Marine Scotland

SeabORD Example

Worked Example for SeabORD v1.2

Mobbs, D.C., Searle, K., Butler A., Daunt, F
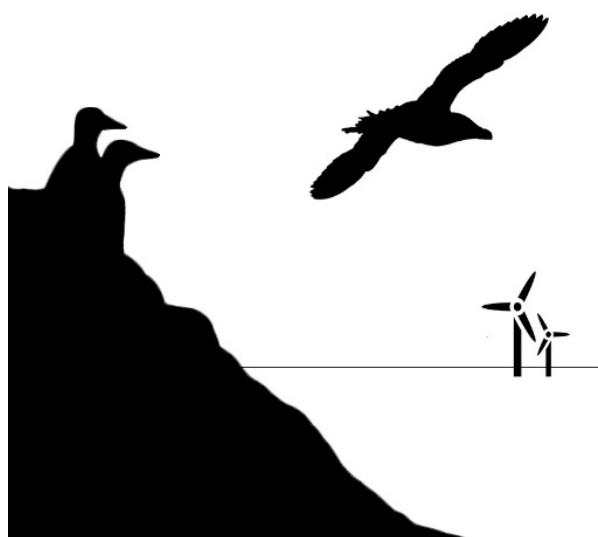
SeabORD Example

Worked Example for SeabORD v1.2

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Title	SeabORD Example
Client	Marine Scotland
Client reference	
CEH reference	NEC05978
CEH contact details	Dr Deena C Mobbs Bush Estate, Penicuik, Midlothian, EH26 0QB t: 0131 445 4343 f: 0131 445 3943 e: dcmo@ceh.ac.uk
Date	03/01/2018

Contents

1 Introduction

The prototype tool SeabORD quantifies the fate of displaced and barrier-affected seabirds encountering offshore renewable energy developments (ORDs), significantly improving existing methods for estimating the impact of marine developments on breeding seabirds.

The tool estimates the survival and reproductive success for individuals from breeding colonies affected by offshore renewable energy developments using an individual-based stochastic simulation model describing the foraging, energetics and reproductive success of seabirds during the breeding season.

Four species have been modelled within this project: common guillemot, black-legged kittiwake, razorbill and Atlantic puffin. The prototype tool outputs estimates for both individual and population level impacts of ORDs on the breeding success and survival of adult birds. In addition, the methodology underpinning the tool allows for a quantitative linkage to be made between observations derived from snapshot surveys through to the average demographic consequences for those observed individuals.

The model is fully described in the associated report (Searle, et al. 2018) and the User Guide (Mobbs, et al 2018).

This document describes the recommended procedure for running the prototype tool to estimate the impact of ORDs using black-legged kittiwakes in the Forth and Tay region, with three hypothetical ORDs, as an example.

2 Data files

SeabORD uses input files from the 'data' folder (which is created by the user when the tool is installed). The following diagram lists the folder structure and files required for the example described in this document. All files are supplied with SeabORD but those in green will be regenerated by the tool if not found when the run is executed. Files displayed in red are the key files that are chosen by the user through the graphical interface of the tool, these can be edited or replaced with alternative versions to simulate different conditions.

```
+---Bathymetry
|       BathymetryMap_GEBCO.mat
|       Rg_GEBCO.mat
+---Colonies
|   |   Forth and Tay.xlsx
|   \---Forth and Tay
|           Kw_birddensity.csv
+---Flightpaths
|   \---Forth and Tay
|           Waypoints_bod_526_617.mat
|           Waypoints_fow_526_617.mat
|           Waypoints_iom_526_617.mat
|           Waypoints_sta_526_617.mat
|           WFPerimeter_bod_526_617_WFA_WFB_WFC_500.mat
|           WFPerimeter_fow_526_617_WFA_WFB_WFC_500.mat
|           WFPerimeter_iom_526_617_WFA_WFB_WFC_500.mat
|           WFPerimeter_sta_526_617_WFA_WFB_WFC_500.mat
|           RZones_bod_526_617_WFA_WFB_WFC_500.mat
|           RZones_fow_526_617_WFA_WFB_WFC_500.mat
|           RZones_iom_526_617_WFA_WFB_WFC_500.mat
|           RZones_sta_526_617_WFA_WFB_WFC_500.mat
+---Location
|   |   UKcoast.mat
|   \---Forth and Tay
|           BZoneMap_bod_526_617.mat
|           BZoneMap_fow_526_617.mat
|           BZoneMap_iom_526_617.mat
|           BZoneMap_sta_526_617.mat
|           SeaMask_526_617.mat
+---Prey
|   \---Forth and Tay
|           Kw_preydensity.csv
|           Kw_4_369_preycapture.mat
+---Windfarm
|       ForthWindfarms.xlsx
|       WFA_WGS84.shp (and related files)
|       WFB_WGS84.shp (and related files)
|       WFC_WGS84.shp (and related files)
```

