

## APPENDIX A - Marine Invasive Ranking System

**Scientific name:** [Insert here]

**Common name:** [Insert here]

**Ranking Score = (Total Score/Total Possible)\*100**

Category	Score	Possible Points	Data Deficient Points
Distribution and Habitat	##	30	
Anthropogenic Transportation and Establishment	##	10	
Biological Characteristics	##	30	
Ecological and Socioeconomic Impacts	##	30	
<i>Feasibility of Prevention, Detection and Control</i> <small>*not included in final rank</small>	*	*	
<b>TOTAL</b>			

### Basic Biological Information

#### *Physical description*

**Documentation:**

Sources:

#### *General information*

**Documentation:**

Sources:

## Invasiveness Ranking

### 1. Distribution and Habitat - Similarity between study area and current distribution

#### *1.1 Survival requirements - Water temperature*

- A. Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for year-round survival (3.75)
- B. Moderate overlap – A moderate area ( $\geq 25\%$ ) of the Bering Sea has temperatures suitable for year-round survival (2. 5)
- C. Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for year-round survival (1.25)
- D. No overlap – Temperatures required for survival do not exist in the Bering Sea (0)
- E. Unknown/Data deficient (U)

Score: #/3.75

**Documentation:**

Rationale:

Sources:

#### *1.2 Survival requirements - Water salinity*

- A. Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for year-round survival (3.75)
- B. Moderate overlap – A moderate area ( $\geq 25\%$ ) of the Bering Sea has salinities suitable for year-round survival (2.5)
- C. Little overlap – A small area (<25%) of the Bering Sea has salinities suitable for year-round survival (1.25)
- D. No overlap – Salinities required for survival do not exist in the Bering Sea (0)
- E. Unknown/Data deficient (U)

Score: #/3.75

**Documentation:**

Rationale:

Sources:

**1.3 Establishment requirements - Water temperature**

- A. Considerable overlap – A large area (>75%) of the Bering Sea has temperatures suitable for reproduction (3.75)
- B. Moderate overlap – A moderate area ( $\geq 25\%$ ) of the Bering Sea has temperatures suitable for reproduction (2.5)
- C. Little overlap – A small area (<25%) of the Bering Sea has temperatures suitable for reproduction (1.25)
- D. No overlap – Temperatures required for reproduction do not exist in the Bering Sea (0)
- E. Unknown/Data deficient (U)

Score: #/3.75

**Documentation:**

Rationale:

Sources:

**1.4 Establishment requirements - Water salinity**

- A. Considerable overlap – A large area (>75%) of the Bering Sea has salinities suitable for reproduction (3.75)
- B. Moderate overlap – A moderate area ( $\geq 25\%$ ) of the Bering Sea has salinities suitable for reproduction (2.5)
- C. Little overlap – A small area (<25%) of the Bering Sea has salinities suitable for reproduction (1.25)
- D. No overlap – Salinities required for reproduction do not exist in the Bering Sea (0)
- E. Unknown/Data deficient (U)

Score: #/3.75

**Documentation:**

Rationale:

Sources:

**1.5 Local ecoregional distribution**

- A. Present in the Bering Sea (5)
- B. Present in an ecoregion adjacent to the Bering Sea (3.75)
- C. Present in an ecoregion two regions away from the Bering Sea (*i.e.* adjacent to an adjacent ecoregion) (2.5)
- D. Present in an ecoregion greater than two regions away from the Bering Sea (1.25)
- E. Unknown/Data deficient (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**1.6 Global ecoregional distribution**

- A. In many ecoregions globally (5)
- B. In a moderate number of ecoregions globally (3.3)
- C. In few ecoregions globally (1.7)
- D. Unknown/Data deficient (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**1.7 Current distribution trends**

- A. Recent rapid range expansion and/or long-distance dispersal (within the last ten years) (5)
- B. History of rapid expansion or long-distance dispersal (prior to the last ten years) (3.3)
- C. Established outside of native range, but no evidence of rapid expansion or long-distance dispersal (1.7)
- D. Not well established outside of native range (0)
- E. Unknown/Data deficient (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

<b>Total:</b>	<input type="text"/>
<b>Total Possible:</b>	<input checked="" type="text"/> 30
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## 2. Anthropogenic Transportation and Establishment

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### 2.1 Transport requirements: relies on use of shipping lanes (hull fouling, ballast water), fisheries, recreation, mariculture, etc. for transport

- A. Has been observed using anthropogenic vectors for transport and transports independent of any anthropogenic vector once introduced (4)
- B. Has been observed using anthropogenic vectors for transport but has rarely or never been observed moving independent of anthropogenic vectors once introduced (2)
- C. Has not been observed using anthropogenic vectors (0)
- D. Unknown (U)

Score: #/4

**Documentation:**

Rationale:

Sources:

### 2.2 Establishment requirements: relies on marine infrastructure, (e.g. harbors, ports) to establish

- A. Readily establishes in areas with anthropogenic disturbance/infrastructure and in natural, undisturbed areas (4)
- B. Readily establishes in areas with anthropogenic disturbance/infrastructure; occasionally establishes in undisturbed areas (2.7)
- C. Uses anthropogenic disturbance/infrastructure to establish; never observed establishing in undisturbed areas (1.3)
- D. Does not use anthropogenic disturbance/infrastructure to establish (0)
- E. Unknown (U)

Score: #/4

**Documentation:**

Rationale:

Sources:

### 2.3 Is this species currently or potentially farmed or otherwise intentionally cultivated?

- A. Yes (2)
- B. No (0)
- C. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

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<b>Total Possible:</b>	<b>10</b>
<b>Total %:</b>	
<b>Data Deficient:</b>	

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## 3. Biological Characteristics

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### 3.1 Dietary specialization

- A. Generalist at all life stages and/or foods are readily available in the study area (5)
- B. Generalist or specialist at different life stages and/or foods are moderately available in the study area (3.3)
- C. Specialist, dependent on a narrow range of foods for all life stages and/or foods are not commonly available in the study area (1.7)
- D. Unknown (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**3.2 Habitat specialization and water tolerances**

*Does the species use a variety of habitats or tolerate a wide range of temperatures, salinity regimes, dissolved oxygen levels, calcium concentrations, hydrodynamics, pollution, etc.?*

- A. Generalist; wide range of habitat tolerances at all life stages (5)
- B. Requires specialized habitat for some life stages (e.g., reproduction) (3.3)
- C. Specialist; dependent on a narrow range of habitats for all life stages (1.7)
- D. Unknown (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**3.3 Desiccation tolerance**

- A. Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle (5)
- B. Moderately tolerant (1-7 days) during one or more stages during its life cycle (3.3)
- C. Little to no tolerance (<1 day) of desiccation during its life cycle (1.7)
- D. Unknown (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**3.4 Likelihood of success for reproductive strategy**

- i. Asexual or hermaphroditic
  - ii. High fecundity (e.g. >10,000 eggs/kg)
  - iii. Low parental investment and/or external fertilization
  - iv. Short generation time
- A. High – Exhibits three or four of the above characteristics (5)
  - B. Moderate – Exhibits one or two of the above characteristics (3.3)
  - C. Low – Exhibits none of the above characteristics (1.7)
  - D. Unknown (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

**3.5 Likelihood of long-distance dispersal or movements**

*Consider dispersal by more than one method and/or life stages e.g., broadcast spawners, float, swim, crawl, carried in currents; planktonic larvae vs. sessile adult.*

- A. Disperses long (>10 km) distances (2.5)
- B. Disperses moderate (1-10 km) distances (0.7)
- C. Disperses short (< 1 km) distances (0.8)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**3.6 Likelihood of dispersal or movement events during multiple life stages**

- i. Can disperse at more than one life stage and/or highly mobile
  - ii. Larval viability window is long (days v. hours)
  - iii. Different modes of dispersal are achieved at different life stages (e.g. unintentional spread of eggs, migration of adults)
- A. High – Exhibits two or three of the above characteristics (2.5)
  - B. Moderate – Exhibits one of the above characteristics (1.7)
  - C. Low – Exhibits none of the above characteristics (0.8)
  - D. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**3.7 Vulnerability to predators**

- A. Lacks natural predators (5)
- B. Few predators only in its home range, and not suspected in the Bering Sea or neighboring regions (3.75)
- C. Few predators suspected present in the Bering Sea and neighboring regions, and/or multiple predators in its native range (2.5)
- D. Multiple predators present in the Bering Sea or neighboring regions (1.25)
- E. Unknown (U)

Score: #/5

**Documentation:**

Rationale:

Sources:

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<b>Total Possible:</b>	<input type="text" value="30"/>
<b>Total %:</b>	<input type="text"/>

**Data Deficient:** 

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**4. Ecological and Socioeconomic Impacts****I. Ecological Impacts****4.1 Impact on community composition**

- A. High – Entire community and/or may cause extirpation or extinction at the species or trophic level (2.5)
- B. Moderate – More than one trophic level; may cause declines but not extirpation (1.7)
- C. Limited – Single trophic level; may cause decline but not extirpation (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**4.2 Impact on habitat for other species**

- A. High – Is known to cause changes to multiple habitats (2.5)
- B. Moderate – Causes or has potential to cause changes to one or more habitats (1.7)
- C. Limited – Has limited potential to cause changes in one or more habitats (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**4.3 Impact on ecosystem structure and function**

*Does this species impact food webs or ecosystems by affecting more than one trophic level or abiotic components? Through feeding, burrowing, excretion, or other behaviors, does it change ecosystem functions (e.g., water flow, light availability, nutrient cycling)? Consider species that are top predators, that create major changes to their habitat, and/or that occur at very high densities.*

- A. High – Is known to cause moderate to severe changes to food webs and/or ecosystem functions; effects have been documented in several areas (2.5)

- B. Moderate – Causes moderate changes to food webs *or* ecosystem functions in several areas, or causes severe effects in only one or a few areas (e.g., in areas where species occurs at high densities) (1.7)
- C. Limited – Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**4.4 Impact on rare, sensitive, or high ecological value species and/or communities**

- A. High – Is known to cause degradation of multiple species or communities and/or is expected to have severe impacts (2.5)
- B. Moderate – Causes or has potential to cause degradation of one or more species or communities, with moderate impact (1.7)
- C. Limited – Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**4.5 Introduction of diseases, parasites or travelers**

*What level of impact could the species' associated diseases, parasites, or travelers have on other species in the assessment area? Is it a host and/or vector for recognized pests or pathogens, particularly other non-native organisms?*

- A. High – Is known to spread multiple organisms and/or is expected to have severe impacts and/or will impact the entire region (2.5)
- B. Moderate – Spreads or has potential to spread one or more organisms, with moderate impact and/or within only a portion of region (1.7)
- C. Limited – Has limited potential to spread one or more organisms, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

**4.6 Level of genetic impact on native species**

*Can this invasive species hybridize with native species?*

- A. High – Is known to cause genetic changes to multiple species (e.g. hybridization), and/or is expected to have severe impacts and/or will impact the entire region (2.5)
- B. Moderate – Causes or has potential to cause genetic changes in one or more species, with moderate impact and/or within only a portion of the region (1.7)
- C. Limited – Has limited potential to cause genetic changes in one or more species, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

**Documentation:**

Rationale:

Sources:

## **II. Socioeconomic Impacts**

### **4.7 Infrastructure**

- A. High – Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate – Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited – Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

#### **Documentation:**

Rationale:

Sources:

### **4.8 Commercial fisheries and aquaculture**

- A. High – Is known to cause degradation to fisheries and aquaculture and/or is expected to have severe impacts in the region (3)
- B. Moderate – Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region (1.5)
- C. Limited – Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

#### **Documentation:**

Rationale:

Sources:

### **4.9 Subsistence**

- A. High – Is known to cause degradation to subsistence resources and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate – Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited – Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

#### **Documentation:**

Rationale:

Sources:

### **4.10 Recreation**

- A. High – Is known to cause degradation to recreation opportunities and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate – Causes or has the potential to cause degradation to recreation opportunities, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited – Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

#### **Documentation:**

Rationale:

Sources:

**4.11 Human health and water quality**

- A. High – Is known to pose a threat to human health and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate – Causes or has the potential to pose a threat to human health, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited – Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

**Documentation:**

Rationale:

Sources:

<b>Total:</b>	<input type="text"/>
<b>Total Possible:</b>	<b>30</b>
<b>Total %:</b>	<input type="text"/>
<b>Data Deficient:</b>	<input type="text"/>

**5. Feasibility of prevention, detection and control – \* Not included in invasiveness score****5.1 History of management, containment, and eradication**

- A. Attempted; control methods are not successful (2)
- B. Not attempted (1.5)
- C. Attempted; control methods are currently in development/being studied (1)
- D. Attempted and control methods are established and effective (0.5)
- E. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

**5.2 Cost and methods of management, containment, and eradication**

- A. Major long-term investment, or is not feasible at this time (2)
- B. Major short-term and/or moderate long-term investment (1.4)
- C. Easy and inexpensive (minor investment) (0.7)
- D. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

**5.3 Regulatory barriers to prevent introductions and transport**

- A. Little to no regulatory restrictions (2)
- B. Regulatory oversight, but compliance is voluntary (1.6)
- C. Regulatory oversight and/or trade restrictions (1.2)
- D. Strict prohibition and some infrastructure for interception (0.8)
- E. Transport and trade are illegal (0.4)
- F. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

**5.4 Presence and frequency of monitoring programs**

- A. No surveillance takes place (2)

- B. Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g., citizen science programs) (1.6)
- C. State and/or federal monitoring programs exist, but monitoring is infrequent (1.2)
- D. State and/or federal monitoring programs exist, and monitoring is conducted frequently (0.8)
- E. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

**5.5 Current efforts for outreach and education**

- A. No education or outreach takes place (2)
- B. Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions (1.5)
- C. Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions (1)
- D. Programs and materials exist and are readily available in the Bering Sea or adjacent regions (0.5)
- E. Unknown (U)

Score: #/2

**Documentation:**

Rationale:

Sources:

<b>Total:</b>	<input type="text"/>
<b>Total Possible:</b>	<b>10</b>
<b>Total %:</b>	
<b>Data Deficient:</b>	

## APPENDIX B: COMMON SCENARIOS & RANKING RATIONALE

During the ranking process, common scenarios arose for various animal groups, which required a standardized ranking approach to ensure consistency across species and reviewers. This document outlines the recommended scores and justification for these scenarios in the context of ranking the threat of non-native marine species to the Bering Sea. These scores are meant to serve as recommendations for general animal groups only. When available, species-specific information should always be used to supplement the information provided here.

This document is organized to follow the layout of the ranking system. Please note that this document is not a comprehensive guide to all questions in the ranking system, but highlights common scenarios that arose during the ranking process for non-native species in the Bering Sea.

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## INTRODUCTION SECTION: GENERAL INFORMATION

This section of the ranking system presents general information about each species including water temperature and salinity thresholds required for survival and reproduction, and general notes about the species biology, habitat or distribution. This section is not scored and is intended to provide the reader with general information about the species.

## GENERAL CAVEAT: DIADROMOUS SPECIES

For species that require freshwater for part their life cycle, a caveat should be included in the General Biology Notes section. The following example is for an anadromous species:

“Atlantic Salmon require freshwater to spawn. A thorough risk assessment for this species must therefore consider compatibility with both freshwater and marine conditions. However, in keeping with the scope of this project (the Bering Sea ecosystem), we assess this species' impacts and establishment potential only with respect to its marine life phase.”

## CATEGORY 1: DISTRIBUTION AND HABITAT

This section of the ranking system addresses the presence of suitable habitat in the Bering Sea, and the species' regional and global distribution. Species with widespread ranges are more likely to have a wide niche tolerance, and therefore more likely to establish additional populations (because of increased propagule pressure) than species with restricted ranges (Ehrlich 1986; Carlton 1996; Rouget and Richardson 2003). However, although a species may be globally widespread, if it is unable to survive and successfully reproduce in climates similar to the Bering Sea, the ecological threat is greatly reduced. Therefore, this section also considers whether the species' climatic tolerances fall within the range encountered in the Bering Sea.

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## QUESTIONS 1.1 TO 1.4 - SURVIVAL & ESTABLISHMENT REQUIREMENTS

Questions 1.1 to 1.4 assess whether suitable habitat exists in the Bering Sea for survival (1.1 and 1.2) and reproduction (1.3 and 1.4), based on the species' temperature and salinity thresholds. The answers to each question are similarly phrased as follows:

- A. Considerable overlap – A large area ( $>75\%$ ) of the Bering Sea has [temperatures/salinities] suitable for [year-round survival/reproduction] (3.75)
- B. Moderate overlap – A moderate area ( $\geq 25\%$ ) of the Bering Sea has [temperatures/salinities] suitable for [year-round survival/reproduction] (2.5)
- C. Little overlap – A small area ( $<25\%$ ) of the Bering Sea has [temperatures/salinities] suitable for [year-round survival/reproduction] (1.25)
- D. No overlap – [Temperatures/Salinities] required for [year-round survival/reproduction] do not exist in the Bering Sea (0)
- E. Unknown/Data deficient (U)

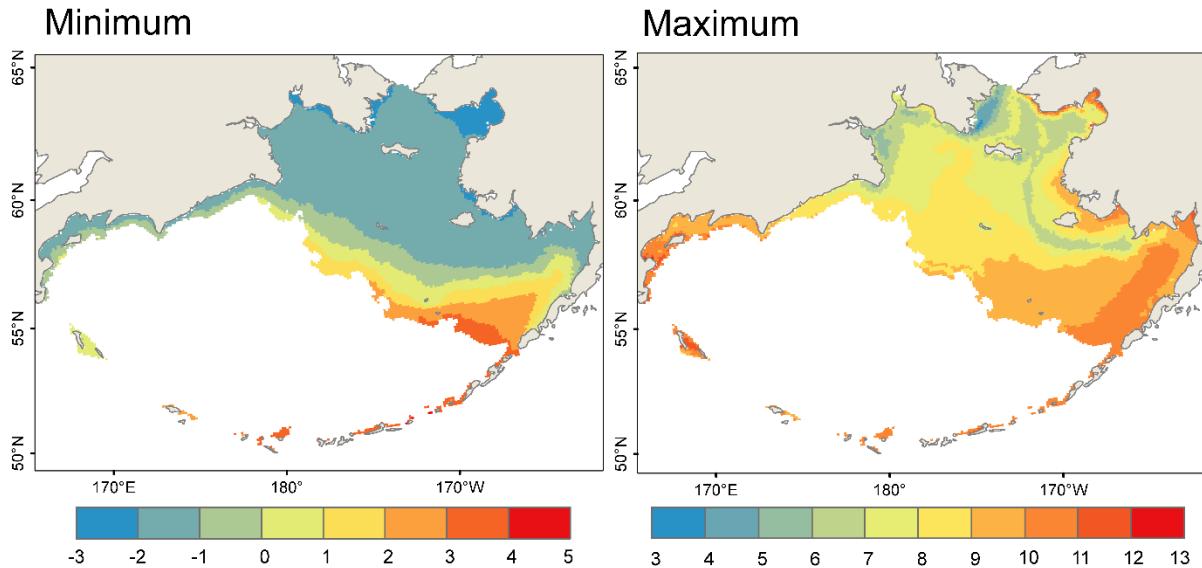
Score: #/3.75

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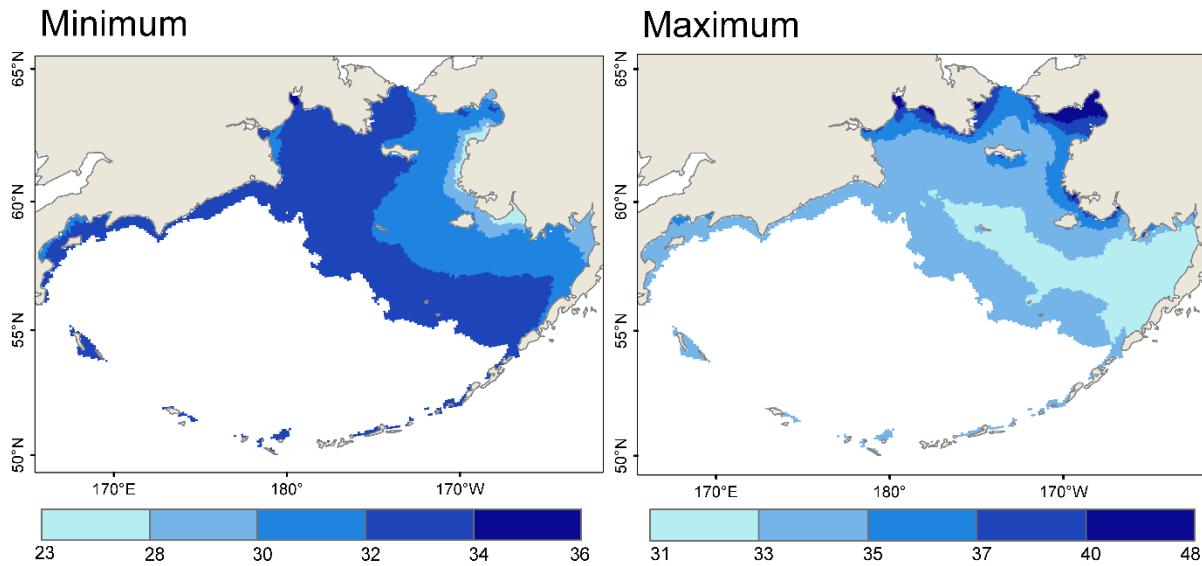
### I. QUANTIFYING SUITABLE HABITAT FOR SURVIVAL AND REPRODUCTION – SPECIES WITH KNOWN THRESHOLDS REPORTED IN THE LITERATURE

To quantify the amount of habitat suitable for survival/reproduction, use the maps below to estimate the amount of area in the Bering Sea that does not exceed the minimum or maximum temperature/salinity survival/reproduction threshold for a species, as defined in the literature.

## Model-averaged temperature ( $^{\circ}\text{C}$ ) of the Bering Sea, 2003-2012



## Model-averaged salinity (ppt) of the Bering Sea, 2003-2012



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## II. QUANTIFYING SUITABLE HABITAT FOR SURVIVAL AND REPRODUCTION – SPECIES WITH THRESHOLDS DERIVED FROM GEOGRAPHIC DISTRIBUTION

To quantify the amount of habitat suitable for survival/reproduction, use the maps above (section I) to estimate the amount of area in the Bering Sea that does not exceed the minimum or maximum temperature/salinity survival/reproduction threshold for a species, as identified from its current geographic distribution.

Recommended Rank: *Variable*, depending on how much area is predicted as suitable. In all cases, rank with *High Uncertainty*

Example Rationale: Thresholds are based on geographic distribution, which may not represent physiological tolerances. We therefore ranked this question with high uncertainty.

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## III. SPECIES THAT REQUIRE FRESHWATER FOR REPRODUCTION

Recommended Rank: **D**; No overlap, for both 1.3 and 1.4. Due to their inability to reproduce in a marine system, regardless of temperature overlap, these species should generate a score of zero for reproduction.

Recommended Rationale: This species requires freshwater to spawn.

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## IV. MARINE SPECIES WITH UNKNOWN SALINITY THRESHOLDS

Recommended Rank: **A**; Considerable overlap, with *High Uncertainty*

Example Rationale:

*For survival:* Although salinity thresholds are unknown, this species is a marine organism. We therefore assume that it can survive in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

*For reproduction:* Although salinity thresholds are unknown, this species is a marine organism that does not require freshwater to reproduce. We therefore assume that this species can reproduce in saltwater (31 to 35 ppt). These salinities occur in a large (>75%) portion of the Bering Sea.

### CATEGORY 3: BIOLOGICAL CHARACTERISTICS

This category addresses core life history characteristics that may increase the potential for a species to spread and become established. Generalist species with broad diets or environmental tolerances are more likely to survive and thrive in new areas (Smith 2009; Katsanevakis et al. 2014). Additionally, species that reproduce throughout the year or that have high population growth rates are more likely to quickly create a viable population in the new area. Lastly, species capable of frequent or long-distance movements are more likely to disperse to expand their range and recruit from other areas (Swearer et al. 2002; Hastings et al. 2005).

Within this category, information on desiccation tolerance was often missing at the species-level, but was available at higher taxonomic levels. Two taxonomic groups, which were represented by several species in our ranking list, are addressed here: ray-finned fish (Class: Actinopterygii) and tunicates (Class: Ascidiacea).

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### QUESTION 3.3 - DESICCATION TOLERANCE

- A. Highly tolerant (>7 days) of desiccation at one or more stages during its life cycle (5)
- B. Moderately tolerant (1-7 days) during one or more stages during its life cycle (3.3)
- C. Little to no tolerance (<1 day) of desiccation during its life cycle (1.7)
- D. Unknown (U)

Score: #/5

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#### I. RAY-FINNED FISH

Recommended Rank: **C**; Little to no tolerance.

Example Rationale: “[Species X] cannot survive out of water for extended periods of time.”

Example Documentation: “[Species X] is a ray-finned fish that requires water for respiration (Randall 1970).”

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#### II. TUNICATES

Recommended Rank: **C**; Little to no tolerance, with *High Uncertainty*

Recommended Rationale: In general, tunicates have low to little desiccation tolerance.

Example Documentation: Tunicates are easily killed by desiccation, which has been used successfully as a field management tool to remove fouling tunicates (Pleus 2008).

## CATEGORY 4: ECOLOGICAL AND SOCIOECONOMIC IMPACTS

This category addresses the severity of the threat of a species to natural and anthropogenic systems, based on impacts that have been reported elsewhere in its introduced range. Questions are divided into two sections: ecological impacts that address effects to populations, communities, and ecosystem processes; and socioeconomic impacts that address effects to commercial and subsistence activities, recreation, and human health and water quality.

The impacts of a non-native species may be difficult to rank because many impacts are context-specific, dependent not only on the invading species itself, but also on the properties of the ecosystem it invades. For example, some species can have large deleterious impacts in one area, but can be relatively benign in another.

In this chapter we focused on ranking guidelines for taxonomic or functional groups that are represented by several species in our ranking list. These groups include: fouling organisms, bivalves (Class: Bivalvia), species that affect seagrass, and species that affect bivalves. Fouling organisms include species that foul habitats or other organisms (e.g. grow on bivalves, seagrass, rocky substrates), or that foul man-made structures and gear (e.g. vessel hulls, sea chests, fishing nets, docks).

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#### GENERAL CAVEAT: DIADROMOUS SPECIES

Diadromous species should only be evaluated with respect to their impacts on marine systems. Species that have large impacts on freshwater systems, but are not known to impact marine systems (e.g. *Esox lucius*) should receive low scores for most questions in this category.

#### GENERAL CAVEAT: SPECIES WITH NO DOCUMENTED IMPACTS

For species where no effects have been documented, and none are expected based on a species' biology and previous history in regions outside the Bering Sea, a recommended rank of **D**; No impact, is suggested for all applicable impact questions.

Recommended Rationale: No impacts have been reported. Given its ecology, we do not expect this species to impact [e.g. ecosystem processes, habitat, infrastructure] in the Bering Sea.

#### QUESTION 4.2 - IMPACT ON HABITAT FOR OTHER SPECIES

- A. High - Is known to cause changes to multiple habitats (2.5)
- B. Moderate - Causes or has potential to cause changes to one or more habitats (1.7)
- C. Limited - Has limited potential to cause changes in one or more habitats (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

#### I. FOULING ORGANISMS

##### Recommended Rank:

Bivalves that create extensive reefs or beds should be ranked **A**; High.

Flat species (e.g. encrusting bryozoans) and species that do not create extensive and/or three-dimensional habitat (e.g. some tunicates) may warrant a rank of **B**; Moderate or **C**; Limited.

If no species-specific information is provided, but similar species are known to impact habitat, rank **C**; Limited.

Recommended Rationale: By fouling substrates, this species [may] reduce available habitat for some organisms. Conversely, it may create secondary settlement habitat for other fouling organisms.

#### II. SPECIES THAT AFFECT SEAGRASS

Recommended Rank: **A – C**, depending on severity of effects.

Documentation: In Alaska, eelgrass (*Zostera marina*) is the dominant seagrass species, ranging almost continuously from southeast Alaska north into the Bering Sea, up to ~67°N (Hogrefe et al. 2014). Seagrass meadows provide habitat and refuge for several taxa including juvenile fish, shellfish, epiphytes, and other invertebrates (Winfree 2005; Orth et al. 2006).

#### QUESTION 4.3 - IMPACT ON ECOSYSTEM STRUCTURE AND FUNCTION

- A. High- Is known to cause moderate to severe changes to food webs and/or ecosystem functions; effects have been documented in several areas (2.5)
- B. Moderate- Causes moderate changes to food webs *or* ecosystem functions in several areas, or causes severe effects in only one or a few areas (e.g. in rare cases when species occurs at high densities) (1.7)
- C. Limited- Causes or potentially causes changes to food webs and/or ecosystem functions, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

---

#### I. SPECIES THAT AFFECT SEAGRASS

Recommended Rank: **A – C**, depending on severity of effects.

Documentation: Seagrass support a variety of ecosystem functions through their role as primary producers, by affecting water flow, stabilizing sediments, assimilating nutrients, and by supporting a high diversity of plants and animals (Costanza et al. 1997; Winfree 2005; Orth et al. 2006).

#### QUESTION 4.4 - IMPACT ON RARE, SENSITIVE, OR HIGH ECOLOGICAL VALUE SPECIES AND/OR COMMUNITIES

- A. High - Is known to cause degradation of multiple species or communities and/or is expected to have severe impacts (2.5)
- B. Moderate - Causes or has potential to cause degradation of one or more species or communities, with moderate impact (1.7)
- C. Limited - Has limited potential to cause degradation of one more species or communities, with limited impact and/or within a very limited region (0.8)
- D. No impact (0)
- E. Unknown (U)

Score: #/2.5

---

#### I. SPECIES THAT AFFECT SEAGRASS

Recommended Rank: **A – C**, depending on severity of effects.

Recommended Rationale: This species affects seagrasses, which are sensitive and ecologically valuable taxa.

Documentation: Seagrass support a variety of ecosystem functions through their role as primary producers, by affecting water flow, stabilizing sediments, assimilating nutrients, and by supporting a high diversity of plants and animals (Costanza et al. 1997; Winfree 2005; Orth et al. 2006). Seagrass are sensitive species and are declining worldwide from threats such as climate change and anthropogenic disturbance (Orth et al. 2006; Hogrefe et al. 2014).

#### QUESTION 4.7 INFRASTRUCTURE

- A. High - Is known to cause degradation to infrastructure and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate - Causes or has the potential to cause degradation to infrastructure, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited - Has limited potential to cause degradation to infrastructure, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

#### I. FOULING ORGANISMS

Recommended Rank: *Variable*, depending on severity of effects.

If the species is known to foul infrastructure (e.g. vessels, docks, or fishing gear), but no species-specific effects have been reported, and species does not occur at high densities rank **C**; Limited.

If species occurs at high densities and moderate effects have been documented, rank **B**; Moderate.

If species occurs at high densities, but no effects have been documented, rank **B**; Moderate, with *High Uncertainty*.

Recommended Rationale: Limited/Moderate/High impacts on infrastructure are expected given its abundance as a fouling organism.

Documentation: Fouling organisms on ships cause drag, reduce maneuverability, and increase fuel costs. It is estimated that hull fouling organisms cost the U.S. Navy over \$50 million a year in fuel due to increased drag (Cleere 2001).

#### QUESTION 4.8 - COMMERCIAL FISHERIES AND AQUACULTURE

- A. High - Is known to cause degradation to fisheries and aquaculture and/or is expected to have severe impacts in the region (3)
- B. Moderate - Causes or has the potential to cause degradation to fisheries and aquaculture, with moderate impact in the region (1.5)
- C. Limited - Has limited potential to cause degradation to fisheries and aquaculture, and/or is restricted to a limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

---

## I. SPECIES THAT AFFECT BIVALVES

Recommended Rank: This rank should not exceed **B**; Moderate.

Example Rationale: The following can be stated after species-specific rationale is described: "Since shellfish aquaculture is currently a small industry in Alaska and occurs only in a restricted area of the Bering Sea, the overall impacts to fisheries and aquaculture are anticipated to be relatively small."

Documentation: The mariculture industry in Alaska is estimated at \$1 million, with 95% of sales coming from Pacific oysters (PSI 2017). Mariculture is most important in the Gulf of Alaska, and only occurs in limited parts of the Bering Sea (Mathis et al. 2015). In contrast, commercial fisheries in the Bering Sea (including groundfish, crabs, and salmon) generates an estimated harvest value of over \$1 billion per year (ASMI 2017).

### QUESTION 4.9 - SUBSISTENCE

- A. High - Is known to cause degradation to subsistence resources and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate - Causes or has the potential to cause degradation to subsistence resources, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited - Has limited potential to cause degradation to subsistence resources, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

---

## I. SPECIES THAT AFFECT BIVALVES

Recommended Rank: This rank should not exceed **B**; Moderate.

Example Rationale: "This species negatively affects the growth and recruitment of bivalves through [fouling and/or predation]. Given the limited importance of shellfish to subsistence harvesting in the Bering Sea, it is expected to have a relatively [moderate or limited] impact on subsistence in general in this region."

Documentation: In most municipalities of the Bering Sea, shellfish such as oysters, clams, and mussels comprise a small percentage of subsistence catch (< 5% when measured by weight, except for the Western Aleutians; Mathis et al. 2015).

### QUESTION 4.10 - RECREATION

- A. High - Is known to cause degradation to recreation opportunities and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate - Causes or has the potential to cause degradation to recreation opportunities, with moderate impact and/or within only a portion of the region (1.5)

- C. Limited - Has limited potential to cause degradation to recreation opportunities, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

## I. SPECIES THAT AFFECT BIVALVES

Recommended Rank: Should not exceed **C**; Limited. Recreational harvesting of shellfish is uncommon in the Bering Sea. If a species fouls gear and equipment for bivalve harvest (e.g. mussel socks), but not the bivalves themselves, rank as **D**; No Impact.

Recommended Rationale: Although this species [may] negatively affect bivalves, recreational harvesting of shellfish in the Bering Sea is limited.

## QUESTION 4.11 - HUMAN HEALTH AND WATER QUALITY

- A. High - Is known to pose a threat to human health and/or is expected to have severe impacts and/or will impact the entire region (3)
- B. Moderate - Causes or has the potential to pose a threat to human health, with moderate impact and/or within only a portion of the region (1.5)
- C. Limited - Has limited potential to pose a threat to human health, with limited impact and/or within a very limited region (0.75)
- D. No impact (0)
- E. Unknown (U)

Score: #/3

## I. BIVALVE SPECIES

Recommended Rank: **C**; Limited.

Recommended Rationale: Cases of PSP and other shellfish syndromes are rare in Alaska. Current regulations and safety procedures greatly reduce the risk of bacterial transmission, especially in cultivated mussels. Recreational harvesting of shellfish in the Bering Sea is limited.

Documentation: All bivalves can bioaccumulate toxins in their tissues as a result of consuming toxic dinoflagellates. Consuming raw or cooked bivalves can lead to Paralytic Shellfish Poisoning (PSP), which can cause health issues and even death (NIMPIS 2009). The state of Alaska discourages harvesting on untested beaches (ADEC 2013)."

## CATEGORY 5: FEASIBILITY OF PREVENTION, DETECTION AND CONTROL

This category addresses the feasibility of controlling a species once it becomes invasive. The questions consider the history and cost of management outside of Alaska, current regulations, and current monitoring efforts. Since few invasive species have established in the Bering Sea, and the feasibility of control is largely speculative, this section was created to inform managers as a supplement to the invasiveness rank. The guidelines presented here focus on taxonomic or functional groups that are represented by several species in our ranking list. These groups include: species transported by ballast water, species transported by hitchhiking (e.g. accidentally transported or introduced alongside other organisms), species transported by fouling (e.g. on hulls, anchors, sea chests, or other wetted surfaces), bivalves (Class: Bivalvia), fish species (Class: Actinopterygii) and tunicates (Class: Ascidiacea).

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## GENERAL CAVEAT: SPECIES TRANSPORTED BY MULTIPLE VECTORS

For species transported by more than one anthropogenic vectors (e.g. larvae in ballast tanks, adults on vessel hulls), scores should be based on the worst case scenario (i.e. the vector associated with the highest score), unless there is evidence that one vector acts as the primary transportation vector.

## QUESTION 5.1 - HISTORY OF MANAGEMENT, CONTAINMENT, AND ERADICATION

- A. Attempted; control methods are not successful (2)
- B. Not attempted (1.5)
- C. Attempted; control methods are currently in development/being studied (1)
- D. Attempted and control methods are established and effective (0.5)
- D. Unknown (U)

Score: #/2

---

### I. SPECIES TRANSPORTED BY MULTIPLE VECTORS

Documentation: Controlling the spread of invasive species that use anthropogenic vectors for transport is an active area of research (e.g. Ruiz and Reid 2007; Hagan et al. 2014).

---

### II. SPECIES TRANSPORTED BY BALLAST WATER

Recommended Rank: **C**; Attempted; control methods are currently in development/being studied.

Documentation: Ballast water exchange is the method currently used by most ships to reduce the spread of species by ballast water. However, it is considered a short-term or “stop-gap” option until more effective, technology-based methods become available e.g., ballast water treatment systems (Ruiz and Reid 2007). The treatment of ballast water is an active area of research as vessels must comply with new regulations.

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### III. SPECIES TRANSPORTED BY FOULING

Recommended Rank: **C**; Attempted; control methods are currently in development/being studied.

Documentation: Fouling technologies that treat and safely dispose of marine organisms are currently being studied (Frey et al. 2014; Hagan et al. 2014).

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### IV. SPECIES TRANSPORTED BY HITCHHIKING

Recommended Rank: **B**; Not attempted; *High Uncertainty*

Recommended Rationale: No information regarding management, containment or eradication were found in the literature.

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## V. SOLITARY TUNICATES

Recommended Rank: **C**; Attempted; control methods are currently in development/being studied.

Documentation: Several control methods are being tested and include high-pressure washing and cleaning with a lime solution (DFO 2010)."

### QUESTION 5.2 - COST AND METHODS OF MANAGEMENT, CONTAINMENT, AND ERADICATION

- A. Major long-term investment, or is not feasible at this time (2)
- B. Major short term, or moderate long term investment (1.4)
- C. Easy and inexpensive (minor investment) (0.7)
- D. Unknown (U)

Score: #/2

---

## I. SPECIES TRANSPORTED BY MULTIPLE VECTORS

Recommended Rank: **A**; Major long-term investment, or is not feasible at this time.

Documentation: Methods to control the spread of marine invasive species (e.g. through ballast water treatment or vessel cleaning) are being studied, and currently necessitate major long-term investments (Zagdan 2010; Hagan et al. 2014).

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## II. SPECIES TRANSPORTED BY BALLAST WATER

Recommended Rank: **B**; Major short term, or moderate long term investment.

Recommended Rationale: To comply with ballast water regulations, vessels will have to equip themselves with an onboard ballast water treatment system. These systems represent a major short-term cost for vessel owners (up to \$3 million), with additional costs over time to maintain and replace equipment (e.g. chemicals, filters, UV light bulbs).

Documentation: The costs associated with purchasing a ballast water treatment system depend on the volume of water that needs to be treated. Systems with a pump capacity of 200-250 m<sup>3</sup>/h can cost from \$175,000 to \$490,000. The estimated price for larger systems ranges from \$650,000 to nearly \$3 million.

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## III. SPECIES TRANSPORTED BY FOULING

Recommended Rank: **B**. Major short term, or moderate long term investment.

Recommended Rationale: Current hull fouling technologies that specifically address invasive species require specialized equipment and regular cleaning.

Documentation: Vessels can be cleaned in-water or when dry docking. In-water cleaning costs range from AUD \$18 800 to \$255 000+ and takes between 16 to 48 hours (Franmarine 2013). The cost of dry

docking (including cleaning and loss of business costs) varies from AUD \$62 200 to > \$1.3 million, depending on vessel size (Franmarine 2013). There are few technologies currently available that are specifically designed to safely dispose of biological organisms. One such cleaning system is the Australian Franmarine cleaning system, which collects, treats, and disposes of fouling organisms. This system costs between AUD ~ \$500 000 to \$750 000, depending on vessel size (Franmarine 2013).

#### QUESTION 5.3 - REGULATORY BARRIERS TO PREVENT INTRODUCTIONS AND TRANSPORT

- A. Little to no regulatory restrictions (2)
- B. Regulatory oversight exist, but compliance is voluntary (1.6)
- C. Regulatory oversight and/or trade restrictions (1.2)
- D. Strict prohibition and some infrastructure for interception (0.8)
- E. Transport and trade are illegal (0.4)
- F. Unknown (U)

Score: #/2

---

#### I. SPECIES TRANSPORTED BY MULTIPLE VECTORS

Recommended Rank: **B**; Regulatory oversight exist, but compliance is voluntary.

Recommended Rationale: This species is transported by numerous vectors, not all of which are mandatory or addressed by regulations.

Documentation: In the U.S., ballast water management is mandatory and regulated by the U.S. Coast Guard (CFR 33 § 151.2). However, compliance with ship fouling regulations remains largely voluntary (Hagan et al. 2014).

---

#### II. SPECIES TRANSPORTED BY BALLAST WATER

Recommended Rank: **C**; Regulatory oversight and/or trade restrictions.

Recommended Rationale: U.S. federal regulations require mandatory reporting and ballast water treatment or exchange.

Documentation: In the U.S., ballast water management is mandatory and regulated federally by the U.S. Coast Guard, with additional permitting by the Environmental Protection Agency (CFR 33 § 151.2; EPA 2013; EPA 2014). Certain vessels are exempted from USCG and EPA regulations.

---

#### III. SPECIES TRANSPORTED BY FOULING

Recommend Rank: **B**. Regulatory oversight exist, but compliance is voluntary.

Recommended Rationale: Compliance with fouling regulations is voluntary.

Documentation: In the U.S., Coast Guard regulations require masters and ship owners to clean vessels and related infrastructure on a regular basis (CFR 33 § 151.2050). Failure to remove fouling organisms is

punishable with a fine (up to \$27 500). However, because the word “regular” is not defined, regulations are hard to enforce and compliance remains largely voluntary (Hagan et al. 2014). Cleaning of recreational vessels is also voluntary. In summer 2016, state and federal agencies conducted voluntary inspections for aquatic invasive species on trailered boats entering the state of Alaska (Davis 2016).

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#### IV. SPECIES TRANSPORTED BY HITCHHIKING

Recommended Rank: **A**; Little to no regulatory restrictions.

Recommended Rationale: No regulations exist to prevent the spread of invasive species by hitchhiking.

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#### V. BIVALVE SPECIES

Recommended Rank: **C**; Regulatory oversight and/or trade restrictions.

Recommended Rationale: Regulations exist in Alaska regarding the transport and introduction of shellfish in water bodies.

Documentation: Under Alaska law, a permit must be obtained from the Alaska Department of Fish and Game in order to collect, possess, or transport shellfish for educational, scientific, or propagative uses.

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#### VI. FISH SPECIES

Recommended Rank: **C**; Regulatory oversight and/or trade restrictions.

Documentation: According to the Alaska Administrative Code, “No person may transport, possess, export from the state, or release into the waters of the state, any live fish unless the person holds a fish transport permit [...] and the person is in compliance with all conditions of the permit and the provisions of this chapter.” Permits are issued by the Alaska Department of Fish & Game and are project- and time-specific.

#### QUESTION 5.4 - PRESENCE AND FREQUENCY OF MONITORING PROGRAMS

- A. No surveillance takes place (2)
- B. Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g. citizen science programs) (1.6)
- C. State and/or federal monitoring programs exist, but monitoring is infrequent (1.2)
- D. State and/or federal monitoring programs exist, and monitoring is conducted frequently (0.8)
- E. Unknown (U)

Score: #/2

---

## I. TUNICATES

Recommended Rank: **B**; Surveillance takes place, but is largely conducted by non-governmental environmental organizations (e.g. citizen science programs).<sup>1</sup>

Documentation: In Alaska, Plate Watch and the Kachemak Bay National Estuarine Research Reserve (KBNERR) conduct monitoring for non-native tunicates and other invasive species. The programs involve teachers, students, outdoor enthusiasts, environmental groups and professional biologists to detect invasive species. While monitoring efforts do take place in the Bering Sea, they are not annual events (L. Shaw pers. comm. 2017).

### QUESTION 5.5 - CURRENT EFFORTS FOR OUTREACH AND EDUCATION

- A. No education or outreach takes place (2)
- B. Some educational materials are available and passive outreach is used (e.g. signs, information cards), or programs exist outside Bering Sea and adjacent regions (1.5)
- C. Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions (1)
- D. Programs and materials exist and are readily available in the Bering Sea or adjacent regions (0.5)
- E. Unknown (U)

Score: #/2

---

## I. TUNICATES

Recommended Rank: **C**; Educational materials are available and outreach occurs only sporadically in the Bering Sea or adjacent regions.

Documentation: Plate Watch and the Kachemak Bay National Estuarine Research Reserve (KBNERR) provide training opportunities for identifying and detecting non-native fouling organisms, and public education events on coastal and marine ecosystems more generally. "Bioblitzes" were held in Southeast AK in 2010 and 2012; these events engage and educate the public on marine invasive species. Outreach activities also took place on the Pribilof Islands for Bering Sea Days during 2017. Field identification guides for native and non-native tunicates, as well as common fouling organisms, are readily available.

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<sup>1</sup> Some tunicates are monitored by state agencies and should be ranked accordingly (e.g. *Didemnum vexillum* is monitored by the Alaska Department of Fish & Game)

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## APPENDIX C

### Proximity of non-native species to the Bering Sea

To develop a list of potential invasive species to the Bering Sea, we downloaded or digitized spatially-explicit occurrence records for non-native species in surrounding regions from the National Exotic Marine and Estuarine Species Information System (NEMESIS; Fofonoff et al. 2003b) and the Nonindigenous Aquatic Species Database (NAS; Fuller and Benson 2013). For each record, we assigned each species a ‘proximity rank’ based on the geographic proximity of closest known occurrence records to the Bering Sea. We defined proximity to the Bering Sea using the Marine Ecoregions of the World classification by Spalding et al. (2007). Species present in an ecoregion that encompassed the Bering Sea (Aleutian Islands, Eastern Bering Sea, and Kamchatka shelf) received a proximity value of 0; species present in an ecoregion adjacent to the Bering Sea received a proximity value of 1; species present in an ecoregion once-removed from the Bering Sea received a proximity value of 2, and so on (Figure 1). Species with a proximity value of 0 to 3 were included in the potential invasive species list (Table C-1). We included marine species (salinity tolerance > 30 ppt.) and species that spend a portion of their lifecycle in a marine environment (diadromous and brackish species). We did not include plants.

Please note: because not all species with a proximity value of 3 were assessed during the ranking process, this list may include brackish species that cannot tolerate the salinities of the Bering Sea. Future assessment may further reduce this list.

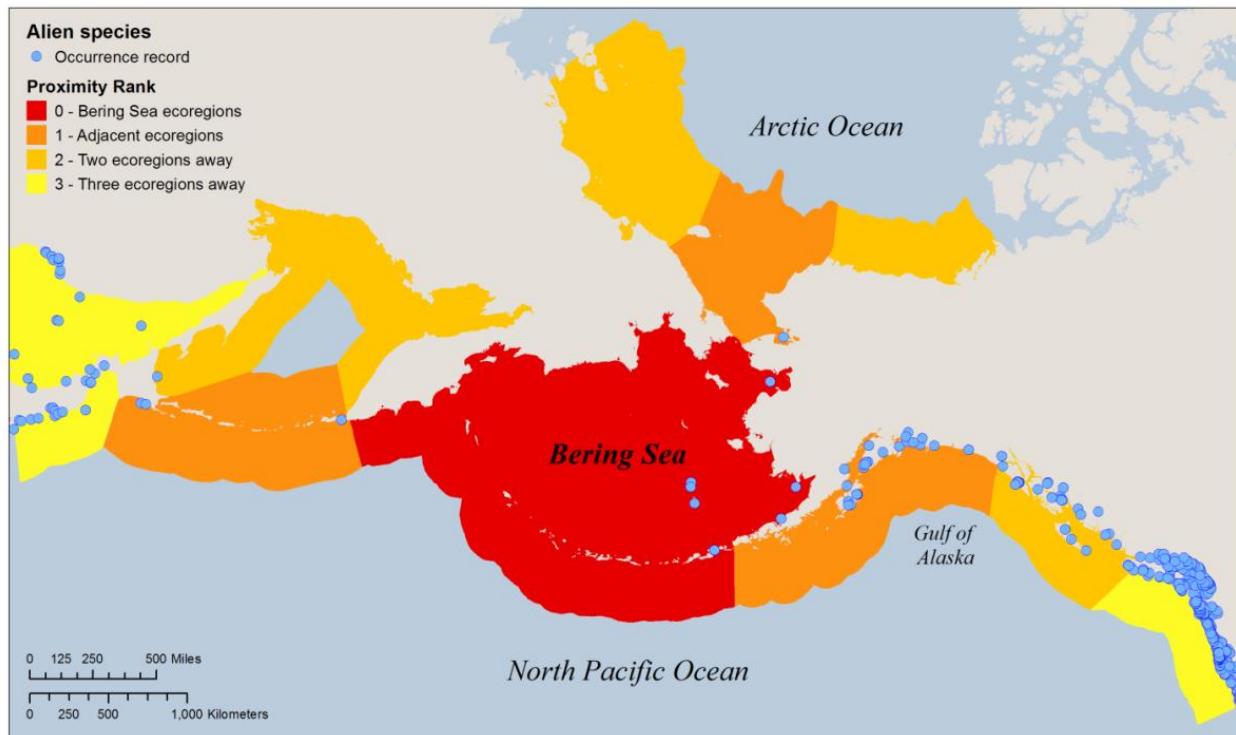


Figure 1. Occurrence records (blue dots) for non-native species and their geographic proximity to the Bering Sea. Ecoregions are based on the classification system by Spalding et al. (2007). Data source: NEMESIS and NAS databases.

Table C-1. Proximity of non-native and invasive species to the Bering Sea, based on nearest occupied ecoregion.

Group	Scientific Name	Proximity Rank	Nearest Occupied Ecoregion(s)	Bering Sea Rank Assessed
Crustaceans - Amphipod	<i>Caprella mutica</i>	0	Bering Sea	Y
Fishes	<i>Alosa sapidissima</i>	0	Bering Sea	Y
Fishes	<i>Salmo salar</i>	0	Bering Sea	Y
Mollusks - Bivalves	<i>Mya arenaria</i>	0	Bering Sea	Y
Crustaceans - Amphipod	<i>Jassa marmorata</i>	I	Oyashio Current / Sea of Okhotsk (1W)	Y
Crustaceans - Barnacles	<i>Amphibalanus amphitrite</i>	I	Oyashio Current / Sea of Okhotsk (1W)	Y
Crustaceans - Barnacles	<i>Amphibalanus improvisus</i>	I	Gulf of Alaska (1E)	Y
Crustaceans - Tanaids	<i>Sinelobus cf. stanfordi</i>	I	Oyashio Current / Sea of Okhotsk (1W)	Y
Mollusks - Bivalves	<i>Crassostrea gigas</i>	I	Gulf of Alaska (1E)	Y
Mollusks - Bivalves	<i>Mytilus galloprovincialis</i>	I	Oyashio Current / Sea of Okhotsk (1W)	Y
Tunicates - Tunicates	<i>Botrylloides violaceus</i>	I	Gulf of Alaska (1E)	Y
Tunicates - Tunicates	<i>Molgula citrina</i>	I	Gulf of Alaska (1E)	Y
Tunicates - Tunicates	<i>Styela clava</i>	I	Oyashio Current / Sea of Okhotsk (1W)	Y
Bryozoans	<i>Watersipora subtorquata complex</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Cnidarians - Hydrozoan	<i>Ectopleura crocea</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Crustaceans - Copepods	<i>Mytilicola orientalis</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Crustaceans - Crabs	<i>Carcinus maenas</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Mollusks - Bivalves	<i>Teredo navalis</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Mollusks - Bivalves	<i>Venerupis philippinarum</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Mollusks - Gastropods	<i>Batillaria attramentaria</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Tunicates - Tunicates	<i>Botryllus schlosseri</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Tunicates - Tunicates	<i>Ciona savignyi</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Tunicates - Tunicates	<i>Didemnum vexillum</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Tunicates - Tunicates	<i>Molgula manhattensis</i>	II	Alaskan Panhandle/ British Columbia (2E)	Y
Annelid - Polychaete	<i>Alitta succinea</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Annelid - Polychaete	<i>Ficopomatus enigmaticus</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Annelid - Polychaete	<i>Hediste diadroma</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Annelid - Polychaete	<i>Heteromastus filiformis spp. complex</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Annelid - Polychaete	<i>Hobsonia florida</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Annelid - Polychaete	<i>Hydroides diramphus</i>	III	East Sea/ Sea of Japan (3W)	
Annelid - Polychaete	<i>Hydroides elegans</i>	III	East Sea/ Sea of Japan (3W)	
Annelid - Polychaete	<i>Polydora cornuta</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	Y

Group	Scientific Name	Proximity Rank	Nearest Occupied Ecoregion(s)	Bering Sea Rank Assessed
Annelid - Polychaete	<i>Pseudopolydora cf. kempfi</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Annelid - Polychaete	<i>Pseudopolydora paucibranchiata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Annelid - Polychaete	<i>Streblospio benedicti</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Bryozoans	<i>Bowerbankia gracilis</i>	III	East Sea/ Sea of Japan (3W)	
Bryozoans	<i>Bugula neritina</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Bryozoans	<i>Bugulina stolonifera</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Bryozoans	<i>Conopeum tenuissimum</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Bryozoans	<i>Cryptosula pallasiana</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Bryozoans	<i>Schizoporella japonica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Bryozoans	<i>Stephanella hina</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Bryozoans	<i>Watersipora n. sp.</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Anthozoans	<i>Diadumene leucolena</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Anthozoans	<i>Diadumene lineata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Cnidarians - Anthozoans	<i>Diadumene sp.</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Anthozoans	<i>Nematostella vectensis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Cnidarians - Hydrozoan	<i>Blackfordia virginica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Hydrozoan	<i>Clava multicornis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Hydrozoan	<i>Climacocodon ikariae</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Hydrozoan	<i>Cordylophora caspia</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Cnidarians - Hydrozoan	<i>Craspedacusta sowerbyi</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Cnidarians - Hydrozoan	<i>Laomedea calceolifera</i>	III	East Sea/ Sea of Japan (3W)	
Crustaceans - Amphipod	<i>Ampithoe valida</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Aoroides secundus</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Caprella drepanochir</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Chelura terebrans</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	

Group	Scientific Name	Proximity Rank	Nearest Occupied Ecoregion(s)	Bering Sea Rank Assessed
Crustaceans - Amphipod	<i>Grandidierella japonica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Incisocalliope derzhavini</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Melita nitida</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Amphipod	<i>Microdeutopus gryllotalpa</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Monocorophium acherusicum</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Crustaceans - Amphipod	<i>Monocorophium insidiosum</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Crustaceans - Amphipod	<i>Monocorophium uenoi</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Amphipod	<i>Paracorophium spp.</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Amphipod	<i>Stenothoe valida</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Barnacles	<i>Amphibalanus eburneus</i>	III	East Sea/ Sea of Japan (3W)	
Crustaceans - Barnacles	<i>Megabalanus coccopoma</i>	III	East Sea/ Sea of Japan (3W)	
Crustaceans - Copepods	<i>Eurytemora affinis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Eurytemora carolleeae</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Harpacticella paradoxa</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Limnoithona sinensis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Limnoithona tetraspina</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Copepods	<i>Pseudodiaptomus forbesi</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Pseudodiaptomus inopinus</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Copepods	<i>Sinocalanus doerri</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Copepods	<i>Tachidius triangularis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Crabs	<i>Eriocheir sinensis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Crabs	<i>Rhithropanopeus harrisii</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Isopods	<i>Iais californica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Isopods	<i>Limnoria quadripunctata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	

Group	Scientific Name	Proximity Rank	Nearest Occupied Ecoregion(s)	Bering Sea Rank Assessed
Crustaceans - Isopods	<i>Limnoria tripunctata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Isopods	<i>Orthione griffenis</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Crustaceans - Isopods	<i>Pseudosphaeroma sp. A</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Isopods	<i>Sphaeroma quoianum</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Crustaceans - Isopods	<i>Synidotea laticauda</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Ostracods	<i>Eusarsiella zostericola</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Crustaceans - Shrimp	<i>Palaemon macrodactylus</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	Y
Entoprocts	<i>Barentsia benedeni</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	
Fishes	<i>Hypomesus nipponensis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Fishes	<i>Lucania parva</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Fishes	<i>Salmo trutta</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Fishes	<i>Tinca tinca</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Bivalves	<i>Gemma gemma</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Bivalves	<i>Laternula gracilis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Bivalves	<i>Macoma petalum</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Mollusks - Bivalves	<i>Neotrapezium liratum</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Bivalves	<i>Nuttallia obscurata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Bivalves	<i>Petricolaria pholadiformis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Mollusks - Gastropods	<i>Assiminea parasitologica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Catriona rickettsi</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Cecina manchurica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Crepidula convexa</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Crepidula fornicata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	

Group	Scientific Name	Proximity Rank	Nearest Occupied Ecoregion(s)	Bering Sea Rank Assessed
Mollusks - Gastropods	<i>Crepidula onyx</i>	III	Oregon, Washington, and Vancouver Coasts (3E) and East Sea/ Sea of Japan (3W)	Y
Mollusks - Gastropods	<i>Crepidula plana</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Ilyanassa obsoleta</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Mollusks - Gastropods	<i>Myosotella myosotis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Ocenebra inornata</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Philine auriformis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Mollusks - Gastropods	<i>Tenellia adspersa</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Mollusks - Gastropods	<i>Urosalpinx cinerea</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Tunicates	<i>Ciona intestinalis</i>	III	East Sea/ Sea of Japan (3W)	
Tunicates	<i>Clavelina lepadiformis</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Tunicates	<i>Diplosoma listerianum</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	Y
Tunicates	<i>Perophora japonica</i>	III	Oregon, Washington, and Vancouver Coasts (3E)	
Tunicates	<i>Polyandrocarpa zorritensis</i>	III	East Sea/ Sea of Japan (3W)	
Tunicates	<i>Ascidia aspersa</i>	III	East Sea/ Sea of Japan (3W)	

**LEGEND**

Proximity Rank 0: Current range is within the Bering Sea

Proximity Rank I: Current range extends to an ecoregion one away from (bordering) the Bering Sea

Proximity Rank II: Current range extends to an ecoregion two away from the Bering Sea

Proximity Rank III: Current range extends to an ecoregion three away from the Bering Sea

**APPENDIX D - Invasiveness rank scores for non-native species to the Bering Sea**

Phylum	Class	Order	Family	Group	Scientific name	Common name	Rank Score	Distribution Score	Anthropogenic Score	Biological Score	Impacts Score
Mollusca	Bivalvia	Ostreoida	Ostreidae	Mollusks - Bivalves	<i>Crassostrea gigas</i>	Pacific oyster	74.25	75.00	100.00	87.50	51.67
Arthropoda	Malacostraca	Decapoda	Portunidae	Crustaceans - Crabs	<i>Carcinus maenas</i>	European green crab	69.50	83.33	40.00	84.17	50.83
Mollusca	Bivalvia	Mytiloidea	Mytilidae	Mollusks - Bivalves	<i>Mytilus galloprovincialis</i>	Mediterranean mussel	67.75	70.83	100.00	79.17	42.50
Chordata	Asciidiacea	Aplousobranchia	Didemnidae	Tunicates	<i>Didemnum vexillum</i>	carpet sea squirt	65.64	79.17	80.00	72.50	38.18
Arthropoda	Maxillopoda	Sessilia	Balanidae	Crustaceans - Barnacles	<i>Amphibalanus improvisus</i>	bay barnacle	65.21	87.50	47.50	79.17	31.48
Arthropoda	Malacostraca	Amphipoda	Caprellidae	Crustaceans - Amphipods	<i>Caprella mutica</i>	Japanese skeleton shrimp	64.95	94.17	80.00	62.50	21.59
Mollusca	Bivalvia	Veneroida	Veneridae	Mollusks - Bivalves	<i>Venerupis philippinarum</i>	Japanese littleneck	63.24	75.00	100.00	85.00	17.27
Bryozoa	Gymnolaemata	Cheilostomatida	Bugulidae	Bryozoans	<i>Bugula neritina</i>	brown bryozoan	62.63	83.33	60.00	86.00	23.33
Mollusca	Bivalvia	Myoida	Myidae	Mollusks - Bivalves	<i>Mya arenaria</i>	softshell clam	59.50	84.17	60.00	75.83	18.33
Bryozoa	Gymnolaemata	Cheilostomatida	Watersiporidae	Bryozoans	<i>Watersipora subtorquata complex</i>	red-rust bryozoan	58.51	76.19	32.50	76.00	30.00
Chordata	Asciidiacea	Stolidobranchia	Styelidae	Tunicates	<i>Botryllus schlosseri</i>	golden star tunicate	57.95	68.33	47.50	72.50	34.55
Arthropoda	Maxillopoda	Sessilia	Balanidae	Crustaceans - Barnacles	<i>Amphibalanus amphitrite</i>	striped barnacle	57.50	72.50	47.50	73.33	30.00
Arthropoda	Malacostraca	Amphipoda	Ischyroceridae	Crustaceans - Amphipods	<i>Jassa marmorata</i>	a tube-building amphipod	57.18	95.24	67.50	64.00	10.91
Chordata	Asciidiacea	Stolidobranchia	Styelidae	Tunicates	<i>Botrylloides violaceus</i>	chain tunicate	56.25	73.33	47.50	68.33	30.00
Chordata	Asciidiacea	Stolidobranchia	Styelidae	Tunicates	<i>Styela clava</i>	club sea squirt	55.25	72.50	67.50	76.67	12.50
Cnidaria	Hydrozoa	Anthomedusae	Tubulariidae	Cnidarians - Hydrozoan	<i>Ectopleura crocea</i>	pink mouthed hydroid	54.47	68.33	47.50	78.00	23.33
Mollusca	Bivalvia	Myoida	Teredinidae	Mollusks - Bivalves	<i>Teredo navalis</i>	naval shipworm	54.00	68.33	32.50	75.00	25.83
Chordata	Asciidiacea	Stolidobranchia	Molgulidae	Tunicates	<i>Molgula citrina</i>	sea grape	53.15	78.10	47.50	65.00	15.00
Chordata	Asciidiacea	Aplousobranchia	Didemnidae	Tunicates	<i>Diplosoma listerianum</i>	compound sea squirt	52.75	70.83	67.50	65.00	17.50
Chordata	Asciidiacea	Enterogona	Cionidae	Tunicates	<i>Ciona savignyi</i>	Pacific transparent sea squirt	52.25	68.33	60.00	70.83	15.00
Bryozoa	Gymnolaemata	Cheilostomatida	Schizoporellidae	Bryozoans	<i>Schizoporella japonica</i>	orange ripple bryozoan	51.78	74.29	60.00	68.00	15.83
Arthropoda	Malacostraca	Decapoda	Varunidae	Crustaceans - Crabs	<i>Eriocheir sinensis</i>	Chinese mitten crab	51.75	52.50	60.00	70.00	30.00
Annelida	Polychaeta	Canalipalpata	Spionidae	Annelids - Polychaetes	<i>Polydora cornuta</i>	whip mudworm	51.25	68.33	47.50	76.67	10.00
Arthropoda	Malacostraca	Tanaidacea	Tanaididae	Crustaceans-Tanaids	<i>Sinelobus cf. stanfordi</i>	a tube-building crustacean	50.42	88.57	47.50	64.00	2.73
Cnidaria	Anthozoa	Actiniaria	Diadumenidae	Cnidarians - Anthozoa	<i>Diadumene lineata</i>	orange-striped anemone	50.13	74.29	60.00	73.33	2.50
Arthropoda	Malacostraca	Isopoda	Limnoriidae	Crustaceans - Isopods	<i>Limnoria tripunctata</i>	a wood-boring isopod	50.00	60.83	67.50	64.17	16.36
Arthropoda	Malacostraca	Decapoda	Palaemonidae	Crustaceans - Shrimp	<i>Palaemon macrodactylus</i>	oriental shrimp	49.87	76.19	67.50	68.33	2.50
Mollusca	Gastropoda	Cephalaspidea	Philinidae	Mollusks - Gastropods	<i>Philine auriformis</i>	tortellini snail	49.71	61.11	80.00	81.00	5.00
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Fishes	<i>Alosa sapidissima</i>	American shad	49.25	45.83	100.00	69.17	15.83
Chordata	Actinopterygii	Salmoniformes	Salmonidae	Fishes	<i>Salmo salar</i>	Atlantic salmon	49.25	54.17	72.50	62.50	23.33
Annelida	Polychaeta	Canalipalpata	Spionidae	Annelids - Polychaetes	<i>Pseudopolydora cf. kempfi</i>	spionid worm	47.40	76.19	47.50	64.00	8.33
Arthropoda	Malacostraca	Amphipoda	Melitidae	Crustaceans - Amphipods	<i>Melita nitida</i>	an amphipod	47.30	61.90	47.50	65.56	7.50
Cnidaria	Hydrozoa	Anthomedusae	Cordylophoridae	Cnidarians - Hydrozoan	<i>Cordylophora caspia</i>	freshwater hydroid	46.84	56.67	60.00	71.00	12.50
Mollusca	Gastropoda	Neotaenioglossa	Calyptreidae	Mollusks - Gastropods	<i>Crepidula onyx</i>	onyx slippersnail	46.84	45.83	80.00	82.00	7.50
Mollusca	Bivalvia	Veneroida	Tellinidae	Mollusks - Bivalves	<i>Macoma petalum</i>	Atlantic macoma	46.75	53.33	40.00	81.67	7.50
Mollusca	Gastropoda	Neogastropoda	Nassariidae	Mollusks - Gastropods	<i>Ilyanassa obsoleta</i>	eastern mudsnail	46.41	49.17	47.50	67.50	20.00
Mollusca	Gastropoda	Neotaenioglossa	Batillariidae	Mollusks - Gastropods	<i>Batillaria attramentaria</i>	Japanese false cerith	46.00	54.44	60.00	68.00	16.67
Chordata	Asciidiacea	Stolidobranchia	Molgulidae	Tunicates	<i>Molgula manhattensis</i>	sea grapes	45.00	48.33	47.50	68.33	17.50
Mollusca	Bivalvia	Veneroida	Petricolidae	Mollusks - Bivalves	<i>Petricolaria pholadiformis</i>	false angelwing	44.11	51.43	40.00	78.00	10.83

Phylum	Class	Order	Family	Group	Scientific name	Common name	Rank Score	Distribution Score	Anthropogenic Score	Biological Score	Impacts Score
Cnidaria	Anthozoa	Actiniaria	Edwardsiidae	Cnidarians - Anthozoa	<i>Nematostella vectensis</i>	starlet sea anemone	43.47	56.19	33.33	70.00	6.00
Arthropoda	Malacostraca	Isopoda	Idoteidae	Crustaceans - Isopods	<i>Synidotea laticauda</i>	an isopod	39.45	47.62	47.50	72.00	2.50
Annelida	Polychaeta	Phyllodocida	Nereididae	Annelids - Polychaetes	<i>Hediste diadroma</i>	a clam worm	38.83	32.50	47.50	75.00	6.12
Arthropoda	Maxillopoda	Cyclopoida	Mytilicolidae	Crustaceans - Copepods	<i>Mytilicola orientalis</i>	a bivalve-parasitic copepod	36.12	53.33	32.50	53.00	12.50
Arthropoda	Maxillopoda	Cyclopoida	Cyclopettidae	Crustaceans - Copepods	<i>Limnoithona tetraspina</i>	a copepod	34.26	28.57	33.33	65.45	10.83
Arthropoda	Ostracod	Myodocopida	Sarsiellidae	Crustaceans - Ostracods	<i>Eusarsiella zostericola</i>	a free-living benthic ostracod	33.91	57.14	47.50	47.50	0.00
Arthropoda	Malacostraca	Amphipoda	Corophiidae	Crustaceans - Amphipods	<i>Paracorophium spp.</i>	an amphipod	29.15	49.09	20.00	53.33	2.73

## APPENDIX E

### **Temperature and salinity ranges for survival and reproduction of non-native taxa**

We developed habitat suitability models for non-native taxa in the Bering Sea using temperature and salinity (T-S) ranges obtained through the literature. Emphasis was placed on finding physiological tolerances (e.g. lethal temperature limits), but approximate values based on geographic distribution were used when physiological tolerances were not available. Due to the marine focus of our project, species with survival salinity tolerances <30 ppt were excluded from the assessment.

