Resultater fra Fase 4

Fra Rapport: Acona 2018. Chapter. 3.1 Threshold for oil film thickness in *WP2a. Sensitivity and Uncertainty testing*. Version/Date: 07.02.2018. Document ID: ERA Acute 2A-1.

Threshold for oil film thickness

The lethal oil film thickness is 2 and 10 μm for seabirds and marine mammals and sea turtles, respectively. The threshold thickness of 2 μm for seabirds is derived from literature review of other impact models (French-McCay, 2009, 2004; Koops et al., 2004; Scholten et al., 1996), experimental studies (Hughes et al., 1990; Jenssen, 1994; Jenssen and Ekker, 1991a, 1991b), studies of the microstructure of seabird's feathers (O'Hara and Morandin, 2010) and expert judgment (e.g. Peakall et al., 1985; Stephenson, 1997) (cf. Bjørgesæter and Damsgaard Jensen, 2015 for more details). The default threshold level for seabirds in in ERA Acute was originally 10 μm (Spikkerud et al., 2010).

The lethal threshold oil film thickness for marine and aquatic mammals was kept at 10 μm based on that these animals rely on their blubber for thermoregulation and the pelage of aquatic mammals which is less sensitive to effects of oil fouling on thermoregulation than the plumage of birds. Also, there was no available data supporting that the original film thickness threshold should be altered (cf. Bjørgesæter and Damsgaard Jensen, 2015 for more details).

To investigate the importance of the threshold oil film thickness value (T), stochastic oil drift simulations with six different *pre-processing thresholds values* have been performed. The threshold thicknesses investigated were 0, 2, 4, 6, 8 and 10 μm.

The endpoints investigated are:

(1) Number of grid cells with oil film thicker than T
(2) Sea surface area with oil film thicker than T
(3) Exposure time of oil film thicker than T
(4) Impact (population loss)

The number of grid cells above T yields an indication of the geographical extent of harmful oil (oil thicker than the threshold T). The more cells above the threshold, T the larger geographical area is affected by oil. The sea surface area and exposure time of oil film thicker than T is directly linked to the size of the impact (population loss), although the impact may vary considerable depending on the distribution and relative abundance of the VECs in relation to the distribution of oil.

Oil drift simulations

Stochastic oil drift simulations were performed for a topside release of 5000 Sm^3/day for duration of 15 days. The oil type was Oseberg Øst 13 °C. The OSCAR model was set up according to the best practice set-up for performing stochastic oil drift simulations for MIRA analyses (Acona; Akvaplan-niva; DNV GL, 2016), except that the refinement parameter was set to 3. This means that the 9 km^2 grids are divided into 3×3 = 9 smaller cells for more detailed calculation of film thickness and coverage. The resolution of coverage in the oil drift model is therefore 1/9 = 11% or approximately 1 km^2 (before exported to the larger 10×10 km grid).

A total of 237 simulations were performed for each threshold thickness (release scenario).

Each simulation was run for 15 days (duration of the oil release) and continued for 20 days after the release has been stopped (i.e. the simulation period is 15 + 20 = 35 days). A follow-time of 20 days is a trade-off between ensuring that the fate of the oil is included in the simulation results without adding extra uncertainty in the predictions (cf. Acona; Akvaplan-niva; DNV GL, 2016). The internal computational time steps were set to 20 minutes and the output time step to 60 minutes. The oil drift simulation results were post-processed with *pysemble v.03*, a Python script developed by SINTEF for the ERA Acute project to ensure correct estimates of oil film thickness, coverage and exposure time in the 10×10 km UTM grid cells.

Calculating impact: The impact was calculated using the ERA Acute Calculator v.0.59 (Brönner, 2017; Brönner et al., 2017). For each scenario (thickness tested) the following procedure was performed (see also Figure 1):

(1) Change thickness values ("threshold_map") in the *seasurface.py*
(2) Change the threshold value for the VECs in *surface_thickness_thresholds.csv*
(3) Run the ERA Acute calculator

Statistical analyses were done in R v. 3.4.2 (R Core Team, 2017). Maps for illustrations was constructed using the ERA Acute Tool v. 1.0.0.37.

```python
def read_seasurface_thresholds(era_setup):
    """
    Read sea surface thresholds for each wildlife group.

    :param my_project: path to main project directory
    :returns: dictionary[wildlife_group] -> dictionary[MICROM/CATEGORY]
    """
    threshold_filepath = era_setup['surface_threshold_file']

    threshold_map = {10: T1, 10: T2}
    col_names = ['Group', 'p_beh_LO', 'p_beh_BG', 'p_beh_HI', 'p_phy_LO', 'p_phy_BG', 'p_phy_HI', THRESHOLD]
    df = pd.read_csv(threshold_filepath, index_col=[0], names=col_names, header=0)
```

Group	p_beh_LO	p_beh_BG	p_beh_HI	p_phy_LO	p_phy_BG	p_phy_HI	Threshold
Pelagic diving seabirds	7.9E-01	7.9E-01	8.9E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Pelagic surface foraging seabirds	4.5E-01	4.5E-01	5.1E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Coastal diving seabirds	6.7E-01	6.7E-01	7.6E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Coastal surface feeding seabirds	3.1E-01	3.3E-01	4.4E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Wetland surface feeding seabirds	4.8E-01	4.8E-01	5.4E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Wading seabirds	3.5E-01	3.5E-01	3.5E-01	8.0E-01	9.0E-01	1.0E+00	**10**
Baleen whales	4.0E-01	6.0E-01	1.0E+00	4.0E-03	4.0E-03	4.0E-03	**10**
Toothed whale	4.0E-01	6.0E-01	1.0E+00	8.0E-03	8.0E-03	8.0E-03	**10**
True seals, walruses and sea lions	8.3E-01	9.0E-01	9.6E-01	4.0E-03	2.6E-02	5.8E-02	**10**
Fur seals	6.3E-01	7.8E-01	9.3E-01	3.3E-01	5.7E-01	8.7E-01	**10**
Sea cows	9.5E-01	9.8E-01	1.0E+00	8.0E-03	4.2E-02	8.3E-02	**10**
Aquatic mammals	7.9E-01	8.8E-01	9.7E-01	4.0E-01	6.3E-01	9.0E-01	**10**
Sea turtles	9.5E-01	9.8E-01	1.0E+00	2.9E-02	2.9E-02	3.0E-02	**10**

Figure 1. The Python code showing the "*threshold_map*" in the seasurface.py (left) and the "surface_thickness_thresholds.csv" (right) where the threshold thickness was altered for the different tests (here testing Scenario T10).