3 Setting up a basic simulation

Start SeabORD to open the 'check-in' user interface. Use the browse button to navigate to the folder you are going to use for the input and output files. This folder will contain the main **data** folder, as shown in Figure 3-1 and optionally a folder called **SimulationFiles** (containing output created in any earlier sessions).
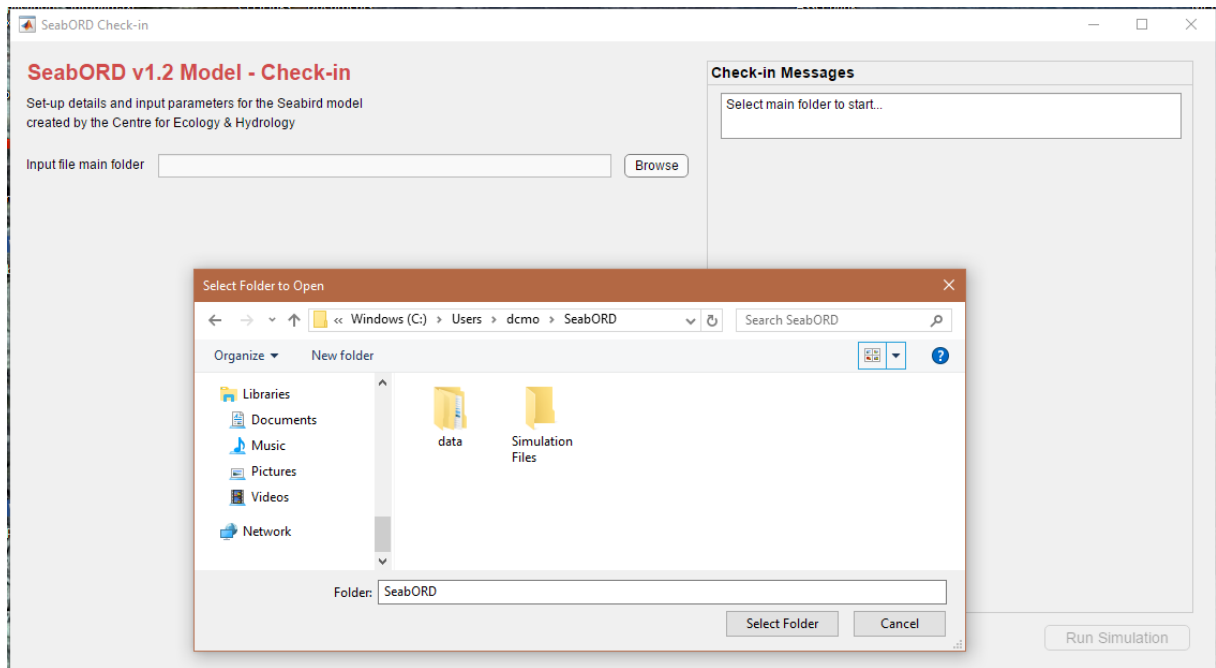

Figure 3-1 Setting the main folder for the simulations.

When this folder is selected, a set of six 'tabs' will appear on the interface; each tab must be completed to set up a simulation.

On the Colony tab, use the browse button to select and open the file 'Forth and Tay.xlsx' from the Colonies folder (see section 2 Data files). This loads basic information about the extent of the region of interest and the location of the colonies within the region. In this example we are interested in the impact of three hypothetical ORDs on birds from the Forth Islands. Birds from different colonies may compete for prey when their ranges overlap so it is important to include all other colonies even if the impact on these colonies is not specifically of interest. Figure 3-2 shows all colony switches in the 'Yes' position.

Figure 3-2 Four colonies are used in this example; the switches are set to 'Yes'.

In this example we are looking at black-legged kittiwakes, using a 'Map'-based (derived from local GPS tracking data) forage site selection method, assuming 40% of the population are susceptible to displacement, all displacement-susceptible birds are also barriered and all barriered birds navigate around ORD barriers by following the perimeter of the ORD footprint border.

The completed Species tab with these options is shown in Figure 3-3. The forage selection file is 'Kw_birddensity.csv' from the **Colonies\Forth and Tay** data folder (see section 2 Data files)

Figure 3-3 The completed Species tab for this example

The three hypothetical ORDs are named in the file 'ForthWindfarms.xlsx' (from the **Windfarm** folder), including the names of the shapefile containing the footprint (one polygon per file, WGS84).

For this example the ORD footprint will have a 0.5 km border added to it and the buffer area (into which birds are displaced) will be 5 km. For the first part of the procedure we need to carry out baseline runs without ORDs to assess how adult mass loss and chick survival over the breeding season vary at the colony of interest in relation to the assumed total prey in the region (median regional prey density). Therefore, at this stage all the ORD switches are set to 'No'. The correctly completed ORD tab is shown in Figure 3-4.
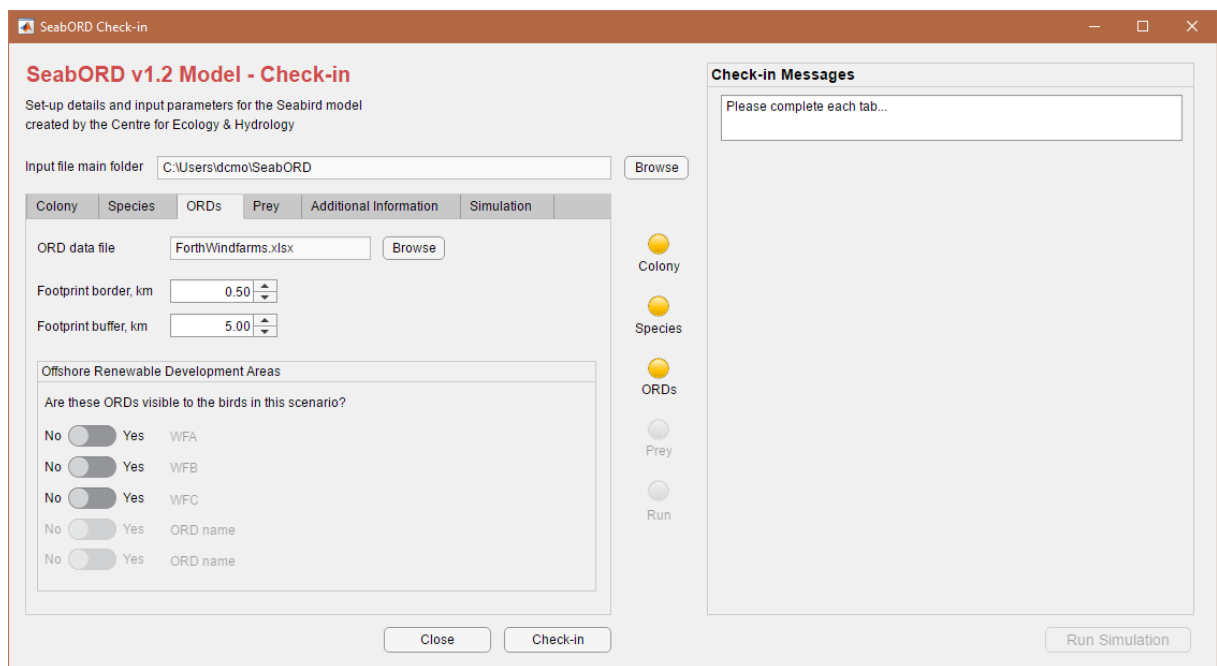

Figure 3-4 The offshore renewable developments, WFA, WFB and WFC are loaded but not active at this stage.