Temperatures and salinities listed for survival ('survival thresholds') represent the absolute minimum and maximum value ( $^{\circ}\text{C}$  or ppt) reported in the literature for each taxon across all life stages. Temperatures and salinities listed for reproduction ('reproduction and development thresholds') represent the narrowest range ( $^{\circ}\text{C}$  or ppt) required for reproduction and/or early development. If the maximum temperature threshold was unknown, but survival (or reproduction) had been observed in temperatures higher than the maximum temperature of the Bering Sea (approximately  $17^{\circ}\text{C}$ ), we set the maximum temperature to an arbitrary value of +999 to ensure its inclusion in our analysis. When information was lacking for salinity range values, and the taxon does not require fresh or brackish water for survival and/or reproduction, we assumed a standard tolerance value for marine salinities between 31 and 35 ppt. Species-specific analyses required minimum and maximum values for both temperature and salinity in order to run. Of the 46 species included in the ranking system, we found adequate T-S thresholds for survival for 42 species, and adequate T-S thresholds for reproduction and development for 29 species. These values are listed in the table below.

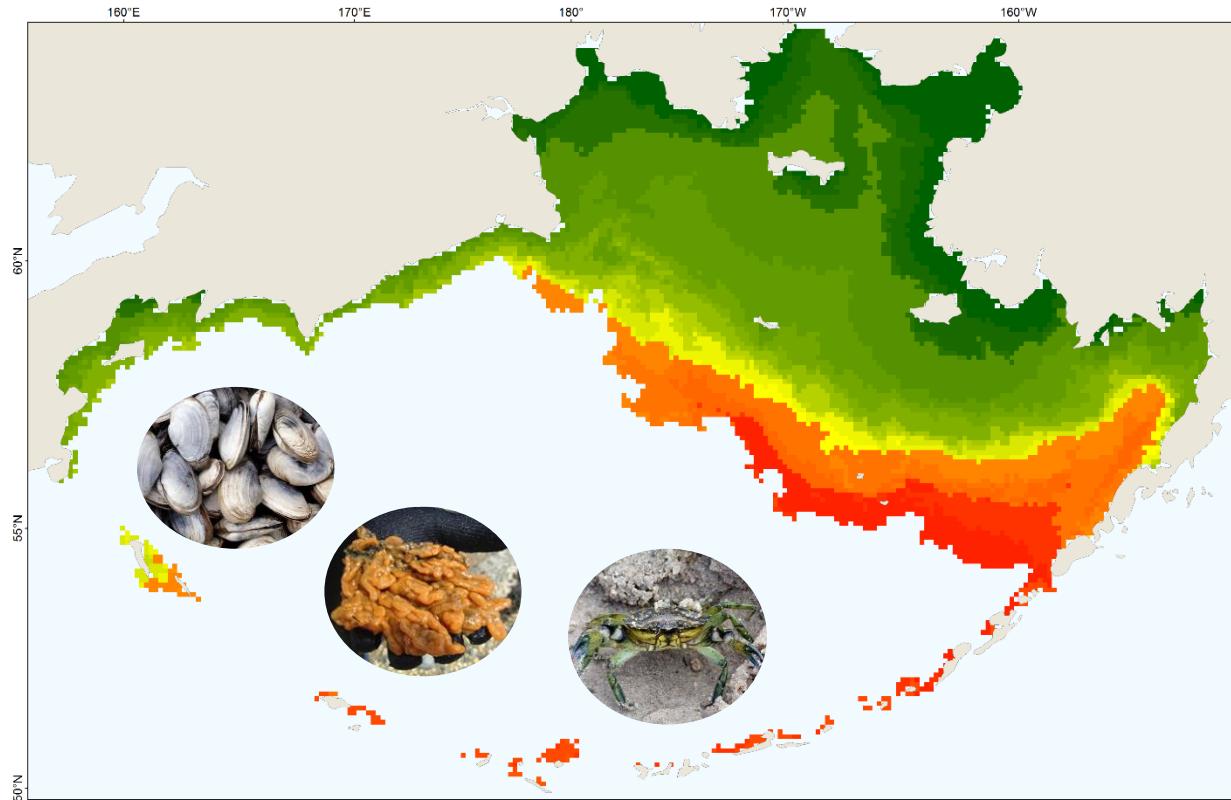
Table E-1. Temperature and salinity ranges for survival and reproduction of non-native and invasive taxa. 'DD' indicates data deficient

Scientific Name	Survival Thresholds				Reproduction and Development Thresholds			
	Min. Temp. (°C)	Max. Temp. (°C)	Min. Salinity (ppt)	Max. Salinity (ppt)	Min. Temp. (°C)	Max. Temp. (°C)	Min. Salinity (ppt)	Max. Salinity (ppt)
<i>Alosa sapidissima</i>	2	26	5	33	8	26	0	7.6
<i>Amphibalanus amphitrite</i>	0	40	10	52	12	23	20	35
<i>Amphibalanus improvisus</i>	-2	38	0	40	10	30	2	40
<i>Batillaria attramentaria</i>	-2	40	7	33	DD	DD	DD	DD
<i>Botrylloides violaceus</i>	-0.6	29	20	38	15	25	26	38
<i>Botryllus schlosseri</i>	-1	30	14	44	11	999	25	35
<i>Bugula neritina</i>	2	30.6	18	40	7	999	31	35
<i>Caprella mutica</i>	-2	28	11	40	4	20	31	35
<i>Carcinus maenas</i>	-1	35	4	54	9	26	17	35
<i>Ciona savignyi</i>	-1.7	27	24	37	12	25	31	35
<i>Cordylophora caspia</i>	-10	30	0	35	10	28	0.2	30
<i>Crassostrea gigas</i>	-1.9	25	5	41	16	30	20	30
<i>Crepidula onyx</i>	10	30	10	45	15	999	15	45
<i>Diadumene lineata</i>	0	27.5	7	74	DD	DD	DD	DD
<i>Didemnum vexillum</i>	-2	24	10	35	14	20	31	35
<i>Diplosoma listerianum</i>	-0.6	30	18	40	15	999	31	35
<i>Ectopleura crocea</i>	0	30	23	34	12	26	31	34
<i>Eriocheir sinensis</i>	0	30	0	35	12	18	15	25
<i>Eusarsiella zostericola</i>	3	33	18	42	DD	DD	DD	DD
<i>Hediste diadroma</i>	5	20	4	34	18	999	4	20
<i>Ilyanassa obsoleta</i>	0	30	10	35	16.5	28	21	35
<i>Jassa marmorata</i>	-2	27	12	38	DD	DD	DD	DD
<i>Limnoithona tetraspina</i>	4	999	1	30	DD	DD	DD	DD
<i>Limnoria tripunctata</i>	2	30	19	50	15	30	31	35
<i>Macoma petalum</i>	0	33	2.5	35	10	14	31	35
<i>Melita nitida</i>	0	32	0	35	DD	DD	DD	DD
<i>Molgula citrina</i>	-1.4	12.2	17	35	DD	DD	DD	DD

Scientific Name	Survival Thresholds				Reproduction and Development Thresholds			
	Min. Temp. (°C)	Max. Temp. (°C)	Min. Salinity (ppt)	Max. Salinity (ppt)	Min. Temp. (°C)	Max. Temp. (°C)	Min. Salinity (ppt)	Max. Salinity (ppt)
<i>Molgula manhattensis</i>	5	999	10	35	10	999	31	35
<i>Mya arenaria</i>	-0.2	32.5	3	35	4	23	10	35
<i>Mytilus galloprovincialis</i>	7	31	10	38	15	25	20	38
<i>Mytilicola orientalis</i>	DD	DD	31	35	DD	DD	31	35
<i>Nematostella vectensis</i>	-1.5	32.5	7	52	DD	DD	DD	DD
<i>Palaemon macrodactylus</i>	2	33	0.7	51	DD	DD	DD	DD
<i>Paracorophium sp.</i>	DD	DD	0	31	DD	DD	DD	DD
<i>Petricolaria pholadiformis</i>	1	26	10	35	DD	DD	DD	DD
<i>Philine auriformis</i>	DD	DD	18	35	DD	DD	31	35
<i>Polydora cornuta</i>	-2	29	2	75	10	29	5	75
<i>Pseudopolydora cf. kempfi</i>	DD	29	1.6	37	DD	DD	31	35
<i>Salmo salar</i>	-0.7	28	0	35.3	7.2	10	0	0
<i>Schizoporella japonica</i>	7	19	15	35	DD	DD	DD	DD
<i>Sinelobus cf. stanfordi</i>	-2	27	0	52	DD	DD	DD	DD
<i>Styela clava</i>	-2	27	18	35	15	999	20	35
<i>Synidotea laticauda</i>	0	30	1	35	4	33	10	30
<i>Teredo navalis</i>	0	30	5	45	11	30	9	35
<i>Venerupis philippinarum</i>	0	37	12	50	DD	DD	DD	DD
<i>Watersipora subtorquata complex</i>	6.7	30.6	25	40	DD	DD	DD	DD

## APPENDIX F

### Bering Sea Habitat Suitability Model Atlas



To investigate where non-native species may survive and persist in the Bering Sea, we compared species' temperature and salinity thresholds to environmental conditions of the Bering Sea. Environmental conditions were obtained from three Regional Ocean Modeling Systems and investigated under two time periods: current (2003-2012) and mid-century (2030-2039). We identified potential habitat for survival for 42 species, and potential habitat for reproduction for 29 species.

This atlas is a companion document to NPPR project 1523, The Pervasive Invasive: Assessing the Risk of Non-native Marine Species in the Bering Sea.

Detailed methods and project information are presented in the final project report: Reimer, J.P., A. Droghini, A. Fischbach, J.T. Watson, B. Bernard, and A. Poe. 2017. Assessing the Risk of Non-Native Marine Species in the Bering Sea. Alaska Center for Conservation Science, University of Alaska Anchorage, AK. 40 pp.

Digital copies of all spatial data and publications are available online: [www.beringinvaders.org](http://www.beringinvaders.org)

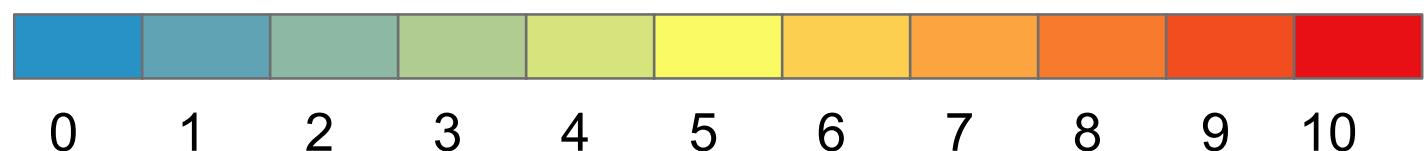
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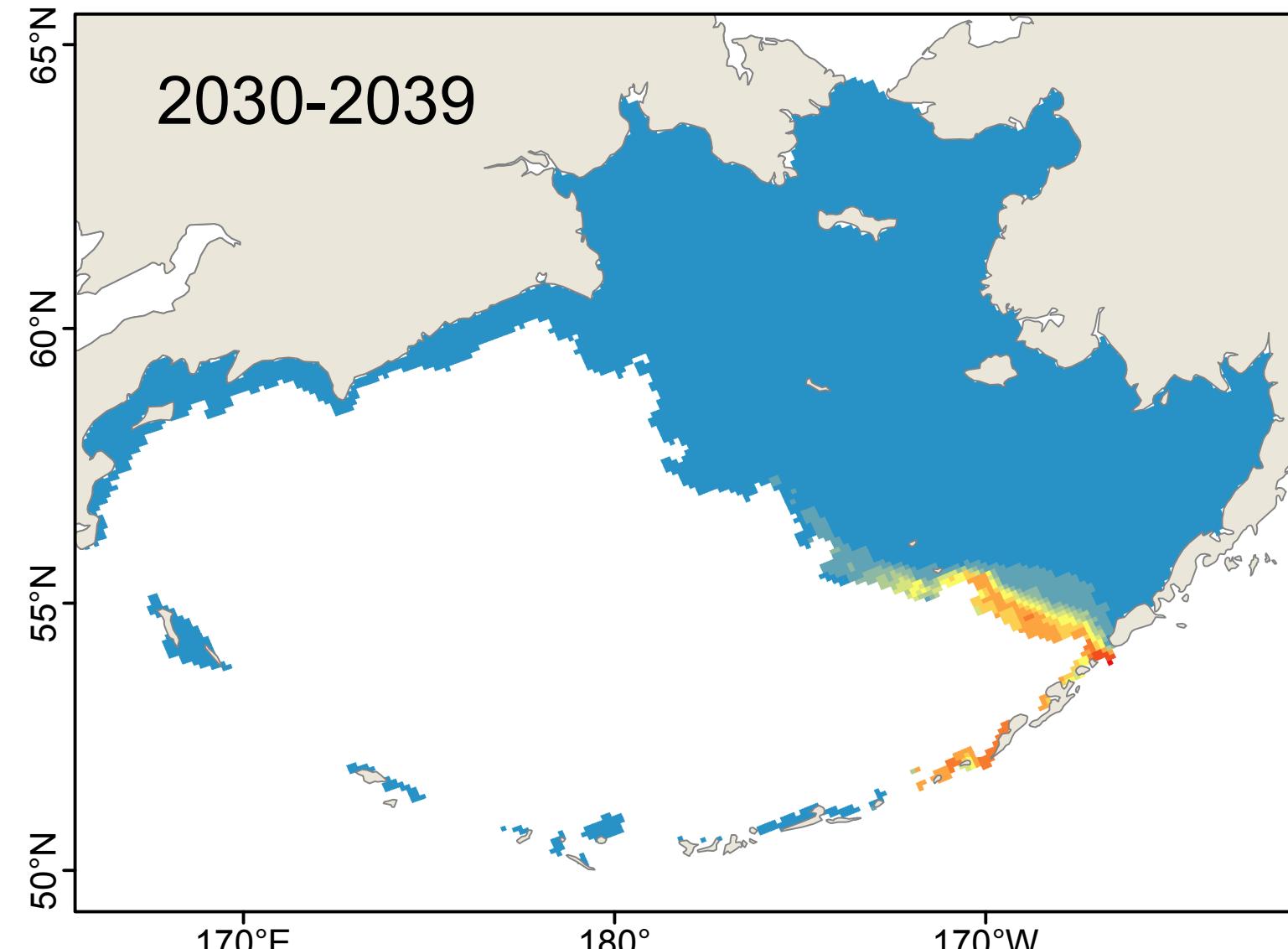
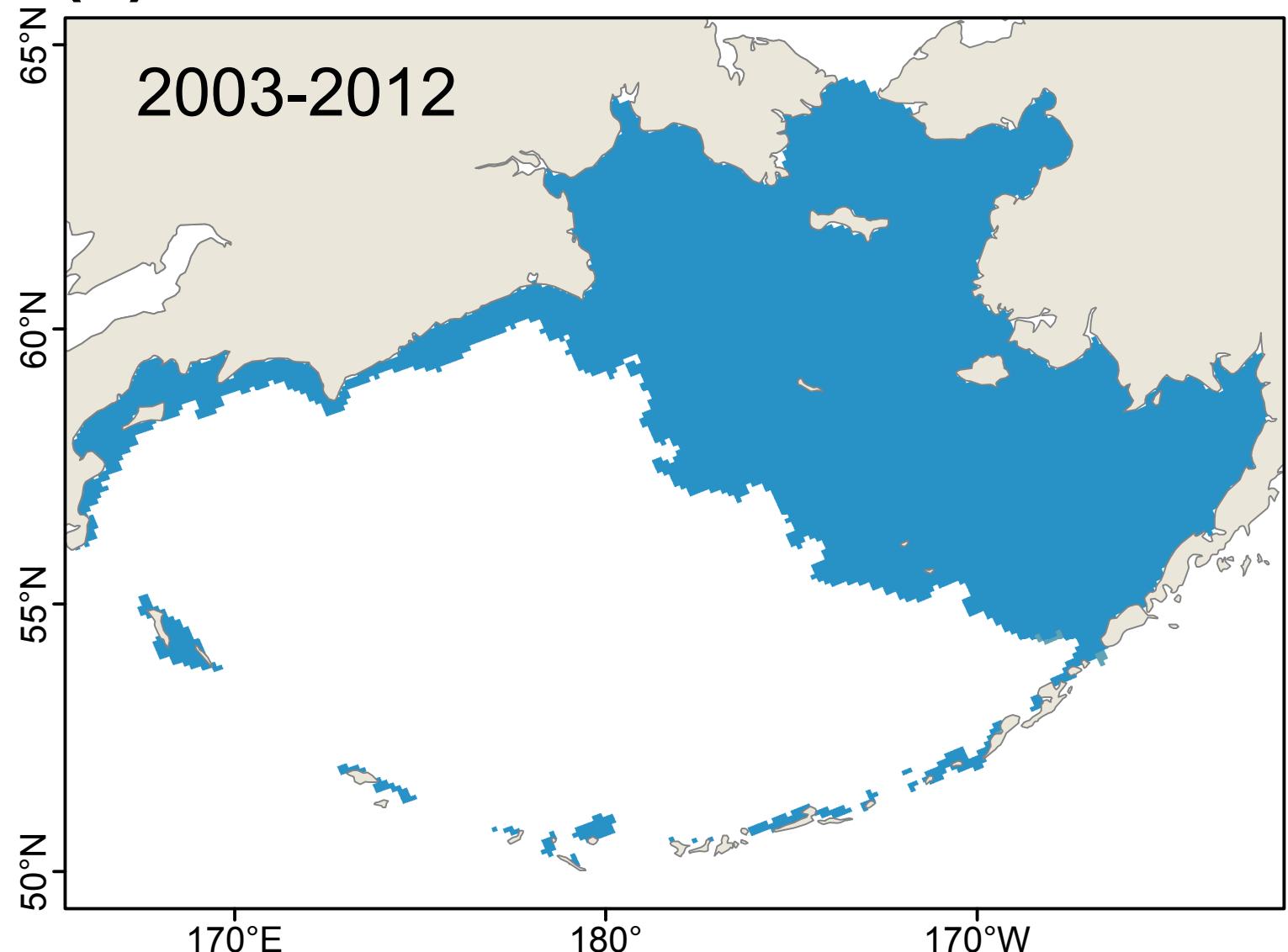
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# *Hediste diadroma: Year-round Survival*

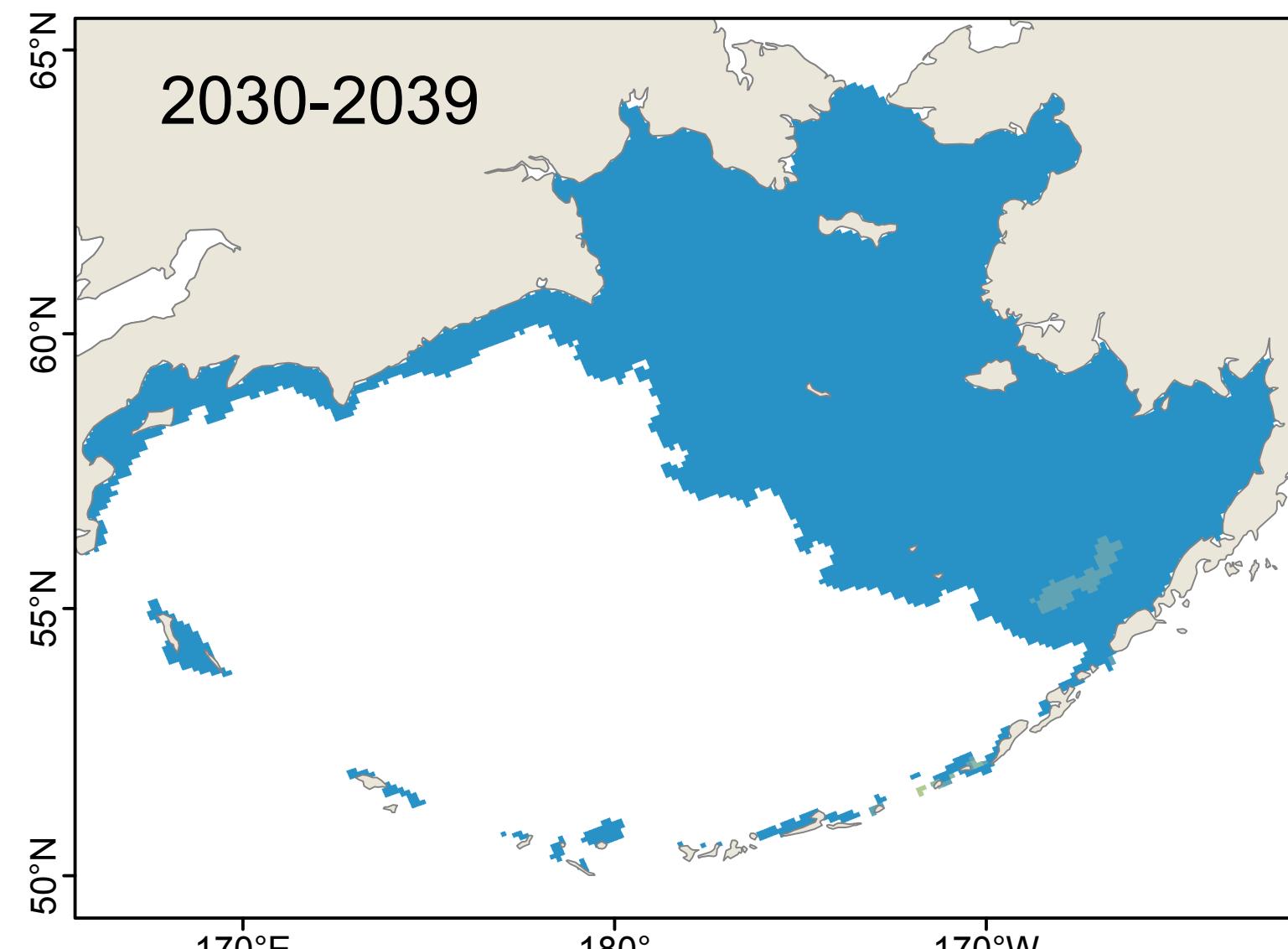
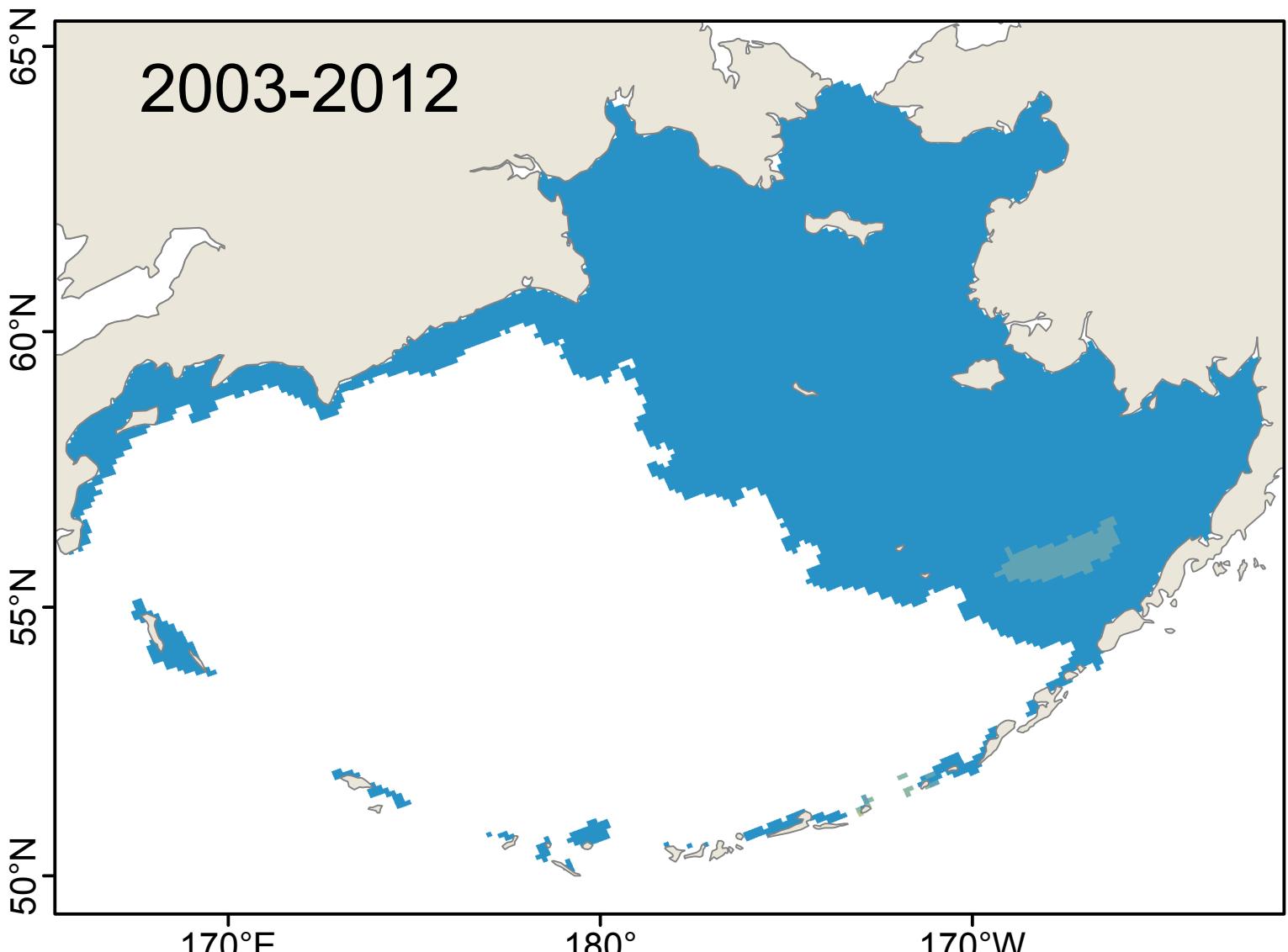
Number of years with suitable habitat



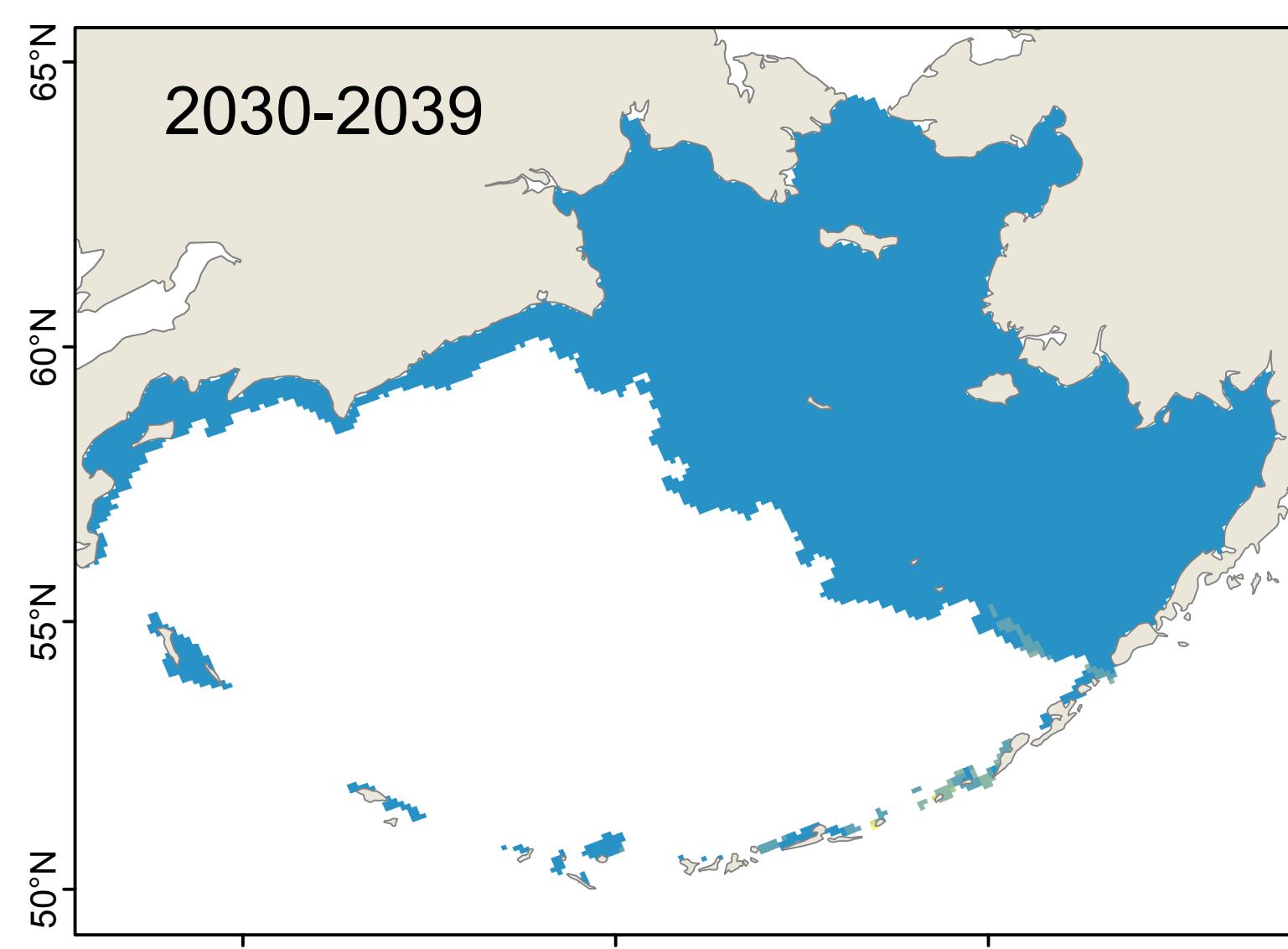
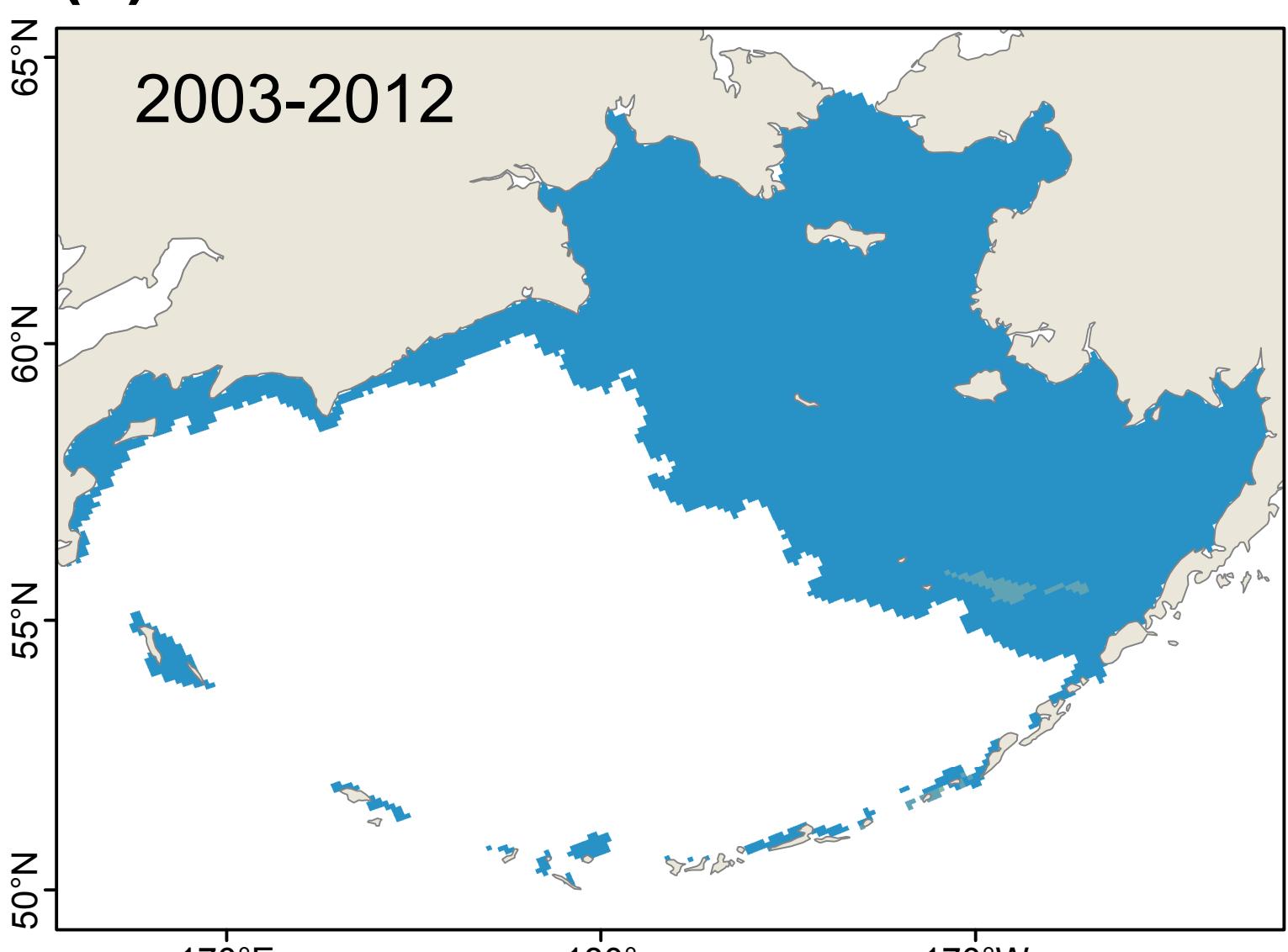
(a) Model: CGCM3-t47



(b) Model: ECHO-G

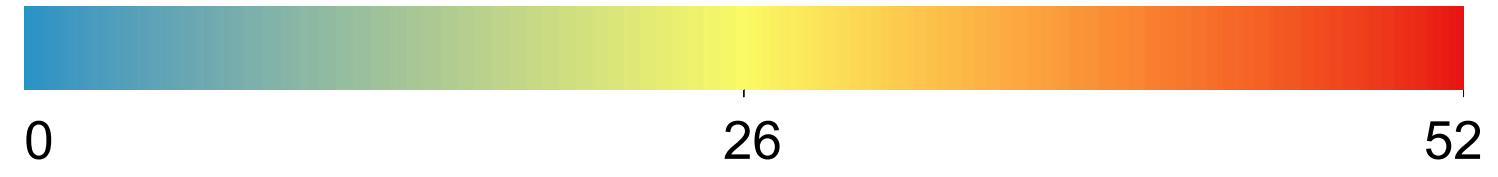


(c) Model: MIROC3.2

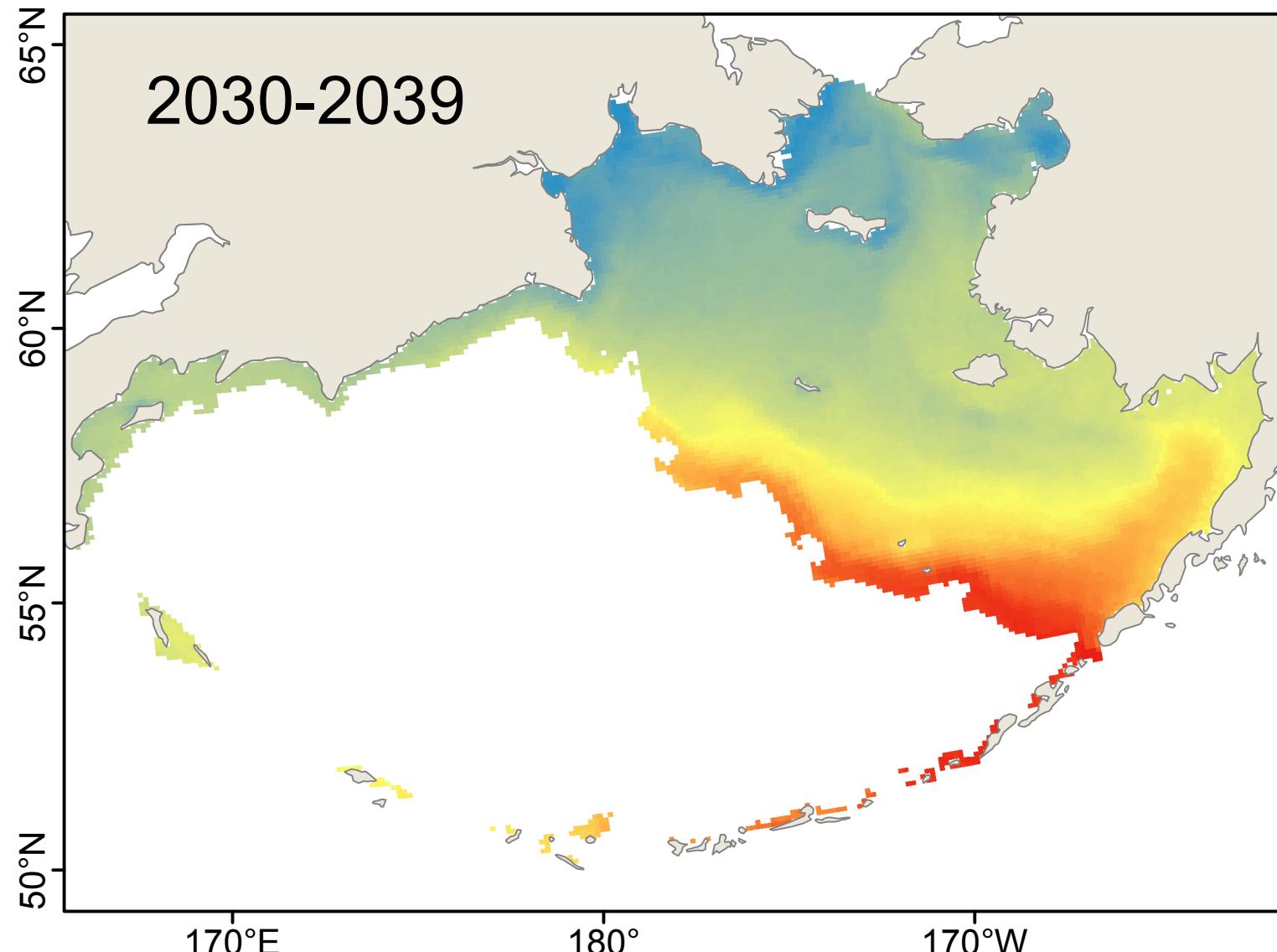
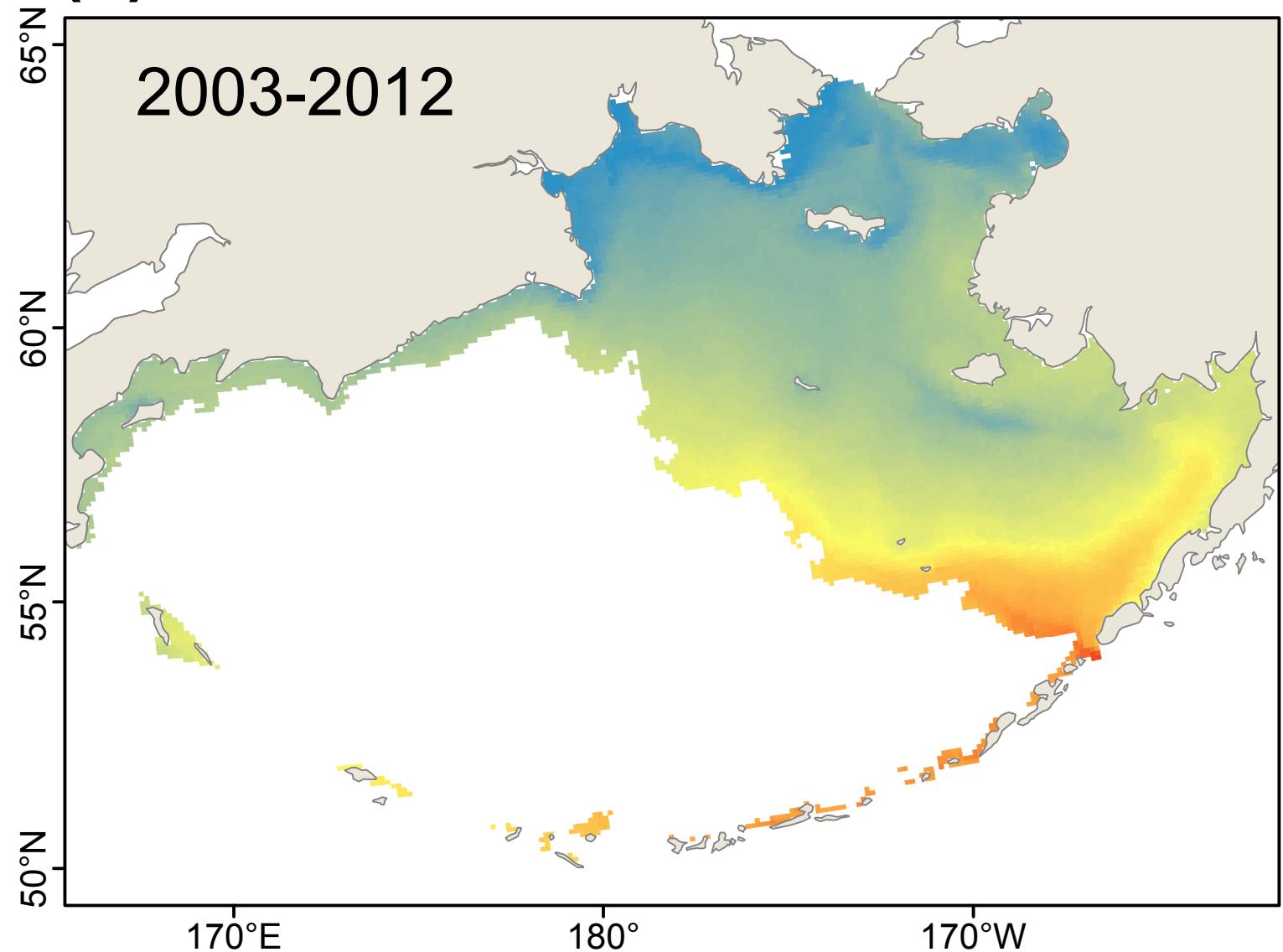


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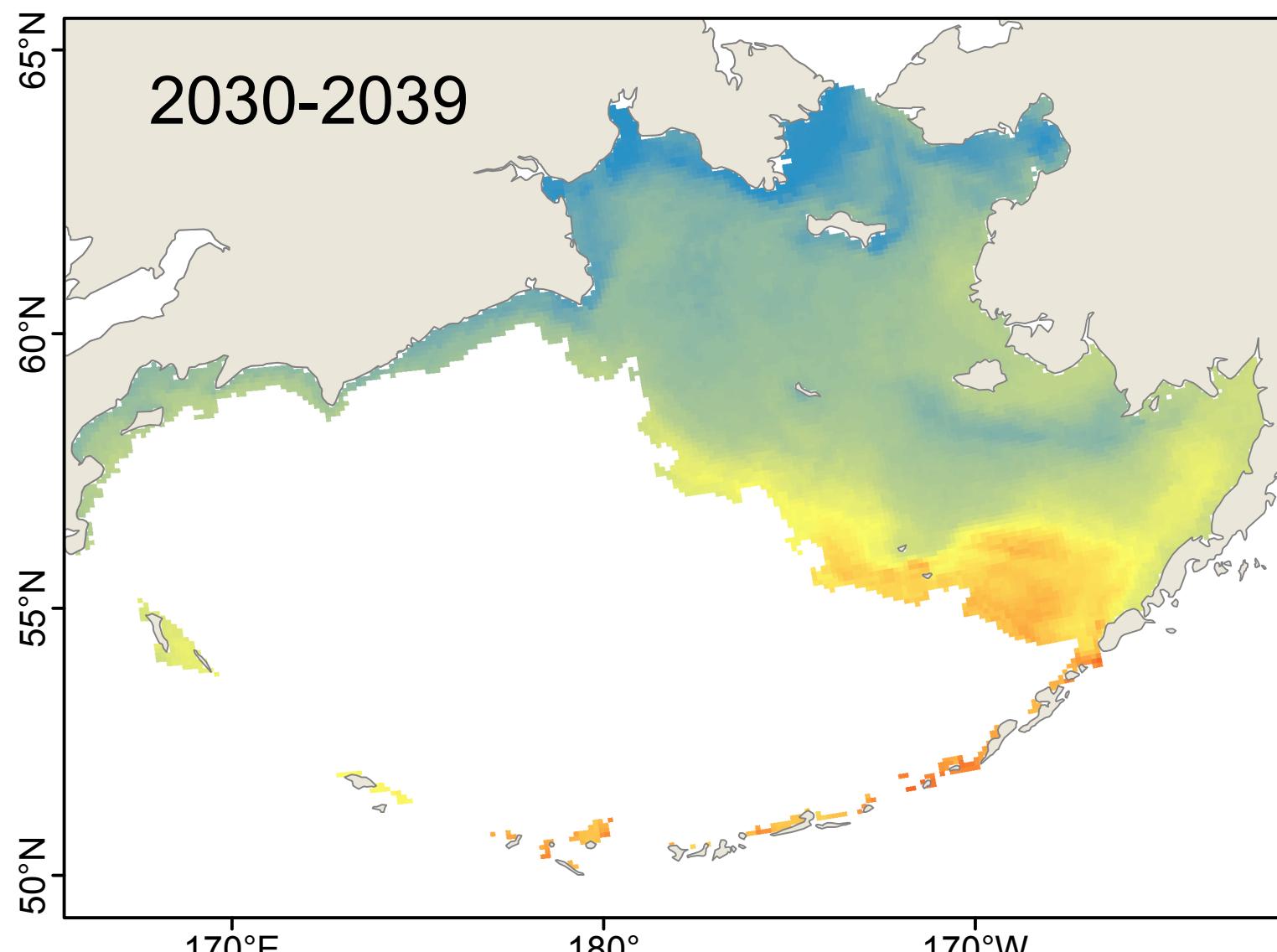
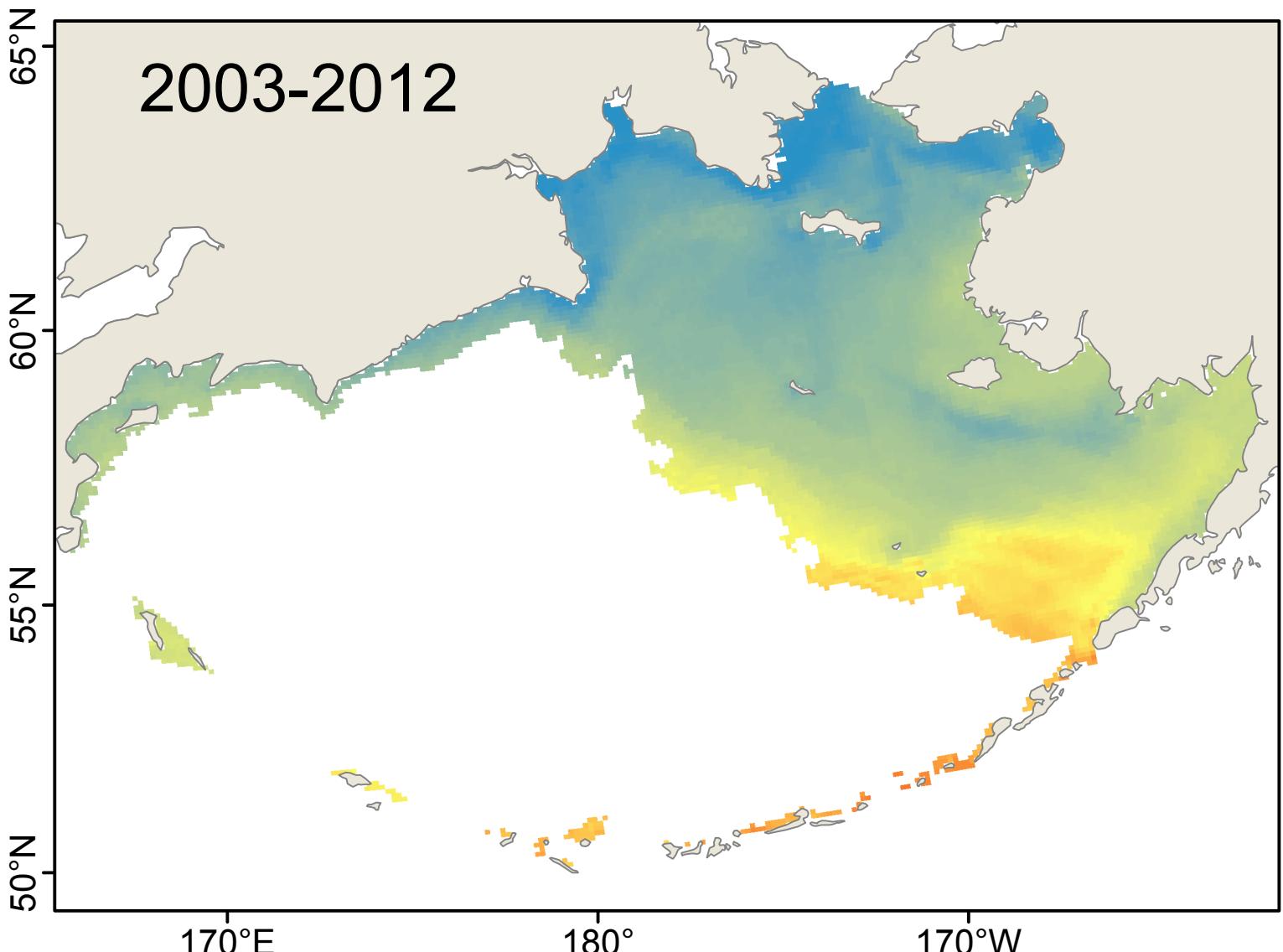
Average number of weeks of suitable habitat



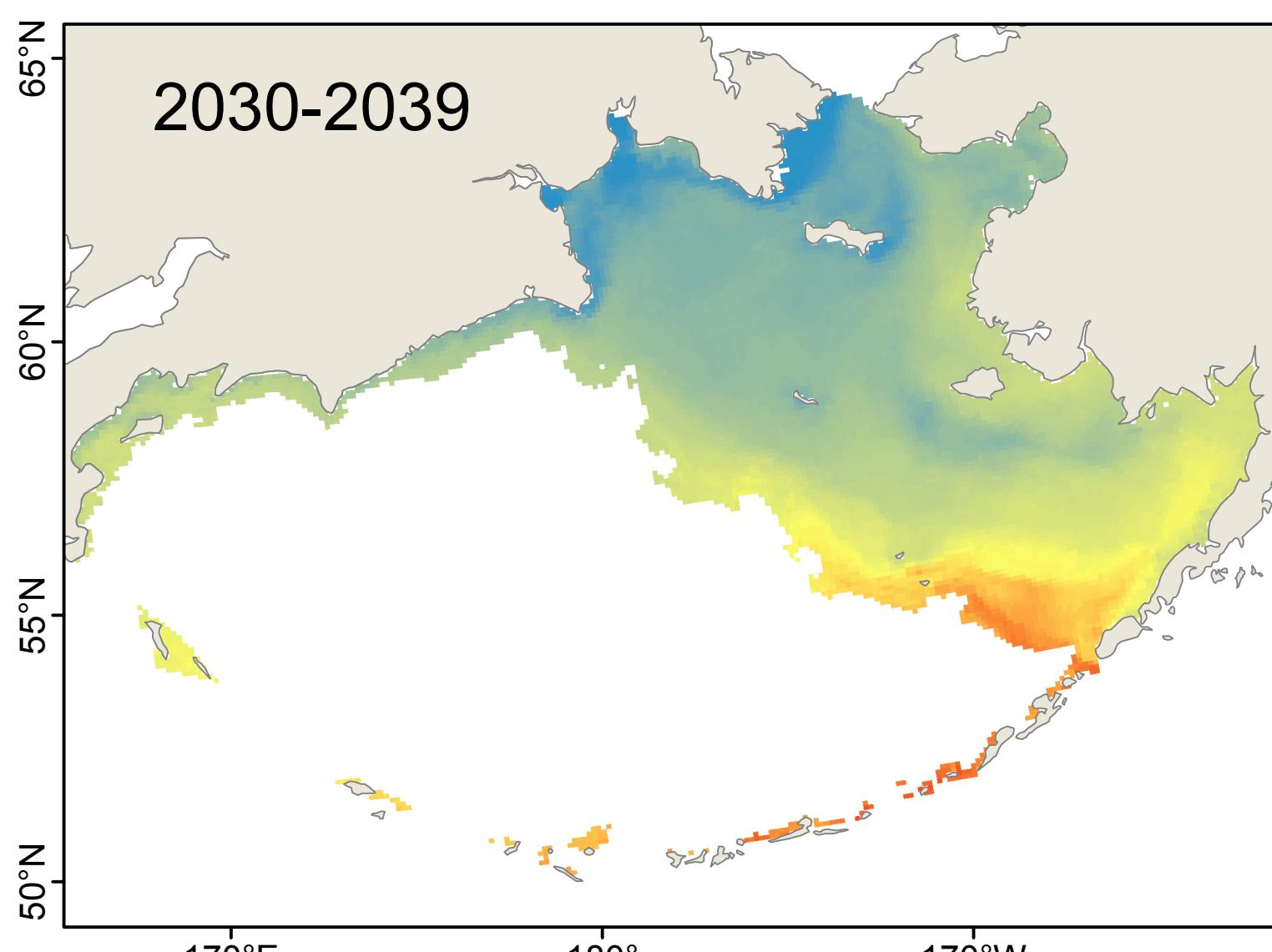
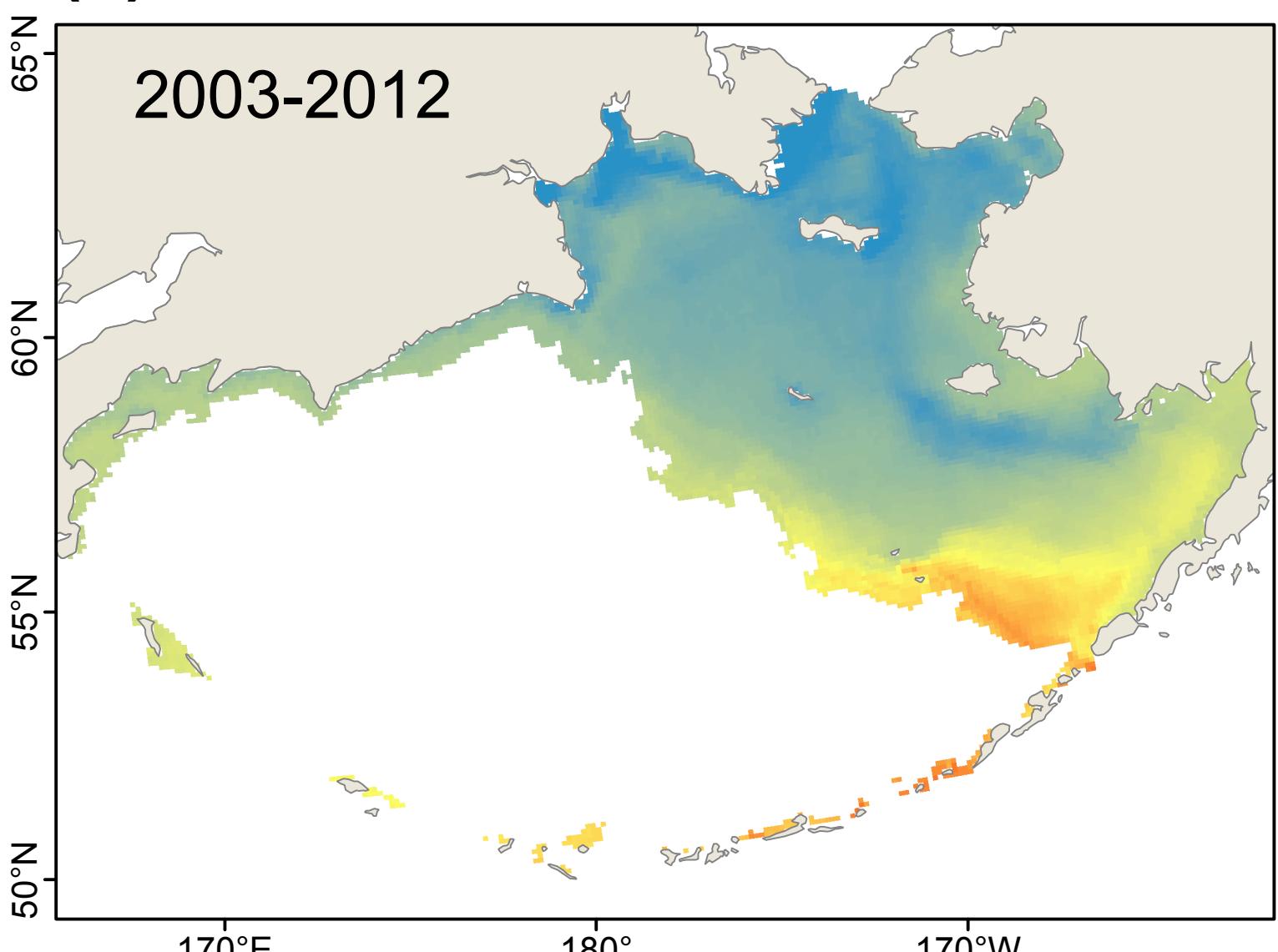
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(b) Model: ECHO-G

