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Open-File Report 2023–1048

U.S. Department of the Interior
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Contents

Figures

Tables

Abbreviations

CMIP6	Coupled Model Intercomparison Project Phase 6
CS	Chukchi Sea
ESM	Earth System Model
SB	southern Beaufort Sea
SSP1-2.6	greenhouse gas emission scenario SSP 1-2.6
SSP2-4.5	greenhouse gas emission scenario SSP 2-4.5
SSP5-8.5	greenhouse gas emission scenario SSP 5-8.5

Forecasts of Polar Bear (*Ursus maritimus*) Land Use in the Southern Beaufort and Chukchi Seas, 2040–65

By Karyn D. Rode[1], David C. Douglas[1], Todd C. Atwood[1], and Ryan R. Wilson[2]

Abstract

This report provides analysis to extend the 2040 forecasts of polar bear (*Ursus maritimus*) land use for the southern Beaufort and Chukchi Sea populations presented in a recent publication (Rode and others, 2022) through the year 2065. To inform long-term polar bear management considerations, we provide point-estimate forecasts and 95-percent prediction intervals of the proportion of polar bear populations summering onshore for 21 days or more (≥) and their duration onshore every 5 years from 2040 to 2065. Because sea-ice projections based on earth system models show greater divergence with emission scenarios after 2040, we have provided forecasts for three greenhouse gas emission scenarios, SSP1-2.6, SSP2-4.5 and SSP5-8.5, compared to the two emission scenarios used in Rode and others (2022). Our forecasting methods estimated that 61–97 percent of polar bears in the southern Beaufort Sea and 80–100 percent of polar bears in the Chukchi Sea populations may summer onshore for ≥21 days by 2065. Forecasts of mean duration onshore were 105–158 days for polar bears in the southern Beaufort Sea and 111–178 days in the Chukchi Sea populations by 2065. Sea ice conditions projected to occur by 2065 could alter the current patterns of bear behavior from what has been observed over the past 30 years. As a result, these extended projections are associated with a higher degree of uncertainty than estimates through 2040, especially under the SSP5-8.5 scenario.

Introduction

In November 2022, U.S. Geological Survey scientists, in collaboration with the U.S. Fish and Wildlife Service, forecasted summer land use by polar bears (*Ursus maritimus*) in the two populations whose range occurs in Alaska: the southern Beaufort Sea (SB) and Chukchi Sea (CS) populations (Rode and others, 2022). Location data collected from collared female polar bears in each population were used to identify the percentage of bears that summered on land and the relations between land use and sea-ice conditions between the 1980s and 2017. Forecasts of future land use were made using two approaches: (1) extrapolating the observed trends between the 1980s and 2017 and (2) using sea-ice projections from earth systems models (ESMs) in combination with observed relations between land use and sea-ice conditions. Here, we expand on this earlier work to forecast summer land use to the year 2065 in response to needs expressed by management agencies for forecasting beyond the previously-published period of 2023–40.

Forecasts based on sea-ice projections (hereinafter “sea-ice-based forecast”) used sea-ice projections estimated directly from global models when forced with different greenhouse gas emission scenarios. However, these sea-ice-based forecasts resulted in values that were below the endpoints of present-day trends in observed sea-ice conditions. This tendency for global climate models to overestimate current sea-ice extent has been referred to as “faster than forecast” (Stroeve and others, 2007). To compensate for these apparent overestimates, we have applied an ad hoc adjustment as described below and in Rode and others (2022), and we hereinafter refer to them as “adjusted-sea ice-based forecasts.” For both sea-ice-based forecasts, we diverge from Rode and others (2022) by analyzing three, rather than two, emission scenarios. Rode and others (2022) forecasted summer land use using sea-ice projections based on SSP1-2.6, in which greenhouse gas emissions are promptly and aggressively mitigated, and SSP5-8.5, in which atmospheric greenhouse gas concentrations rise unabated. Nevertheless, sea-ice projections showed little to no variation with emission scenario through 2040. However, after 2040, sea-ice projections begin to diverge with emission scenario. Therefore, in extending our forecasts to 2065, we added the SSP2-4.5 scenario, which represents a middle-of-the-road scenario in which emissions and land-use pathways are not extreme (O’Neill and others, 2016).