With the exception of the ORD switches, the setting on these three tabs will not change throughout the example in this document.

4 Procedure

4.1 Find the optimum prey level range

Here we demonstrate how to use SeabORD to generate a single estimate for each metric assessing ORD effects, by identifying the boundaries of the 'moderate' prey range and using stratified random sampling to complete sets of paired runs across the moderate prey range which are then averaged to produce a single estimate, plus prediction interval, for each metric.

Upper and lower boundaries for 'moderate' regional prey conditions are set by comparing model output in baseline runs (no ORDs present) for the change in adult mass (percent) and the nest or chick mortality (percent). Using empirical data (Harris (1979); Harris & Wanless (1988); Gaston & Hipfner (2006); Nelson (2013); Newell et al. (2016)) we identified percent adult mass loss over the course of the chick-rearing period and nest survival rates (for kittiwakes) or chick survival rates (for auks) that reflect those observed during 'moderate' environmental conditions (Table 4-1). Because adult mass loss (%) is the most reliable model output (less variable than chick survival) and of primary interest to population trends in long-lived species such as seabirds because of its influence on over-wintering survival probability of adults (Oro & Furness 2002; Erikstad et al. 2009), we base the upper bound for moderate conditions solely using changes in adult mass loss. The lower bound is set using both adult mass loss and chick/nest survival (Table 4-1). If, however, chick or nest survival should fall below the 5th percentile observed in empirical data before the adult mass loss lower bound is reached, we consider that corresponding regional prey value to represent the lower bound of moderate conditions for that species. For instance, in black-legged kittiwakes, if at the end of a baseline run, adult mass loss was 8% but nest survival was 10%, this would be classed as 'poor' conditions.

Table 4-1. Conditions used to set upper and lower boundaries for the median regional prey value corresponding to 'moderate' conditions for each species.

	Percent adult mass loss		Chick/nest survival
	Upper bound	Lower bound	Lower bound
Black-legged kittiwake	5	15	11
Common guillemot	3.5	10.5	49
Razorbill	3.5	10.5	50
Atlantic Puffin	3.5	10.5	50

In this example we are using mapped prey and the relative prey density derived from local GPS tracking data across the region is given in the file 'Kw_preydensity.csv' from the **Prey\Forth and Tay** folder. Once the relative prey density is loaded, we need to set the actual amount of available prey (grams per forage volume) to simulate different prey conditions (with low or high available prey). The prey availability value set by the user is used as the median across the entire region and different colonies may experience different local conditions for the season. It is important to run the model with a range of prey values to find the suitable baseline

conditions of adult mass loss and chick survival for the colony or colonies of interest because these will form the basis by which impacts of ORDs are assessed.

SeabORD v1.2 allows the user to set a forage quantity upper and lower bounds; the aim is to find the minimum and maximum prey values that result in moderate body mass loss in adult birds at the colony of interest. For kittiwake, this means an adult mass loss of around 10% over the season and chick survival of about 50% (Table 4-1). A season is considered to have been good conditions if there has been no adult mass loss and poor conditions if 20% mass loss. Thus we consider 'moderate' to be a mass loss between 5% and 15% over the season.

For this part of the procedure, we run a set of simulations to identify the correct upper and lower bounds for 'moderate' baseline conditions for the colony of interest. (Note that this procedure must be repeated for every colony as each may experience different local conditions for a given regional median prey value).

In the first run the Prey tab, shown in Figure 4-1, is set up with an initial prey of 175g. Set the upper and lower values to be the same; only one season is being simulated here and this fixes the median prey to a known value.
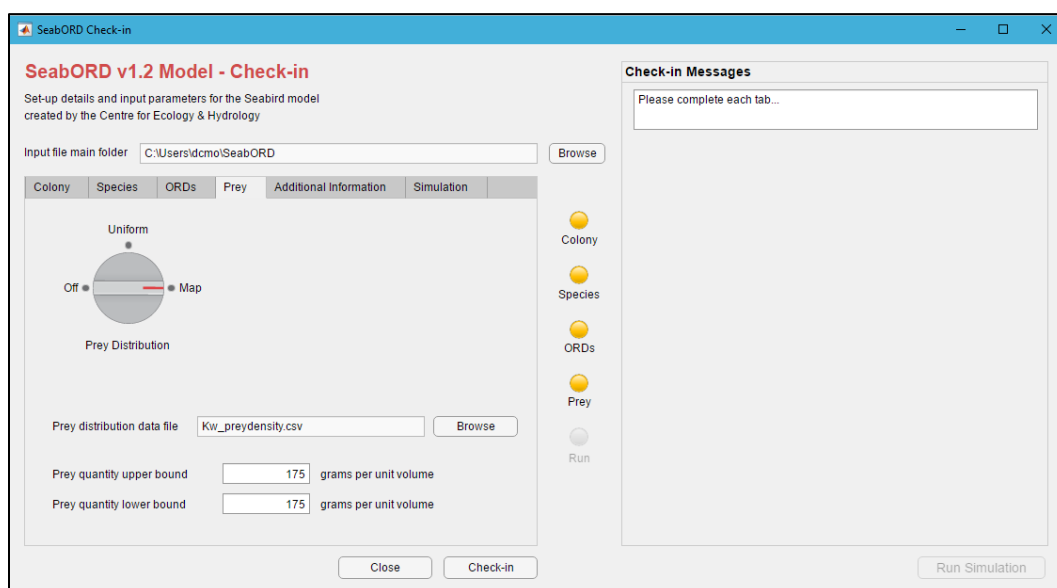

Figure 4-1 The Prey tab should be set to a mapped prey distribution and the chosen starting prey value.

