Appendix 9.1 Annex E

Collision Risk Assessment

RWE

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Revision: 1

Annex E Collision Risk Assessments

A Collision Risk Analysis Area (CRAA) was created using a 500 metre (m) buffer around proposed turbine locations (**Figure 9.1**). Using the larger 500 m area around the turbines (rather than rotor diameter) accounts for possible inaccuracies in the recording of flightlines, micrositing and ensures the assessment is precautionary.

For the Proposed Development, analysis has been undertaken using two potential turbine specifications identified for the Proposed Development:

- A maximum tip height of 200m, maximum rotor diameter of 163m and hub height of 118.5m (above ground clearance of 37m) based on a Nordex 163; and,
- A maximum tip height of 180m, maximum rotor diameter of 170m and hub height of 95m (above ground clearance of 10m) based on a Siemens Gamesa (SG) 7.0-170.

Table E-1, **Table E-2** and **Table E-3** present the parameters which apply to each Collision Risk Model (CRM).

Table E-1: Wind farm parameters

Size of wind farm envelope	690.19	hectares (ha)
Number of turbines	13	turbines
Rotor diameter	163 or 170	metres (m)
Hub height	95 or 118.5	m
Max. rotor depth	1.07419 or 1.1647	m (at 15° pitch angle)
Max. chord	4.15 or 4.5	m
Pitch	15	degrees (°)
Rotation period	5.9465 or 6.5076	seconds (secs)
Turbine operation time	0.85	percent (%)
Risk height: highest	200	m
Risk height: lowest	10	m
Flight risk volume	1125011463 or 1173324839	m3

Table E-2: CRM parameters per species

Species	Length (m)	Wingspan (m)	Assumed flight speed, v (ms-1)	Avoidance rate	Probability of collision	Bird transit time (secs)
Dunlin	0.2	0.43	15.3	0.98	0.0392	0.0891
Golden eagle	0.815	2.12	15	0.99	0.0621	0.1320
Golden plover	0.28	0.72	17.9	0.98	0.0407	0.0807
Goshawk	0.62	1.65	9.7	0.98	0.0703	0.1840
Greenshank	0.315	0.69	14	0.98	0.0446	0.1057
Hen harrier	0.48	1.1	12	0.99	0.0549	0.1371
Merlin	0.28	0.56	13	0.98	0.0446	0.1111

Species	Length (m)	Wingspan (m)	Assumed flight speed, v (ms-1)	Avoidance rate	Probability of collision	Bird transit time (secs)
Pink-footed goose	0.675	1.525	17.3	0.998	0.0530	0.106
Red kite	0.66	1.95	12	0.99	0.0640	0.1521
Red-throated diver	0.73	1.3	17	0.995	0.0536	0.1115

Table E-3: Visible area within the CRAA per vantage point

VP	Area (ha)
1	318.76
3	319.81
4	105.35
5	47.55
6	0[1]

Birds are assumed to be active during all the daylight hours and this is estimated by calculating the number of hours per day between sunrise and sunset (adjusting for correct latitude) for the survey seasons as defined in **Table E-4** below.

Table E-4: Season definitions per species/species group

Species	Breeding season			Non-breeding season		
	Start date	End date	Hours presumed present	Start date	End date	Hours presumed present
Golden eagle	1st February	31st August	2,832	1st September	31st January	1,675
Divers	15th April	31st August	2,308	1st September	14th April	2,199
Geese and swans	15th May	31st August	1,845	1st September	14th May	2,662
Raptors	15th March	31st August	2,709	1st September	14th March	1,798
Waders	1st April	31st July	2,023	1st August	31st March	2,484

Table E-5 and Table E-6 present a summary of collision mortality risks based on a Nordex 163 and SG 7.0-170 respectively.

[1] Following final scheme design the viewshed of VP6 does not overlap with the CRAA and so data derived from this location is not used in subsequent analysis.

Table E-5: Estimated collision mortality risks (Nordex 163).