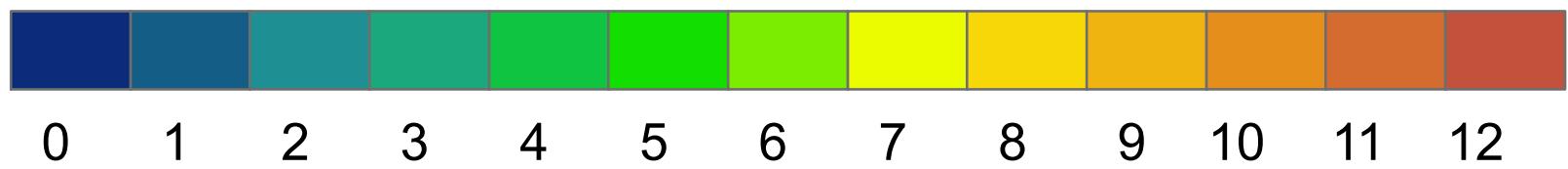


(c) Model: MIROC3.2

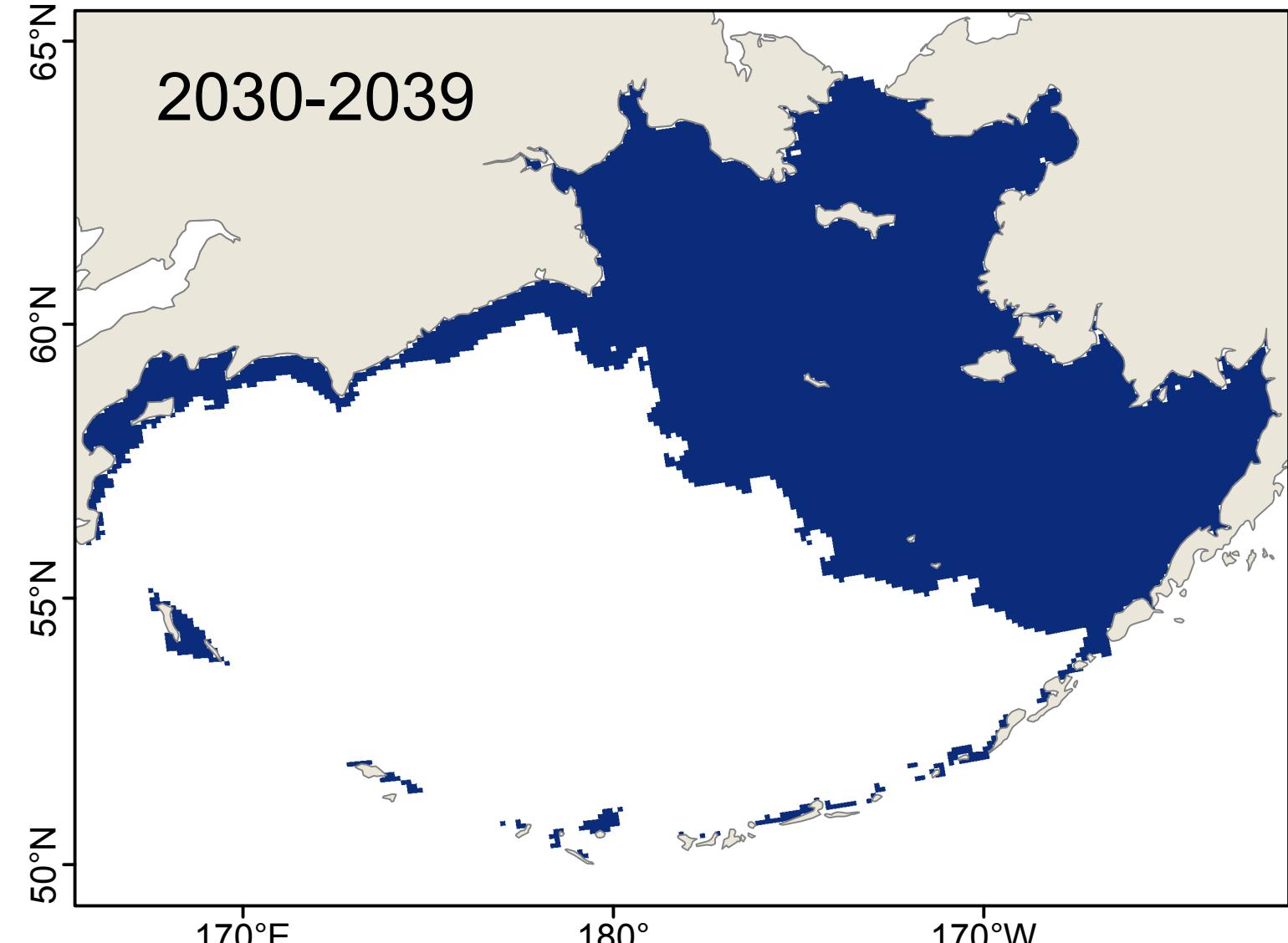
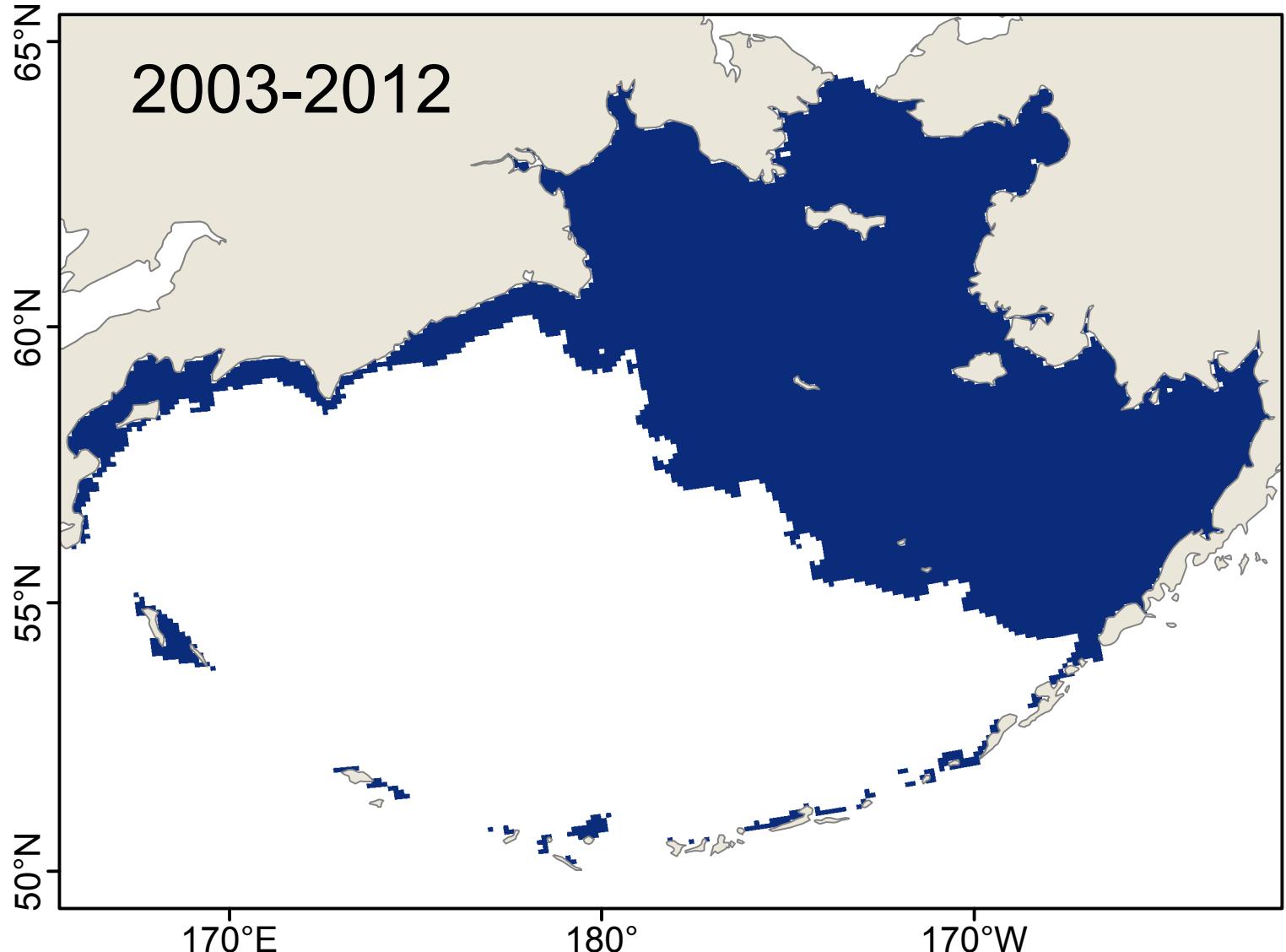


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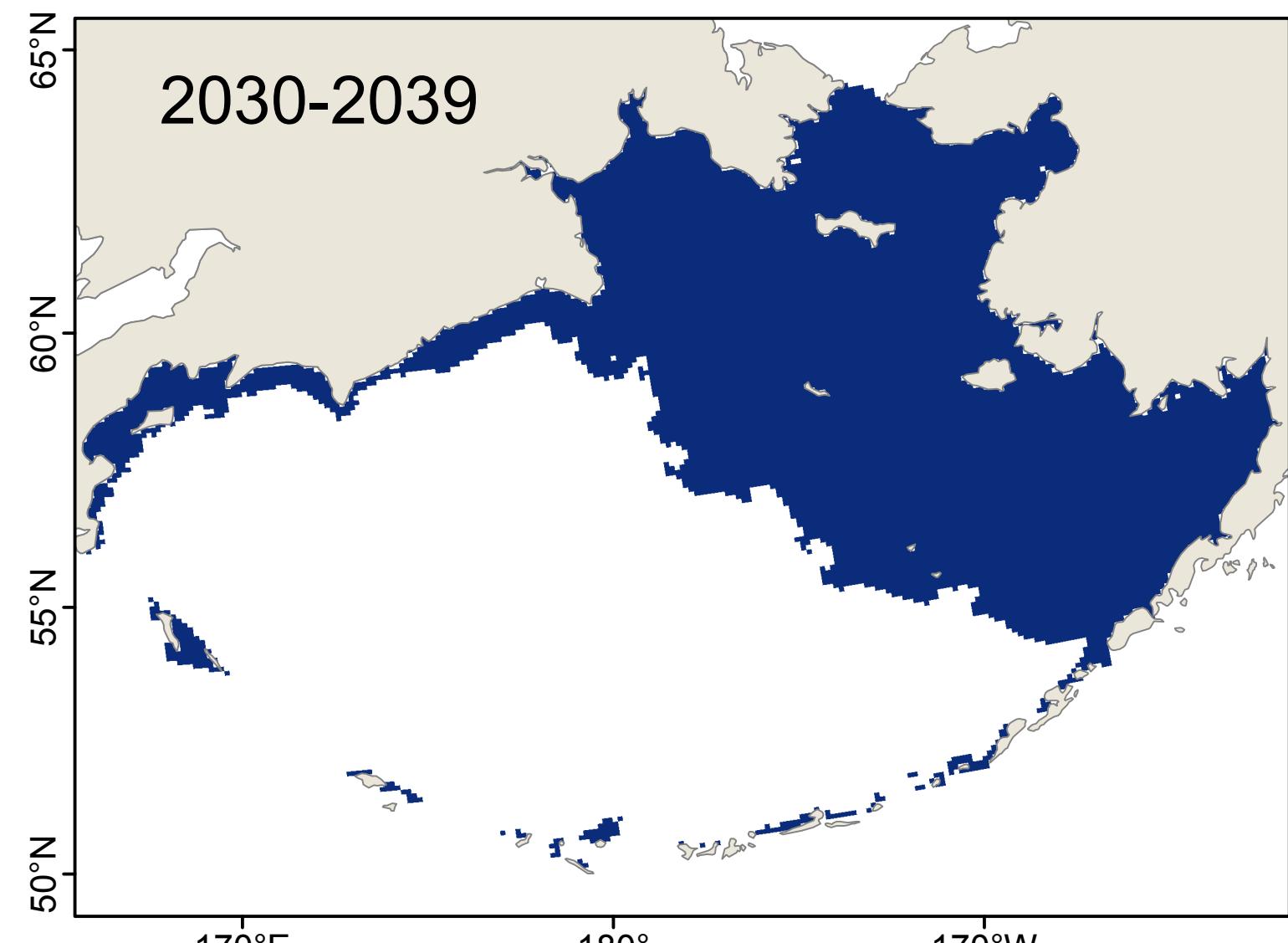
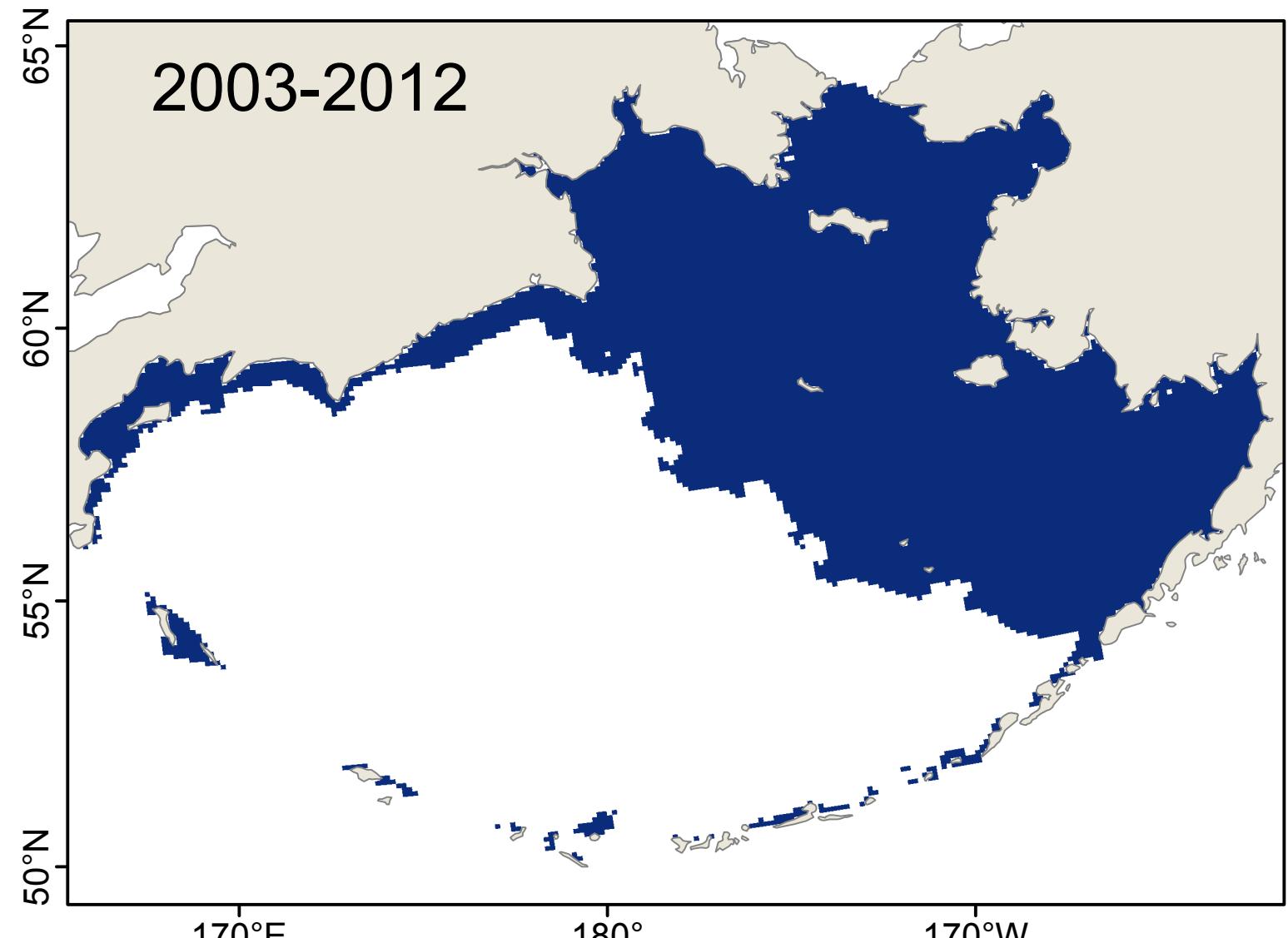
Average number of consecutive weeks of suitable habitat



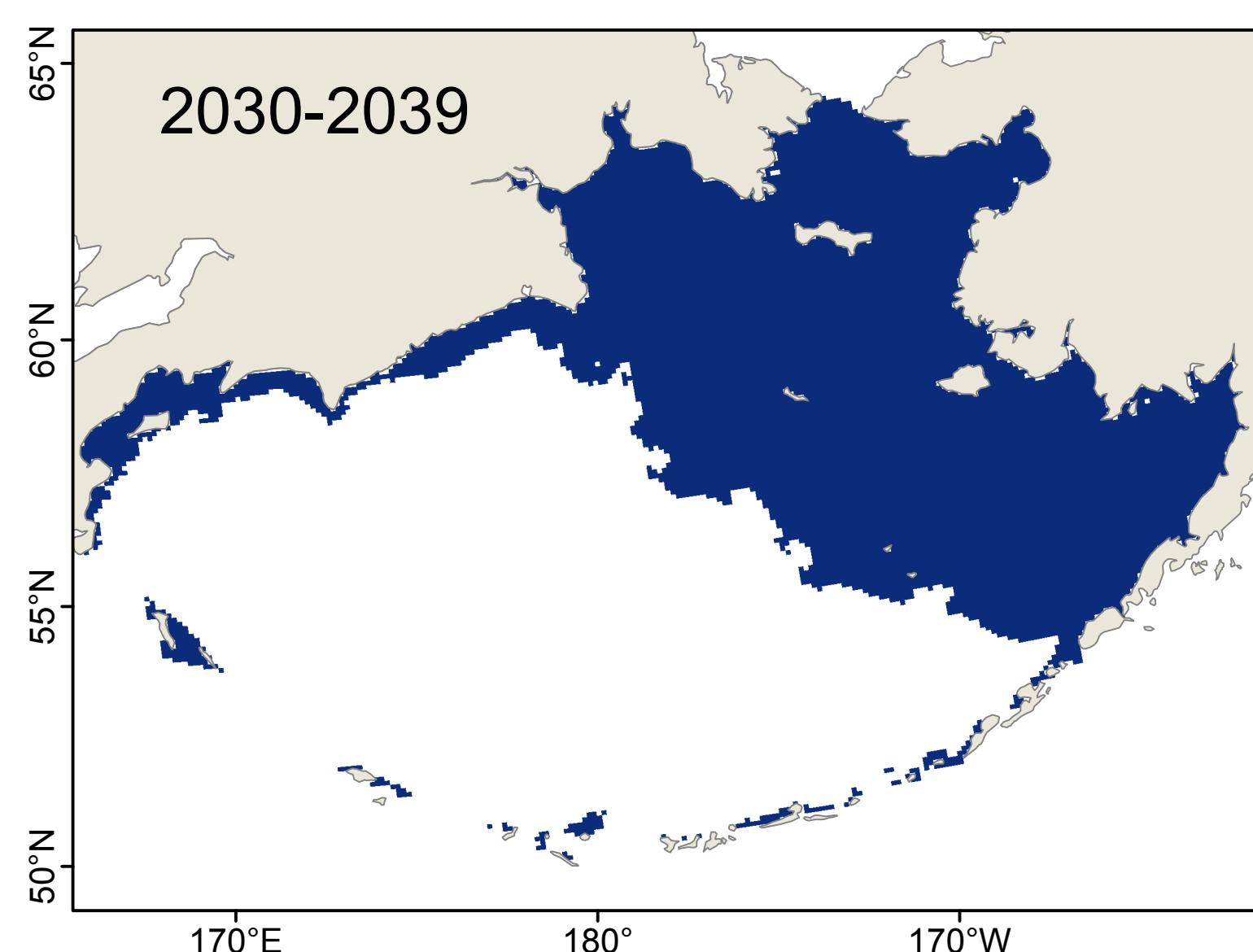
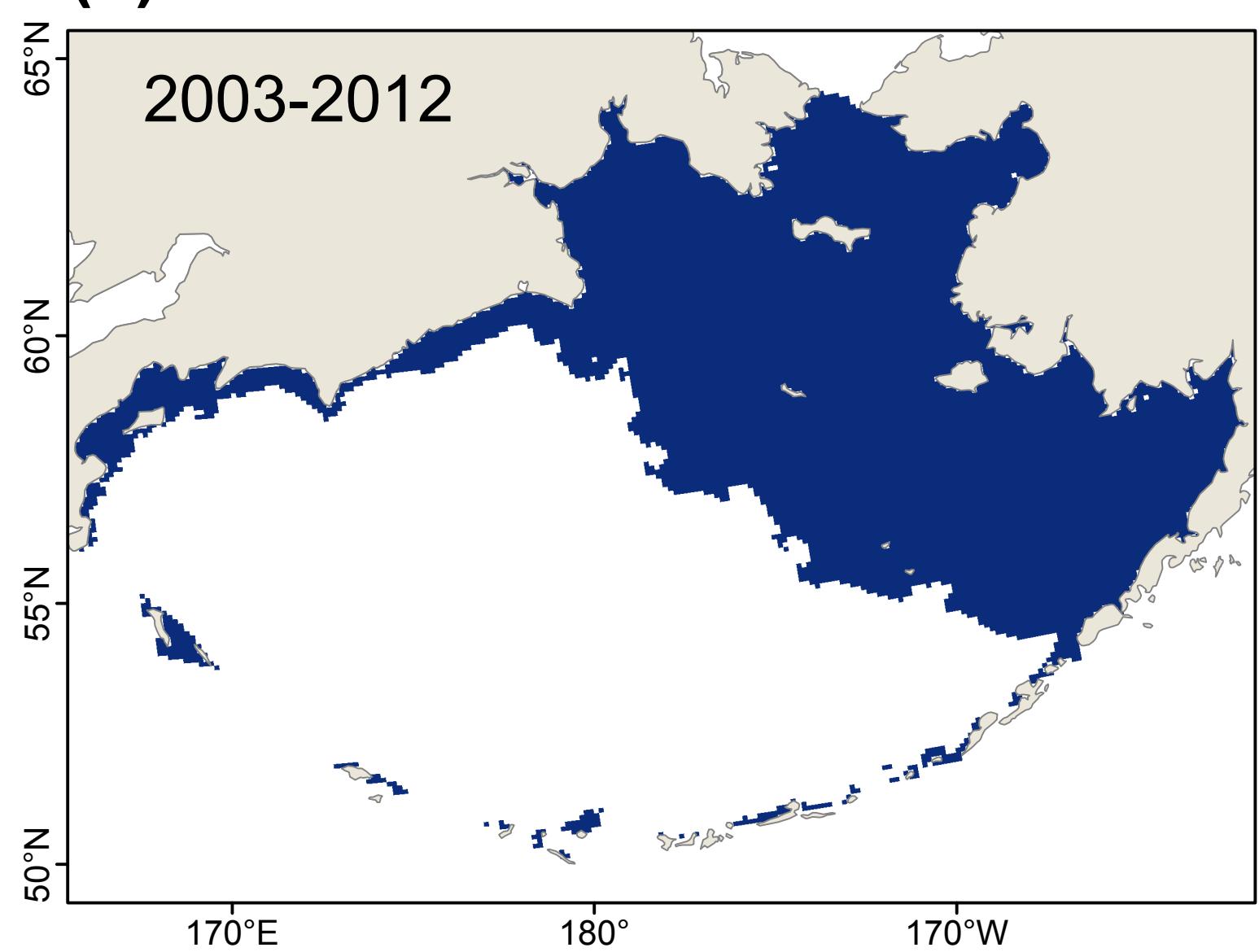
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(b) Model: ECHO-G

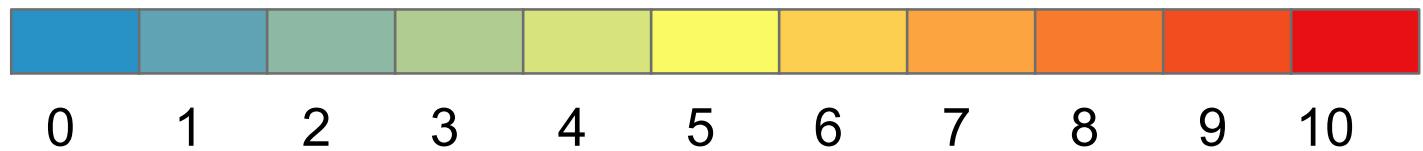


(c) Model: MIROC3.2

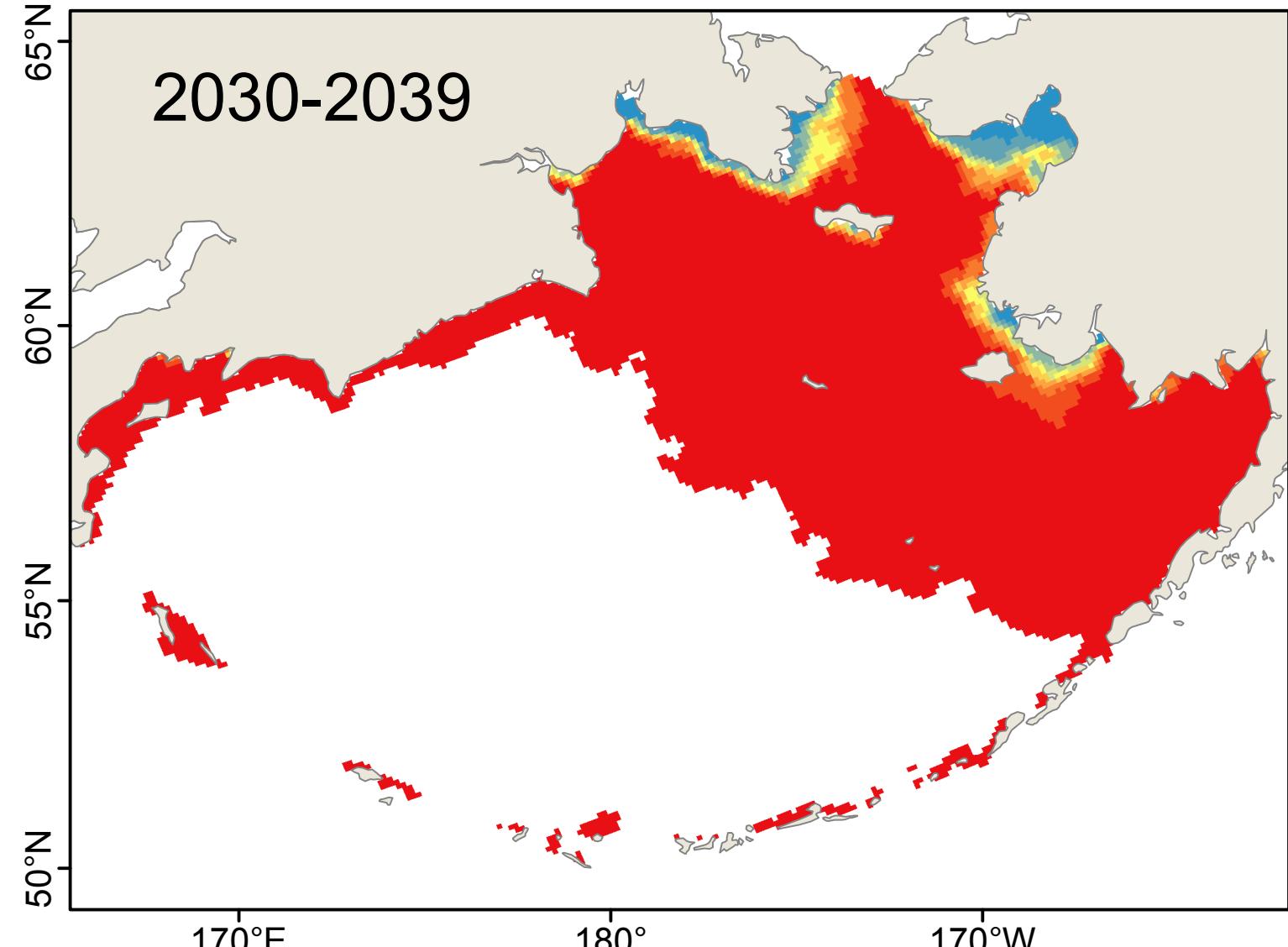
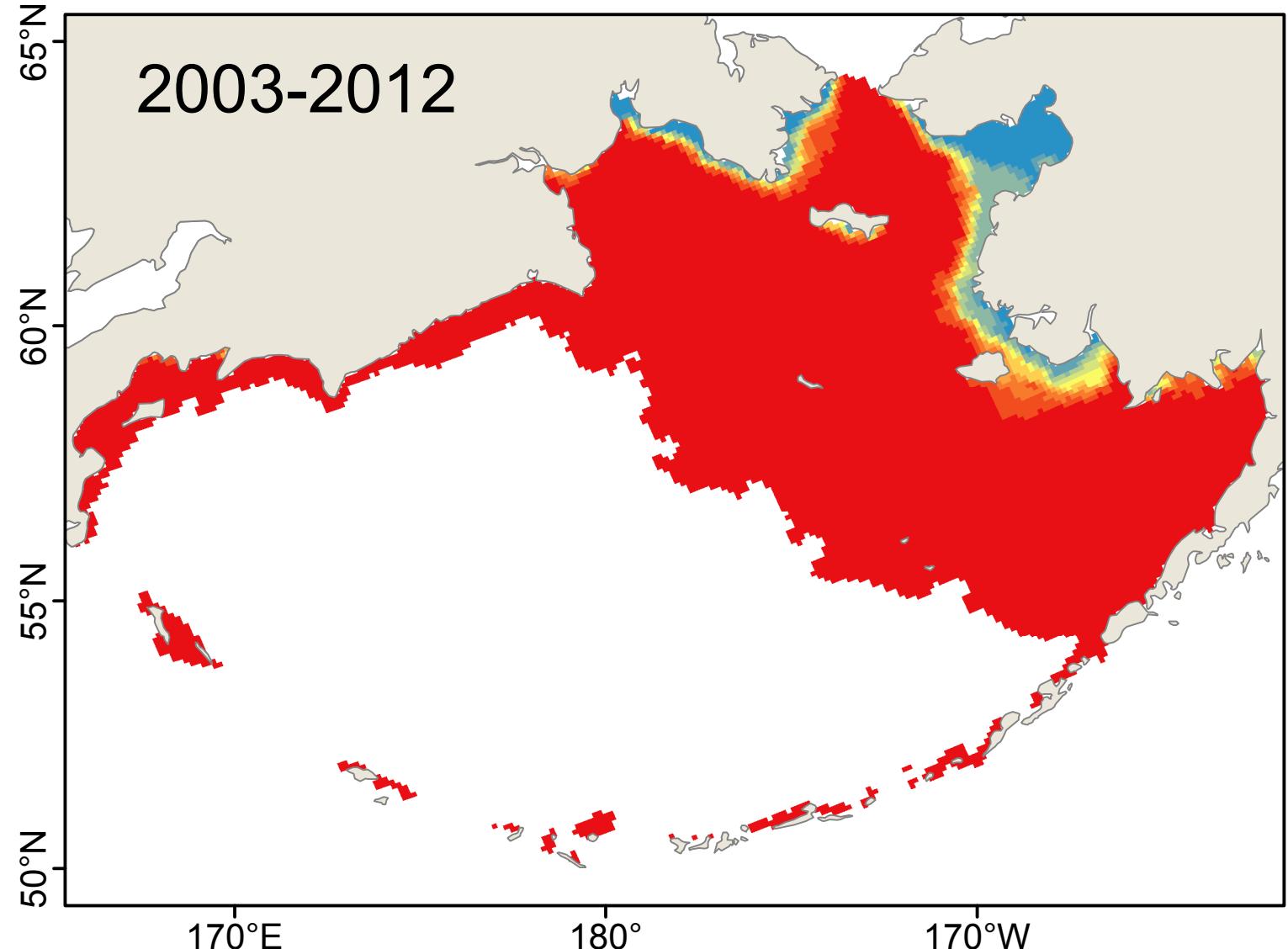


# *Polydora cornuta*: Year-round Survival

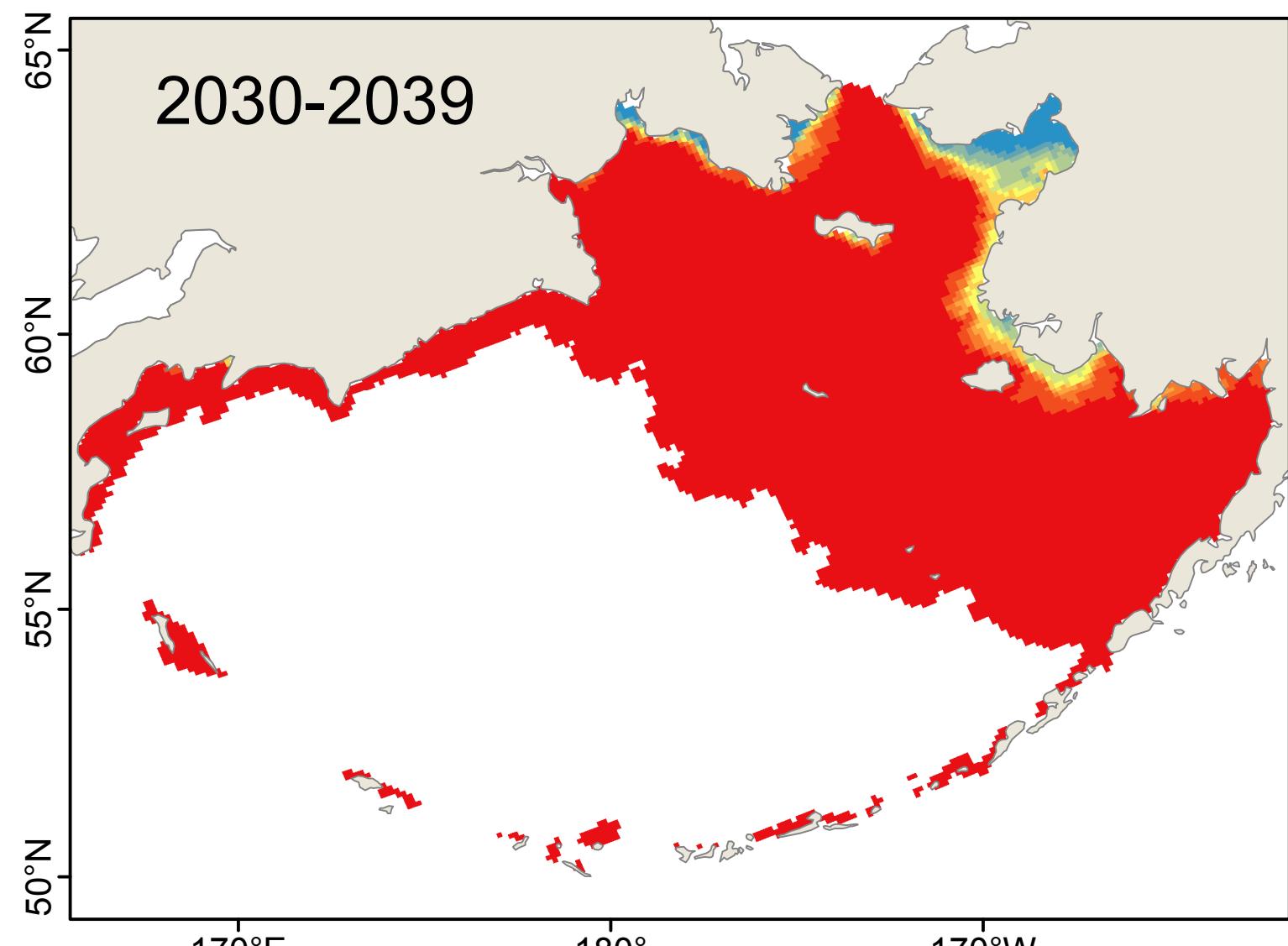
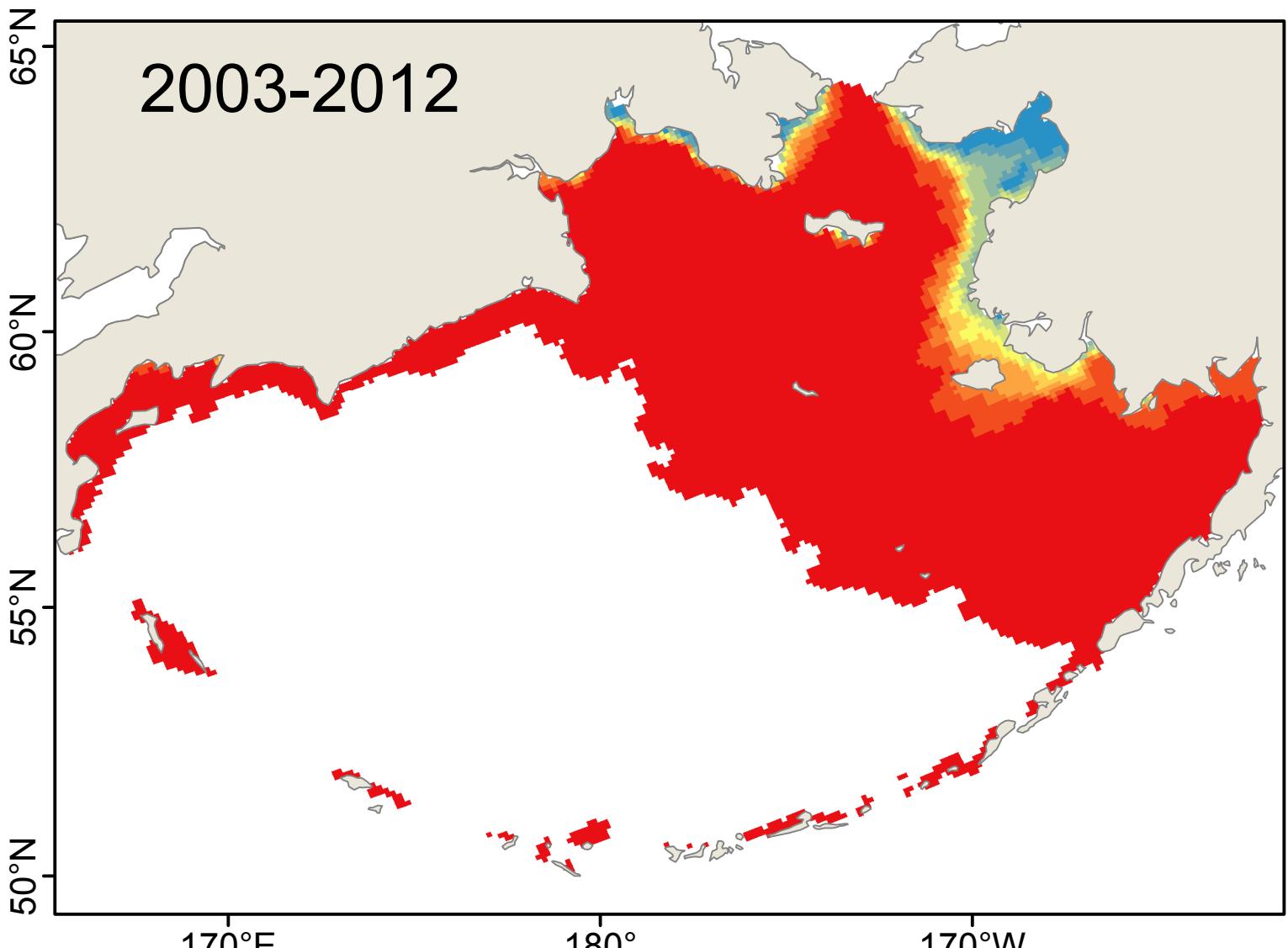
Number of years with suitable habitat



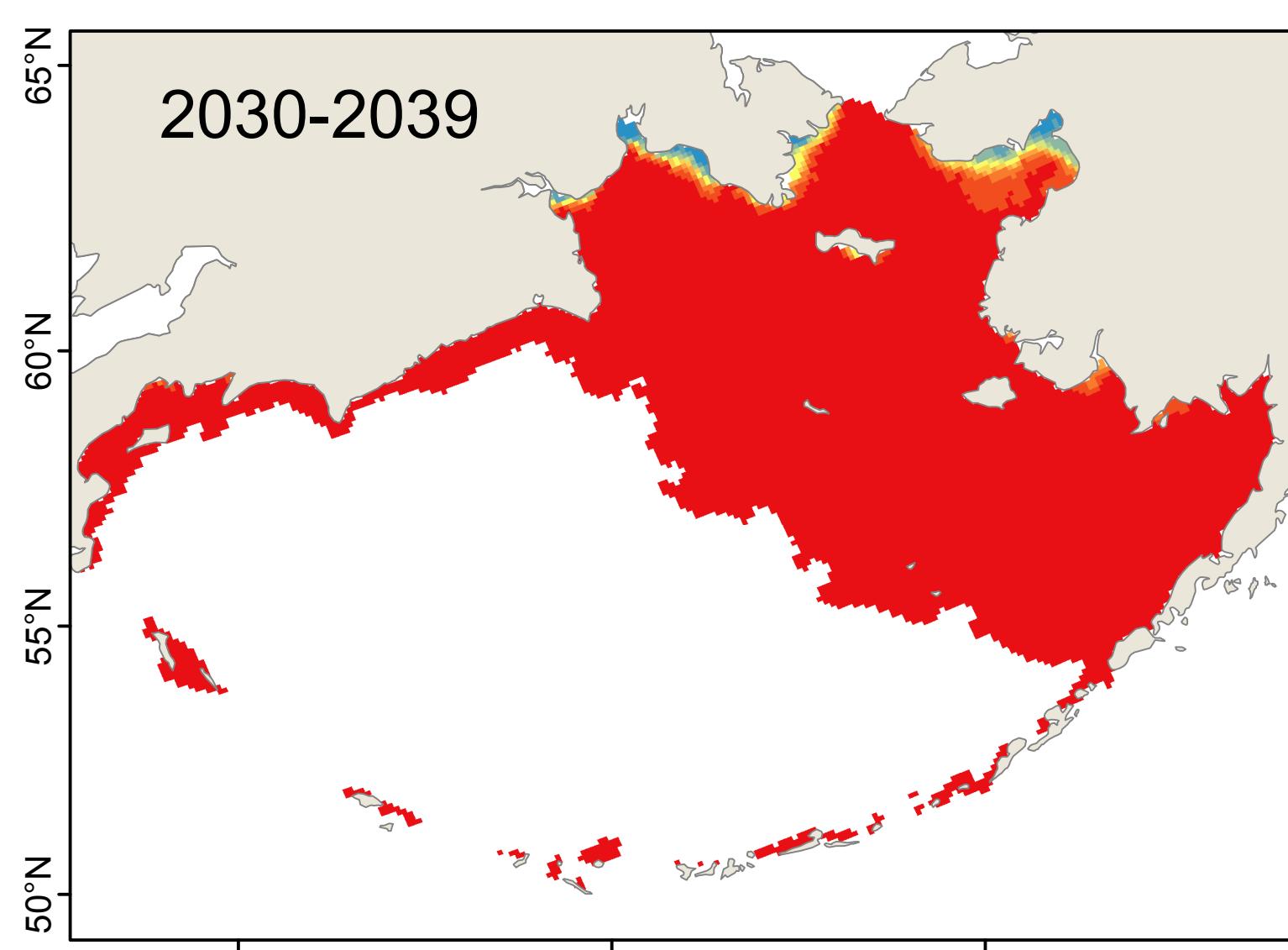
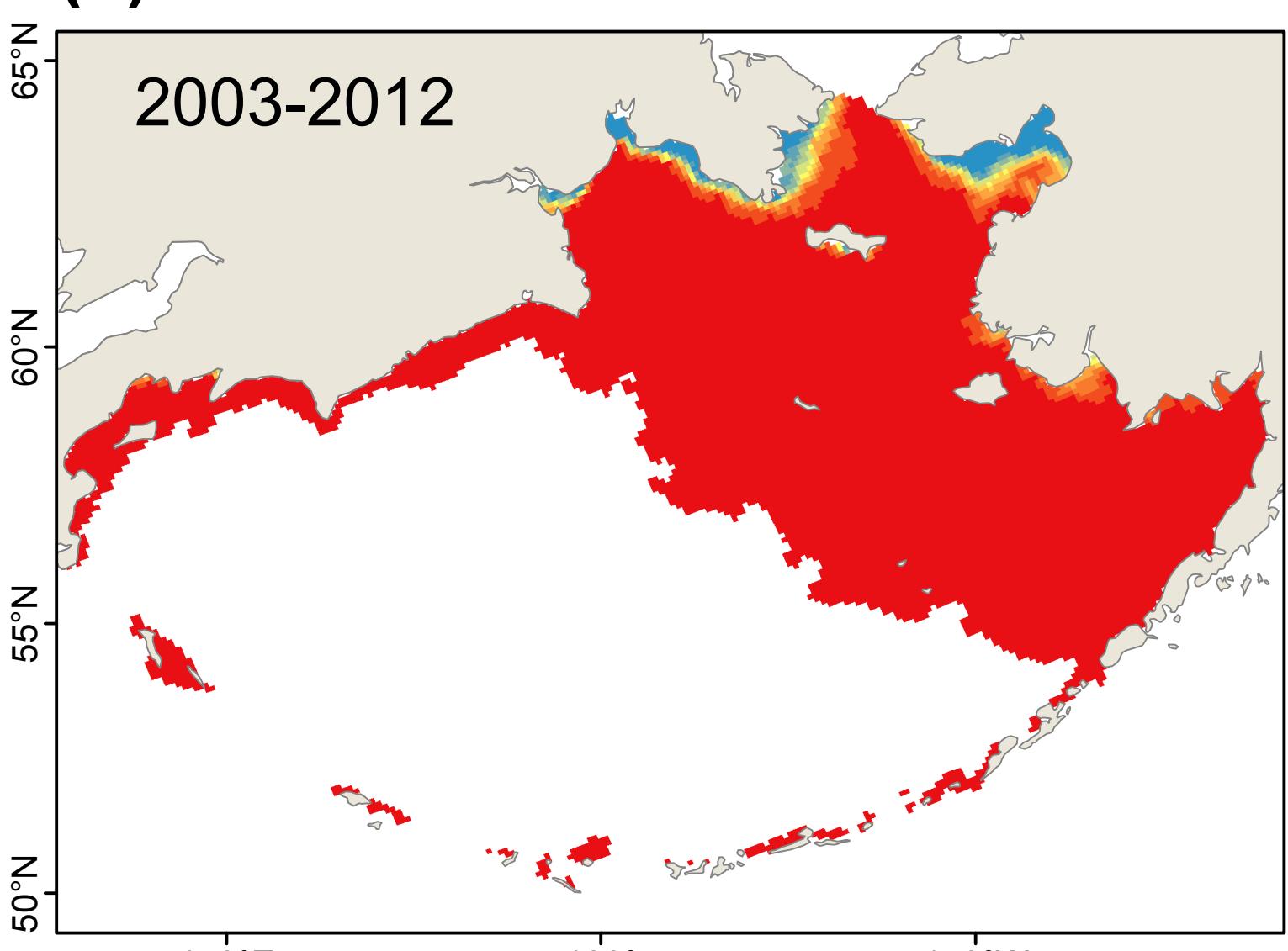
(a) Model: CGCM3-t47



(b) Model: ECHO-G

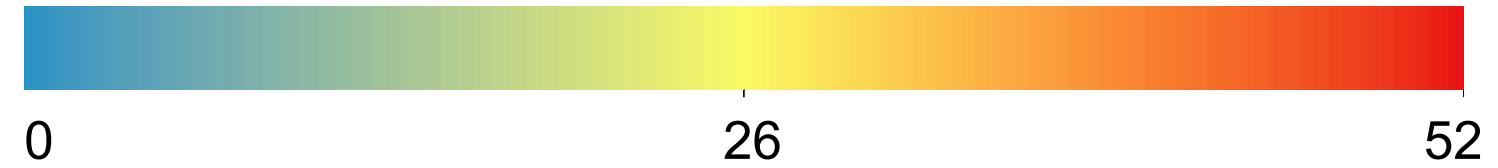


(c) Model: MIROC3.2

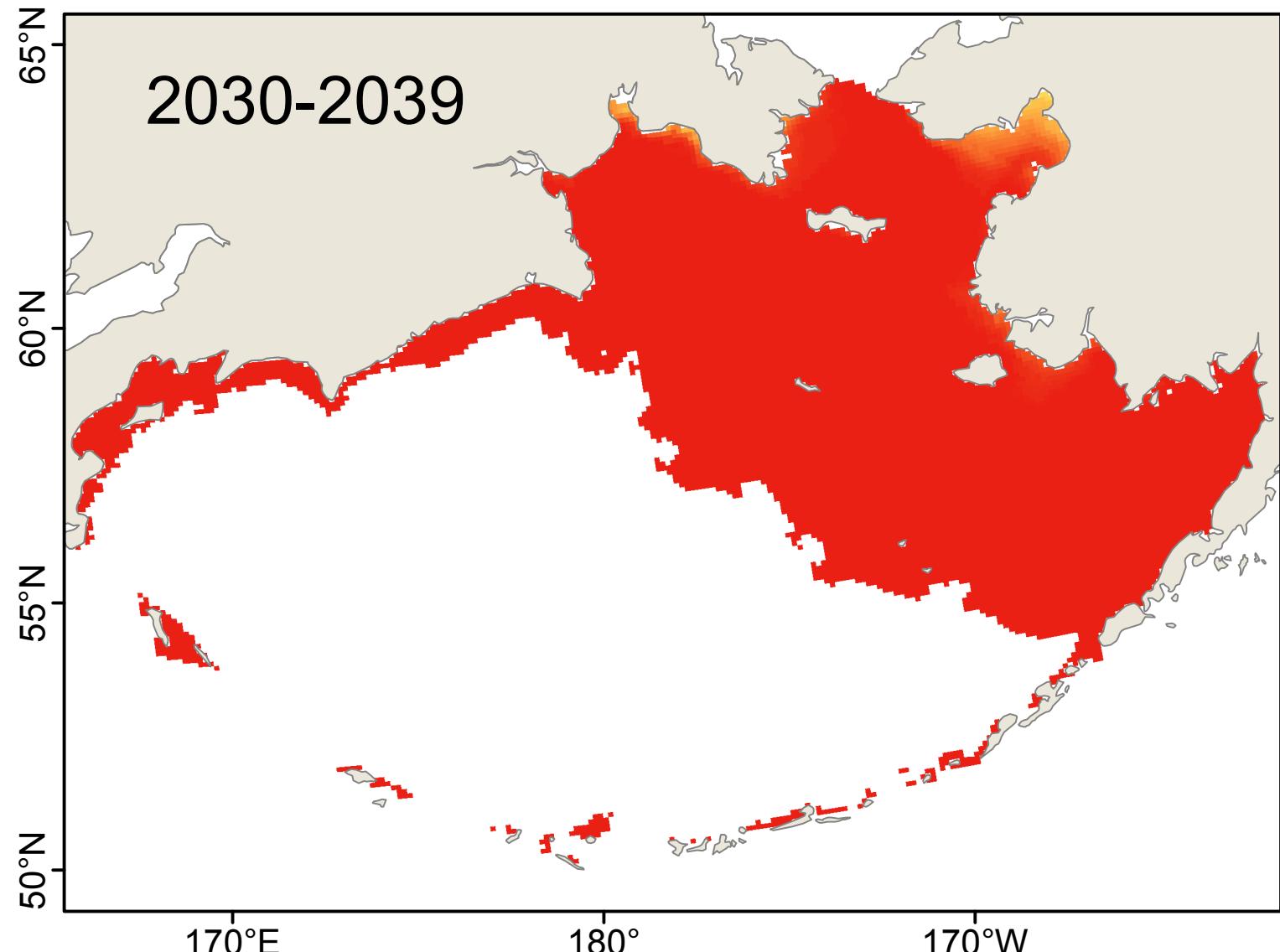
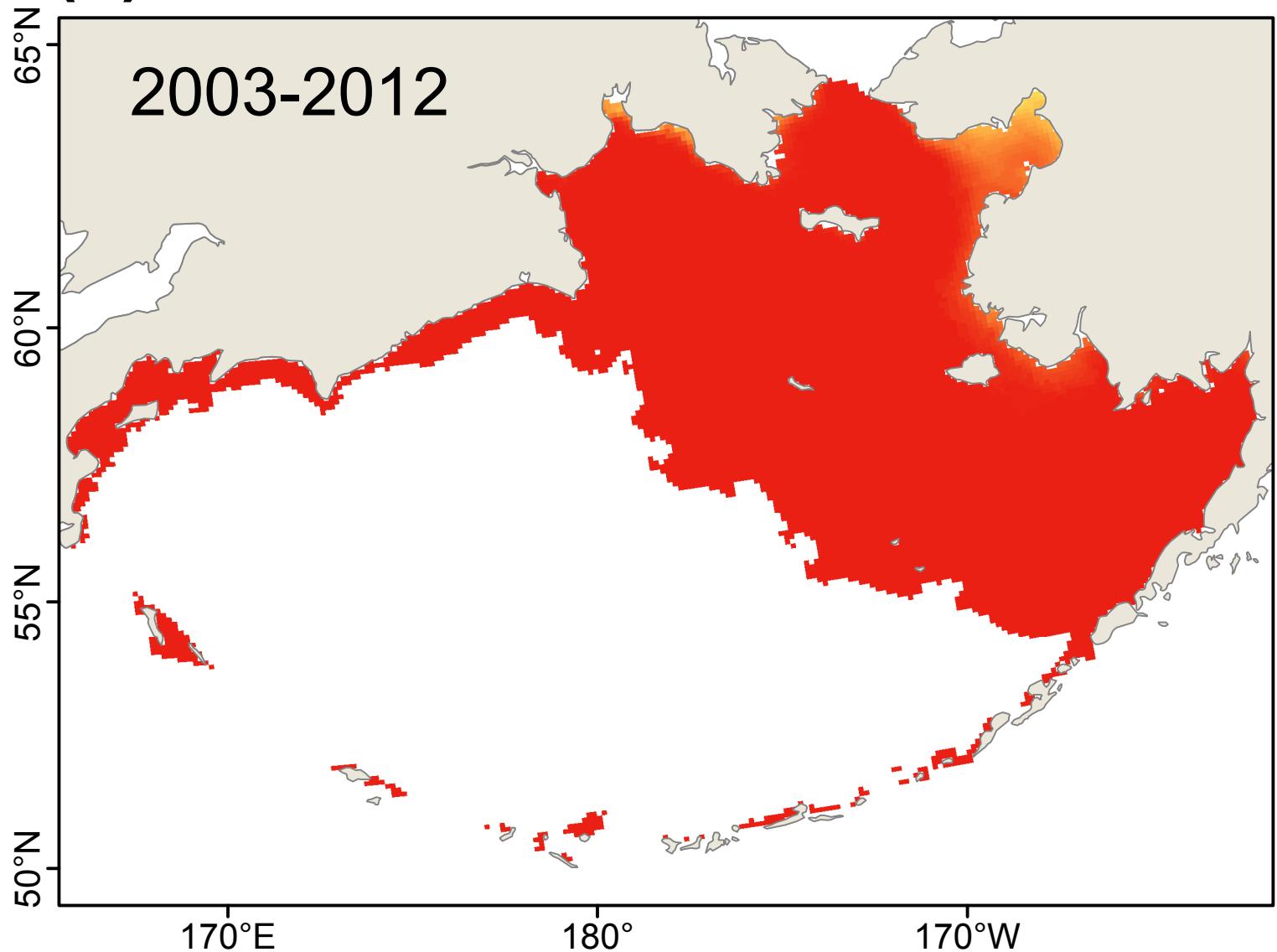


# *Polydora cornuta: Weekly Survival*

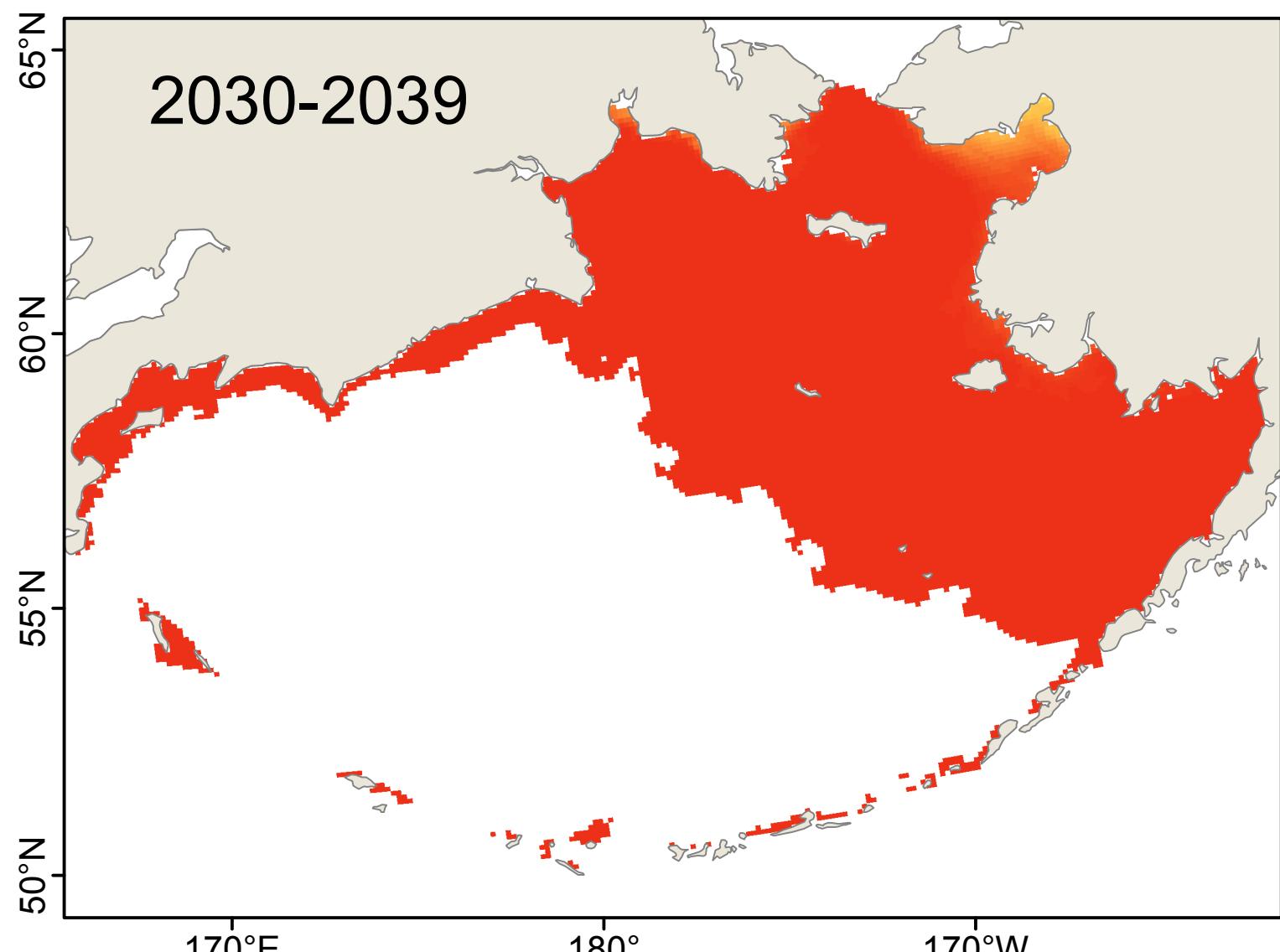
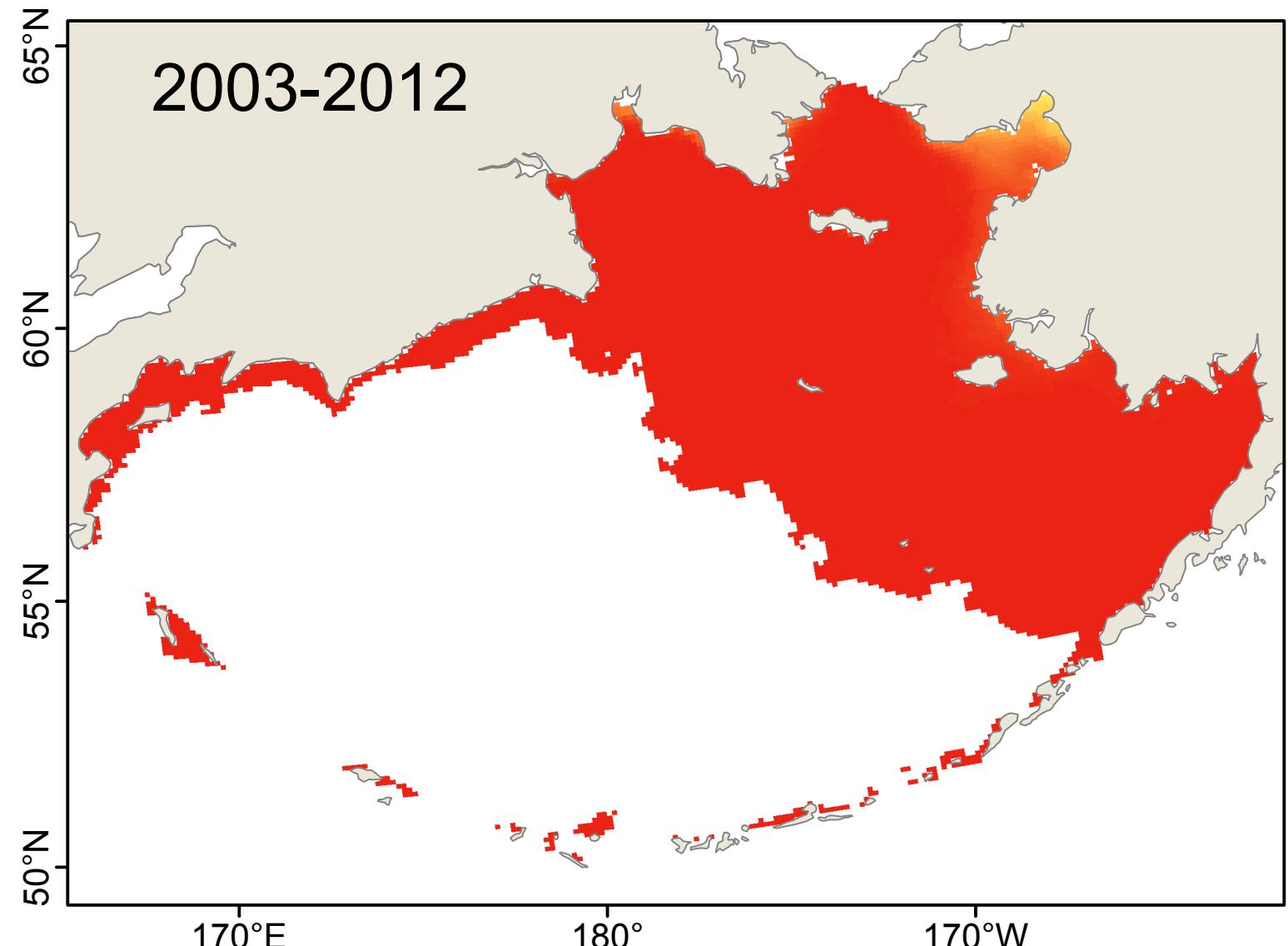
Average number of weeks of suitable habitat



