Final Report

FEHMARNBELT FIXED LINK BIRD SERVICES (FEBI)

Fauna and Flora - Birds – Impact Assessment

Birds of the Fehmarnbelt Area

E3TR0015

APPENDIX – Impact maps and PBR

Prepared for: Femern A/S
By: DHI / BioConsult SH Consortium
in association with University of Copenhagen and BIOLA

Responsible editor:
FEBI consortium / co DHI
Agern Allé 5
DK-2970 Hørsholm
Denmark

FEBI Project Director: Anders Malmgren Hansen, DHI
www.dhigroup.com

Please cite as:
FEBI (2013). Fehmarnbelt Fixed Link EIA.
Fauna and Flora – Impact Assessment -
Birds of the Fehmarnbelt Area.
Report No. E3TR0015
Appendix: Impact maps and PBR

Appendix: 38 pages

(Main report: ISBN 978-87-92416-56-8)

May 2013

ISBN 978-87-92416-87-2

Maps:
Unless otherwise stated:
DDO Orthofoto: DDO®, copyright COWI
Geodatastyrelsen (formerly Kort- og Matrikelstyrelsen), Kort10 and 25 Matrikelkort
GEUS (De Nationale Geologiske Undersøgelser for Danmark og Grønland)
HELCOM (Helsinki Commission – Baltic Marine Environment Protection Commission)
Landesamt für Vermessung und Geoinformation Schleswig-Holstein (formerly Landesvermessungsamt Schleswig-Holstein) GeoBasis-DE/LVermGeo SH

Photos:
Monika Dorsch (Cover page)

Co-financed by the European Union
Trans-European Transport Network (TEN-T)

CONTENTS

A. IMPACT MAPS (NON-BREEDING WATERBIRDS) 1
A.1 Immersed tunnel 1
A.1.1 Habitat loss from footprint 1
A.1.2 Habitat change from sediment spill 1
A.1.3 Water turbidity 4
A.1.4 Disturbance from construction vessels 17
A.2 Cable stayed bridge 23
A.2.1 Habitat loss from footprint 23
A.2.2 Habitat change from sediment spill 23
A.2.3 Water turbidity 23
A.2.4 Disturbance from construction vessels 28
A.2.5 Disturbance from bridge structure and traffic 29

B. POTENTIAL BIOLOGICAL REMOVAL – PBR 31

Lists of figures and tables are included as the final pages

Note to the reader:
In this report the time for start of construction is artificially set to 1 October 2014 for the tunnel and 1 January 2015 for the bridge alternative. In the Danish EIA (VVM) and the German EIA (UVS/LBP) absolute year references are not used. Instead the time references are relative to start of construction works. In the VVM the same time reference is used for tunnel and bridge, i.e. year 0 corresponds to 2014/start of tunnel construction; year 1 corresponds to 2015/start of bridge construction etc. In the UVS/LBP individual time references are used for tunnel and bridge, i.e. for tunnel construction year 1 is equivalent to 2014 (construction starts 1 October in year 1) and for bridge construction year 1 is equivalent to 2015 (construction starts 1st January).

A. IMPACT MAPS (NON-BREEDING WATERBIRDS)

Impact maps shown in the following refer to pressures resulting in displacement of birds only. Pressures resulting in a barrier effect or collision incidents are assessed separately and cannot be displayed in maps.

A.1 Immersed tunnel

A.1.1 Habitat loss from footprint

The distribution of the most abundant species using offshore habitats was modelled on a resolution of 750x750 m grid cells and such maps were overlaid with the small-scale project footprint map. The relatively small area of the footprint and mismatch in spatial scales provided limited information about the severity of habitat loss to birds. Therefore, only one example map for the most abundant species, the Common Eider, is given.

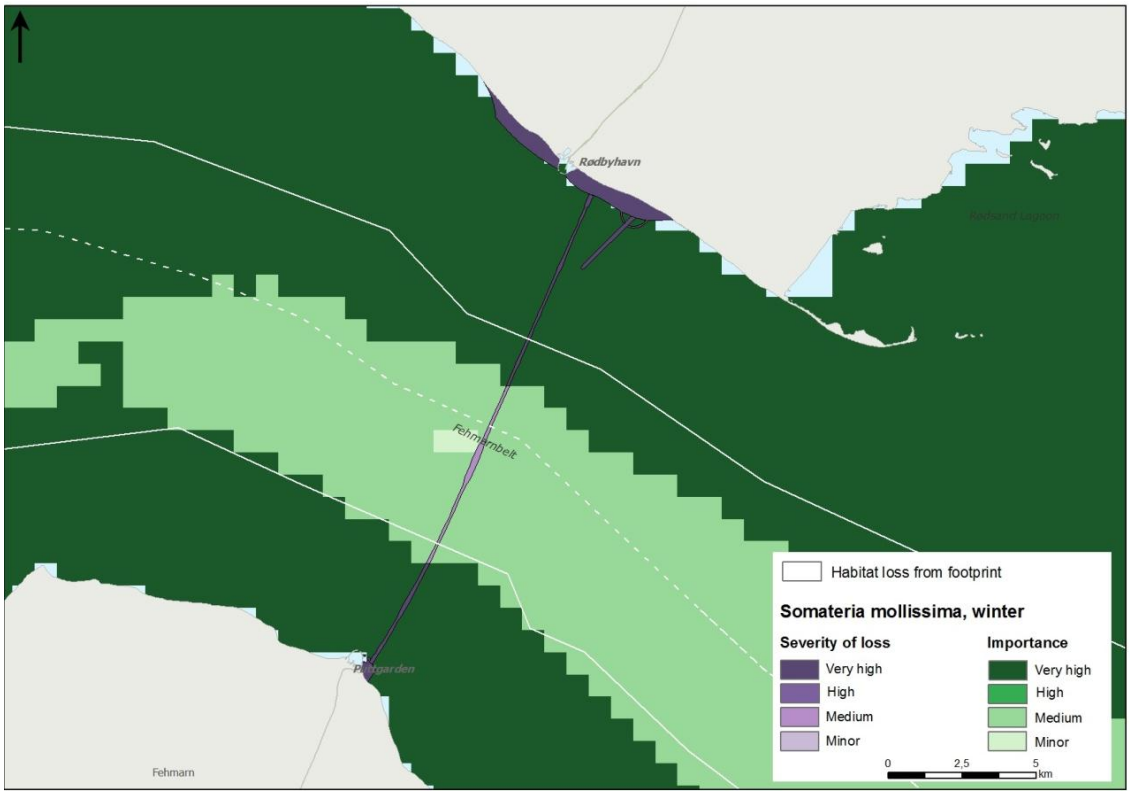

Figure A.1 Severity of loss from footprint of the immersed tunnel for Common Eiders in winter.

A.1.2 Habitat change from sediment spill

Indirect impacts from sediment spill (habitat changes) are predicted to have minor impact on piscivorous waterbirds. Indirect impacts on benthivorous waterbirds are predicted for winter 2014/2015 only.

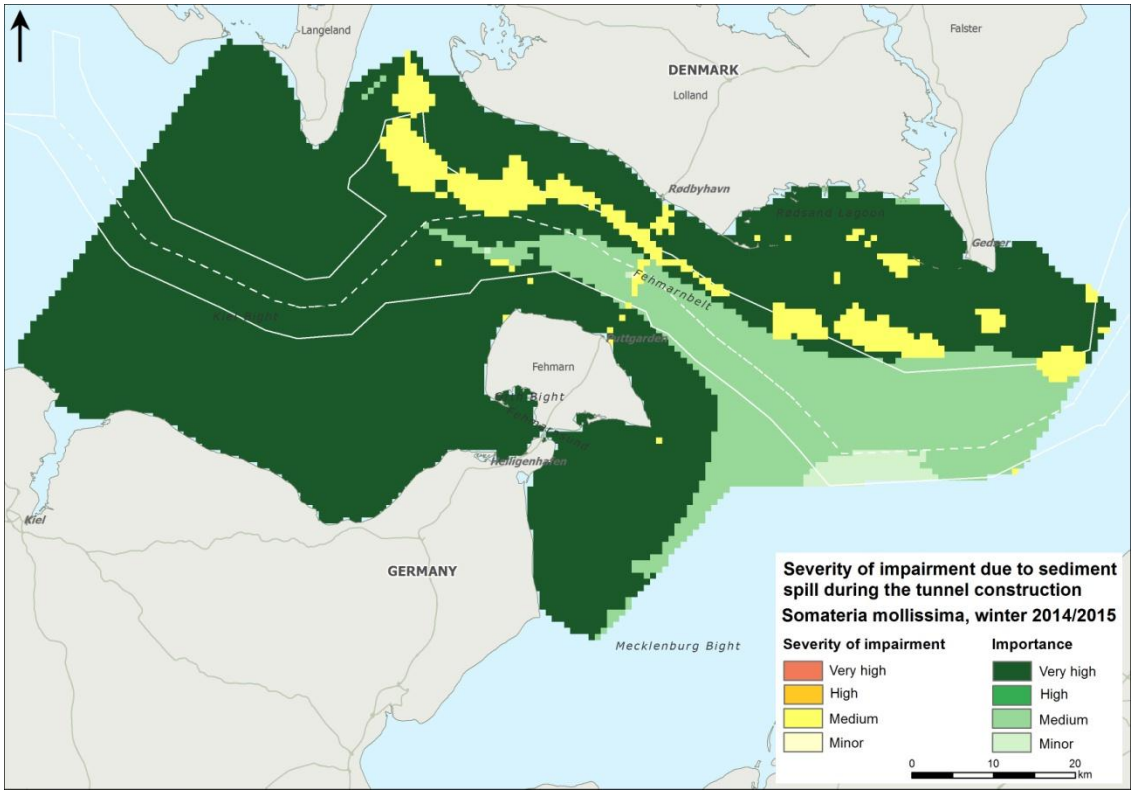

Figure A.2 *Severity of impairment from the pressure habitat change from sediment spill to Common Eider in the first winter of the tunnel construction (2014/2015; Common Eider winter distribution).*

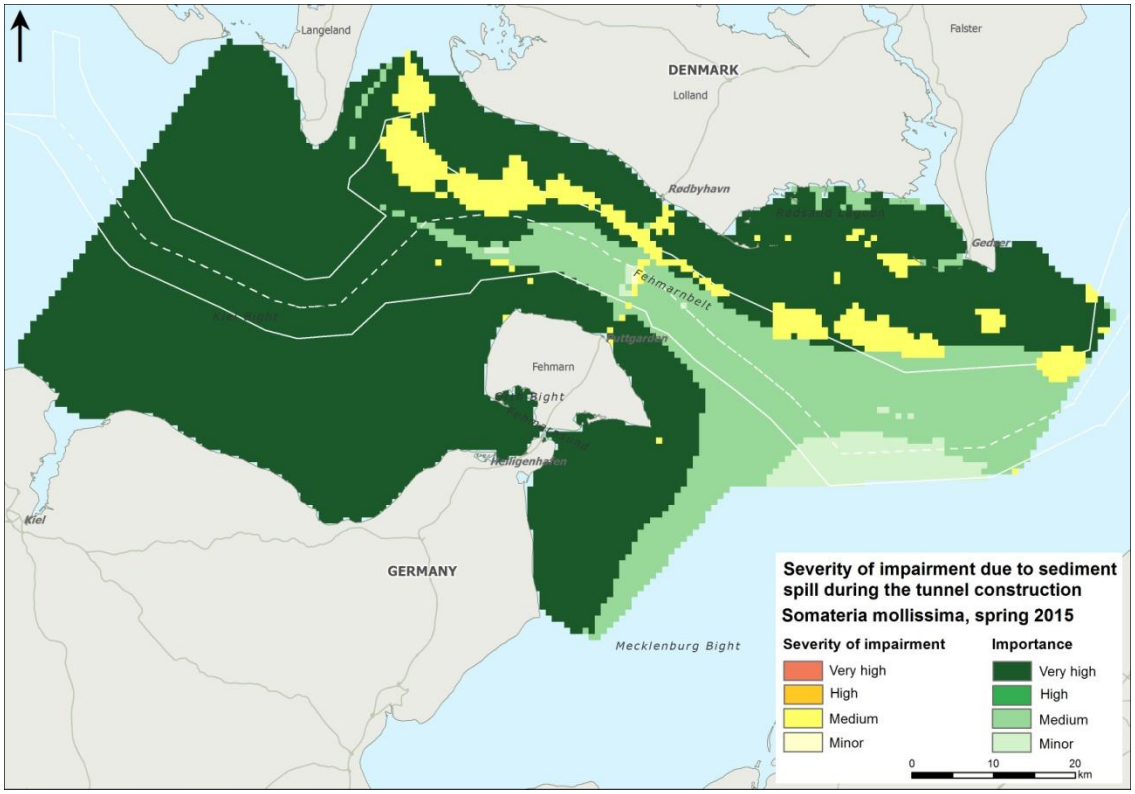

Figure A.3 *Severity of impairment from the pressure habitat change from sediment spill to Common Eider in the first winter of the tunnel construction (2014/2015; Common Eider spring distribution).*

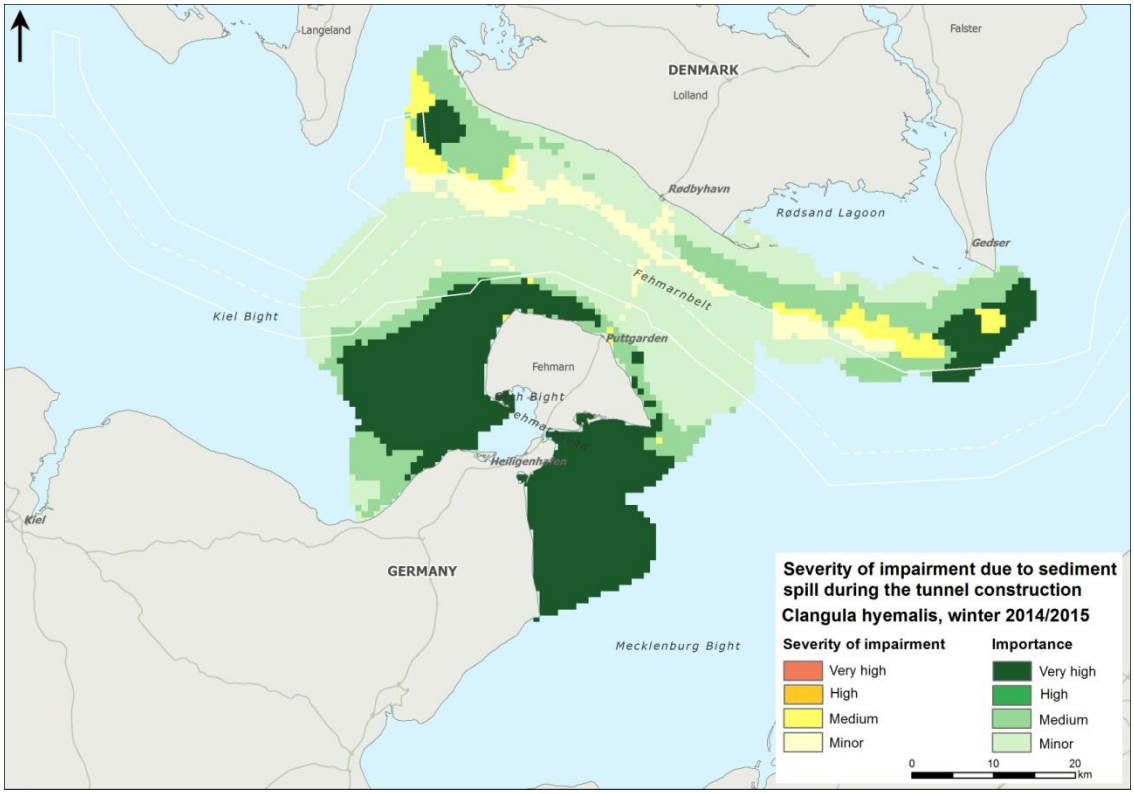

Figure A.4 *Severity of impairment from the pressure habitat change from sediment spill to Long-tailed Duck in the first winter of the tunnel construction (2014/2015).*

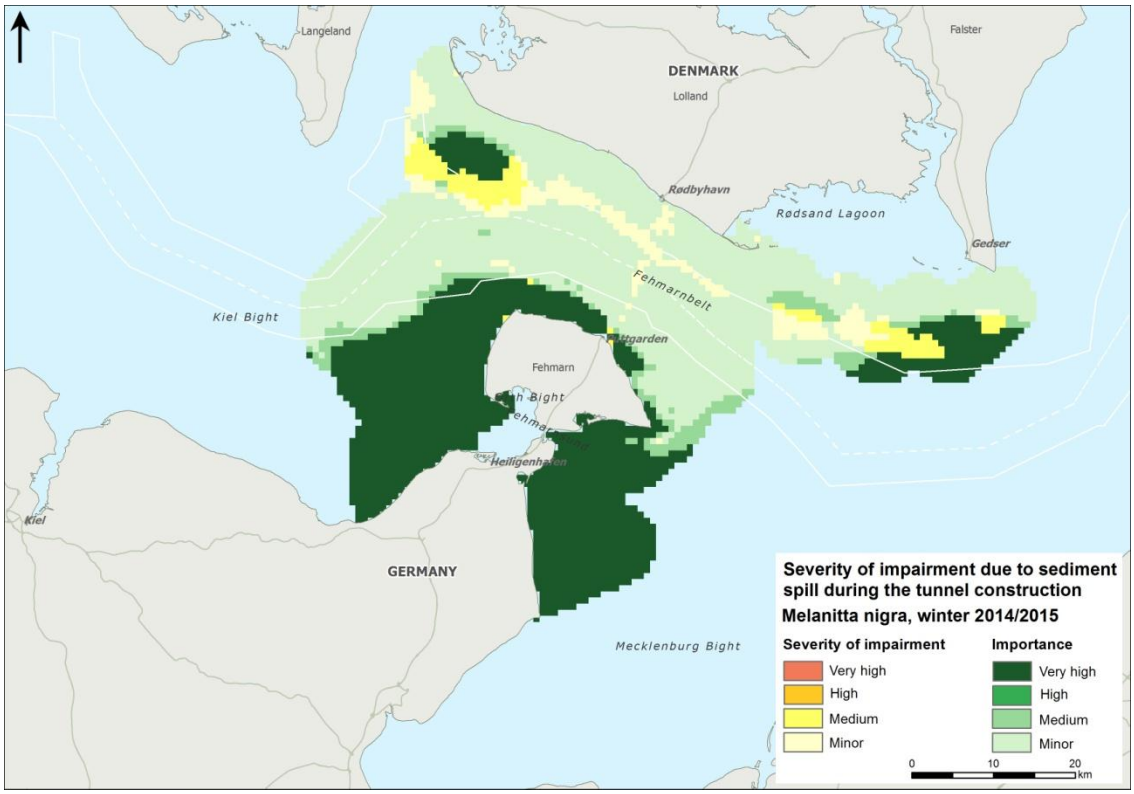

Figure A.5 *Severity of impairment from the pressure habitat change from sediment spill to Common Scoter in the first winter of the tunnel construction (2014/2015).*

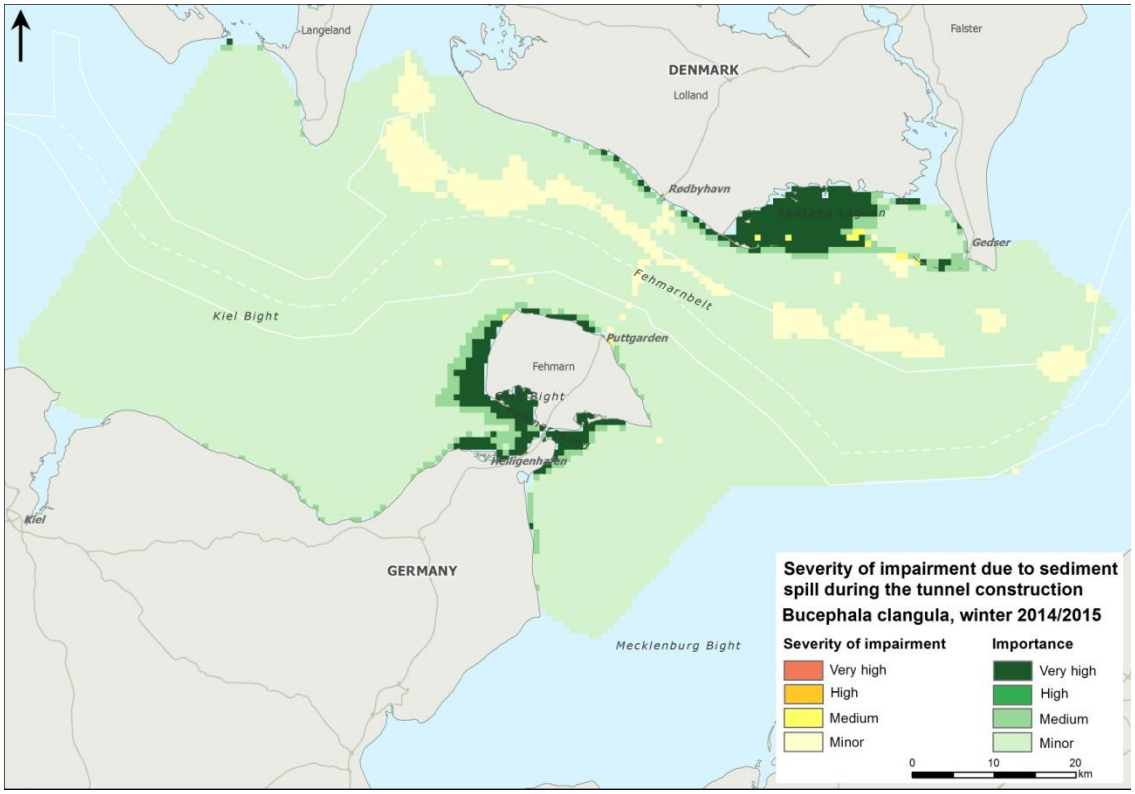

Figure A.6 Severity of impairment from the pressure habitat change from sediment spill to Common Goldeneye in the first winter of the tunnel construction (2014/2015).

A.1.3 Water turbidity

Direct impacts from sediment spill (increased water turbidity) are presented for the first two winters of the tunnel construction period (2014/2015, 2015/2016), the years with the highest predicted impact. For the Common Eider additionally the impact for the third and fourth construction year is displayed.