Species	2022 breeding season	2022/23 non-breeding season	2023 breeding season	2023/24 non-breeding season	Mean breeding	Mean non-breeding	Mean annual	No. of years per collision
Golden eagle	0.0260	0.0042	0.0013	0.0333	0.0187	0.0137	0.0324	30.86
Golden plover	0.0000	0.0214	0.0361	0.0000	0.0107	0.0181	0.0287	34.79
Goshawk	0.0015	0.0000	0.0000	0.0001	0.0000	0.0008	0.0008	1280.22
Greenshank	0.0142	0.0000	0.0000	0.0000	0.0000	0.0071	0.0071	140.93
Hen harrier	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	8421.31
Merlin	0.0002	0.0000	0.0000	0.0038	0.0019	0.0001	0.0020	492.08
Pink-footed goose	0.0000	0.0119	0.0000	0.0787	0.0453	0.0000	0.0453	22.07
Red kite	0.0031	0.0000	0.0000	0.0000	0.0000	0.0015	0.0015	652.64
Red-throated diver	0.0032	0.0014	0.0000	0.0000	0.0007	0.0016	0.0023	433.44

Table E-6: Estimated collision mortality risks (SG 7.0-170).

Species	2022 breeding season	2022/23 non-breeding season	2023 breeding season	2023/24 non-breeding season	Mean breeding	Mean non-breeding	Mean annual	No. of years per collision 1
Dunlin	0.0016	0.0000	0.0000	0.0000	0.0000	0.0008	0.0008	1246.99
Golden eagle	0.0210	0.0170	0.0021	0.0322	0.0246	0.0115	0.0362	27.65
Golden plover	0.0000	0.0574	0.0616	0.0000	0.0287	0.0308	0.0595	16.80
Goshawk	0.0112	0.0000	0.0000	0.0004	0.0002	0.0056	0.0058	172.90
Greenshank	0.0455	0.0000	0.0000	0.0000	0.0000	0.0228	0.0228	43.93
Hen harrier	0.0017	0.0000	0.0000	0.0000	0.0000	0.0009	0.0009	1170.17
Merlin	0.0084	0.0000	0.0000	0.0044	0.0022	0.0042	0.0064	155.29
Pink-footed goose	0.0000	0.0813	0.0000	0.0518	0.0666	0.0000	0.0666	15.02
Red kite	0.0031	0.0000	0.0000	0.0000	0.0000	0.0016	0.0016	636.28
Red-throated diver	0.0032	0.0022	0.0000	0.0000	0.0011	0.0016	0.0027	367.62

Detailed outputs for the CRM based on the SG 7.0-170, and which represents the worst case for all species, are presented in the following order below:

- Dunlin

- Golden eagle
- Golden plover
- Goshawk
- Greenshank
- Hen harrier
- Merlin
- Pink-footed goose
- Red kite
- Red-throated diver

E.1 Dunlin

Breeding Season 2022 (SG 7.0-170)

Table E-7: Dunlin flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0	7650.21	0
3	0	7675.33	0
4	8.5	2528.40	0.0000001
5	0	1141.09	0

Table E-8: Dunlin mortality estimates

Mean activity in wind farm at rotor height	0.0001	hr^{-1}
Total Combined rotor swept volume	402683	m^3
Bird occupancy	0.1736	hrs/season
Bird occupancy of rotor swept volume	0.2145	bird-sec
No. of transits through rotors	2.4046	per season
Estimated collisions	0.0943	per season
Estimated collisions after correction for operation	0.0802	per season
Estimated collisions after avoidance factor	0.0016	per season

E.2 Golden eagle

Breeding Season 2022 (SG 7.0-170)

Table E-9: Golden eagle flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	60.38	11475.31	0.0000006
3	92.93	11512.99	0.0000009
4	0.00	3792.60	0
5	0.00	1711.64	0

Table E-10: Golden eagle mortality estimates

Mean activity in wind farm at rotor height	0.0010	hr^{-1}
Total Combined rotor swept volume	584154	m^3
Bird occupancy	2.9214	hrs/season
Bird occupancy of rotor swept volume	5.2361	bird-sec
No. of transits through rotors	39.6736	per season
Estimated collisions	2.4647	per season
Estimated collisions after correction for operation	2.0950	per season
Estimated collisions after avoidance factor	0.0210	per season

