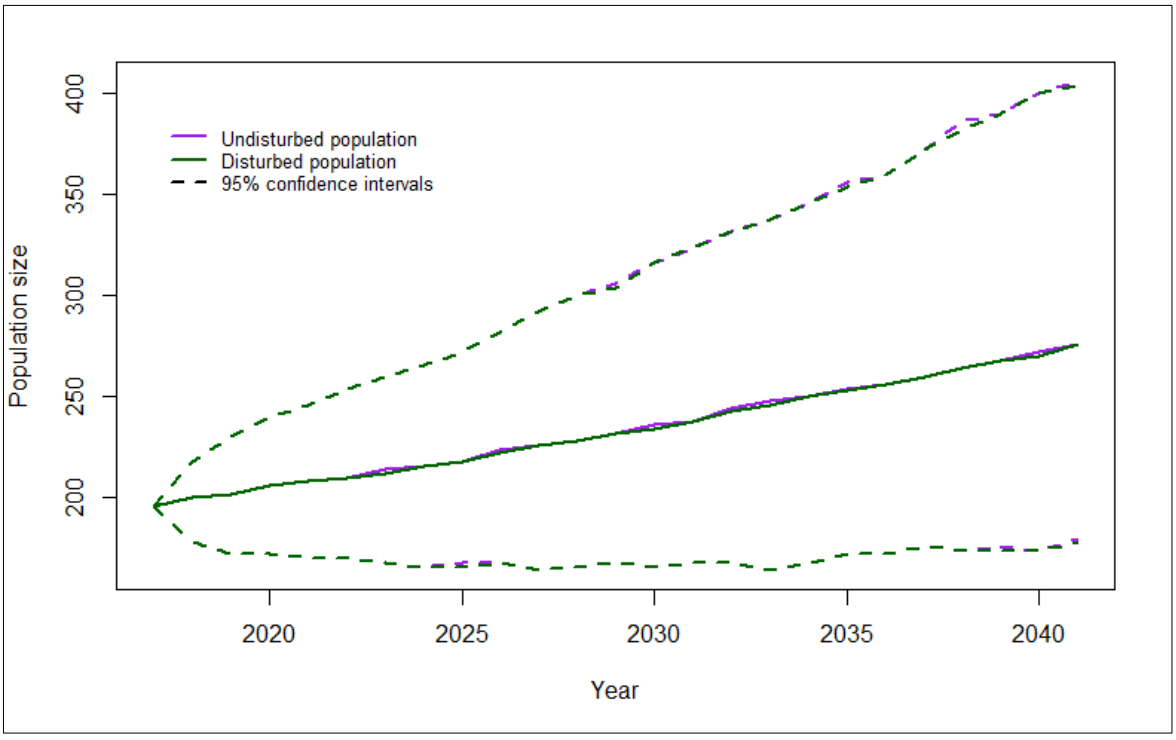

Figure 10A.8: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with piling monopiles (disturbed population) at the Development with simultaneous piling using two vessels