[1] U.S. Geological Survey

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Methods

Detailed methods used to generate the land-use forecasts are presented in Rode and others (2022). Here, rather than providing a single forecast for 2065, we provide point estimates and prediction intervals every 5 years during 2040–65 to assist in management planning. The results for 2040 presented here are identical to those in Rode and others (2022).

In Rode and others (2022), forecasts were made using three methods: (1) extrapolation of the observed trend in land use over the previous three decades, (2) use of sea-ice projections from earth system models (ESMs) with observed relationships between sea-ice availability and land use, and (3) use of the linear slope in sea-ice projections from ESMs with an adjustment on the y-axis to begin the projected sea-ice trend at the value obtained from regressing the past 20 years of observational sea-ice data. Here, we used the same three methods as we applied previously but for method 3, we generated point estimate forecasts from sea-ice projections in 5-year increments. Because the trajectory of the sea-ice projections was not always linear depending on the end year of the forecast, the slope of the ESM multi-model sea-ice projection was specific to each end year and emission scenario (Rode and others, 2022, fig. S2). These longer-range forecasts in comparison to forecasting in Rode and others (2022) resulted in some of the forecasted estimates for the percentage of the population summering onshore exceeding 100 percent. Because that is not plausible, we report the estimates capped at 100 percent. We present results for both the sea-ice-based and adjusted-sea-ice-based forecasts but focus our summary on the latter forecast in addition to the extrapolated forecast.

Results

A summary of forecasted point estimates in 2065 using all three forecasting methods is provided in table 1. Figure 1 shows forecasted point estimates and prediction intervals for each land-use metric (percentage onshore and duration onshore) for the SB and CS populations every 5 years from 2040 to 2065 based on method 1 (extrapolation) and method 3 (adjusted sea-ice-based forecast). Results in figure 1 are presented in tables 2–5, accompanied by additional results obtained with forecasting method 2 (sea-ice projections that were not corrected for faster than forecast).

Polar bear land-use forecasts for 2040 through 2065 differed considerably depending on the greenhouse gas emissions scenario used by ESMs to project future sea-ice conditions (fig. 1). Under the SSP1-2.6 scenario, sea-ice loss after mid-century stabilizes so polar bear land-use forecasts based on sea ice (methods 2 and 3) also stabilize. In contrast, under SSP5-8.5, forecasted land use by polar bears continues to increase as more sea ice melts.

Table 1. Estimates of the percentage of polar bears (*Ursus maritimus*) summering onshore in the southern Beaufort Sea (SB) and Chukchi Sea (CS) populations and their estimated duration onshore in the year 2065 for three greenhouse gas emission scenarios from global circulation models (SSP1-2.6, 2-4.5, and 5-8.5).

[Ninety-five percent prediction intervals are shown in parentheses adjacent to the point estimates. NA, not applicable]

Scenario	SB		CS	
	Percentage onshore	**Duration (days)**	**Percentage onshore**	**Duration (days)**
Method 1—Extrapolation				
NA	75 (31–100)	140 (96–184)	100 (48–100)	178 (108–247)
Method 2—Sea-ice-based forecast				
SSP1-2.6	51 (21–80)	91 (53–130)	75 (32–100)	105 (56–154)
SSP2-4.5	72 (32–100)	123 (77–168)	97 (44–100)	130 (74–186)
SSP5-8.5	80 (36–100)	135 (86–184)	100 (46–100)	135 (78–193)
Method 3—Adjusted-sea-ice-based forecast				
SSP1-2.6	61 (26–95)	105 (64–146)	80 (34–100)	111 (60–161)
SSP2-4.5	79 (35–100)	132 (84–180)	100 (48–100)	138 (80–197)
SSP5-8.5	97 (43–100)	158 (104–214)	100 (53–100)	150 (87–212)