Non-Breeding season 2022/2023 (SG 7.0-170)

Table E-11: Golden eagle flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	180.44	10519.03	0.000002
3	0.00	9274.36	0
4	0.00	3055.15	0
5	0.00	1569.00	0

Table E-12: Golden eagle mortality estimates

Mean activity in wind farm at rotor height	0.0014	hr^{-1}
Total Combined rotor swept volume	584154	m^3
Bird occupancy	2.3732	hrs/season
Bird occupancy of rotor swept volume	4.2535	bird-sec
No. of transits through rotors	32.2282	per season
Estimated collisions	2.0022	per season
Estimated collisions after correction for operation	1.7019	per season
Estimated collisions after avoidance factor	0.0170	per season

Breeding Season 2023 (SG 7.0-170)

Table E-13: Golden eagle flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	12431.59	0
3	0.00	13751.63	0
4	6.84	4530.05	0.0000001
5	11.08	1854.28	0.0000001

Table E-14: Golden eagle mortality estimates

Mean activity in wind farm at rotor height	0.0001	hr^{-1}
Total Combined rotor swept volume	584154	m^3
Bird occupancy	0.2987	hrs/season
Bird occupancy of rotor swept volume	0.5354	bird-sec
No. of transits through rotors	4.0569	per season
Estimated collisions	0.2520	per season
Estimated collisions after correction for operation	0.2142	per season
Estimated collisions after avoidance factor	0.0021	per season

Non-Breeding Season 2023/2024 (SG 7.0-170)

Table E-15: Golden eagle flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	202.54	9881.52	0.000002
3	140.70	9913.97	0.000002
4	0.00	3265.85	0
5	0.00	1473.91	0

Table E-16: Golden eagle mortality estimates

Mean activity in wind farm at rotor height	0.0027	hr^{-1}
Total Combined rotor swept volume	584154	m^3
Bird occupancy	4.4927	hrs/season
Bird occupancy of rotor swept volume	8.0523	bird-sec
No. of transits through rotors	61.0121	per season
Estimated collisions	3.7904	per season
Estimated collisions after correction for operation	3.2219	per season
Estimated collisions after avoidance factor	0.0322	per season

E.3 Golden plover

Non-Breeding Season 2022/2023 (SG 7.0-170)

Table E-17: Golden plover flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	216.44	15300.41	0.000002
3	7.44	15350.66	0.0000001
4	182.83	4951.45	0.000001
5	0.00	2282.19	0

Table E-18: Golden plover mortality estimates

Mean activity in wind farm at rotor height	0.0021	hr^{-1}
Total Combined rotor swept volume	426289	m^3
Bird occupancy	5.1118	hrs/season
Bird occupancy of rotor swept volume	6.6859	bird-sec
No. of transits through rotors	82.8405	per season
Estimated collisions	3.3746	per season
Estimated collisions after correction for operation	2.8684	per season
Estimated collisions after avoidance factor	0.0574	per season

Breeding Season 2023 (SG 7.0-170)

Table E-19: Golden plover flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	69.31	7650.21	0.000001
3	0.00	7675.33	0
4	199.65	2528.40	0.000003
5	0.00	1141.09	0

Table E-20: Golden plover mortality estimates

Mean activity in wind farm at rotor height	0.0027	hr^{-1}
Total Combined rotor swept volume	426289	m^3
Bird occupancy	5.4929	hrs/season
Bird occupancy of rotor swept volume	7.1844	bird-sec
No. of transits through rotors	89.0161	per season
Estimated collisions	3.6262	per season
Estimated collisions after correction for operation	3.0822	per season
Estimated collisions after avoidance factor	0.0616	per season

E.4 Goshawk

Breeding Season 2022 (SG 7.0-170)

Table E-21: Goshawk flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	0.00	11512.99	0
4	58.47	3792.60	0.000001
5	0.00	1711.64	0