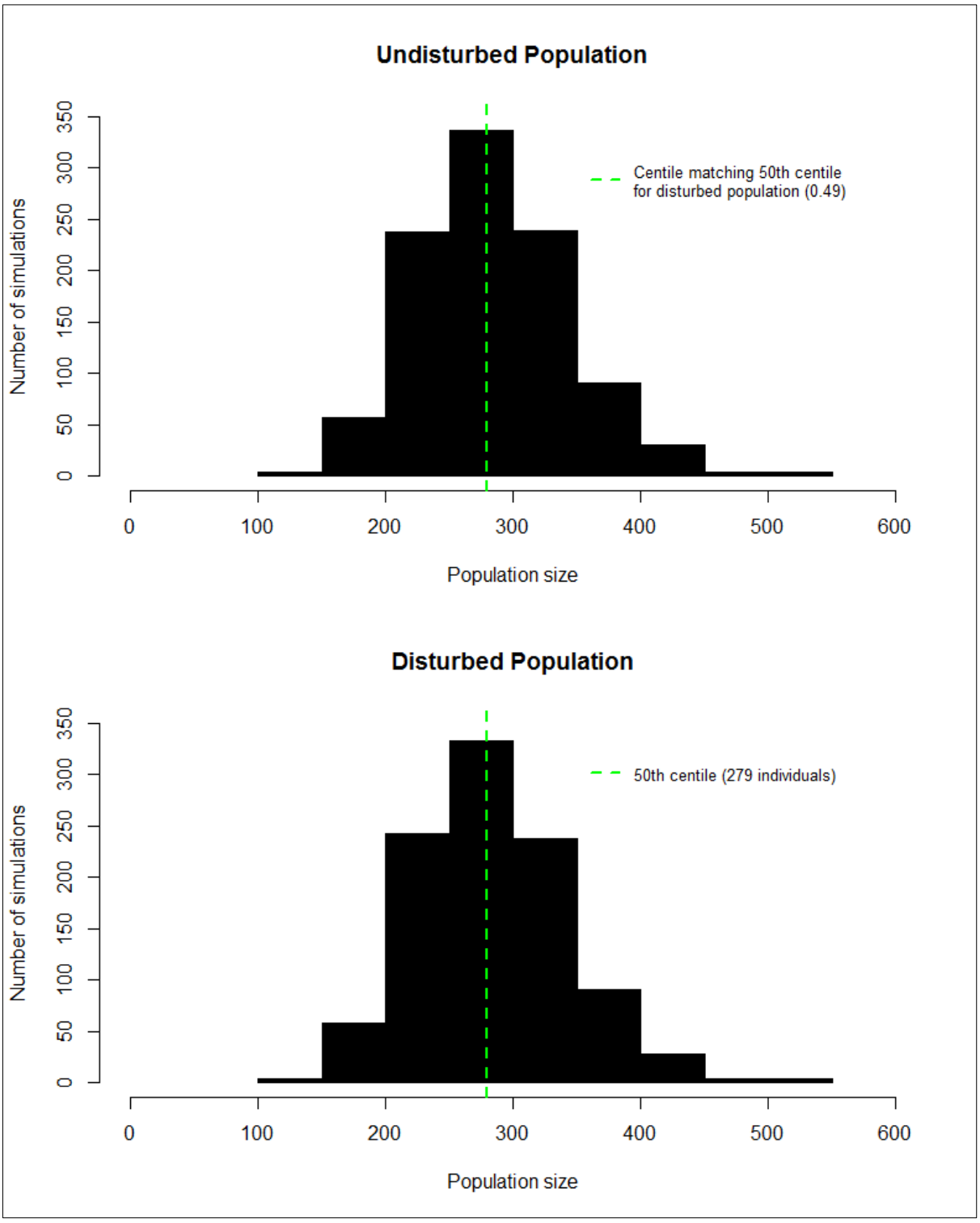

Table 10A.6: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated with piling monopiles at the Development with simultaneous piling using two vessels. Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	280
IC monopile two vessels	1.00 (0.00)	1.00 (0.00)	0.49	279

10A.3.2 Cumulative

12 Although predicted bottlenose dolphin population growth with displacement (disturbed population) can be differentiated from predicted bottlenose dolphin population growth with no displacement (undisturbed population), disturbed population growth follows the same trajectory as undisturbed population growth in the years after construction/displacement (which have been modelled to occur between 2017 and 2021 inclusive; see *Figure 10A.9* and *Figure 10A.11*). The end population size of the disturbed population is similar to (95 per cent of) that of the undisturbed population in each of the two cumulative scenarios modelled (see *Figure 10A.10* and *Figure 10A.12*).

13 The median ratio of disturbed to undisturbed growth rate, and disturbed to undisturbed population size, was equal to one for each of the two cumulative scenarios (see *Table 10A.7* and *Table 10A.8*). This indicates that, on average, the disturbance levels experienced by the population have no impact on population size over the 25 year period modelled.

14 In conclusion, displacement from pile driving/blasting may affect the size and growth of the bottlenose dolphin population off the east coast of Scotland. However, the outputs from iPCoD suggest that the size of this effect is likely to be small for both cumulative scenarios. The precision of estimates from the current monitoring programme for this population (and other similar populations) suggest that an effect of this size is unlikely to be detectable.