Results

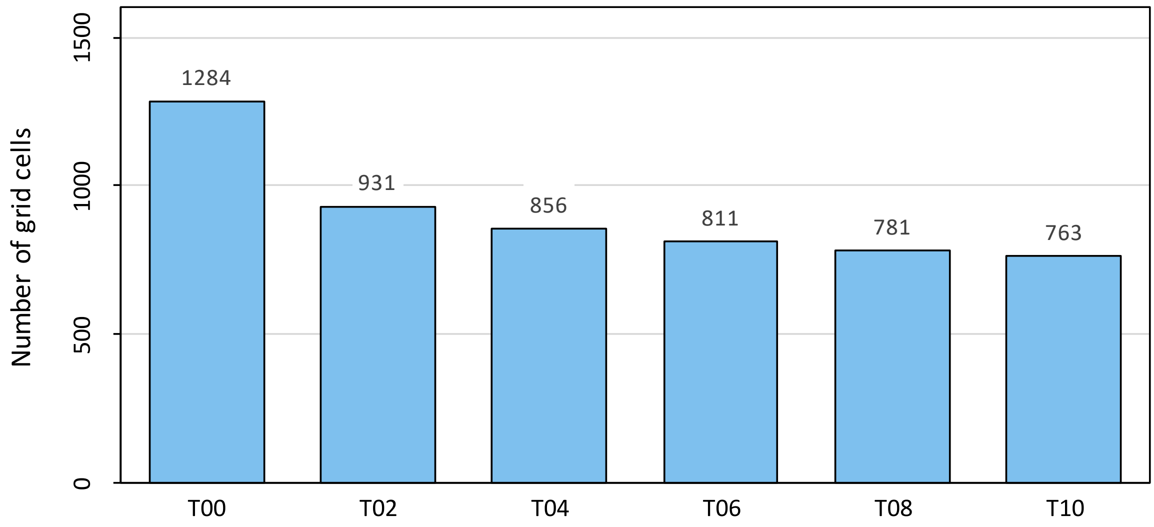
Effect on oil drift parameters: A summary of the effect of different thickness thresholds on the oil drift parameters is presented in Table 1 and illustrated in Figure 2 (number of grid cells), Figure 3 (area) and Figure 4 (exposure time). All three oil drift parameters decrease with increasing oil film thickness threshold. The effect of lowering the threshold level from 2 to 10 micrometres have a significant effect on all three oil-drift statistical endpoints at a 5% significance level (ANOVA with a Tukey's range test). There was no statistically significant difference in the number of grid cells for Scenario T04 and T06 (p=0.22), T06 and T08, T10 (p=0.69, p=0.17) and T08 and T10 (p=0.94), while for the area above T, all scenarios were statistically significantly different except Scenario T08 and T10 (p=0.41). For exposure time there were no statistically significant difference between Scenario T4 and T6 (p=0.33), T06 and T8, T10 (p=0.65, p=0.11) and Scenario T08 and T10 (p=0.90).

Statistical maps for the oil drift parameters constructed from the stochastic oil drift simulations are illustrated in Figure 5, Figure 6 and Figure 7. The area above 2 μm is on average 1.82 times larger than the area above 10 μm (27,431 km^2 ± SD 13,562 versus 15,067 km^2 ± SD 3,345) (cf Table 1). Similarly, the exposure time for oil thicker than 2 μm is on average 1.41 times longer than the exposure time for oil thicker than 10 μm (1.22 days ± SD 0.50 versus 0.87 days ± SD 0.39) and the number of grid cells above 2 μm versus 10 μm is 1.2 (931 cells ± SD 220 versus 781 ± SD 192) (cf. Table 1).

Table 1. The mean number of grid cells, total area and exposure time with film thickness above the oil film threshold thicknesses (T).

Scenario	Threshold T (μm)	Number of grid cells above T		Area above T (km^2)		Exposure time above T (days)	
		Mean	SD	Mean	SD	Mean	SD
Scenario T00	0	1,284	296	46,335	13,562	1.54	0.50
Scenario T02	2	931	220	27,431	7,066	1.22	0.50
Scenario T04	4	856	206	21,368	5,130	1.06	0.45
Scenario T06	6	811	197	18,256	4,202	0.97	0.42
Scenario T08	8	781	192	16,294	3,695	0.91	0.41
Scenario T10	10	763	188	15,067	3,345	0.87	0.39

Number of 10×10 km grid cells above T



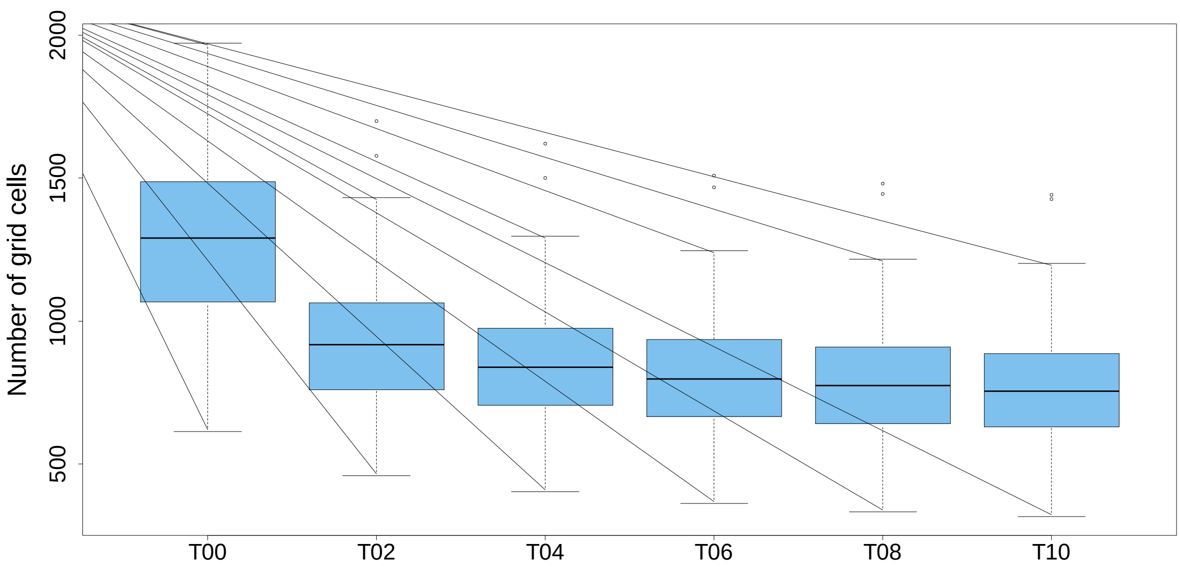


Figure 2. Column plots (top) and box plots (bottom) comparing the number of sea surface grid cells above the threshold thickness (T) for the six scenarios each represented with 237 simulations. The column plot shows the mean values while the box plot illustrates the minimum, first quartile, median (typical value), third quartile, and maximum for the 237 simulations. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values.