To minimise processing time to run this set of simulations, we will use 10% of the population (6000 birds in this case); open the 'Additional Information' tab and set the 'Fraction of population to use for this run' to 0.1 (Figure 4-2).
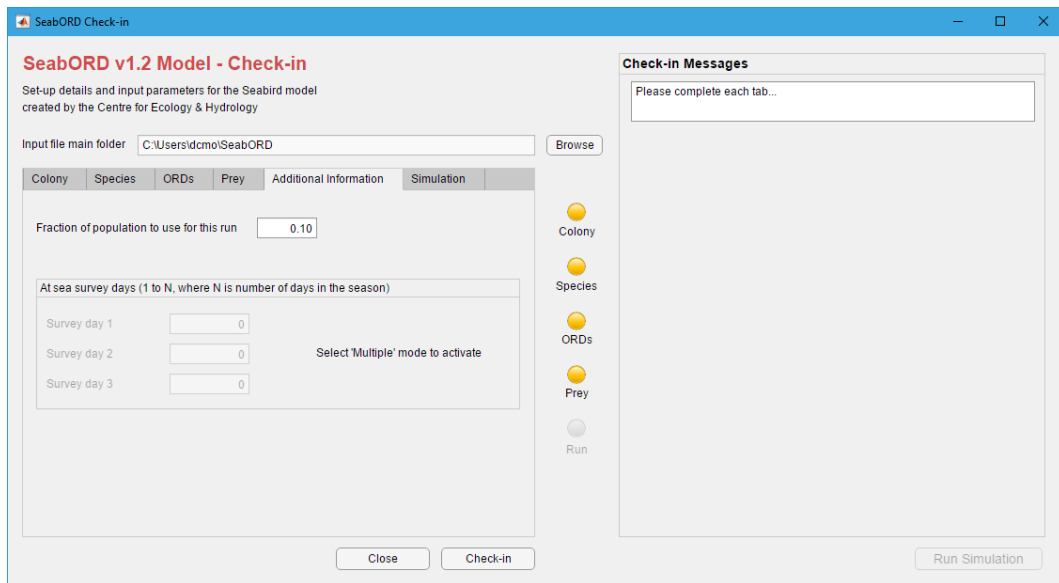
Figure 4-2 Set the fraction of population to use on the additional information tab

The final tab, 'Simulation', is used to set the type of simulation to run. For this initial part of the procedure, we run a 'single' test season, using a seed value of 39173 (this can be any number but to replicate results exactly make a note of the seed used!). As we are running a baseline without ORDs there is no need to specify a matching baseline folder.

The simulation reference name can be any text and is used in the output folder and file names; we recommend using the prey value (e.g. 175) so that the output folder can be easily identified later (Figure 4-3).
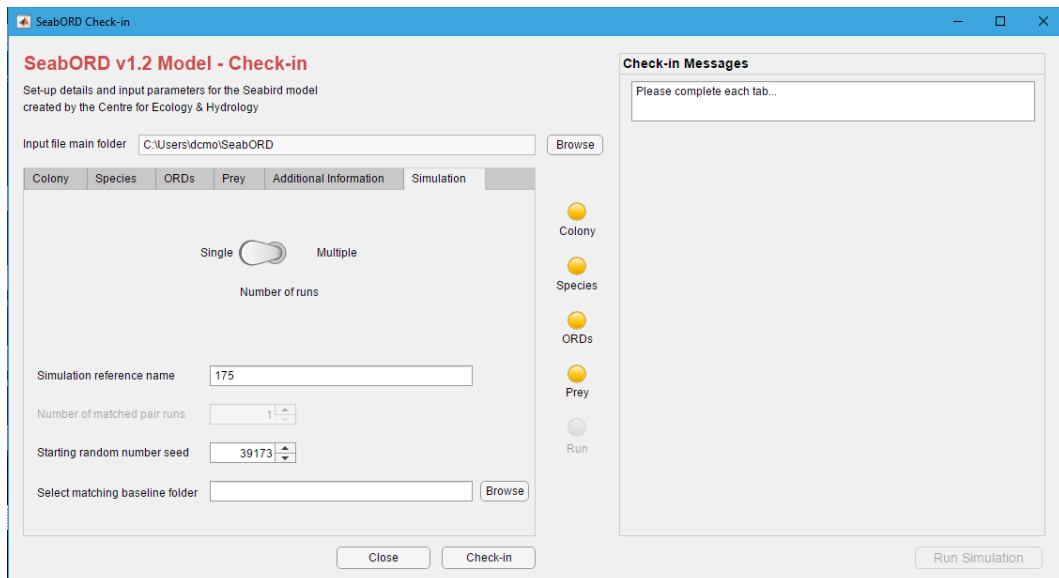
Figure 4-3 The final tab is used to set the simulation type

Everything is set, so click the 'Check-in' button and SeabORD will run a quick check to see that all the required input data are present. If everything is found, the indicator lights the 'Run Simulation' button will become active and the first season can be simulated.

The run should take approximately 10 minutes to complete (if the Kw_4_369_preycapture.mat file has been generated previously, otherwise it will take longer) with the final graphical results as seen in Figure 4-4.