Cumulative pin piles one vessel (Scenario E)

Figure 10A.9: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with five East coast projects including piling pin piles at the Development with a single vessel (disturbed population)

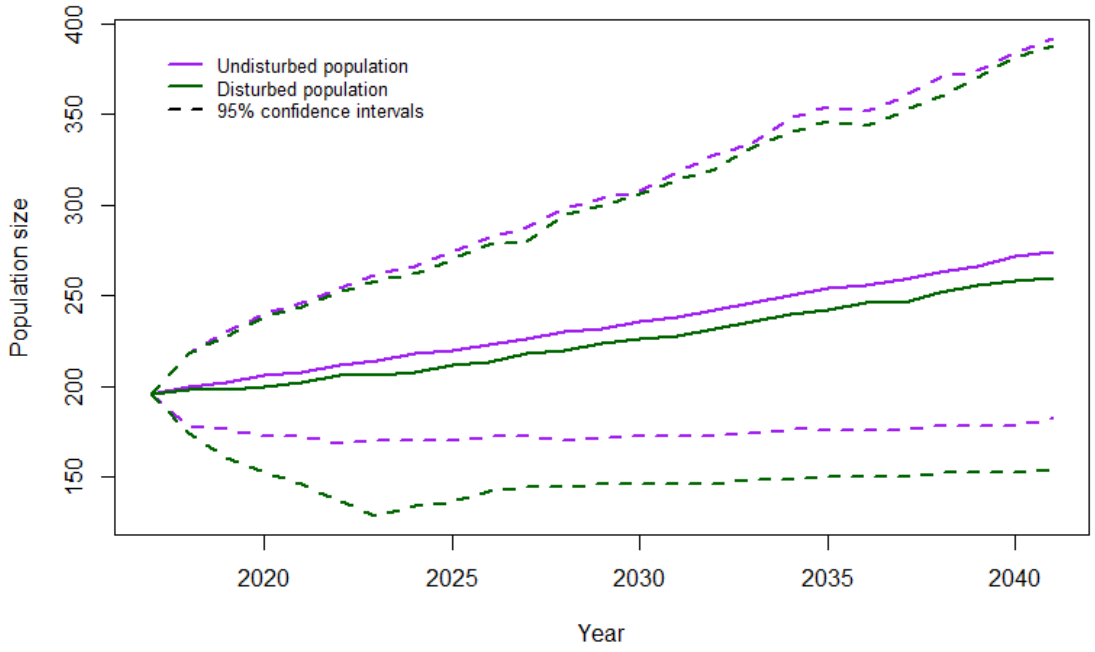

Figure 10A.10: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with five East coast projects including piling pin piles at the Development with a single vessel (disturbed population)