Area (km^2) above T

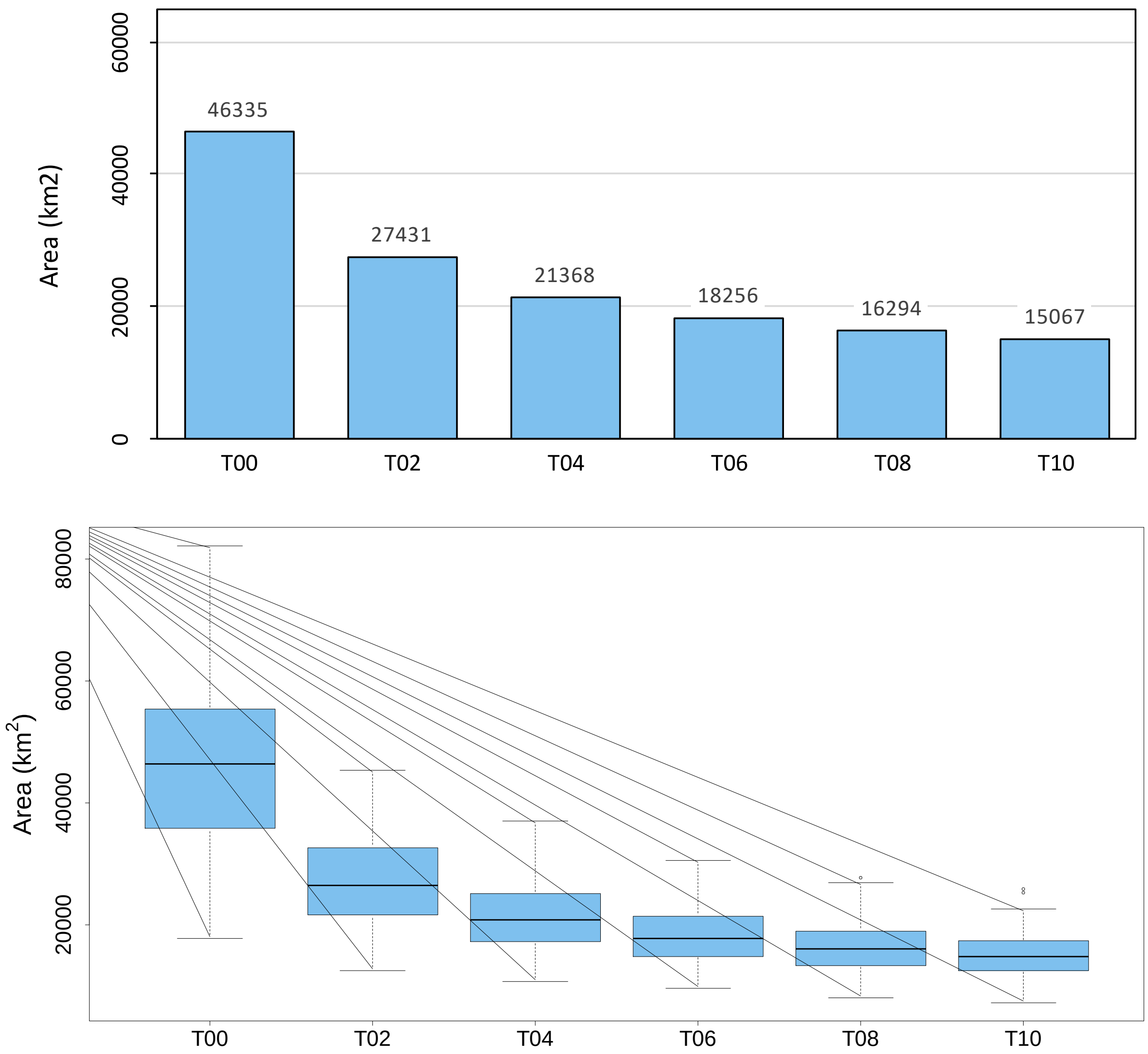


Figure 3. Column plots (top) and box plots (bottom) comparing the sea surface area above the threshold thickness (T) for the six scenarios each represented with 237 simulations. The column plot shows the mean values while the box plot illustrates the minimum, first quartile, median (typical value), third quartile, and maximum for the 237 simulations. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values.

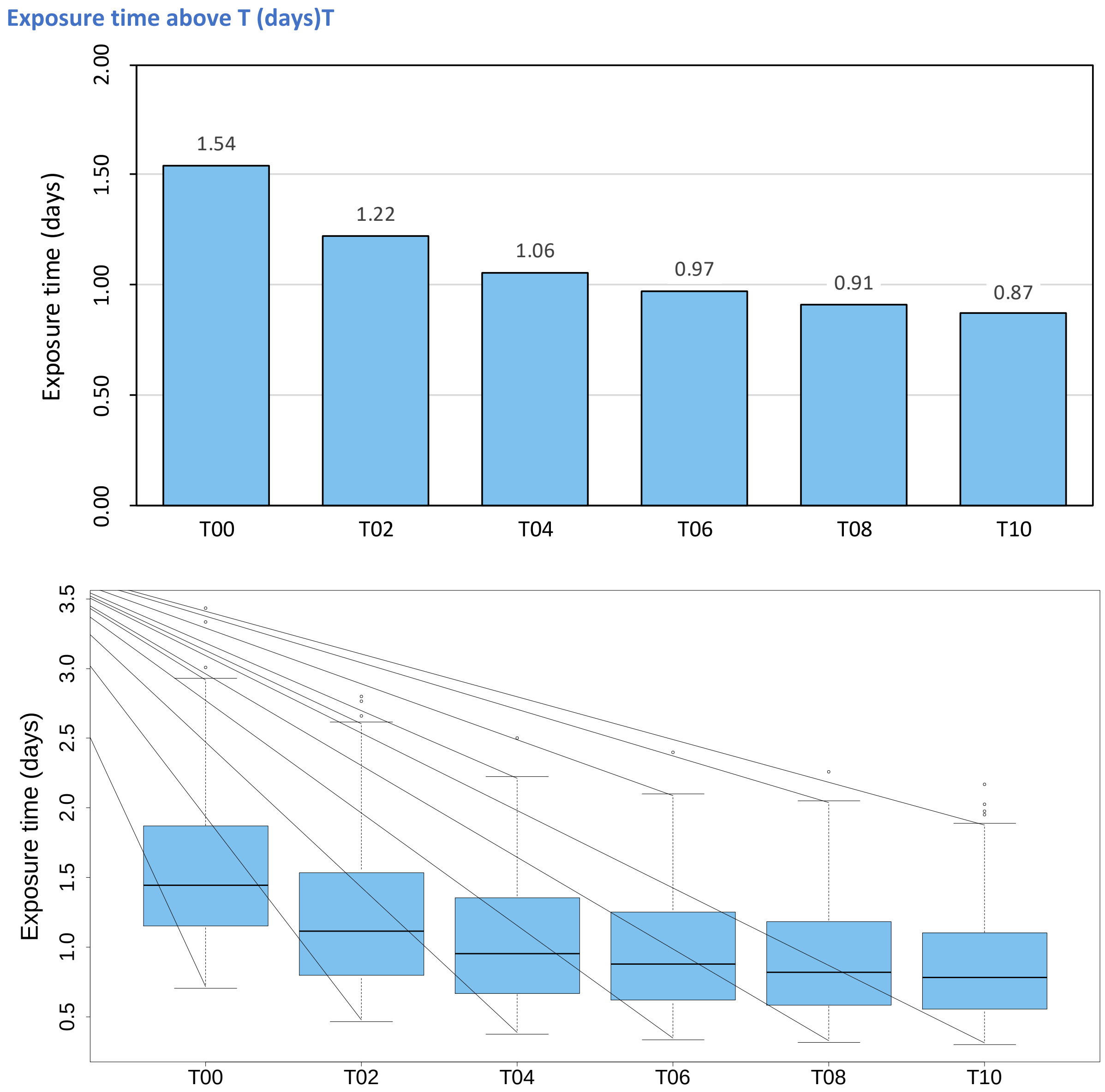
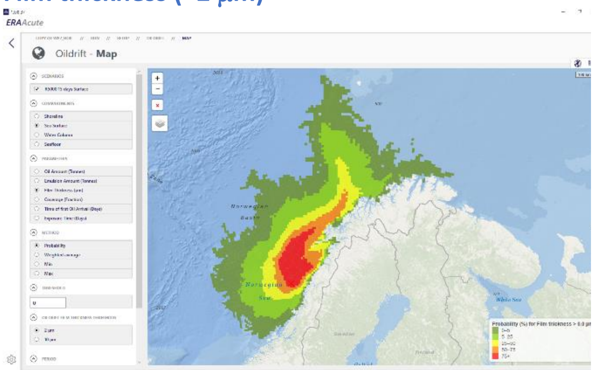


Figure 4. Column plots (top) and box plots (bottom) comparing the exposure time above the threshold thickness (T) for the six scenarios each represented with 237 simulations. The column plot shows the mean values while the box plot illustrates the minimum, first quartile, median (typical value), third quartile, and maximum for the 237 simulations. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values.