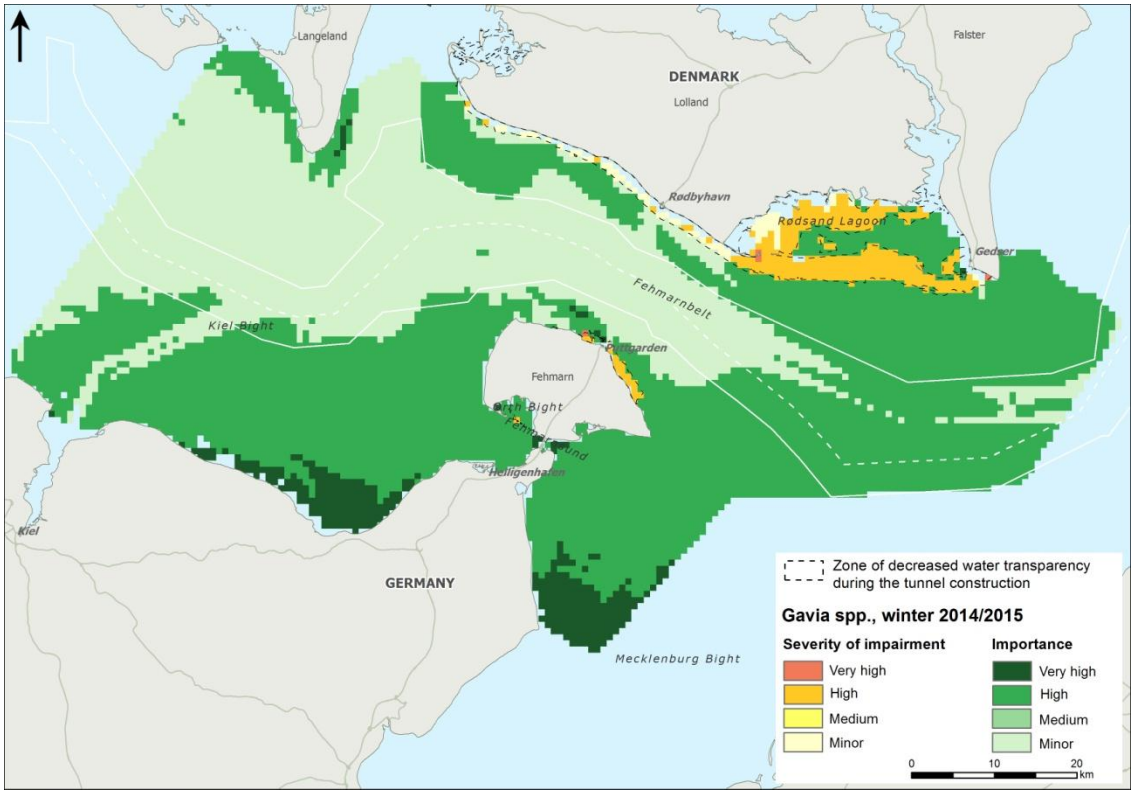

Figure A.7 *Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the tunnel construction (2014/2015; diver winter distribution).*

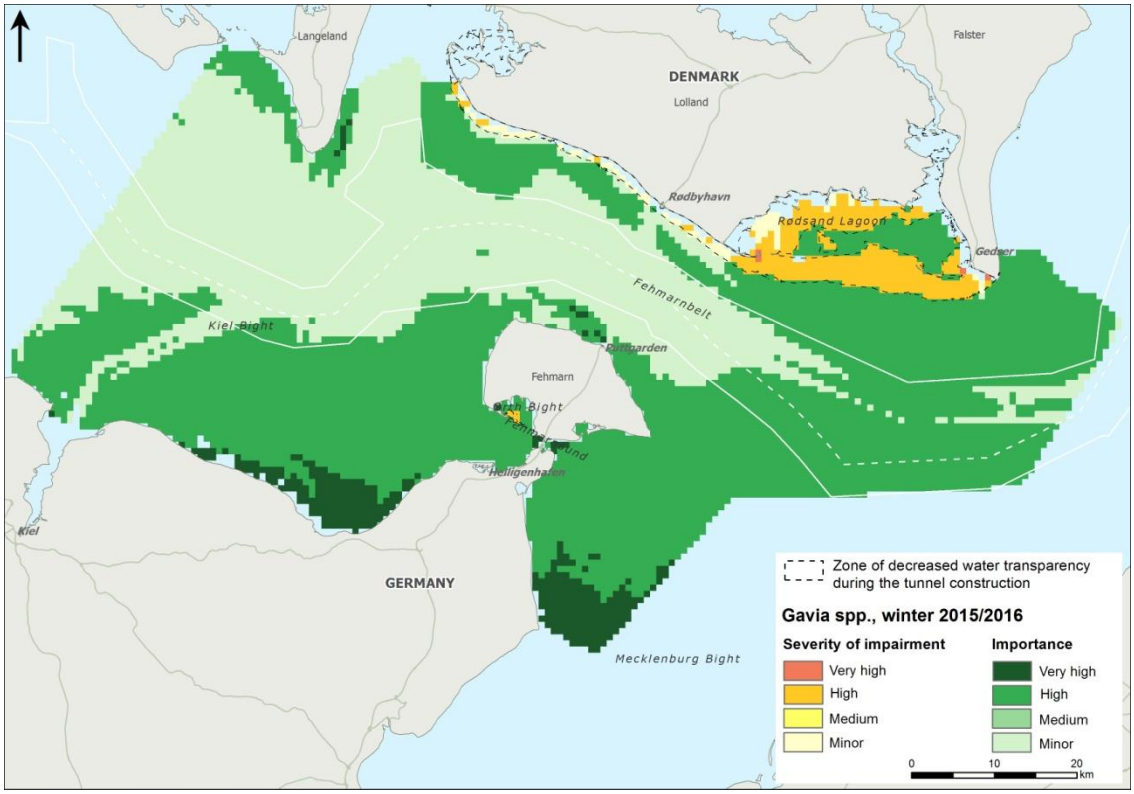

Figure A.8 *Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the second winter of the tunnel construction (2015/2016; diver winter distribution).*

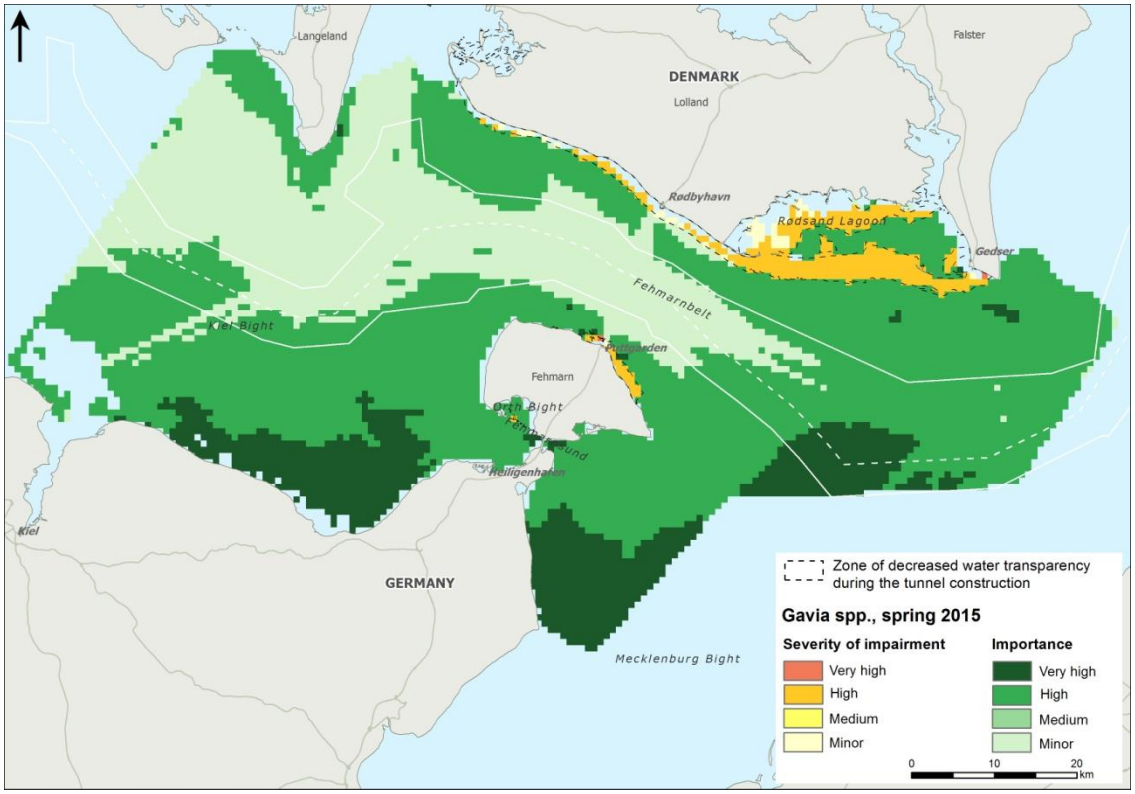

Figure A.9 *Severity of impairment from the pressure water turbidity to divers (Red-throated and Black-throated Diver) in the first winter of the tunnel construction (2014/2015; diver spring distribution).*

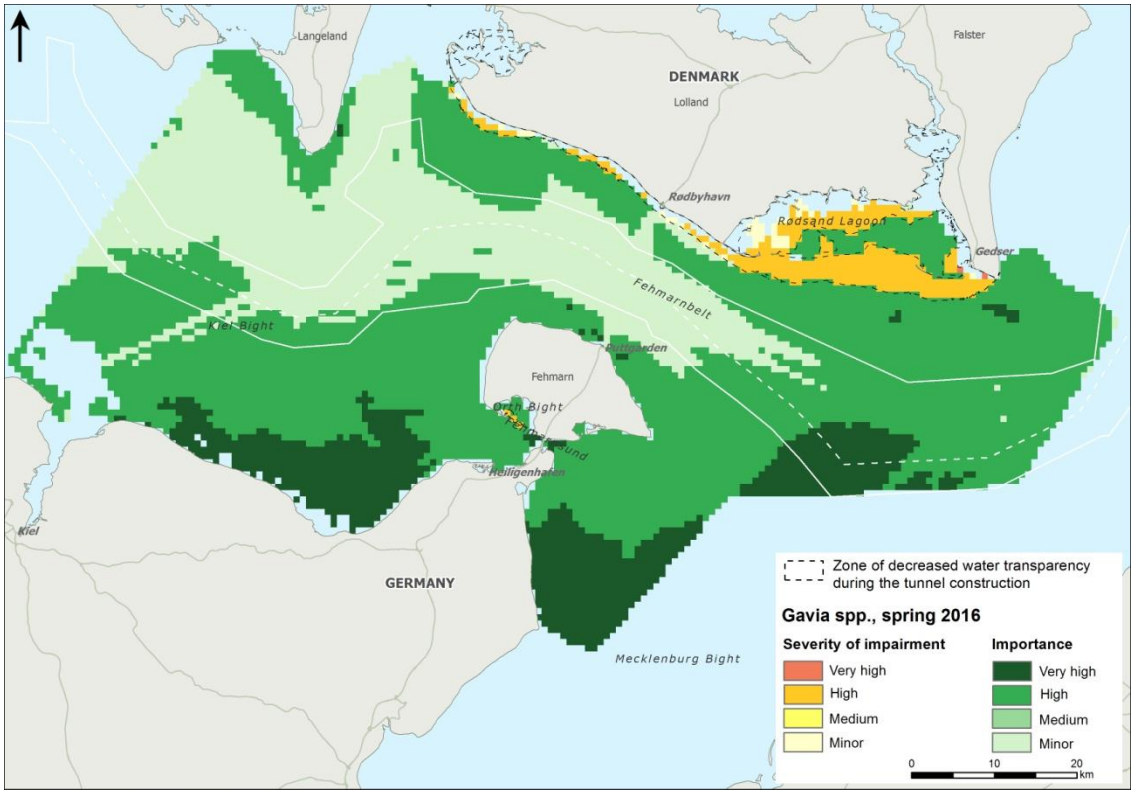

Figure A.10 *Severity of impairment from the pressure water turbidity to divers (Red-throated and Black-throated Diver) in the second winter of the tunnel construction (2015/2016; diver spring distribution).*

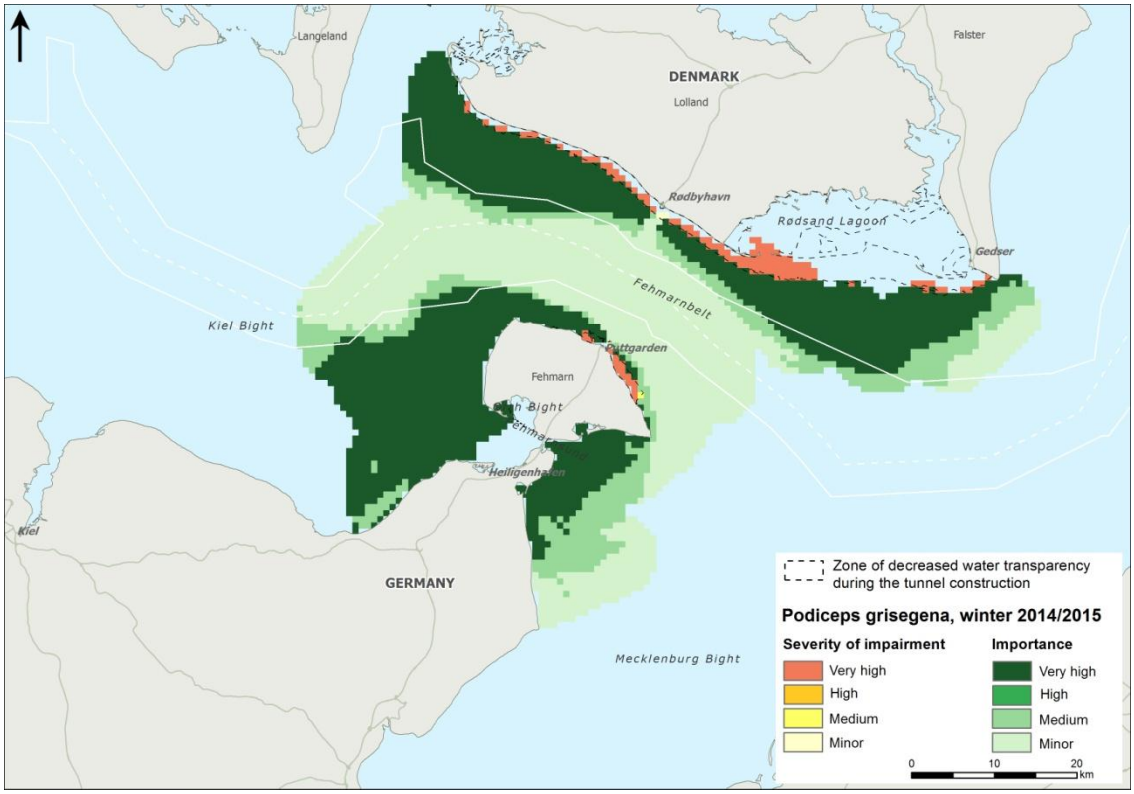

Figure A.11 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the first winter of the tunnel construction (2014/2015).

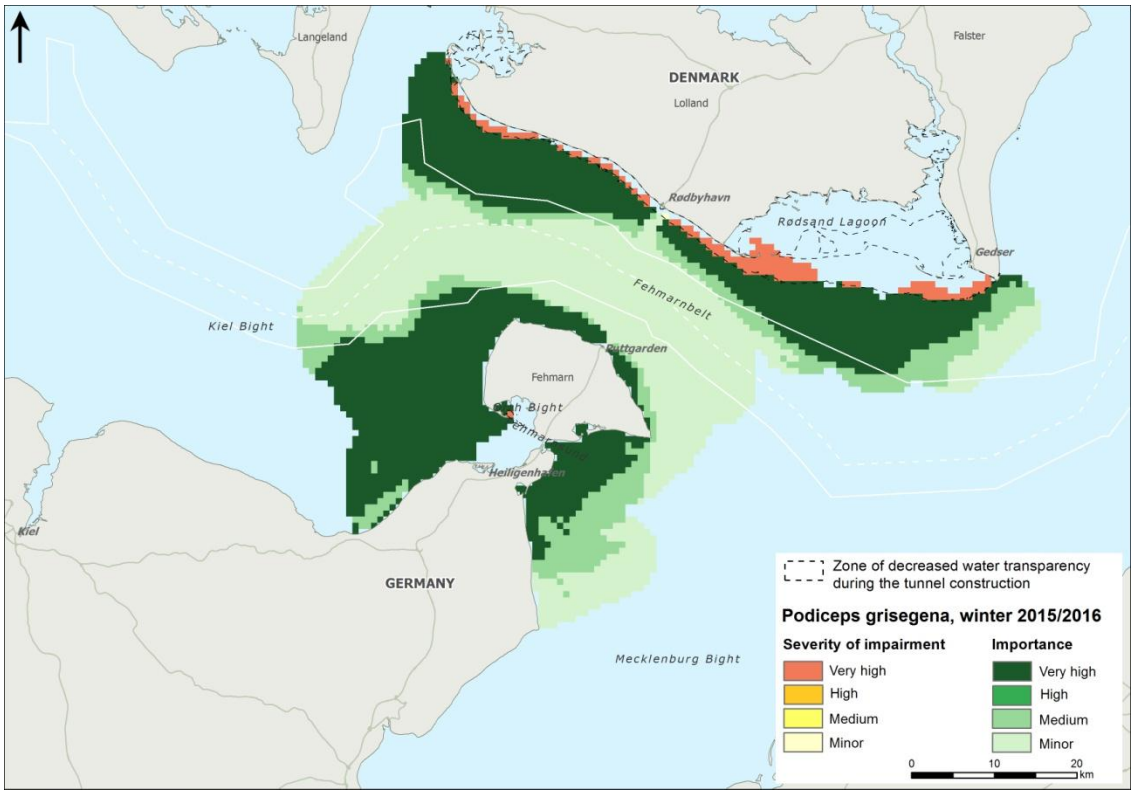

Figure A.12 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the second winter of the tunnel construction (2015/2016).

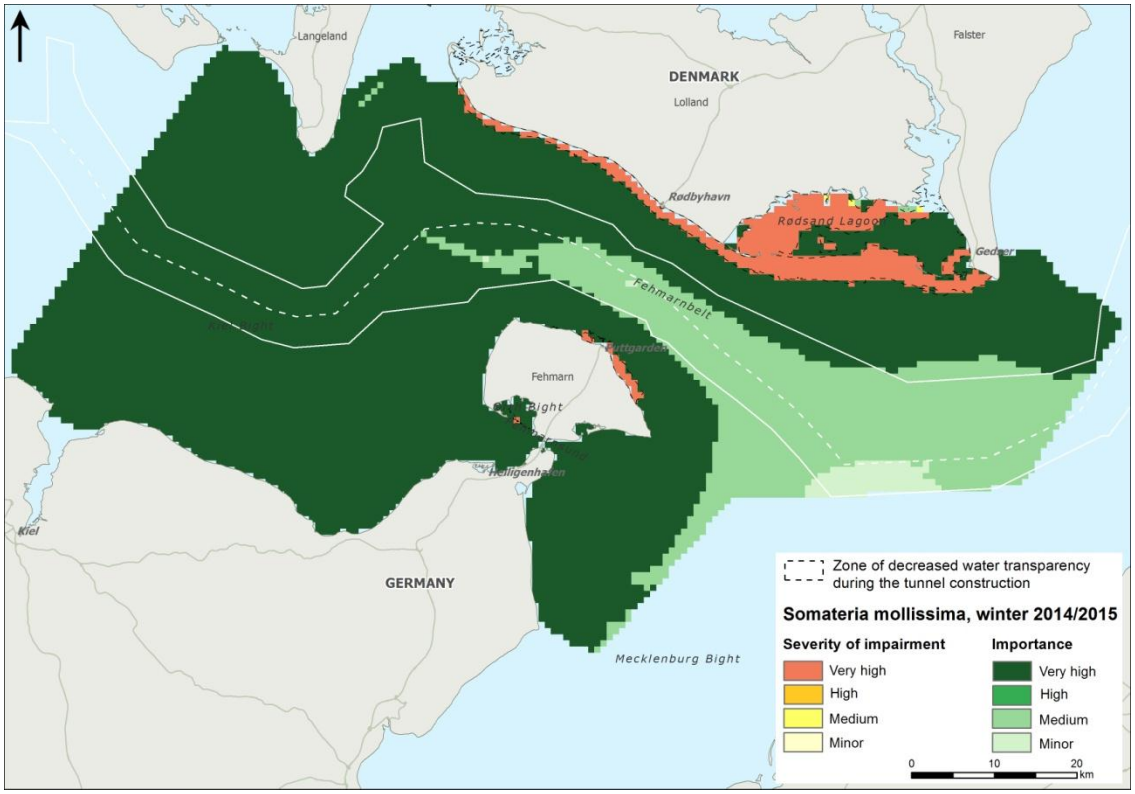

Figure A.13 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the tunnel construction (2014/2015; Common Eider winter distribution).

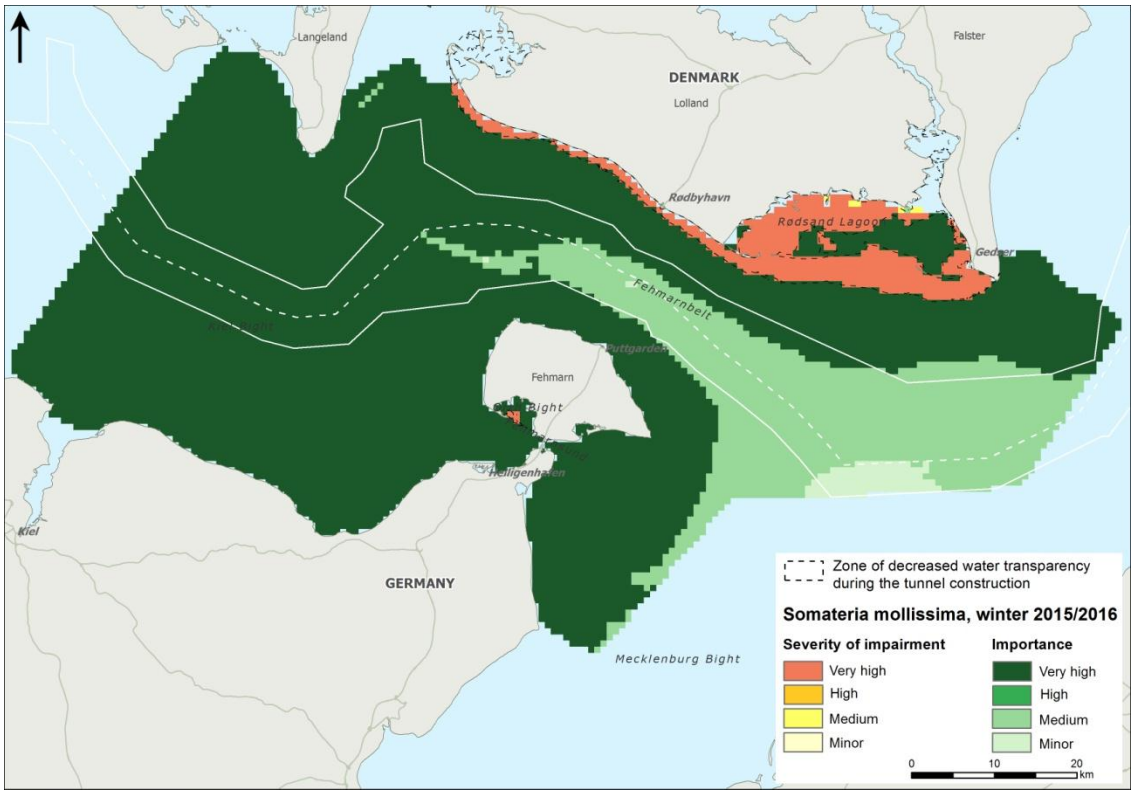

Figure A.14 Severity of impairment from the pressure water turbidity to Common Eiders in the second winter of the tunnel construction (2015/2016; Common Eider winter distribution).