Figure 4-4 The final screenshot, saved as finalgraphics.png

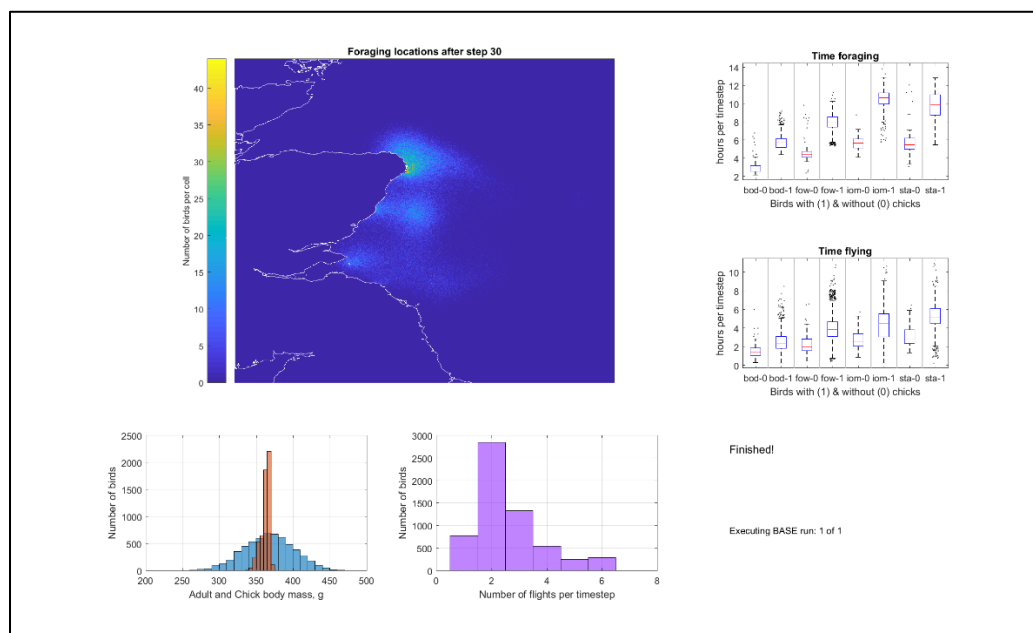The figures in the final output spreadsheet from a single run give the basic results and show (see Table 4-2) that for two of the four colonies the adults lost less than 1% mass over the season (percentLoss) while two colonies lost less than 5% and there was high chick survival (chick_survpc) at all colonies, indicating that 175g is a high prey value for this scenario. The output also shows the survival percentage for adult birds over the breeding season, Adult_Season_survpc, and the starting mean body mass for adults at each colony, AdultBMt0.

Table 4-2 Results with prey = 175g

Colony	N	Adult_Season_ survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
bod	2508	100	371.99	371.74	94.18	Good	0.07	175
fow	1878	100	372.87	369.64	95.10	Good	0.87	175
iom	754	100	374.51	356.53	91.78	Good	4.80	175
sta	862	100	371.86	357.33	94.90	Good	3.91	175

We need to find the upper and lower bounds for 'moderate' conditions for Forth Islands ("iom"). This first result shows we need to try lower prey values to check when the 'iom' result become classed as 'Moderate' rather than 'Good' (Table 4-1).

For the next test run, return to the SeabORD user interface and change the prey values to 170g, change the reference name to '170', press check-in and then run the next simulation. The output is written to a folder including a time and date stamp so the previous result will not be overwritten (even if the same name is used for reference). The output from this (Table 4-3)

show that at 170g the colony experiences moderate conditions with a mean adult mass loss of 6.7%.

Table 4-3 Results with prey = 170g

Colony	N	Adult_Season_survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
bod	2508	100	371.99	371.66	94.18	Good	0.09	170
fow	1878	100	372.87	368.88	95.10	Good	1.07	170
iom	**754**	**100**	**374.51**	**349.26**	**88.06**	**Moderate**	**6.74**	**170**
sta	862	100	371.86	351.86	93.04	Moderate	5.38	170

Prey set at 175g is 'good' and 170g is 'moderate' so we need to try intermediate values to pinpoint the highest value for moderate conditions. Table 4-4 shows the model output for 170g to 175g indicating that a regional median prey value of 174g or below will cause a mass loss of 5% or more; 174g is the upper bound for Forth Islands using the chosen input data.

Table 4-4 Simulation results at higher prey levels for the Forth Islands colony indicate 174g is the upper bound for moderate conditions.

Colony	N	Adult_Season_survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
iom	754	100	374.51	356.53	91.78	Good	4.80	175
iom	**754**	**100**	**374.51**	**355.00**	**91.25**	**Moderate**	**5.21**	**174**
iom	754	100	374.51	353.63	90.98	Moderate	5.58	173
iom	754	100	374.51	352.23	90.72	Moderate	5.95	172
iom	754	100	374.51	350.75	90.19	Moderate	6.35	171
iom	754	100	374.51	349.26	88.06	Moderate	6.74	170

Using the same procedure we need to repeat the simulations at lower prey value to find the lower bound for moderate conditions. Simulation runs at 165g, 160g and 155g all result in an adult mass loss of just under 10% (see Table 4-5) which is moderate for the adult birds. Over this range of prey, the chick survival drops from 72% to 4% and lower prey value result in breeding failure at Forth Islands.

Table 4-5 Simulation results at lower prey levels for the Forth Islands colony indicate 158g is the appropriate lower bound for moderate conditions

Colony	N	Adult_Season_survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
iom	754	100	374.51	341.70	72.15	Moderate	8.76	165
iom	754	100	374.51	338.16	28.65	Moderate	9.71	160
iom	754	100	374.51	337.84	18.83	Moderate	9.79	159
iom	**754**	**100**	**374.51**	**337.68**	**13.79**	**Moderate**	**9.84**	**158**
iom	754	100	374.51	337.59	9.55	Moderate	9.86	157
iom	754	100	374.51	337.55	6.90	Moderate	9.87	156
iom	754	100	374.51	337.43	4.51	Moderate	9.90	155

Note that at some regional median prey availability, such as 170g in Table 4-3, Forth Islands and St Abbs experience moderate conditions while other colonies are experiencing 'good' conditions due to a higher overall local prey density. The procedure described here for Forth Islands ('iom') would have to be repeated to find the moderate range for each colony separately if required.