Film thickness (>2 µm)



Film thickness (>10 µm)

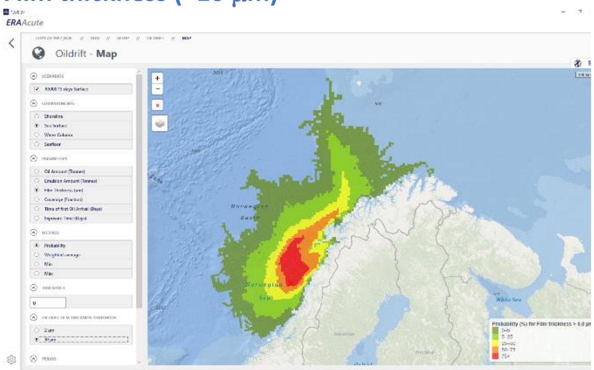
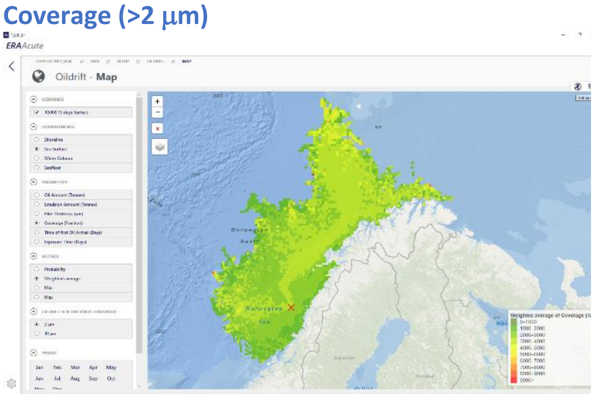


Figure 5. Statistical maps constructed from the stochastic oil drift simulations illustrating the number and probability of grid cells above a threshold thickness of 2 µm (left) and 10 µm (right). Note that the legend does not reflect the threshold thickness (constructed with the ERA Acute Tool v. 1.0.0.37).

Coverage (>2 µm)



Coverage (>10 µm)

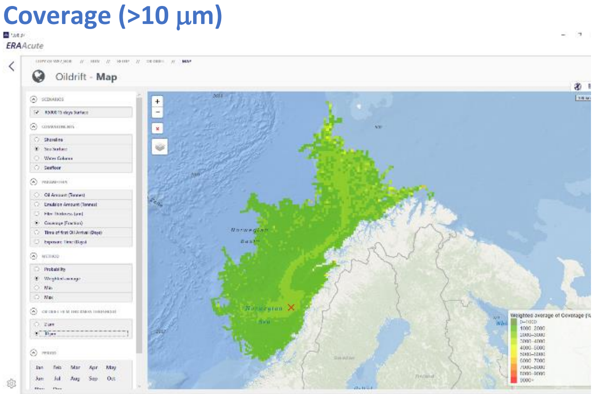
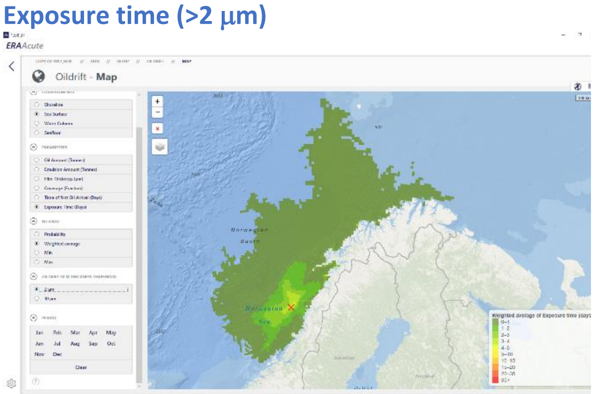


Figure 6. Statistical maps constructed from the stochastic oil drift simulations for all 237 simulations illustrating the mean coverage above a threshold thickness of 2 µm (left) and 10 µm (right). Note that the legend shows two extra zeros (constructed with the ERA Acute Tool v. 1.0.0.37).

Exposure time (>2 µm)



Exposure time (>10 µm)

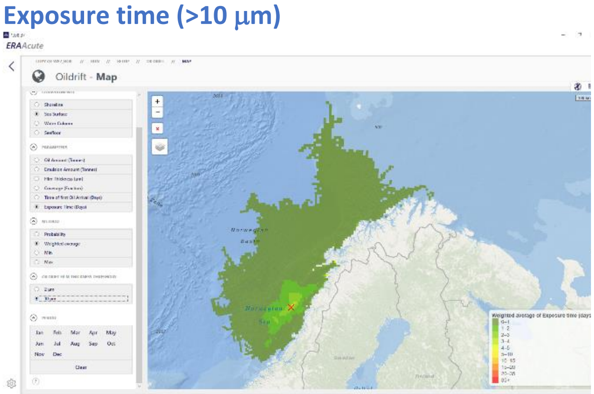


Figure 7. Statistical maps constructed from the stochastic oil drift simulations for all 237 simulations illustrating the mean exposure time above a threshold thickness of 2 µm (left) and 10 µm (right) (constructed with the ERA Acute Tool v. 1.0.0.37).

Effect on impact: A summary of the effect of different thickness threshold on impact (population loss) is summarized in Table 2 and illustrated in Figure 8 to Figure 13. Table 2 presents measures of central tendency (mean) and variability (standard deviation and the 2.5 and 97.5 percentiles) of impact estimated from stochastic oil drift simulations valid for March, April and May (n = 120) using equation **Error! Reference source not found.** and the individual vulnerability factors in **Error! Reference source not found.**. The result of the Tukey's range test is presented in the right panel of the table. It shows the p-values for comparison of the mean impact estimated from simulations with different threshold thickness. For example, T04 vs. T06 shows that the mean impact of Atlantic puffin estimated with a threshold thickness of 4 μm (T04) is statistically significantly different from the mean impact estimated with a threshold thickness of 6 μm (T06) at a 5% significance level (p = 0.0458).

The estimated impact for all VECs decreases with increasing oil film thickness threshold. The mean impact estimated with a threshold thickness of 2 μm is on average 2.3 times higher than the mean impact estimated with a threshold thickness of 10 μm, ranging from 1.9 (Atlantic puffin, coastal dataset and grey seal) to 2.9 (black-legged kittiwake). As for the oil drift statistics, the difference in the estimated mean impact for 2 and 10 μm is statically significant for all VECs at a 5% significance level. The effect of lowering the threshold thickness from 10 to 8 μm is not statistically significant for any of the species.

In this test, the VECs distributed along the coast are less sensitive to lowering the threshold thickness than the VECs distributed on the open sea. The threshold must be lowered from 10 to 4 μm or 2 μm (grey seal) to obtain a statistically significant effect for the VECs exhibiting a coastal distribution.

In summary: The results show that that the effect of lowering the lethal oil film threshold thickness from 10 to 2 micrometres increases the geographical extent of potentially harmful area (i.e. oil spills will have higher probability of reaching areas that would not be reached using a higher T), the probability that a given area will be affected by harmful oil and the size of the environmental damage (population loss, as well as recovery time and the resource damage factor).

The main findings are:

1. All endpoints investigated are negatively correlated with the oil film threshold thickness (i.e. when increasing the threshold, the endpoints decreases).
2. The effect of lowering the film thickness threshold from 2 to 10 μm has a significant effect on the oil drift statistics and the estimated environmental damage for wildlife in the sea surface compartment.
3. The effect of lowering the threshold from 10 to 8 μm, and partly to 6 μm has smaller effect

Although the results are based on a limited dataset (237 simulations pr. scenario/oil film thickness threshold) it is believed that the general trend demonstrated in this test is valid for a broader range of oil spills (rates, durations, oil types and geographical locations).

Table 2. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The results are based on the individual vulnerability factors (low, medium and high) for the species wildlife group. The result from the Tukey's range test is presented with colour codes indicating statistical effect at a 5% significance level.