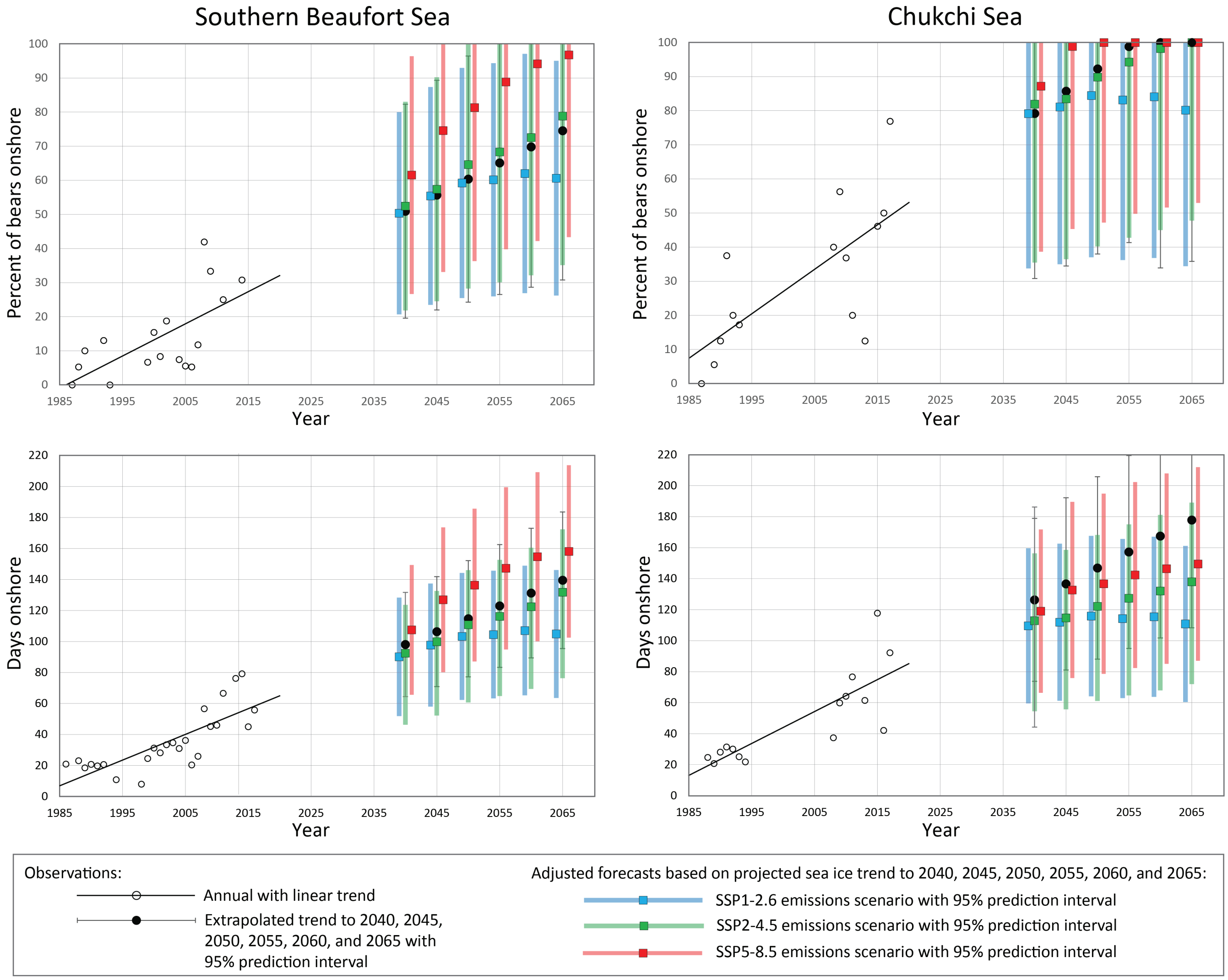

Figure 1. Forecasts of the percent of polar bears (*Ursus maritimus*) summering onshore and their duration onshore in the southern Beaufort Sea and Chukchi Sea populations estimated from the slope of trend in projected sea-ice conditions by earth system models and observed relationships between changes in sea ice availability and changes in land use. Forecasts are provided in 5-year increments for three greenhouse gas emission scenarios.

Table 2. Estimates of the percent of polar bears (*Ursus maritimus*) summering onshore in the southern Beaufort Sea population forecasted for every 5 years from 2040 to 2065 for three greenhouse gas emission scenarios from global circulation models (SSP 1-2.6, 2-4.5, and 5-8.5).