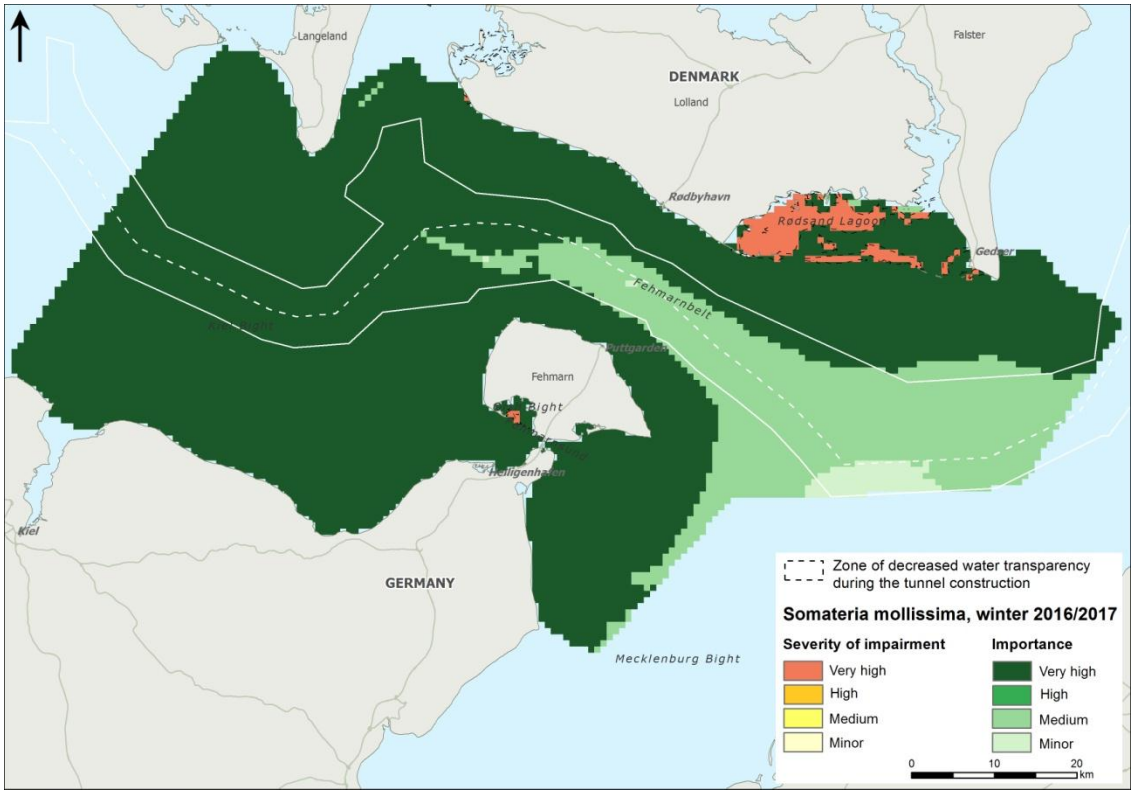

Figure A.15 Severity of impairment from the pressure water turbidity to Common Eiders in the third winter of the tunnel construction (2016/2017; Common Eider winter distribution).

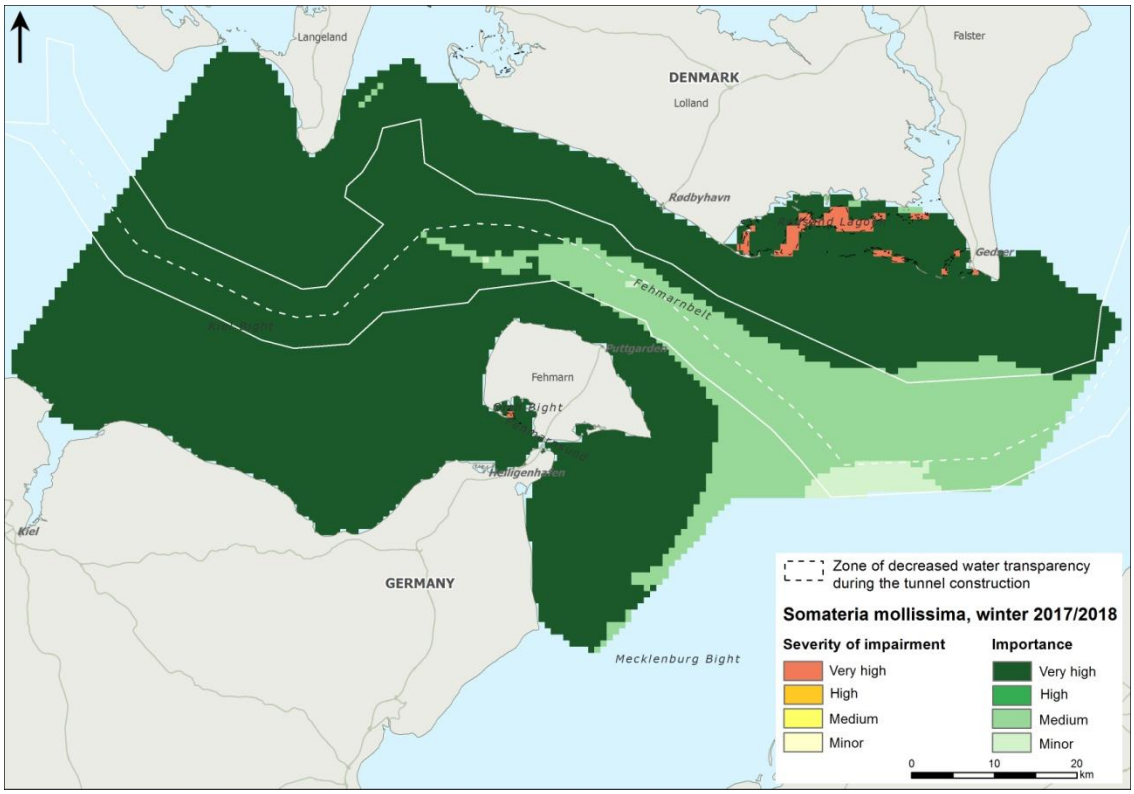

Figure A.16 Severity of impairment from the pressure water turbidity to Common Eiders in the fourth winter of the tunnel construction (2017/2018; Common Eider winter distribution).

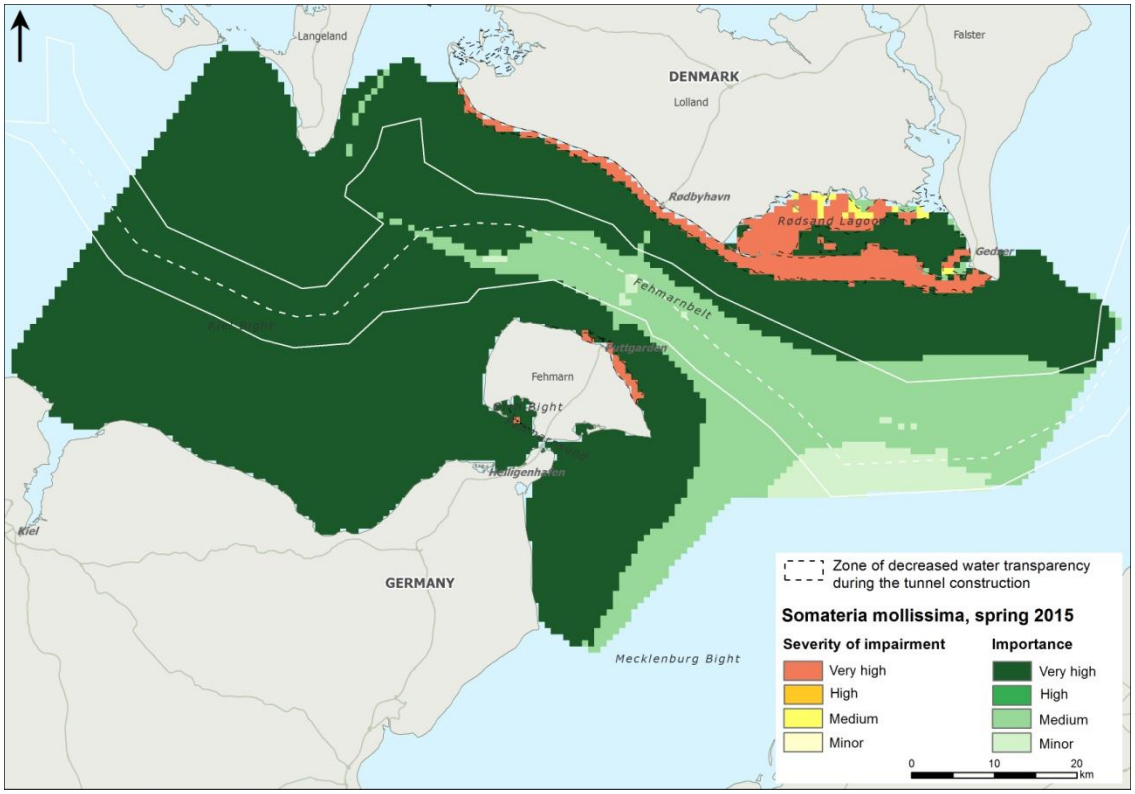

Figure A.17 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the tunnel construction (2014/2015; Common Eider spring distribution).

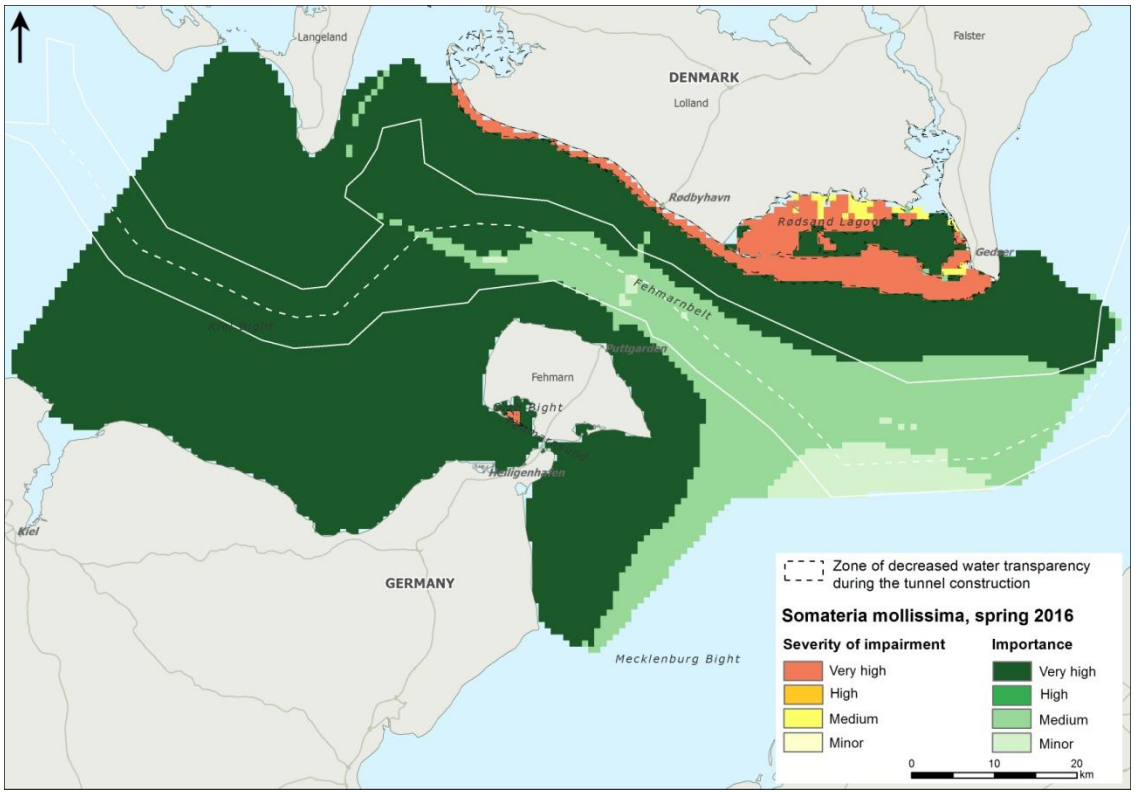

Figure A.18 Severity of impairment from the pressure water turbidity to Common Eiders in the second winter of the tunnel construction (2015/2016; Common Eider spring distribution).

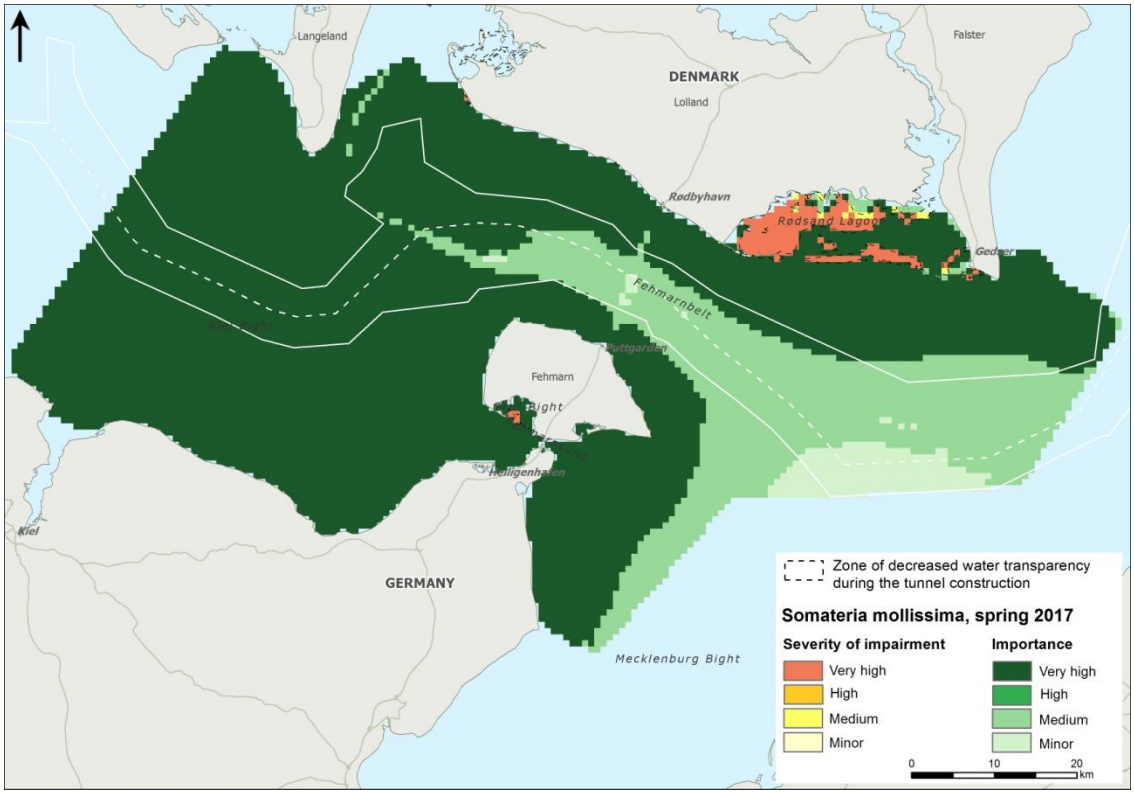

Figure A.19 Severity of impairment from the pressure water turbidity to Common Eiders in the third winter of the tunnel construction (2016/2017; Common Eider spring distribution).

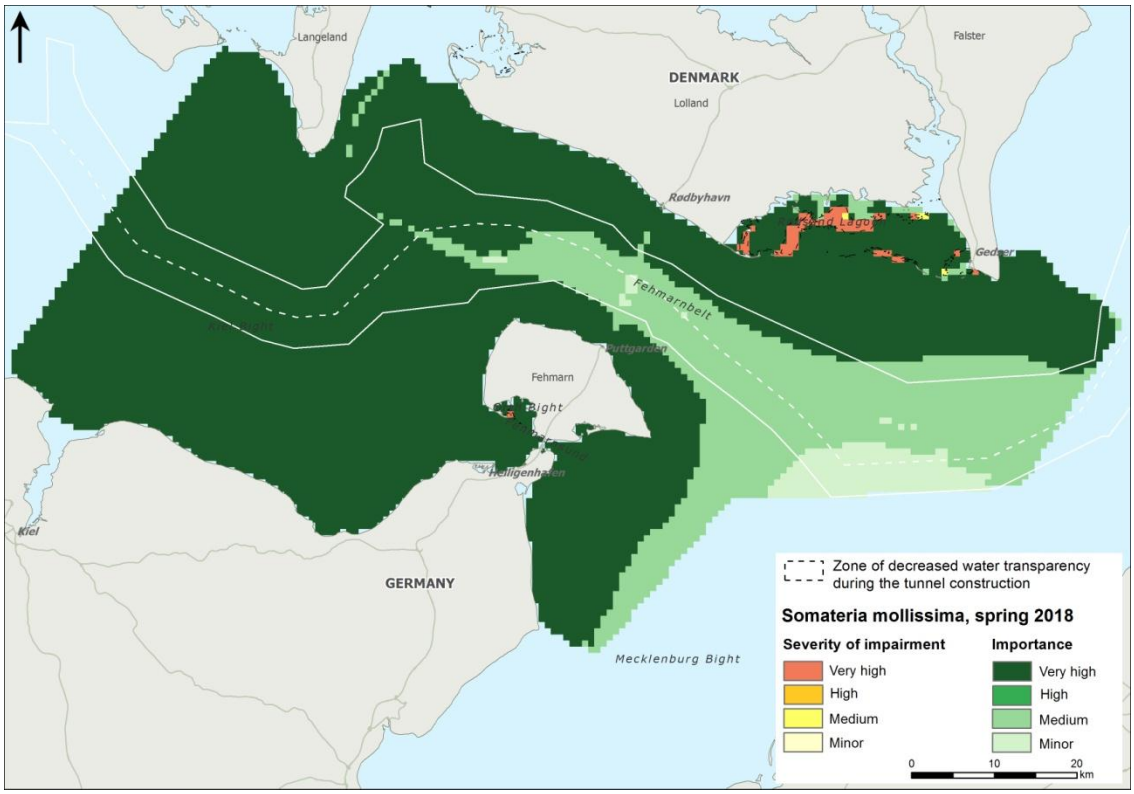

Figure A.20 Severity of impairment from the pressure water turbidity to Common Eiders in the fourth winter of the tunnel construction (2017/2018; Common Eider spring distribution).

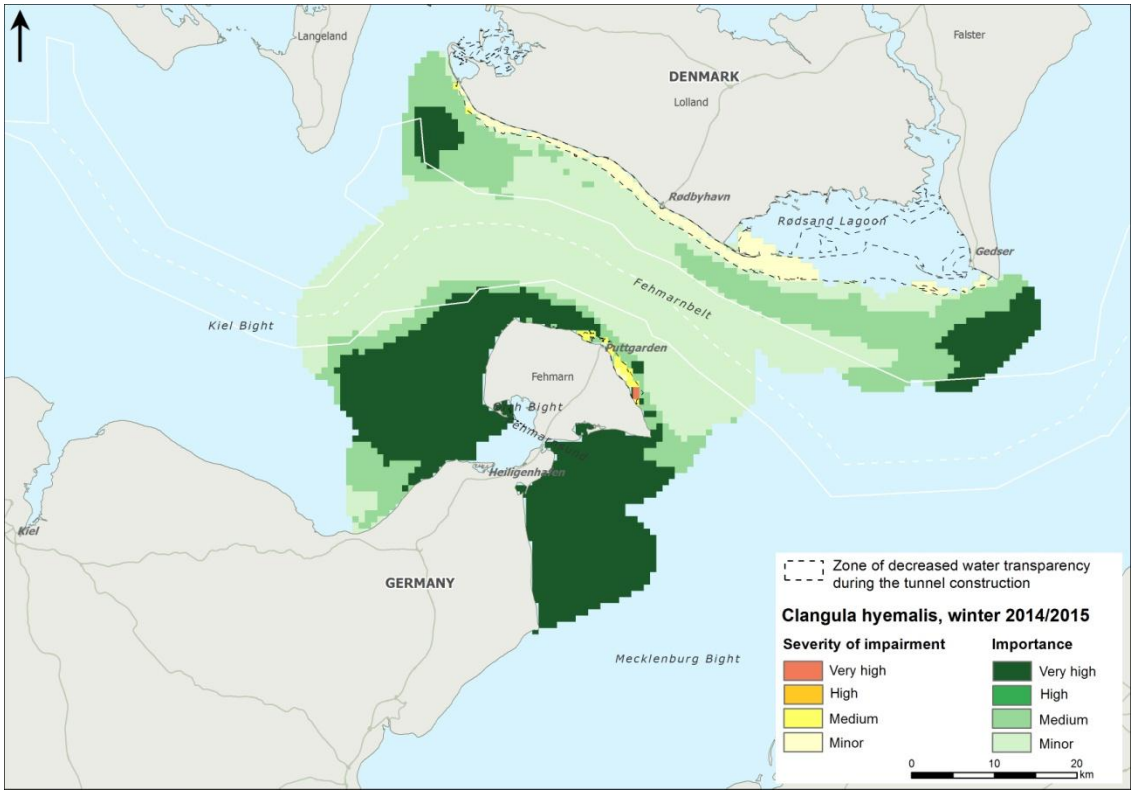

Figure A.21 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the first winter of the tunnel construction (2014/2015).

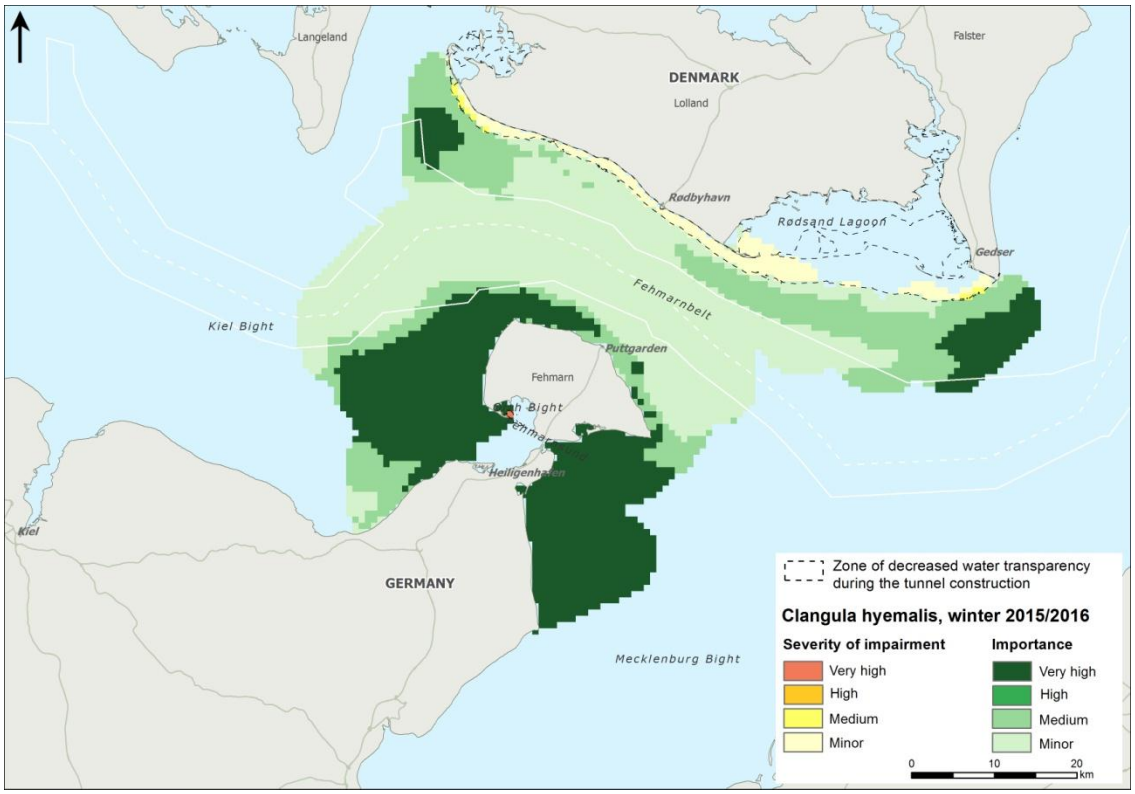

Figure A.22 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the second winter of the tunnel construction (2015/2016).