Resource	Threshold	Impact (Nlet-2)				Tukey's range test				
		Mean	SD	$P_{2.5}$	$P_{97.5}$	T02	T04	T06	T08	T10
Atlantic puffin (WG1) Open Sea Dataset	T00	19.3%	12.4%	3.2%	42.8%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	10.3%	7.1%	1.4%	25.1%	-	0.0000	0.0000	0.0000	0.0000
	T04	6.8%	5.1%	0.9%	18.6%	-	-	0.0458	0.0001	0.0000
	T06	5.4%	4.2%	0.7%	16.0%	-	-	-	0.4937	0.0472
	T08	4.5%	3.7%	0.6%	14.1%	-	-	-	-	0.8754
	T10	4.0%	3.3%	0.5%	12.9%	-	-	-	-	-
Black-legged kittiwake (WG2)	T00	3.1%	1.3%	1.3%	5.8%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	1.5%	0.7%	0.5%	3.1%	-	-	0.0000	0.0000	0.0000
	T04	1.0%	0.5%	0.3%	2.1%	-	-	0.0001	0.0000	0.0000
	T06	0.7%	0.4%	0.2%	1.5%	-	-	-	0.0826	0.0002
	T08	0.6%	0.3%	0.1%	1.3%	-	-	-	-	0.5704
	T10	0.5%	0.3%	0.1%	1.1%	-	-	-	-	-
Pelagic bird with uniform distribution (WG2)	T00	3.4%	1.1%	1.6%	5.8%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	1.9%	0.6%	0.7%	3.2%	-	0.0000	0.0000	0.0000	0.0000
	T04	1.3%	0.5%	0.4%	2.3%	-	-	0.0000	0.0000	0.0000
	T06	1.1%	0.4%	0.3%	2.0%	-	-	-	0.0110	0.0000
	T08	0.9%	0.4%	0.3%	1.7%	-	-	-	-	0.2673
	T10	0.8%	0.4%	0.2%	1.6%	-	-	-	-	-
Atlantic Puffin (WG1) Coastal dataset	T00	11.8%	11.4%	0.0%	33.9%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	7.3%	8.1%	0.0%	26.9%	-	0.0295	0.0001	0.0000	0.0000
	T04	5.6%	6.7%	0.0%	22.9%	-	-	0.6147	0.1105	0.0112
	T06	4.8%	6.0%	0.0%	20.8%	-	-	-	0.9262	0.4925
	T08	4.2%	5.6%	0.0%	19.1%	-	-	-	-	0.9700
	T10	3.8%	5.3%	0.0%	17.9%	-	-	-	-	-
Common Eider (WG3)	T00	2.8%	1.9%	0.0%	7.2%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	1.0%	1.0%	0.0%	3.6%	-	0.0090	0.0000	0.0000	0.0000
	T04	0.7%	0.8%	0.0%	2.8%	-	-	0.6151	0.1153	0.0075
	T06	0.6%	0.7%	0.0%	2.5%	-	-	-	0.9313	0.4173
	T08	0.5%	0.7%	0.0%	2.4%	-	-	-	-	0.9417
	T10	0.4%	0.7%	0.0%	2.3%	-	-	-	-	-
Grey Seal (WG9)	T00	0.5%	0.6%	0.0%	2.2%	0.0000	0.0000	0.0000	0.0000	0.0000
	T02	0.2%	0.2%	0.0%	0.9%	-	0.5300	0.1407	0.0304	0.0073
	T04	0.1%	0.2%	0.0%	0.8%	-	-	0.9763	0.7741	0.4946
	T06	0.1%	0.2%	0.0%	0.7%	-	-	-	0.9926	0.9141
	T08	0.1%	0.2%	0.0%	0.6%	-	-	-	-	0.9980
	T10	0.1%	0.2%	0.0%	0.5%	-	-	-	-	-

Atlantic puffin - open sea (spring)

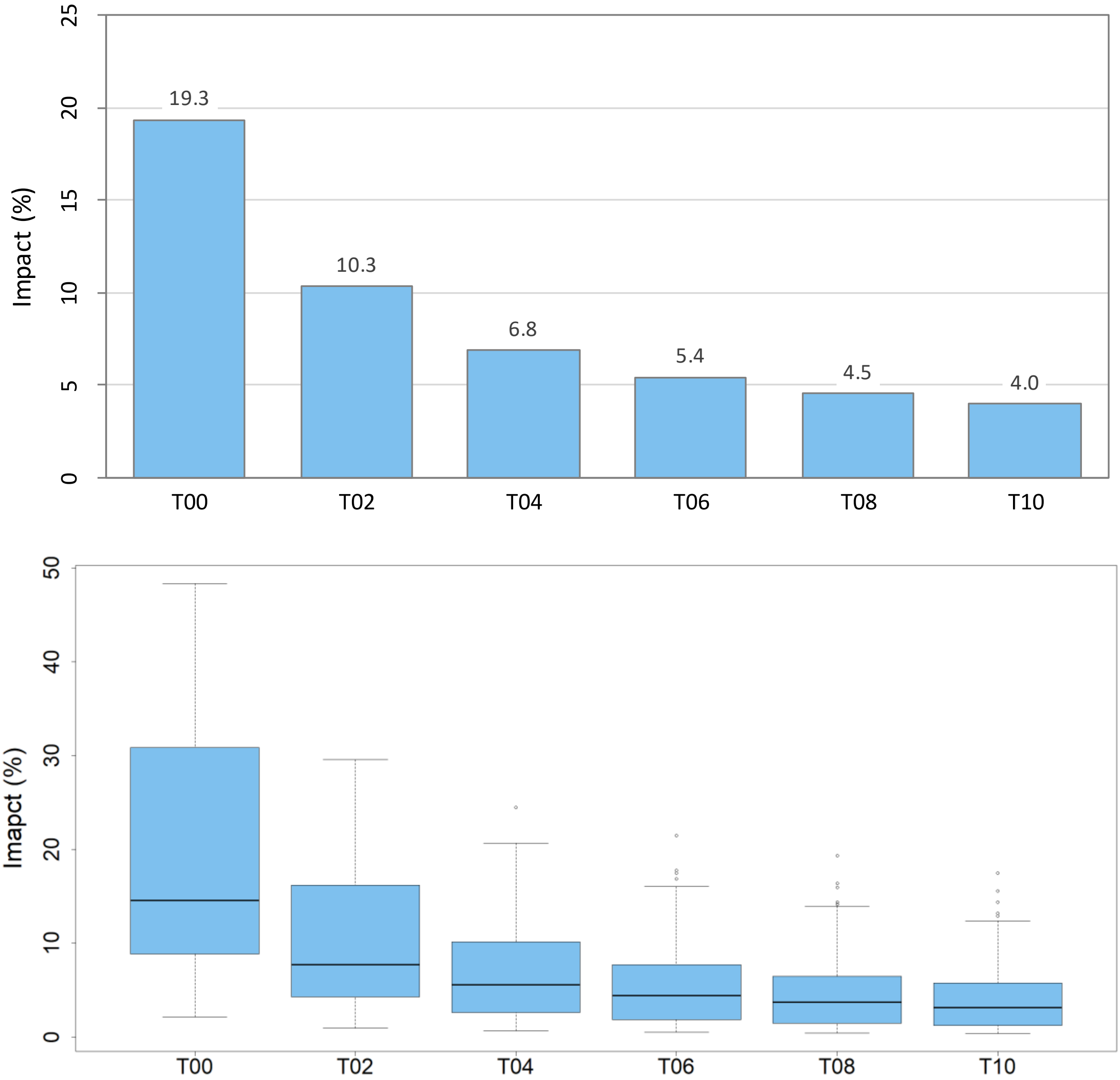


Figure 8. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Black-legged kittiwake (spring)