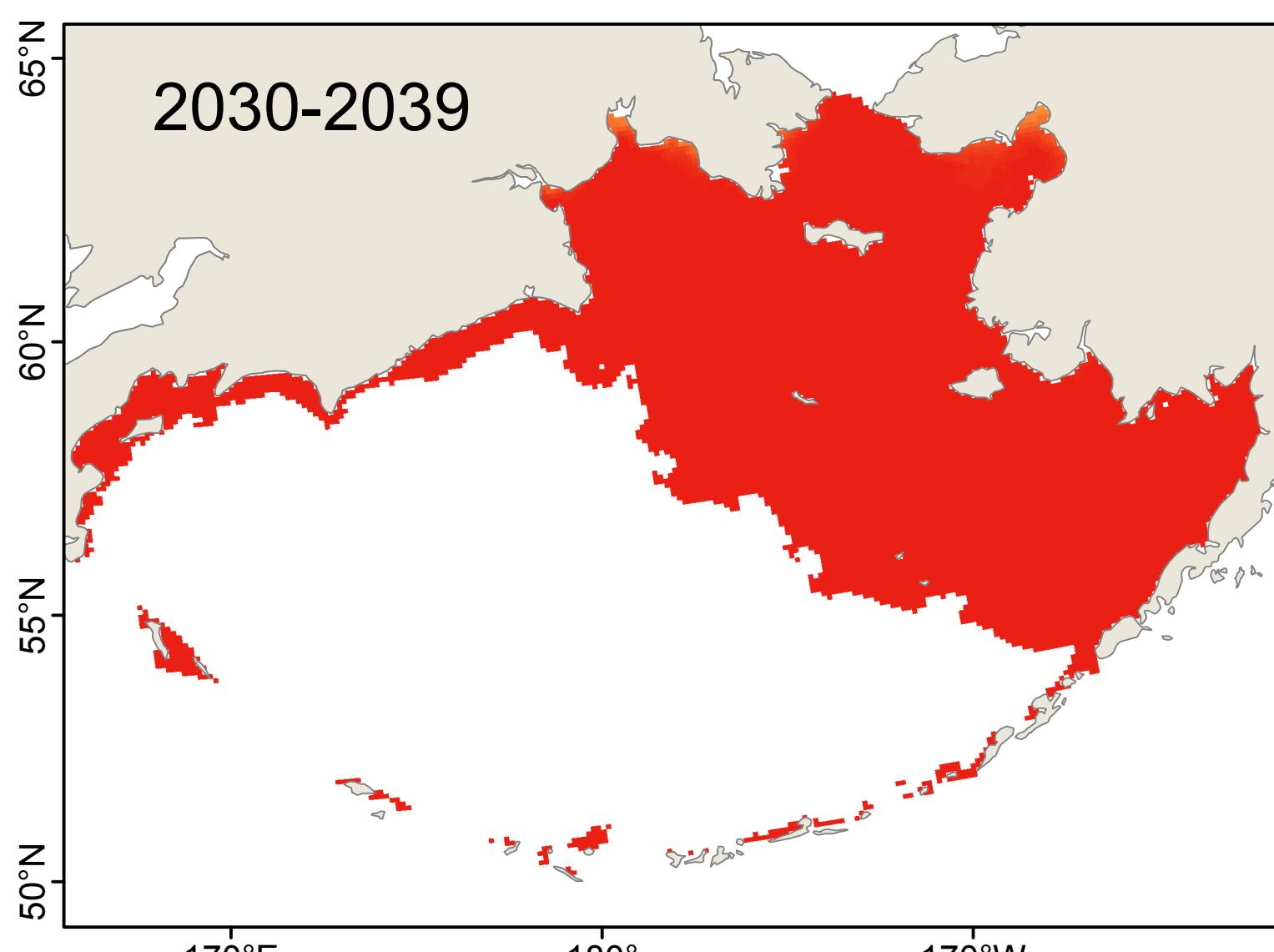
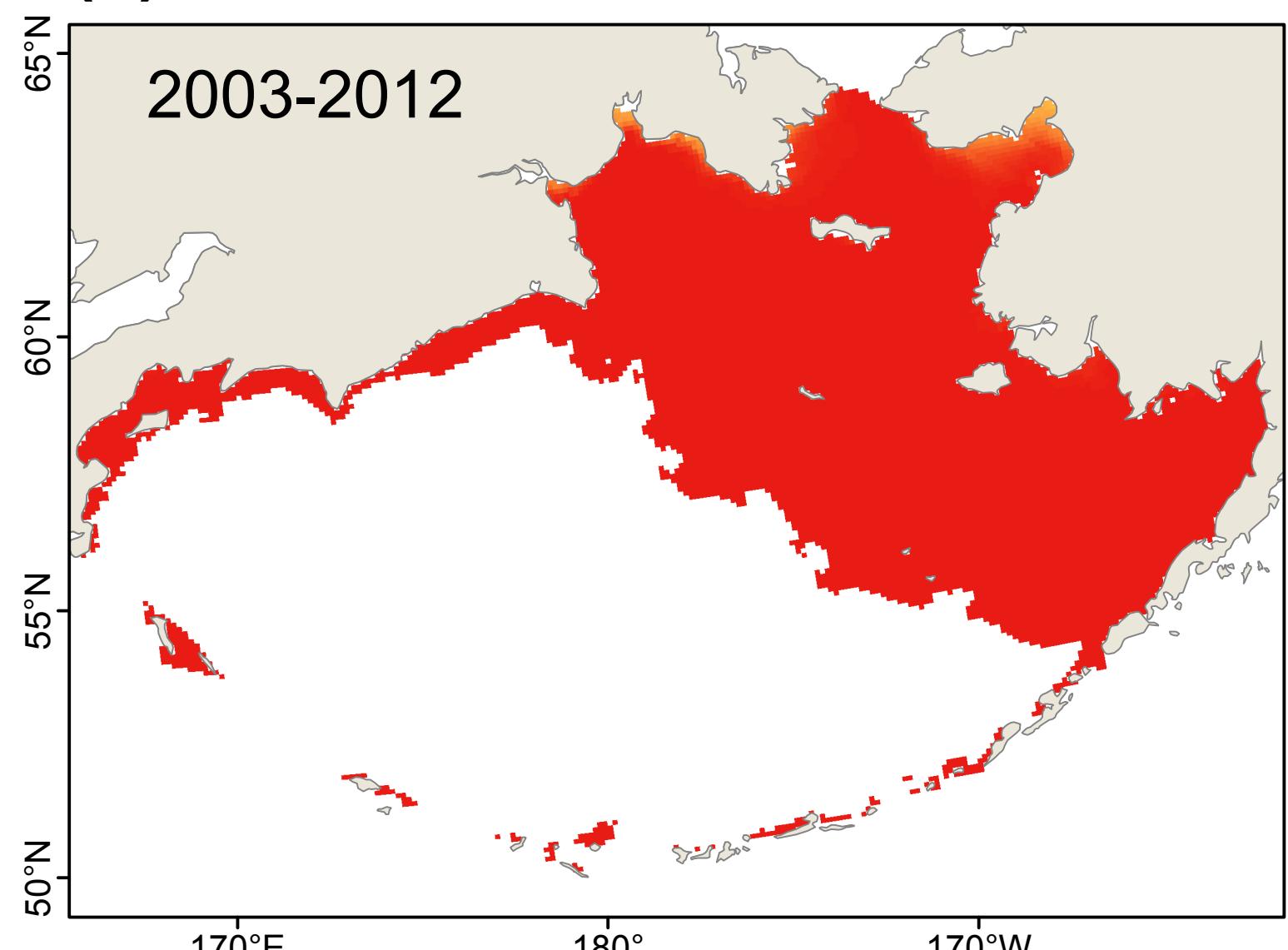
(a) Model: CGCM3-t47



(b) Model: ECHO-G

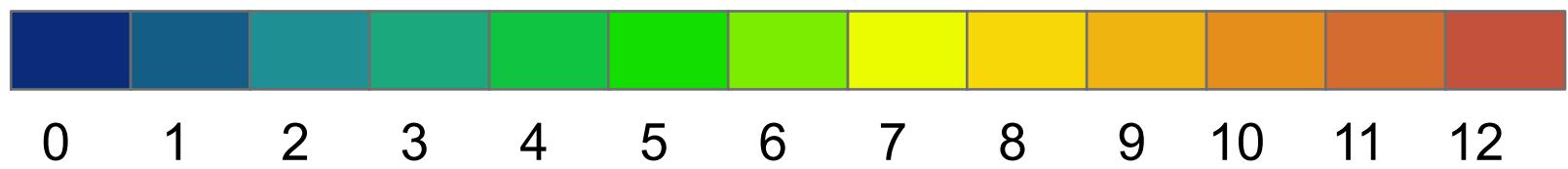


(c) Model: MIROC3.2

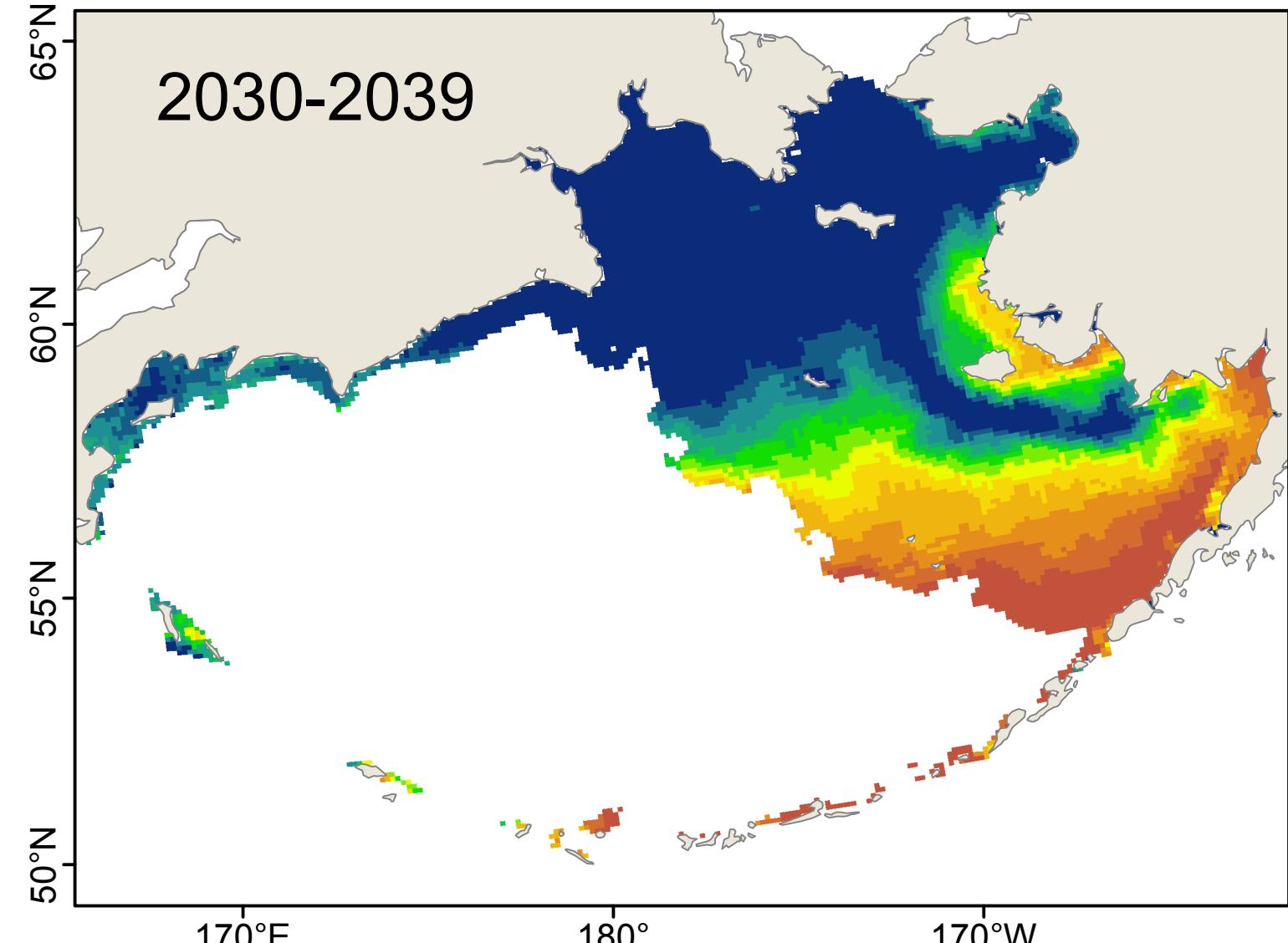
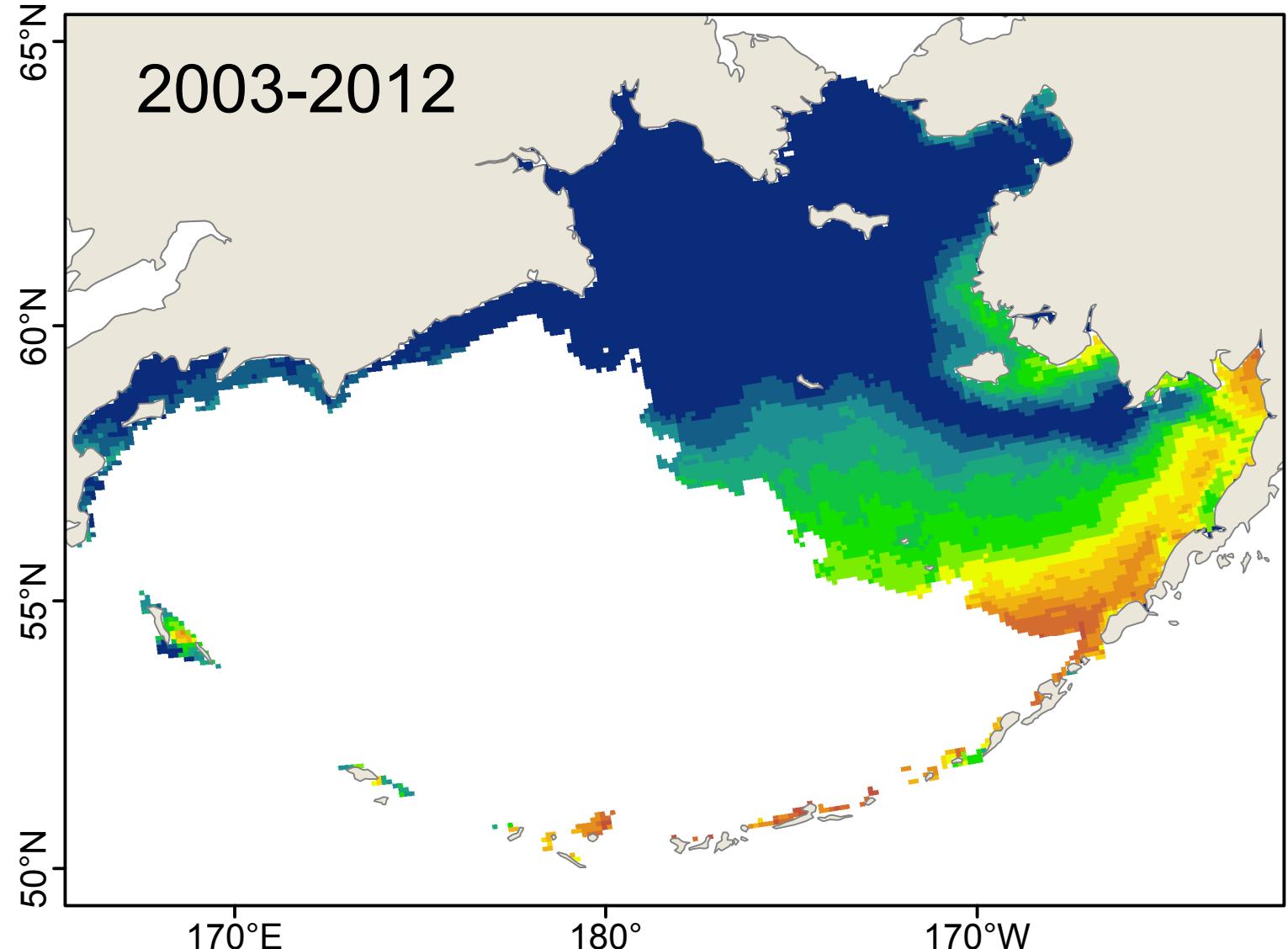


# *Polydora cornuta: Reproduction*

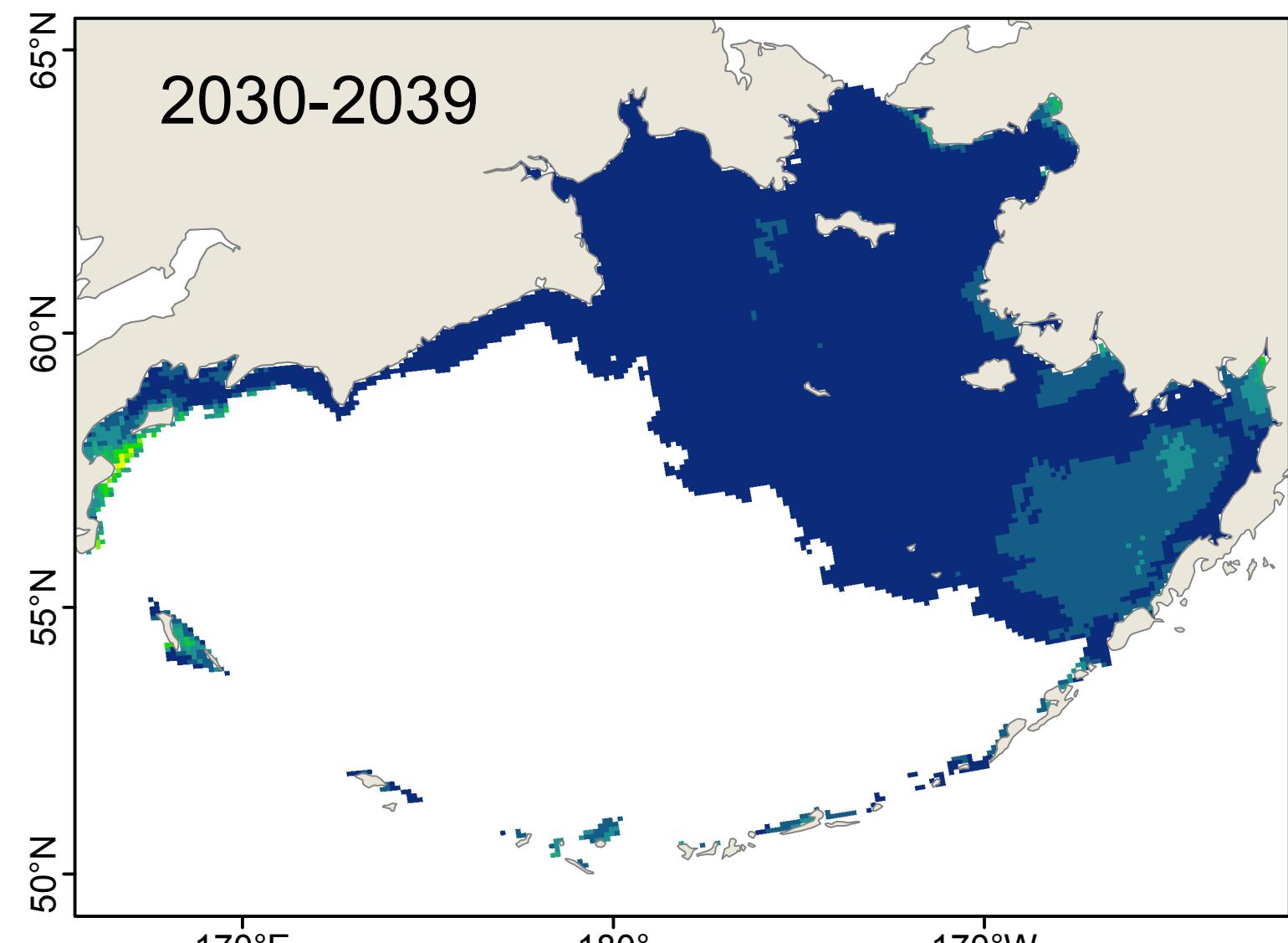
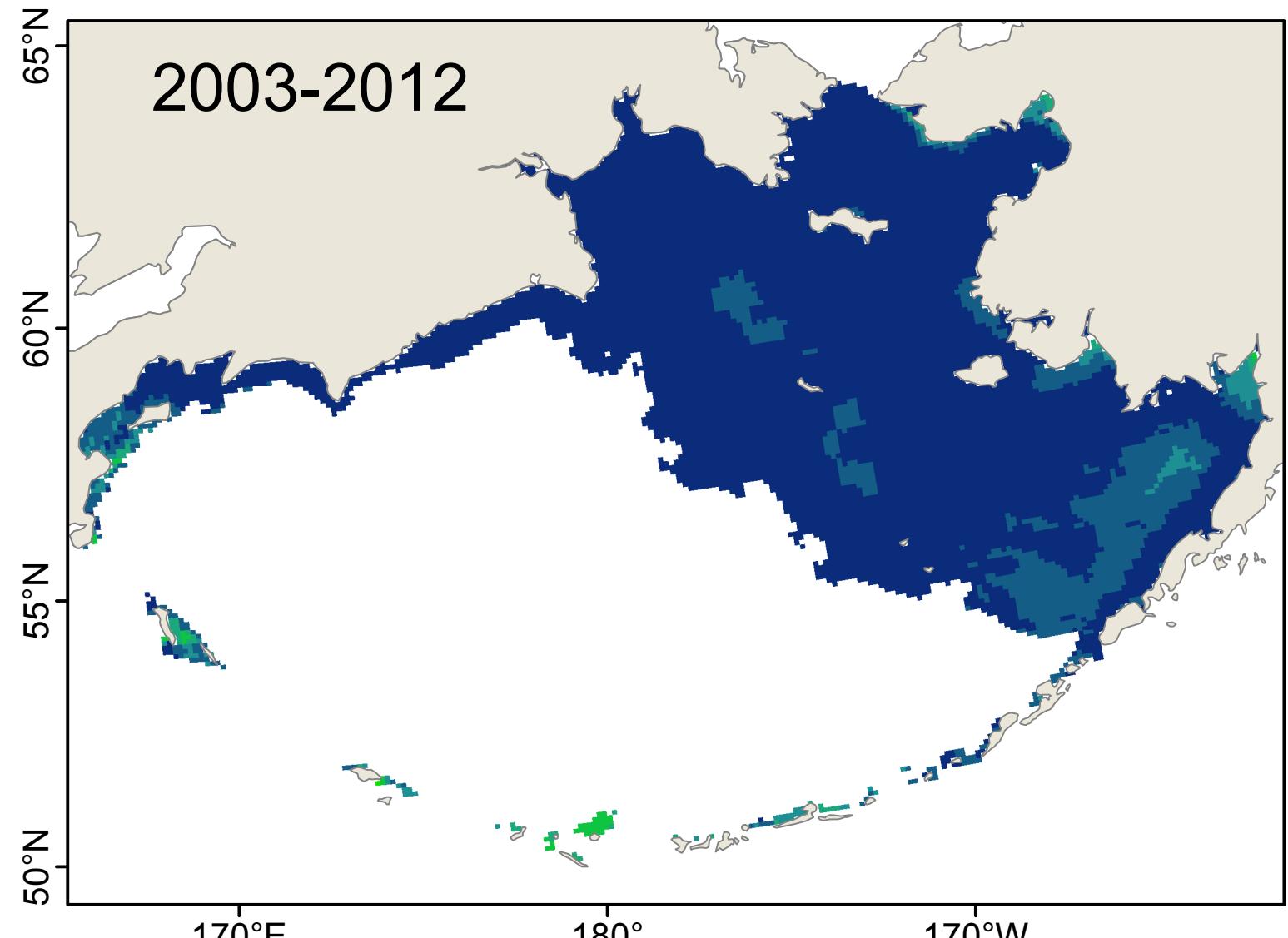
Average number of consecutive weeks of suitable habitat



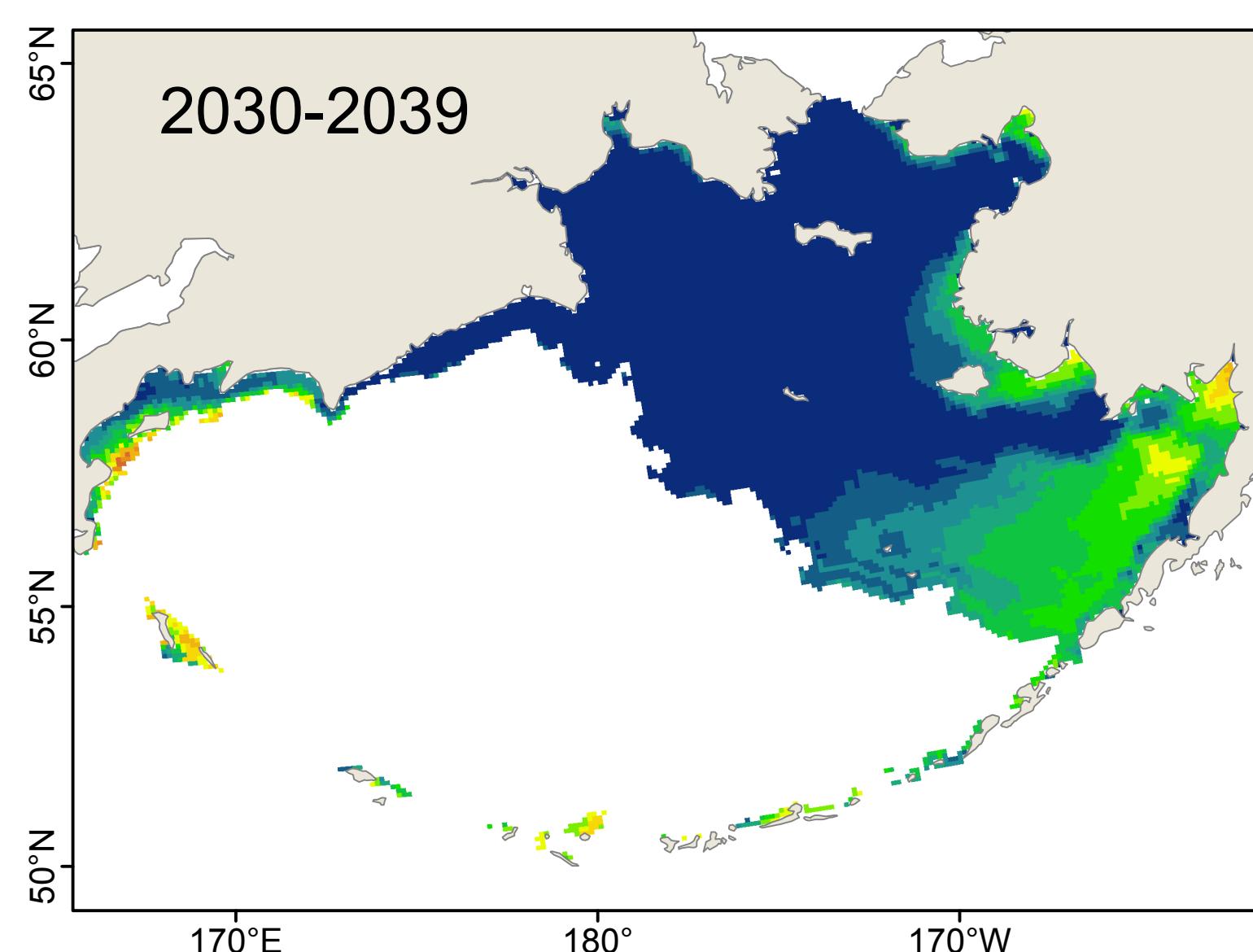
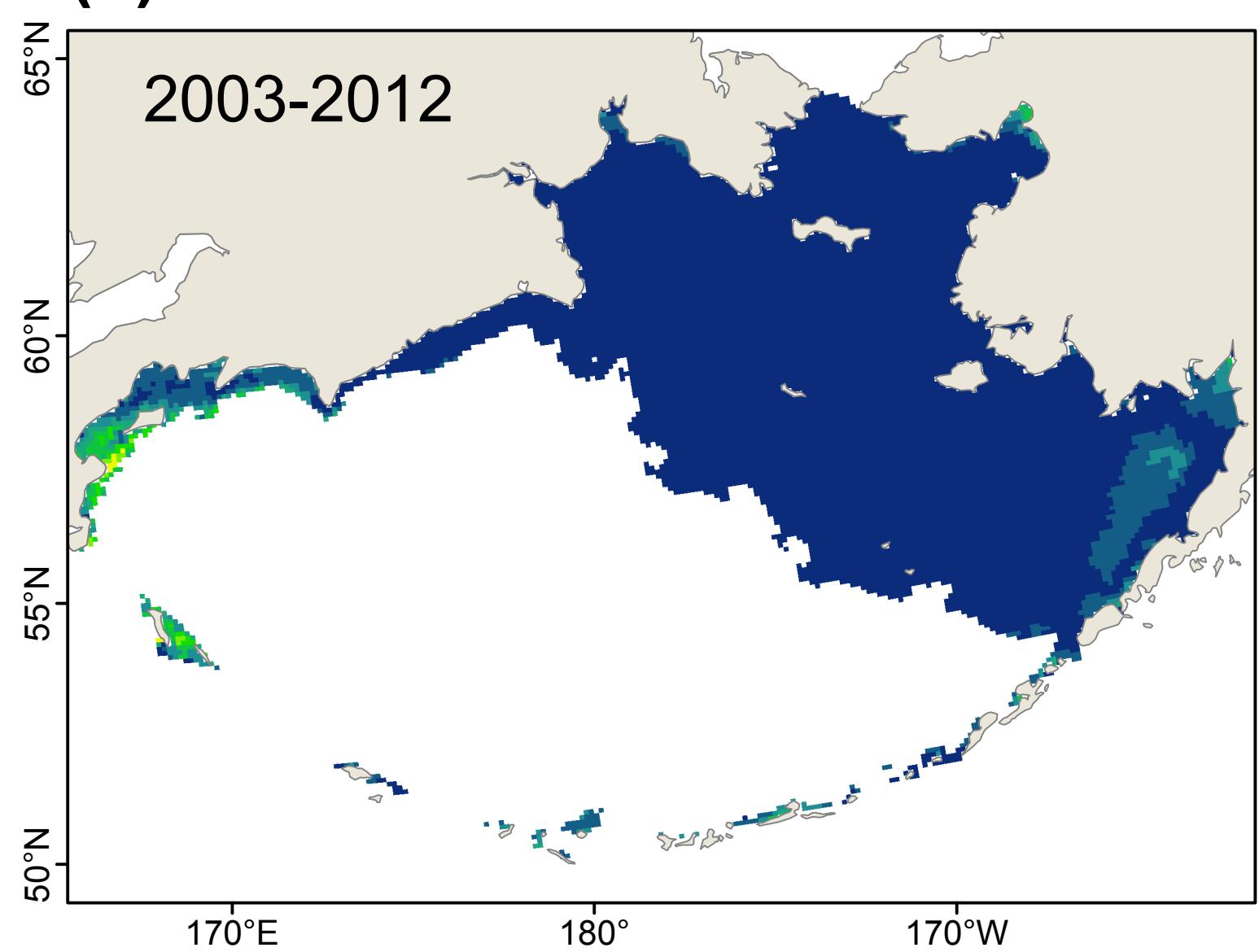
(a) Model: CGCM3-t47



(b) Model: ECHO-G

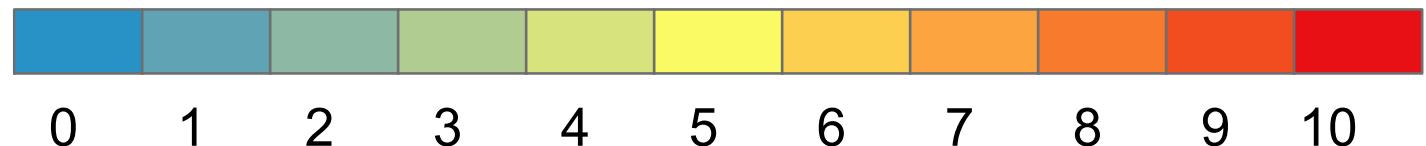


(c) Model: MIROC3.2

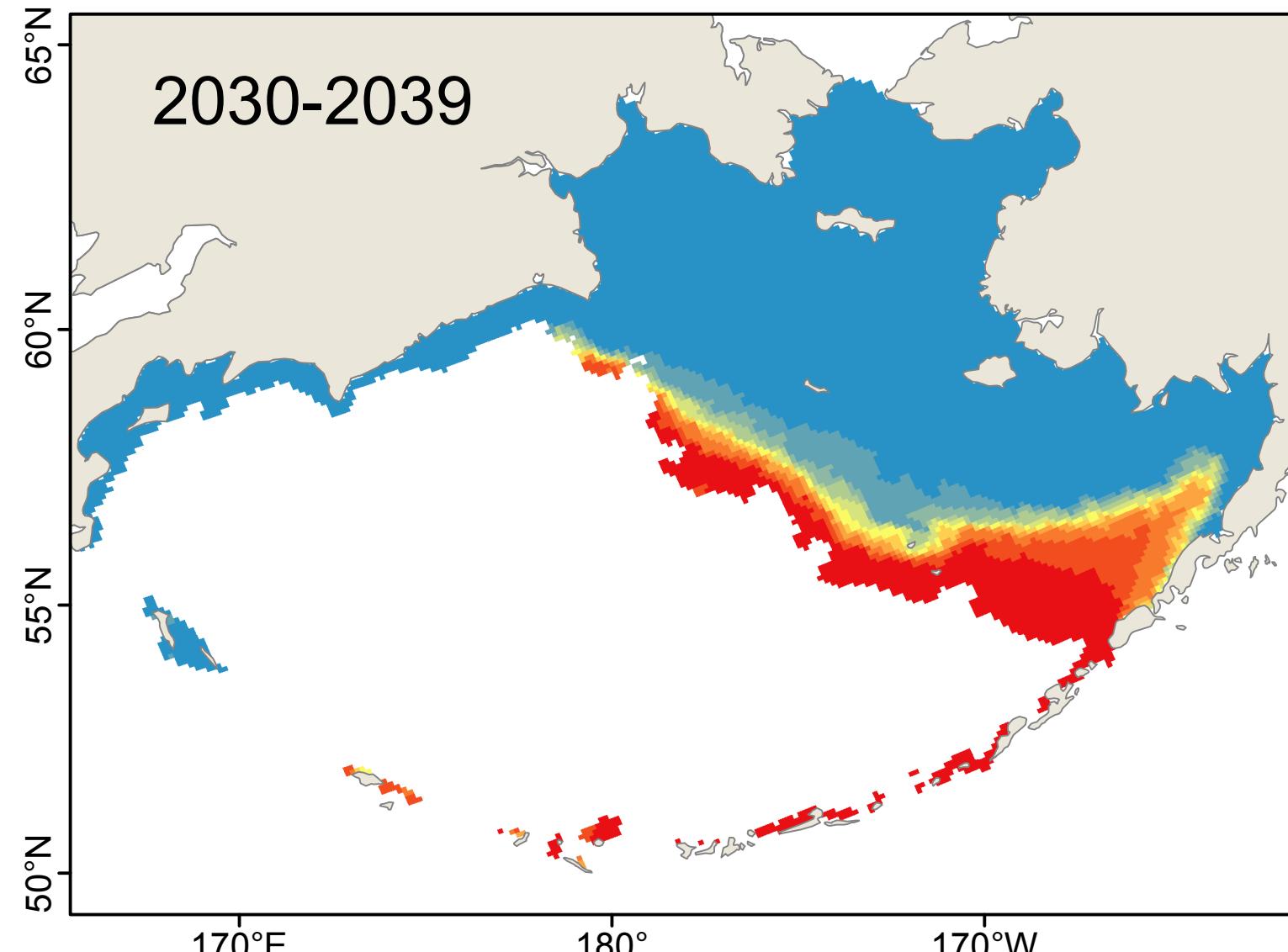
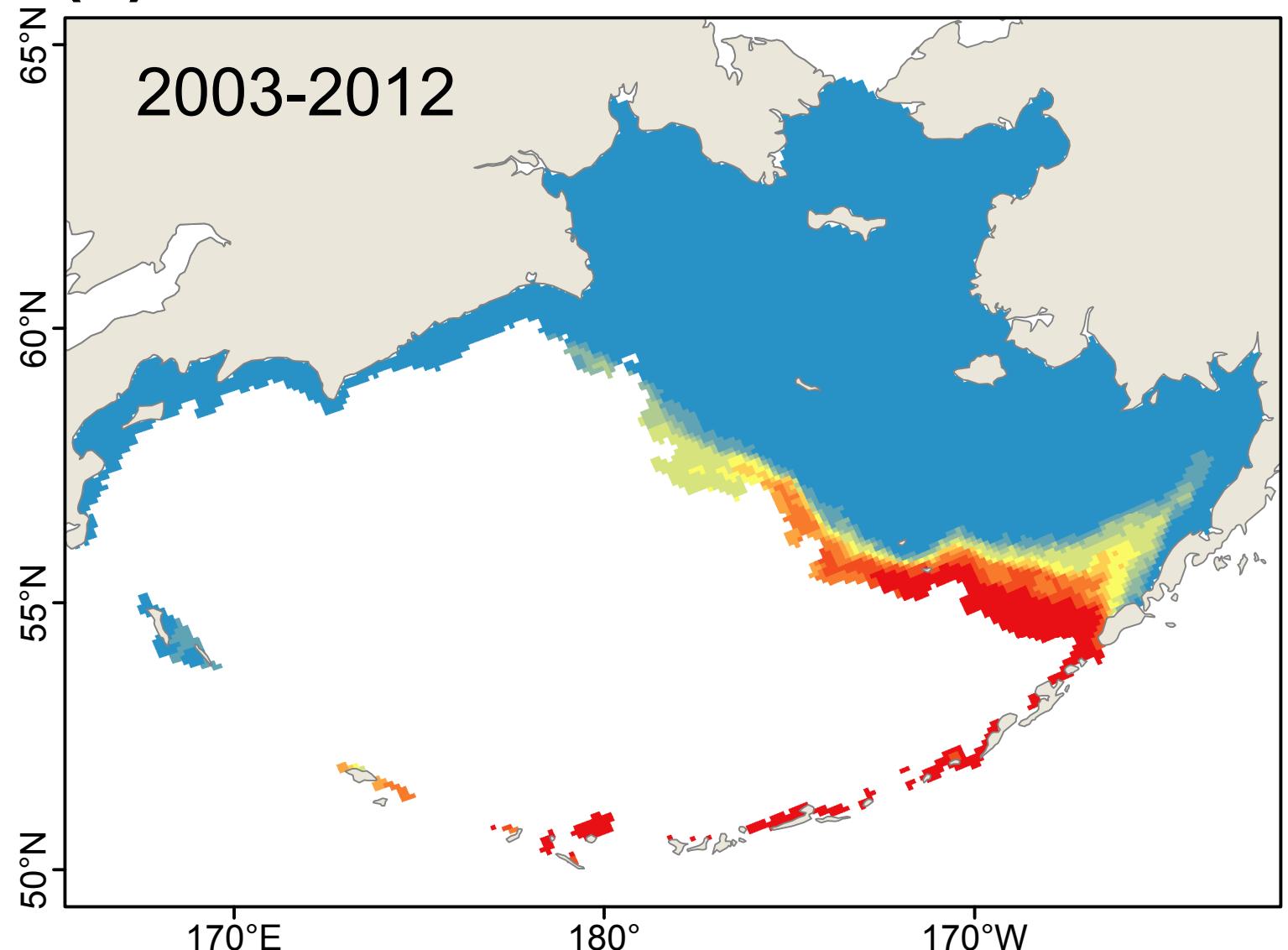


# *Bugula neritina: Year-round Survival*

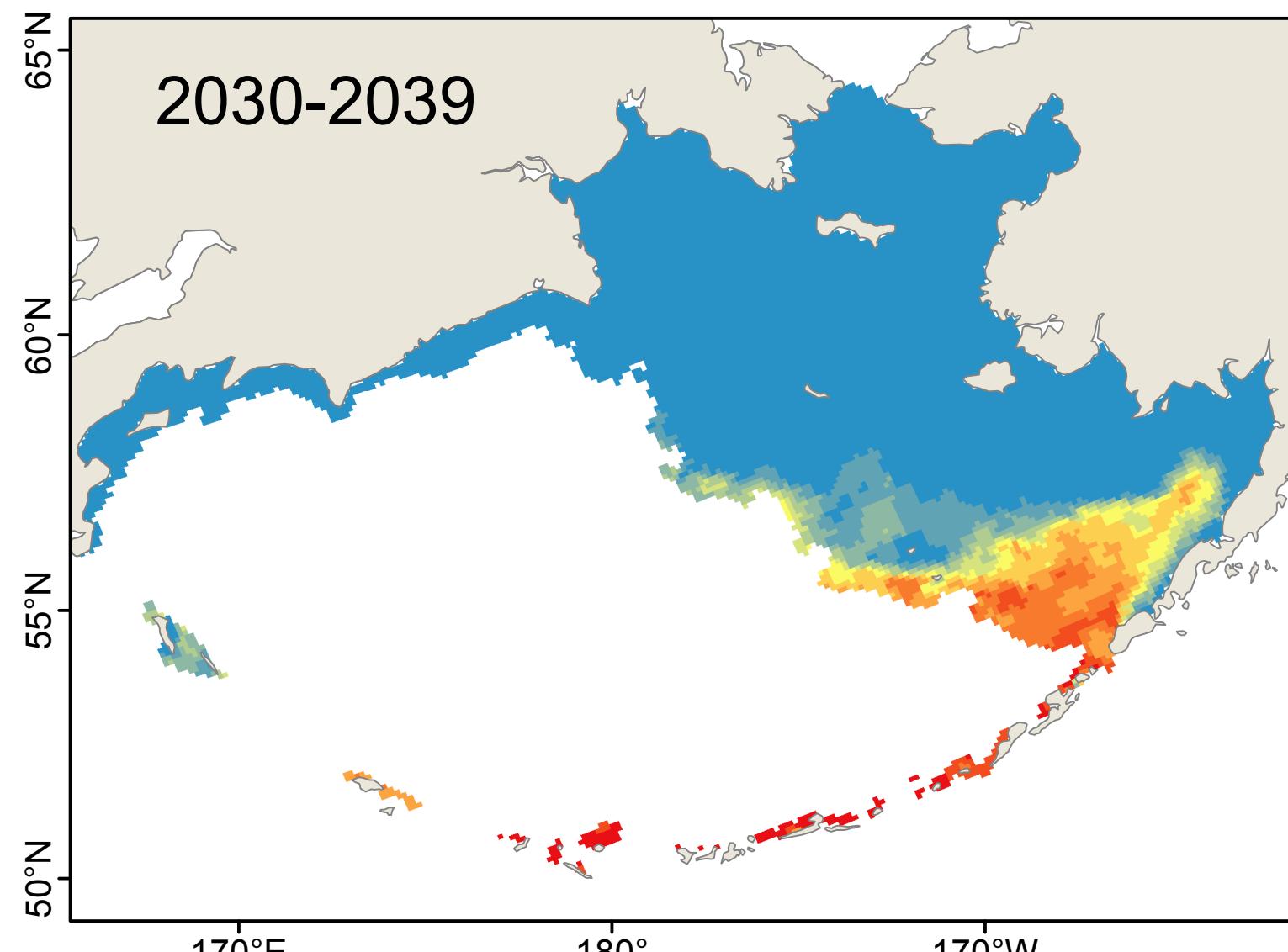
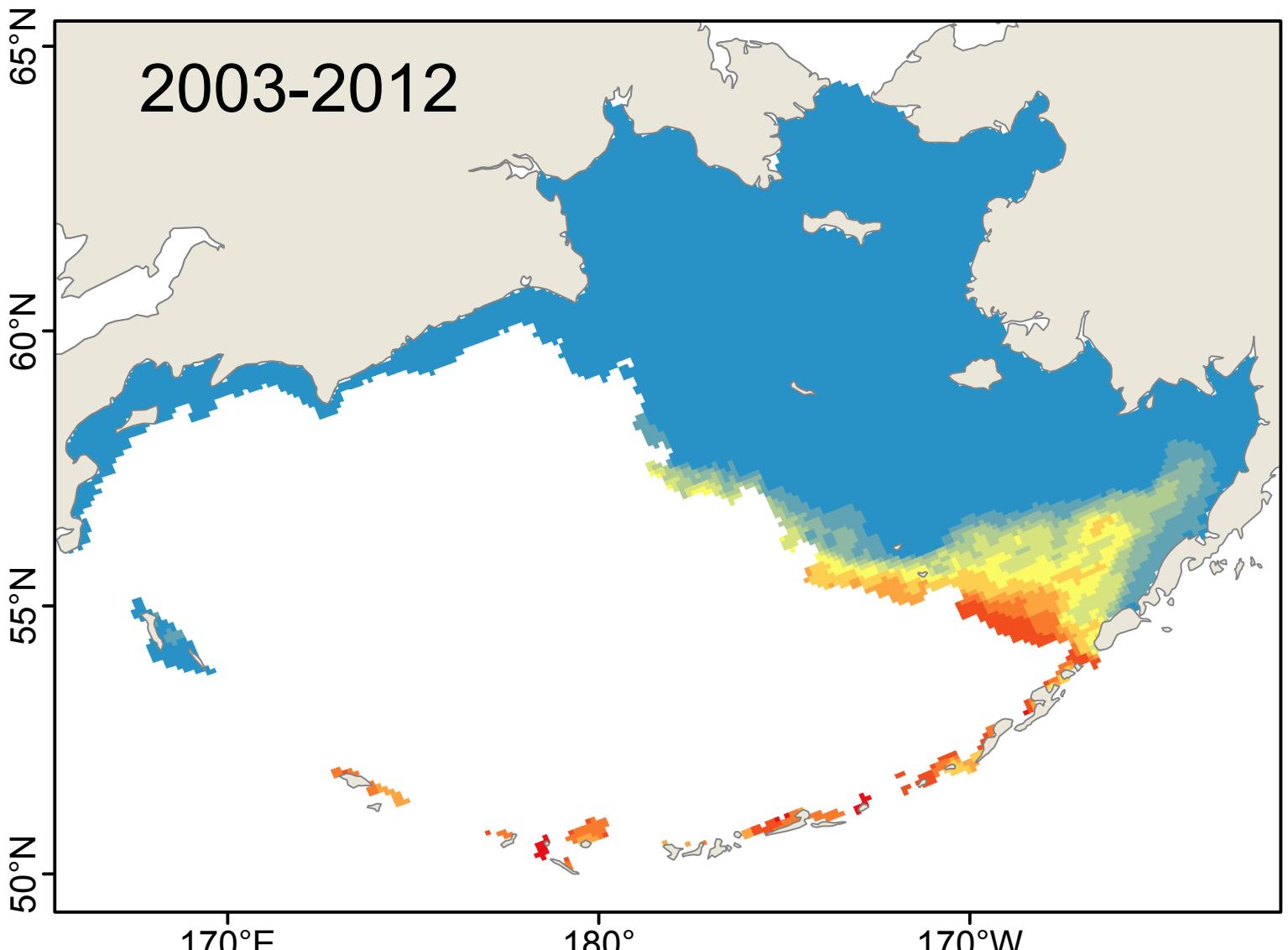
Number of years with suitable habitat



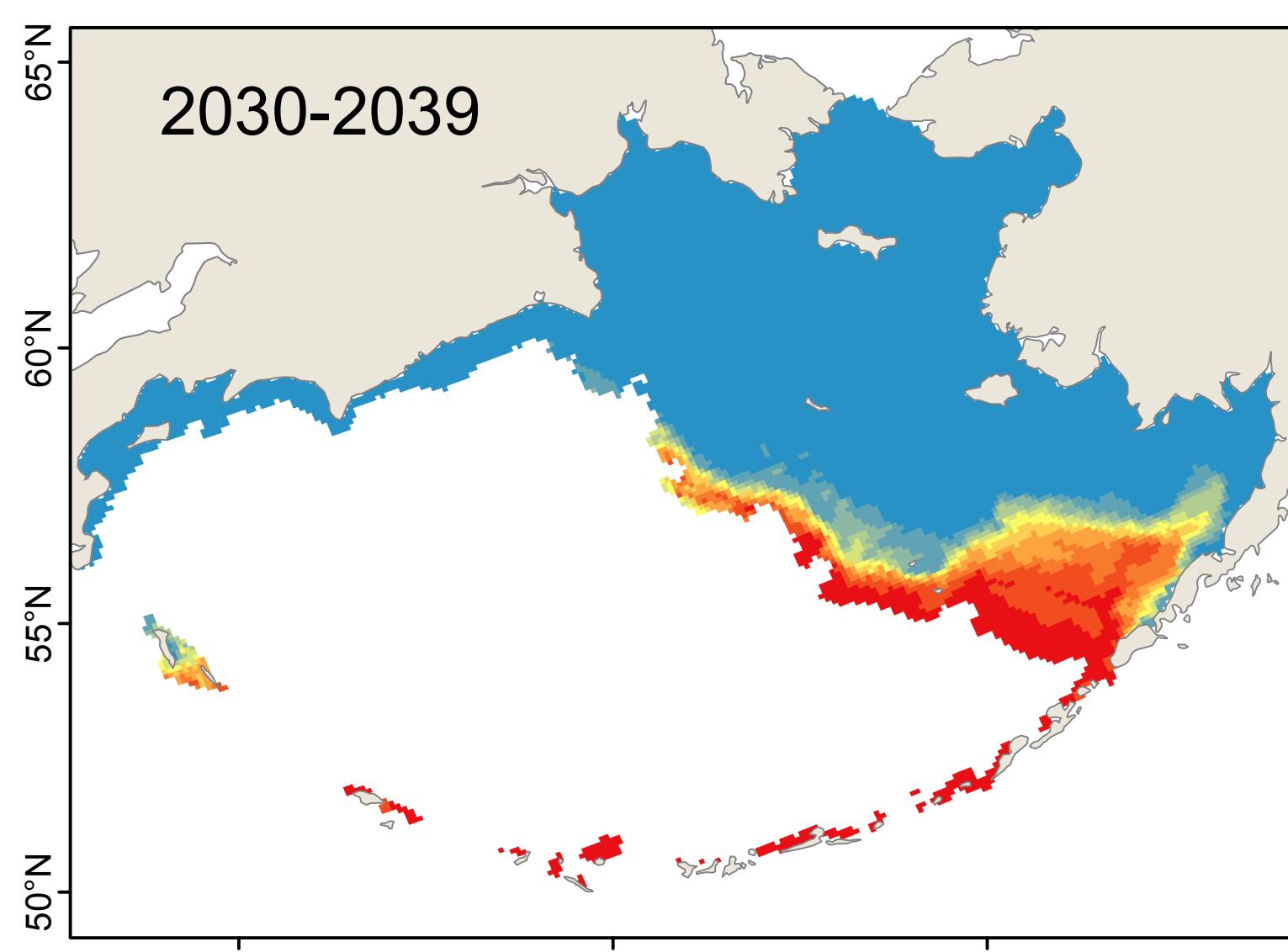
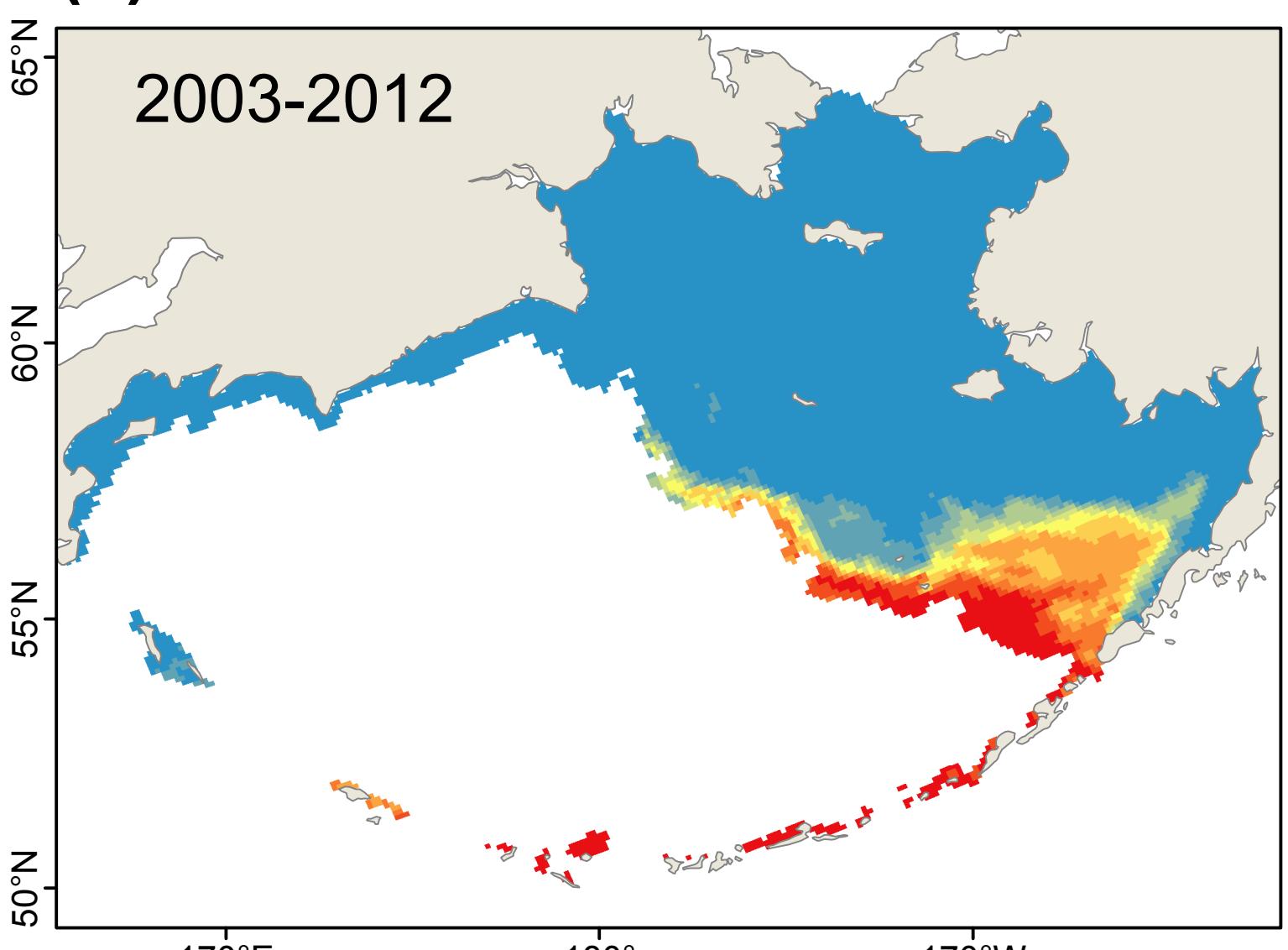
(a) Model: CGCM3-t47



(b) Model: ECHO-G

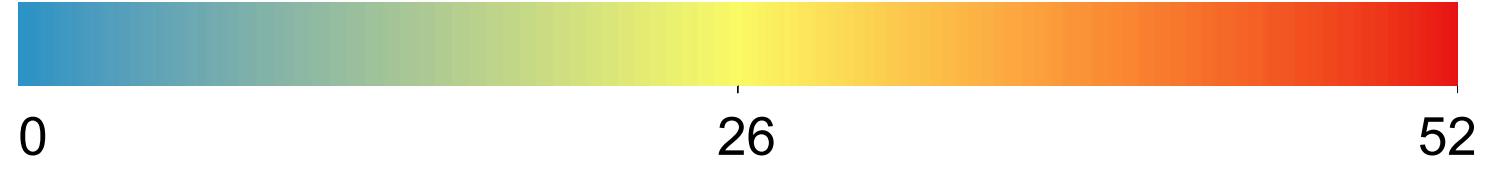


(c) Model: MIROC3.2

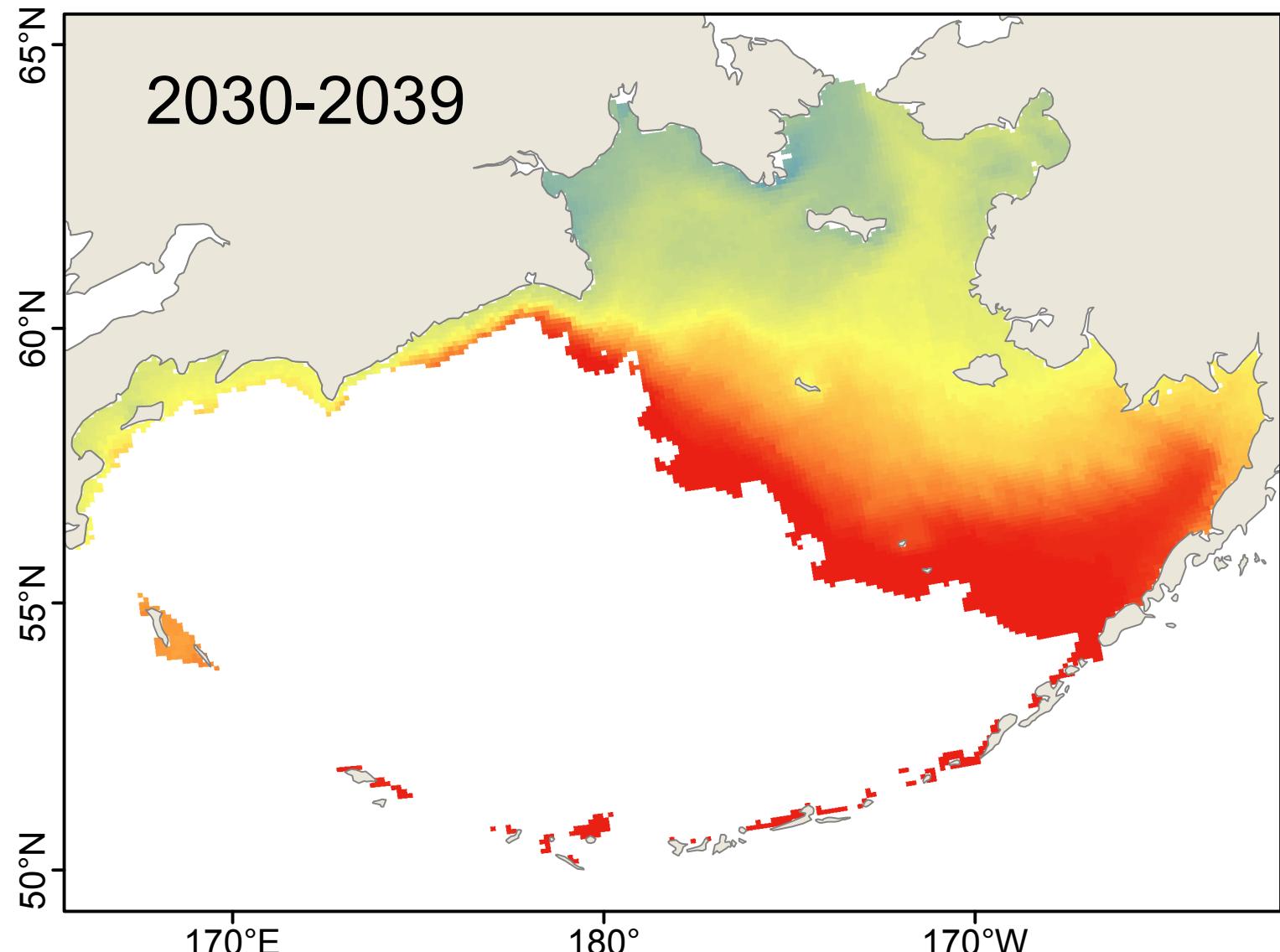
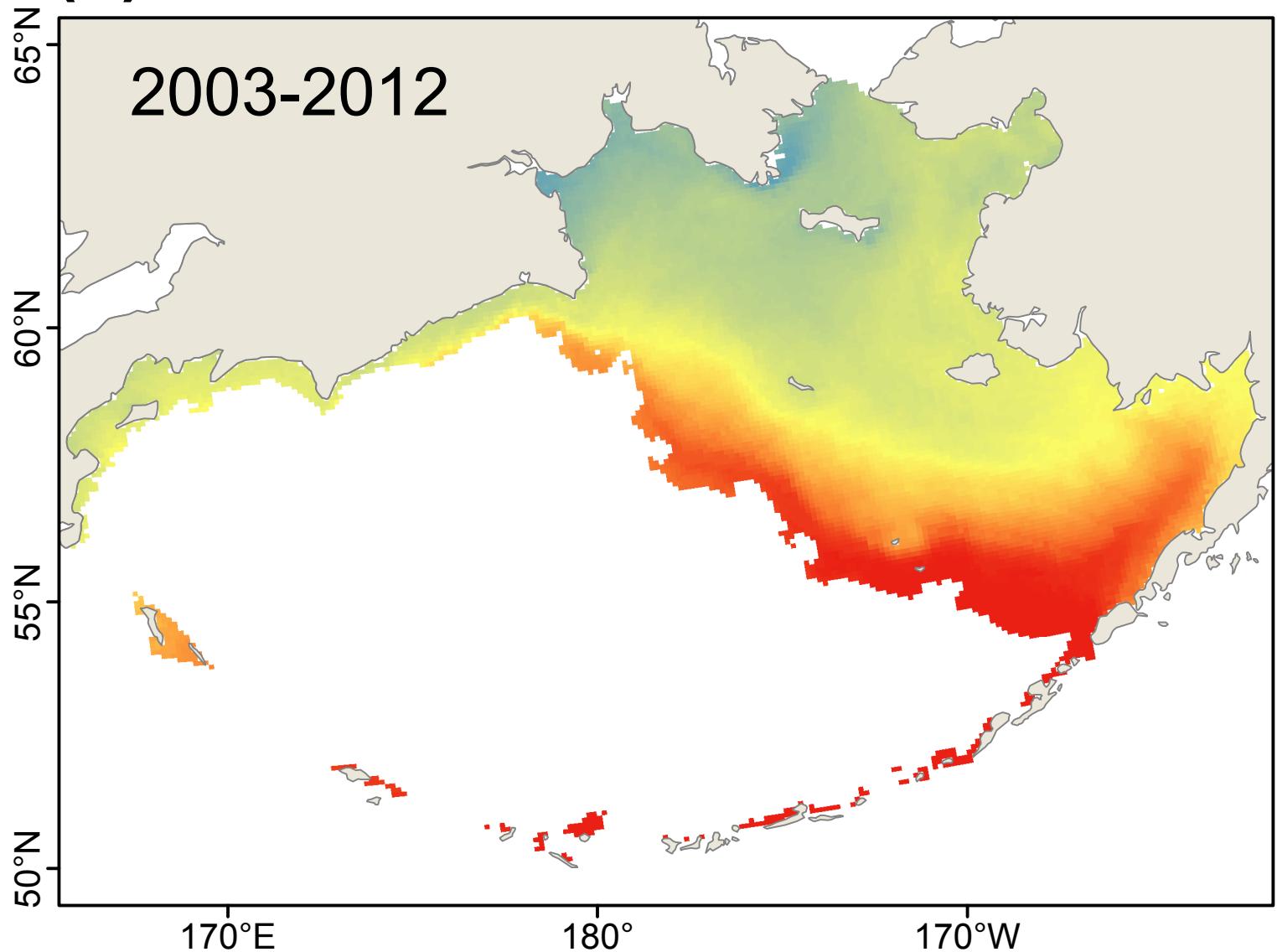