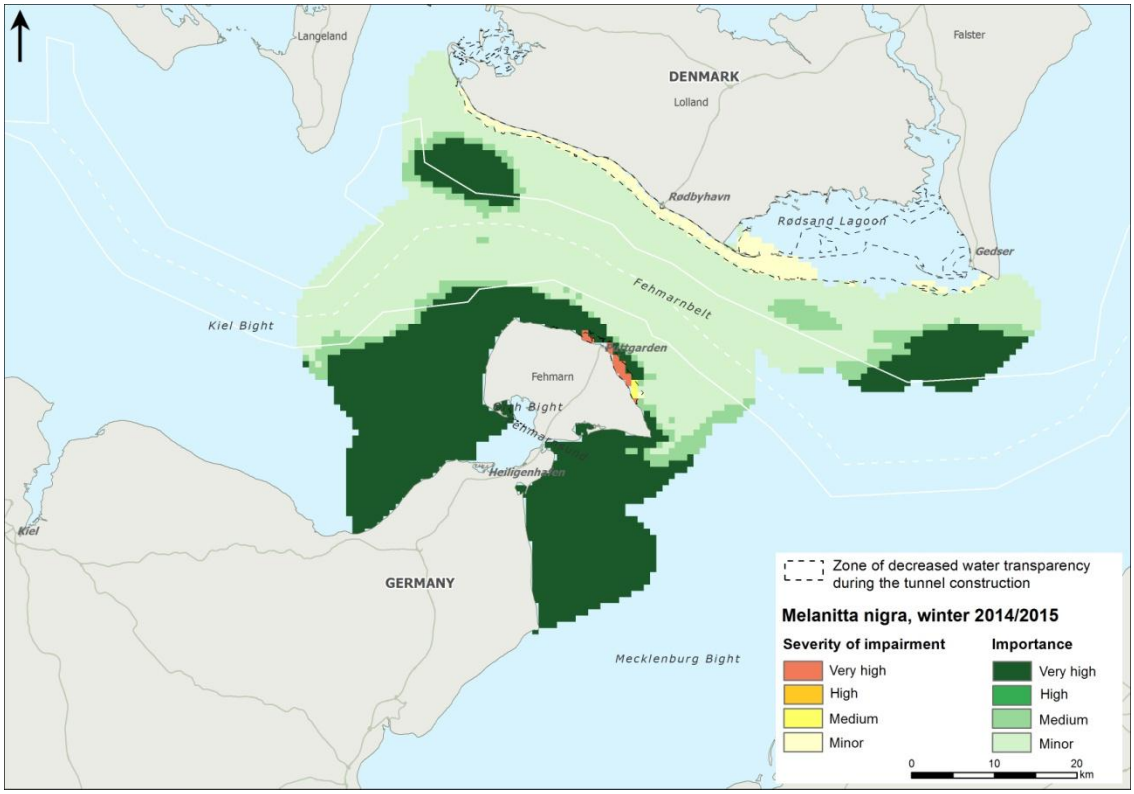

Figure A.23 Severity of impairment from the pressure water turbidity to Common Scoters in the first winter of the tunnel construction (2014/2015).

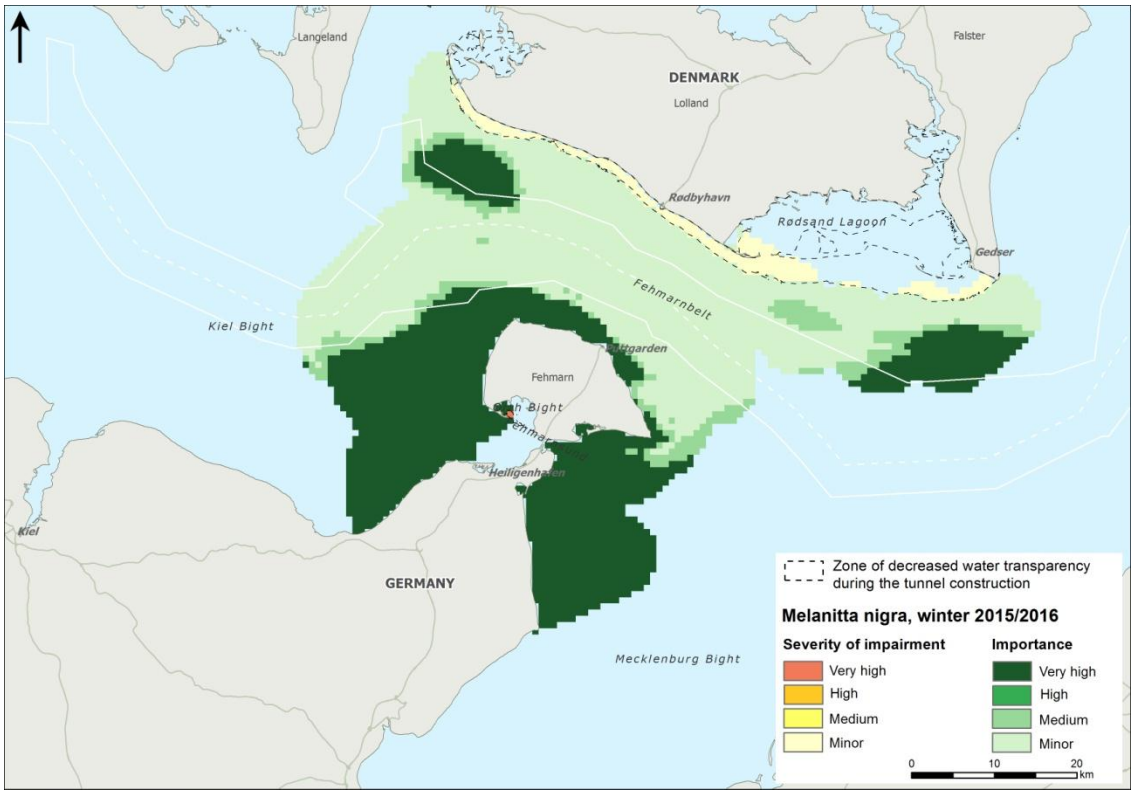

Figure A.24 Severity of impairment from the pressure water turbidity to Common Scoters in the second winter of the tunnel construction (2015/2016).

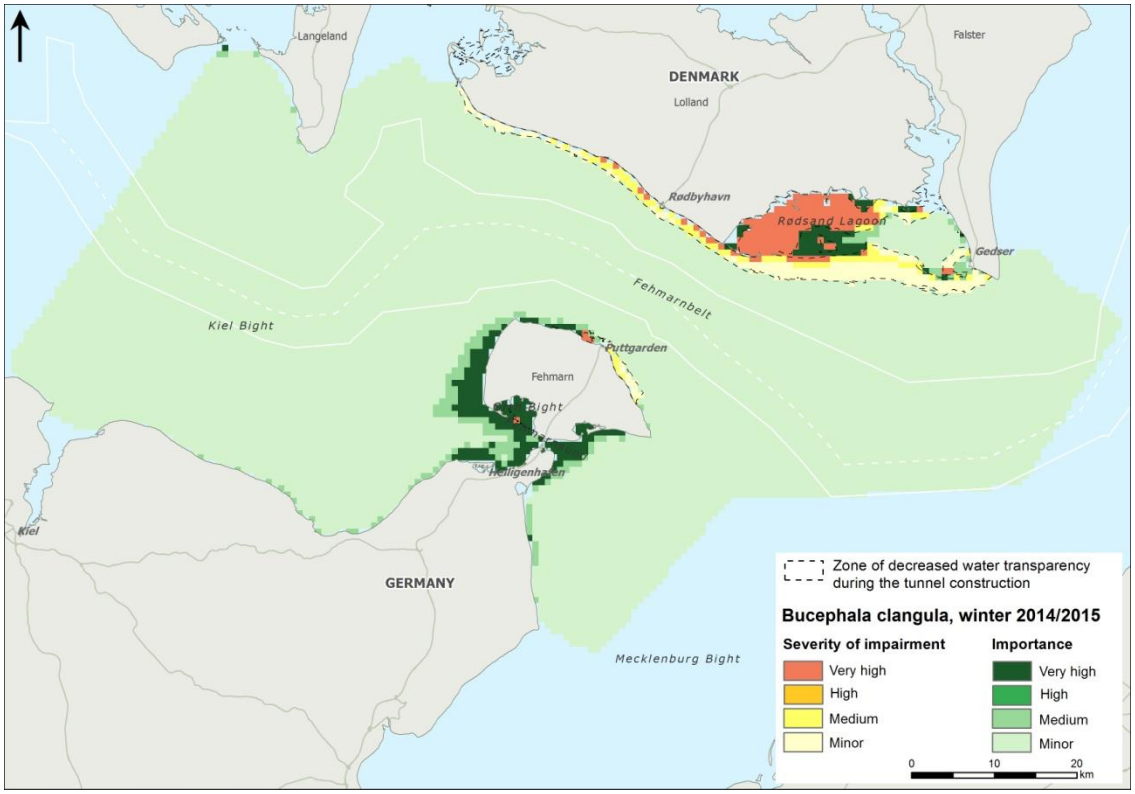

Figure A.25 Severity of impairment from the pressure water turbidity to Common Goldeneye in the first winter of the tunnel construction (2014/2015).

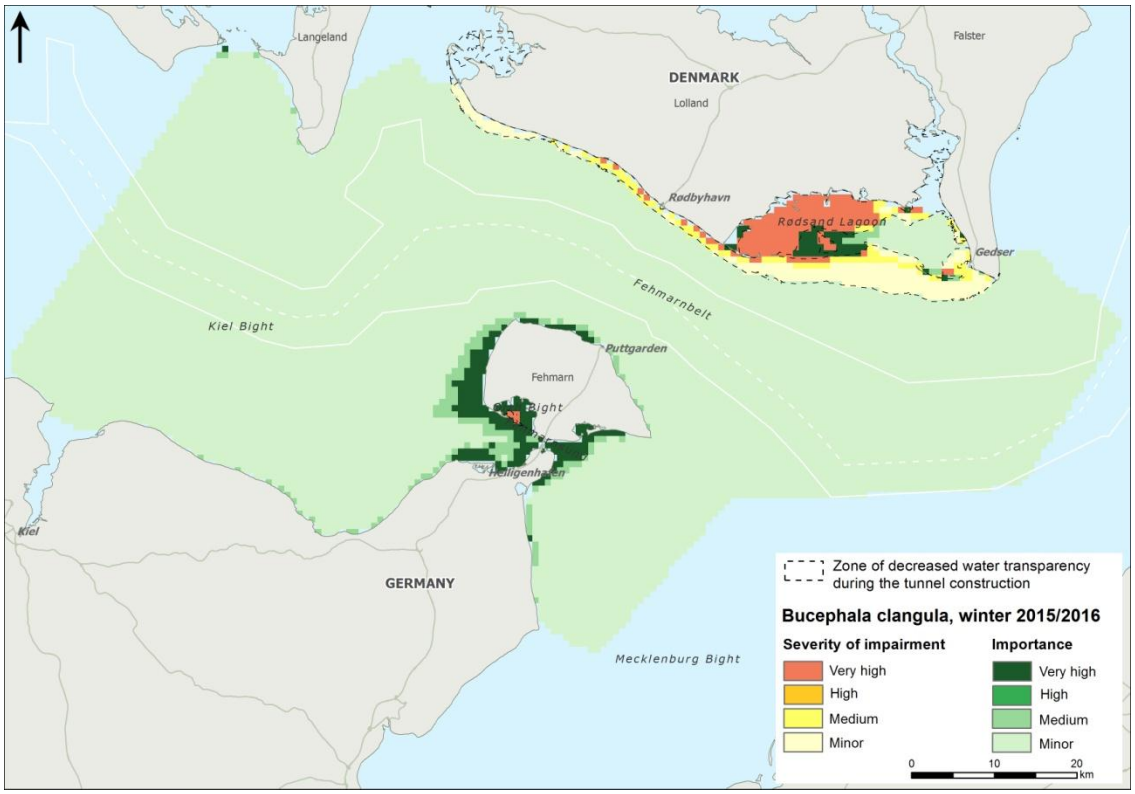

Figure A.26 Severity of impairment from the pressure water turbidity to Common Goldeneye in the second winter of the tunnel construction (2015/2016).

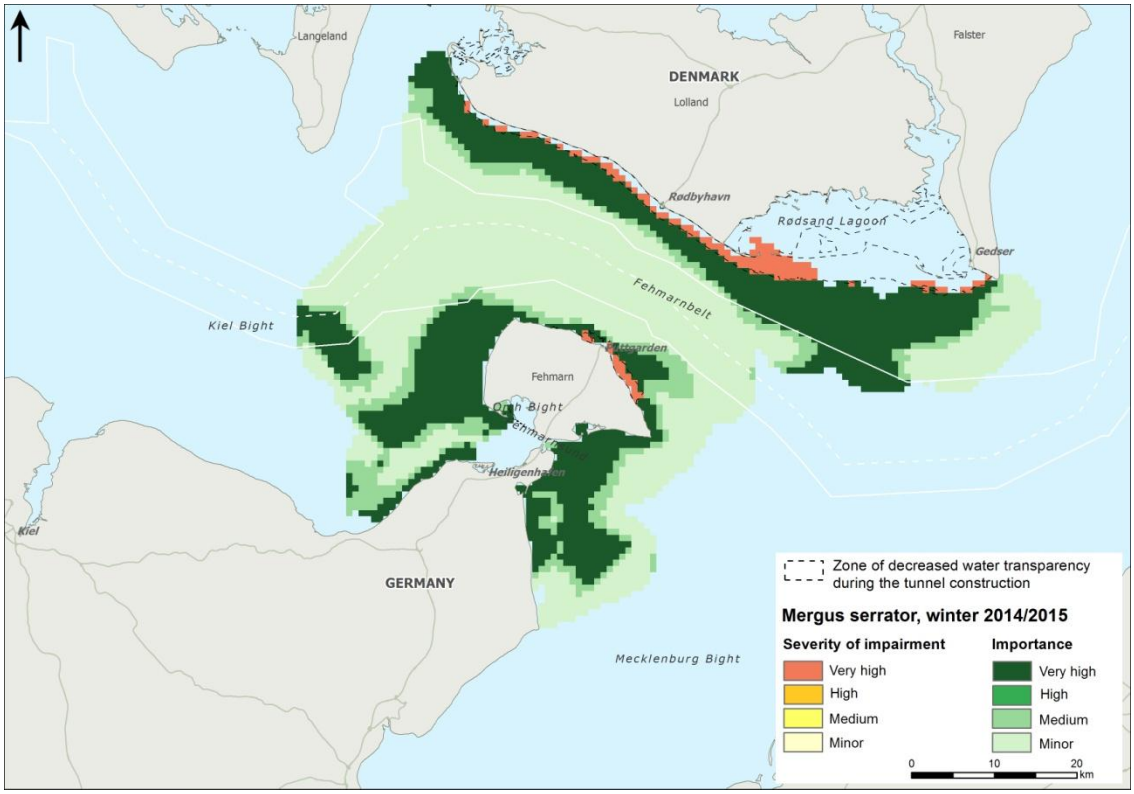

Figure A.27 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the first winter of the tunnel construction (2014/2015).

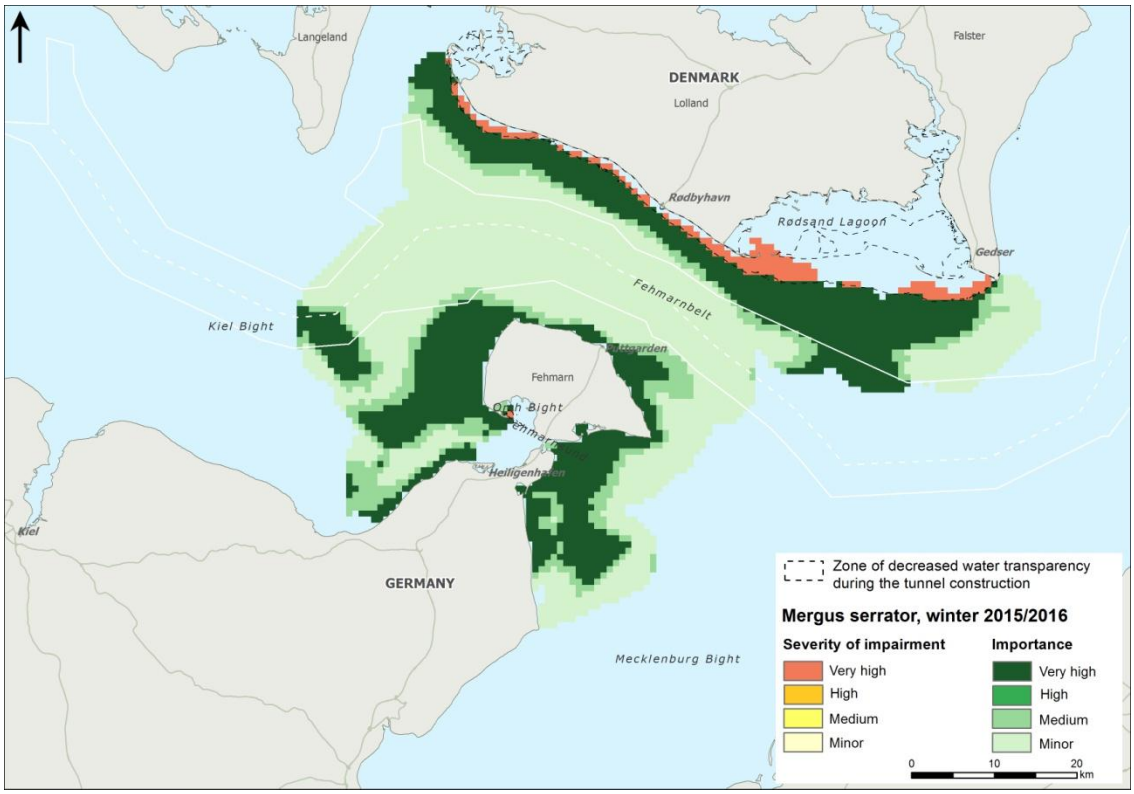

Figure A.28 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the second winter of the tunnel construction (2015/2016).

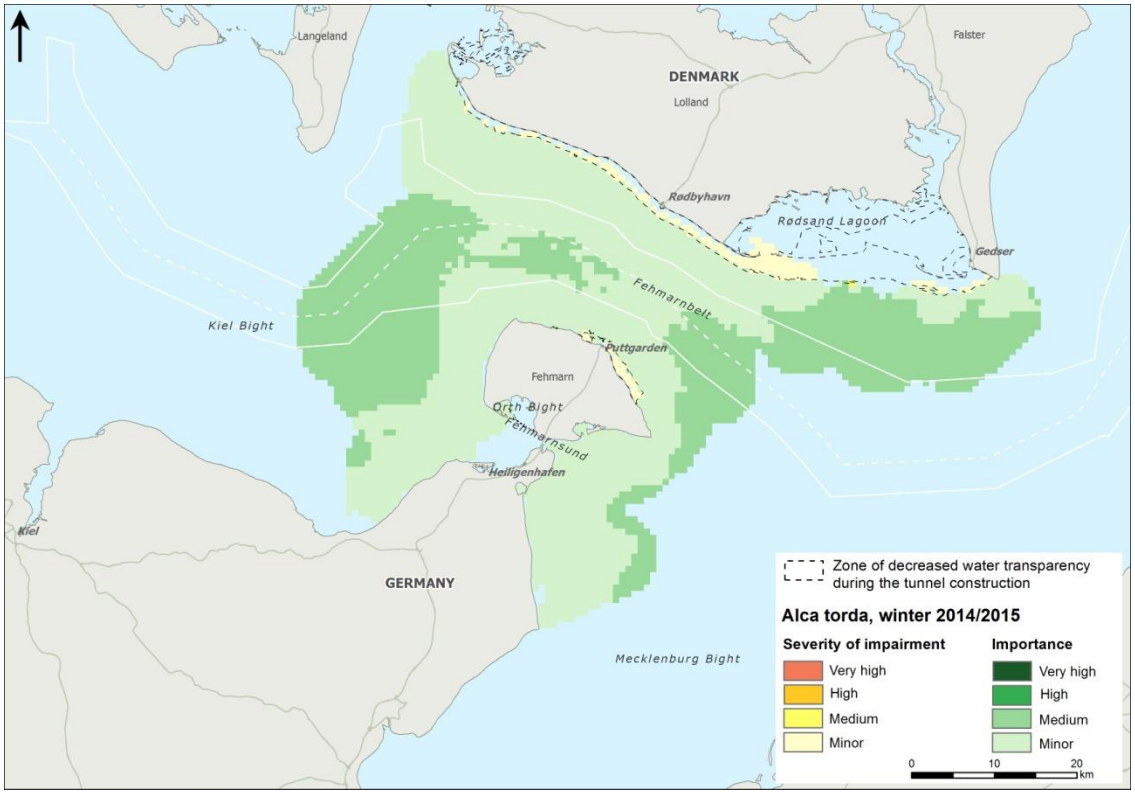

Figure A.29 Severity of impairment from the pressure water turbidity to Razorbills in the first winter of the tunnel construction (2014/2015).

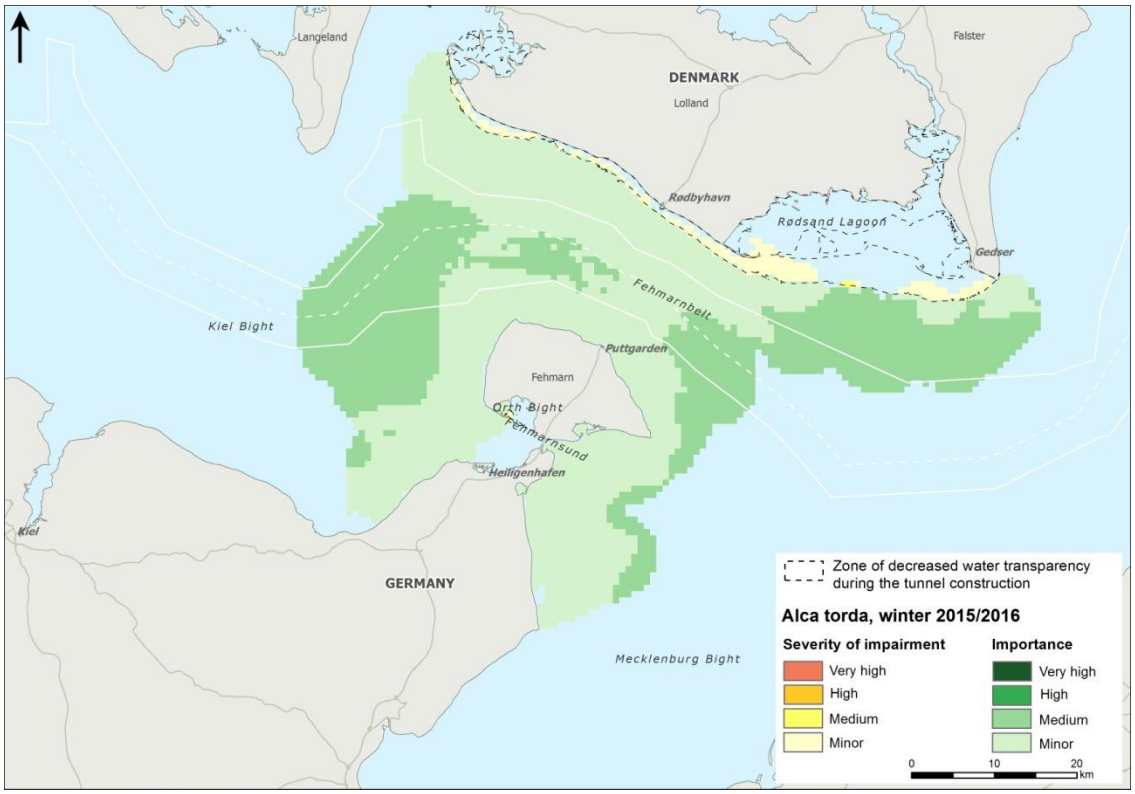

Figure A.30 Severity of impairment from the pressure water turbidity to Razorbills in the second winter of the tunnel construction (2015/2016).