Table E-22: Goshawk mortality estimates

Mean activity in wind farm at rotor height	0.0004	hr^{-1}
Total Combined rotor swept volume	526615	m^3
Bird occupancy	1.0658	hrs/season
Bird occupancy of rotor swept volume	1.7220	bird-sec
No. of transits through rotors	9.3593	per season
Estimated collisions	0.6577	per season
Estimated collisions after correction for operation	0.5591	per season
Estimated collisions after avoidance factor	0.0112	per season

Non-Breeding Season 2023/2024 (SG 7.0-170)

Table E-23: Goshawk flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	0.00	11512.99	0
4	3.04	3792.60	0.00000003
5	0.00	1711.64	0

Table E-24: Goshawk mortality estimates

Mean activity in wind farm at rotor height	0.00002	hr^{-1}
Total Combined rotor swept volume	526615	m^3
Bird occupancy	0.03677	hrs/season
Bird occupancy of rotor swept volume	0.05942	bird-sec
No. of transits through rotors	0.32294	per season
Estimated collisions	0.02269	per season
Estimated collisions after correction for operation	0.01929	per season
Estimated collisions after avoidance factor	0.00039	per season

E.5 Greenshank

Breeding Season 2022 (SG 7.0-170)

Table E-25: Greenshank flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	231.78	7650.21	0.000003
3	0.00	7675.33	0
4	0.00	2528.40	0
5	0.00	1141.09	0

Table E-26: Greenshank mortality estimates

Mean activity in wind farm at rotor height	0.0023	hr^{-1}
Total Combined rotor swept volume	436617	m^3
Bird occupancy	4.7335	hrs/season
Bird occupancy of rotor swept volume	6.3412	bird-sec
No. of transits through rotors	59.9967	per season
Estimated collisions	2.6783	per season
Estimated collisions after correction for operation	2.2766	per season
Estimated collisions after avoidance factor	0.0455	per season

E.6 Hen harrier

Breeding Season 2022 (SG 7.0-170)

Table E-27: Hen harrier flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	18.49	11512.99	0.0000002
4	0.00	3792.60	0
5	0.00	1711.64	0

Table E-28: Hen harrier mortality estimates

Mean activity in wind farm at rotor height	0.0001	hr^{-1}
Total Combined rotor swept volume	485304	m^3
Bird occupancy	0.3370	hrs/season
Bird occupancy of rotor swept volume	0.5018	bird-sec
No. of transits through rotors	3.6612	per season
Estimated collisions	0.2011	per season
Estimated collisions after correction for operation	0.1709	per season
Estimated collisions after avoidance factor	0.0017	per season

E.7 Merlin

Breeding Season 2022 (SG 7.0-170)

Table E-29: Merlin flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	33.81	11512.99	0.0000003
4	18.00	3792.60	0.0000002
5	0.00	1711.64	0

Table E-30: Merlin mortality estimates

Mean activity in wind farm at rotor height	0.0003	hr^{-1}
Total Combined rotor swept volume	426289	m^3
Bird occupancy	0.9444	hrs/season
Bird occupancy of rotor swept volume	1.2352	bird-sec
No. of transits through rotors	11.1149	per season
Estimated collisions	0.4958	per season
Estimated collisions after correction for operation	0.4214	per season
Estimated collisions after avoidance factor	0.0084	per season

Non-Breeding Season 2022/2023 (SG 7.0-170)

Table E-31: Merlin flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.31	11475.31	0.000000003
3	0.00	11512.99	0
4	0.00	3792.60	0
5	0.00	1711.64	0

Table E-32: Merlin mortality estimates

Mean activity in wind farm at rotor height	0.000002	hr^{-1}
Total Combined rotor swept volume	426289	m^3
Bird occupancy	0.0037	hrs/season
Bird occupancy of rotor swept volume	0.0048	bird-sec
No. of transits through rotors	0.0435	per season
Estimated collisions	0.0019	per season
Estimated collisions after correction for operation	0.0016	per season
Estimated collisions after avoidance factor	0.00003	per season

Non-Breeding Season 2023/2024 (SG 7.0-170)

Table E-33: Merlin flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	13.74	11512.99	0.0000001
4	27.16	3792.60	0.0000003
5	0.00	1711.64	0