From this part of the procedure we conclude that, for this prey density map, for the Forth Islands, a range of 158g to 174g covers 'moderate' conditions. These values can now be used in the next phase to assess ORD impacts over a range of moderate conditions.

4.2 Generate the ORD-related files

We now run a full set of simulations with multiple matched pairs for a range of prey values between 158g and 174g. To prepare for this computationally intensive process it is useful to check that the ORD and associated bird flightpath files are all present and correct. To do this, run a 'single' season with ORDs where the matching baseline (without ORDs) has already been created as part of the prey availability test. (If a 'single' simulation is run with ORDs but no matching baseline (without ORDs) there would be no output as the effect of ORDs could not be calculated.)

For this example, we will use the season with prey 170g. This step can be omitted, but is recommended as a useful check especially when using a new or modified ORD footprint.

Leave all settings as described above for the Colony and Species tab (Figure 3-2, Figure 3-3) then make the necessary changes to add the ORDs

- on the ORDs tab switch all three ORDs to 'Yes' (and double-check the border is set to 0.5km).
- on the Prey tab set the upper and lower prey quantity to 170g
- check the population fraction is still set to 0.1 on the Additional information tab
- on the Simulation tab, enter the matching reference name (e.g. 170 if that is what you used for the baseline above – the name entered much exactly match that used in the baseline run) and use the browse button to locate the previously run baseline simulation at prey 170 (it will have your chosen name and the name '_BASE' at the end). Note that SeabORD does expect this folder to be inside the same SimulationFiles folder as the current run.

Run the check-in – this loads a file that was saved with the baseline results and checks it is the appropriate baseline - if all the settings match without an error, the message 'Ready' will appear in the messages panel and the Run Simulation button will become active (Figure 4-5). Run the simulation.
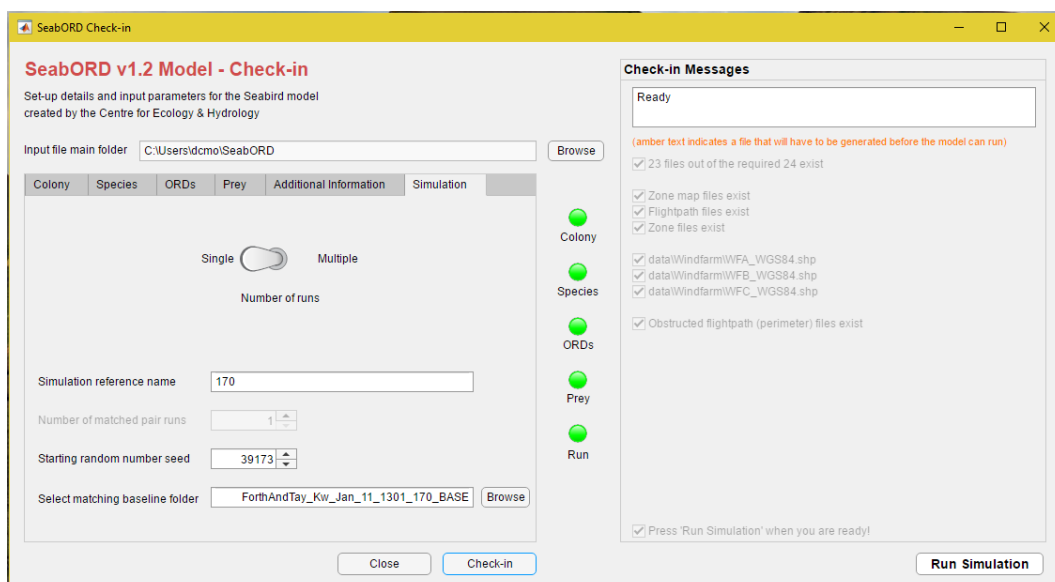
Figure 4-5 The Simulation tab set up to run a single season where a matching baseline has already been completed and saved.

Note: If there is a problem at check-in, an error message will appear in the message box and the Run light will turn red. This usually means a parameter has been incorrectly set so that the current run does not exactly match the baseline selected. If the issue cannot be fixed, we recommend switching to 'multiple' mode and running 1 pair; this simply generates a fresh baseline using the current settings.

During execution of this simulation run, SeabORD requires the files shown in green in 'Section 2 Data files' above. These binary files contain the calculated zones imposed by the ORDs and the estimated flightpaths from every colony to every foraging location that has been found to date. These are the same for every bird species so the files need only be generated once for each unique region and ORD combination. The more simulations are run over time, the larger the files will become as more and more sites are included until all possible paths have been found. Once created, the files can be copied to other computers or moved to new folder locations for repeat use. BEWARE! Each colony and each ORD must have a unique name or the model results may not be as expected due to the incorrect data file being picked up. Delete or move the files to force a recalculation.

Figure 4-6 shows the final graphic from the run. The chosen ORD footprint files and the required flightpath files are now ready for further simulations. Check the output folder to see the images of the zones and bird density maps, confirming everything is as expected. The 'single' run results spreadsheet shows two simple sets of results; one for the saved baseline and one for the scenario for comparison (Table 4-6).