A.1.4 Disturbance from construction vessels

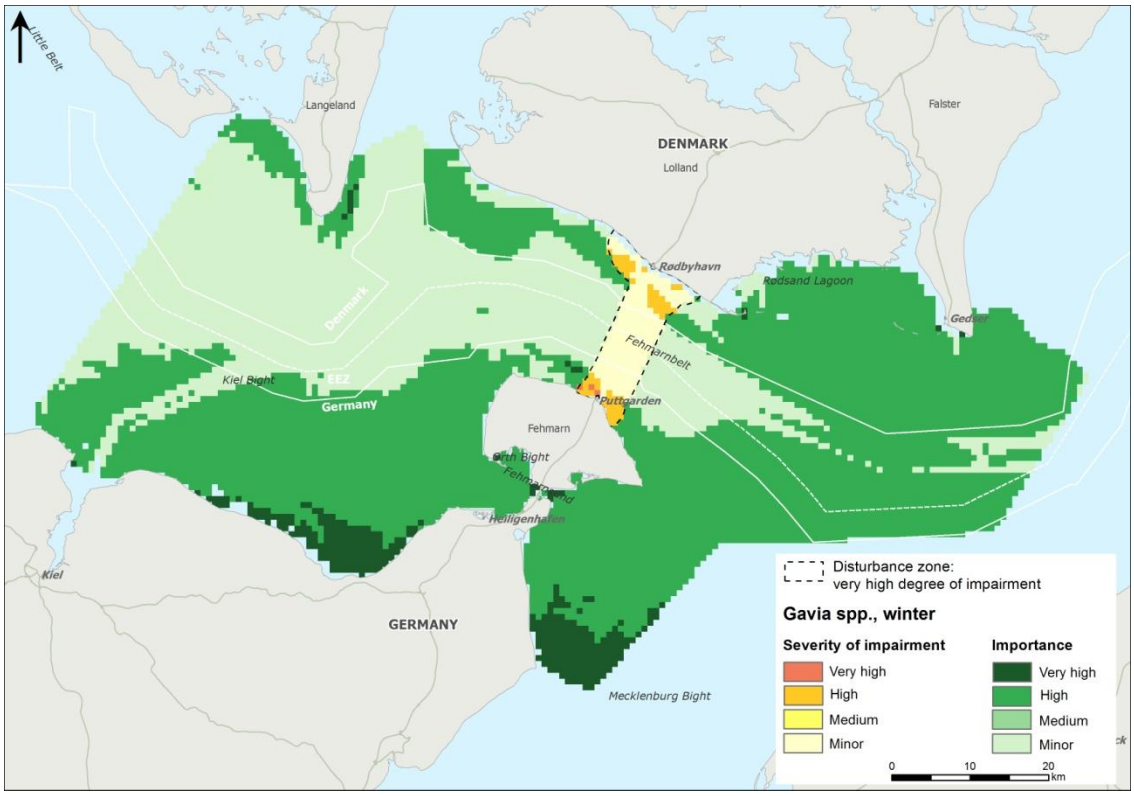

Figure A.31 Severity of impairment from the pressure disturbance from construction vessels to divers (Red-throated and Black-throated Diver) during the tunnel construction period (diver winter distribution).

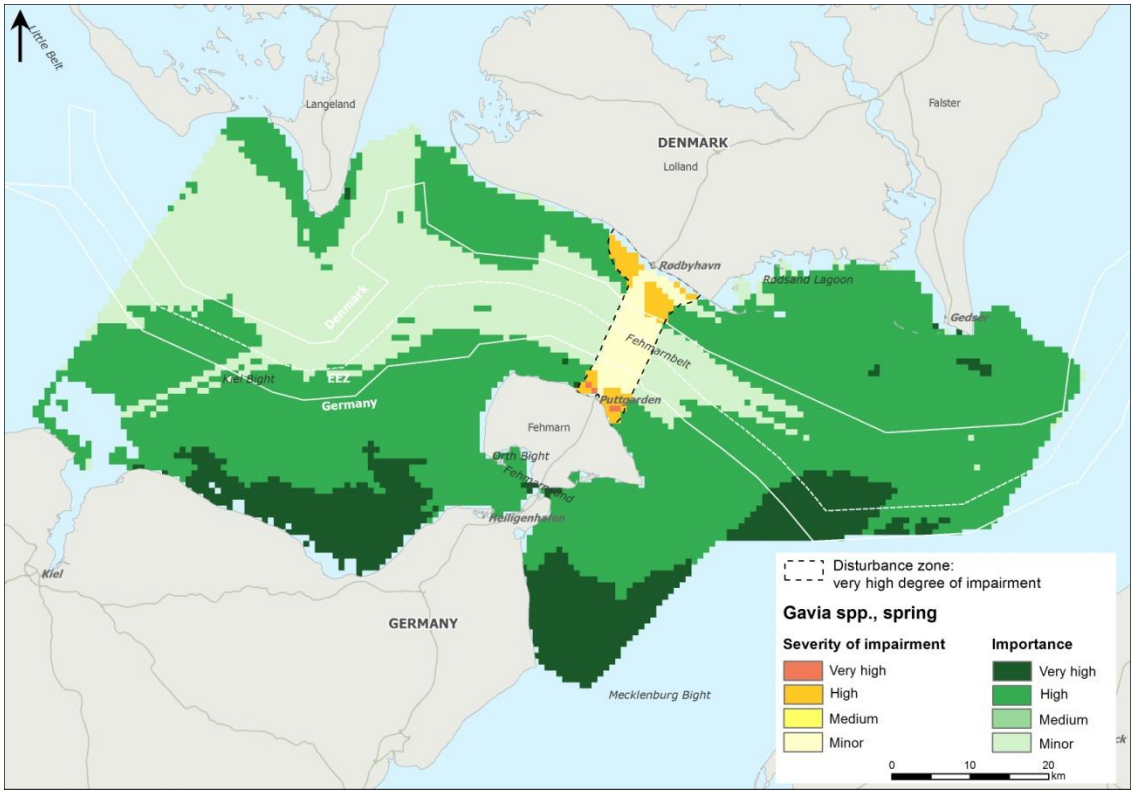

Figure A.32 Severity of impairment from the pressure disturbance from construction vessels to divers (Red-throated and Black-throated Diver) during the tunnel construction period (diver spring distribution).

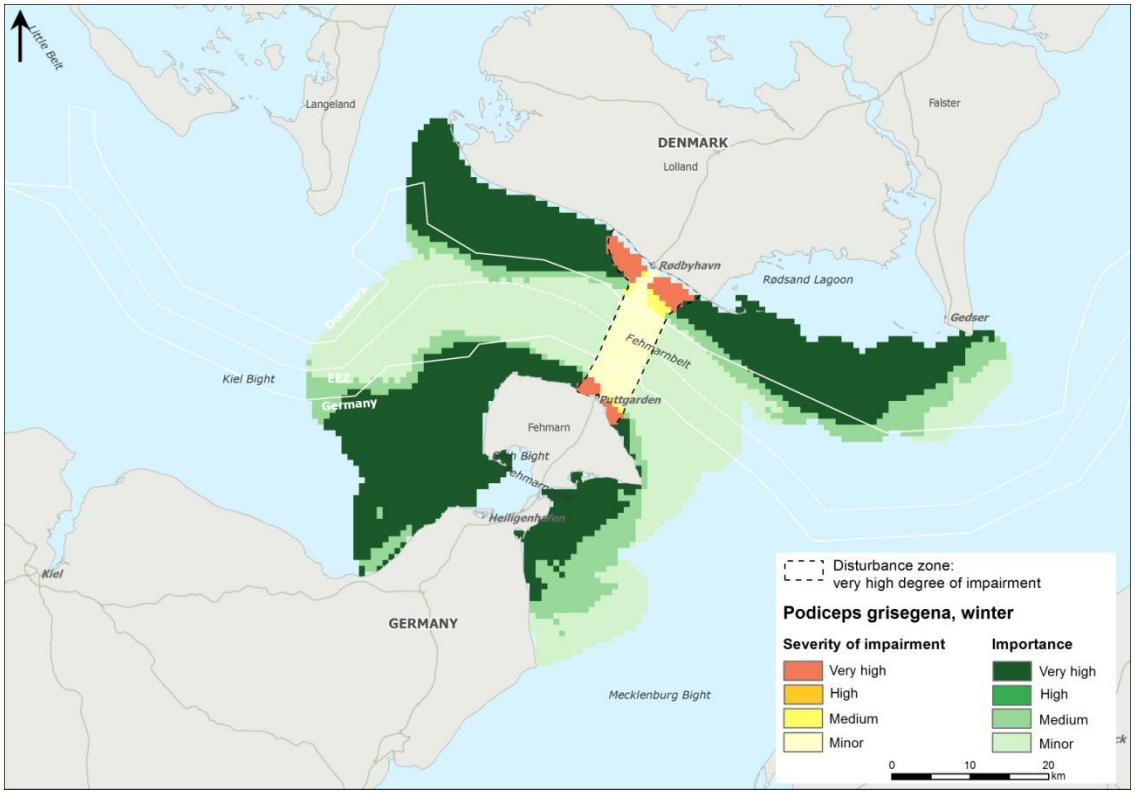

Figure A.33 Severity of impairment from the pressure disturbance from construction vessels to Red-necked Grebes during the tunnel construction period.

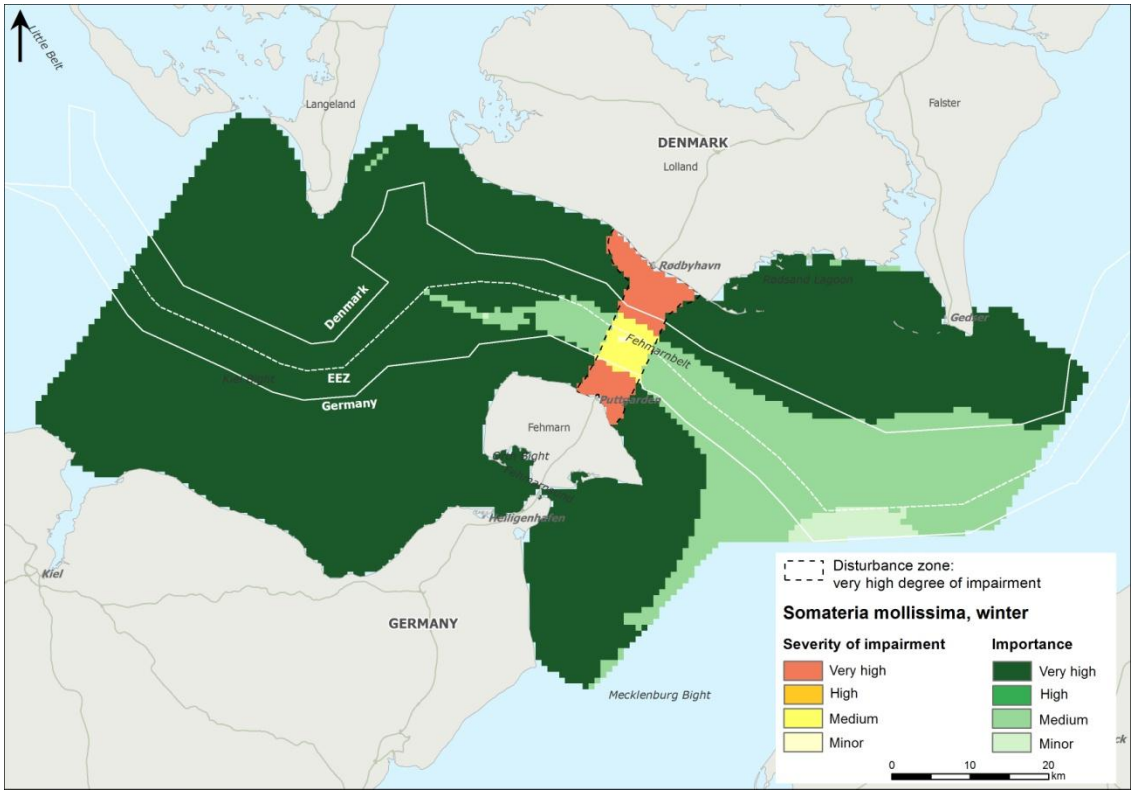

Figure A.34 Severity of impairment from the pressure disturbance from construction vessels to Common Eiders during the tunnel construction period (Common Eider winter distribution).

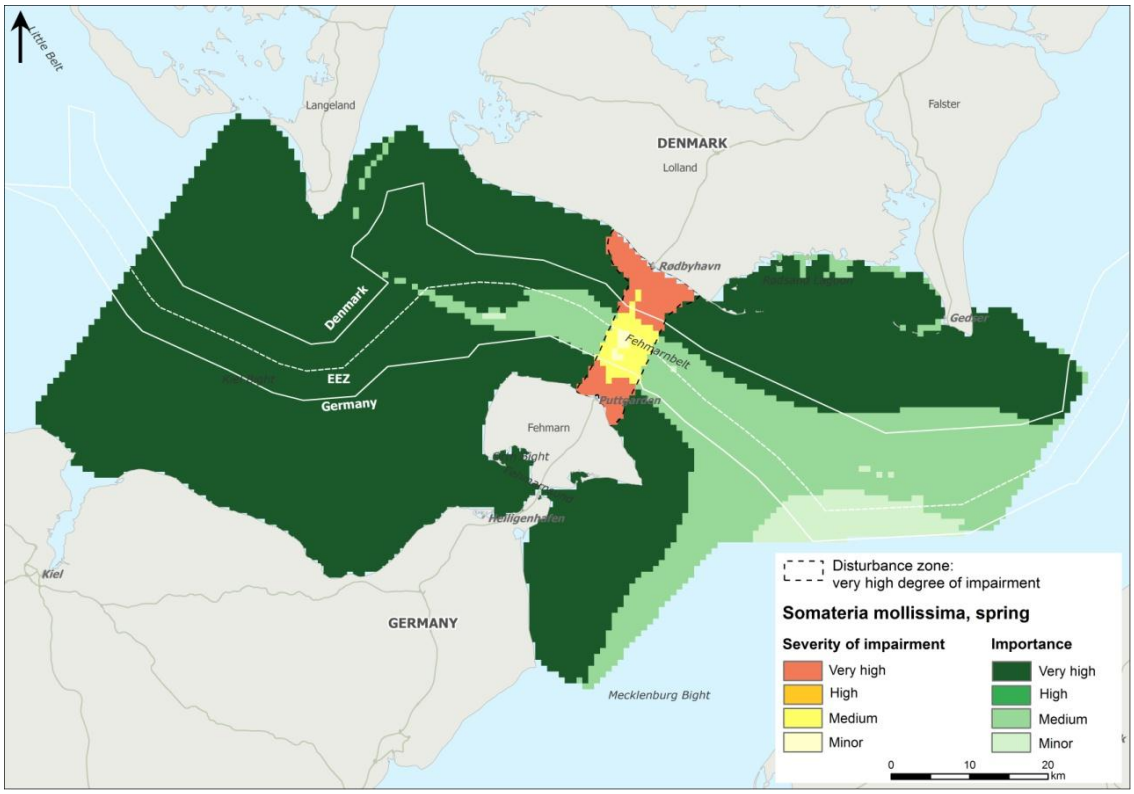

Figure A.35 Severity of impairment from the pressure disturbance from construction vessels to Common Eiders during the tunnel construction period (Common Eider spring distribution).

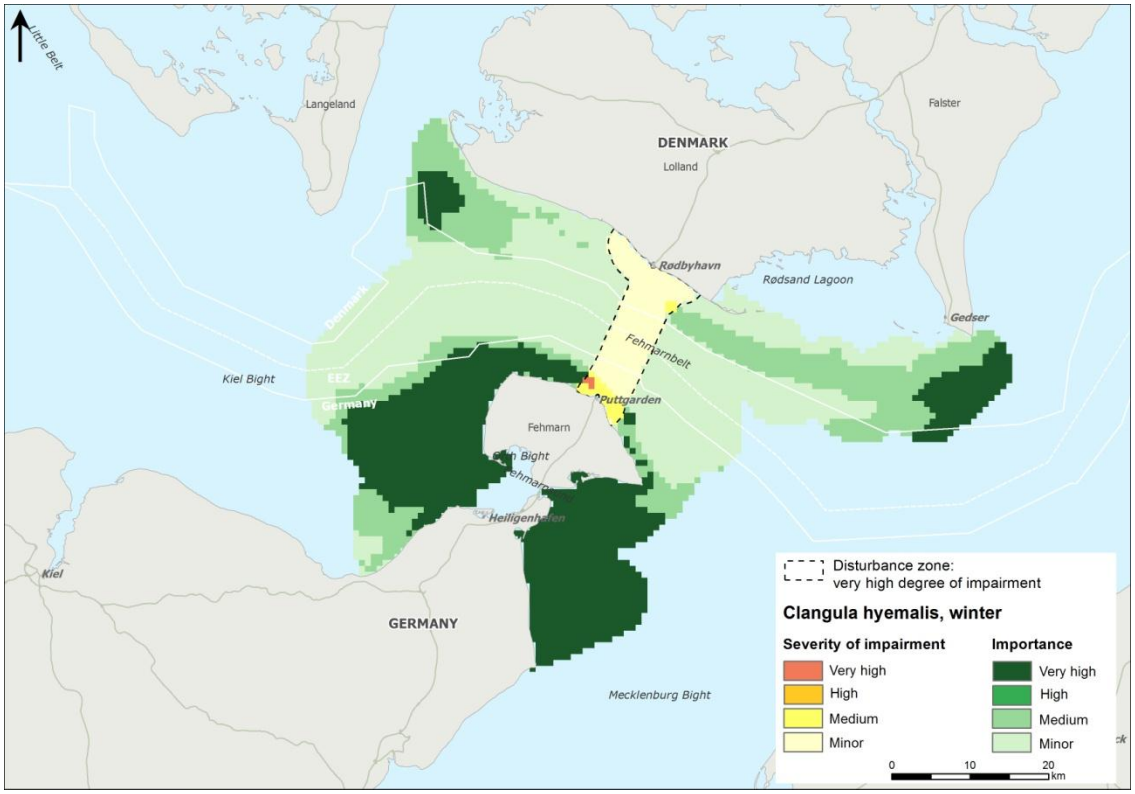

Figure A.36 Severity of impairment from the pressure disturbance from construction vessels to Long-tailed Ducks during the tunnel construction period.

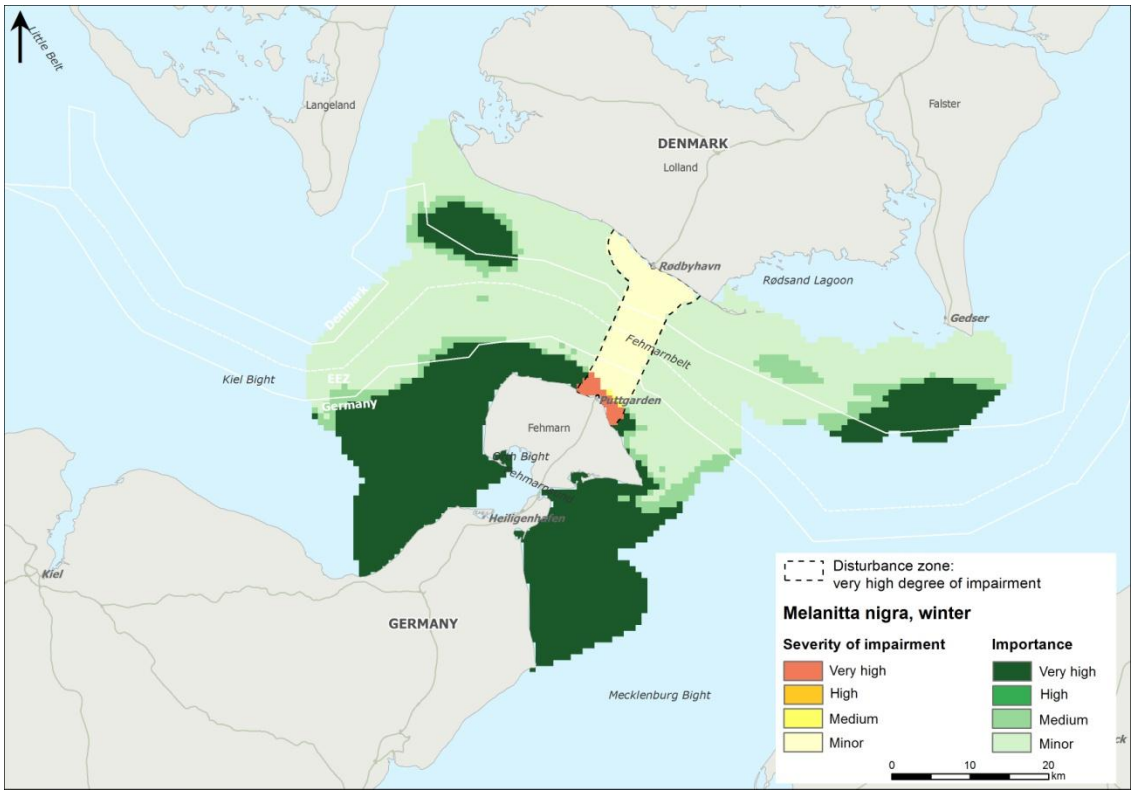

Figure A.37 Severity of impairment from the pressure disturbance from construction vessels to Common Scoters during the tunnel construction period.

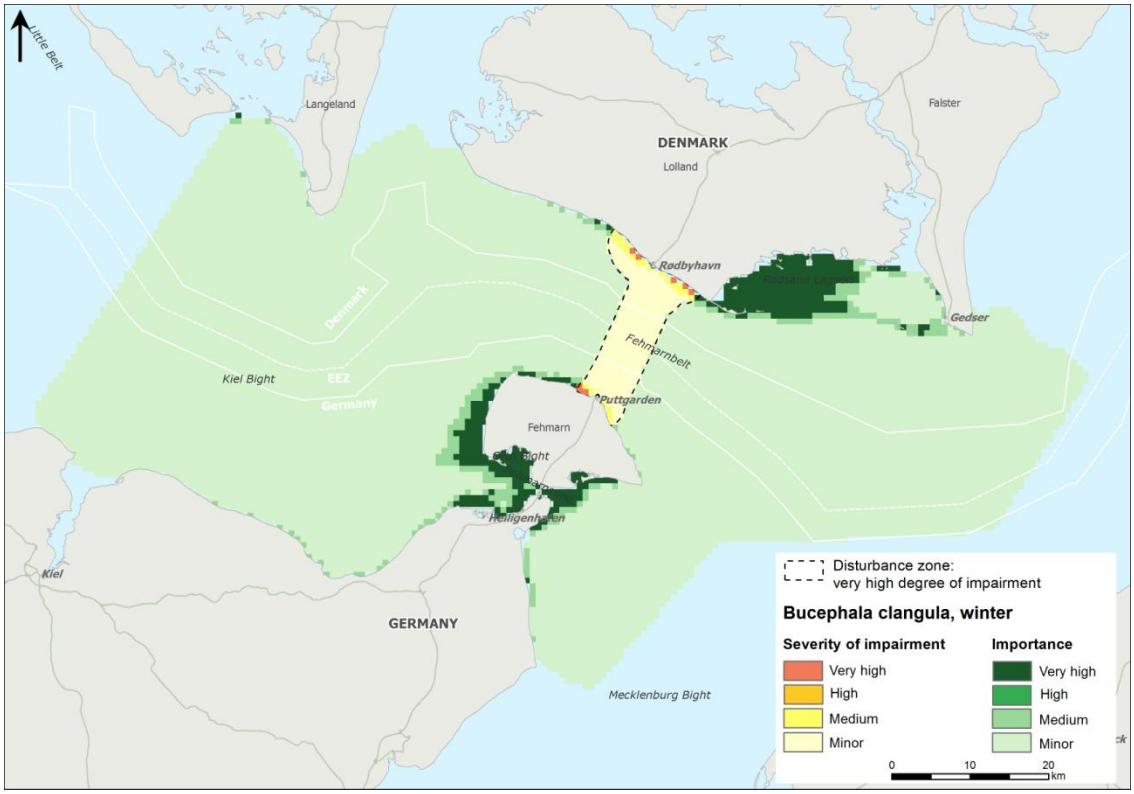

Figure A.38 Severity of impairment from the pressure disturbance from construction vessels to Common Goldeneye during the tunnel construction period.