# *Bugula neritina: Weekly Survival*

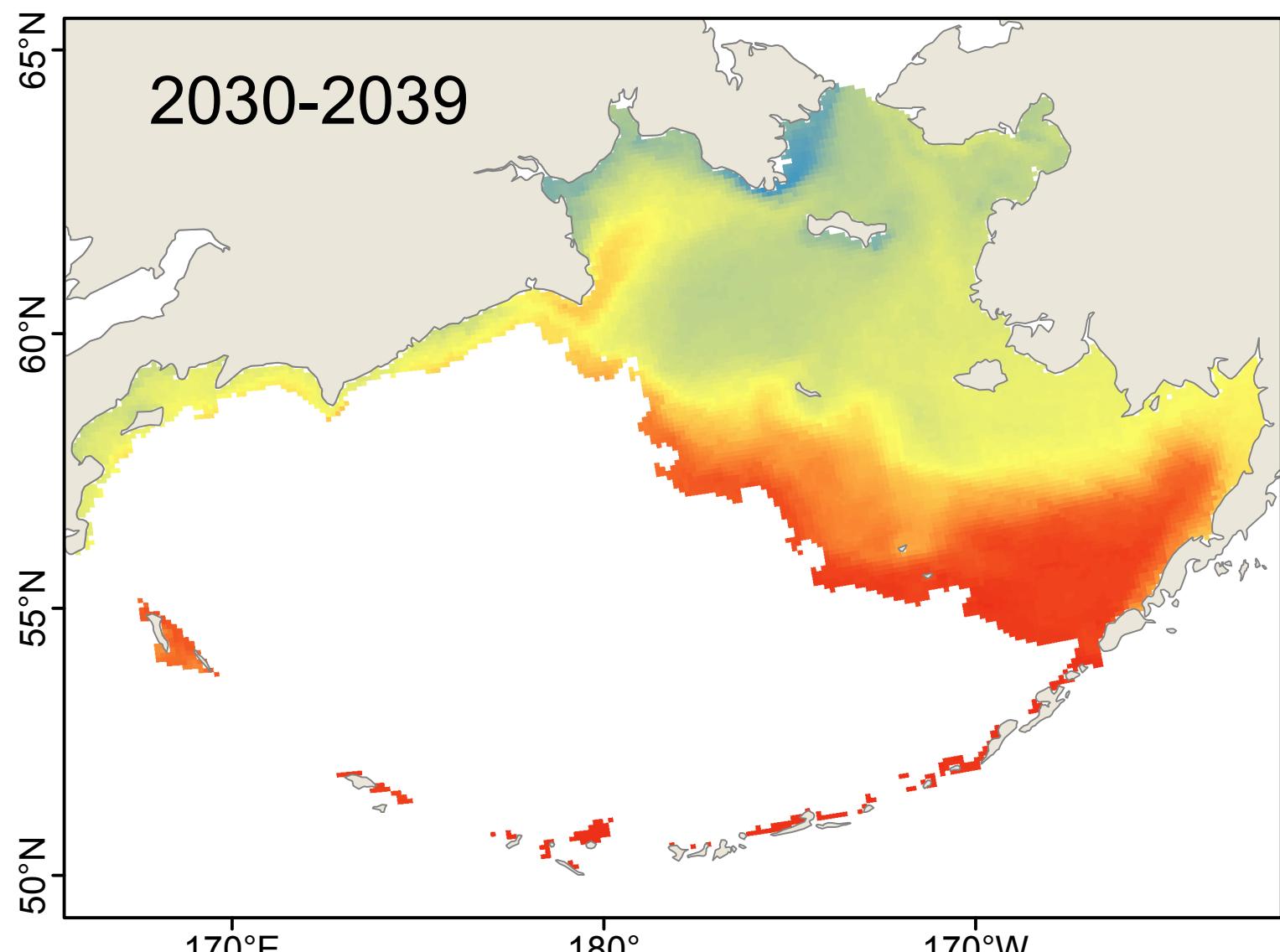
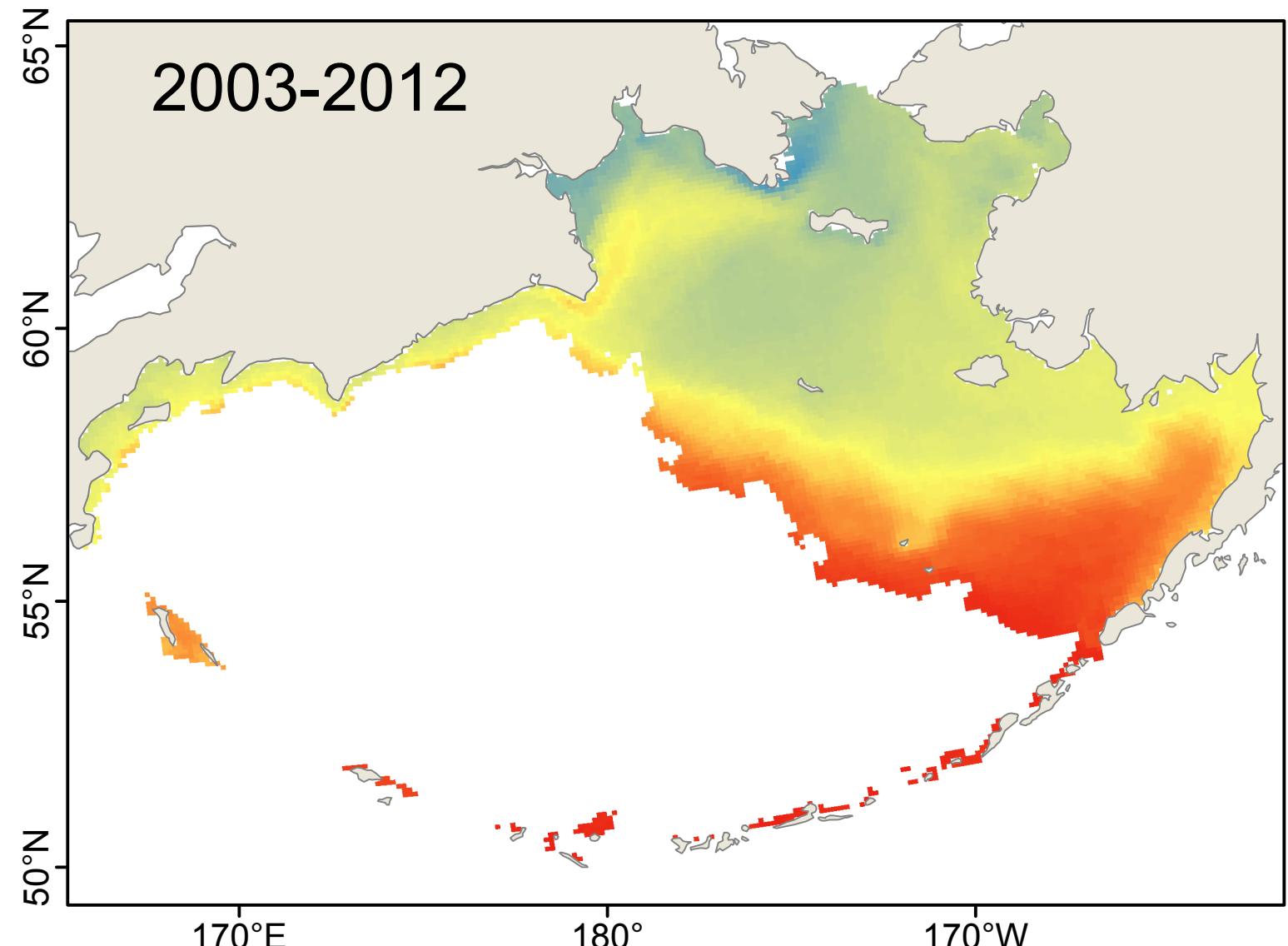
Average number of weeks of suitable habitat



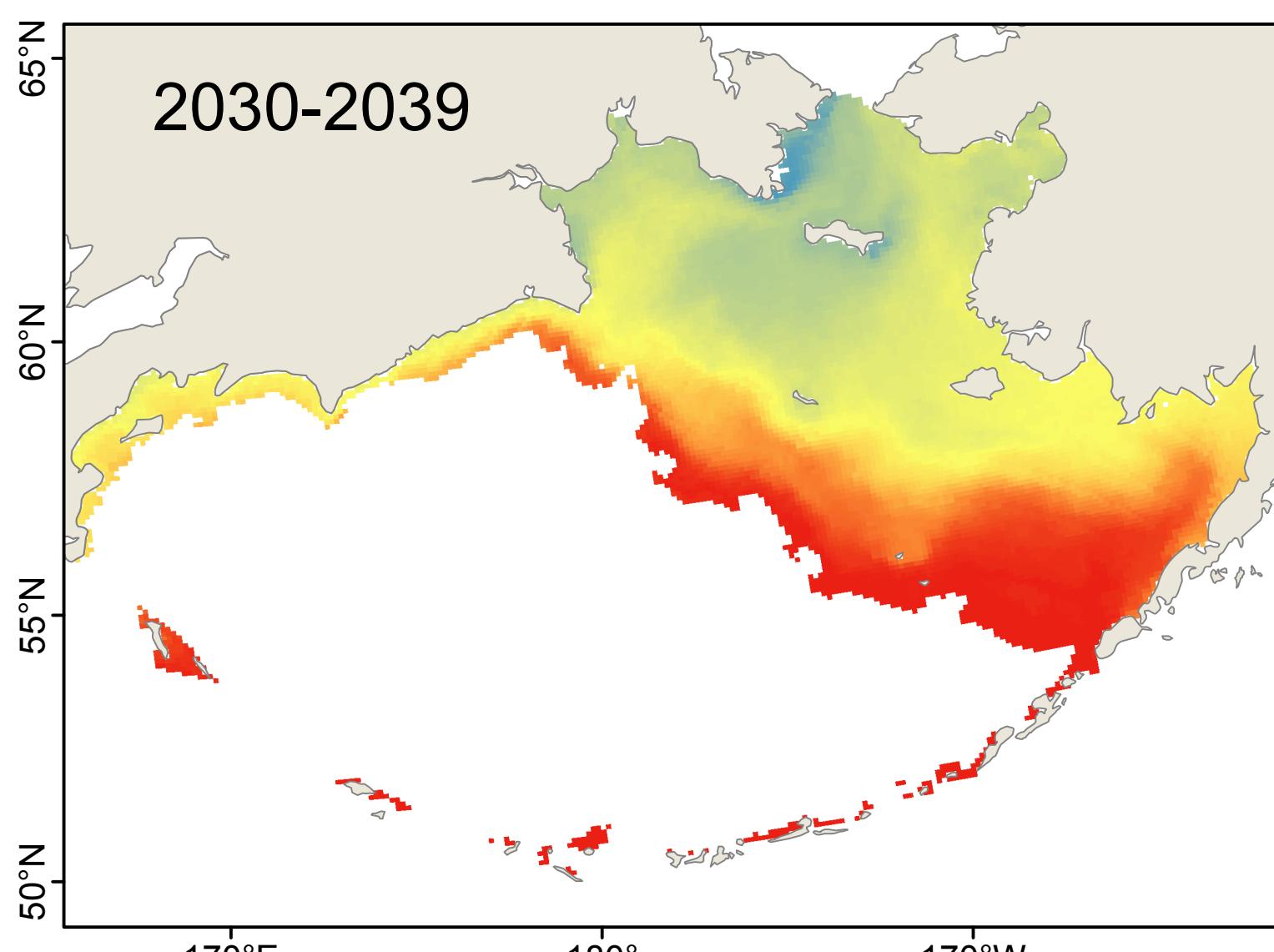
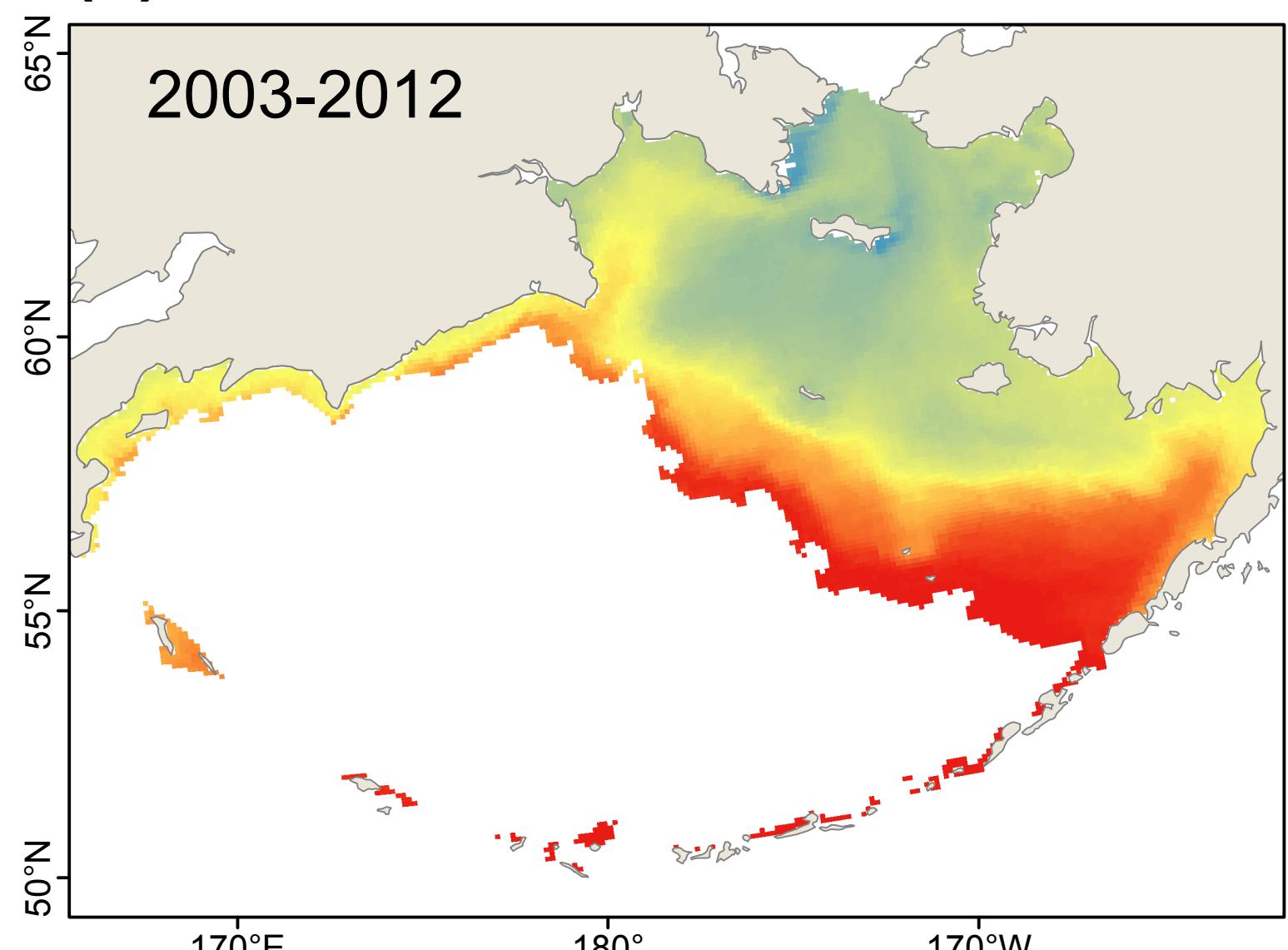
(a) Model: CGCM3-t47



(b) Model: ECHO-G

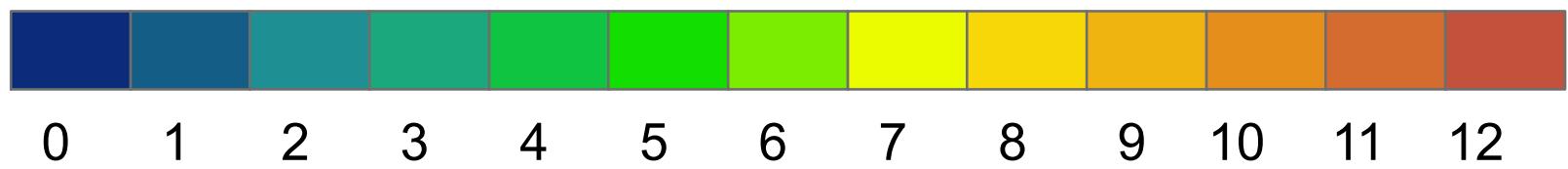


(c) Model: MIROC3.2

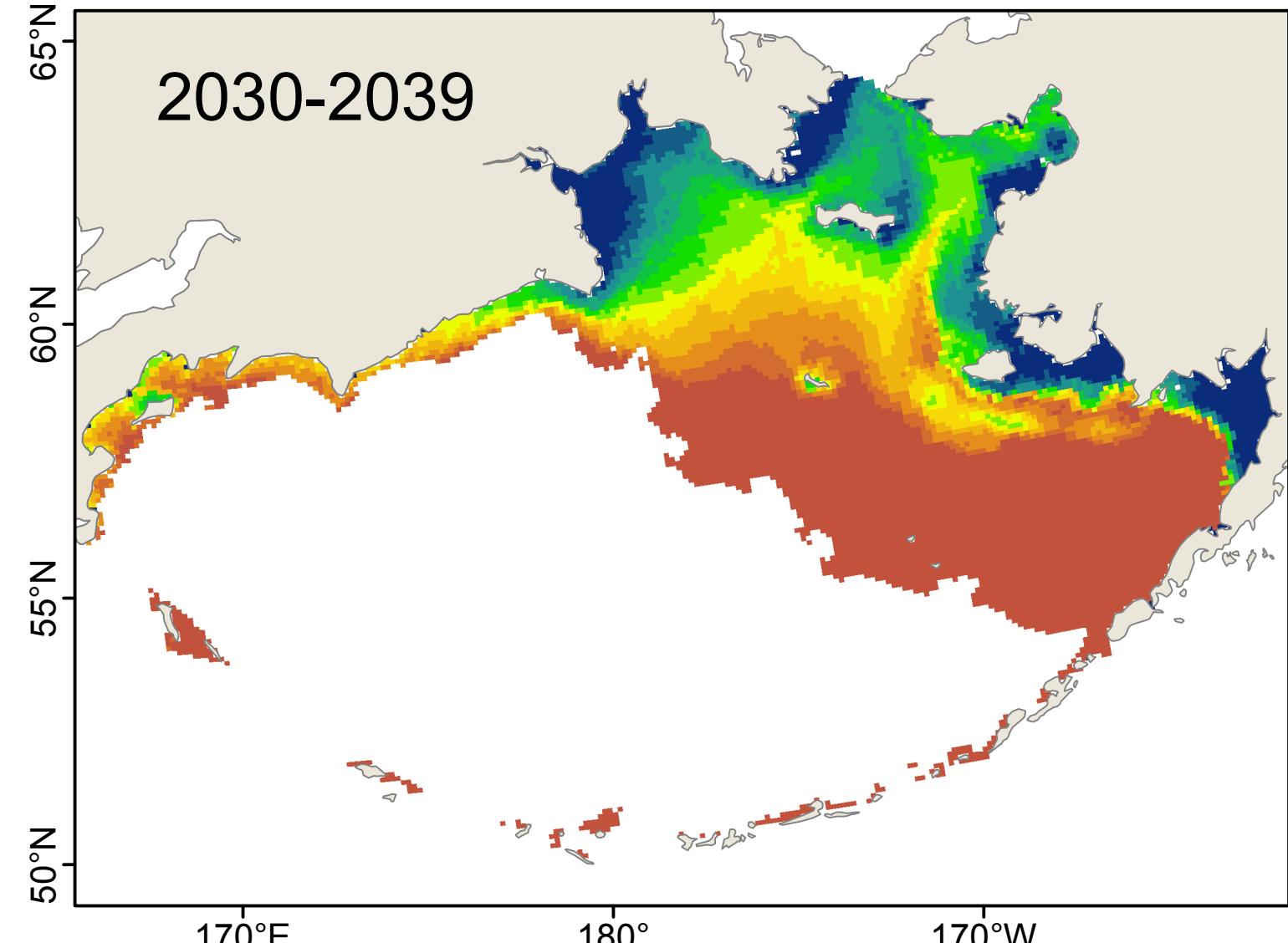
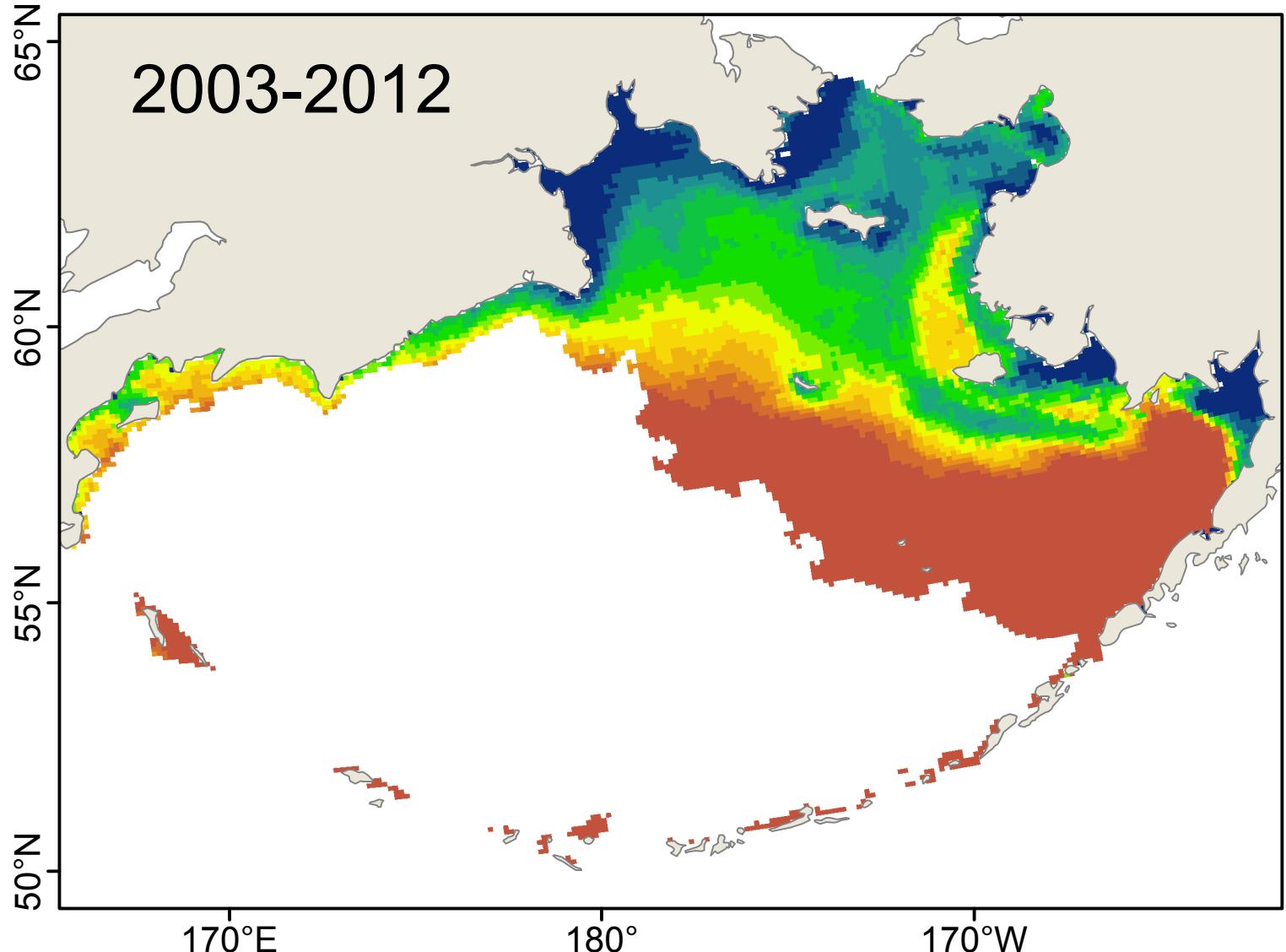


# *Bugula neritina: Reproduction*

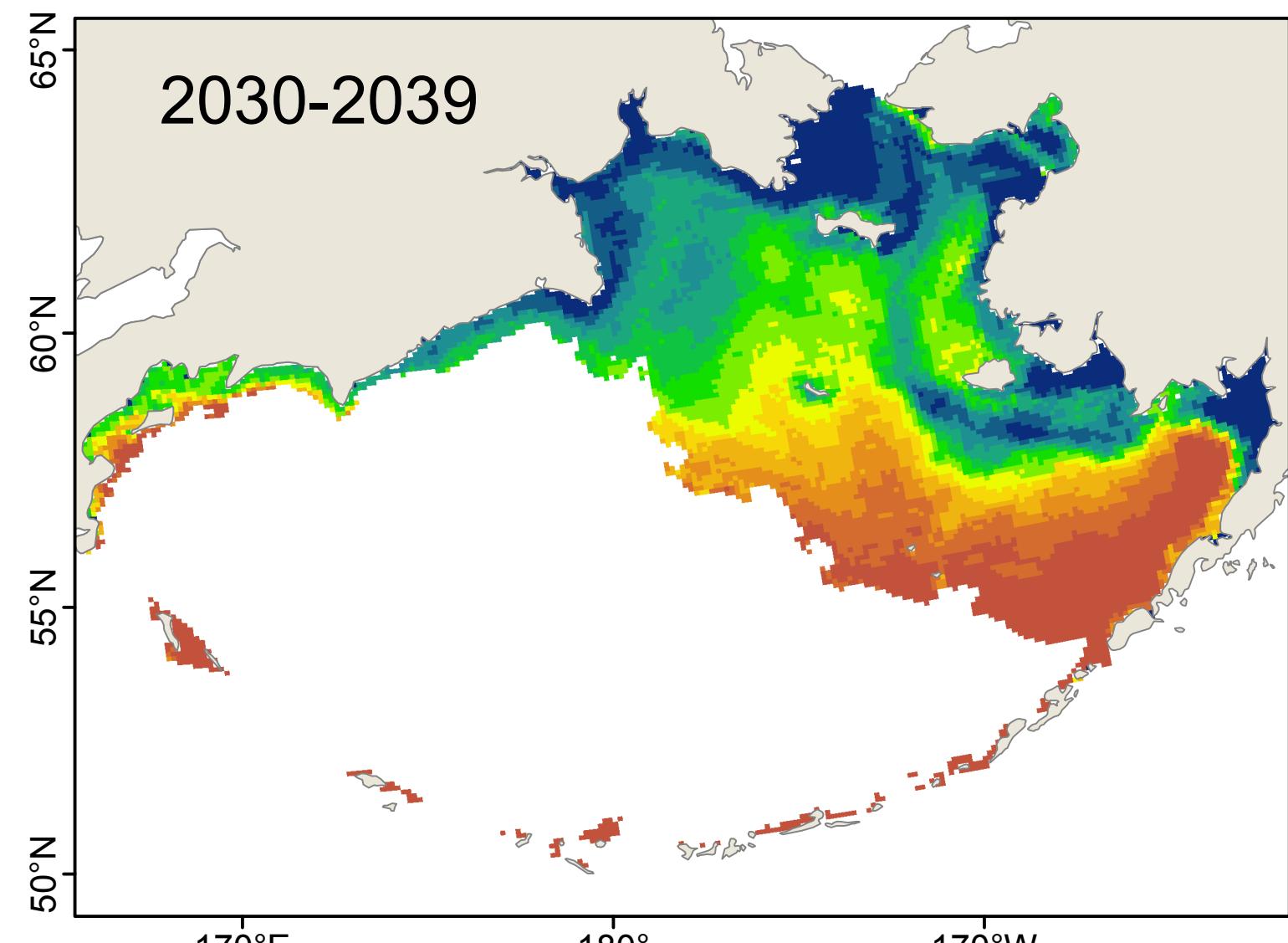
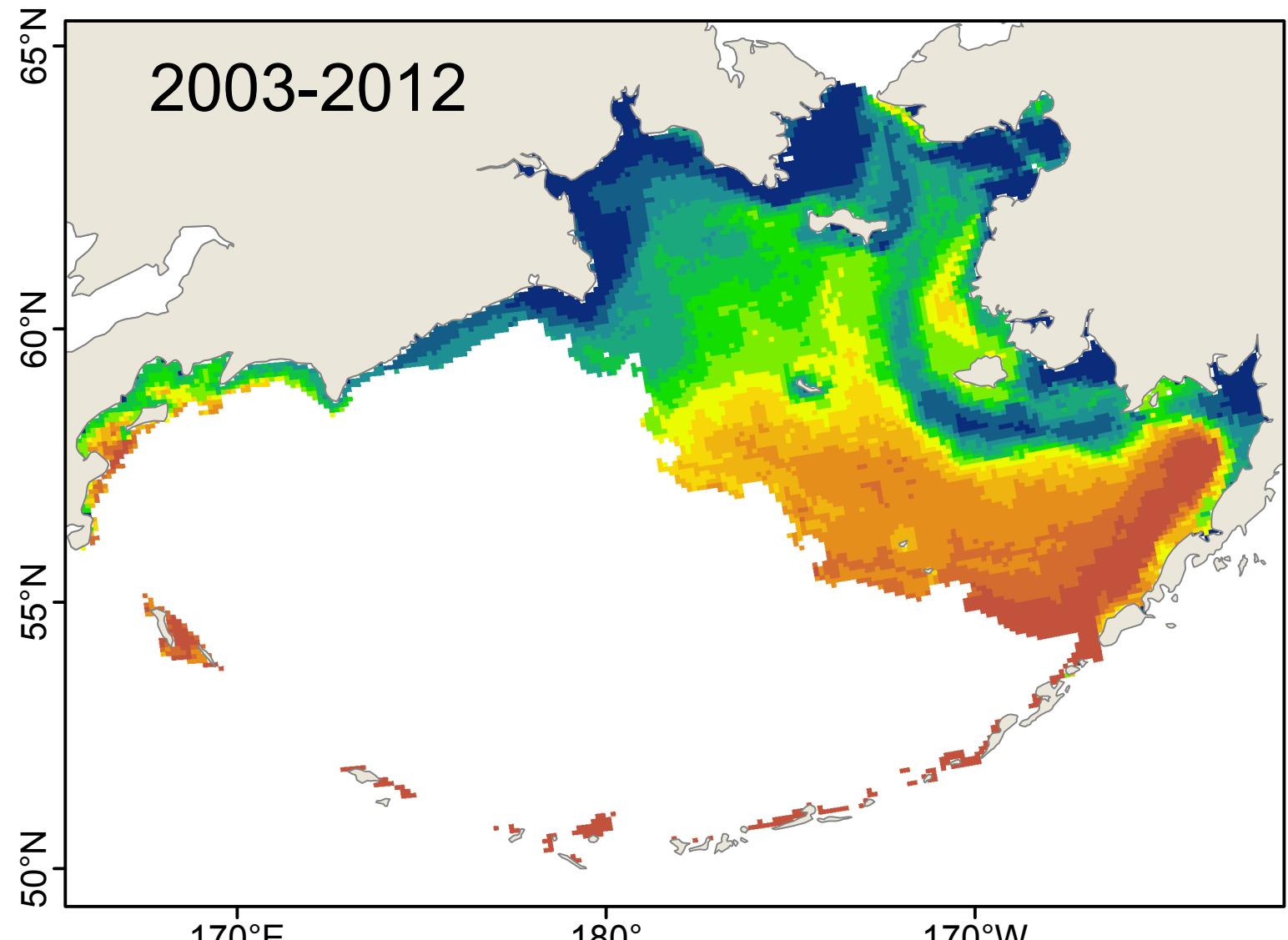
Average number of consecutive weeks of suitable habitat



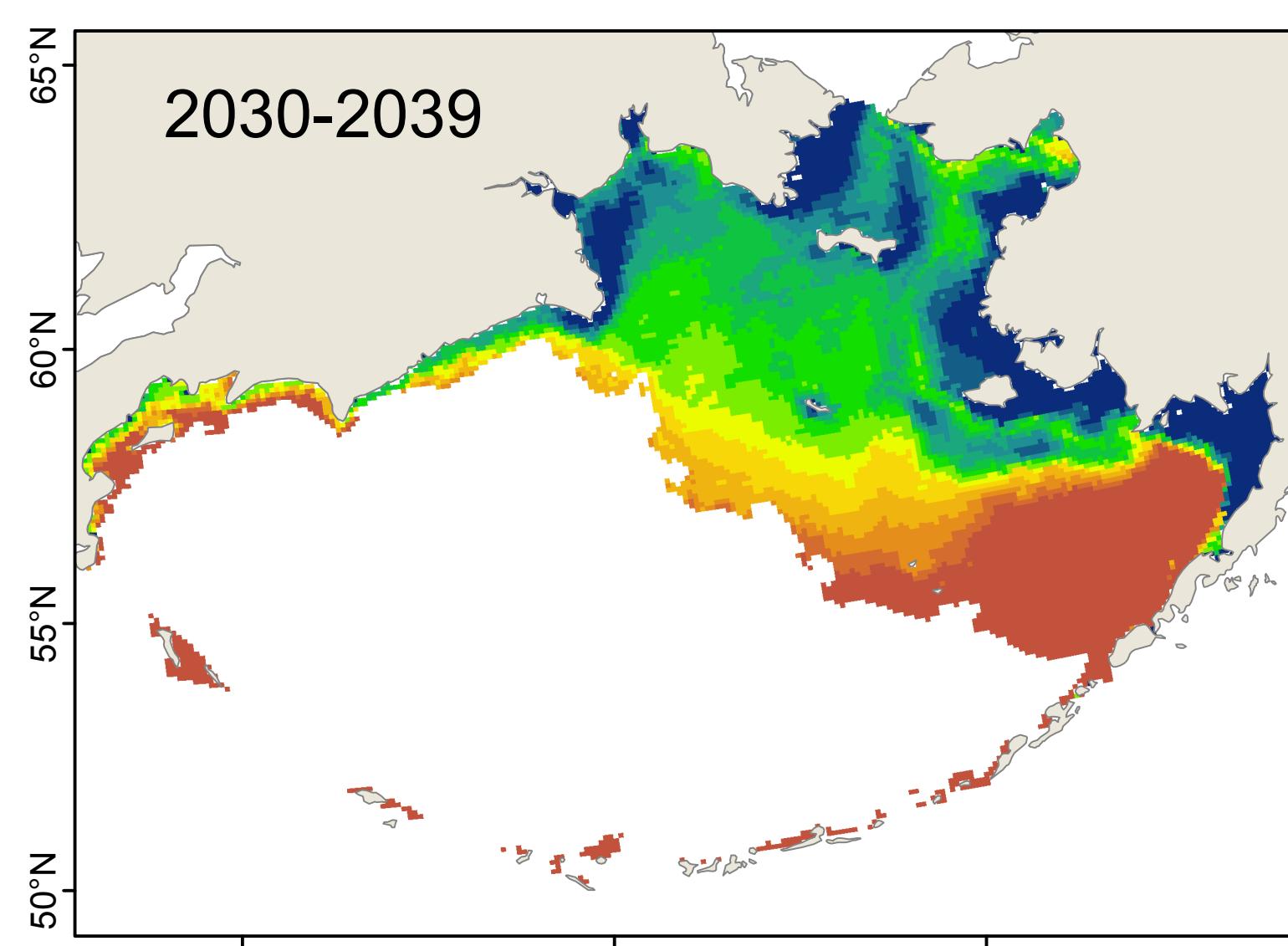
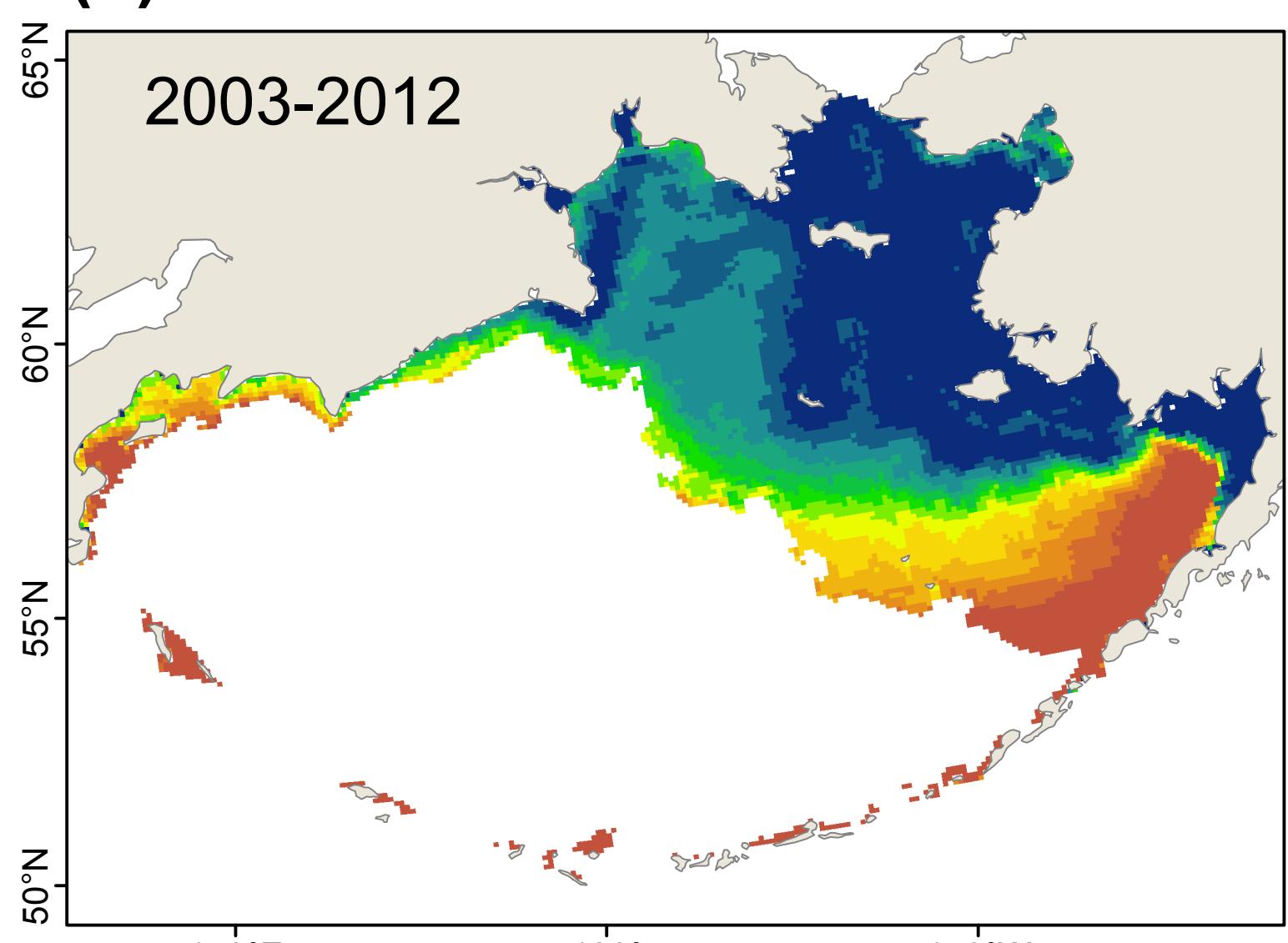
(a) Model: CGCM3-t47



(b) Model: ECHO-G

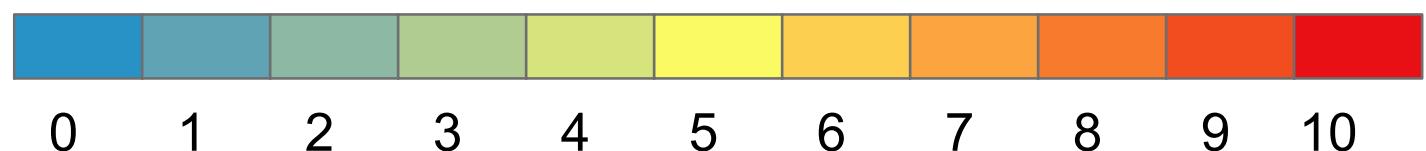


(c) Model: MIROC3.2

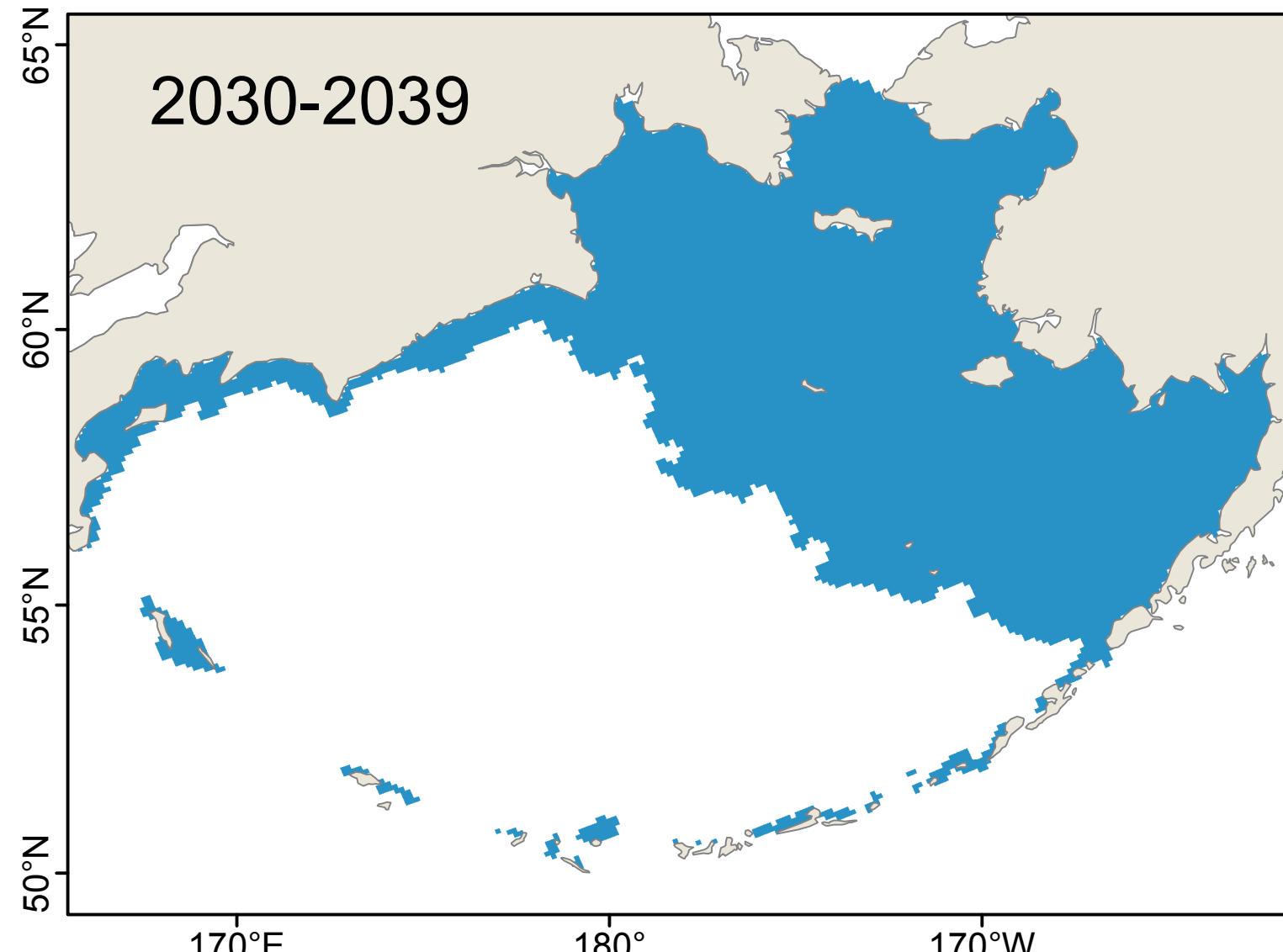
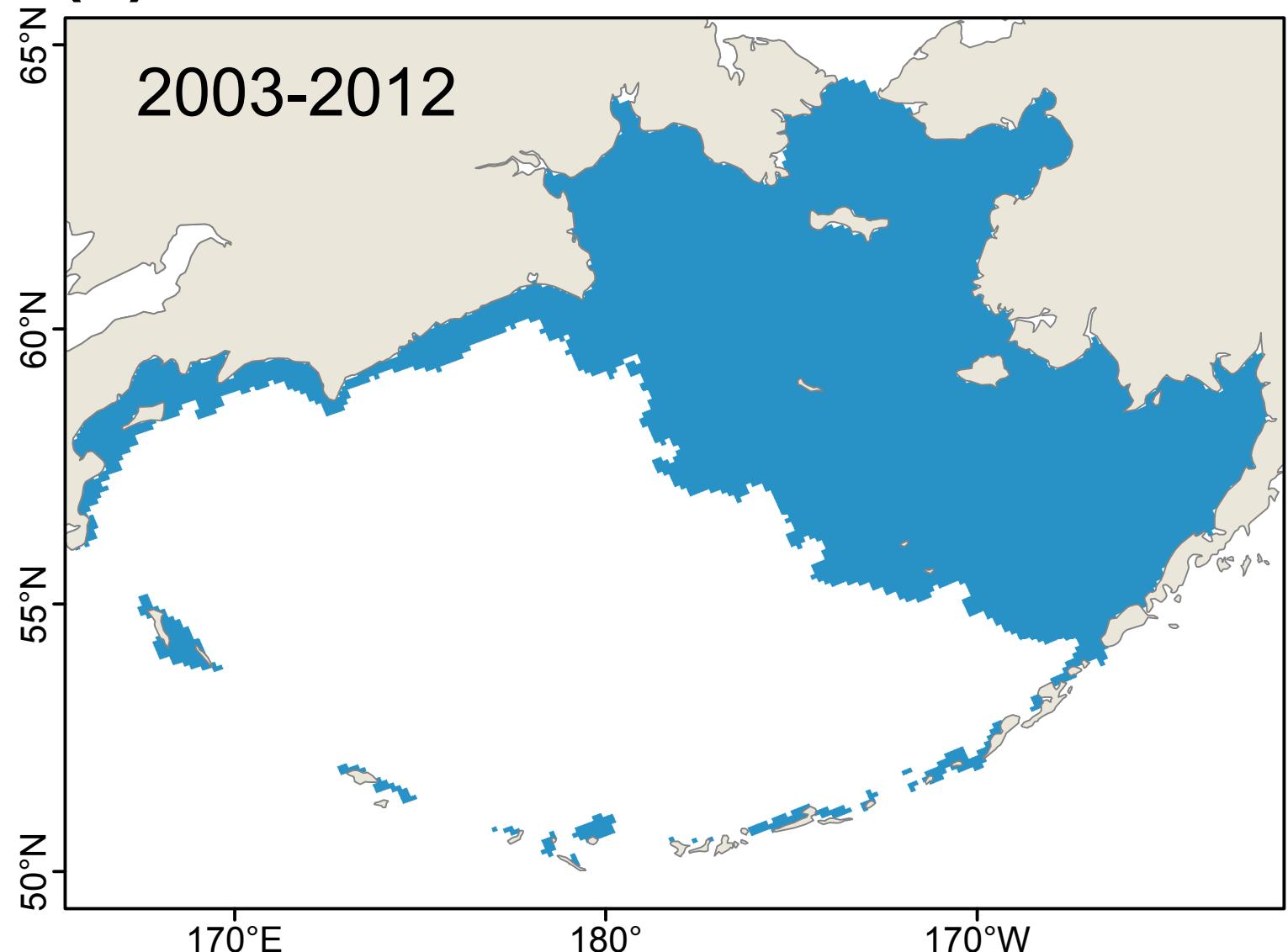


# *Schizoporella japonica*: Year-round Survival

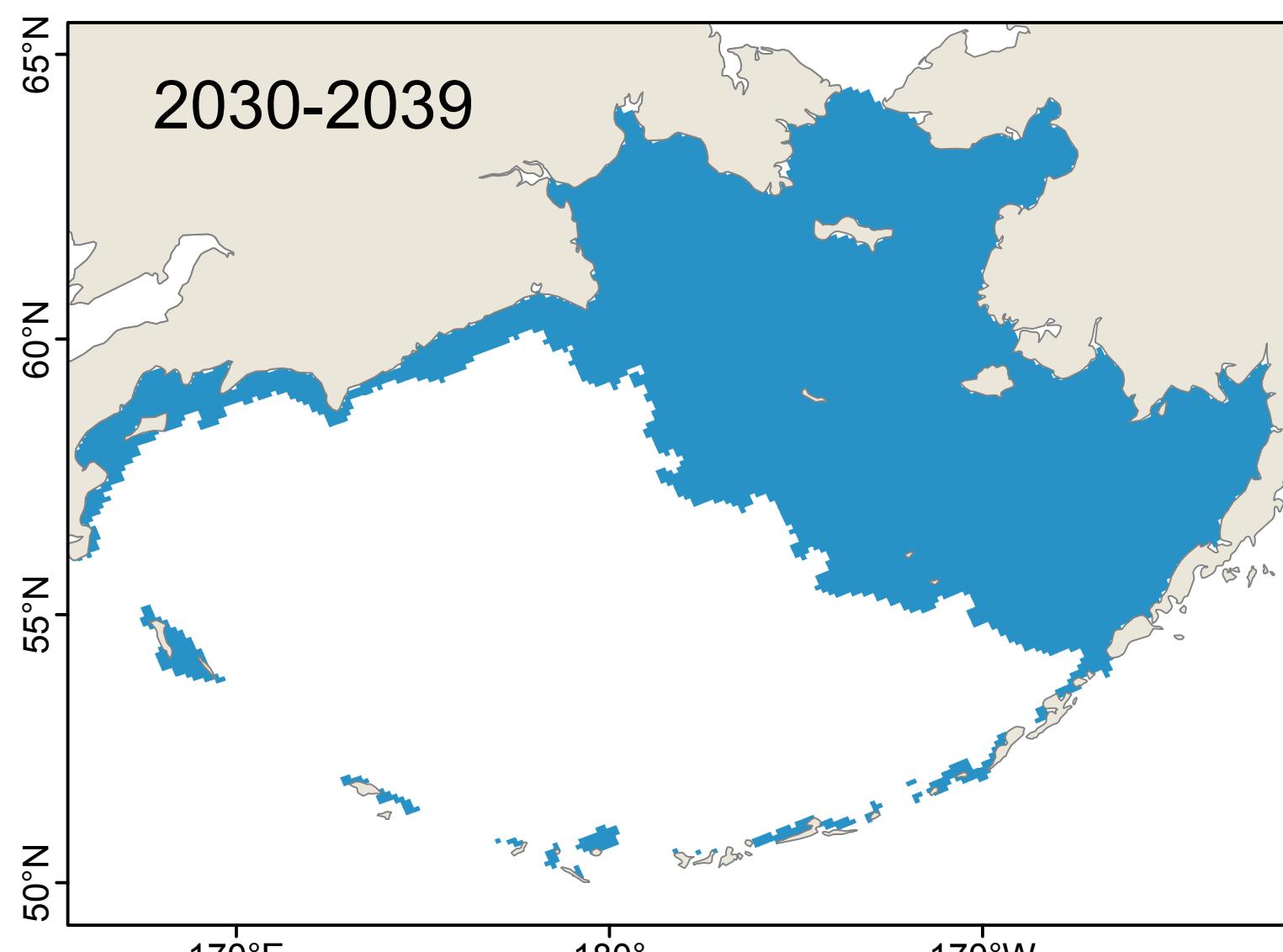
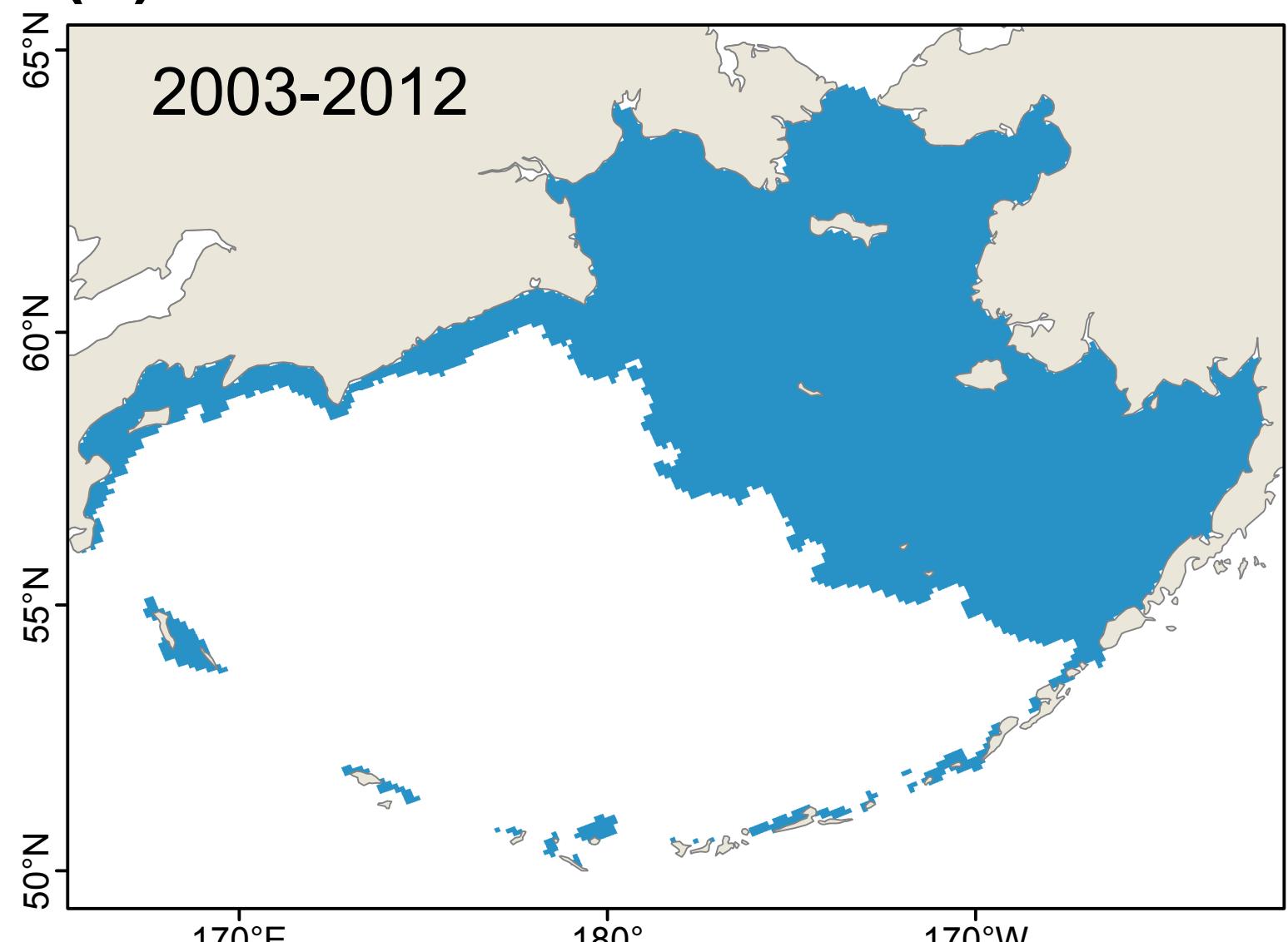
Number of years with suitable habitat



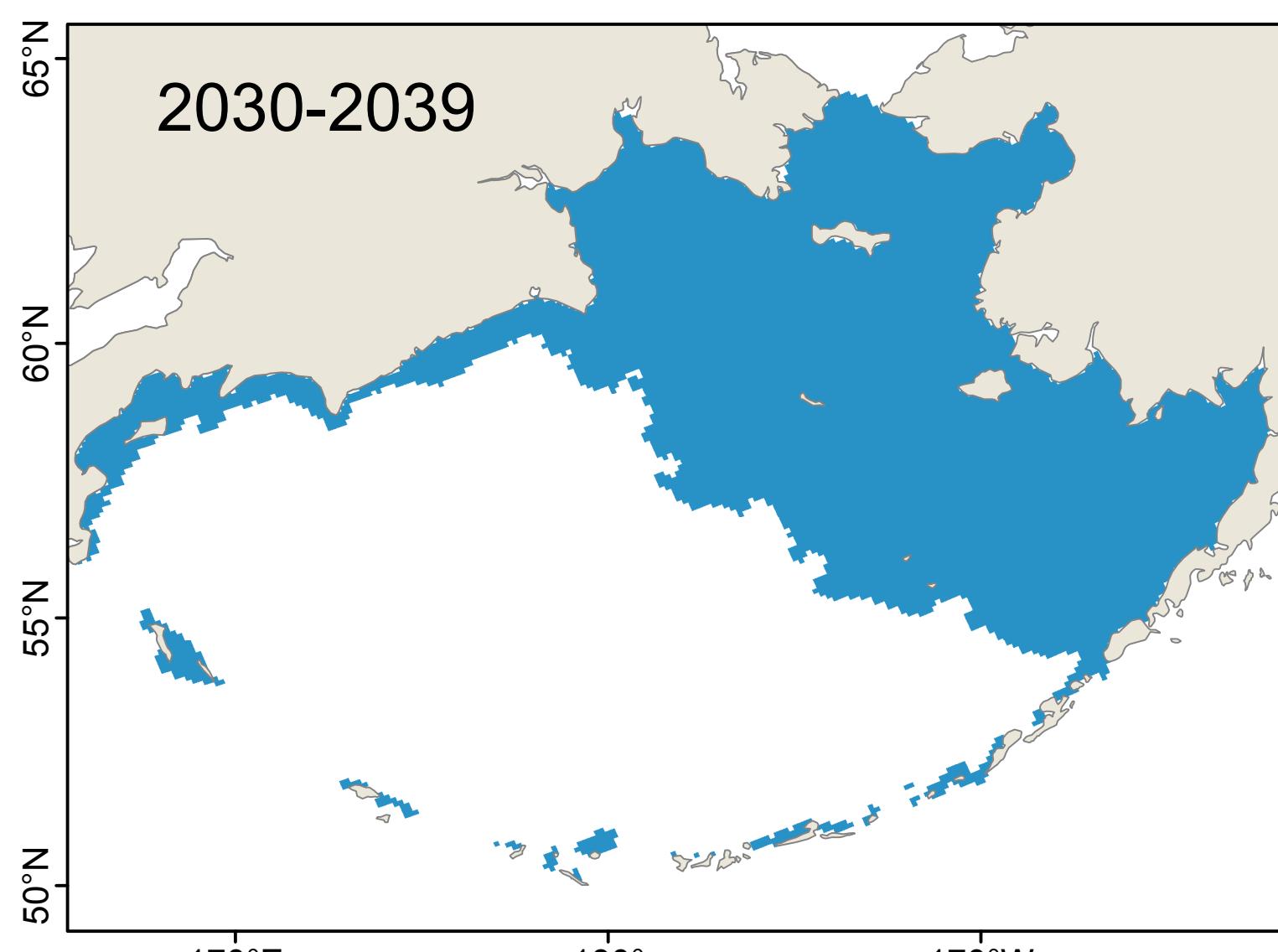
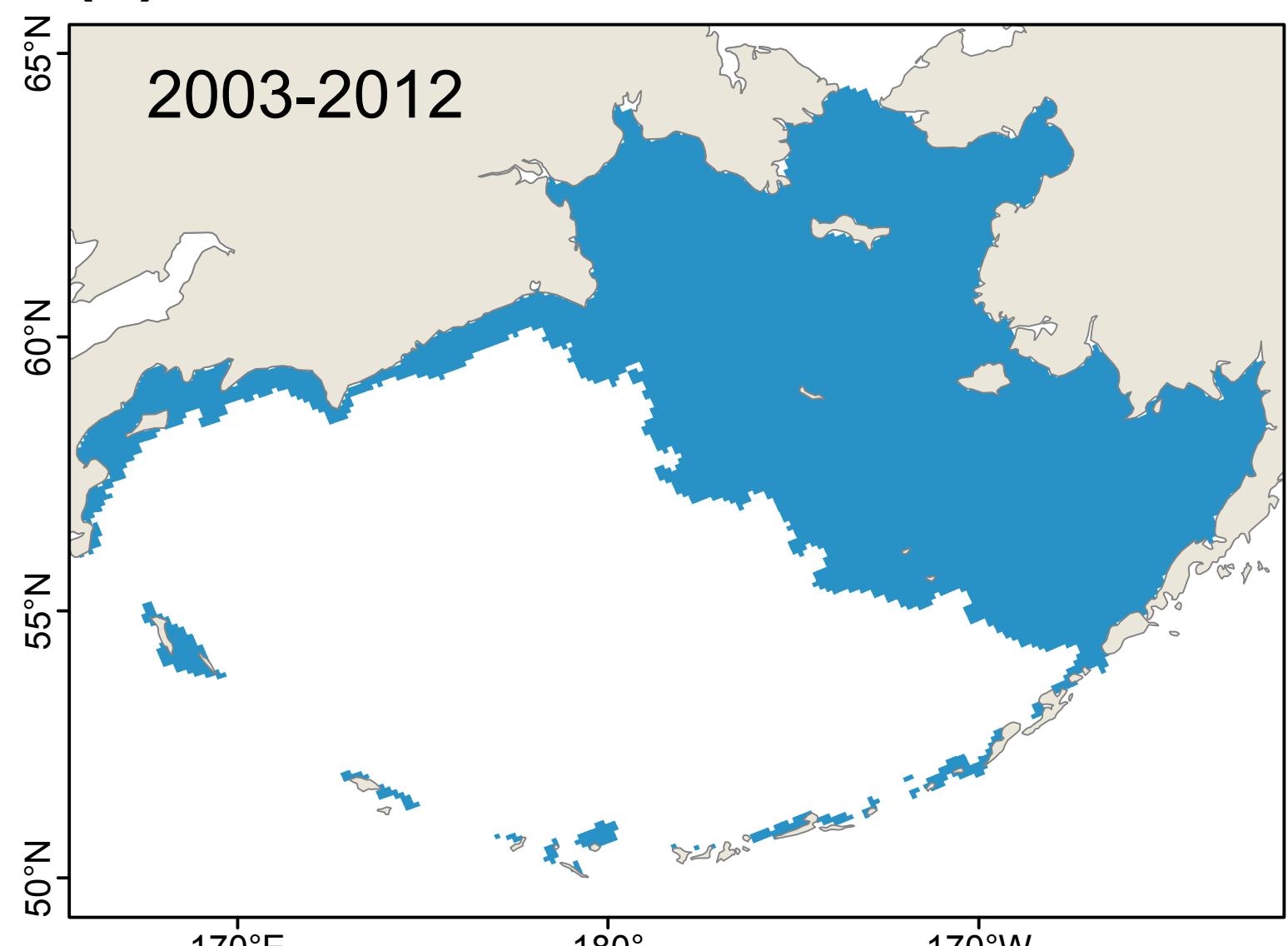
(a) Model: CGCM3-t47