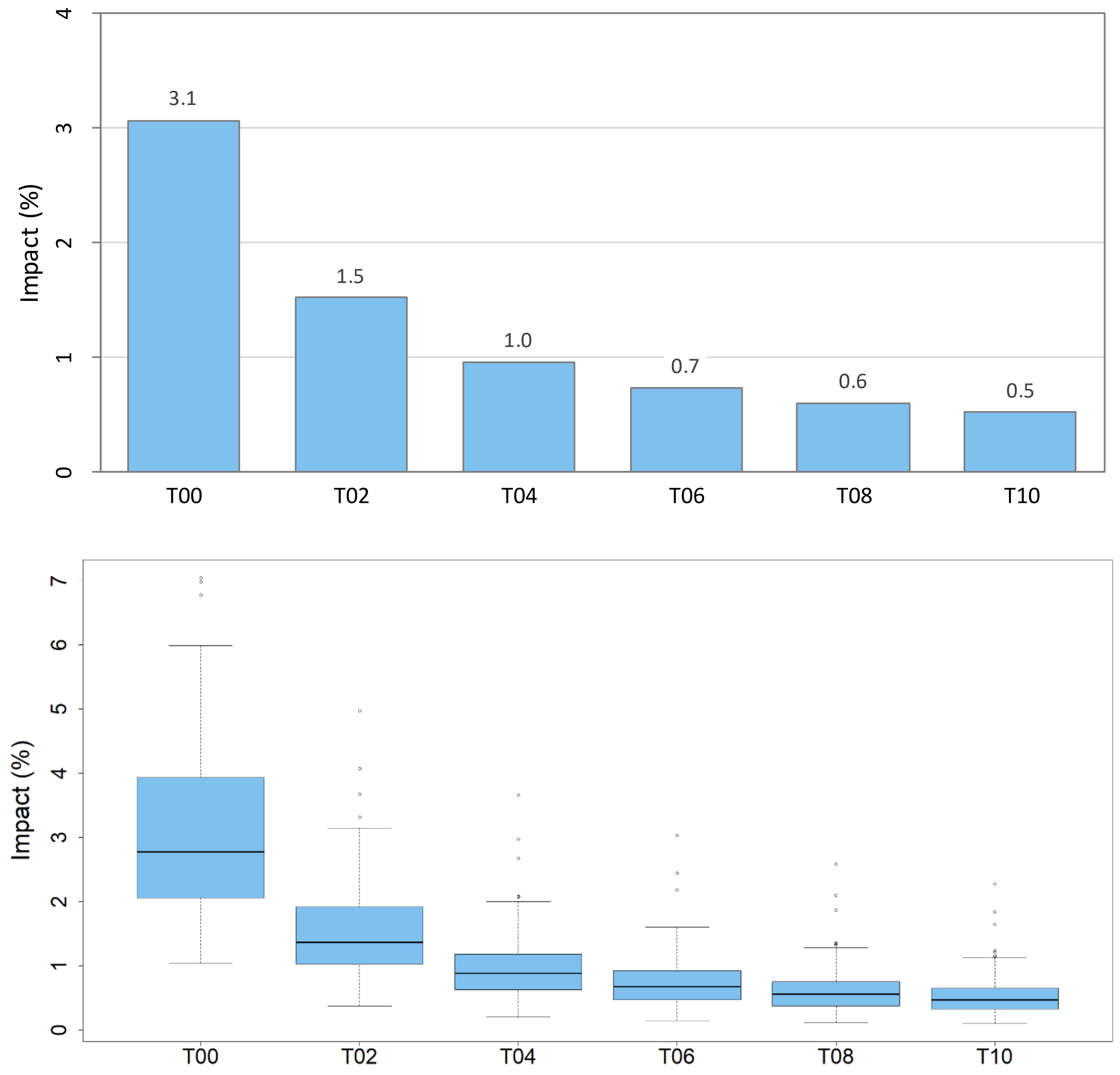
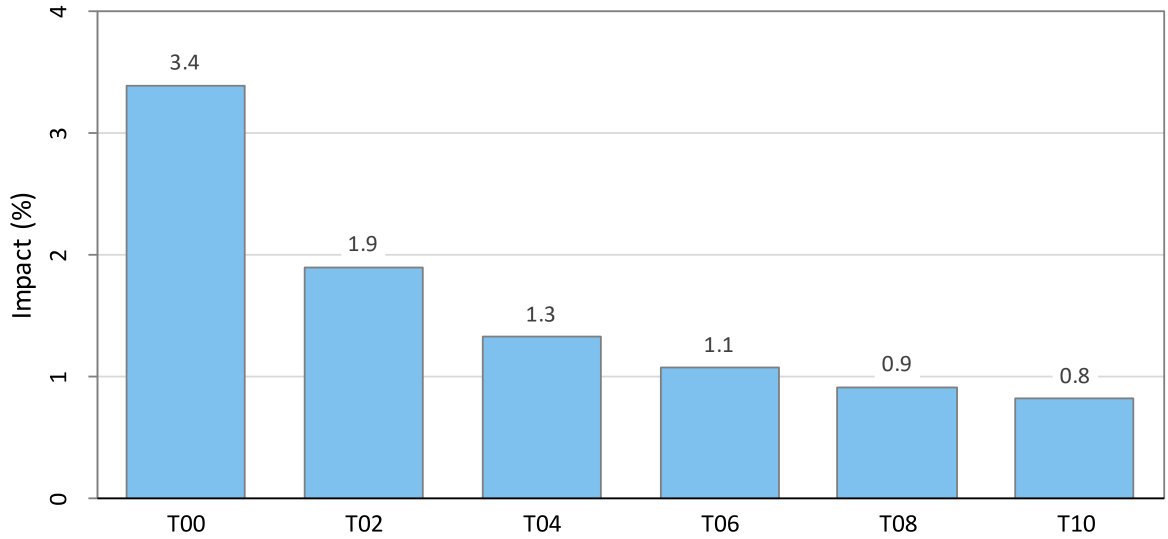


Figure 9. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Pelagic bird with uniform distribution



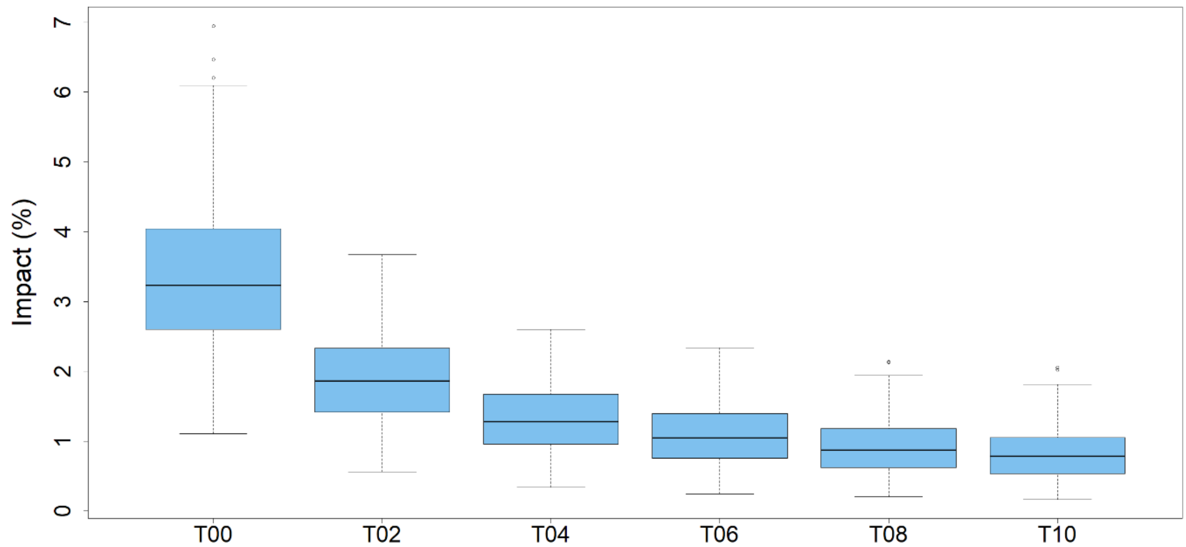


Figure 10. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Atlantic puffin coast