Table E-34: Merlin mortality estimates

Mean activity in wind farm at rotor height	0.0003	hr^{-1}
Total Combined rotor swept volume	426289	m^3
Bird occupancy	0.4950	hrs/season
Bird occupancy of rotor swept volume	0.6474	bird-sec
No. of transits through rotors	5.8255	per season
Estimated collisions	0.2599	per season
Estimated collisions after correction for operation	0.2209	per season
Estimated collisions after avoidance factor	0.0044	per season

E.8 Pink-footed goose

Non-Breeding Season 2022/2023 (SG 7.0-170)

Table E-35: Pink-footed goose flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	15300.41	0
3	4348.69	15350.66	0.00003
4	0.00	5583.55	0
5	0.00	2282.19	0

Table E-36: Pink-footed goose mortality estimates

Mean activity in wind farm at rotor height	0.0216	hr^{-1}
Total Combined rotor swept volume	542844	m^3
Bird occupancy	57.6238	hrs/season
Bird occupancy of rotor swept volume	95.9756	bird-sec
No. of transits through rotors	902.5336	per season
Estimated collisions	47.8269	per season
Estimated collisions after correction for operation	40.6529	per season
Estimated collisions after avoidance factor	0.0813	per season

Non-Breeding Season 2023/2024 (SG 7.0-170)

Table E-37: Pink-footed goose flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	0.00	11512.99	0
4	2051.16	3792.60	0.00002
5	0.00	1711.64	0

Table E-38: Pink-footed goose mortality estimates

Mean activity in wind farm at rotor height	0.0138	hr^{-1}
Total Combined rotor swept volume	542844	m^3
Bird occupancy	36.7419	hrs/season
Bird occupancy of rotor swept volume	61.1956	bird-sec
No. of transits through rotors	575	per season
Estimated collisions	30.4952	per season
Estimated collisions after correction for operation	25.9209	per season
Estimated collisions after avoidance factor	0.0518	per season

E.9 Red kite

Breeding Season 2022 (SG 7.0-170)

Table E-39: Red kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	11475.31	0
3	0.00	11512.99	0
4	0.00	3792.60	0
5	30.10	1711.64	0.0000003

Table E-40: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0002	hr^{-1}
Total Combined rotor swept volume	538417	m^3
Bird occupancy	0.5486	hrs/season
Bird occupancy of rotor swept volume	0.9063	bird-sec
No. of transits through rotors	5.9603	per season
Estimated collisions	0.3816	per season
Estimated collisions after correction for operation	0.3243	per season
Estimated collisions after avoidance factor	0.0032	per season

Non-Breeding Season 2022/2023 (SG 7.0-170)

Table E-41: Red Kite flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	27.67	11475.31	0.0000003
3	0.00	11512.99	0
4	3.05	3792.60	0.00000003
5	0.00	1711.64	0

Table E-42: Red kite mortality estimates

Mean activity in wind farm at rotor height	0.0002	hr^{-1}
Total Combined rotor swept volume	538417	m^3
Bird occupancy	0.3717	hrs/season
Bird occupancy of rotor swept volume	0.6140	bird-sec
No. of transits through rotors	4.0380	per season
Estimated collisions	0.2585	per season
Estimated collisions after correction for operation	0.2197	per season
Estimated collisions after avoidance factor	0.0022	per season