(b) Model: ECHO-G

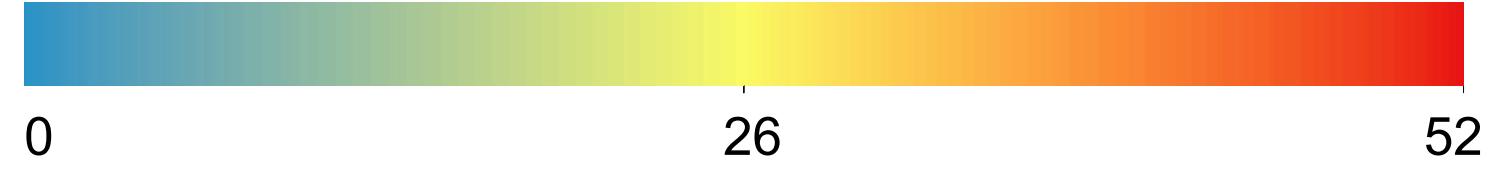


(c) Model: MIROC3.2

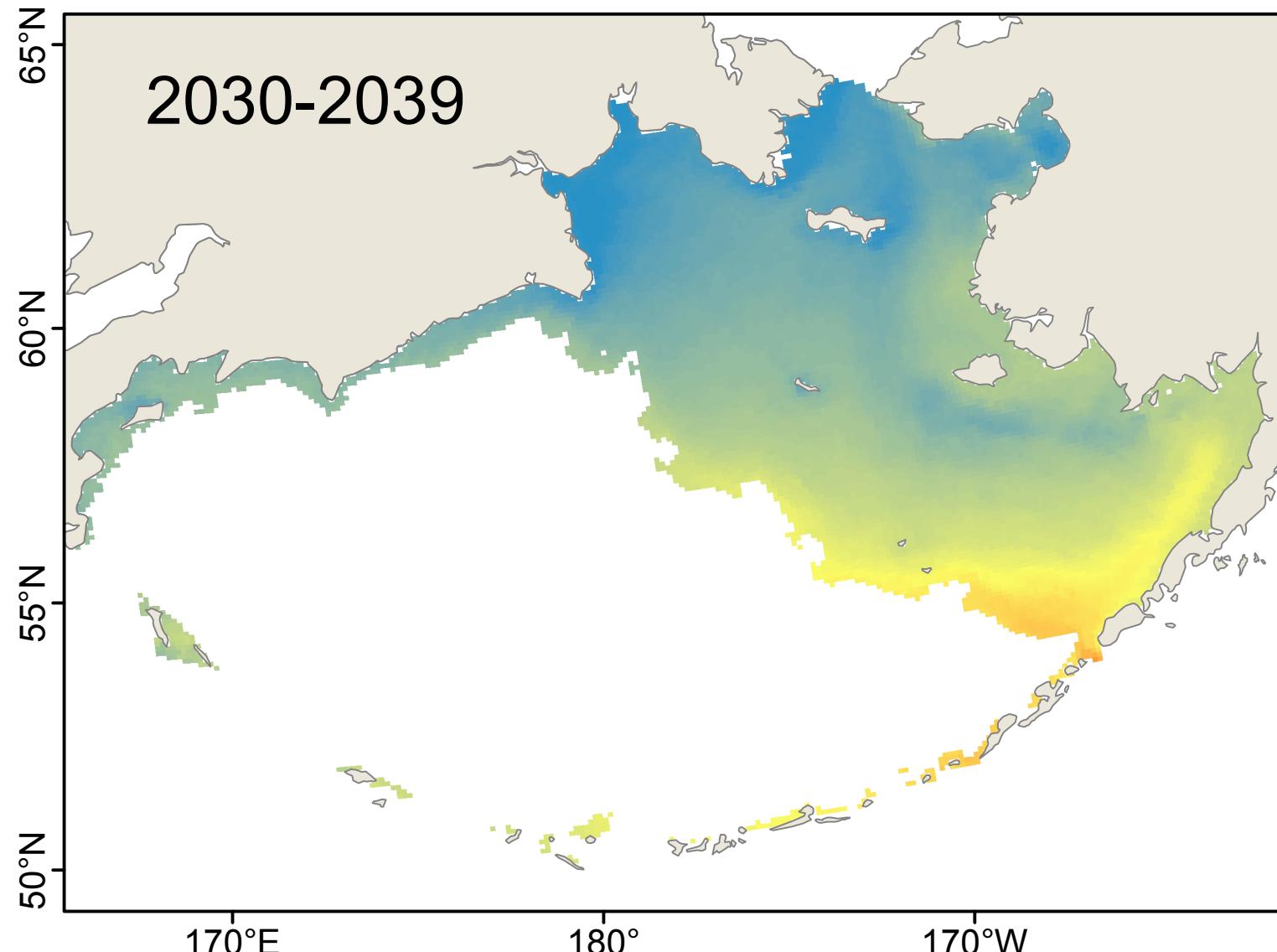
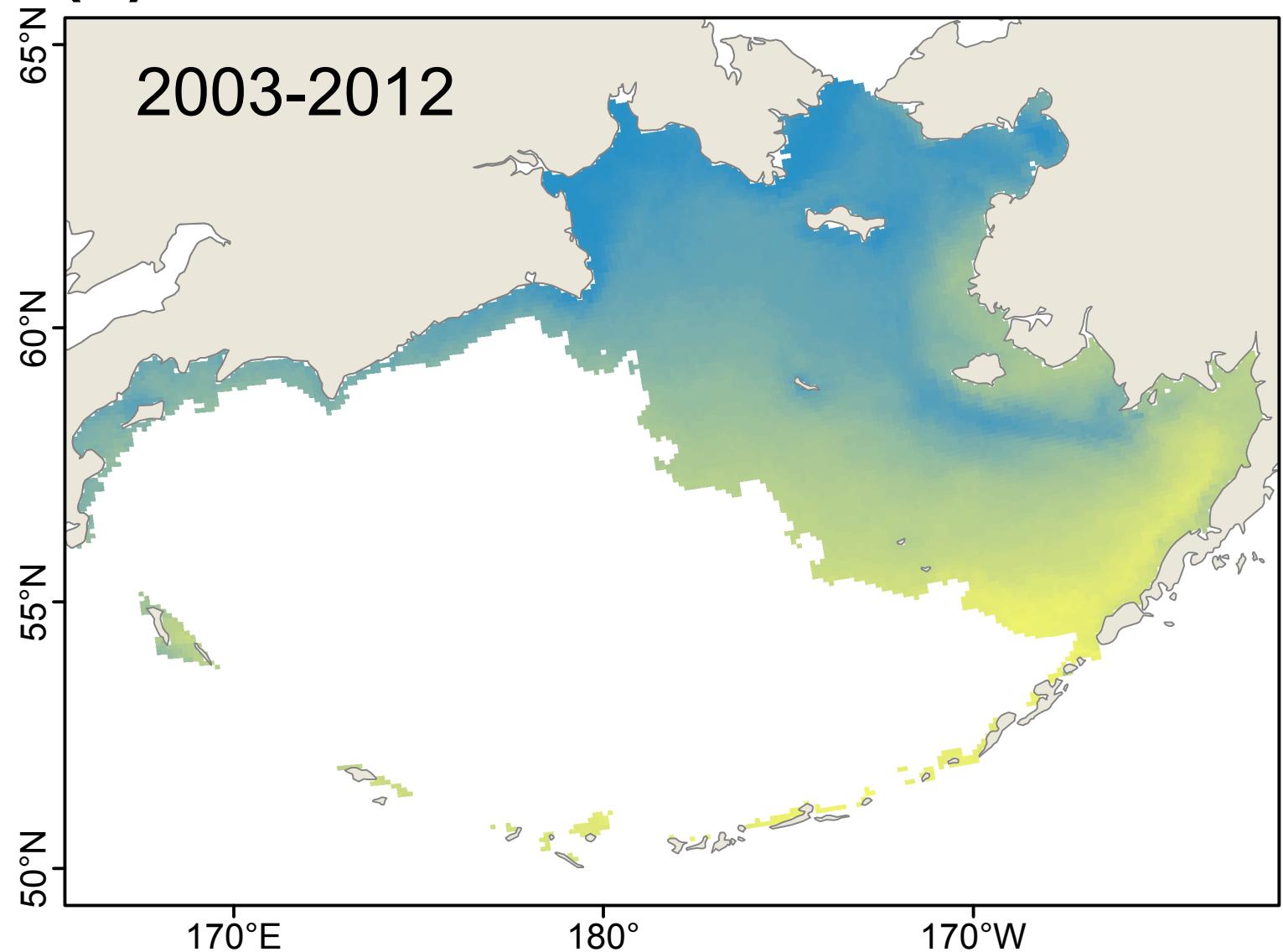


# *Schizophorella japonica: Weekly Survival*

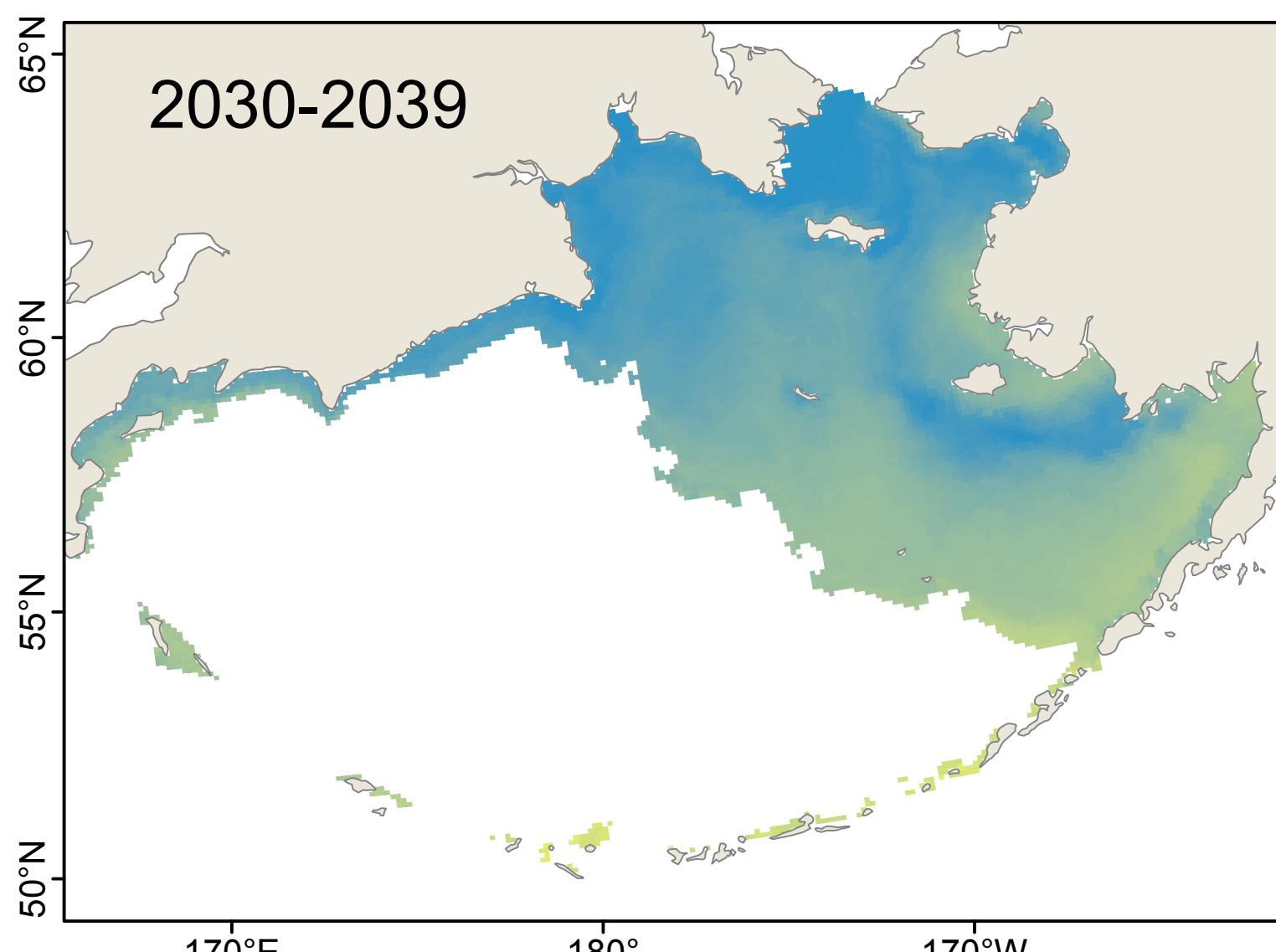
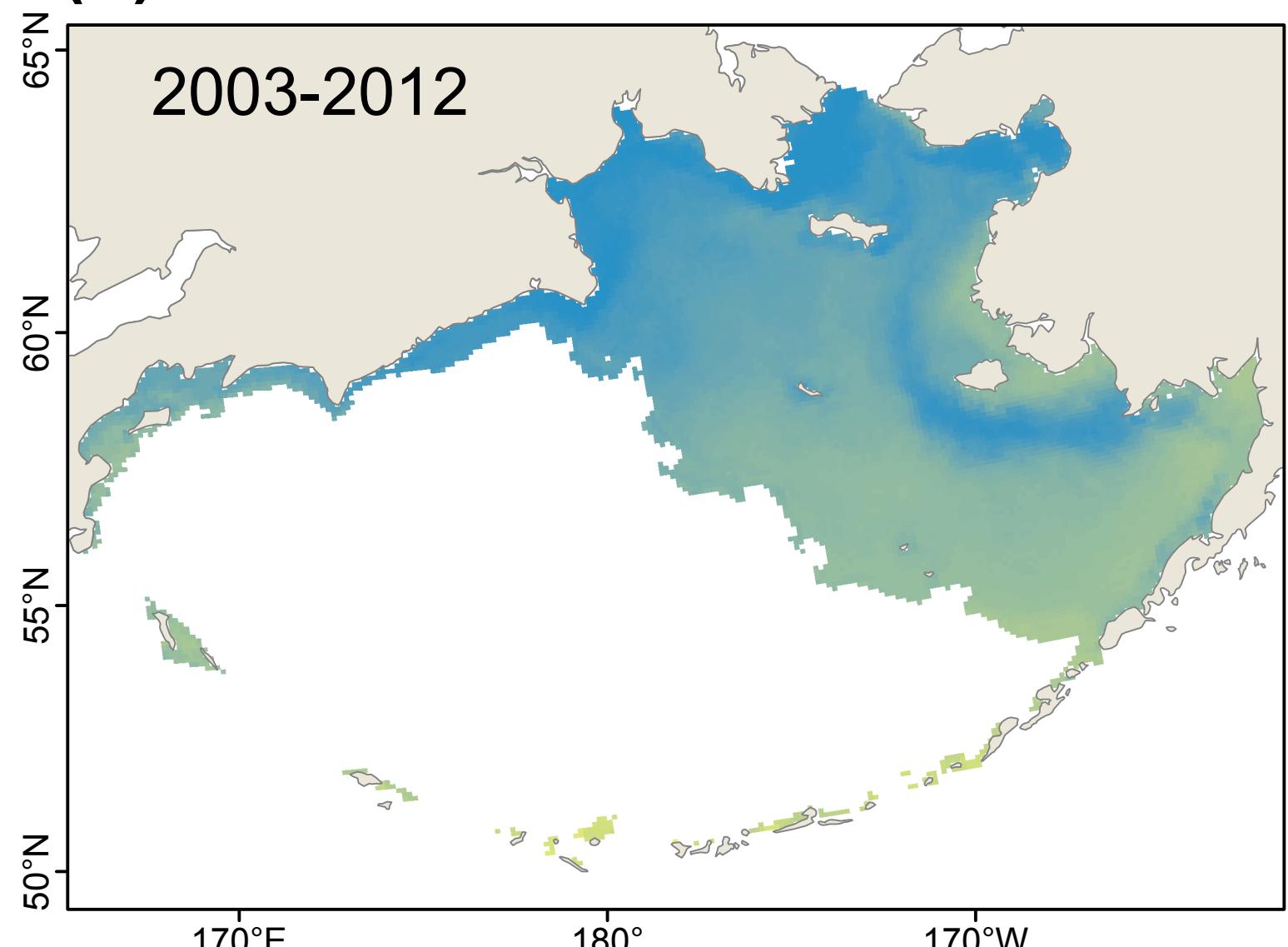
Average number of weeks of suitable habitat



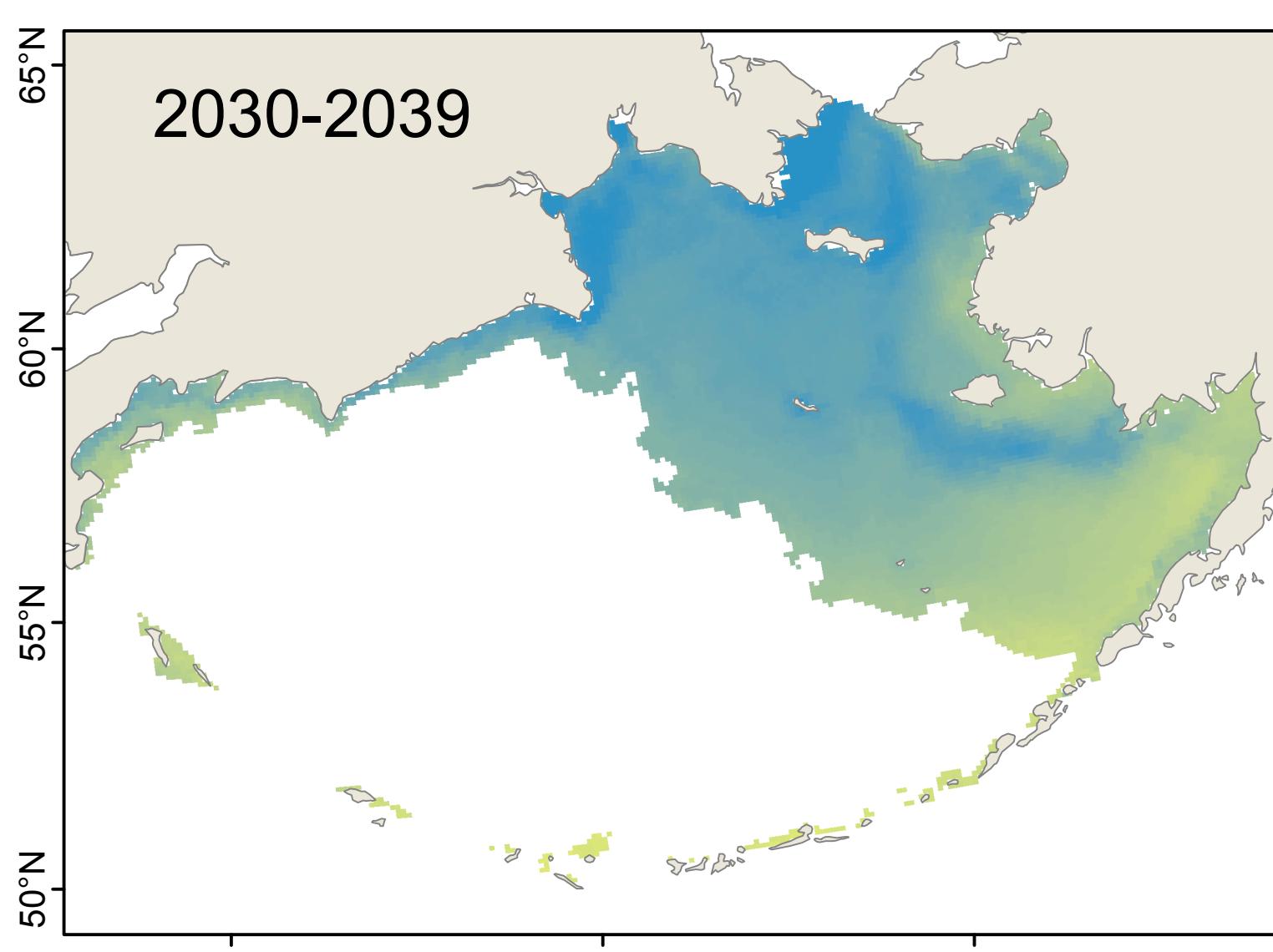
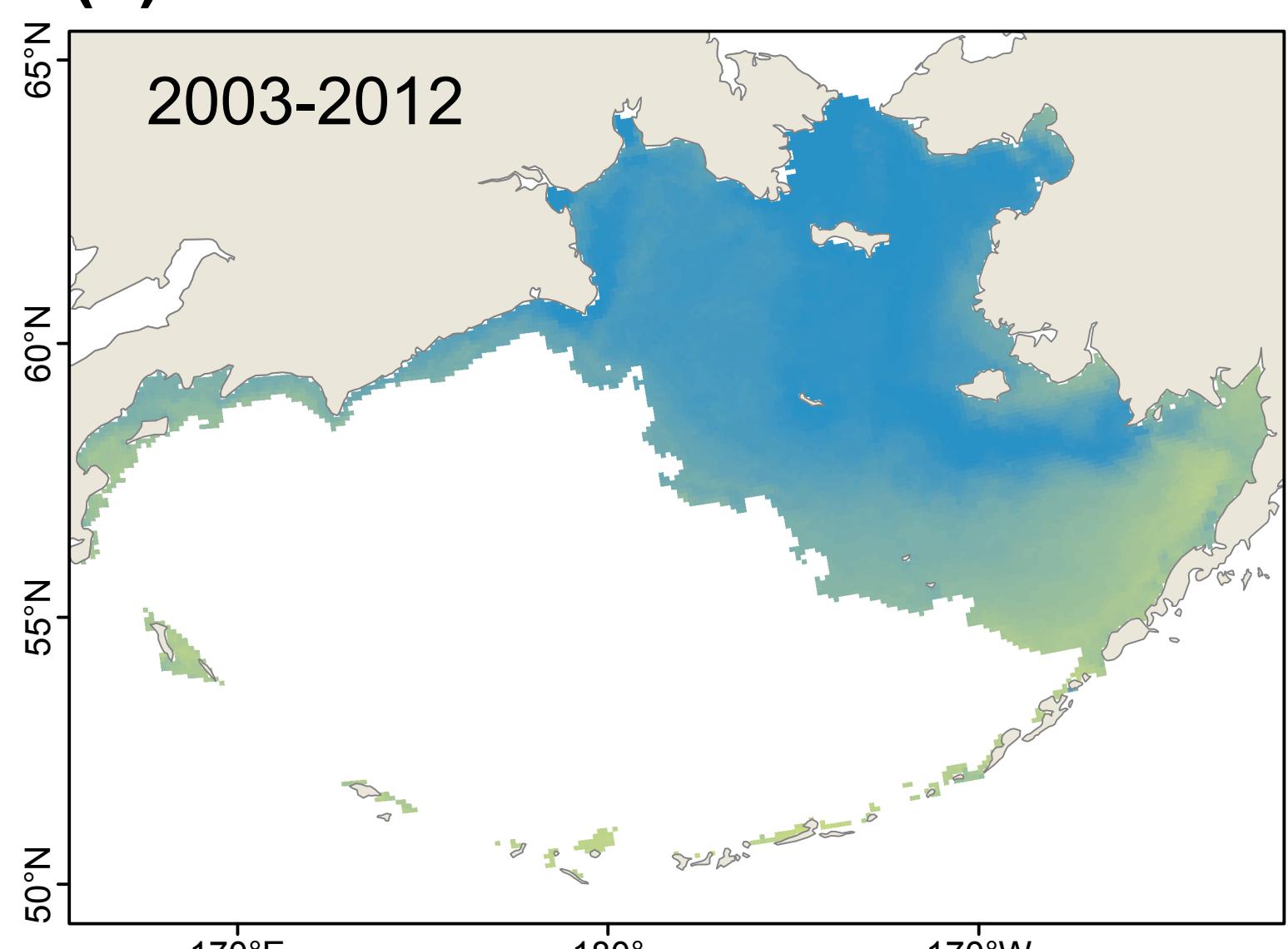
(a) Model: CGCM3-t47



(b) Model: ECHO-G

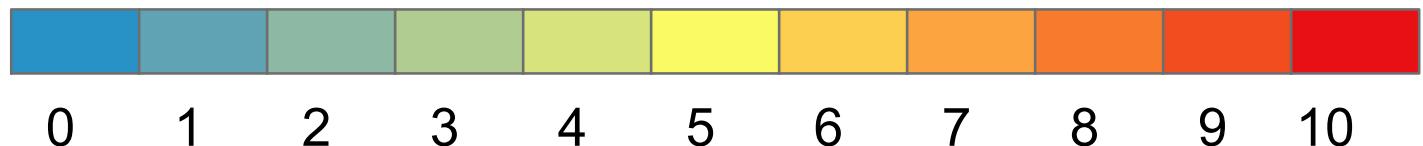


(c) Model: MIROC3.2

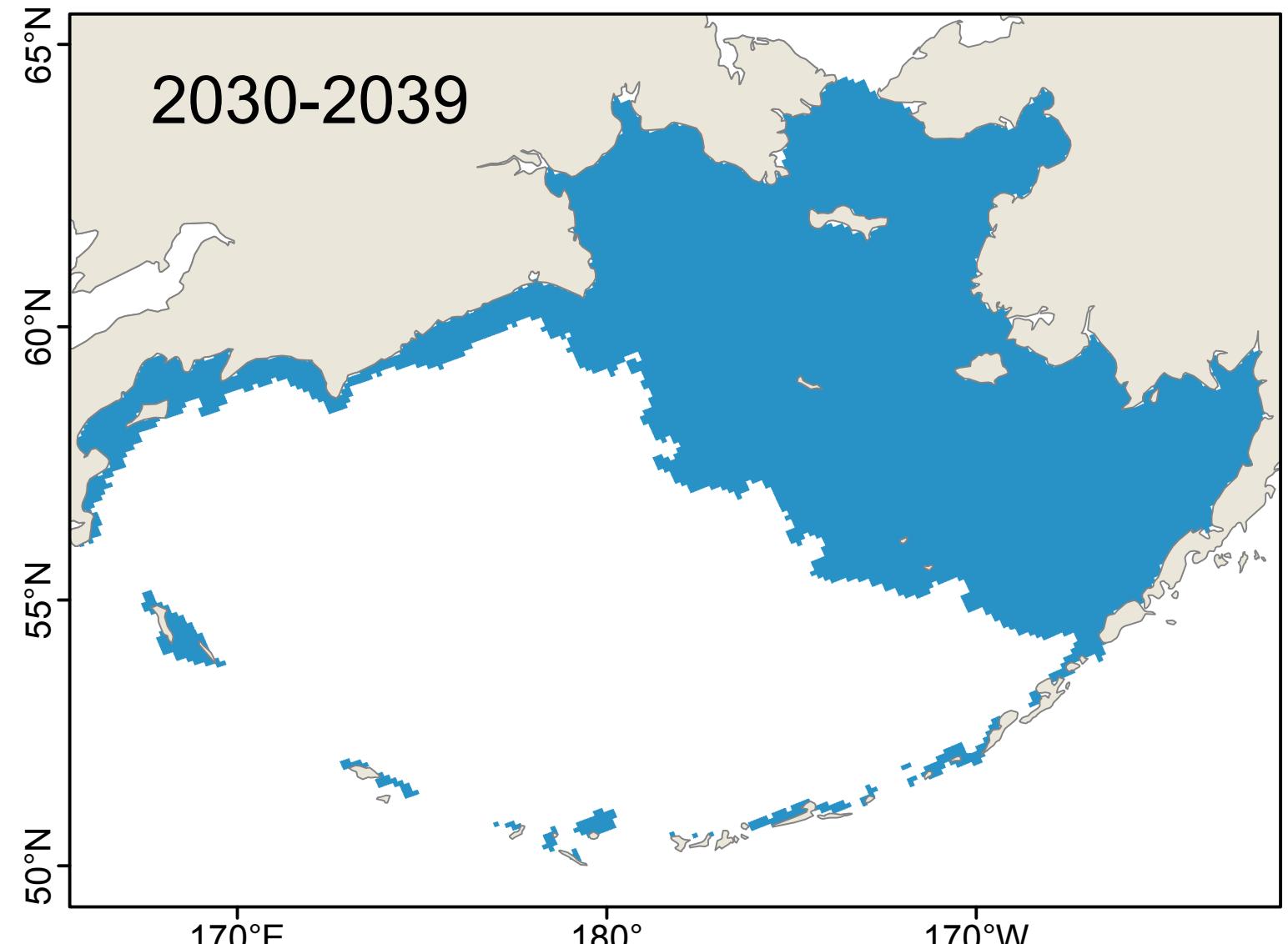
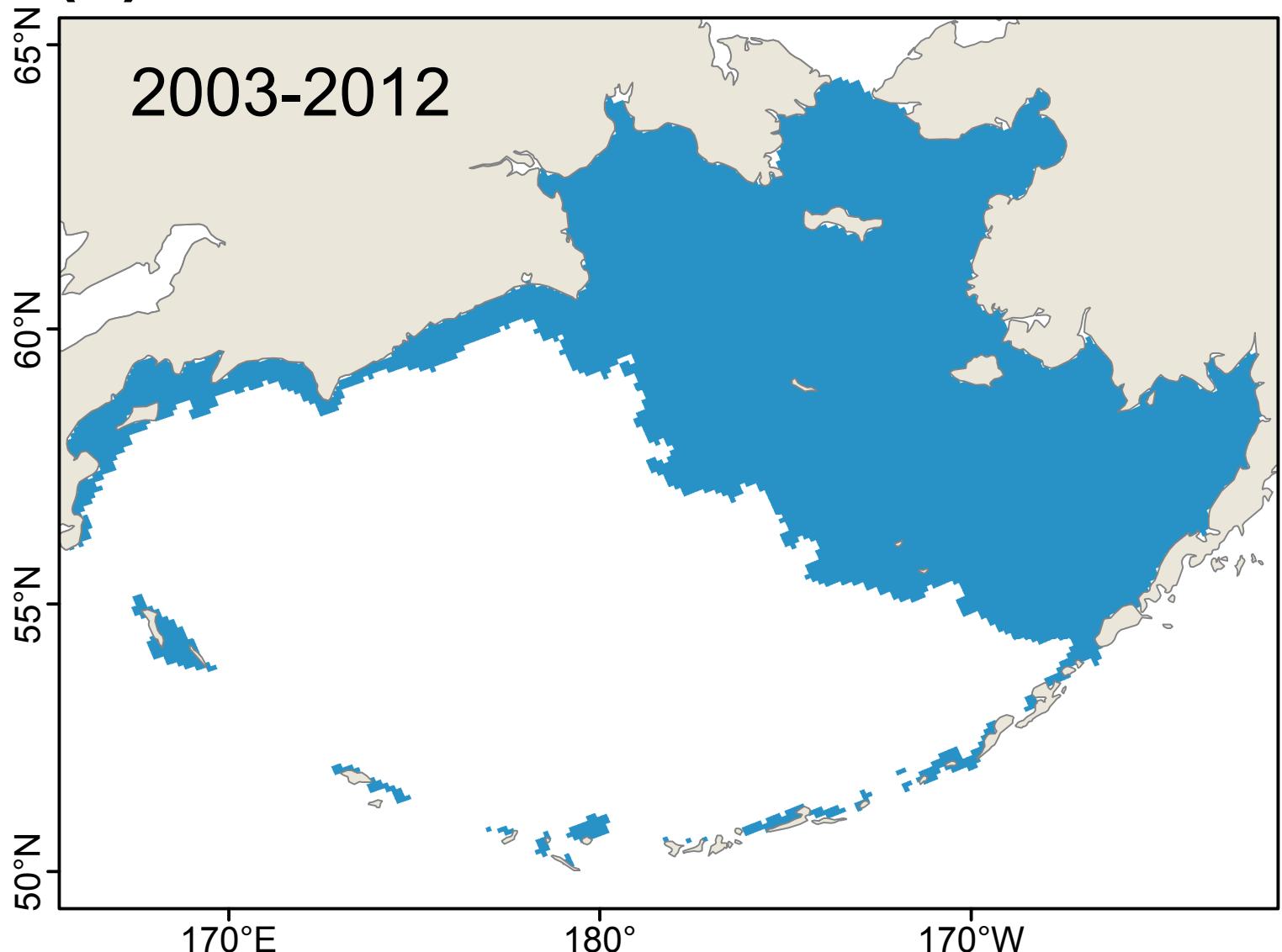


# *Watersipora subtorquata: Year-round Survival*

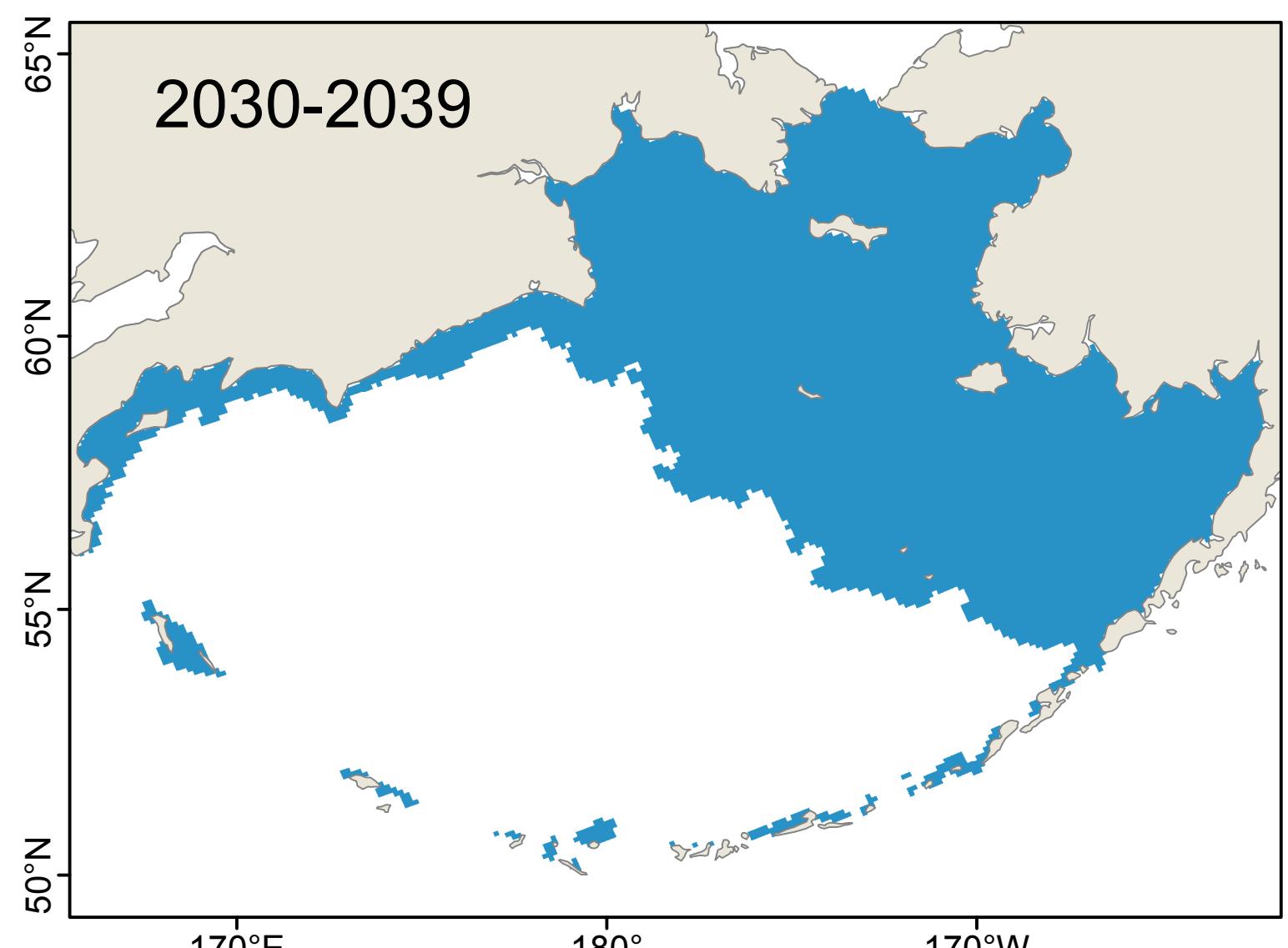
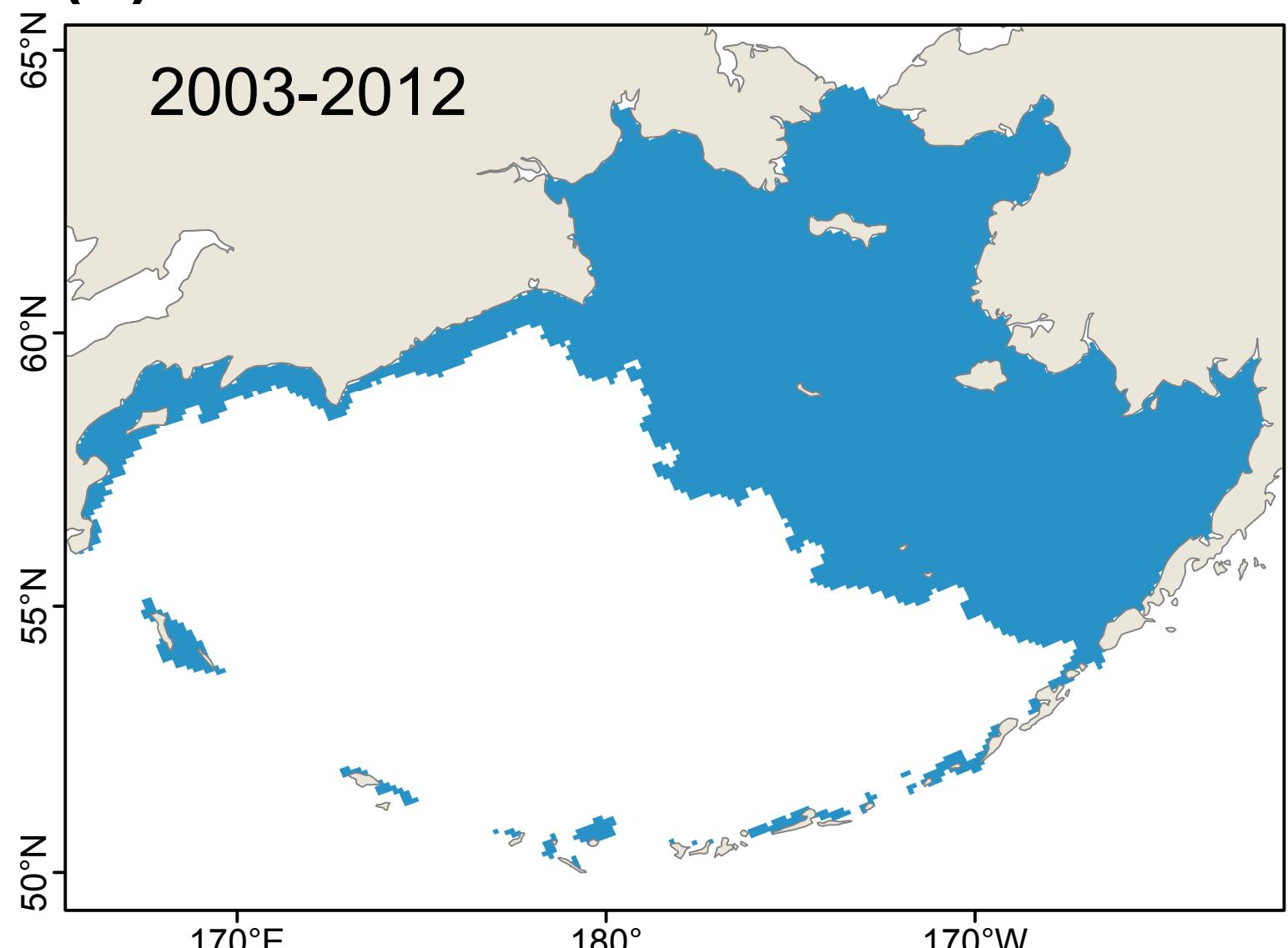
Number of years with suitable habitat



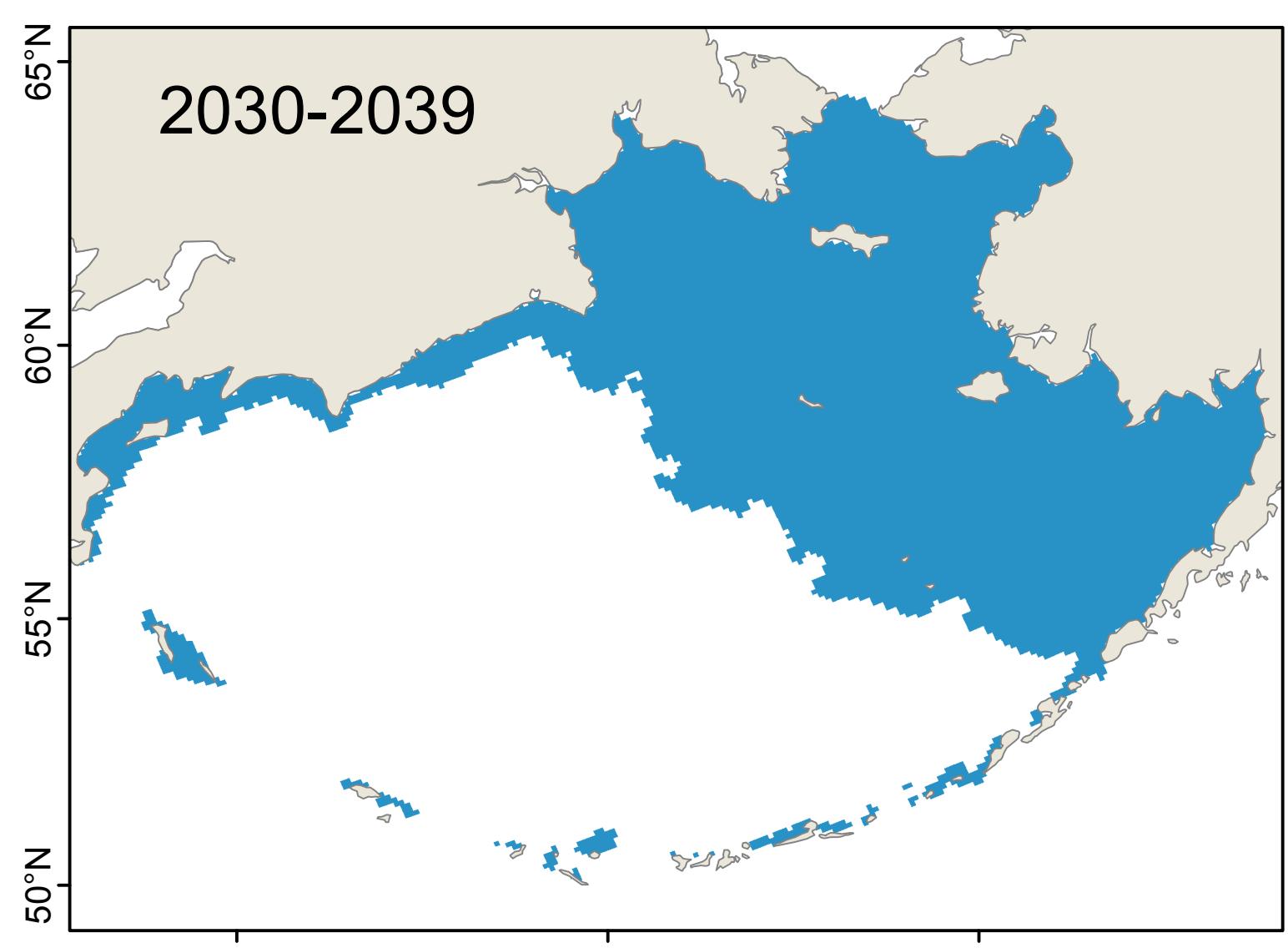
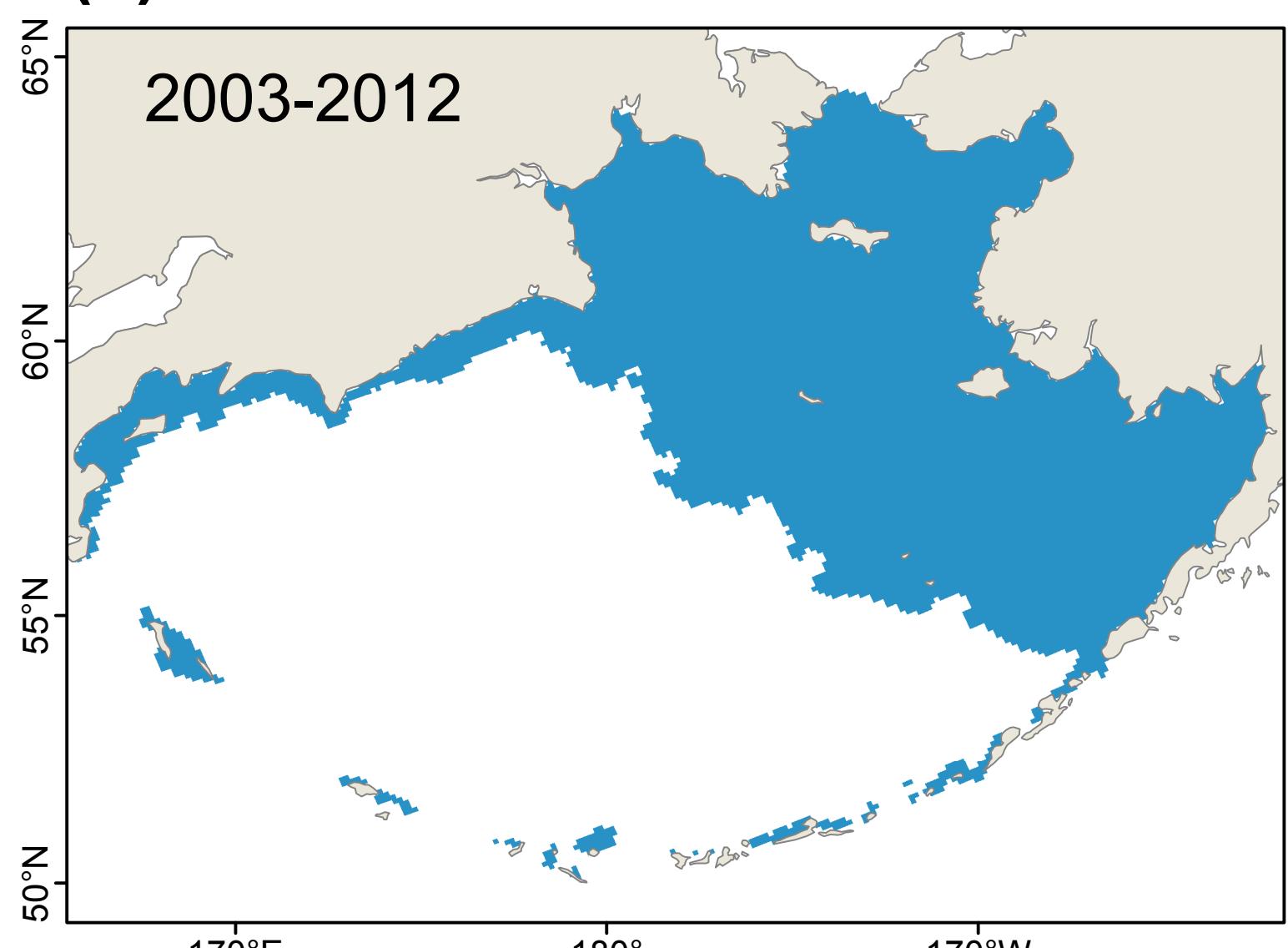
(a) Model: CGCM3-t47



(b) Model: ECHO-G

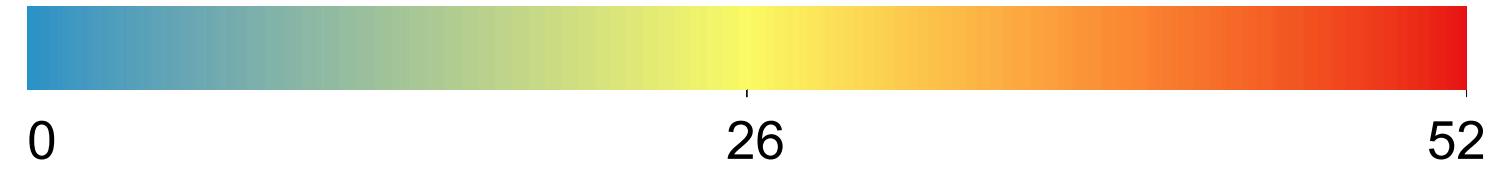


(c) Model: MIROC3.2

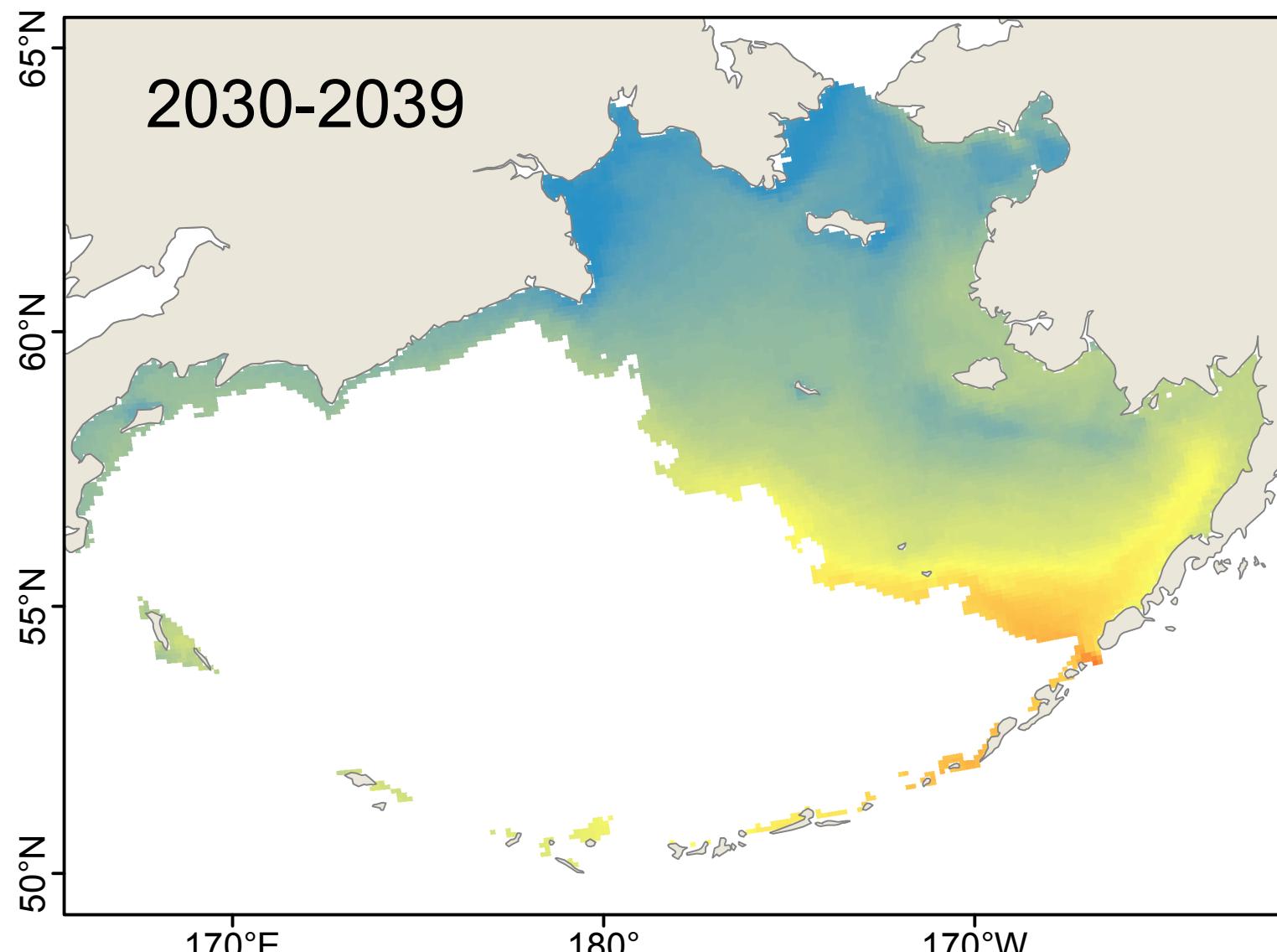
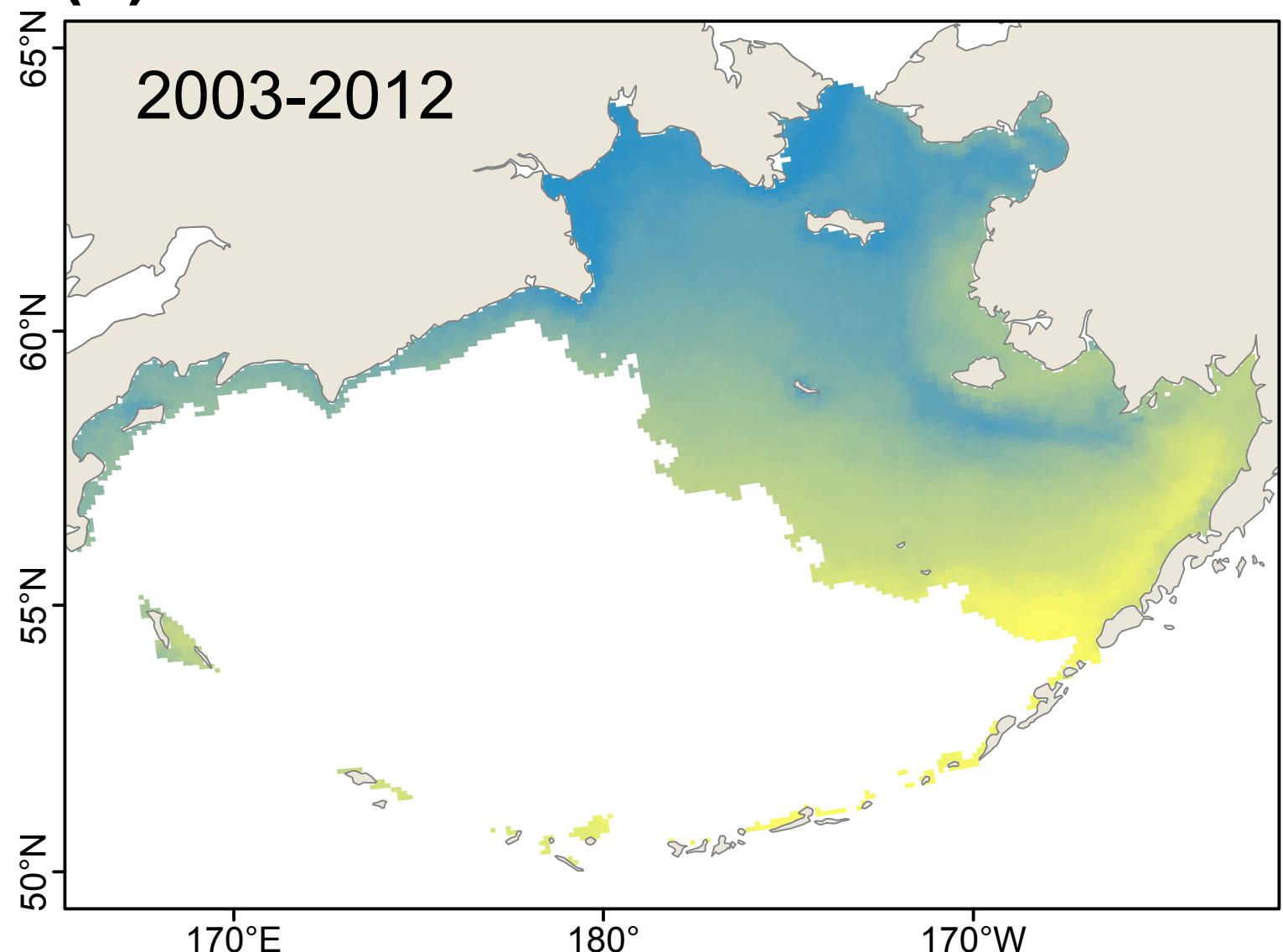


# *Watersipora subtorquata: Weekly Survival*

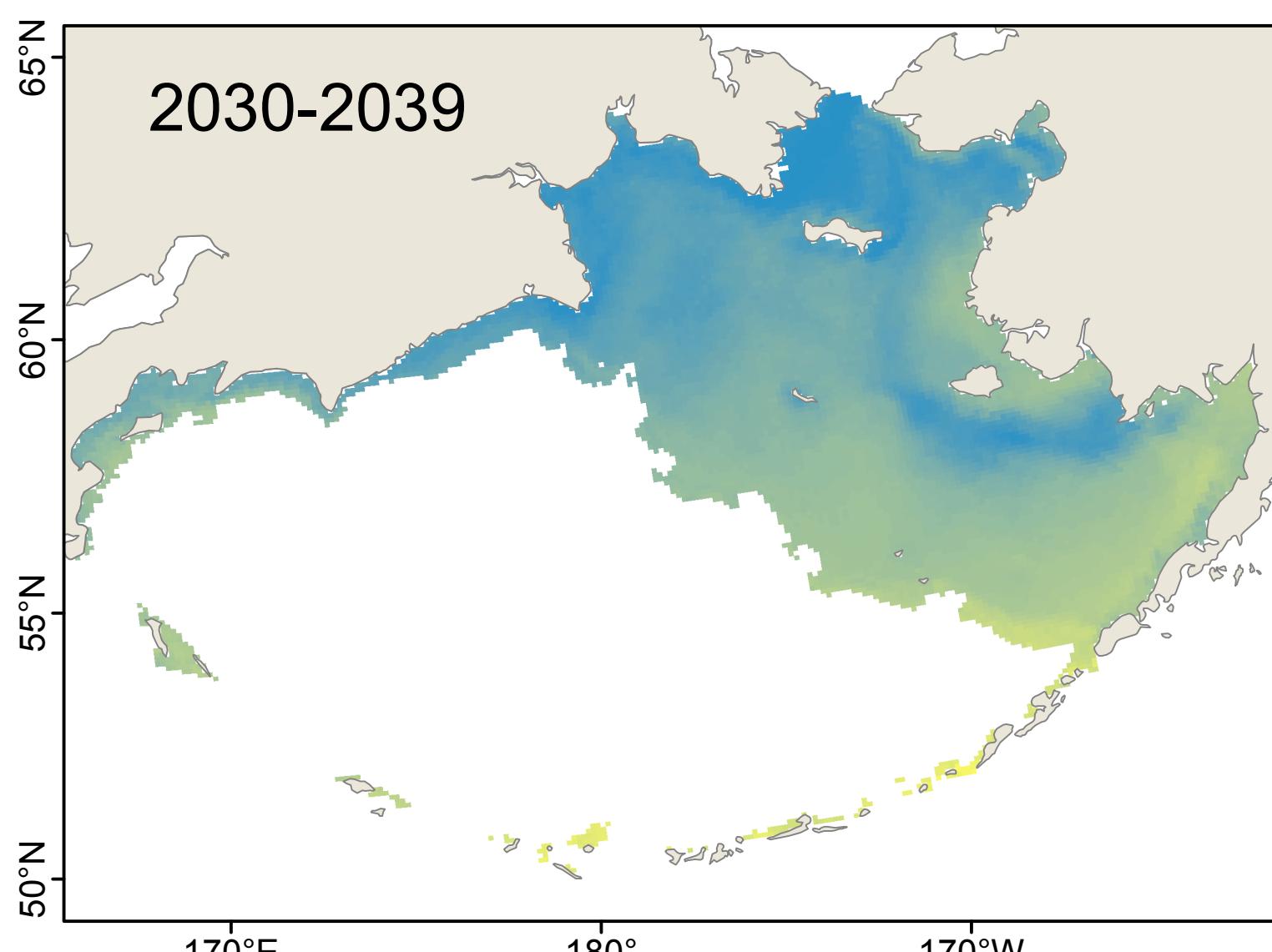
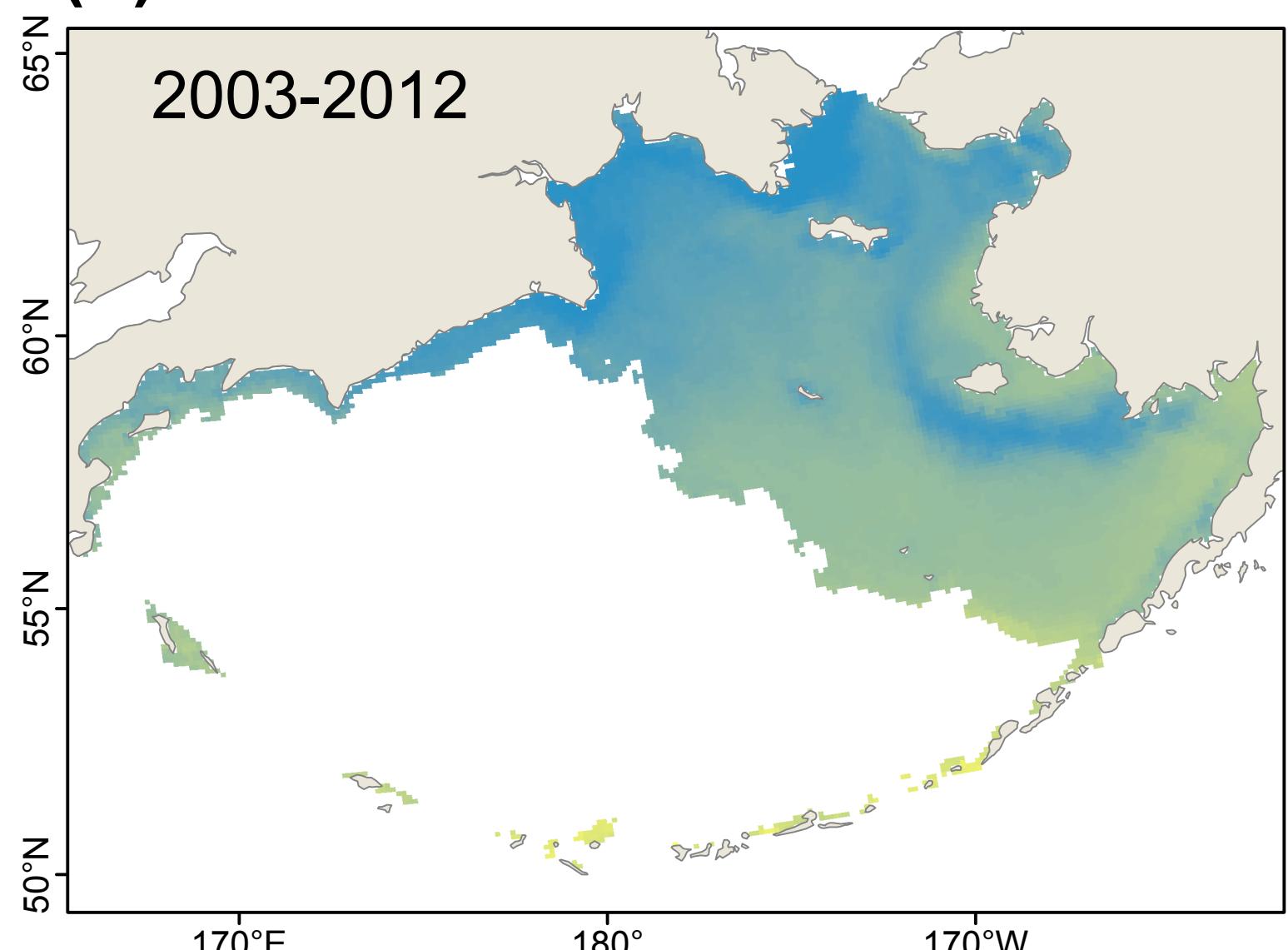
Average number of weeks of suitable habitat