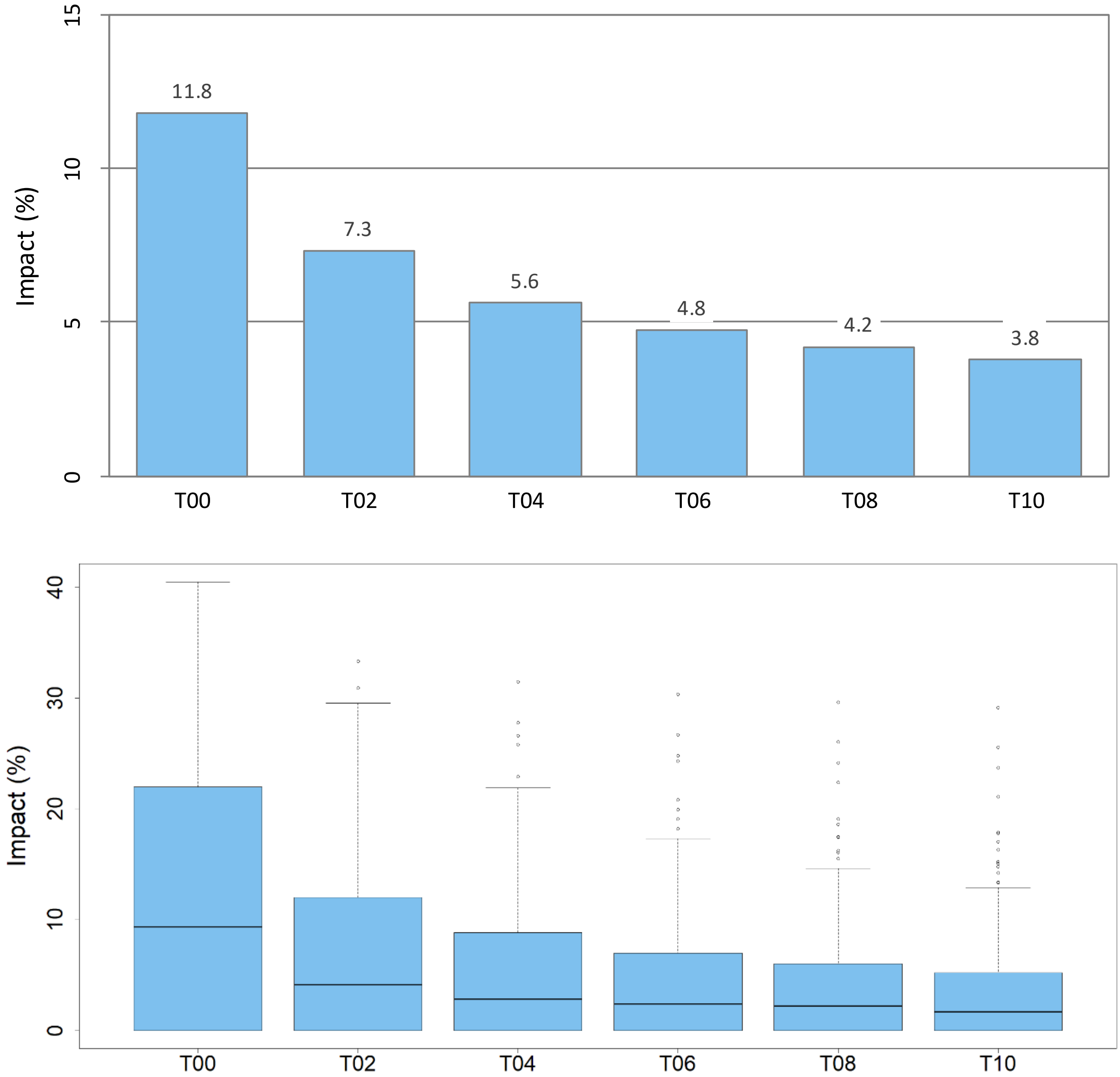
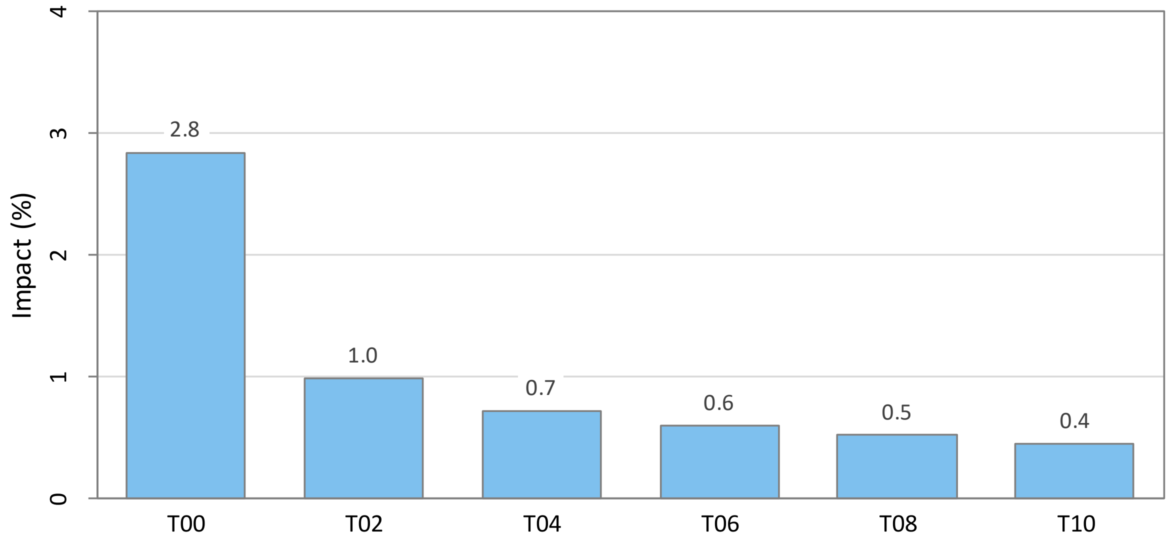