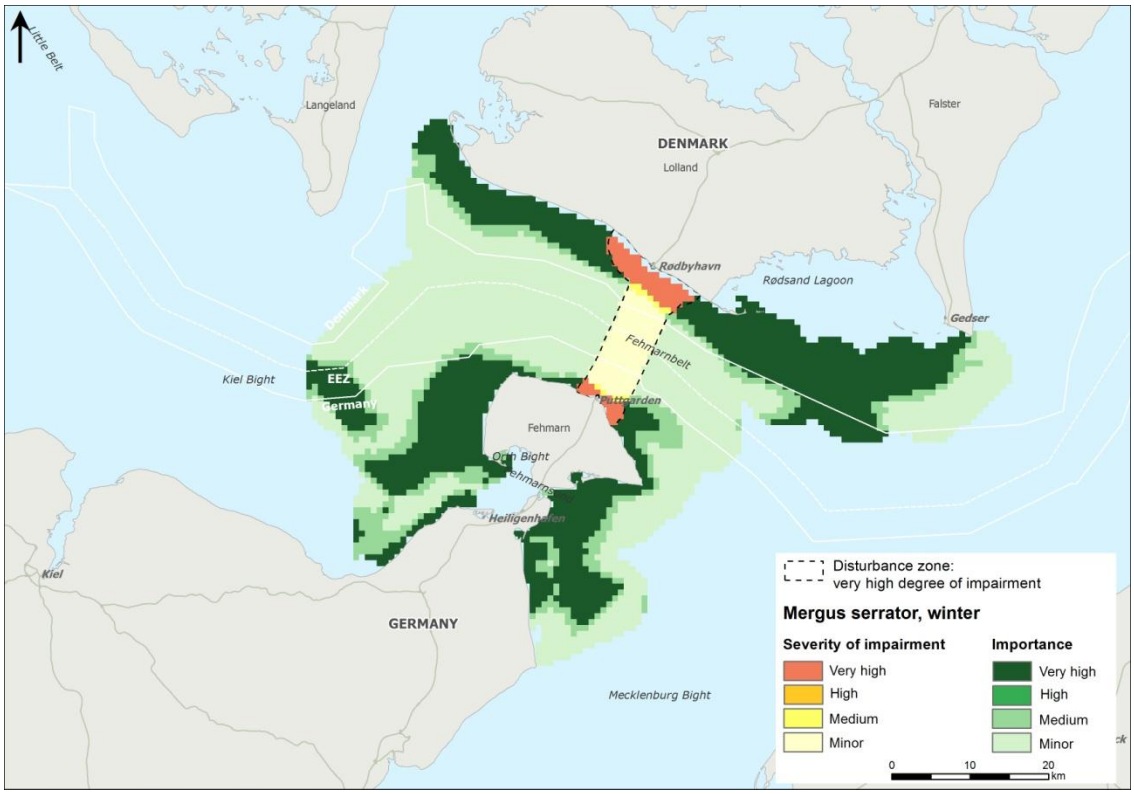

Figure A.39 Severity of impairment from the pressure disturbance from construction vessels to Red-breasted Merganser during the tunnel construction period.

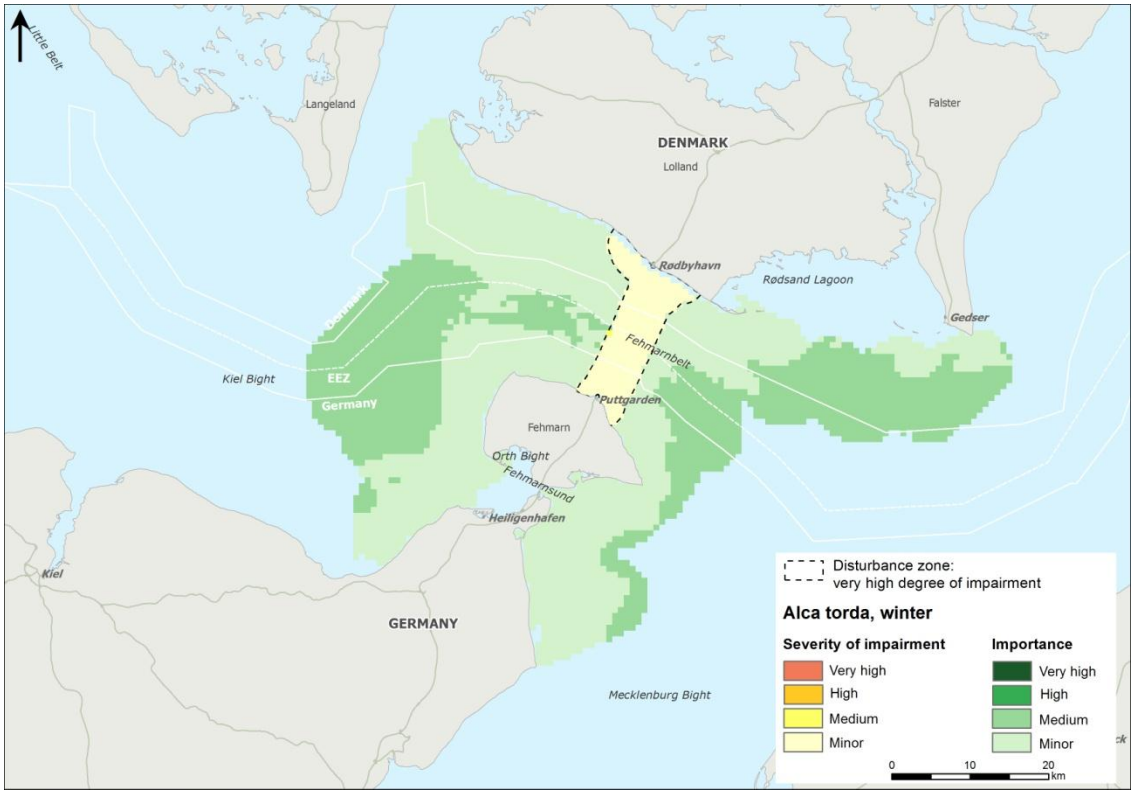

Figure A.40 Severity of impairment from the pressure disturbance from construction vessels to Razorbills during the tunnel construction period.

A.2 Cable stayed bridge

A.2.1 Habitat loss from footprint

The habitat loss from the bridge footprint affects a relatively small area which is predicted to result in minor severity of loss to all non-breeding waterbirds.

A.2.2 Habitat change from sediment spill

Indirect impacts from sediment spill (habitat changes) are predicted to result in minor severity of impairment to all non-breeding waterbirds.

A.2.3 Water turbidity

Direct impacts from sediment spill (increased water turbidity) are presented for the first winter of the bridge construction period (2014/15), the year with the highest predicted impact.

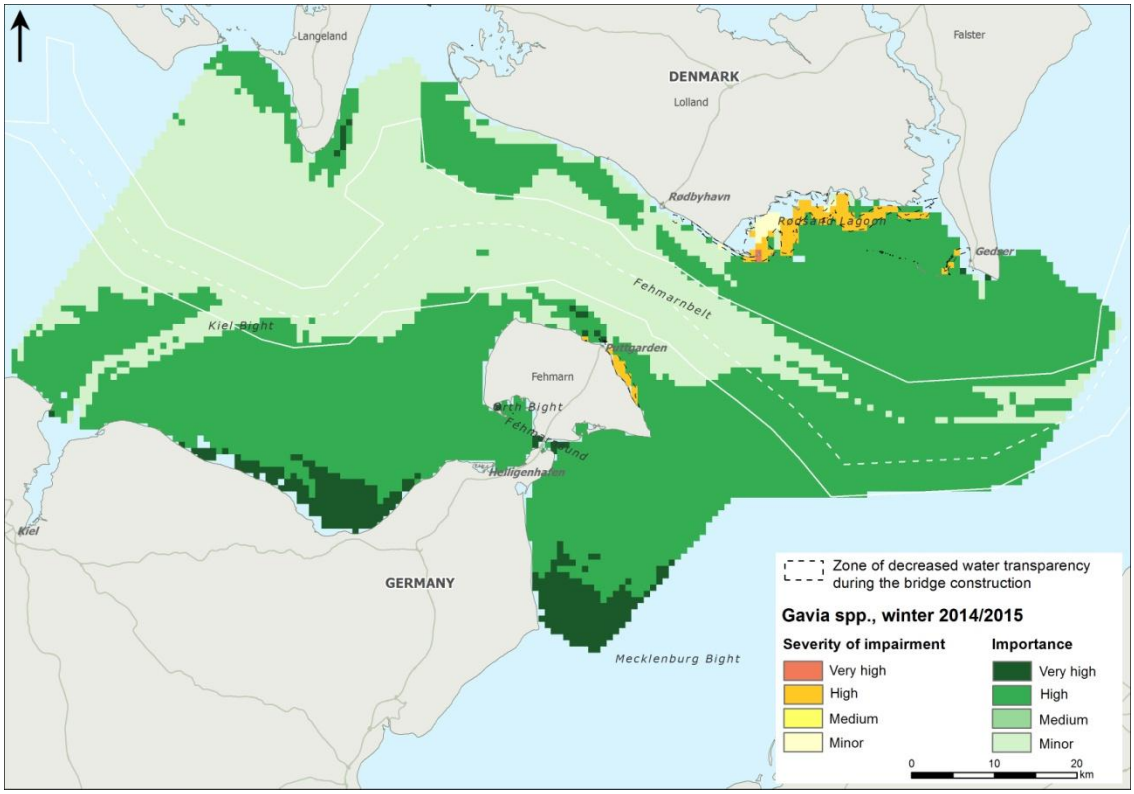

Figure A.41 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the bridge construction (2014/2015; diver winter distribution).

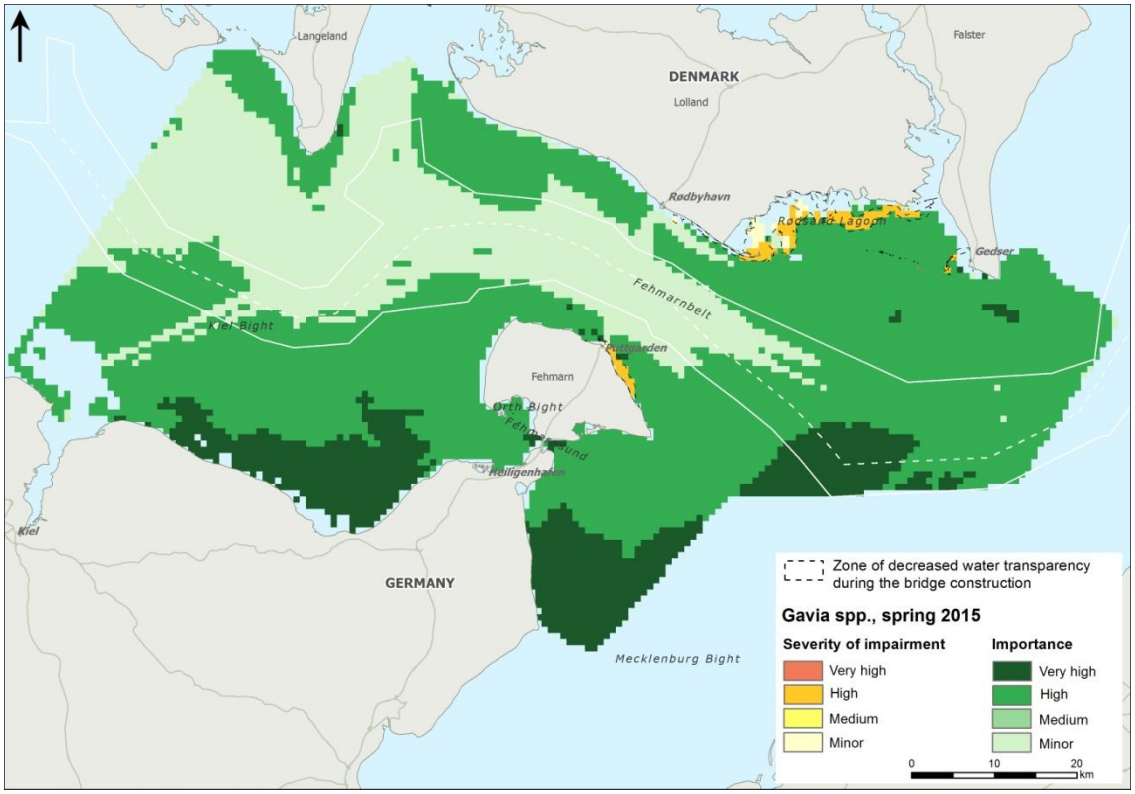

Figure A.42 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the bridge construction (2014/2015; diver spring distribution).

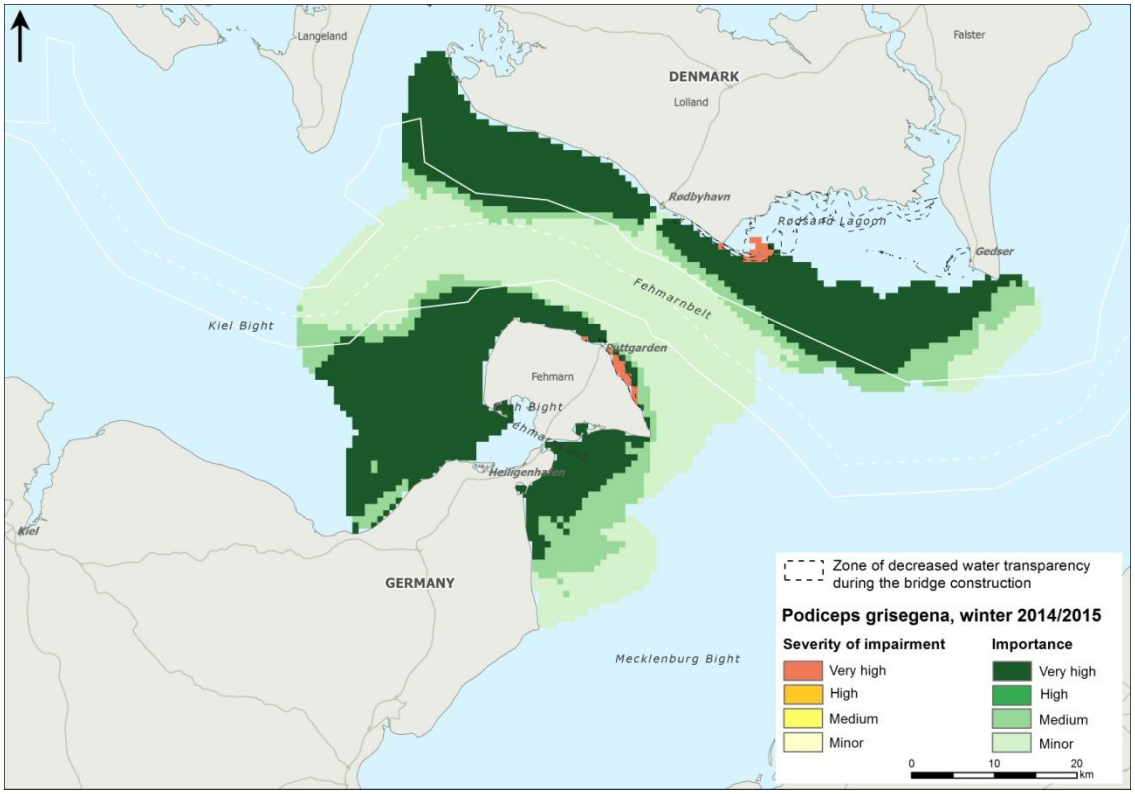

Figure A.43 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the first winter of the bridge construction (2014/2015).

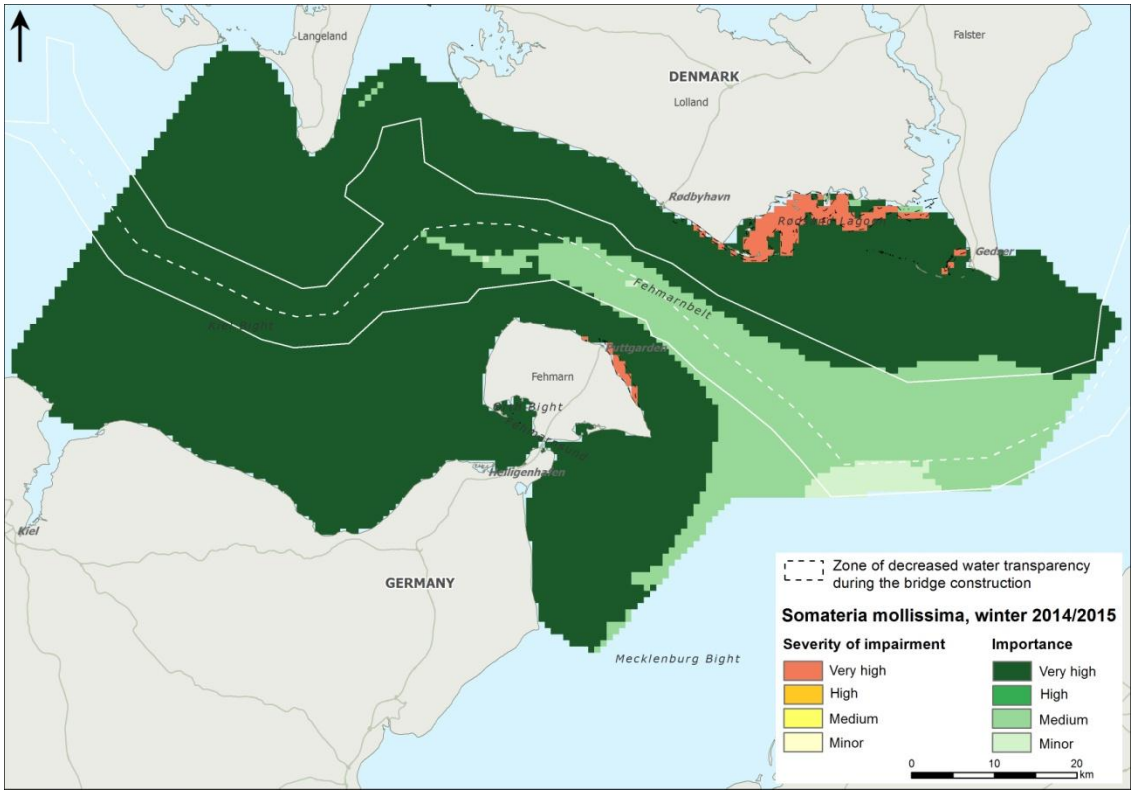

Figure A.44 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the bridge construction (2014/2015; Common Eider winter distribution).

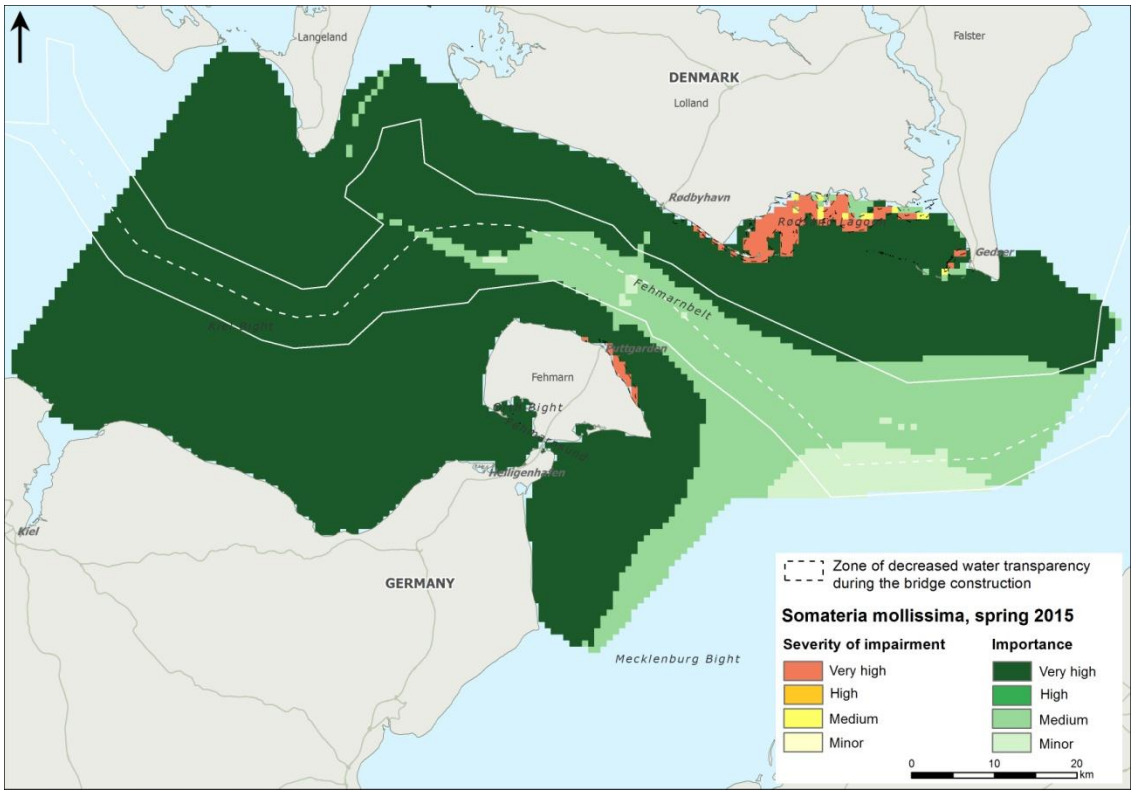

Figure A.45 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the bridge construction (2014/2015; Common Eider spring distribution).

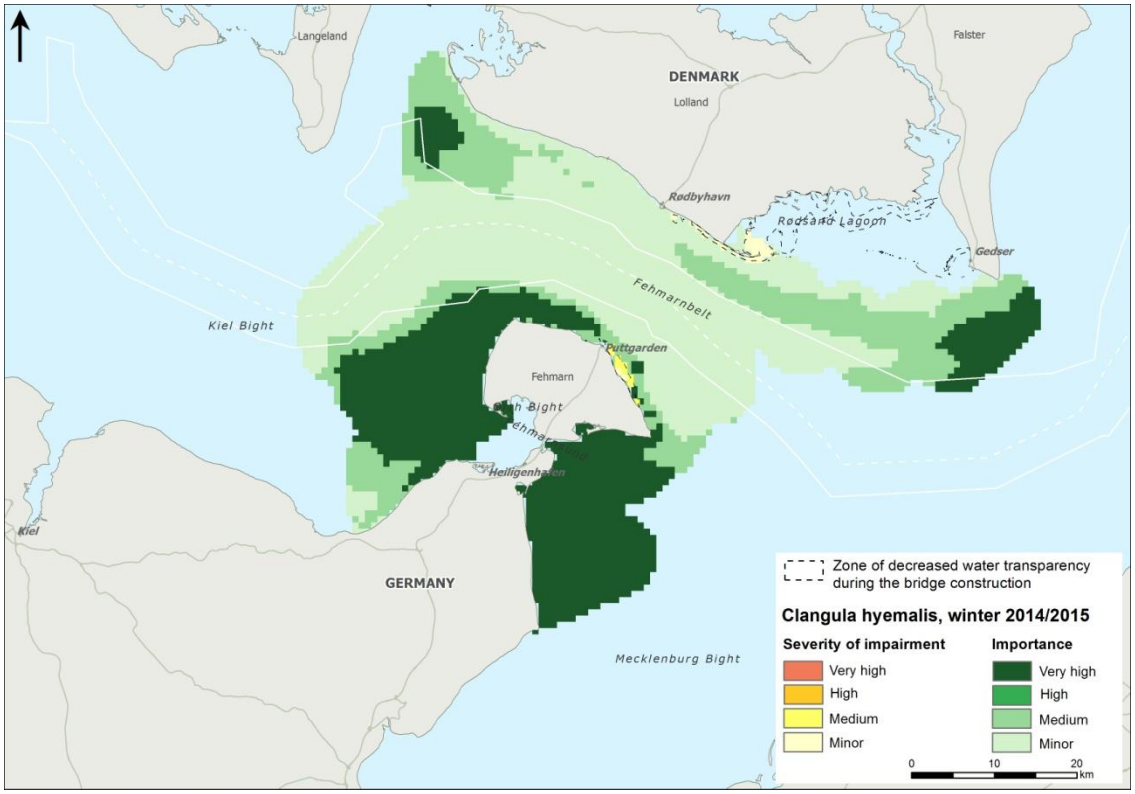

Figure A.46 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the first winter of the bridge construction (2014/2015).