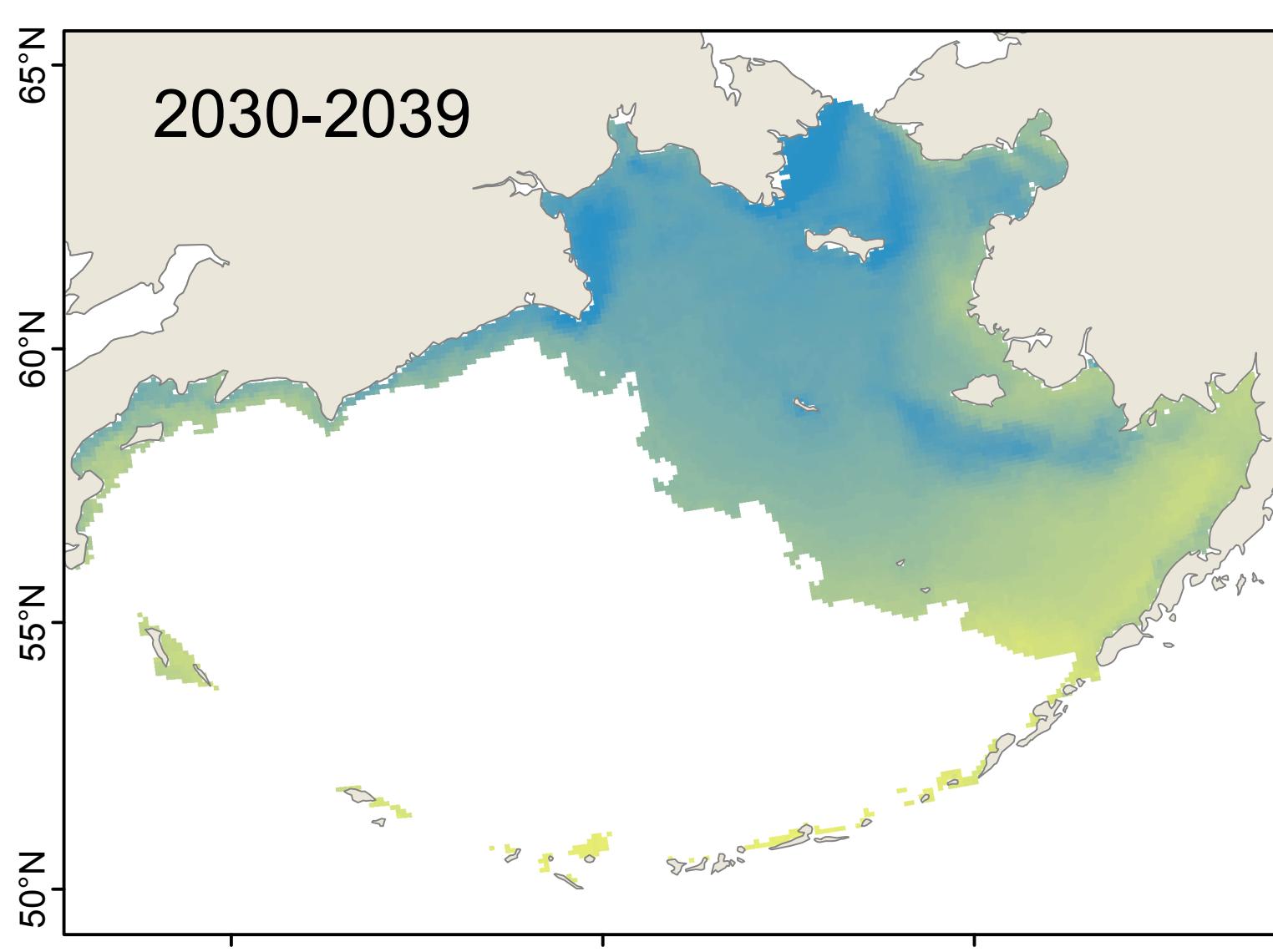
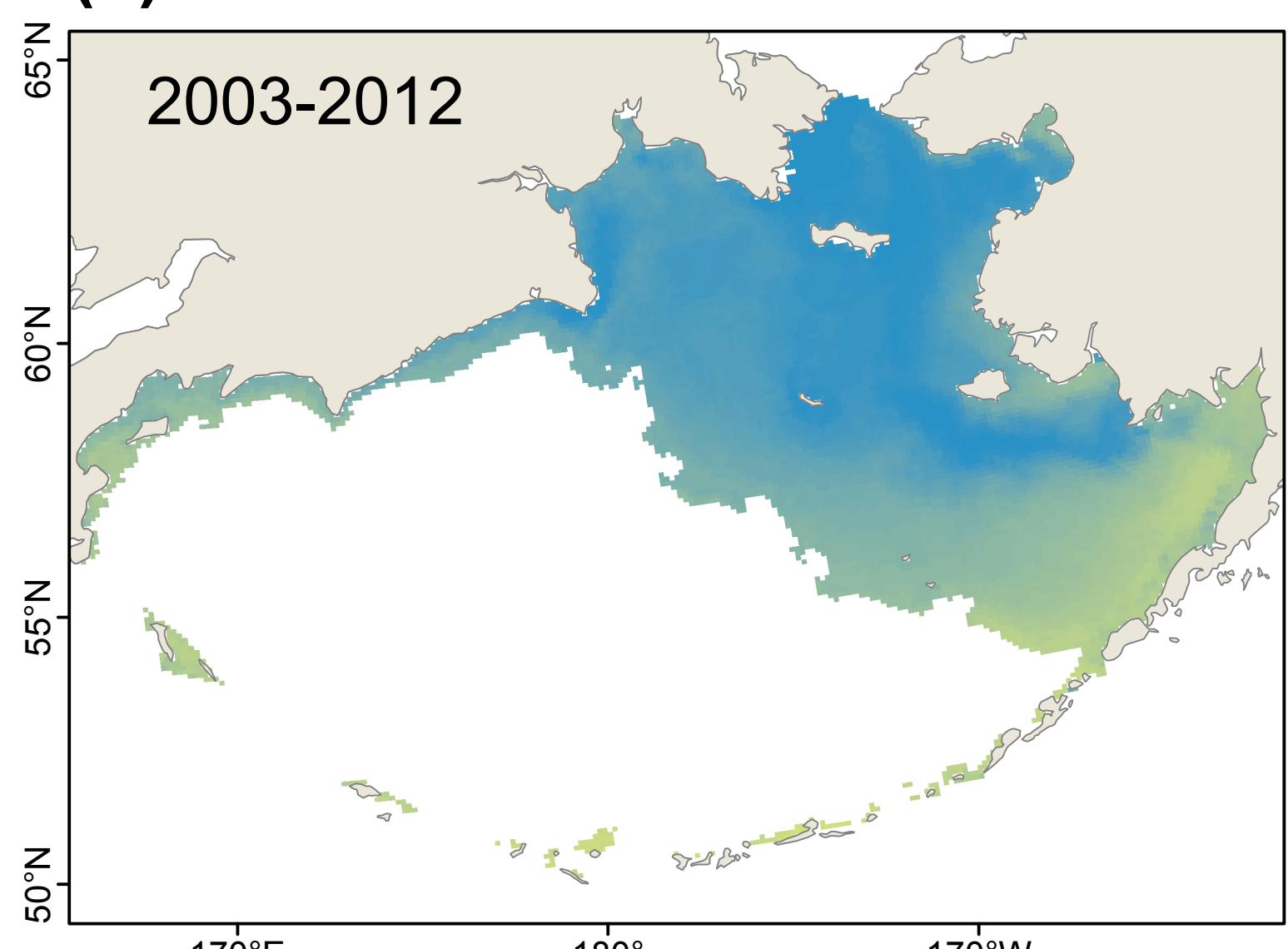
(a) Model: CGCM3-t47



(b) Model: ECHO-G

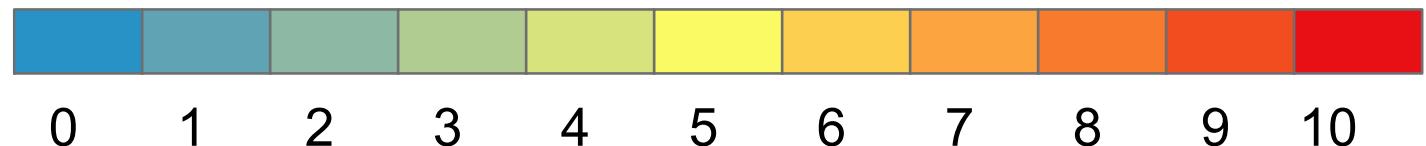


(c) Model: MIROC3.2

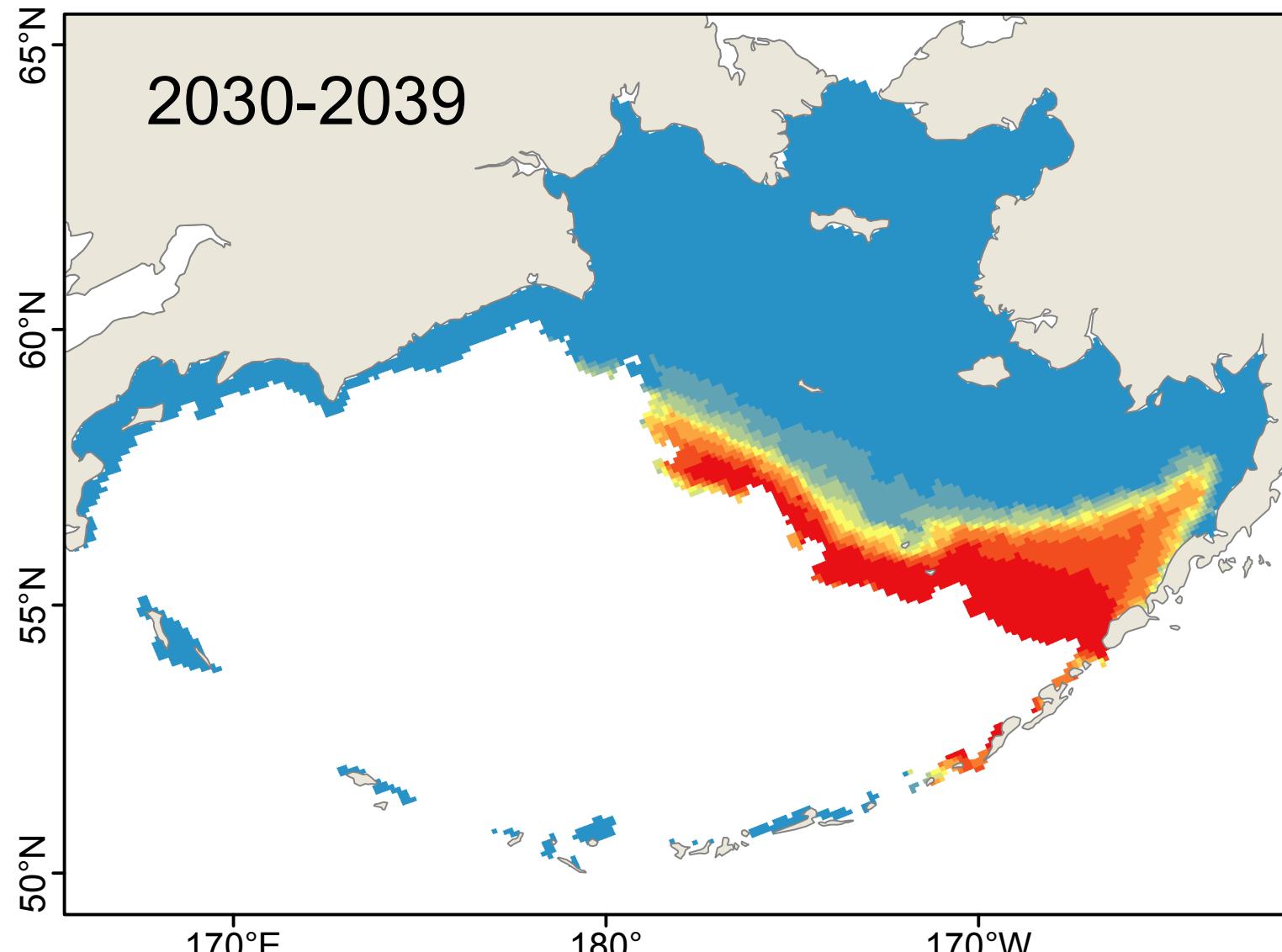
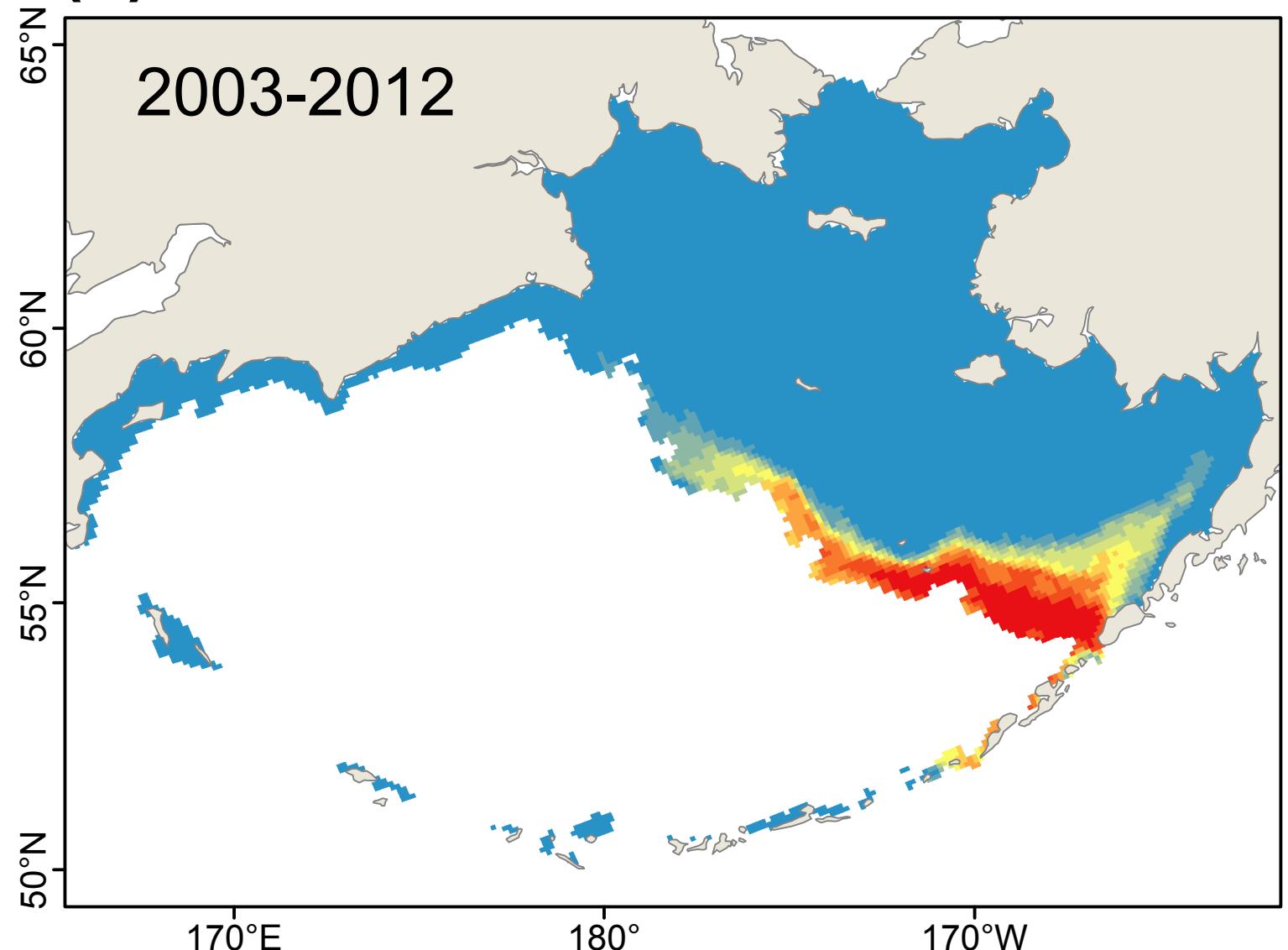


# *Alosa sapidissima*: Year-round Survival

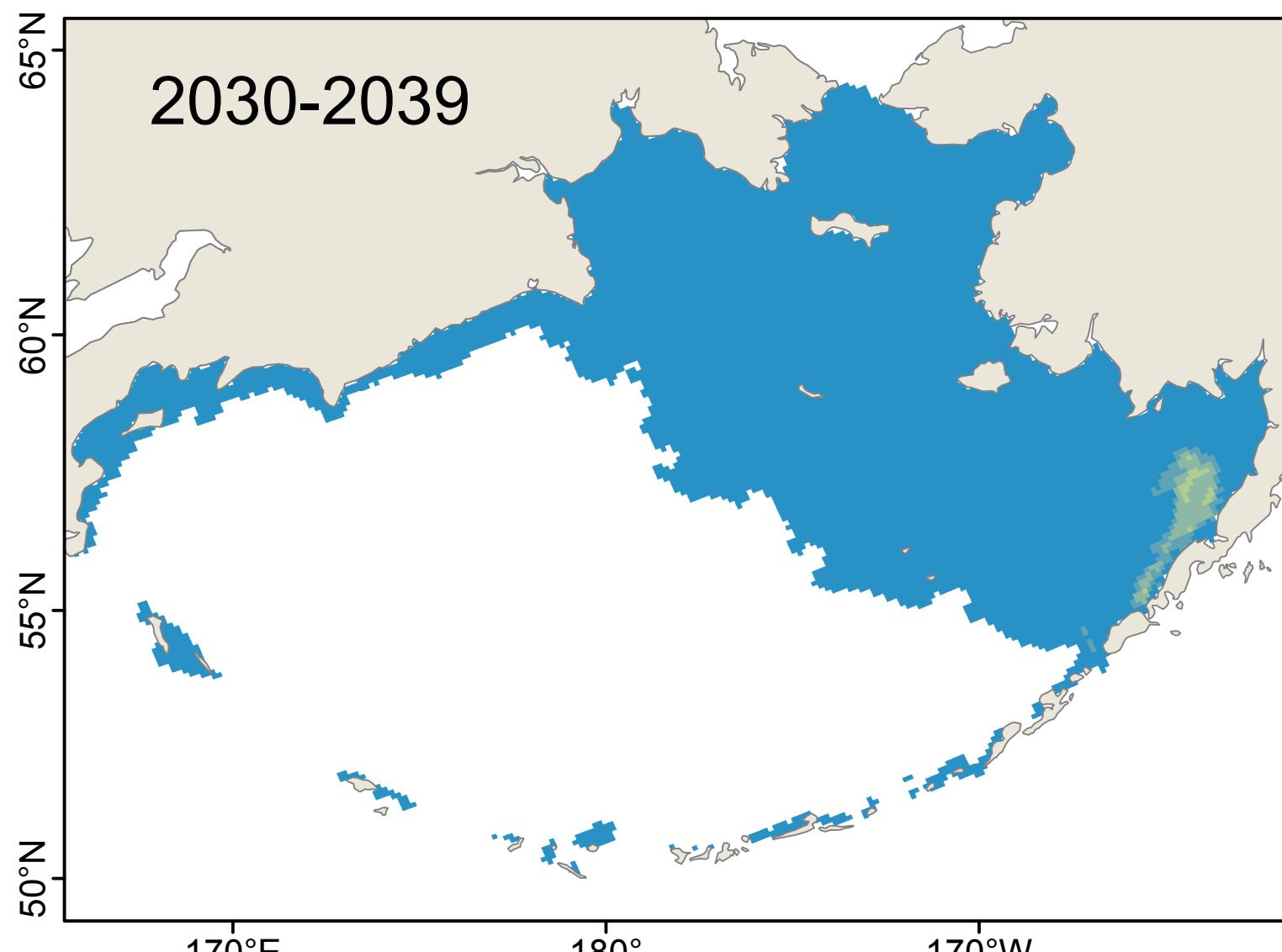
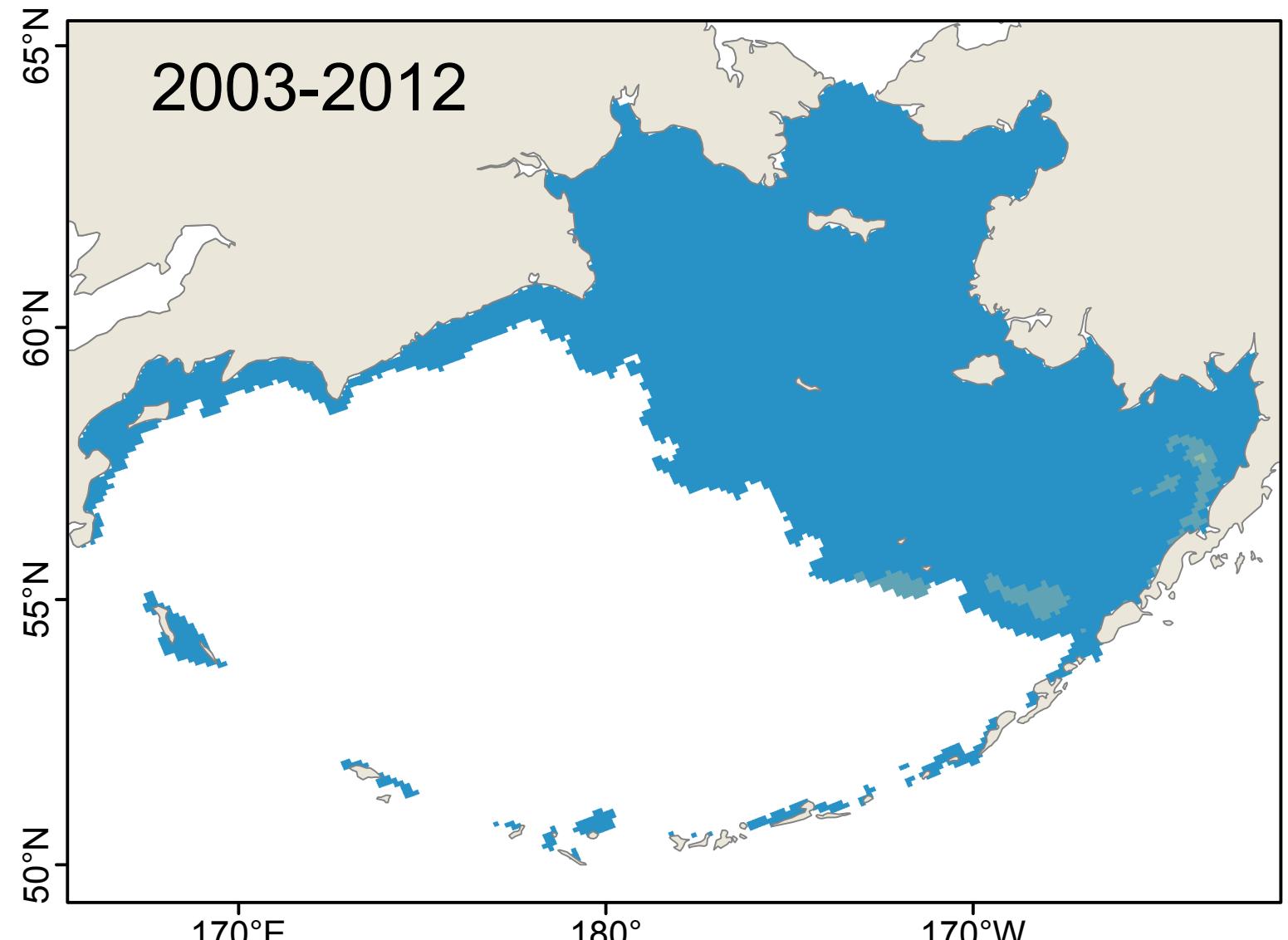
Number of years with suitable habitat



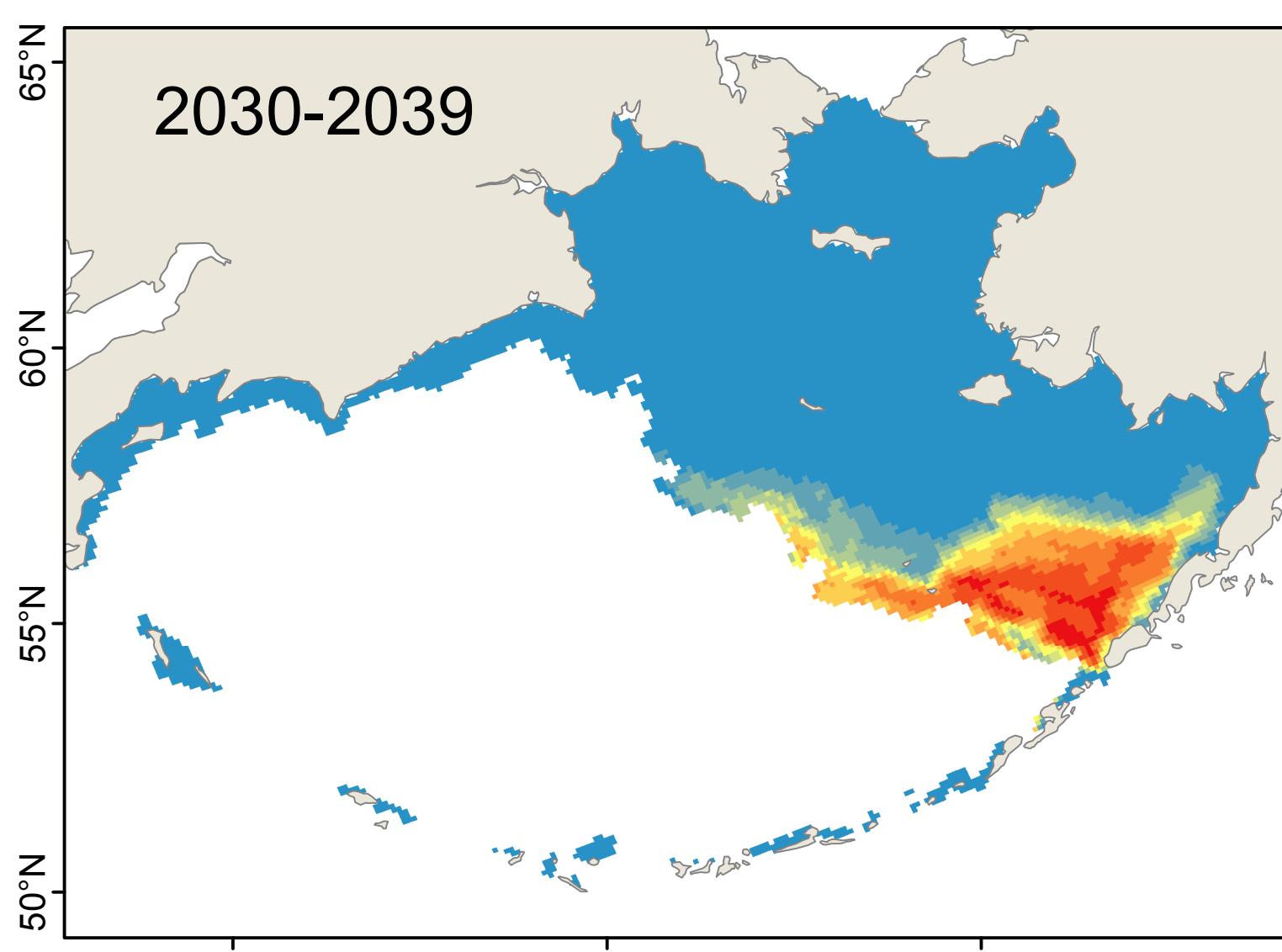
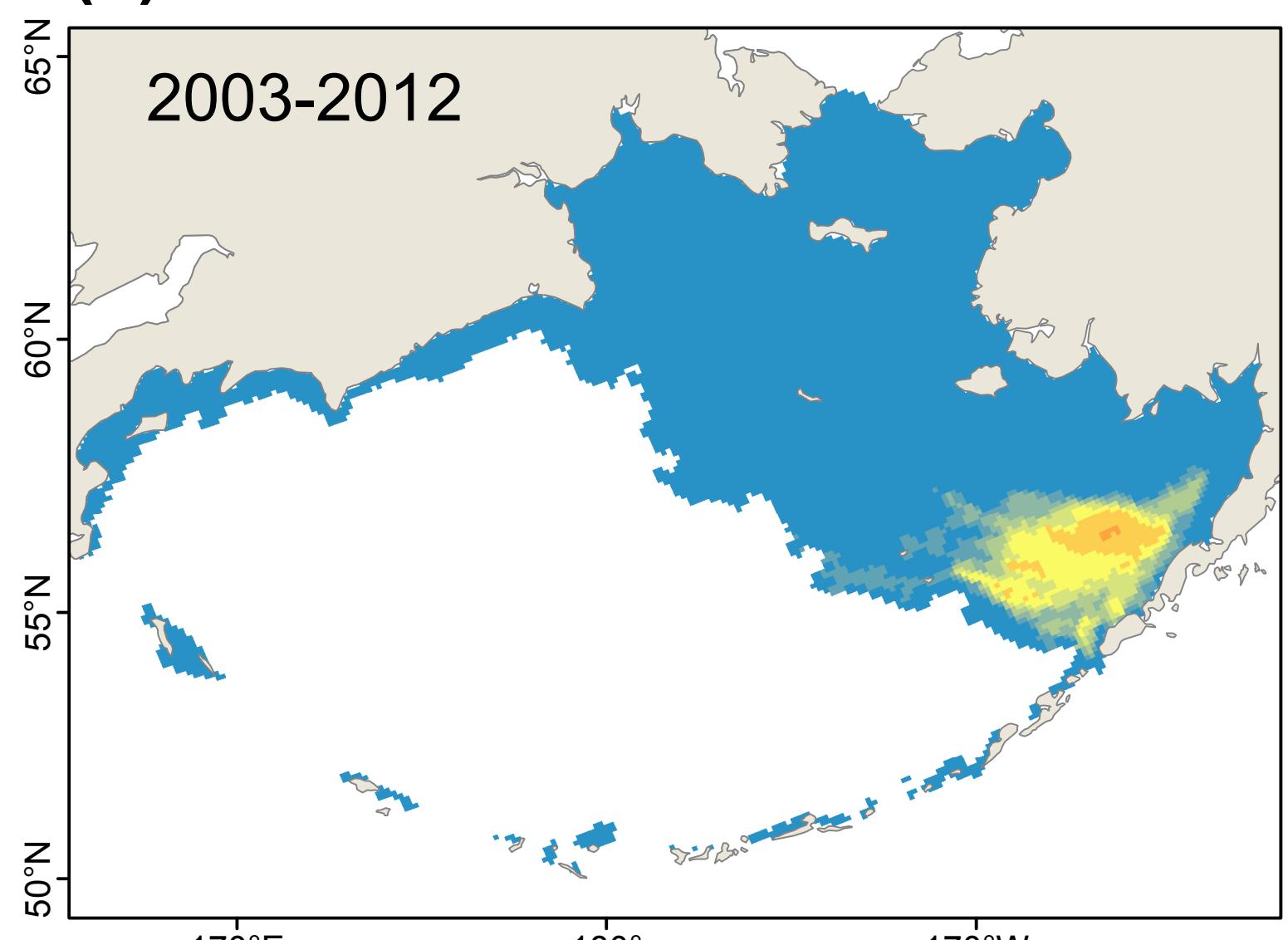
(a) Model: CGCM3-t47



(b) Model: ECHO-G

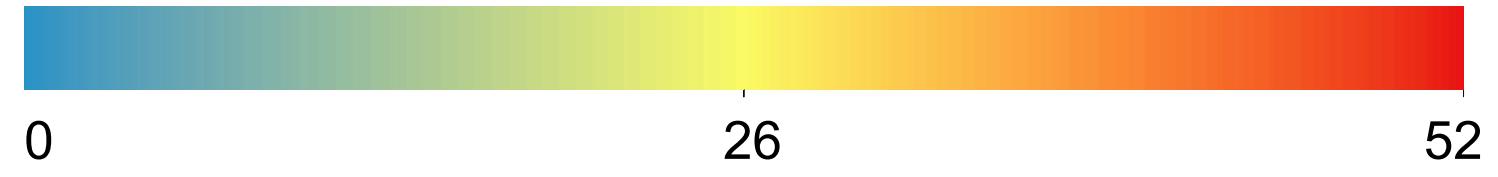


(c) Model: MIROC3.2

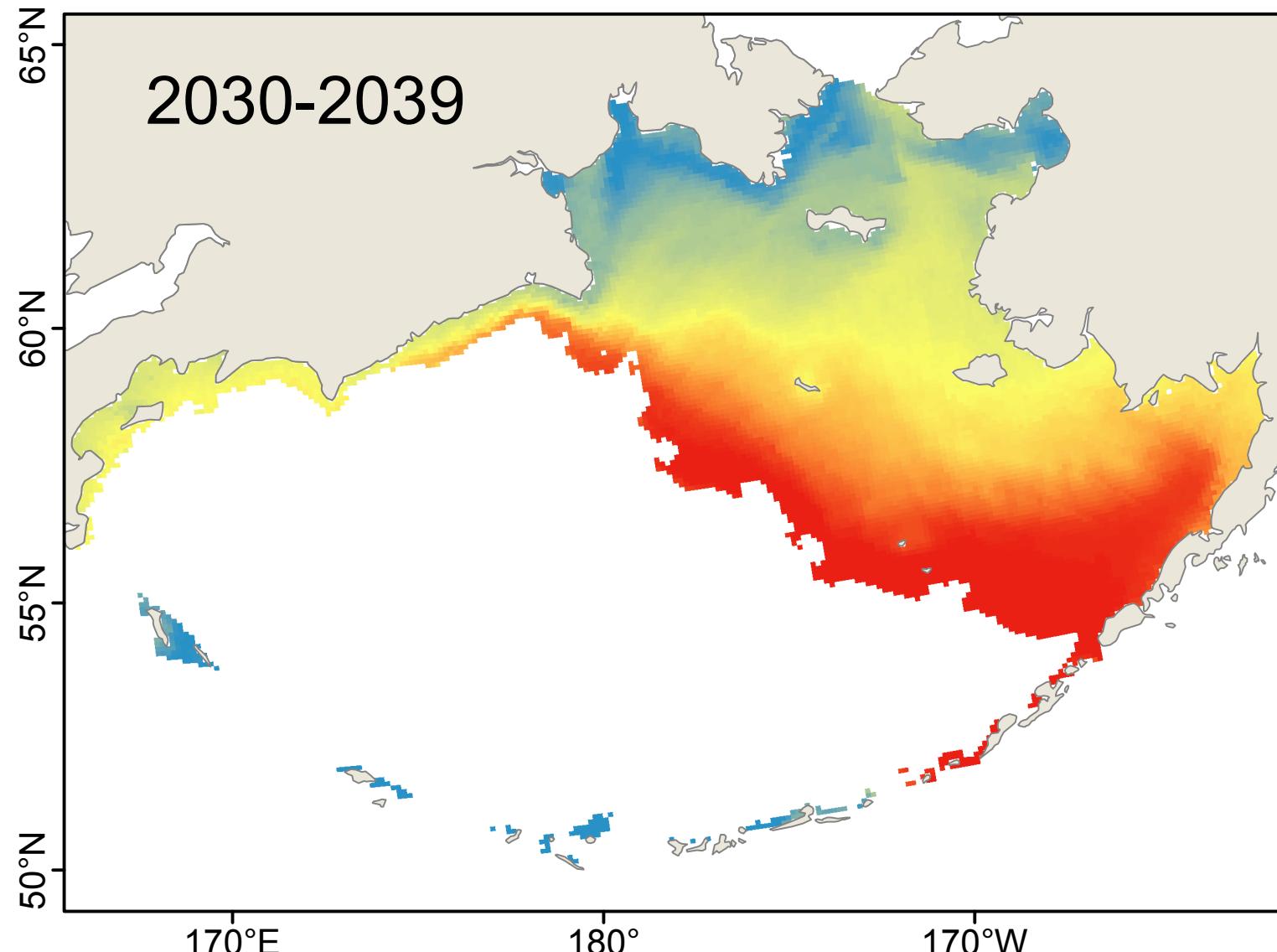
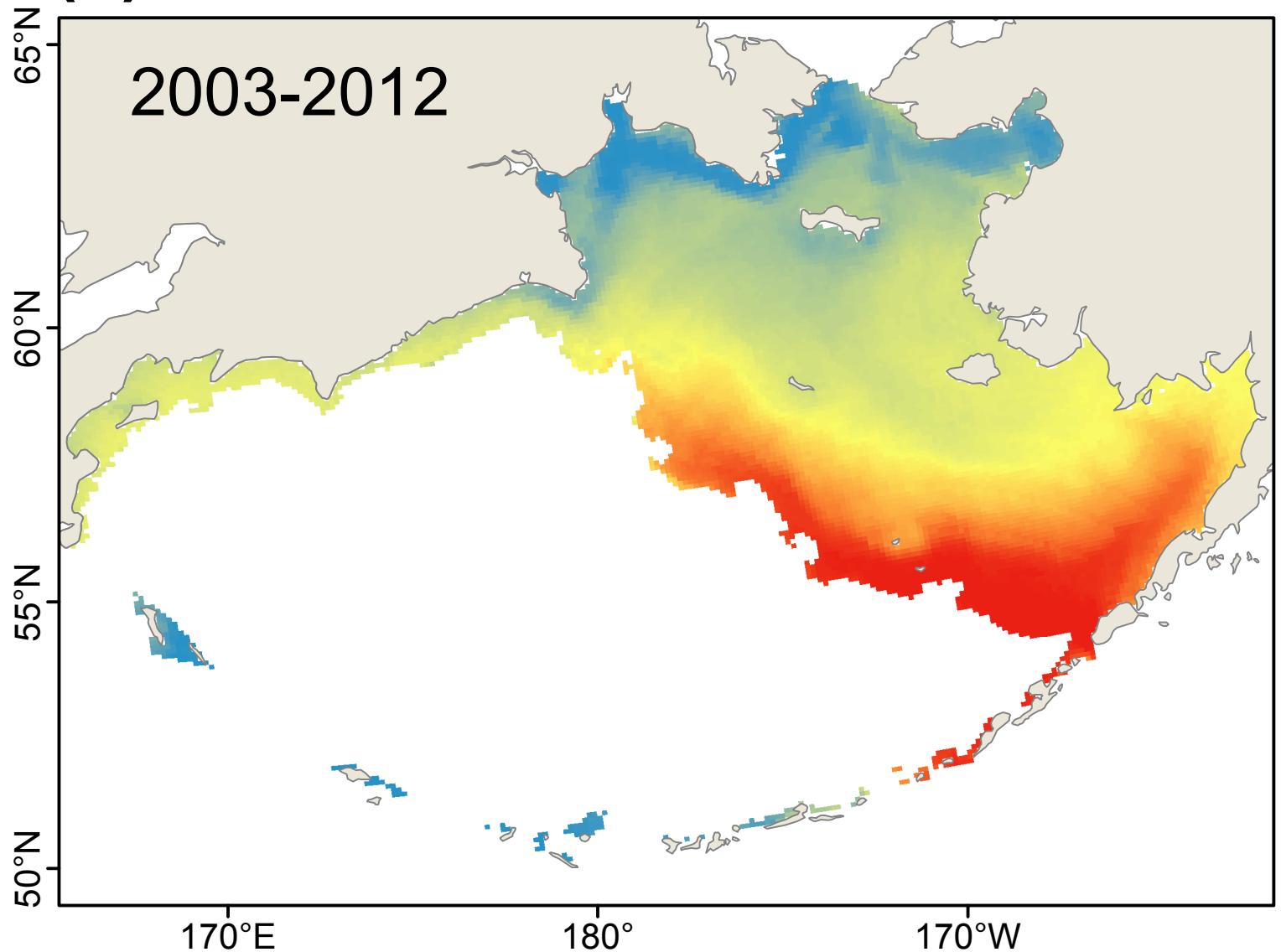


# *Alosa sapidissima: Weekly Survival*

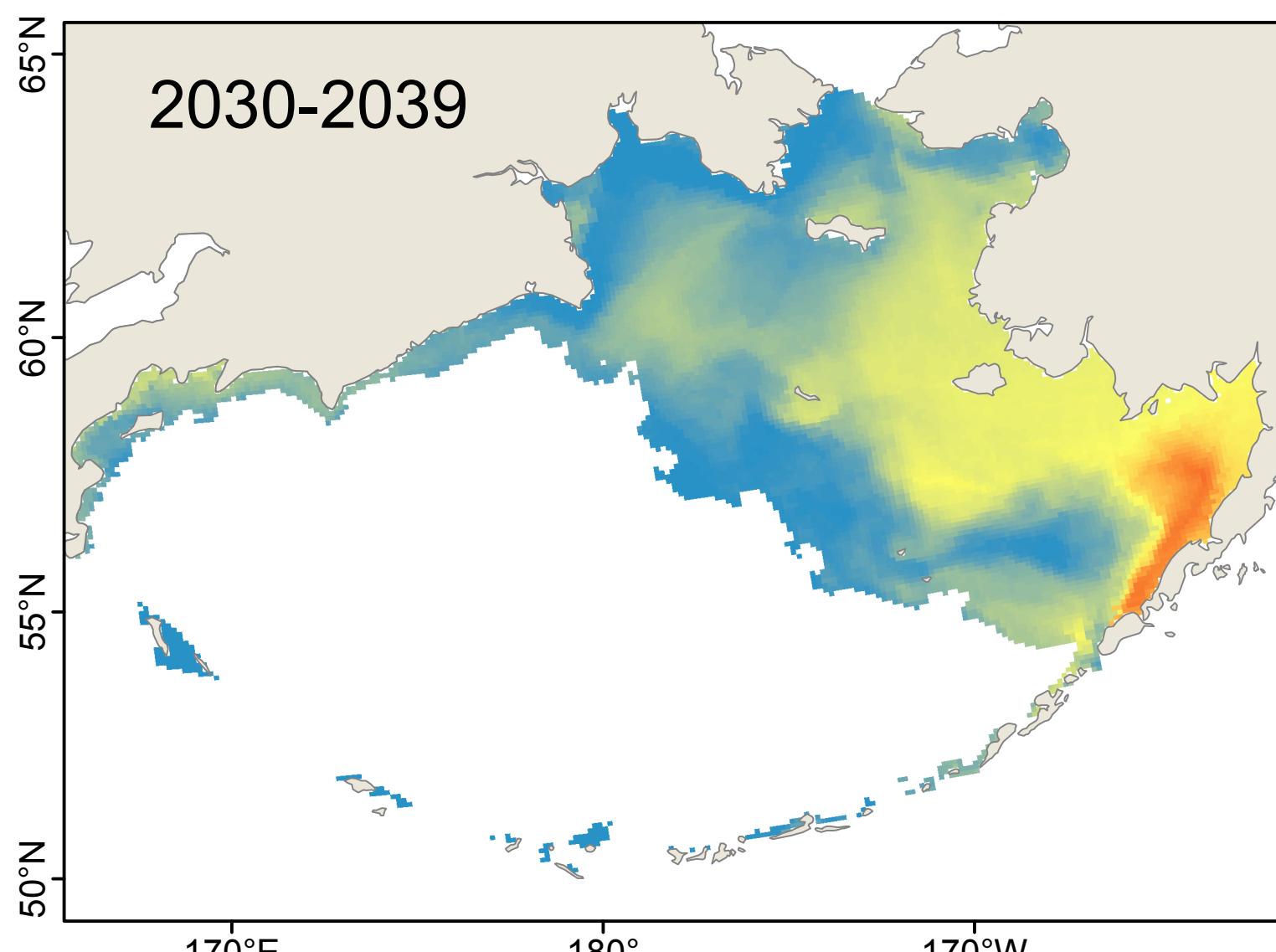
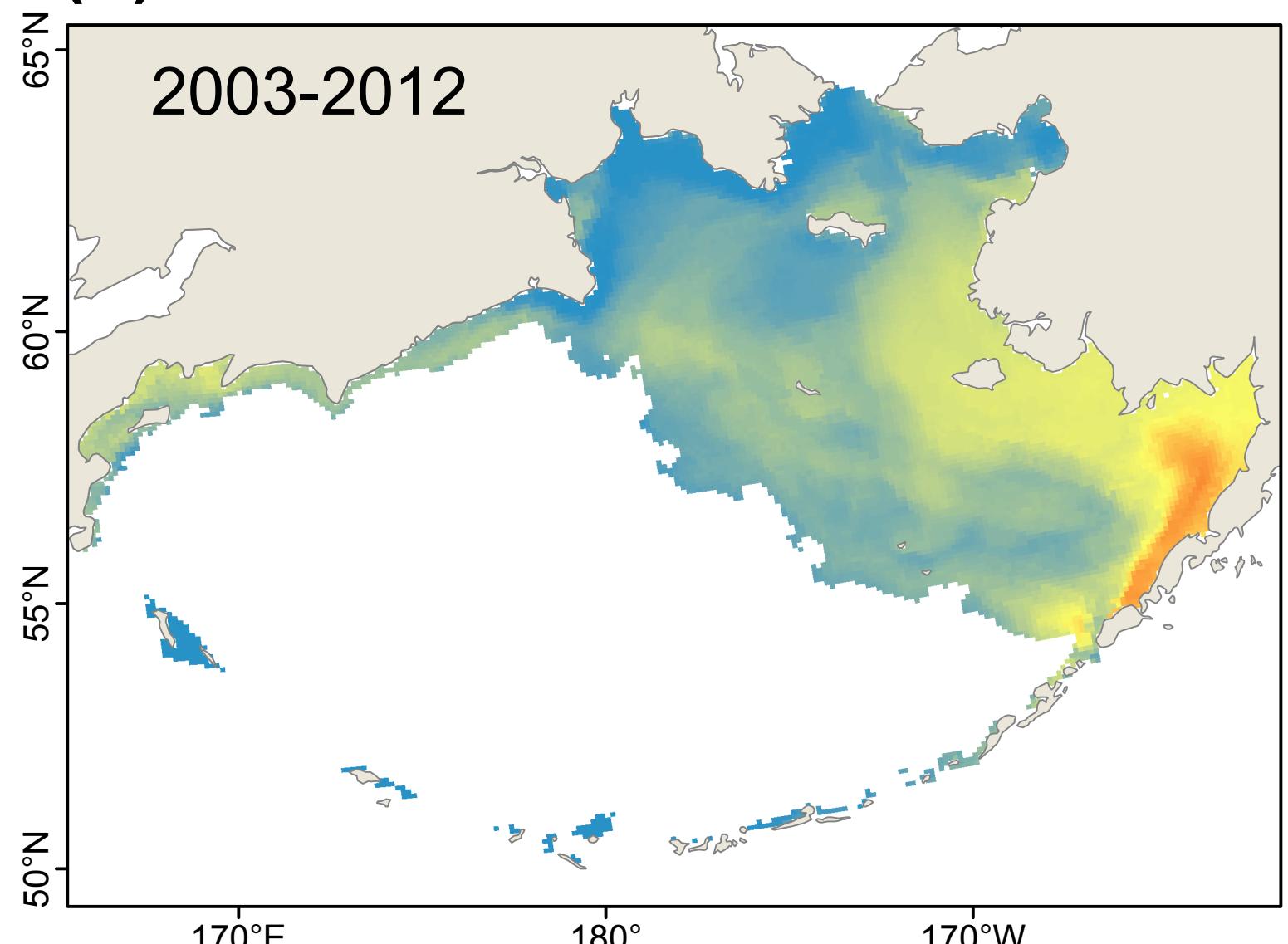
Average number of weeks of suitable habitat



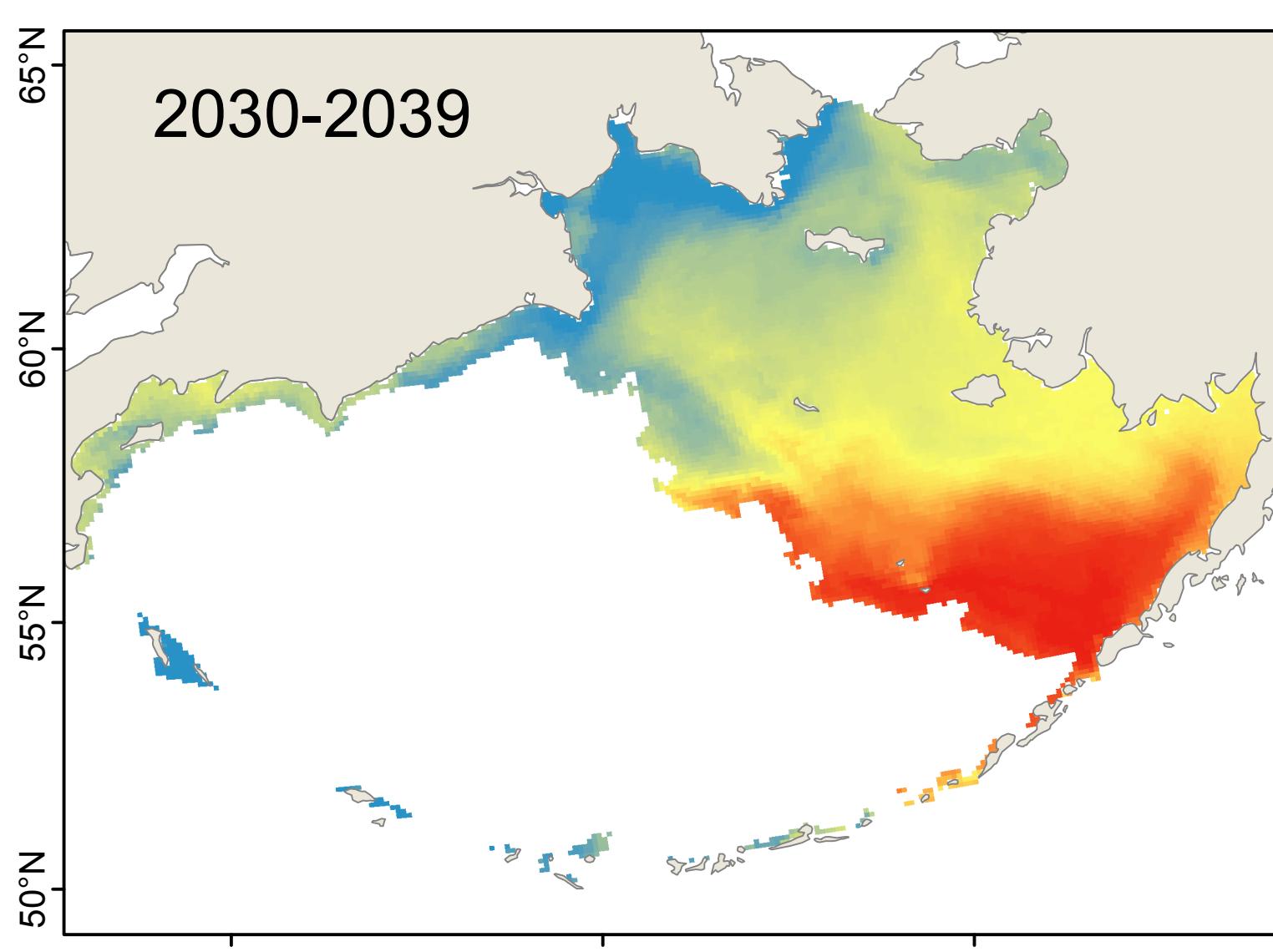
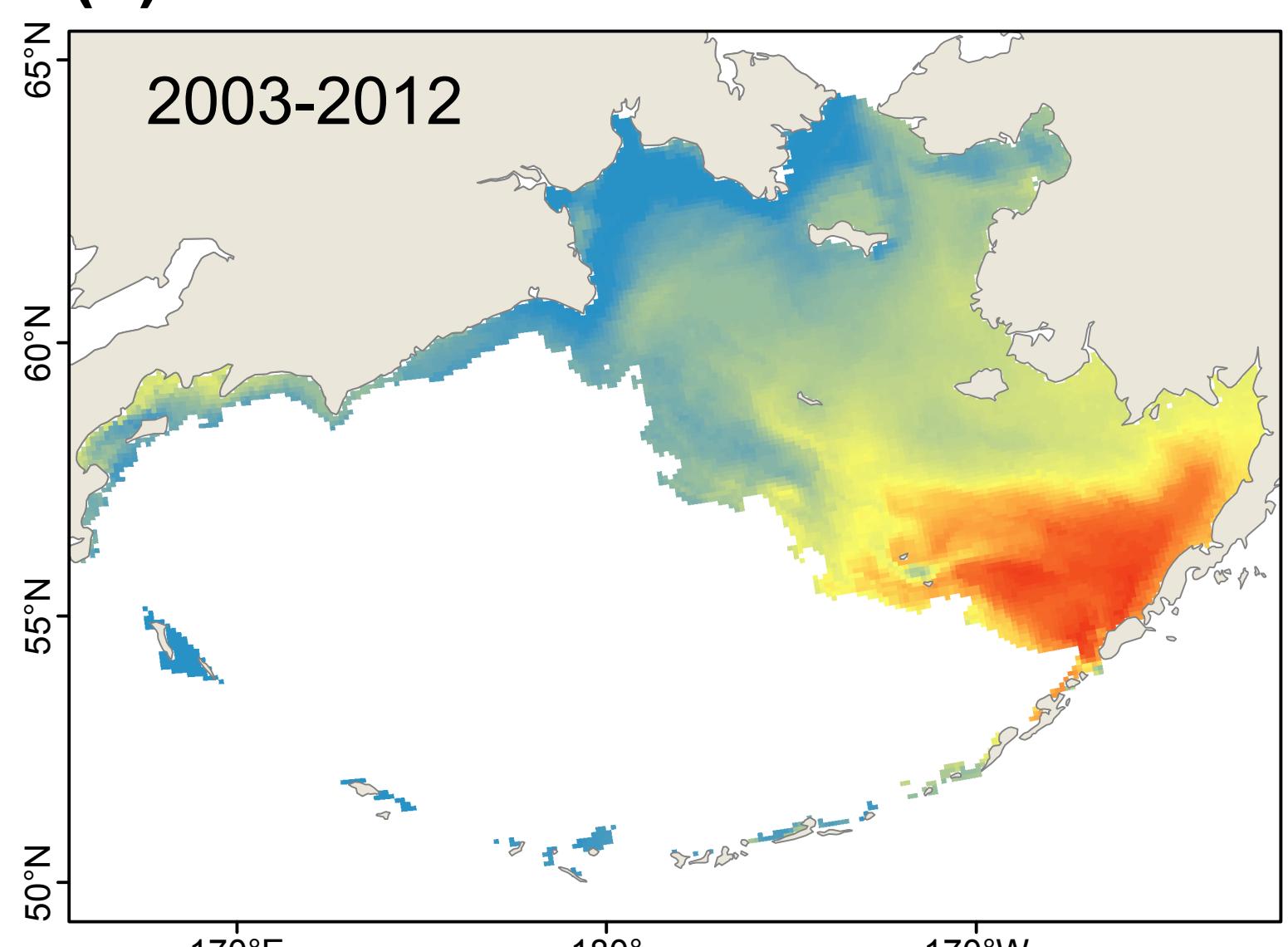
(a) Model: CGCM3-t47



(b) Model: ECHO-G

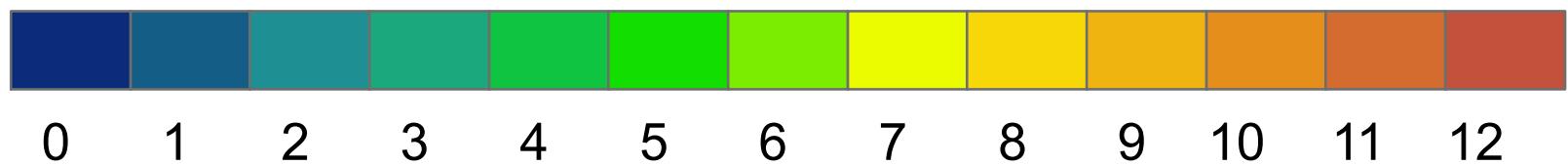


(c) Model: MIROC3.2

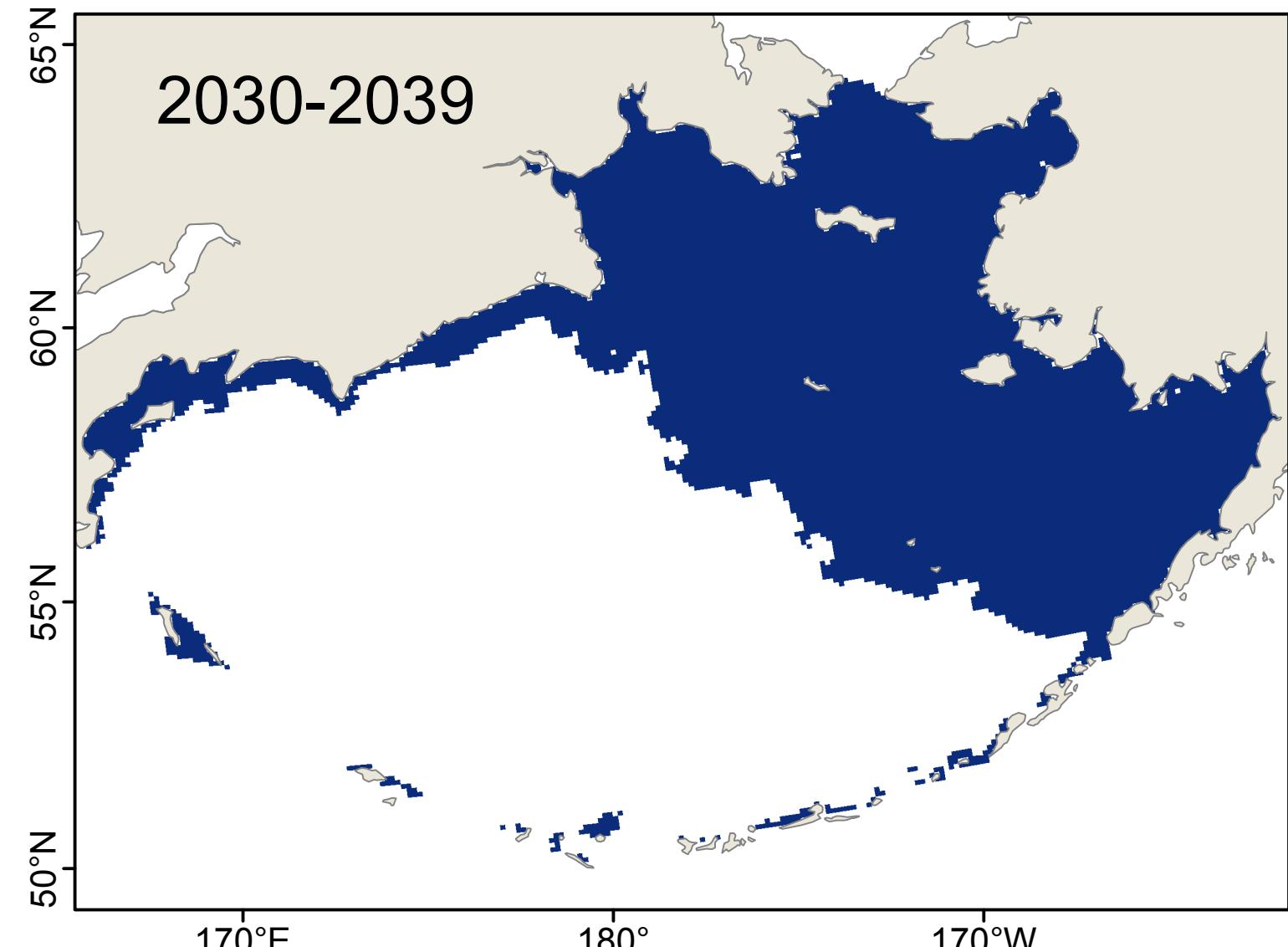
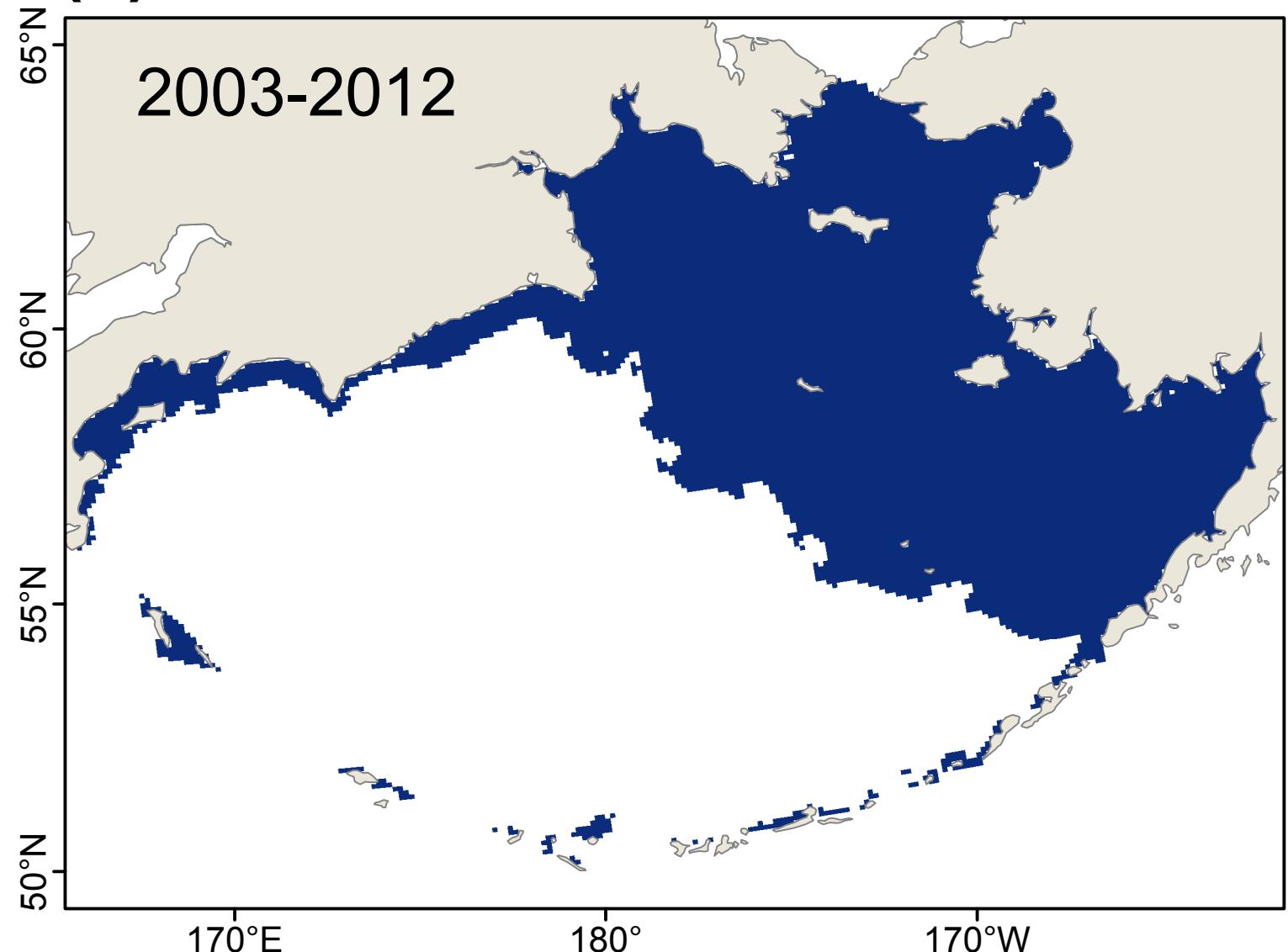