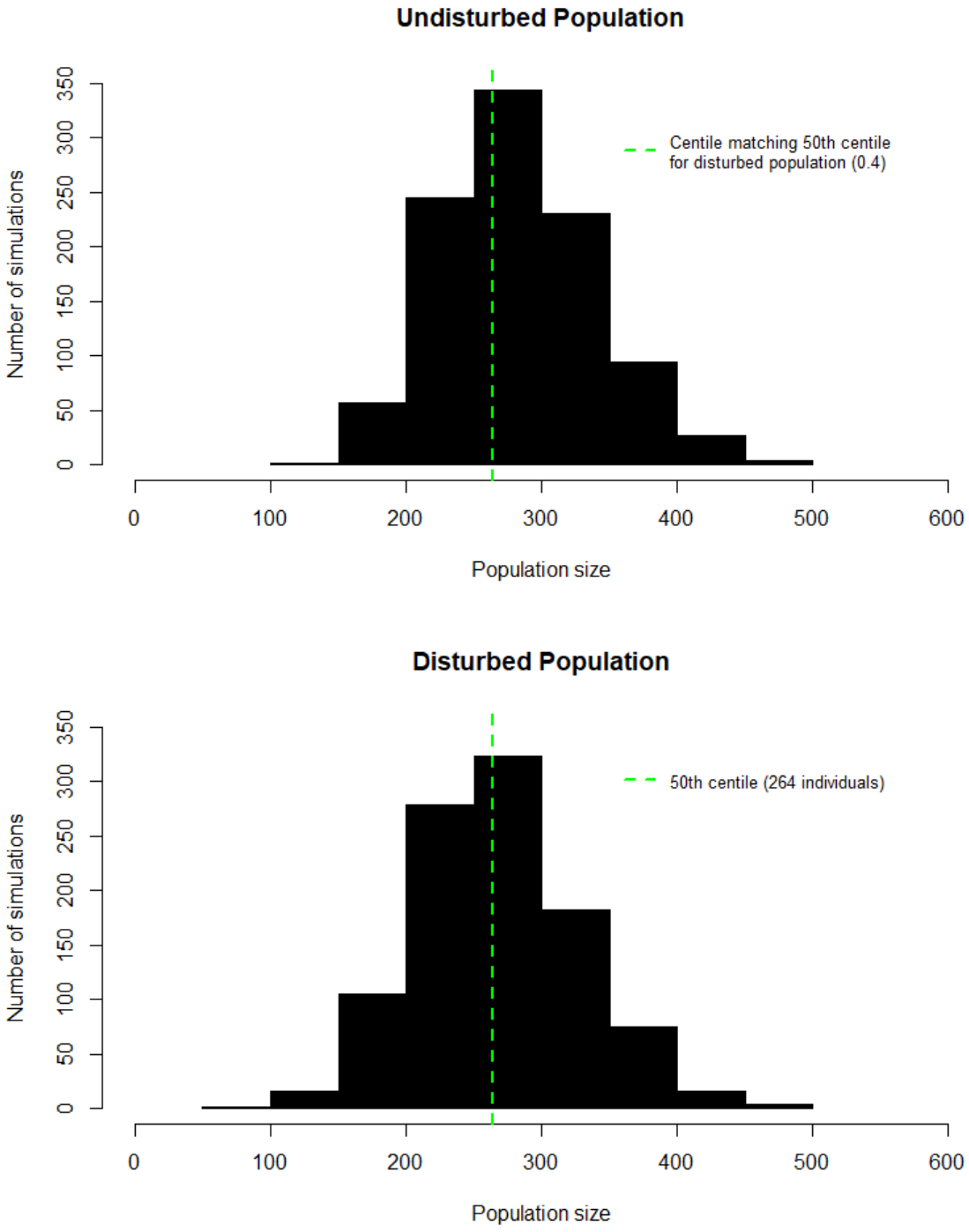

Table 10A.7: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated five East coast projects including piling pin piles at the Development with a single vessel (disturbed population). Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	276
IC pin pile single vessel + cumulative projects	1.00 (0.00)	1.00 (0.00)	0.40	264

Cumulative monopiles one vessel (Scenario F)

Figure 10A.11: Predicted bottlenose dolphin population growth over 25 years with no displacement (undisturbed population) and with displacement associated with five East coast projects including piling monopiles at the Development with a single vessel (disturbed population)