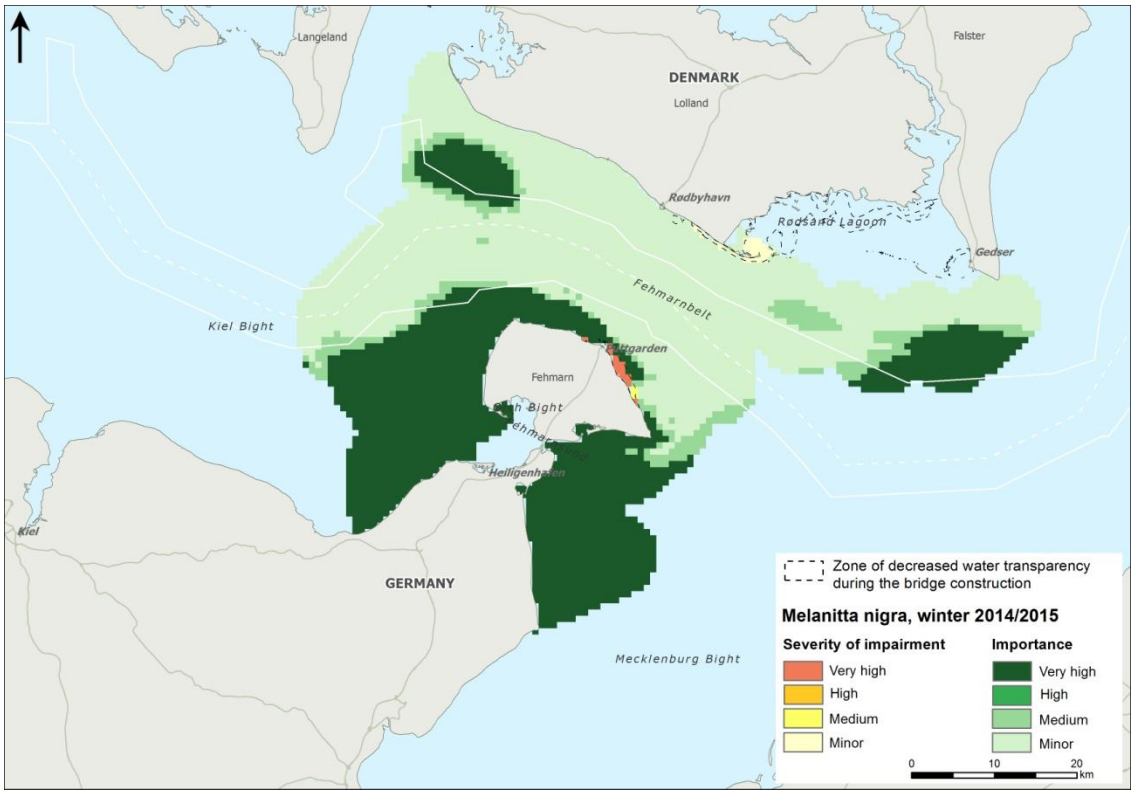

Figure A.47 Severity of impairment from the pressure water turbidity to Common Scoters in the first winter of the bridge construction (2014/2015).

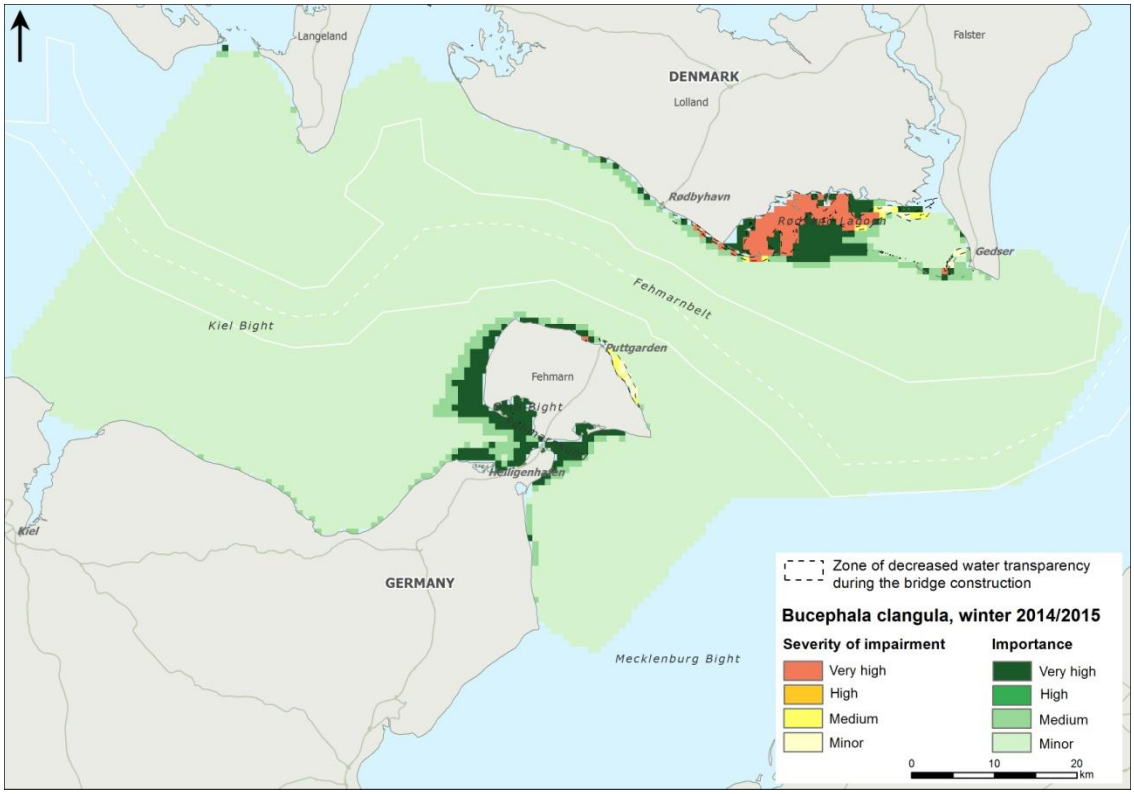

Figure A.48 Severity of impairment from the pressure water turbidity to Common Goldeneye in the first winter of the bridge construction (2014/2015).

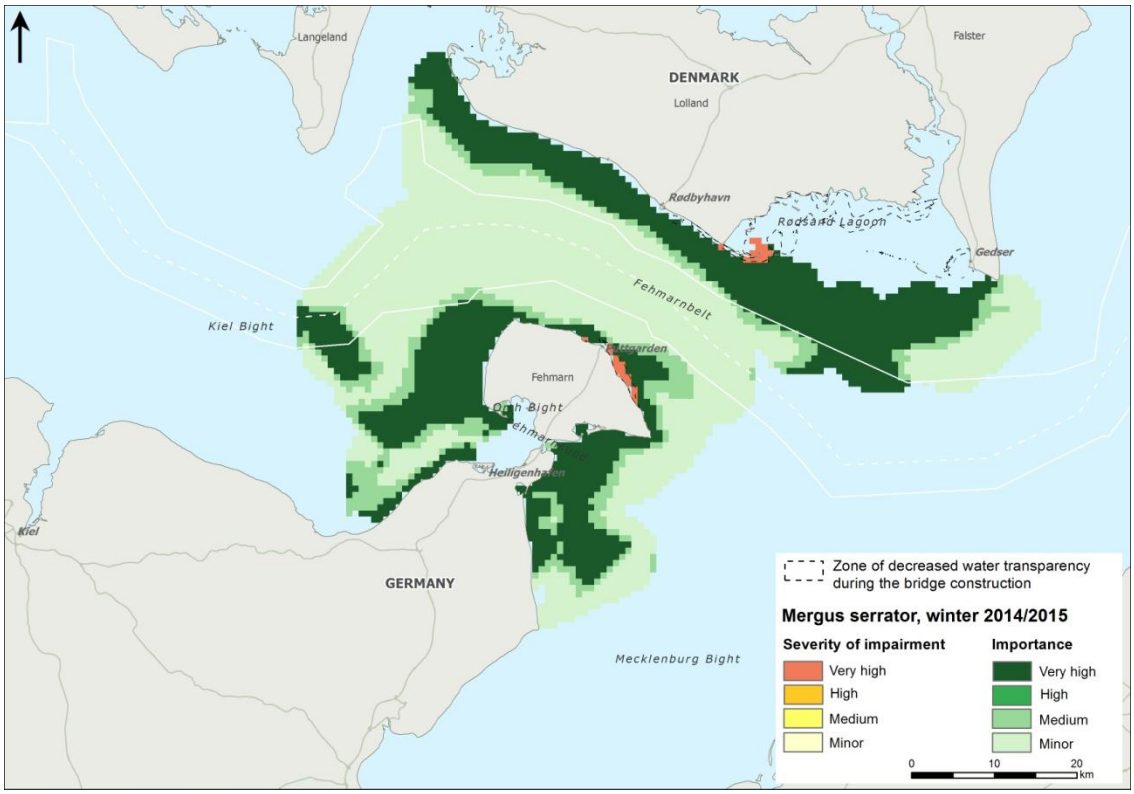

Figure A.49 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the first winter of the bridge construction (2014/2015).

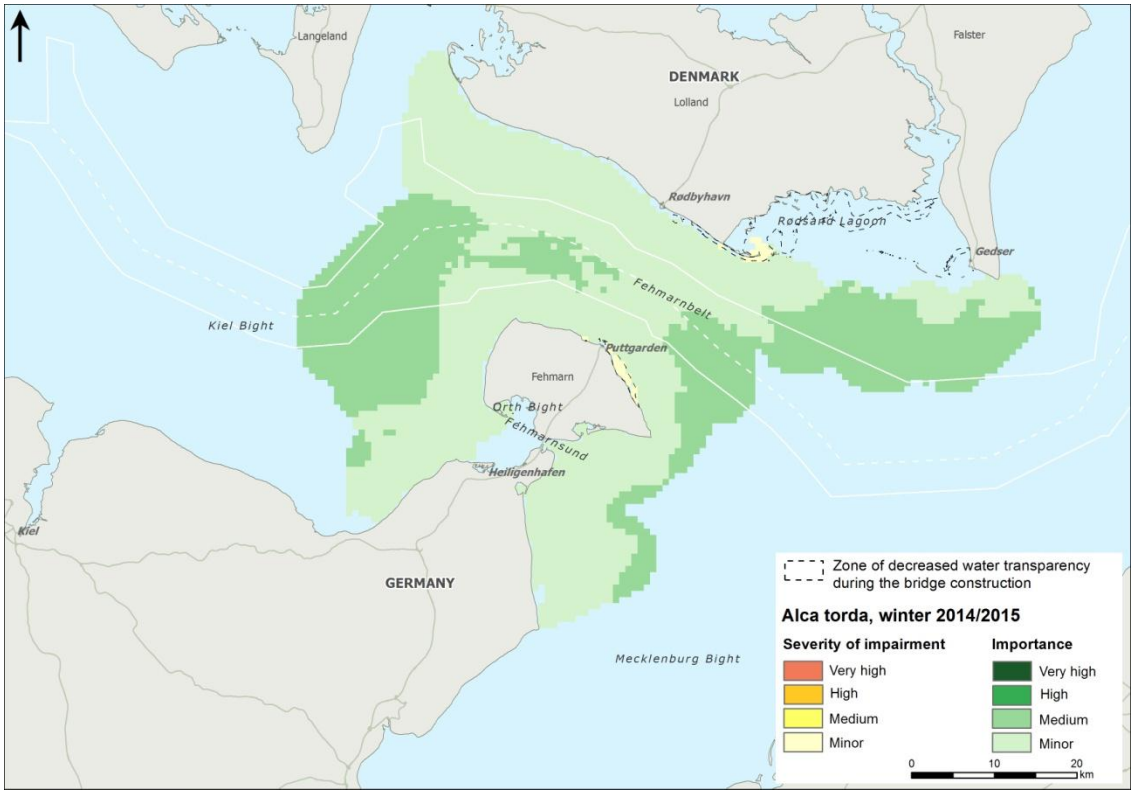

Figure A.50 Severity of impairment from the pressure water turbidity to Razorbills in the first winter of the bridge construction (2014/2015).

A.2.4 Disturbance from construction vessels

The predicted impact zone (disturbance zone) from construction vessels during the bridge construction affects a similar (but smaller) area compared to the disturbance zone predicted for the tunnel alternative (see maps in chapter A.1.4). Therefore, no species specific impact maps are shown for this.

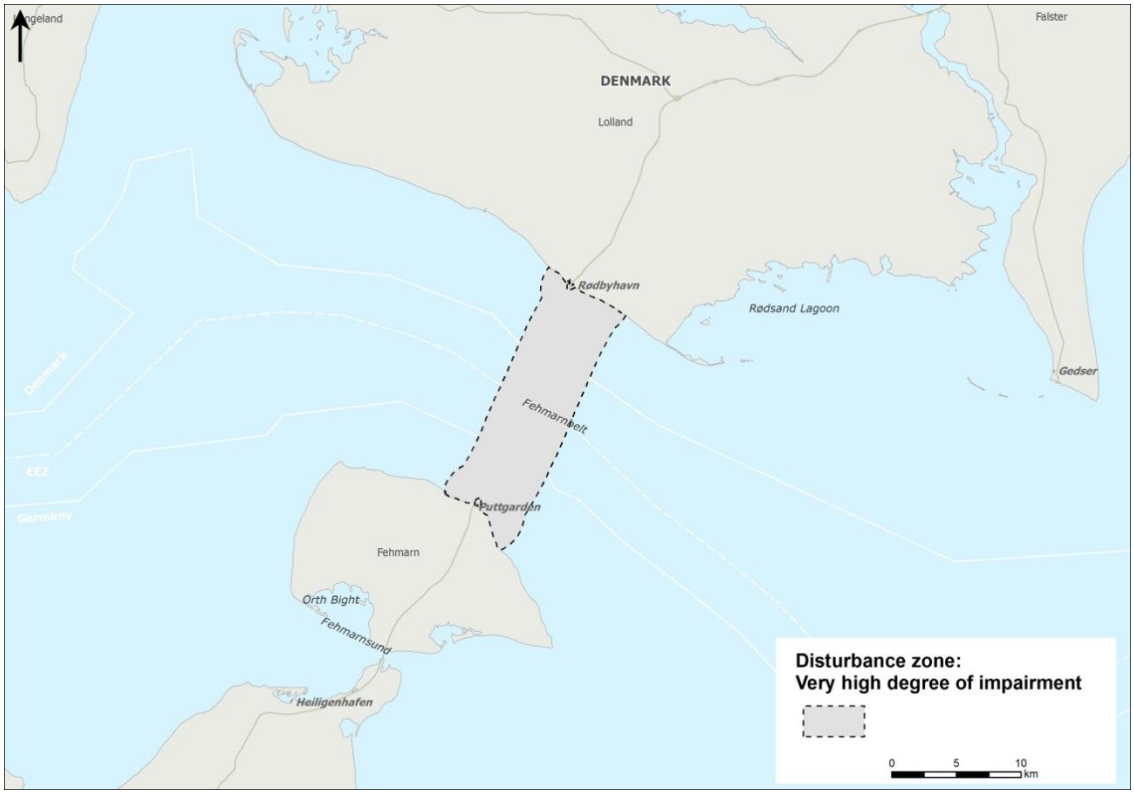

Figure A.51 Disturbance zone of the construction activities defined as a 3 km buffer around the cable stayed bridge footprint.

A.2.5 Disturbance from bridge structure and traffic

The predicted impact zone (disturbance zone) from bridge structure and traffic during operation of a bridge would affect a similar (but smaller) area compared to the disturbance zone predicted for the pressure disturbance from construction vessels for the tunnel alternative (see maps in chapter A.1.4). Therefore, no species specific impact maps are shown for this pressure.

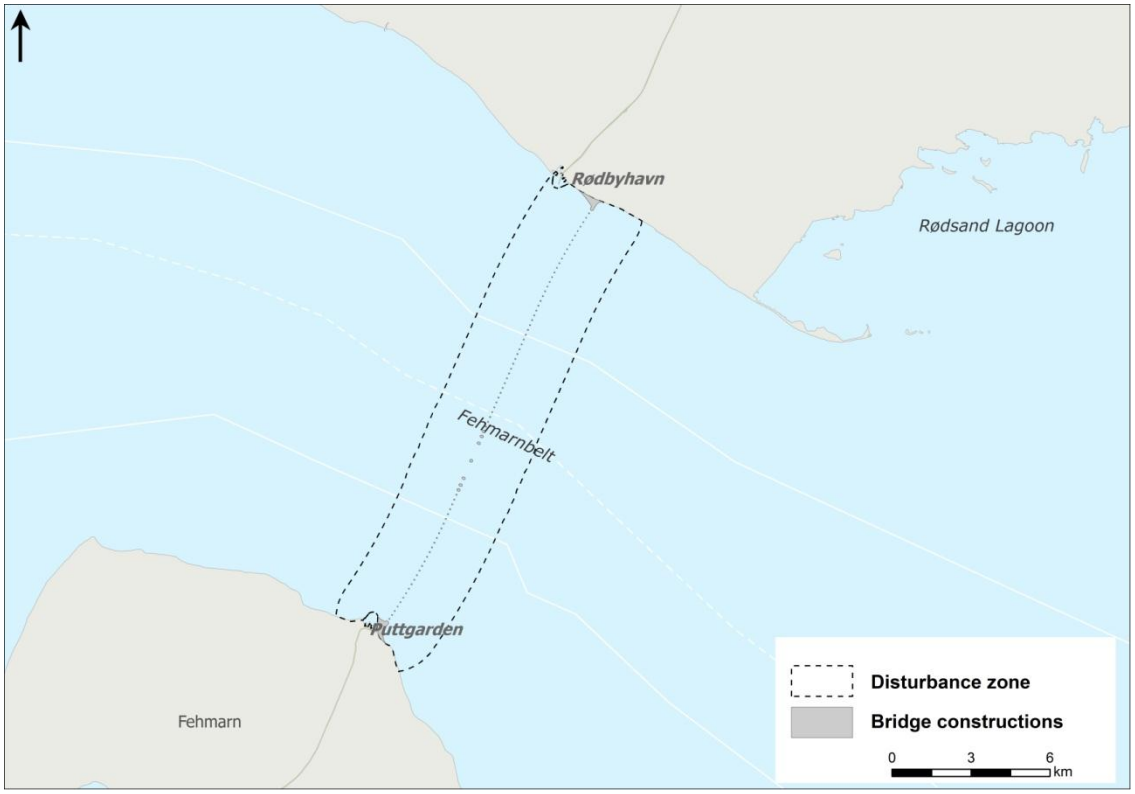

Figure A.52 Disturbance zone from bridge structure and traffic defined as 2 km buffer around the cable stayed bridge (disturbance zone: very high degree of impairment).

B. POTENTIAL BIOLOGICAL REMOVAL – PBR

Table B.1 Calculation of the Potential Biological Removal (PBR) for selected bird species and references where different values were taken from. N – population size, where only one estimate figure was available; N (lower bound) – lower bound of estimated population size that was available in literature; α – age of first reproduction; S_{ad} – adult bird annual survival probability; f – population recovery factor; Status – population status based on the European threat status (BirdLife International 2004): D - Declining, D (vuln) - Declining (vulnerable), D (end) - Declining (endangered), S - Stable, I - Increasing; N_{min} – minimum population size (lower bound of estimated range or 20th percentile of the population estimate if only one figure was available); λ_{max} – maximum annual population growth rate; R_{max} – maximum recruitment rate.

Species	N	N (lower bound)	α	S_{ad}	f	Status	N_{min}	λ_{max}	R_{max}	PBR	Reference N	Reference α	Reference S_{ad}
Red-throated Diver		150,000	2	0.84	0.3	D	150,000	1.30	0.30	6,705	WI 2006	BTO	Hemmingsson and Eriksson 2002
Black-throated Diver		250,000	3	0.89	0.3	D	250,000	1.18	0.18	6,700	WI 2006	guess	Nilsson 1977
Great Crested Grebe		290,000	2	0.715	0.5	S	290,000	1.39	0.39	27,956	WI 2006	BTO	Bellebaum et al. 2008
Red-necked Grebe		42,000	2	0.8	0.5	S	42,000	1.33	0.33	3,460	WI 2006	guess	BTO
Slavonian Grebe		14,200	2	0.7	0.3	D	14,200	1.39	0.39	840	WI 2006	guess	guess
Great Cormorant		380,000	3	0.88	0.7	I	380,000	1.19	0.19	24,645	WI 2006	BTO	Frederiksen and Bregnballe 2000
White Stork	483,000		4	0.78	0.5	S	317,354	1.18	0.18	14,566	WI 2006	BirdLife Factsheets 2011	Barbraud et al. 2005
Mute Swan	250,000		4.5	0.85	0.5	S	164,262	1.15	0.15	5,959	WI 2006	McCleery 2002	McCleery et al. 2002
Whooper Swan	59,000		4	0.801	0.5	S	38,766	1.18	0.18	1,718	WI 2006	BTO	Brazil 2003
Bewick's Swan	20,000		4	0.822	0.1	D (vuln)	13,141	1.17	0.17	112	WI 2006	BTO	Rees 2006
Greylag Goose	500,000		3	0.83	0.5	S	328,523	1.21	0.21	17,552	WI 2006	BTO	Nilsson and Persson 1993
Bean Goose	600,000		3	0.75	0.3	D	394,228	1.25	0.25	14,700	WI 2006	BirdLife Factsheets 2011	Madsen et al. 1999
Barnacle Goose		420,000	3	0.91	0.5	S	420,000	1.16	0.16	17,230	WI 2006	BTO	BTO
Brent Goose	200,000		2	0.9	0.1	D (vuln)	131,409	1.24	0.24	1,578	WI 2006	BTO	Sedinger et al. 2002
Eurasian Wigeon	1,500,000		1	0.53	0.5	S	985,570	2.12	1.12	274,974	WI 2006	BTO	Balmer and Peach 1997

Species	N	N (lower bound)	α	S_{ad}	f	Status	N_{min}	λ_{max}	R_{max}	PBR	Reference N	Reference α	Reference S_{ad}
Gadwall	60,000		1	0.576	0.3	D	39,423	2.05	1.05	6,229	WI 2006	BTO	Giudice2003
Mallard	4,500,000		1	0.627	0.5	S	2,956,711	1.98	0.98	724,901	WI 2006	BTO	Giudice2003
Northern Shoveler	40,000		1	0.58	0.5	S	26,282	2.05	1.05	6,885	WI 2006	BTO	Blums et al. 1996
Northern Pintail	60,000		1	0.663	0.3	D	39,423	1.93	0.93	5,481	WI 2006	BTO	Hestbeck 1993
Garganey	2,000,000		1	0.6	0.3	D	1,314,094	2.02	1.02	200,984	WI 2006	BTO	Guess
Green-winged Teal	500,000		1	0.53	0.5	S	328,523	2.12	1.12	91,658	WI 2006	BTO	Chu et al. 1995
Shelduck	300,000		2	0.886	0.5	S	197,114	1.26	0.26	12,575	WI 2006	BTO	Patterson et al. 1983
Common Pochard	350,000		1	0.65	0.3	D	229,966	1.95	0.95	32,653	WI 2006	BTO	Blums et al. 1996
Tufted Duck	1,200,000		1	0.71	0.3	D	788,456	1.85	0.85	100,894	WI 2006	BTO	Blums et al. 1996
Greater Scaup	310,000		1.3	0.81	0.1	D (end)	203,685	1.50	0.50	5,102	WI 2006	Flint et al. 2006	Flint et al. 2006
Common Eider	760,000		3	0.936	0.5	S	499,356	1.14	0.14	17,671	WI 2006	BTO	Balmer and Peach 1997
Long-tailed Duck	4,600,000		2.5	0.75	0.3	S	3,022,415	1.29	0.29	133,350	WI 2006	Robertson and Savard 2002	Robertson and Savard 2002
Common Scoter	1,600,000		3	0.783	0.3	S	1,051,275	1.24	0.24	37,117	WI 2006	guess	Fox et al. 2003
Velvet Scoter	1,000,000		3	0.84	0.3	D	657,047	1.21	0.21	20,554	WI 2006	guess	Alisauskas et al. 2004
Common Goldeneye		1,000,000	2	0.772	0.5	S	1,000,000	1.35	0.35	87,354	WI 2006	BTO	Dow and Fredga 1984
Smew	40,000		2	0.8	0.3	D	26,282	1.33	0.33	1,299	WI 2006	guess	guess
Red-breasted Merganser	170,000		2	0.82	0.5	S	111,698	1.31	0.31	8,777	WI 2006	guess	guess
Goosander	266,000		2	0.82	0.5	S	174,774	1.31	0.31	13,733	WI 2006	BTO	Pearce et al. 2005
Honey-Buzzard		37,600	3	0.85	0.5	S	37,600	1.20	0.20	1,910	Mebs and Schmidt 2006	BTO	BTO
Red Kite		3,200	2	0.61	0.7	I	3,200	1.44	0.44	495	Mebs and Schmidt 2006	BTO	Seather 1989
White-tailed Eagle	2,400		5	0.936	0.5	D	1,577	1.10	0.10	38	Mebs and Schmidt 2006	guess	BTO