[Ninety-five percent prediction intervals are shown in parentheses adjacent to the point estimates. NA, not applicable]

Scenario	Year					
	2040	2045	2050	2055	2060	2065
Method 1—Extrapolation						
NA	51 (20–82)	56 (22–89)	60 (24–97)	65 (27–100)	70 (29–100)	75 (31–100)
Method 2—Sea-ice-based forecast						
SSP1-2.6	41 (15–67)	51 (21–80)	54 (23–85)	48 (19–76)	56 (23–86)	51 (21–80)
SSP2-4.5	52 (22–83)	53 (22–84)	58 (25–92)	60 (26–93)	64 (27–98)	72 (32–100)
SSP5-8.5	55 (23–87)	62 (27–98)	65 (28–100)	78 (35–100)	77 (34–100)	80 (36–100)
Method 3—Adjusted-sea-ice-based forecast						
SSP1-2.6	50 (21–80)	55 (24–87)	59 (26–93)	60 (26–94)	62 (27–97)	61 (26–95)
SSP2-4.5	52 (22–83)	57 (25–90)	65 (28–100)	68 (30–100)	74 (32–100)	79 (35–100)
SSP5-8.5	62 (27–96)	75 (33–100)	81 (36–100)	89 (40–100)	94 (42–100)	97 (43–100)

Table 3. Estimates of the duration (in days) polar bears (*Ursus maritimus*) may summer onshore in the southern Beaufort Sea population forecasted for every 5 years from 2040 to 2065 for three greenhouse gas emission scenarios from global circulation models (SSP 1-2.6, 2-4.5, and 5-8.5).

[Ninety-five percent prediction intervals are shown in parentheses adjacent to the point estimates. NA, not applicable]

Scenario	Year					
	2040	2045	2050	2055	2060	2065
Method 1—Extrapolation						
NA	98 (65–132)	106 (71–142)	115 (77–152)	123 (83–163)	131 (90–173)	140 (96–184)
Method 2—Sea-ice-based forecast						
SSP1-2.6	77 (41–113)	91 (53–130)	96 (57–136)	87 (50–125)	97 (58–137)	91 (53–130)
SSP2-4.5	94 (55–133)	95 (56–134)	103 (62–144)	105 (63–146)	109 (67–151)	123 (77–168)
SSP5-8.5	98 (59–138)	109 (67–151)	112 (69–155)	131 (84–179)	130 (83–178)	135 (86–184)
Method 3—Adjusted-sea-ice-based forecast						
SSP1-2.6	90 (52–128)	98 (58–137)	103 (62–144)	105 (63–146)	107 (65–149)	105 (64–146)
SSP2-4.5	94 (55–131)	100 (60–140)	111 (68–154)	116 (72–160)	122 (77–168)	132 (84–180)
SSP5-8.5	108 (66–149)	127 (80–174)	136 (87–186)	147 (95–200)	155 (100–209)	158 (103–214)

Table 4. Estimates of the percentage of polar bears (*Ursus maritimus*) summering onshore in the Chukchi Sea population forecasted for every 5 years from 2040 to 2065 for three greenhouse gas emission scenarios from global circulation models (SSP 1-2.6, 2-4.5, and 5-8.5).

[Ninety-five percent prediction intervals are shown in parentheses adjacent to the point estimates. NA, not applicable]

Scenario	Year					
	2040	2045	2050	2055	2060	2065
Method 1—Extrapolation						
NA	79 (31–100)	86 (35–100)	92 (38–100)	99 (41–100)	100 (45–100)	100 (48–100)
Method 2—Sea-ice-based forecast						
SSP1-2.6	69 (27–100)	73 (30–100)	75 (31–100)	84 (36–100)	81 (35–100)	75 (31–100)
SSP2-4.5	72 (29–100)	77 (33–100)	80 (34–100)	87 (39–100)	90 (40–100)	97 (44–100)
SSP5-8.5	82 (36–100)	88 (39–100)	86 (38–100)	200 (46–100)	99 (46–100)	100 (46–100)
Method 3—Adjusted-sea-ice-based forecast						
SSP1-2.6	79 (34–100)	81 (35–100)	85 (37–100)	83 (36–100)	84 (37–100)	80 (34–100)
SSP2-4.5	82 (36–100)	84 (37–100)	90 (40–100)	94 (43–100)	98 (45–100)	100 (48–100)
SSP5-8.5	87 (39–100)	99 (45–100)	100 (47–100)	100 (50–100)	100 (52–100)	100 (53–100)

Table 5. Estimates of the duration (in days) polar bears (*Ursus maritimus*) may summer onshore in the Chukchi Sea population forecasted for every 5 years from 2040 to 2065 for three greenhouse gas emission scenarios from global circulation models (SSP 1-2.6, 2-4.5, and 5-8.5).