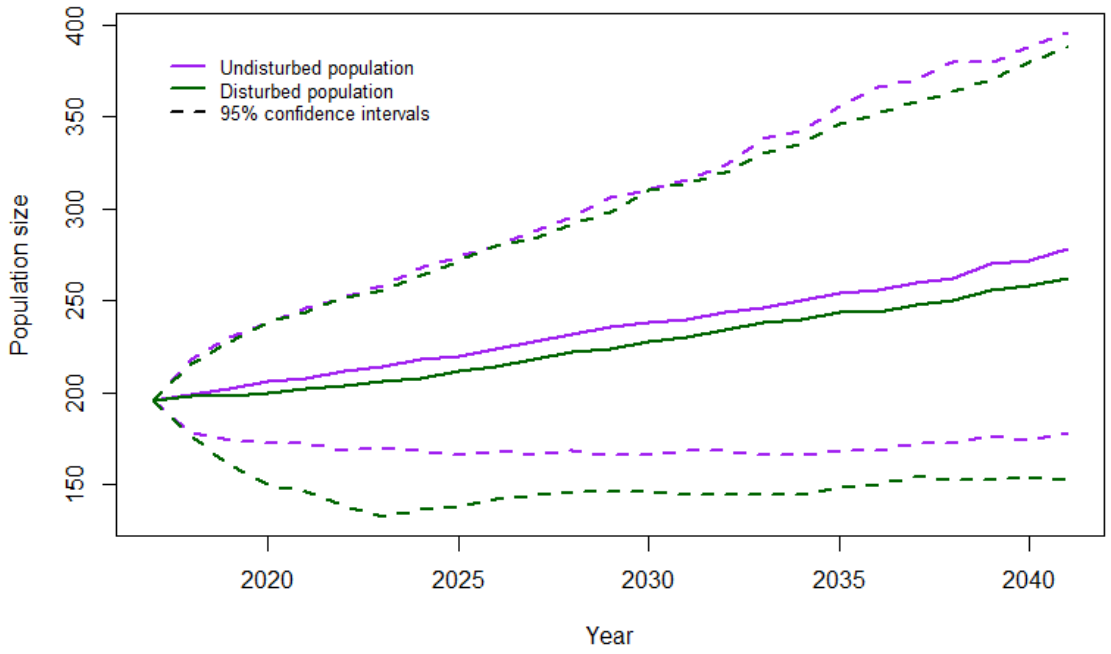

Figure 10A.12: Distribution of predicted bottlenose dolphin population sizes after 25 years with no displacement (undisturbed population) and with displacement associated with five East coast projects including piling monopiles the Development with a single vessel (disturbed population)