Species	N	N (lower bound)	α	S_{ad}	f	Status	N_{min}	λ_{max}	R_{max}	PBR	Reference N	Reference α	Reference S_{ad}
Marsh Harrier		7,000	3	0.74	0.7	I	7,000	1.25	0.25	618	Mebs and Schmidt 2006	BTO	Balmer and Peach 1997
Hen Harrier		9,200	2	0.81	0.5	S	9,200	1.32	0.32	741	Mebs and Schmidt 2006	BTO	Picozzi 1984
European Sparrow Hawk		168,000	1	0.69	0.5	S	168,000	1.89	0.89	37,173	Mebs and Schmidt 2006	BTO	Newton 1986
Eurasian Buzzard		160,000	3	0.9	0.7	I	160,000	1.17	0.17	9,611	Mebs and Schmidt 2006	BTO	Kenward et al. 2000
Rough-legged Buzzard		10,000	3	0.9	0.5	S	10,000	1.17	0.17	429	Mebs and Schmidt 2006	guess	guess
Osprey		17,988	3	0.85	0.7	I	17,988	1.20	0.20	1,279	Mebs and Schmidt 2006	BTO	Poole 1989
Eurasian Kestrel		18,000	1	0.69	0.5	S	18,000	1.89	0.89	3,983	Mebs and Schmidt 2006	BTO	Village 1990
Merlin		24,800	1	0.62	0.5	S	24,800	1.99	0.99	6,144	Mebs and Schmidt 2006	BTO	Lieske et al. 2000
Hobby		16,000	2	0.75	0.3	D	16,000	1.36	0.36	874	Mebs and Schmidt 2006	BTO	Chapmann 1999
Peregrine Falcon		820	2	0.8	0.7	I	820	1.33	0.33	95	Mebs and Schmidt 2006	BTO	Craig et al. 2004
Common Coot	1,750,000		2	0.7	0.5	S	1,149,832	1.39	0.39	113,361	WI 2006	BTO	Perdeck 1998
Crane	150,000		4	0.9	0.7	I	98,557	1.14	0.14	4,718	WI 2006	BTO	Matthews and MacDonald 2001
Oystercatcher	1,020,000		4	0.88	0.5	S	670,188	1.15	0.15	24,607	WI 2006	BTO	Goss-Custard et al. 1982
Avocet	73,000		3	0.78	0.5	S	47,964	1.24	0.24	2,838	WI 2006	guess	Cramp et al. 1977
Little Ringed Plover		200,000	2	0.55	0.5	S	200,000	1.47	0.47	23,472	WI 2006	BTO	Cramp et al. 1977
Ringed Plover	73,000		1	0.77	0.3	D	47,964	1.75	0.75	5,405	WI 2006	BTO	Dobson 1990
Golden Plover		640,000	1	0.73	0.5	S	640,000	1.82	0.82	131,231	WI 2006	BTO	Sandercock 2003
Grey Plover	247,000		2	0.86	0.3	D	162,291	1.28	0.28	6,826	WI 2006	BTO	Evans and Pienkowski 1984
Lapwing		5,100,000	2	0.71	0.3	D	5,100,000	1.39	0.39	297,243	WI 2006	guess	Peach 1994

Species	N	N (lower bound)	a	S_{ad}	f	Status	N_{min}	λ_{max}	R_{max}	PBR	Reference N	Reference a	Reference S_{ad}
Knot	450,000		1	0.84	0.3	D	295,671	1.62	0.62	27,356	WI 2006	BTO	Brochard et al. 2002
Sanderling	123,000		2	0.83	0.5	S	80,817	1.31	0.31	6,188	WI 2006	BTO	Evans and Pienkowski 1984
Curlew Sandpiper	1,000,000		2	0.8	0.7	I	657,047	1.33	0.33	75,786	WI 2006	BTO	guess
Dunlin	1,330,000		2	0.74	0.5	S	873,872	1.37	0.37	80,909	WI 2006	BTO	Warnock et al. 1997
Ruff		1,000,000	2	0.52	0.3	D	1,000,000	1.48	0.48	72,357	WI 2006	BTO	Cramp et al. 1977
Snipe	2,500,000		2	0.48	0.5	S	1,642,617	1.50	0.50	204,839	WI 2006	BTO	Cramp et al. 1977
Bar-tailed Godwit	720,000		2	0.72	0.3	D	473,074	1.38	0.38	27,151	WI 2006	BTO	Cramp et al. 1977
Whimbrel		190,000	2	0.89	0.5	S	190,000	1.25	0.25	11,923	WI 2006	BTO	Balmer and Peach 1997
Curlew		700,000	2	0.74	0.3	D	700,000	1.37	0.37	38,886	WI 2006	BTO	Evans and Pienkowski 1984
Spotted Redshank		60,000	1	0.75	0.5	S	60,000	1.79	0.79	11,794	WI 2006	guess	guess
Redshank	250,000		1	0.74	0.3	D	164,262	1.80	0.80	19,794	WI 2006	BTO	Insley et al. 1997
Greenshank		190,000	2	0.75	0.5	S	190,000	1.36	0.36	17,289	WI 2006	guess	BTO
Green Sandpiper		1,000,000	2	0.55	0.5	S	1,000,000	1.47	0.47	117,361	WI 2006	BTO	guess
Wood Sandpiper		900,000	2	0.54	0.5	S	900,000	1.47	0.47	106,609	WI 2006	Guess	Cramp et al. 1977
Common Sandpiper		1,500,000	2	0.84	0.3	D	1,500,000	1.30	0.30	67,048	WI 2006	BTO	Holland and Yelden 2002
Turnstone		145,000	2	0.86	0.3	D	145,000	1.28	0.28	6,099	WI 2006	BTO	Balmer and Peach 1997
Little Gull		72,000	2	0.85	0.7	I	72,000	1.29	0.29	7,292	WI 2006	guess	guess
Black-headed Gull		3,700,000	2	0.9	0.3	D	3,700,000	1.24	0.24	133,298	WI 2006	BTO	guess
Common Gull		1,200,000	3	0.86	0.3	D	1,200,000	1.20	0.20	35,551	WI 2006	BTO	Buckcicinski and Buckcicinska 2003
Herring Gull		1,700,000	4	0.88	0.7	I	1,700,000	1.15	0.15	87,385	WI 2006	BTO	Wanless et al. 1996
Lesser Black-backed Gull	55,500		4	0.91	0.3	D	36,466	1.13	0.13	717	WI 2006	BTO	Wanless et al. 1996

Species	N	N (lower bound)	α	S_{ad}	f	Status	N_{min}	λ_{max}	R_{max}	PBR	Reference N	Reference α	Reference S_{ad}
Great Black-backed Gull		330,000	4	0.9	0.7	I	330,000	1.14	0.14	15,796	WI 2006	BTO	guess
Sandwich Tern		166,000	3	0.9	0.3	S	166,000	1.17	0.17	4,274	WI 2006	BTO	Robinson 2010
Common Tern		800,000	3	0.9	0.5	S	800,000	1.17	0.17	34,326	WI 2006	BTO	Becker and Ludwigs 2004
Little Tern		42,500	3	0.9	0.3	D	42,500	1.17	0.17	1,094	WI 2006	BTO	Tavecchia et al. 2006
Arctic Tern		1,500,000	4	0.9	0.5	S	1,500,000	1.14	0.14	51,286	WI 2006	BTO	Balmer and Peach 1997
Razorbill	500,000		4	0.9	0.5	S	328,523	1.14	0.14	11,232	BirdLife International 2004	BTO	Chapdelaine 1997
Common Guillemot	4,300,000		5	0.946	0.5	S	2,825,301	1.09	0.09	63,884	BirdLife International 2004	BTO	Harris et al. 2000
Black Guillemot		8,250	4	0.87	0.3	D	8,250	1.15	0.15	187	BirdLife International 2004	BTO	Frederiksen and Petersen 1999

References

Alisauskas, R.T., Traylor, J.J., Swoboda, C.J. and Kehoe, F.P. 2004. Components of population growth rate for White-winged Scoters in Saskatchewan, Canada. Animal Biodiversity and Conservation, 27.1, 451-460.

Balmer, D.E. and Peach, W.J. 1997. Review of Natural Avian Mortality Rates. BTO Research Report 175.

Barbraud, C., Barbraud, J.C., and Barbraud, M. 2005. Population dynamics of the White Stork *Ciconia ciconia* in western France. Ibis 141, 469-479.

Becker, P.H., Ludwigs J.D. 2004. *Sterna hirundo* Common Tern. BWP Update Vol. 6, Nos 1/2,. 93-139. Oxford University Press, Oxford.

Blums, P., Mednis, A., Bauga, I., Nichols, J.D., and Hines, J.E. 1996. Age-specific survival and philopatry in three species of European ducks: a long-term study. Condor 98, 61-74.

Brochard, C., Spaans, B., Prop, J. and Piersma, T. 2002. Use of individual colour-ringing to estimate annual survival in male and female Red Knot *Calidris canutus islandica*: a progress report for 1998-2001. Wader Study Group Bulletin 99, 54-56.

BTO: http://www.bto.org/about-birds/birdfacts

Buckcicinski, D.B. and Buckcicinska, M.B. 2003. BWP Update 5, 13-39.

Chapdelaine G. 1997. Pattern of recoveries of banded Razorbills (*Alca torda*) in the western Atlantic and survival rates of adults and immatures. Colonial Waterbirds 20, 47–54.

Chapmann, A. 1999. The Hobby. Alequin Press.

Craig, G.R., White, G.C. and Enderson, J.H. 2004. Survival, recruitment, and rate of population change of the Peregrine Falcon population in Colorado. Journal of Wildlife Management 68, 1032-1038.

Cramp, S. and Simmons, K.E.L. (eds.) 1977. Handbook of the birds of Europe, the Middle East and North Africa. The birds of the Western Palearctic. Vol. I: Ostrich to ducks. Oxford University Press, Oxford, London, New York.Dobson, A.P. 1990. Current Ornithology 7: 115-146

Dow, H. and Fredga, S. 1984. Factors affecting reproductive output of the goldeneye duck *Bucephala clangula*. Journal of Animal Ecology 53, 679–692.

Duck Unlimited: http://www.ducks.ca/resource/general/wetland/geese.html#breed

Evans, P.R. and Pienkowski, M. 1984. Bheaviour of marine animals (Eds J. Burger and B. Olla). Plenum.

Flint, P.L, Grand, J.B., Fondell, T.F., and Morse, J.A. 2006. Population dynamics of Greater Scaup breeding on the Yukon-Kuskokwim Delta, Alaska. Wildlife Monographs 162, 1-22.

Fox, A.D., Petersen, Æ., and Frederiksen, M. 2003. Annual survival and site-fidelity of breeding female Common Scoter *Melanitta nigra* at Myvant, Iceland, 1925-1958. Ibis 145, E94-E96.

Frederiksen M., A. Petersen. 1999. Philopatry and dispersal within a Black Guillemot colony. Waterbirds 2, 274–281.

Frederiksen, M. and Bregnballe, T. 2000. Evidence for density-dependent survival in adult cormorants from a combined analysis of recoveries and resightings. Journal of Animal Ecology 69, 737-752.

Goss-Custard, J.D., Sitters, H.P. and Swinfen R. 1982. Age-structure and survival of a wintering population of Oystercatchers. Bird Study 29: 23-98.

Harris M. P., Wanless, S., Rothery, P., Swann, R.L., and Jardine, D. 2000. Survival of adult Common Guillemots *Uria aalge* at three Scottish colonies. Bird Study 47, 1-7.

Hestbeck, J. B. 1993. Survival of northern pintails banded during winter in North America, 1950-88. Journal of Wildlife Management 57, 590-59

Holland, P.K. and Yalden, D.W. 2002. Population dynamics of Common Sandpipers *Actitis hypoleucos* in the Peak District of Derbyshire – a different decade. Bird Study 49:131-138.

Insley, H., Peach, W., Swann, B., and Etheridge, B. 1997. Survival rates of Redshank *Tringa totanus* wintering on the Moray Firth. Bird Study 44, 277-289.

Kenward, R.E., Walls, S.S., Hodder, K.H., Pahkala, M., Freeman, S.N. and Simpson, V. R. 2000. The prevalence of non-breeders in raptor populations: evidence from rings, radio-tags and transect surveys. Oikos 91, 271-279.

Lieske, D.J., Warkentin, I.G., Oliphant, L.W., James, P.C. and Espie, R.H.M. 2000. Effects of population density on survival in Merlins (*Falco columbarius*). Auk 117, 184-193.

Madsen, J., Cracknell, G. and Fox, A.D. (eds.) 1999. Goose populations of the Western Palearctic. A review of status and distribution. Wetlands International Publ. No. 48, Wetlands International, Wageningen, The Netherlands. National Environmental Research Institute, Rönde, Denmark.

Matthews, F. and MacDonald, D.W. 2001. The sustainability of the common crane (*Grus grus*) flock breeding in Norfolk - insights from simulation modelling. Biological Conservation 100, 323-333.

Mebs, T. and Schmidt, D. 2006. Die Greifvögel Europas, Nordafrikas und Vorderasiens [Birds of prey of Europe, Northern Africa and the Middle East]. Kosmos, Stuttgart.

Newton, I. 1986. The Sparrowhawk. Poyser

Nilsson, S. G. 1977. Adult survival rate of the Black-throated Diver *Gavia arctica*. Ornis Scandinavica 8, 193–195.

Nilsson, L. and Persson, H. 1993. Variation in survival in an increasing population of the Greylag Goose *Anser anser* in Scania, southern Sweden. Ornis Svecica 3: 137-146.

Peach, W.J., Thompson, P.S., and Coulson, J.C. 1994. Annual and long-term variation in the survival rates of British lapwings *Vanellus vanellus*. Journal of Animal Ecology 63, 60-70.

Pearce, J.M., J.A. Reed and P.L. Flint. 2005. Geographic variation in survival and migratory tendency among North American Common Mergansers. Journal of Field Ornithology 76: 109–216.

Perdeck, A.C. 1998. Poisson regression as a flexible alternative in the analysis of ring recovery data. Euring Newsletter 2: 30-36.

Picozzi, N. 1984. Sex ratio, survival and territorial behaviour of polygynous Hen Harriers *Circus c. cyaneus* in Orkney. Ibis 126, 356-365.

Poole, A. 1989. Ospreys: A natural and unnatural history. Oxford Press

Robertson, G.J., Savard, J.-P.L., 2002. Long-tailed Duck (*Clangula hyemalis*). In: Poole, A. (Ed.), The Birds of North America Online. Ithaca: Cornell Lab of Ornithology.

Robinson, R.A. 2010. Estimating age-specific survival rates from historical ringing data. Ibis 152, 651-653.

Sandercock, B.K. 2003. Estimation of survival rates for wader populations: a review of mark-recapture methods. Wader Study Group Bulletin 100: 163-74.

Seather, B.E. 1989. Survival rates in relation to body weight in European birds. Ornis Scandinavica 20:13-21

Tavecchia, G. et al. 2006. Waterbirds around the World (G. Boere Eds). The Stationary Office.

Village, A. 1990. The Kestrel. Poyser.

Wanless S., Harris M.P., Calladine J., Rothery P. 1996. Modelling responses of herring gull and lesser black-backed gull populations to reduction of reproductive output: implications for control measures. Journal of Applied Ecology 33, 1420-1432.

Warnock, N., G.W. Page and B.K. Sandercock. 1997. Local survival of Dunlin wintering in California. Condor 99, 906-915

List of figures

Figure A.1 Severity of loss from footprint of the immersed tunnel for Common Eiders in winter. ... 1

Figure A.2 Severity of impairment from the pressure habitat change from sediment spill to Common Eider in the first winter of the tunnel construction (2014/2015; Common Eider winter distribution). ... 2

Figure A.3 Severity of impairment from the pressure habitat change from sediment spill to Common Eider in the first winter of the tunnel construction (2014/2015; Common Eider spring distribution)... 2

Figure A.4 Severity of impairment from the pressure habitat change from sediment spill to Long-tailed Duck in the first winter of the tunnel construction (2014/2015). ... 3

Figure A.5 Severity of impairment from the pressure habitat change from sediment spill to Common Scoter in the first winter of the tunnel construction (2014/2015).... 3

Figure A.6 Severity of impairment from the pressure habitat change from sediment spill to Common Goldeneye in the first winter of the tunnel construction (2014/2015). ... 4

Figure A.7 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the tunnel construction (2014/2015; diver winter distribution). ... 5

Figure A.8 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the second winter of the tunnel construction (2015/2016; diver winter distribution). ... 5

Figure A.9 Severity of impairment from the pressure water turbidity to divers (Red-throated and Black-throated Diver) in the first winter of the tunnel construction (2014/2015; diver spring distribution)... 6

Figure A.10 Severity of impairment from the pressure water turbidity to divers (Red-throated and Black-throated Diver) in the second winter of the tunnel construction (2015/2016; diver spring distribution)... 6

Figure A.11 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the first winter of the tunnel construction (2014/2015). ... 7

Figure A.12 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the second winter of the tunnel construction (2015/2016). ... 7

Figure A.13 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the tunnel construction (2014/2015; Common Eider winter distribution). ... 8

Figure A.14 Severity of impairment from the pressure water turbidity to Common Eiders in the second winter of the tunnel construction (2015/2016; Common Eider winter distribution). ... 8

Figure A.15 Severity of impairment from the pressure water turbidity to Common Eiders in the third winter of the tunnel construction (2016/2017; Common Eider winter distribution). ... 9

Figure A.16 Severity of impairment from the pressure water turbidity to Common Eiders in the fourth winter of the tunnel construction (2017/2018; Common Eider winter distribution). ... 9

Figure A.17 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the tunnel construction (2014/2015; Common Eider spring distribution)..... 10

Figure A.18 Severity of impairment from the pressure water turbidity to Common Eiders in the second winter of the tunnel construction (2015/2016; Common Eider spring distribution). 10

Figure A.19 Severity of impairment from the pressure water turbidity to Common Eiders in the third winter of the tunnel construction (2016/2017; Common Eider spring distribution)..... 11

Figure A.20 Severity of impairment from the pressure water turbidity to Common Eiders in the fourth winter of the tunnel construction (2017/2018; Common Eider spring distribution). 11

Figure A.21 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the first winter of the tunnel construction (2014/2015). 12

Figure A.22 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the second winter of the tunnel construction (2015/2016). 12

Figure A.23 Severity of impairment from the pressure water turbidity to Common Scoters in the first winter of the tunnel construction (2014/2015)..... 13

Figure A.24 Severity of impairment from the pressure water turbidity to Common Scoters in the second winter of the tunnel construction (2015/2016). 13

Figure A.25 Severity of impairment from the pressure water turbidity to Common Goldeneye in the first winter of the tunnel construction (2014/2015). 14

Figure A.26 Severity of impairment from the pressure water turbidity to Common Goldeneye in the second winter of the tunnel construction (2015/2016). 14

Figure A.27 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the first winter of the tunnel construction (2014/2015)..... 15

Figure A.28 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the second winter of the tunnel construction (2015/2016). 15

Figure A.29 Severity of impairment from the pressure water turbidity to Razorbills in the first winter of the tunnel construction (2014/2015). 16

Figure A.30 Severity of impairment from the pressure water turbidity to Razorbills in the second winter of the tunnel construction (2015/2016)..... 16

Figure A.31 Severity of impairment from the pressure disturbance from construction vessels to divers (Red-throated and Black-throated Diver) during the tunnel construction period (diver winter distribution). 17

Figure A.32 Severity of impairment from the pressure disturbance from construction vessels to divers (Red-throated and Black-throated Diver) during the tunnel construction period (diver spring distribution). 18

Figure A.33 Severity of impairment from the pressure disturbance from construction vessels to Red-necked Grebes during the tunnel construction period..... 18

Figure A.34 Severity of impairment from the pressure disturbance from construction vessels to Common Eiders during the tunnel construction period (Common Eider winter distribution). 19

Figure A.35 Severity of impairment from the pressure disturbance from construction vessels to Common Eiders during the tunnel construction period (Common Eider spring distribution). 19

Figure A.36 Severity of impairment from the pressure disturbance from construction vessels to Long-tailed Ducks during the tunnel construction period. 20

Figure A.37 Severity of impairment from the pressure disturbance from construction vessels to Common Scoters during the tunnel construction period. 20

Figure A.38 Severity of impairment from the pressure disturbance from construction vessels to Common Goldeneye during the tunnel construction period. 21

Figure A.39 Severity of impairment from the pressure disturbance from construction vessels to Red-breasted Mergansers during the tunnel construction period. 21

Figure A.40 Severity of impairment from the pressure disturbance from construction vessels to Razorbills during the tunnel construction period. 22

Figure A.41 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the bridge construction (2014/2015; diver winter distribution). 23

Figure A.42 Severity of impairment from the pressure water turbidity to divers (Red-throated Diver and Black-throated Diver) in the first winter of the bridge construction (2014/2015; diver spring distribution)..... 24

Figure A.43 Severity of impairment from the pressure water turbidity to Red-necked Grebes in the first winter of the bridge construction (2014/2015). 24

Figure A.44 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the bridge construction (2014/2015; Common Eider winter distribution). 25

Figure A.45 Severity of impairment from the pressure water turbidity to Common Eiders in the first winter of the bridge construction (2014/2015; Common Eider spring distribution). 25

Figure A.46 Severity of impairment from the pressure water turbidity to Long-tailed Ducks in the first winter of the bridge construction (2014/2015). 26

Figure A.47 Severity of impairment from the pressure water turbidity to Common Scoters in the first winter of the bridge construction (2014/2015)..... 26

Figure A.48 Severity of impairment from the pressure water turbidity to Common Goldeneye in the first winter of the bridge construction (2014/2015). 27

Figure A.49 Severity of impairment from the pressure water turbidity to Red-breasted Mergansers in the first winter of the bridge construction (2014/2015)..... 27

Figure A.50 Severity of impairment from the pressure water turbidity to Razorbills in the first winter of the bridge construction (2014/2015). 28

Figure A.51 Disturbance zone of the construction activities defined as a 3 km buffer around the cable stayed bridge footprint. 29

Figure A.52 Disturbance zone from bridge structure and traffic defined as 2 km buffer around the cable stayed bridge (disturbance zone: very high degree of impairment). 30

List of tables

Table B.1 Calculation of the Potential Biological Removal (PBR) for selected bird species and references where different values were taken from. N – population size, where only one estimate figure was available; N (lower bound) – lower bound of estimated population size that was available in literature; α – age of first reproduction; S_{ad} – adult bird annual survival probability; f – population recovery factor; Status – population status based on the European threat status (BirdLife International 2004): D - Declining, D (vuln) - Declining (vulnerable), D (end) - Declining (endangered), S - Stable, I - Increasing; N_{min} – minimum population size (lower bound of estimated range or 20th percentile of the population estimate if only one figure was available); λ_{max} – maximum annual population growth rate; R_{max} – maximum recruitment rate. 31