[Ninety-five percent prediction intervals are shown in parentheses adjacent to the point estimates. NA, not applicable]

Scenario	Year					
	2040	2045	2050	2055	2060	2065
Method 1—Extrapolation						
NA	126 (74–179)	137 (81–192)	147 (88–206)	157 (95–220)	168 (102–233)	178 (108–247)
Method 2—Sea-ice-based forecast						
SSP1-2.6	98 (51–145)	103 (54–151)	105 (56–154)	114 (63–165)	112 (61–162)	105 (56–154)
SSP2-4.5	101 (53–149)	107 (58–157)	110 (60–161)	119 (67–172)	122 (69–176)	130 (74–186)
SSP5-8.5	113 (62–165)	119 (67–172)	118 (66–170)	134 (77–191)	133 (76–190)	135 (78–193)
Method 3—Adjusted-sea-ice-based forecast						
SSP1-2.6	110 (60–160)	112 (61–163)	116 (64–168)	114 (63–166)	115 (64–167)	111 (60–161)
SSP2-4.5	113 (62–164)	115 (63–166)	122 (69–176)	127 (72–183)	132 (75–189)	138 (80–197)
SSP5-8.5	119 (66–172)	133 (76–190)	137 (79–195)	142 (82–202)	147 (85–208)	150 (87–212)

Discussion

Rode and others (2022) reported that over the past three decades, the percentage of polar bears summering onshore increased from 5 to 30 percent in the southern Beaufort Sea (SB) and 10 to 50 percent in the Chukchi Sea (CS). Duration onshore for both populations increased by more than 30 days to 60–70 days between the 1980s and 2020. Based on the extrapolation and adjusted-sea-ice-based forecasts, by 2040, an estimated 50–62 percent of SB and 79–87 percent of CS polar bears were forecasted to respectively spend 90–108 and 110–126 days onshore during the summer months. The forecasts presented here, which extend to 2065, estimate that if patterns observed over the past 30 years continue (that is, the forecast based on extrapolations in tables 2 and 4), 75 percent of polar bears in the SB and 100 percent of polar bears in the CS would summer onshore. Estimates of the percent of bears onshore varied widely with greenhouse gas emission scenario for the adjusted sea-ice-based forecasts (tables 2 and 4) from as low as 61 percent in the SB under SSP1-2.6 to as high as 97 percent under SSP5-8.5. Extrapolation of observed linear trends estimated that polar bears would spend 140 and 178 days summering onshore in the SB and CS, respectively, by 2065. In the SB, forecasted time frame onshore using adjusted sea-ice projections estimated that polar bears would spend 105–158 days onshore by 2065 depending on emission scenario. In the CS, the extrapolated estimate of duration onshore was higher than the range using adjusted sea-ice projections estimated across emission scenarios (111–150 days).

Forecasting polar bear behavior 45 years into the future based on correlations with past observations inherently entails high uncertainty. Rode and others (2022, p. 17) postulated that “the generalized response by polar bears to increasingly use land habitats in response to sea ice loss is likely to continue beyond 2040 and be affected by the level of greenhouse gas emissions” but chose not to estimate land-use metrics beyond 2040 because the observational relations underlying the forecasts could change. For example, many of the CMIP6 ESMs used in this study project that by 2065 sea ice will melt entirely in late summer, especially under the SSP5-8.5 emissions scenario (Douglas and Atwood, 2022). Polar bears choosing to remain on sea ice throughout the summer would need to migrate with the retreating ice pack into the high latitudes of northwestern Canada and northern Greenland (where remnants of sea ice will likely persist the longest) and ultimately come ashore in those areas if the ice melted completely. Such novel environmental conditions are not explicitly represented in the observed responses of polar bears to past sea-ice changes that underlie the forecasts generated here, so the resulting land-use estimates possess a greater degree of uncertainty, especially under the high emissions scenario.

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