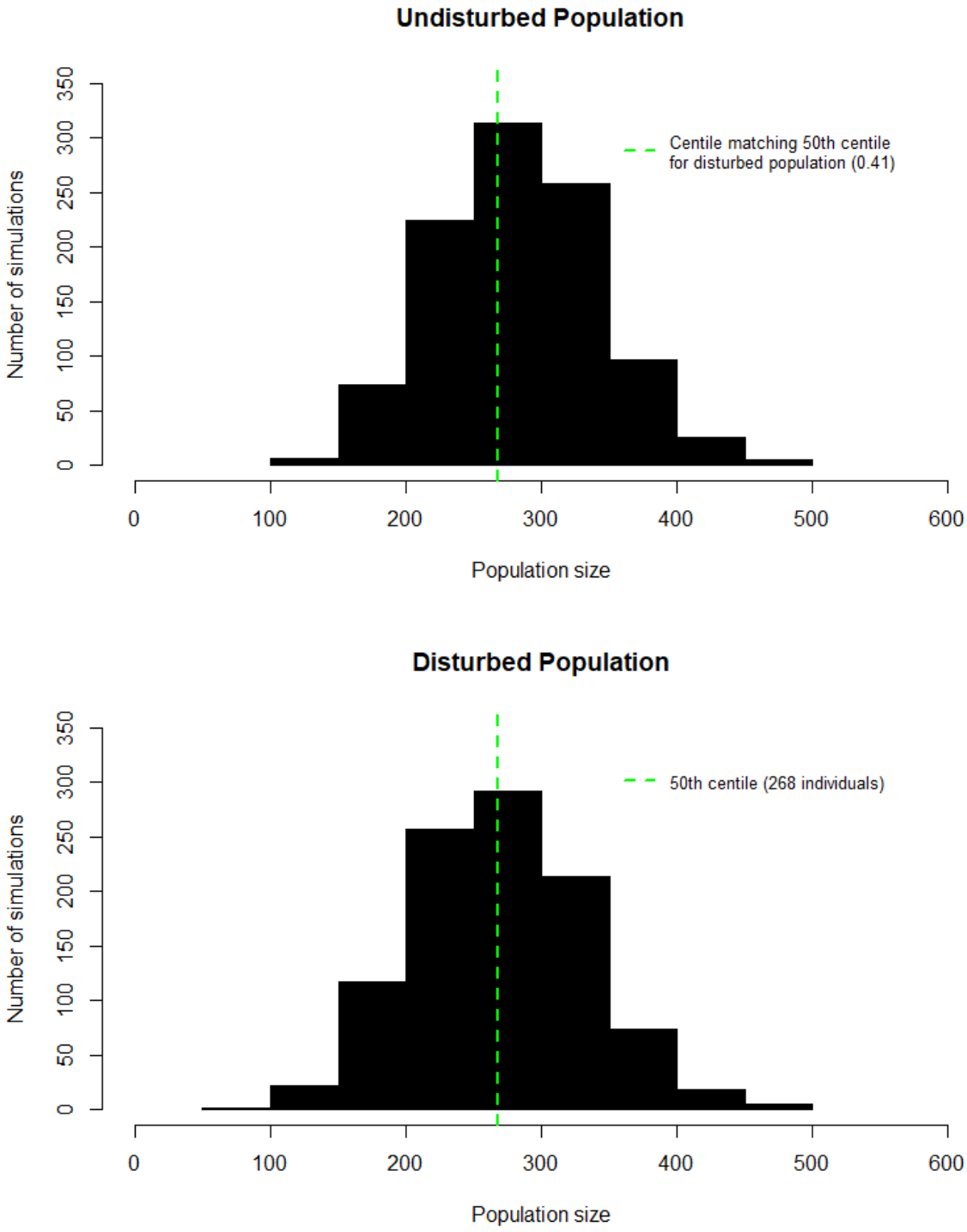

Table 10A.8: Predicted change in bottlenose dolphin population size and growth rate as a result of displacement associated five East coast projects including piling monopiles at the Development with a single vessel (disturbed population). Metrics are described in paragraph 6 above

	Median ratio of impacted to unimpacted growth rate	Median ratio of impacted to unimpacted population size	Centile for unimpacted population that matches 50th centile for impacted population	Median end population size
Unimpacted	1.00	1.00	0.50	282
IC monopile single vessel + cumulative projects	1.00 (0.00)	1.00 (0.00)	0.41	268

References

Booth, C. (2017). iPCoD v3 Release Note. Report number *SMRUC-MSS-2017-009*.

Cheney, B., Thompson, P.M., Ingram, S.N., Hammond, P.S., Stevick, P.T., Durban, J.W., Culloch, R.M., Elwen, S.H., Mandlebreg, L., Janik, V.M., Quick, N.J., Islas-Villanueva, V., Robinson, K.P., Costa, M., Eisfeld, S.M., Walters, A., Phillips, C., Weir, C.R., Evans, P.G.H., Anderwald, P., Reid, R.J., Reid, J.B. and Wilson, B. (2013). Integrating multiple data sources to assess the distribution and abundance of bottlenose dolphins in Scottish waters. *Mammal Review* 43: 71-88.

Cheney, B., Graham, I.M., Barton, T.R., Hammond, P.S. and Thompson, P.M. (2018). Site Condition Monitoring of bottlenose dolphins within the Moray Firth Special Area of Conservation: 2014-2016. *Scottish Natural Heritage Research Report No. 1021*.

Graham, I.M., Pirotta, E., Merchant, N.D., Farcas, A., Barton, T.R., Cheney, B., Hastie, G.D. and Thompson, P.M. (2017). Responses of bottlenose dolphins and harbor porpoises to impact and vibration piling noise during harbor construction. *Ecosphere* 8(5): e01793. 10.1002/ecs2.1793.

Harwood, J. and King, S.L. (2017). The sensitivity of UK marine mammal populations to marine renewables developments – revised version. Report number *SMRUC-MSS-2017-005*.

Jitlal, M., Burthe, S., Freeman, S. and Daunt, F. (2017). Testing and validating metrics of change produced by Population Viability Analysis (PVA). *Scottish Marine and Freshwater Science* 8(23): 1-210.

Plunkett, R., Booth, C. and Harwood, J. (2017). Helpfile for the interim PCoD version 3 model. Report number *SMRUC-MSS-2017-006*.

Vallejo, G.C., Grellier, K., Nelson, E.J., McGregor, R.M., Canning, S.J., Caryl, F.M. and McLean, N. (2017). Responses of two marine top predators to an offshore wind farm. *Ecology and Evolution* 7(21): 8698-8708.

Wilson, B., Thompson, P.M. and Hammond, P.S. (1997). Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology* 34: 1365-1374.