Table 4-6 Results from the 'single' scenario run showing two sets of figures for the baseline (without ORDs) and the scenario (with ORDs)

Colony	N	Adult_Season _survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
bod	2508	100	371.99	371.66	94.18	Good	0.09	170
fow	1878	100	372.87	368.88	95.10	Good	1.07	170

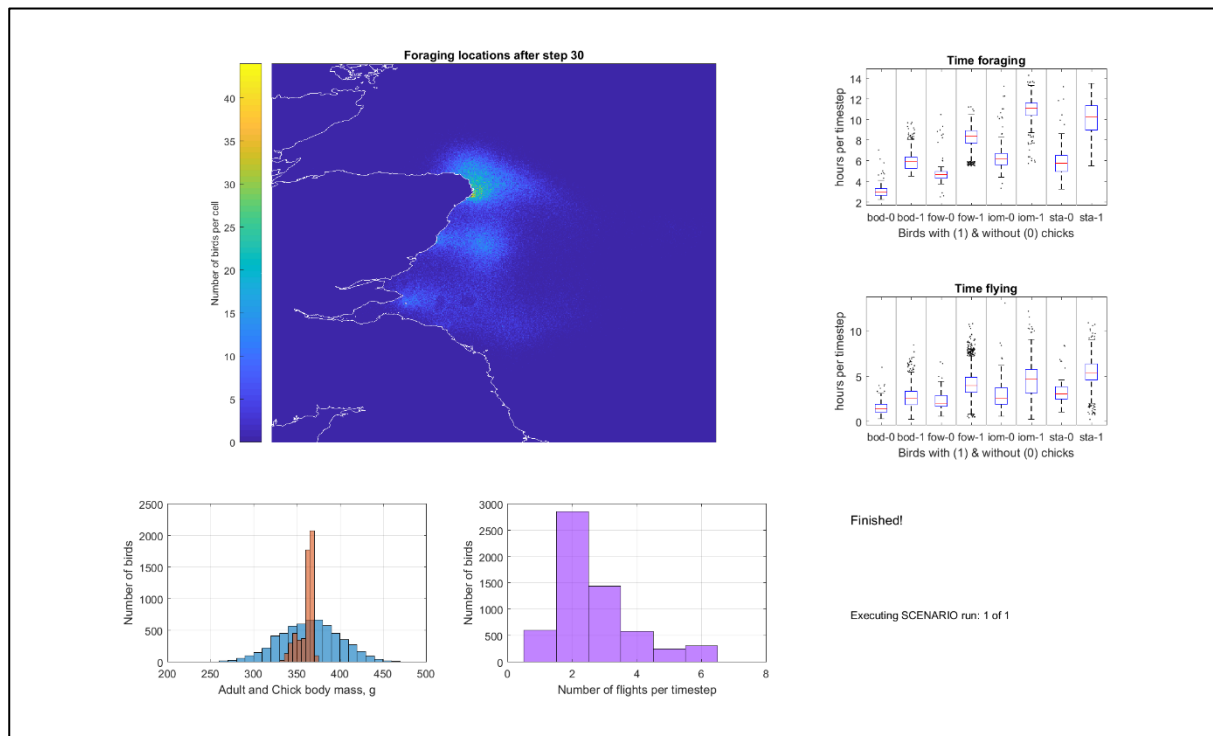| Colony	N	Adult_Season_survpc	AdultBMt0	AdultBM	chick_survpc	yearType	percentLoss	Prey
iom	754	100	374.51	349.26	88.06	Moderate	6.74	170
sta	862	100	371.86	351.86	93.04	Moderate	5.38	170
bod	2508	100	371.99	371.66	94.18	Good	0.09	170
fow	1878	100	372.87	368.88	95.10	Good	1.07	170
iom	754	100	374.51	346.52	81.70	Moderate	7.47	170
sta	862	100	371.86	351.24	92.58	Moderate	5.55	170

Figure 4-6 Final output from the test run showing the 'gap' where birds have been displaced from the three hypothetical ORDs

4.3 Execute a matched pair run

The earlier prey test runs used 10% of the population and a single season took a few minutes to run (on a standard Windows 10 laptop with 8GB RAM). For the final simulation runs we recommend using as high a percentage of the population and as many pairs as computationally feasible. To estimate how long a full run might take it is useful to run one pair of runs at higher population levels. These timings will be approximate as execution time depends in part on the number of new flightpaths SeabORD has to calculate; the more times the model is run for a given location the faster it will become as birds return to known locations.

The fraction of the population is set on the Additional Information tab (see Figure 4-2). As a benchmark, a run with around 30,000 birds is expected to take about 2 hours to run one baseline+scenario pair. Note that the output folder has a time stamp from when the simulation

run starts and the file 'finalgraphics.png' is created at the very last step. Thus the difference between the 'date created' metadata on these two items is a good estimate of the run duration.

4.4 Execute a set of matched pair runs

In this demonstration example we are using 50% of the population and will carry out 10 matched pairs. This is expected to take 15-24 hours to run, depending on the specification of the computer used.

We established earlier that the prey range for moderate is 158g to 174g. If we choose to run 10 matched pairs of runs, SeabORD will select 10 values between the upper and lower bounds using a stratified random selection of values.