E.10 Red-throated diver

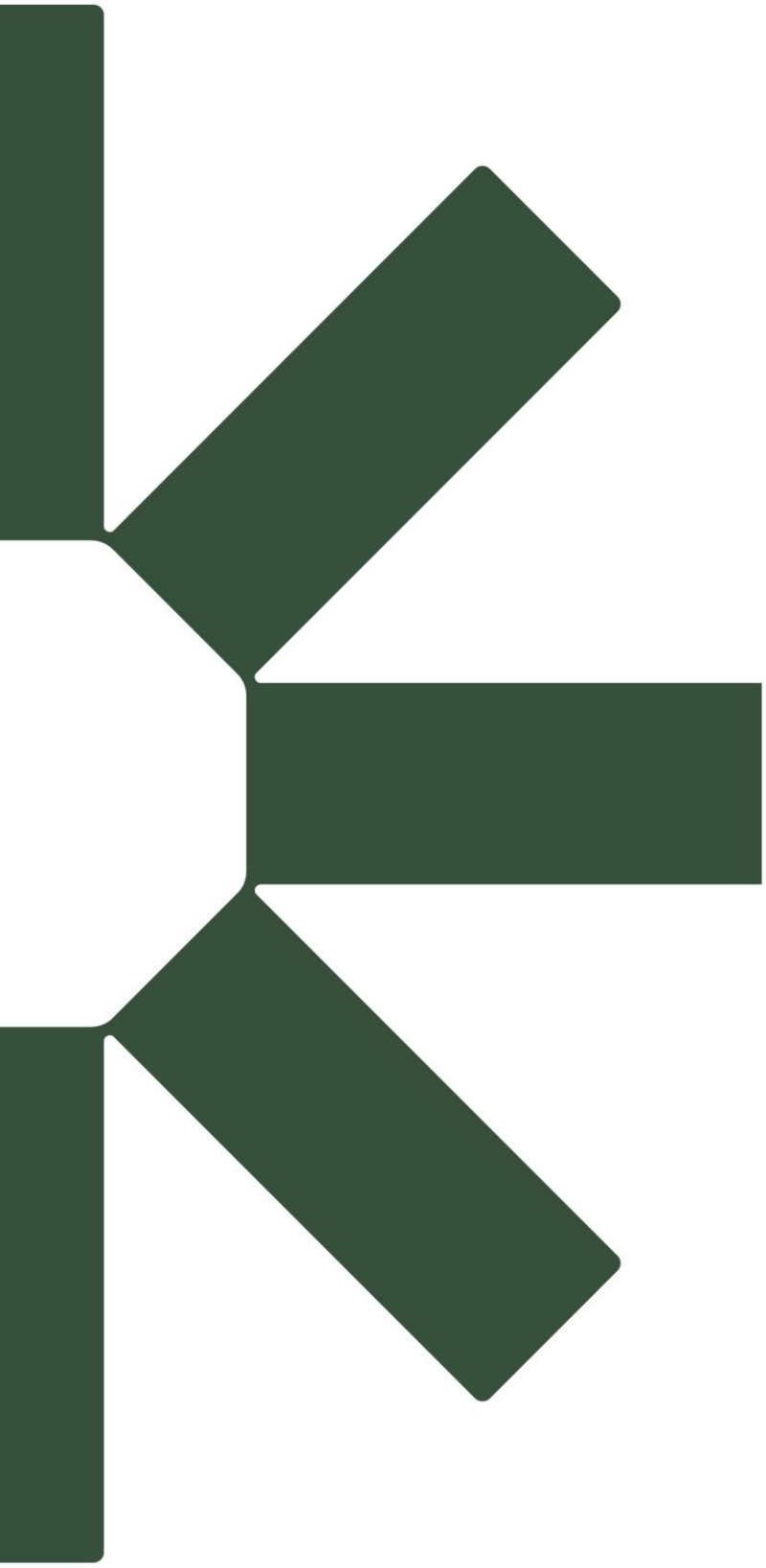
Breeding Season 2022 (SG 7.0-170)

Table E-43: Red-throated diver flight activity

VP	Seconds at risk height	Observation effort (HaHr)	Flying time at risk height (secsHahr^{-1})
1	0.00	9562.76	0
3	0.00	7675.33	0
4	43.64	3160.50	0.000001
5	0.00	1141.09	0

Table E-44: Red-throated diver mortality estimates

Mean activity in wind farm at rotor height	0.0004	hr^{-1}
Total Combined rotor swept volume	559073	m^3
Bird occupancy	0.8963	hrs/season
Bird occupancy of rotor swept volume	1.5374	bird-sec
No. of transits through rotors	13.7945	per season
Estimated collisions	0.7396	per season
Estimated collisions after correction for operation	0.6287	per season
Estimated collisions after avoidance factor	0.0031	per season



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