Figure 11. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Common eider



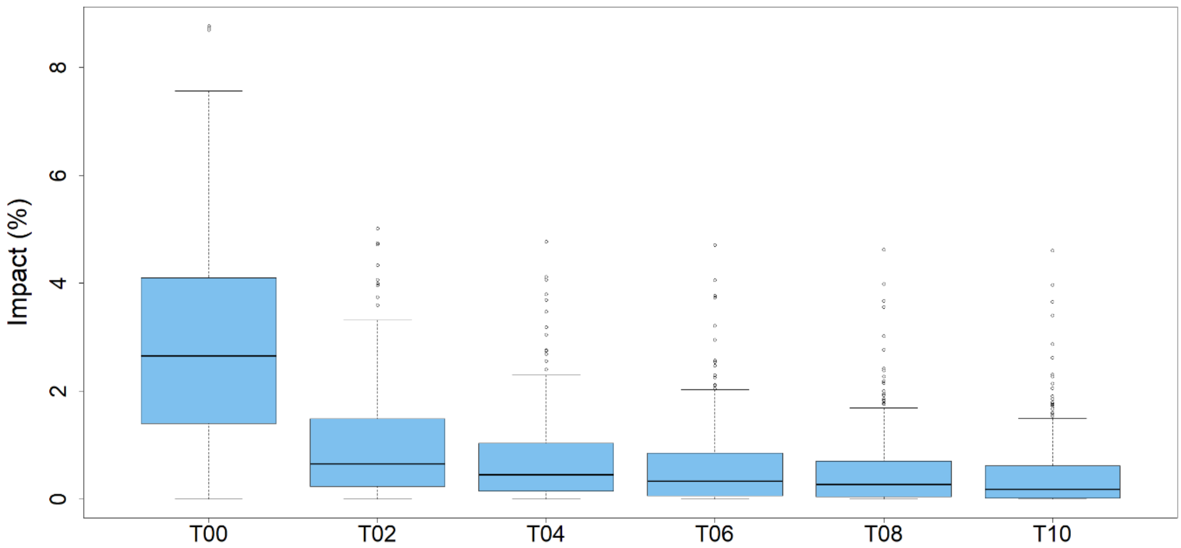


Figure 12. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Grey seal

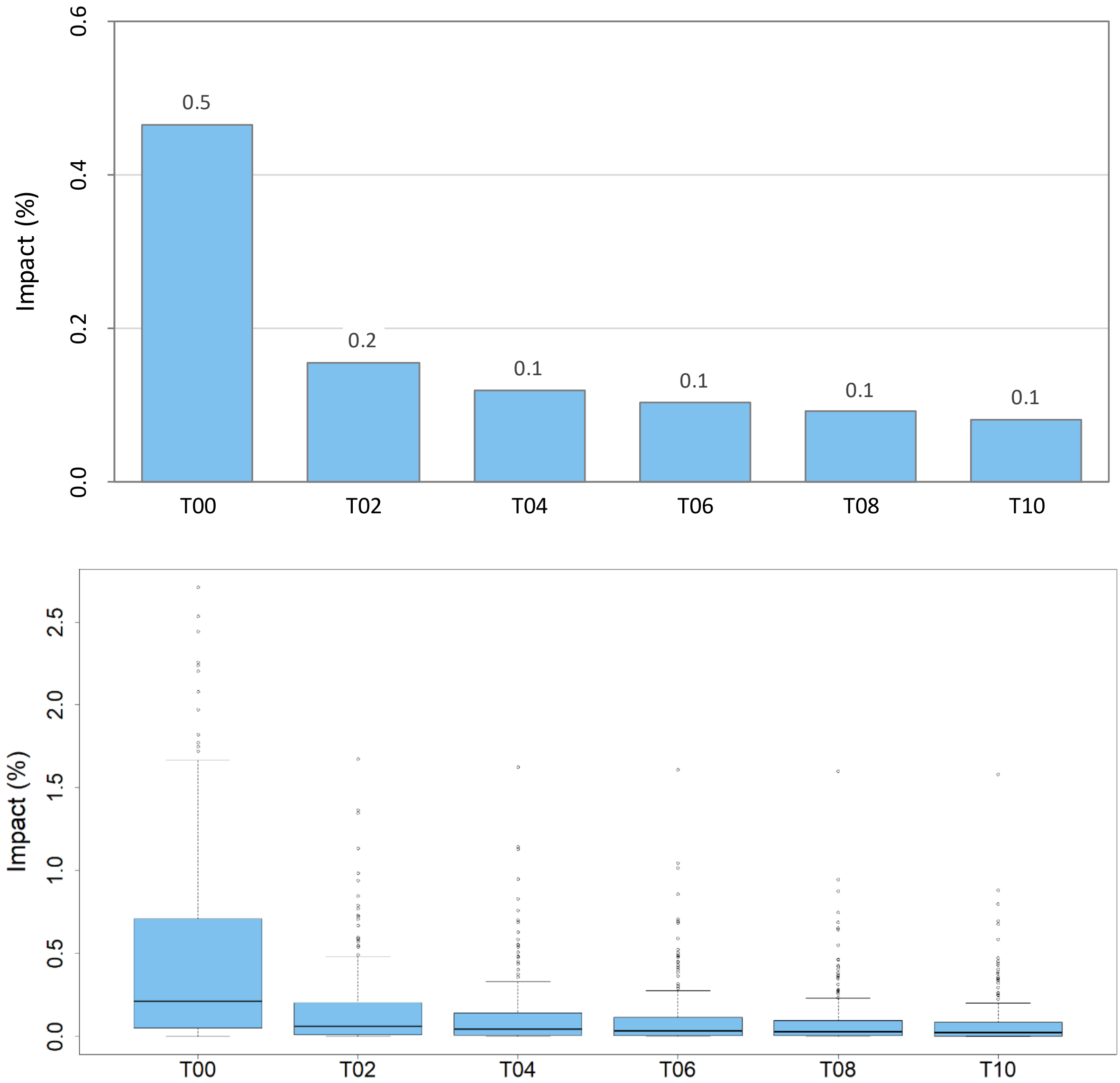


Figure 13. Percentage population loss for different threshold thicknesses estimated from stochastic oil drift simulations valid for March, April and May (n = 120). The bar diagrams (top) shows the mean population loss and the box plot shows the minimum, first quartile, median (typical value), third quartile, and maximum value. The whisker length is set at 1.5 times the inter-quartile range (IQR), with black rings showing outliers, including minimum and maximum values. See Table 2 for details.

Bibliography

Acona; Akvaplan-niva; DNV GL, 2016. Oljedriftsmodellering for standard miljørisikoanalyser ved bruk av OSCAR – beste praksis. A con, Akvaplan-niva & DNV GL.

Bjørgesæter, A., Damsgaard Jensen, J., 2015. ERA Acute Phase 3 – Surface compartment. Acona report to Statoil and Total. Report No. 37571. v.04. Oslo, 22.05.2015.

Brönner, U. (SINTEF), 2017. ERA Acute calculator - User manual. Version/Date: 0.59 / 24.11.2017.

Brönner, U. (SINTEF), Stefanakos, C., Skancke, J., 2017. ERA Acute calculator - Technical specification. Version/Date: 0.53 / 31.03.2017.

French-McCay, D., 2009. State-of-the-art and research needs for oil spill impact assessment modelling, in: Proceedings of the 32nd AMOP Technical Seminar on Environmental Contamination and Response. Emergencies Science Division, Environment Canada, Ottawa, ON, Canada, pp. 601–653.

French-McCay, D., 2004. Oil spill impact modeling: Development and validation. Environ. Toxicol. Chem. 23, 2441–2456.

Hughes, M.R., Kasserra, C., Thomas, B.R., 1990. Effect of externally applied bunker fuel on body mass and temperature, plasma concentration, and water flux of Glaucous-winged Gulls, Larus glaucescens. Can. J. Zool. 68, 716–721.

Jenssen, B.M., 1994. Review article: Effects of oil pollution, chemically treated oil, and cleaning on thermal balance of birds. Environ. Pollut. 86, 207–215.

Jenssen, B.M., Ekker, M., 1991a. Dose dependent effects of plumage oiling on thermoregulation of Common Eiders Somateria mollissima residing in water. Polar Res. 10, 579–584.

Jenssen, B.M., Ekker, M., 1991b. Effects of plumage contamination with crude oil dispersant mixtures on thermoregulation in common eiders and mallards. Arch. Environ. Contam. Toxicol. 20, 398–403.

Koops, W., Jak, R.G., Veen, D. van der P.C. van der, 2004. Use of dispersants in oil spill response to minimize environmental damage to birds and aquatic organisms, in: Interspill 2004. Presentation No 429. p. 21.

O'Hara, P.D., Morandin, L.A., 2010. Effects of sheens associated with offshore oil and gas development on the feather microstructure of pelagic seabirds. Mar. Pollut. Bull. 60, 672–678.

Peakall, D.B., Wells, P.G., Mackay, D., 1985. A hazard assessment of chemically dispersed oil spills and seabirds - a novel approach, in: Proceedings of the Eighth Annual Arctic Marine Oilspill Program Technical Seminar.

R Core Team, 2017. R: A Language and Environment for Statistical Computing.

Scholten, M.C.T., Kaag, N.H.B., Dokkum, H.P. van, Jak, R.G., Schobben, H.P.M., Slob, W., 1996. Toxische effecten van olie in het aquatische milieu. TNO report TNO-MEP – R96/230, Den Helder, The Netherlands.

Spikkerud, C.S., Skeie, G.M., Hoell, E., Mark, R., Brude, O.W., Bjørgesæter, A., 2010. ERA Acute, Oil spill risk assessment tool. Phase 1 - Design basis for model Level A. Akvaplan-niva AS Report: 4531.01.

Stephenson, R., 1997. Effects of oil and other surface-active organic pollutants on aquatic birds. Environ. Conserv. 24, 121–129.