To run a multiple matched pair simulation,

- change the switch on the Simulation tab to 'multiple' and set the number of pairs to 10
- change the population fraction on the Additional Information tab to 0.5
- ensure the ORDs are set to 'Yes' and other parameters are set as previously described
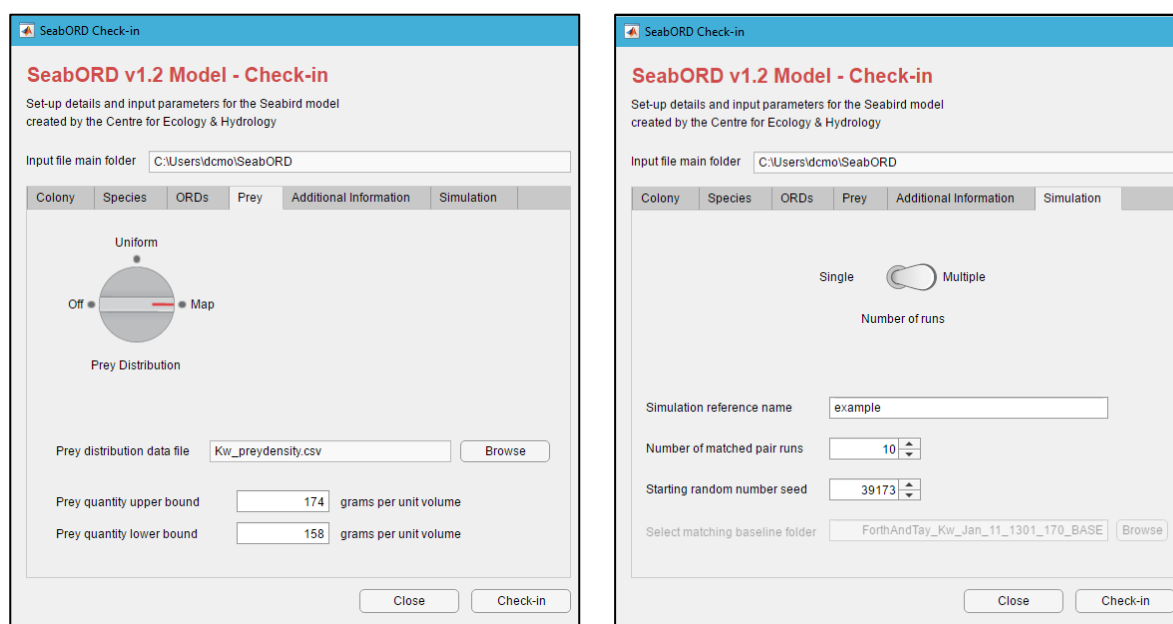- run check-in
- run the simulation.

Figure 4-7 The left hand side of the SeabORD interface showing the changes needed for the Prey tab and the Simulation tab to set up the final simulation set of runs.

The results spreadsheet (Summary sheet, row 50) confirms that over the 10 paired simulations the mean adult mass loss indicates moderate conditions for the Forth Island birds as expected. Two colonies experienced good conditions. Note that the results spreadsheet is much more extensive when using 'multiple' mode.

The final output summary file contains 9 worksheets –

1. Summary: This sheet shows a summary of the parameters used to define the simulation run for reference, plus a set of figures indicating the 'season type' for each colony ('poor', 'moderate' or 'good') based on the adult mass loss over the season.

2. Add.Mort i0: This sheet shows detailed results for all birds in the simulation grouped by colony and a summary of the results assuming each possible season type. We know this was a moderate year so the moderate calculation applies here (i.e., ignore impacts predicted for 'poor' and 'good' conditions). Also, the prey range in this example was defined for Forth Islands so the other colony columns are not used.
3. Add.Mort i1: As described for i0 but for birds that are never directly affected by the ORD.
4. Add.Mort i2: As described for i0 but for birds that are directly impacted at least once.
5. Add.Mort i3: As described for i0 but for birds that are displaced at least once, never barriered.
6. Add.Mort i4: As described for i0 but for birds barriered at least once, never displaced.
7. Add.Mort i5: As described for i0 but for birds barriered and displaced at least once.
8. Add.Mort i6: As described for i0 but shows all possible impact combinations grouped separately.
9. Survey: If an at-sea survey has been selected, results are exported to this sheet.

For Forth Island birds, the additional mortality metrics for a moderate year are shown in Table 4-7: for a) adult birds and b) chicks. Metric P1 ('Additional Mortality' or 'Add.Mort' in the output file) calculates the population-level impact of the ORD: it is equal to (mortality with ORD present - mortality in baseline) / (population size), and represents the overall impact of the ORD.

Metrics i1 - i6 use the same calculation at P1, but apply to subsets of the population: to birds that are never directly impacted by the ORD (i1), to those that are directly impacted at least once (i2), to those that experience displacement but not barrier effects (i3), to those that experience barrier but not displacement effects (i4), and to those that experience both barrier and displacement effects at least once (i5). The final of this set of metrics, I6, focuses on birds that experience specific patterns of barrier and displacement effects – e.g. that were displaced on 5 days and experience barrier effects on 4 days - and so provides the most detailed breakdown of the effects into population sub-groups.

Table 4-7 Additional mortality metrics from a set of 10 pairs of simulations for moderate conditions (158g to 174g median regional prey) for Forth Islands kittiwake, with three hypothetical ORDs (WFA, WFB and WFC).

a) Adult birds	i0	i1	i2	i3	i4	i5
Mean number of birds in group	3766	2242	1524	1	453	1070
Additional mort. %, mean	1.251	-0.120	3.268	0	2.649	3.532
Additional mort. %, stdev	0.689	0.156	1.497	0	1.231	1.670
Additional mort. % lower confidence interval	-0.383	-0.491	-0.284	0	-0.272	-0.431
Additional mort. % upper confidence interval	2.884	0.250	6.819	0	5.570	7.496

b) Chicks	i0
Additional mort. %, mean	8.630
Additional mort. %, stdev	3.623
Additional mort. % lower confidence interval	0.033
Additional mort. % upper confidence interval	17.227

4.5 Summarise impacts

These results show an estimated additional adult mortality from all three ORDs combined of 1.25% (95% prediction interval: -0.38% to 2.88%). Directly affected adult birds suffered an additional mortality of 3.27% (95% prediction interval: -0.28% to 6.82%). Very few birds were only displaced (i3, n=1) so we will not interpret those results. However, 453 adults were barrier affected (i4) and for these individuals the model estimates an additional mortality of 2.65% (95% prediction interval: -0.27% to 5.57%). In addition, 1070 adults were both displaced and barrier affected (i5), suffering an additional mortality of 3.35% (95% prediction interval: -0.43% to 7.50%). The additional chick mortality for the Forth Islands population is 8.63% (95% prediction interval: 0.03% to 17.2%).

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