# *Alosa sapidissima: Reproduction*

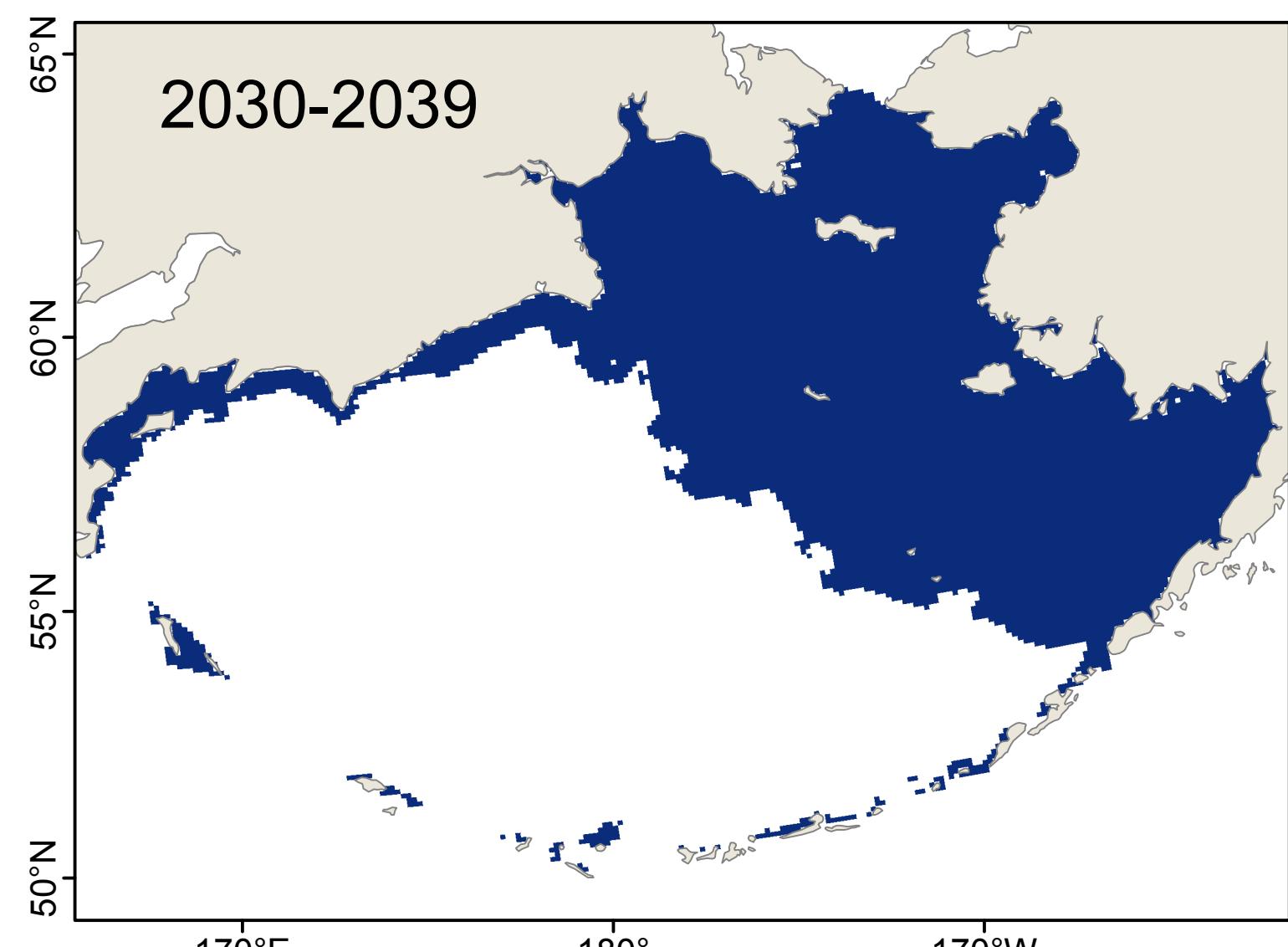
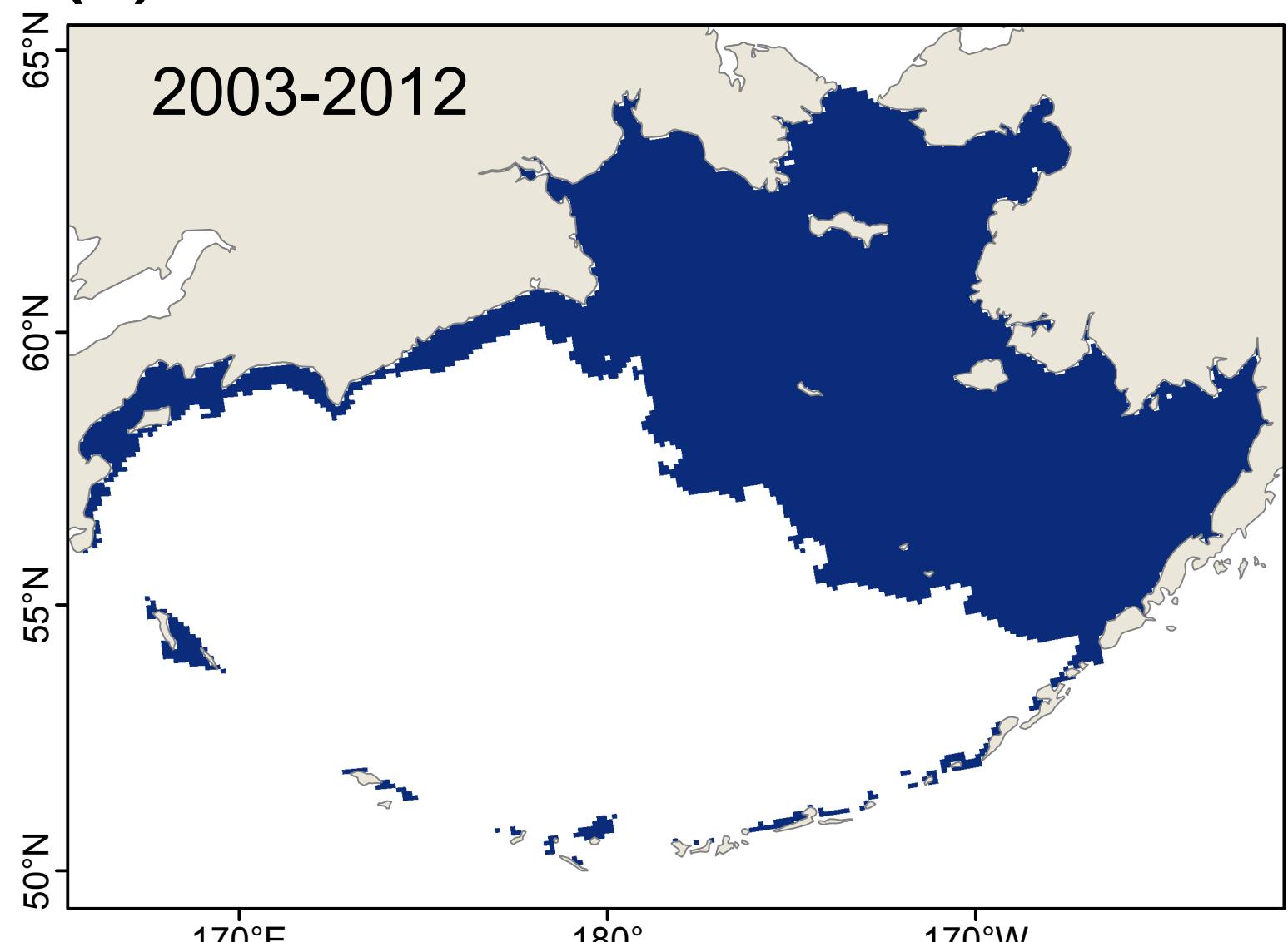
Average number of consecutive weeks of suitable habitat



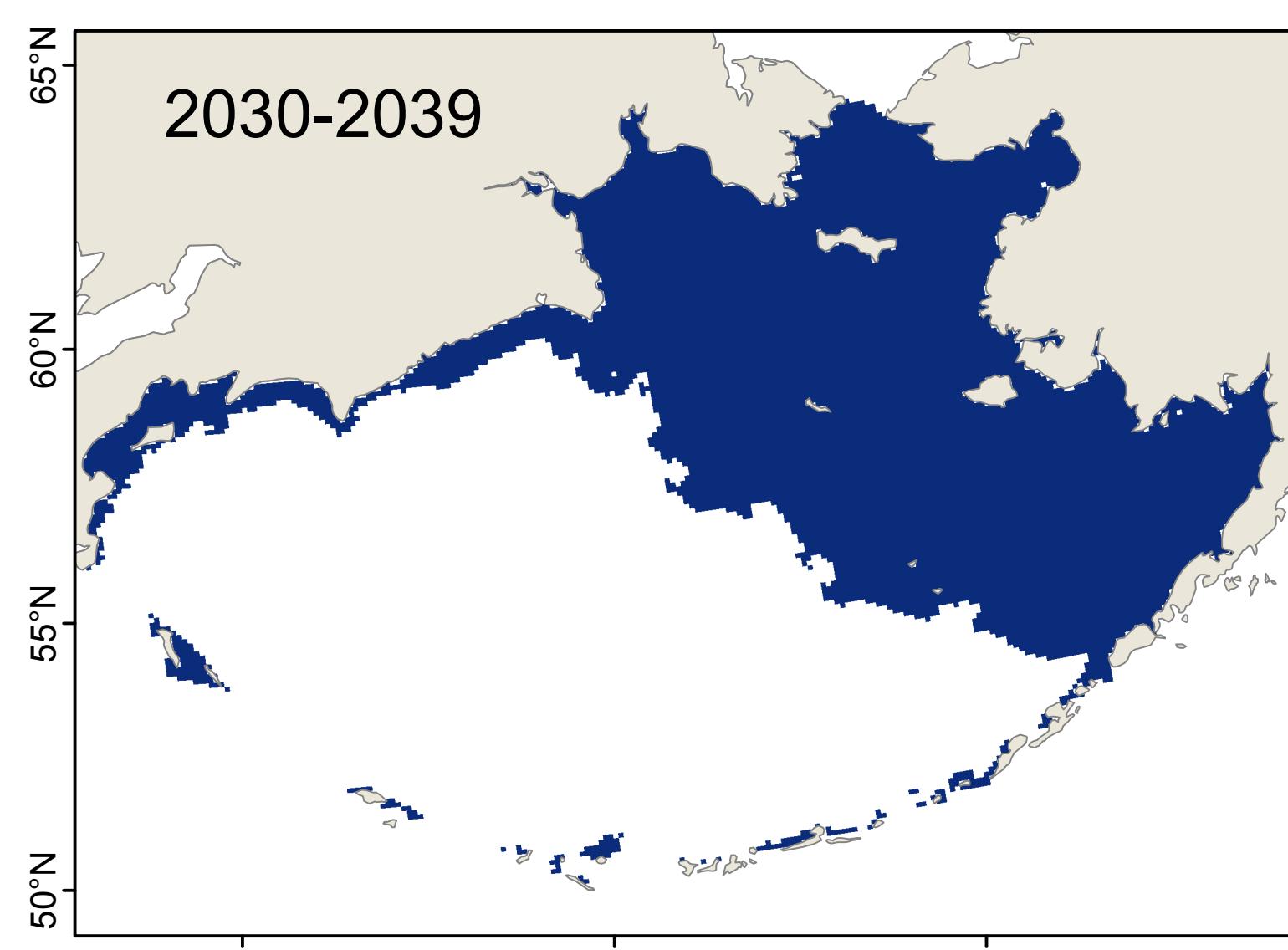
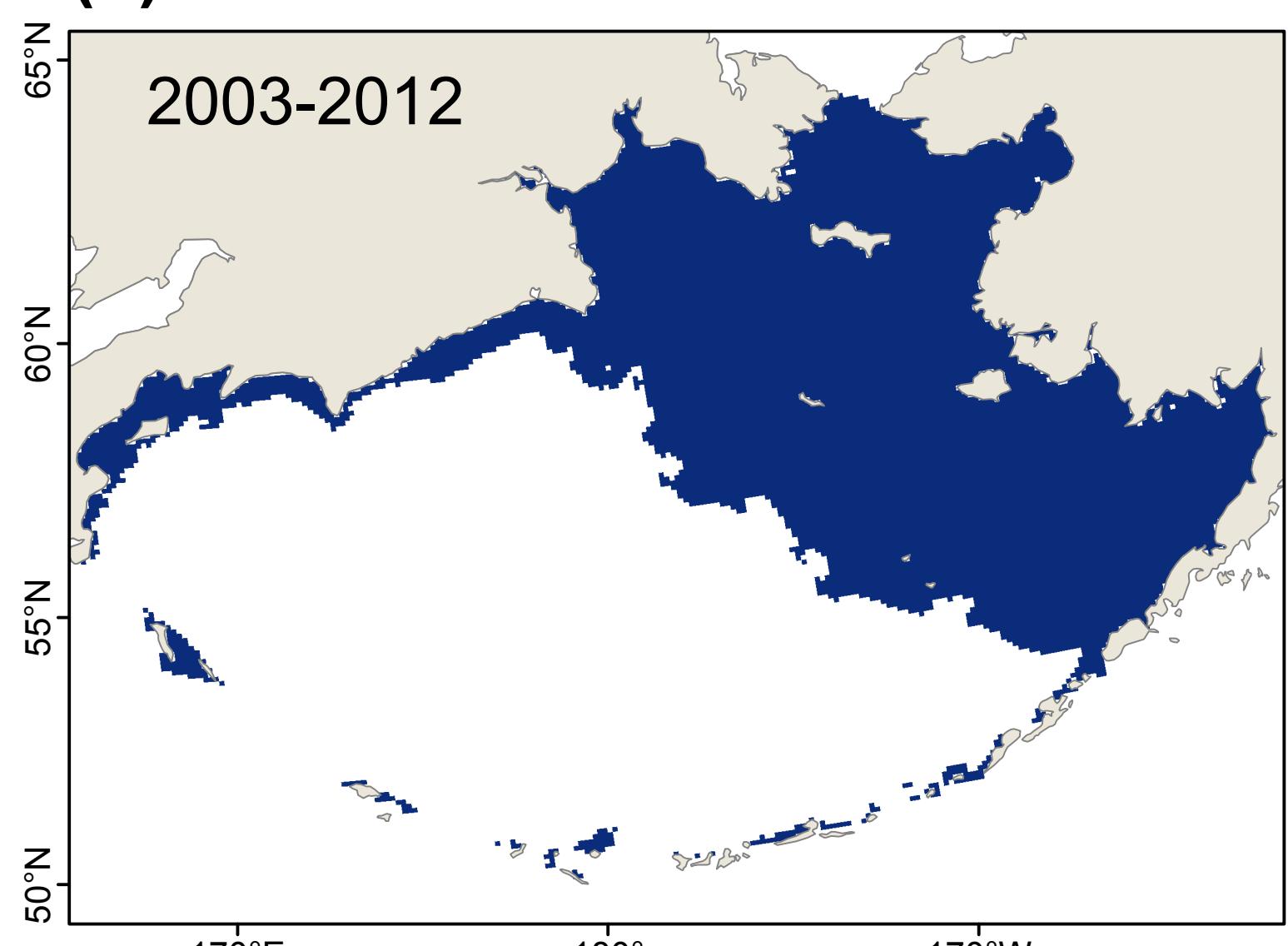
(a) Model: CGCM3-t47



(b) Model: ECHO-G

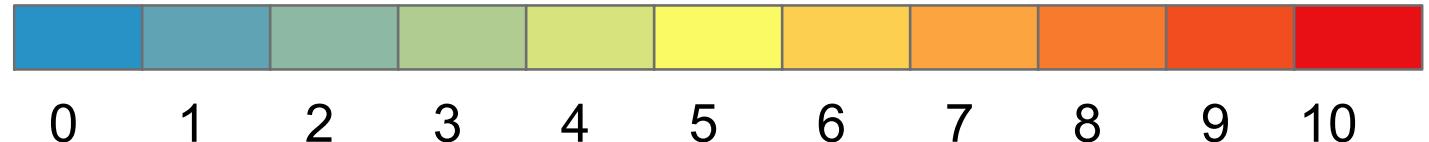


(c) Model: MIROC3.2

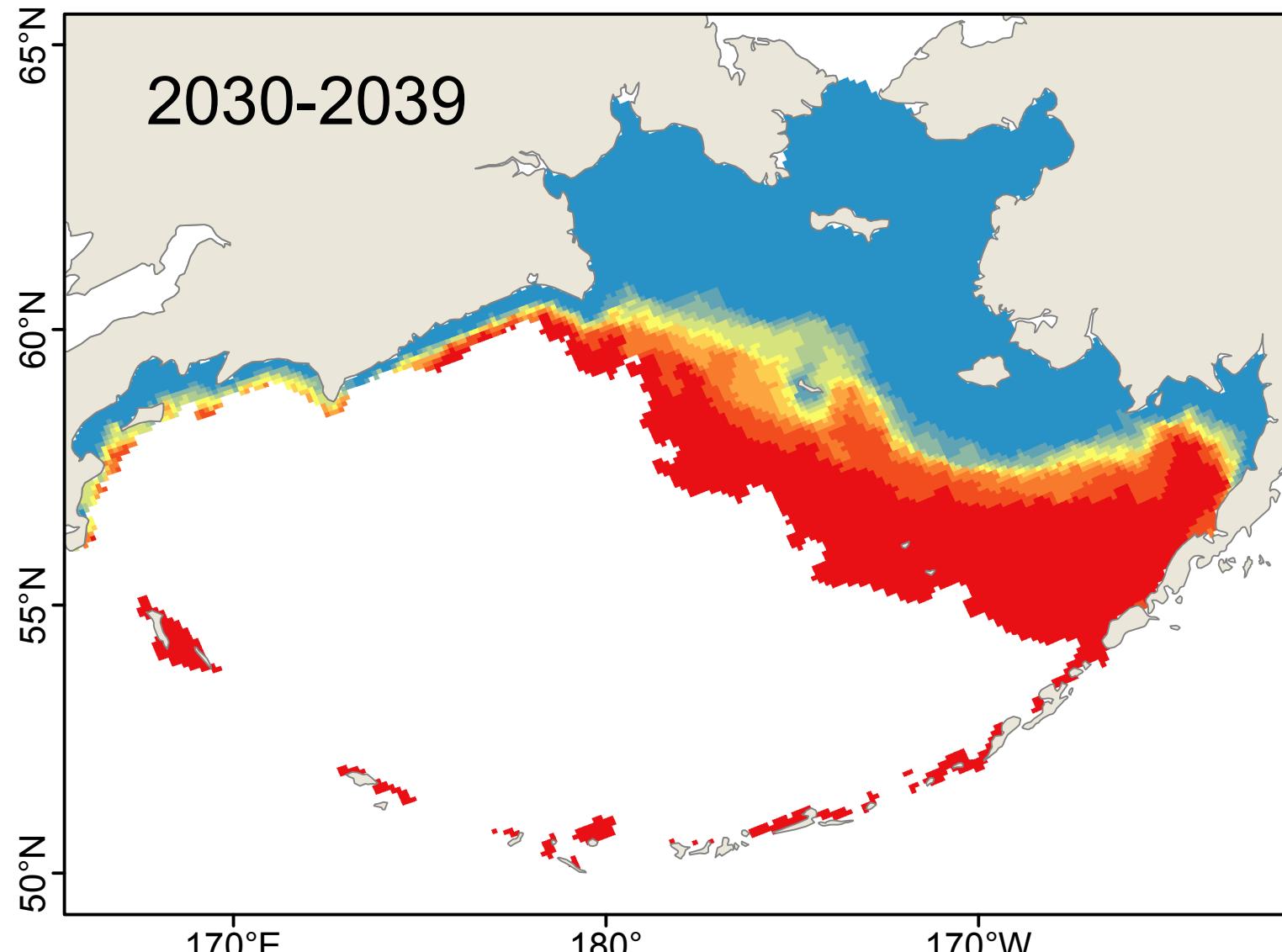
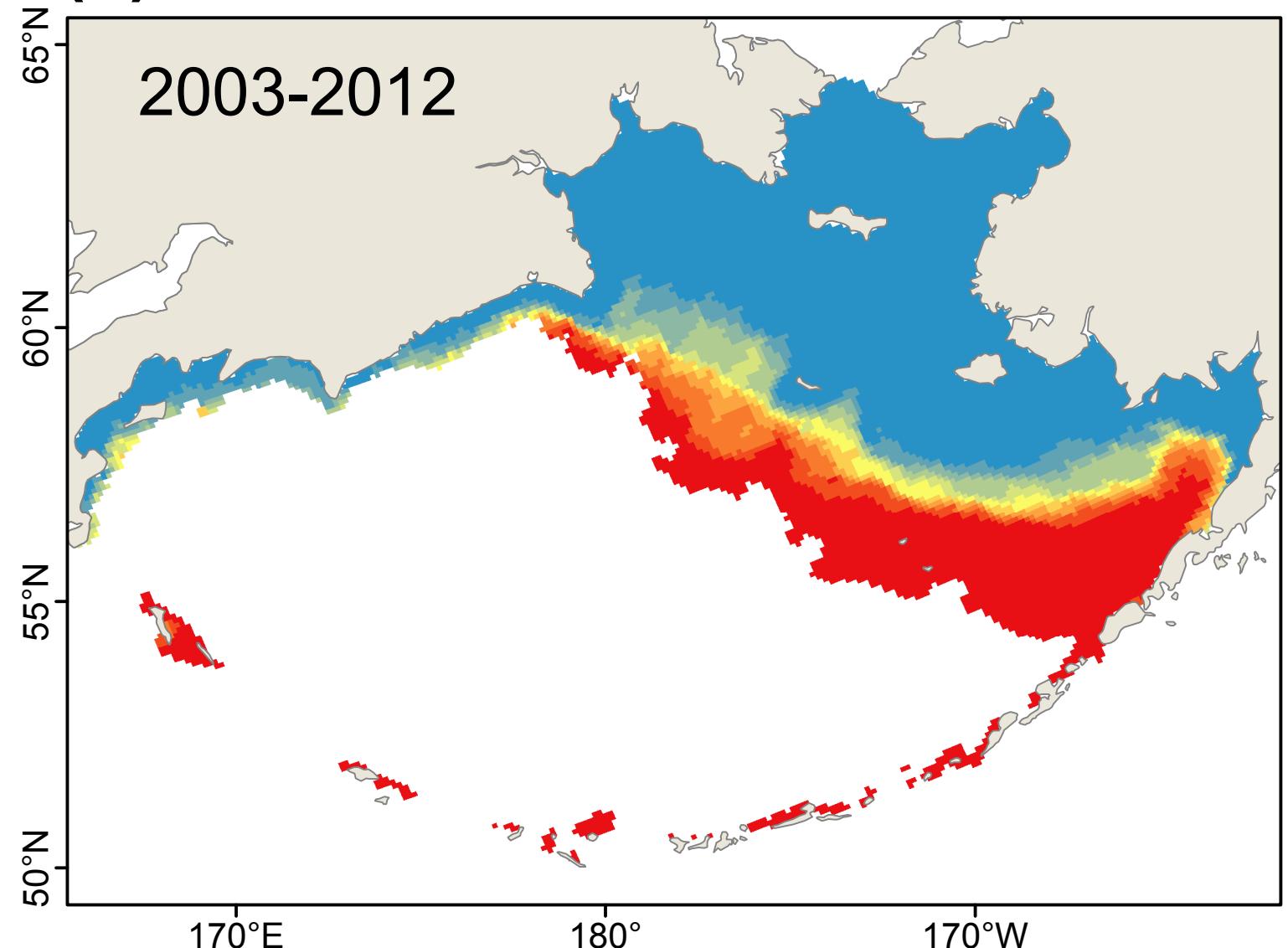


# *Salmo salar: Year-round Survival*

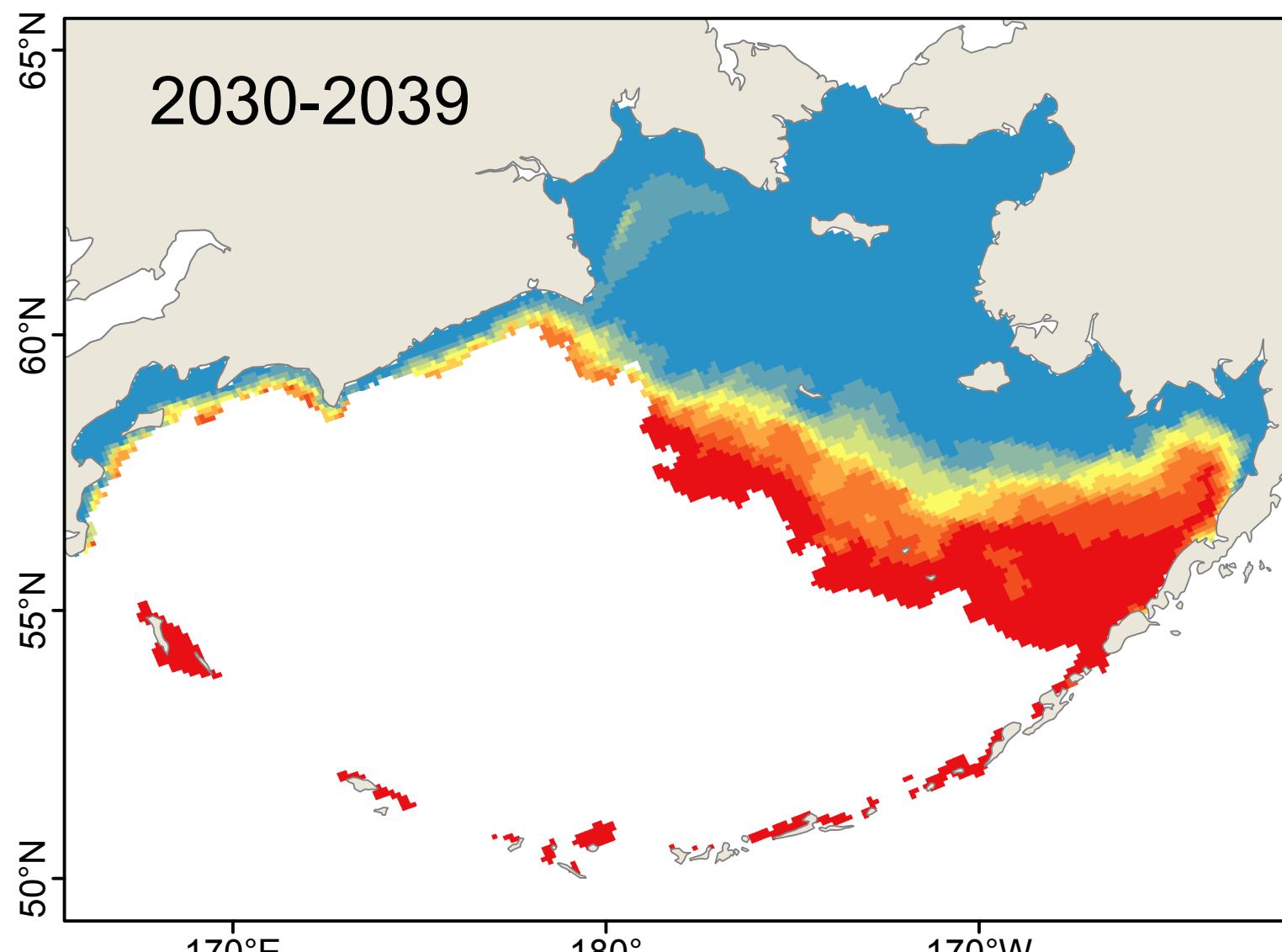
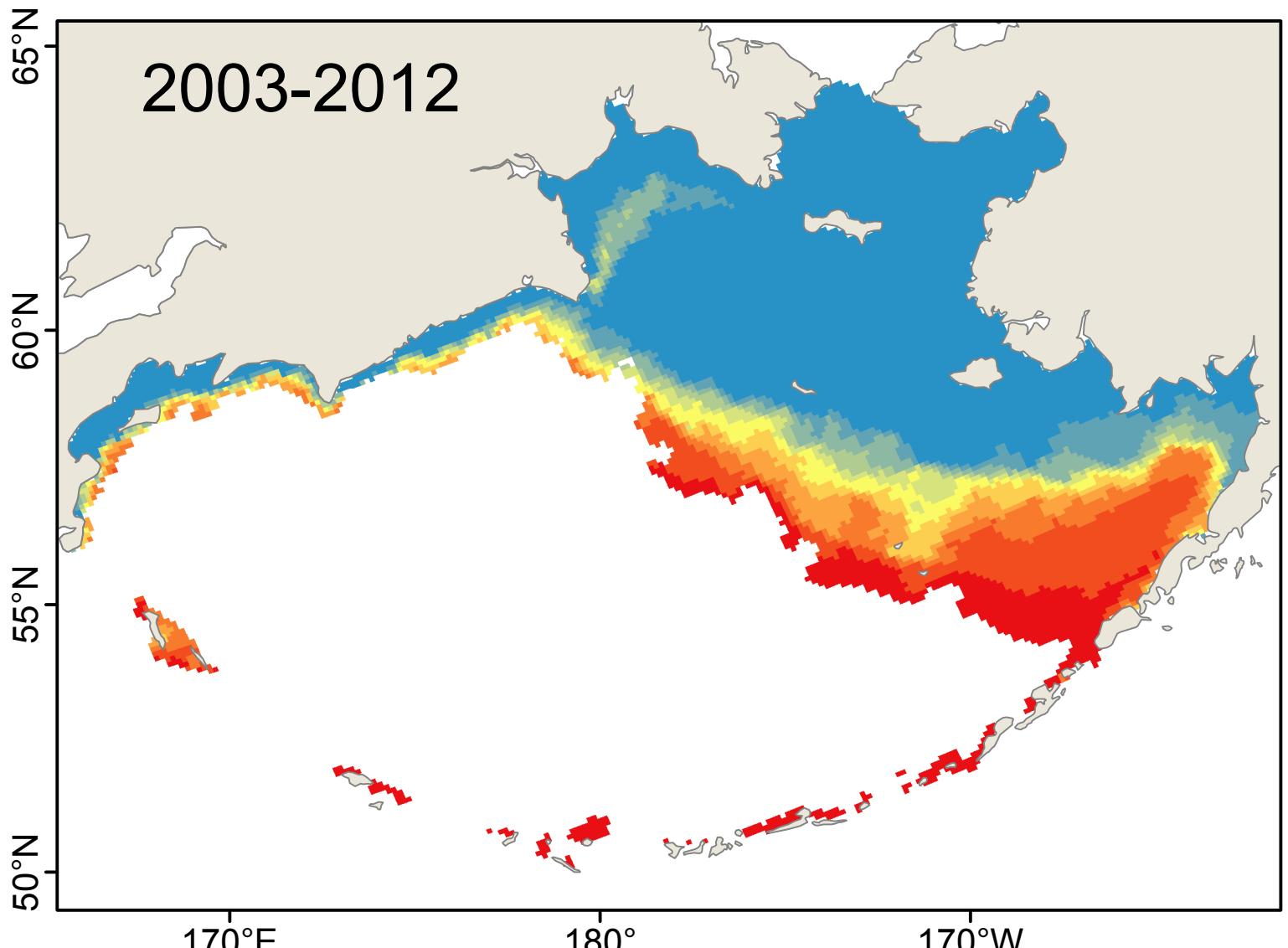
Number of years with suitable habitat



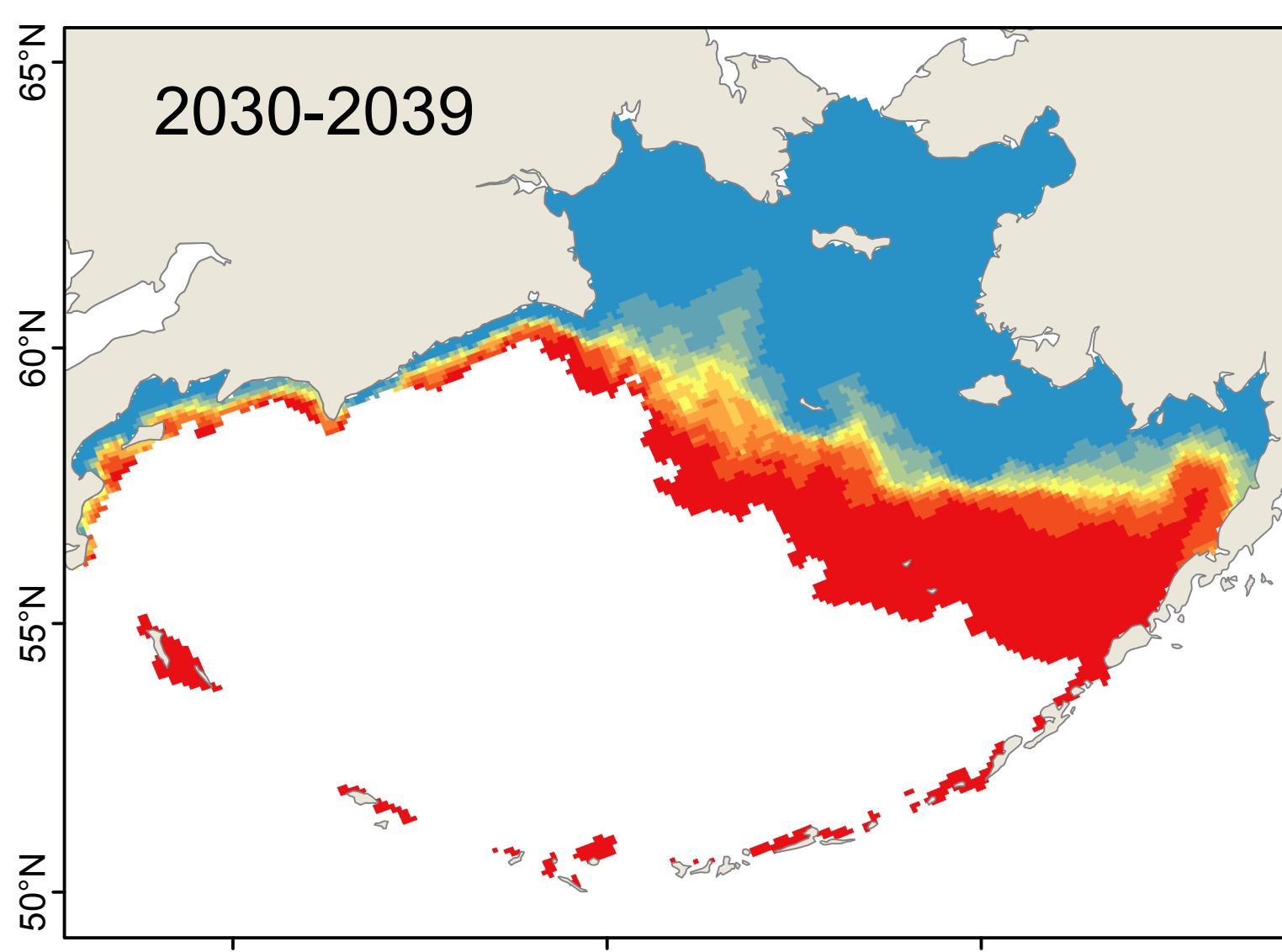
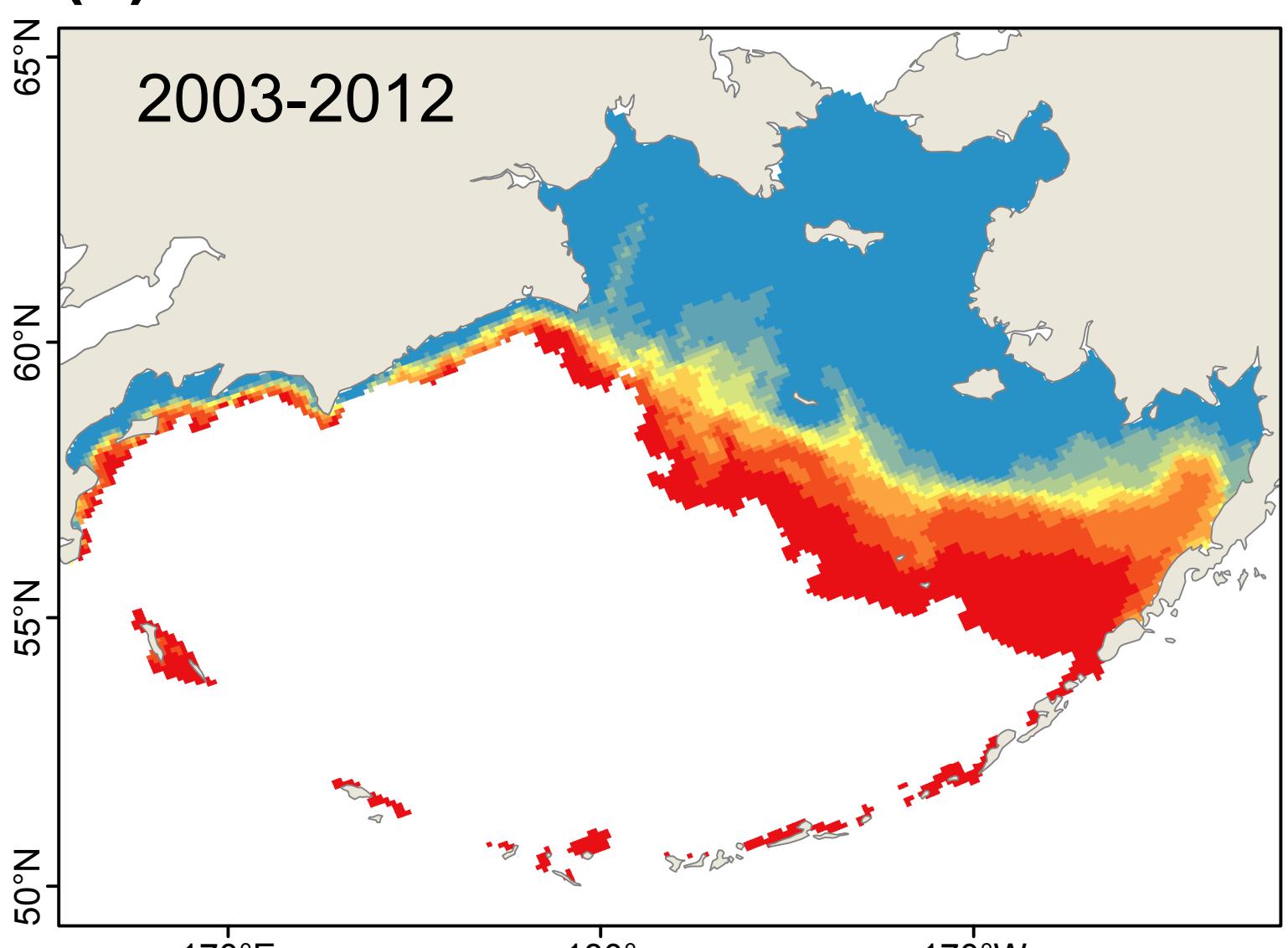
(a) Model: CGCM3-t47



(b) Model: ECHO-G

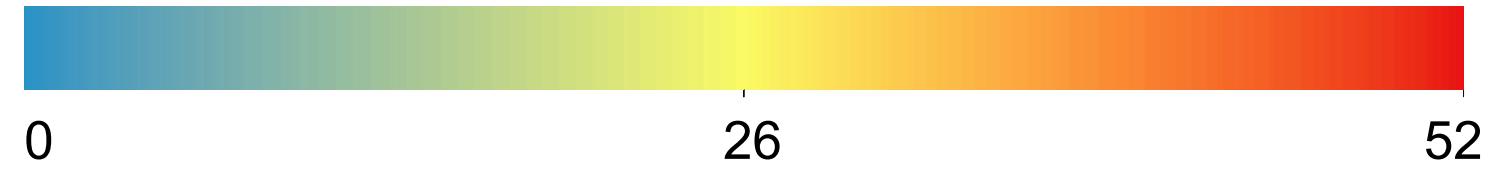


(c) Model: MIROC3.2

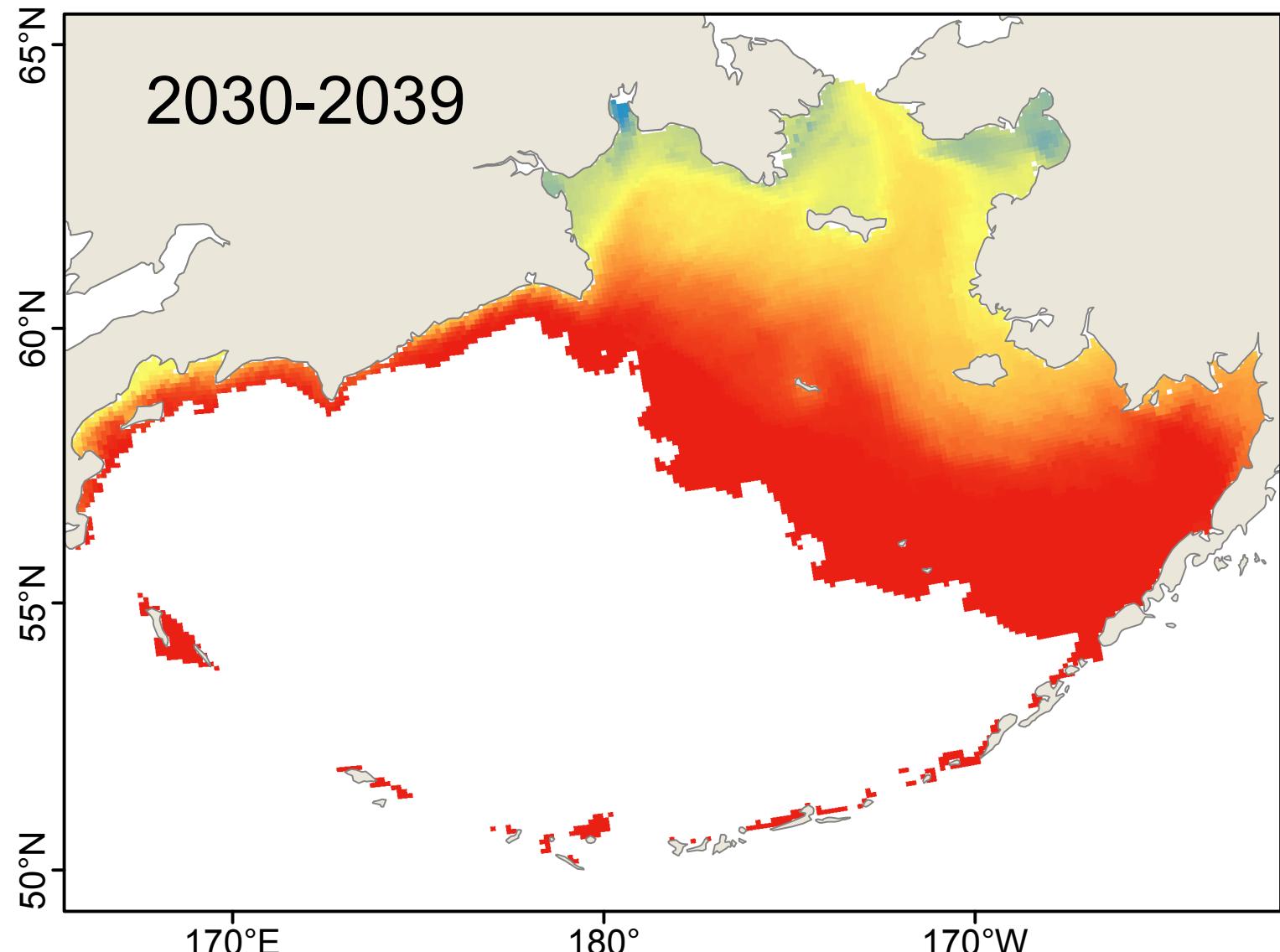
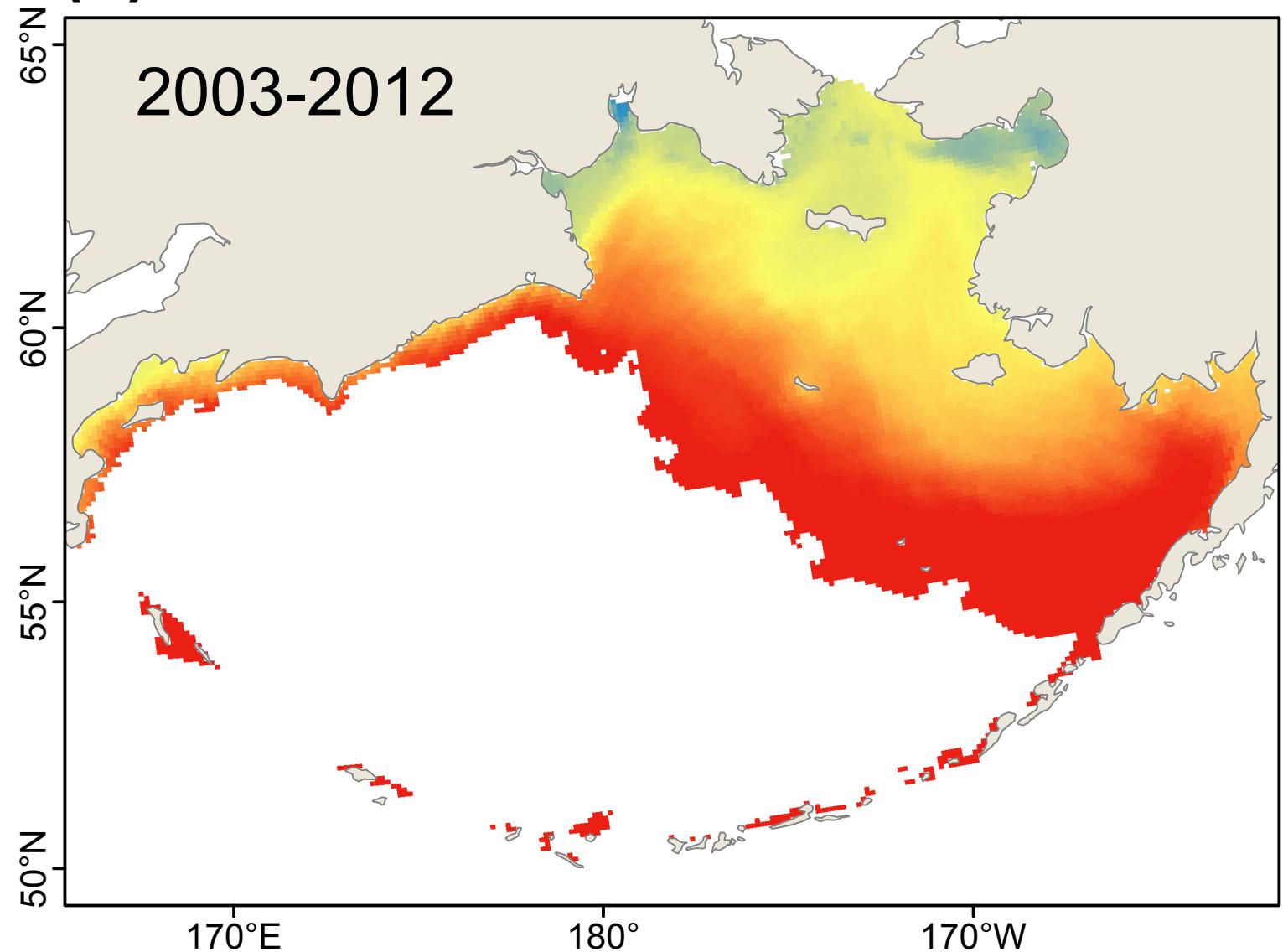


# *Salmo salar: Weekly Survival*

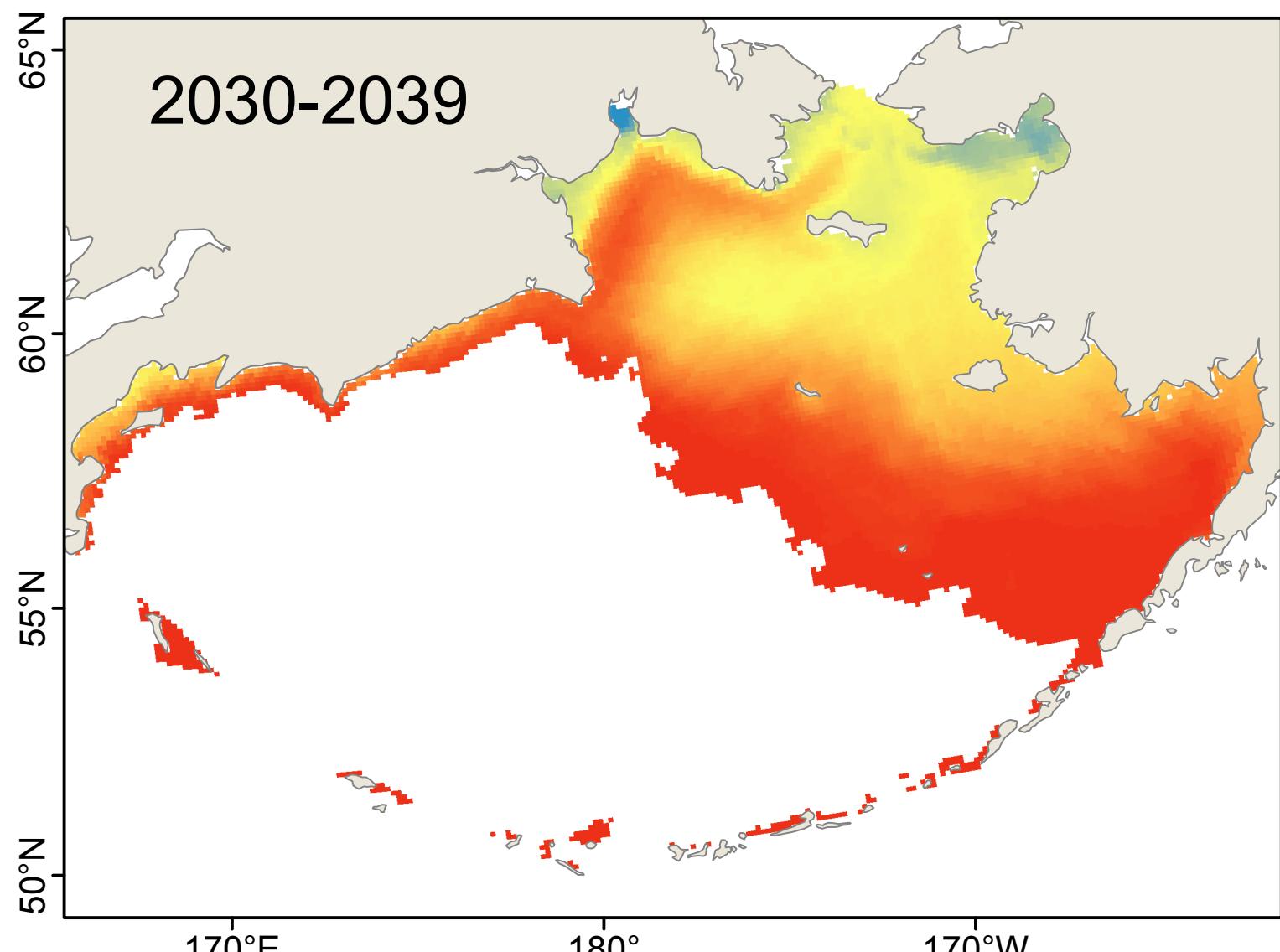
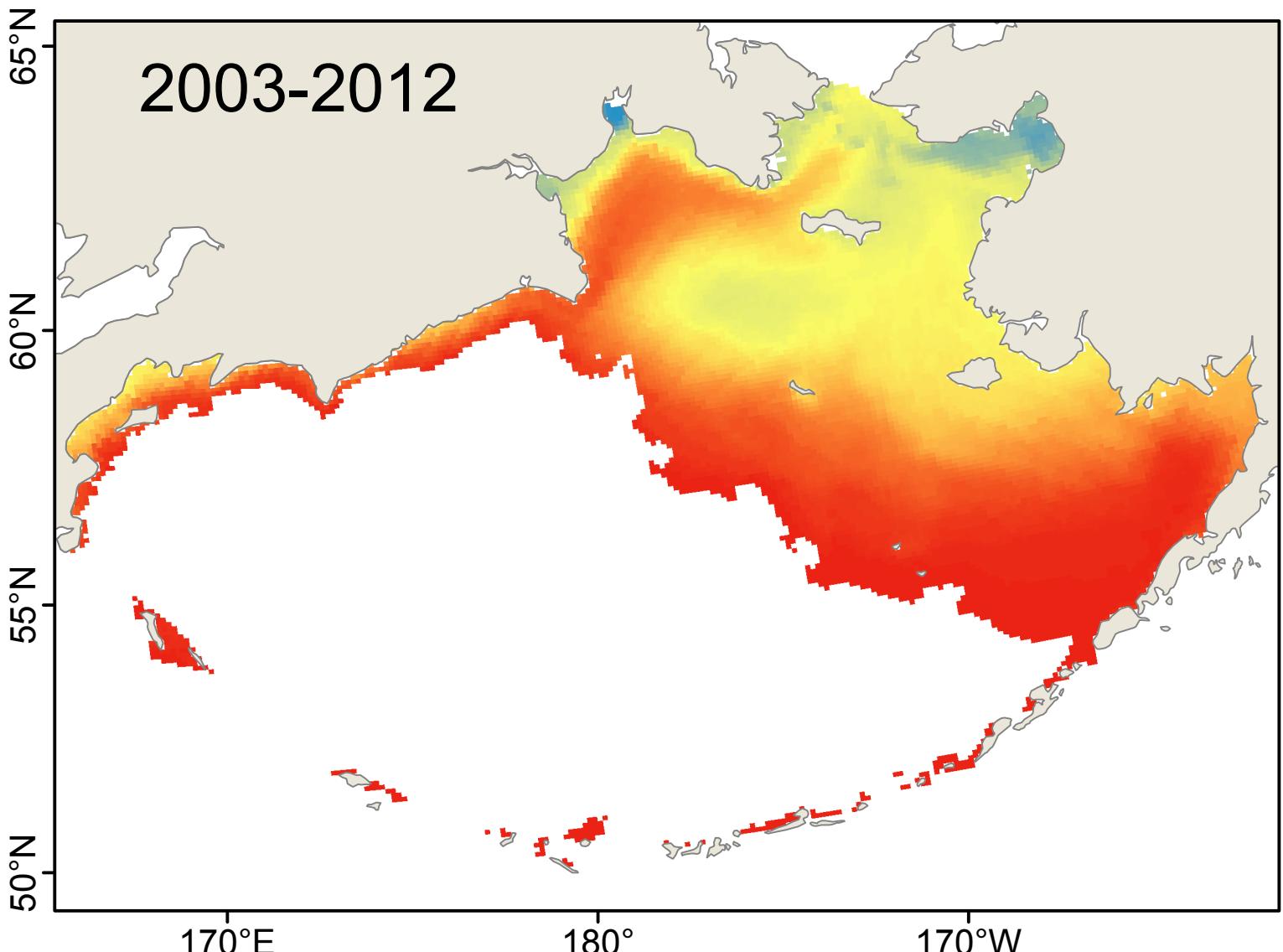
Average number of weeks of suitable habitat



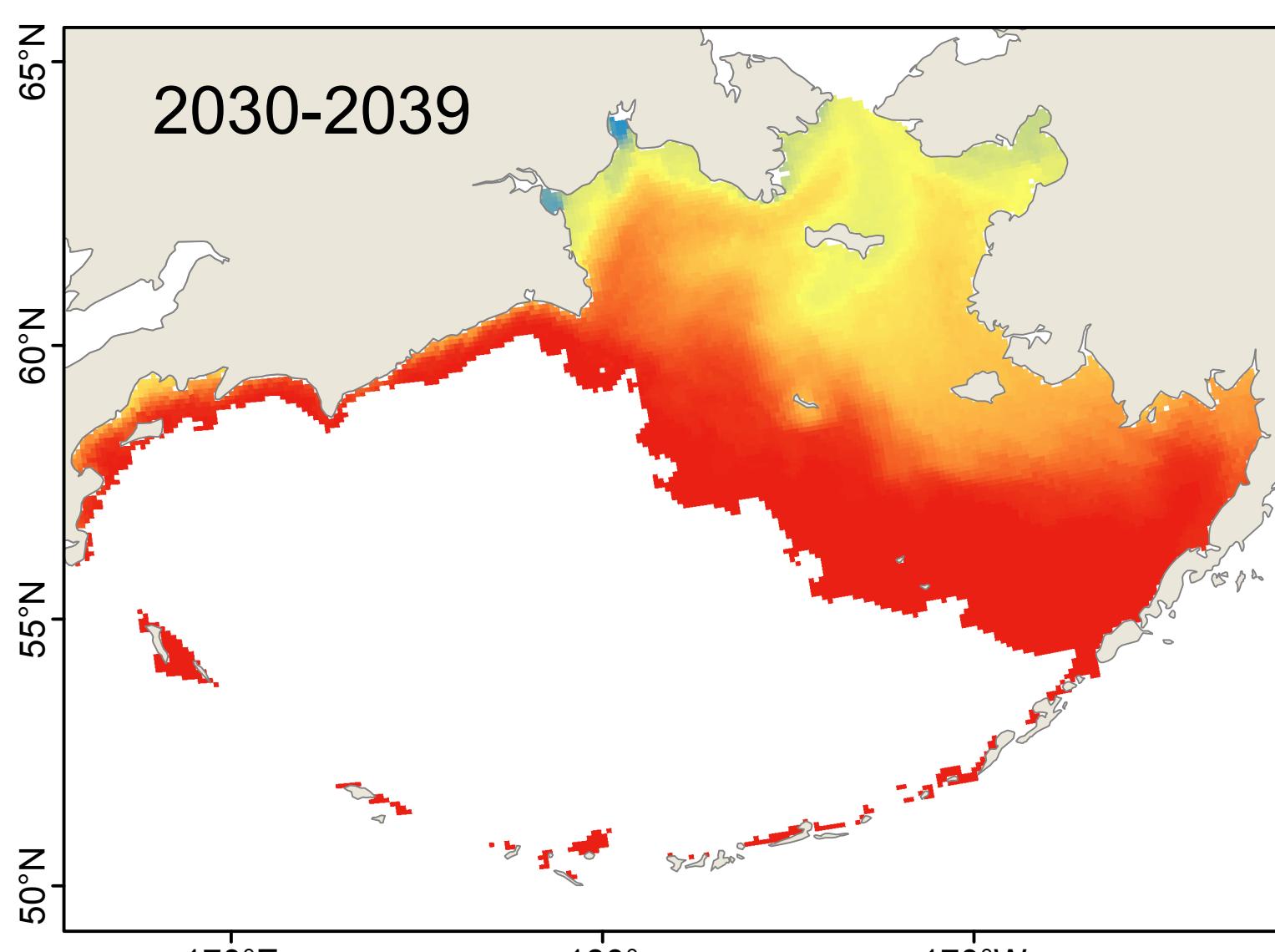
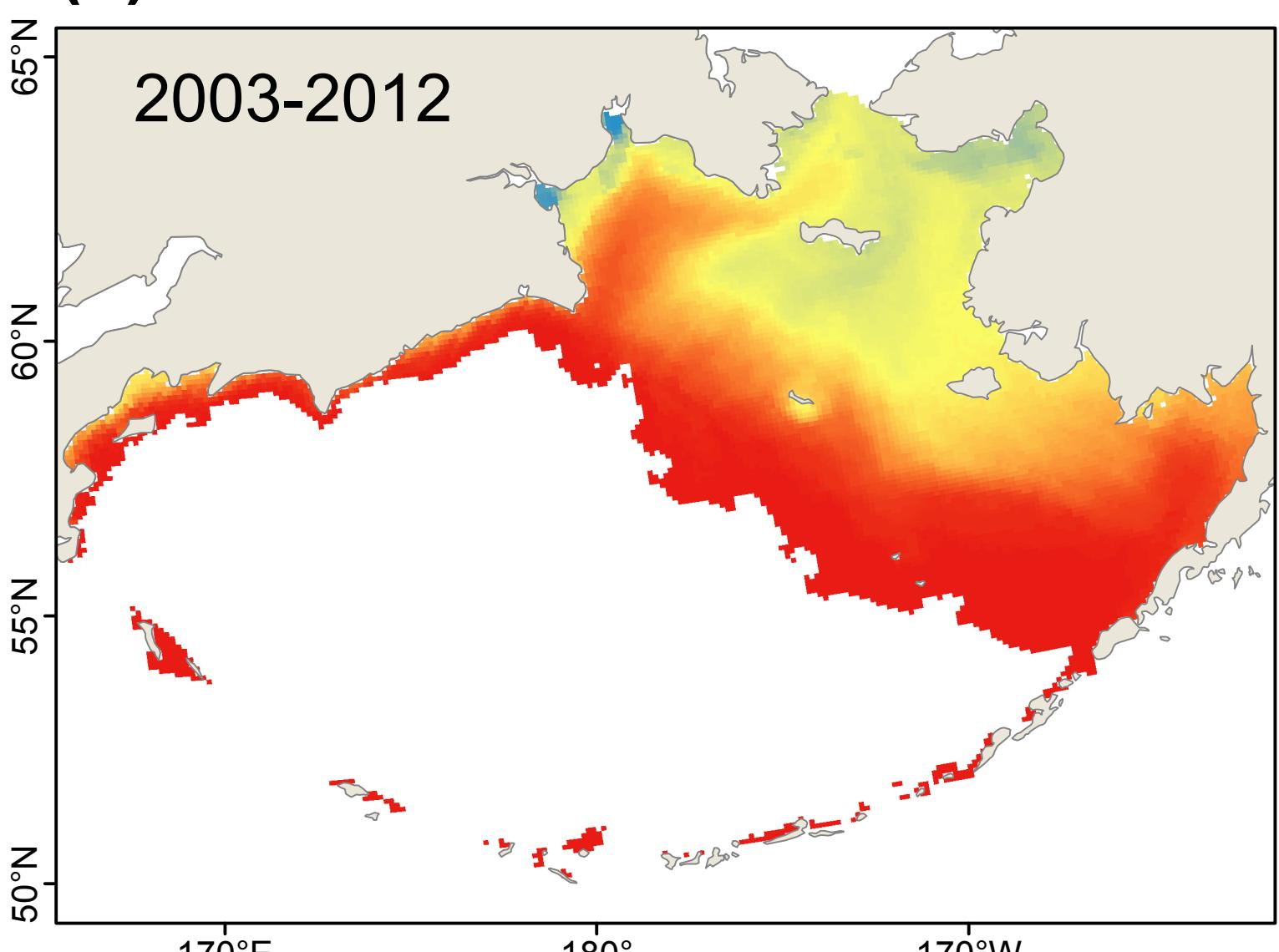
(a) Model: CGCM3-t47



(b) Model: ECHO-G

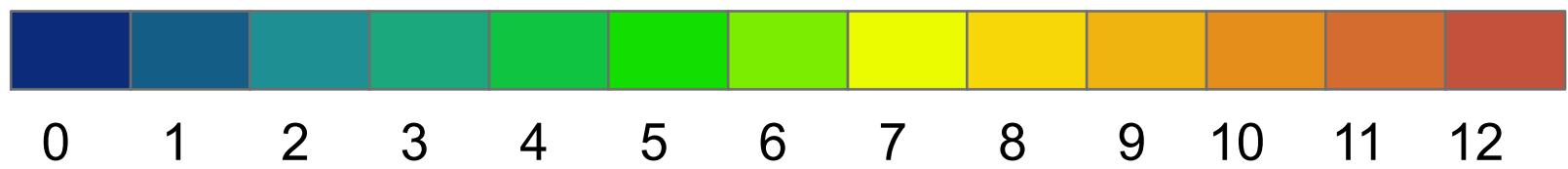


(c) Model: MIROC3.2

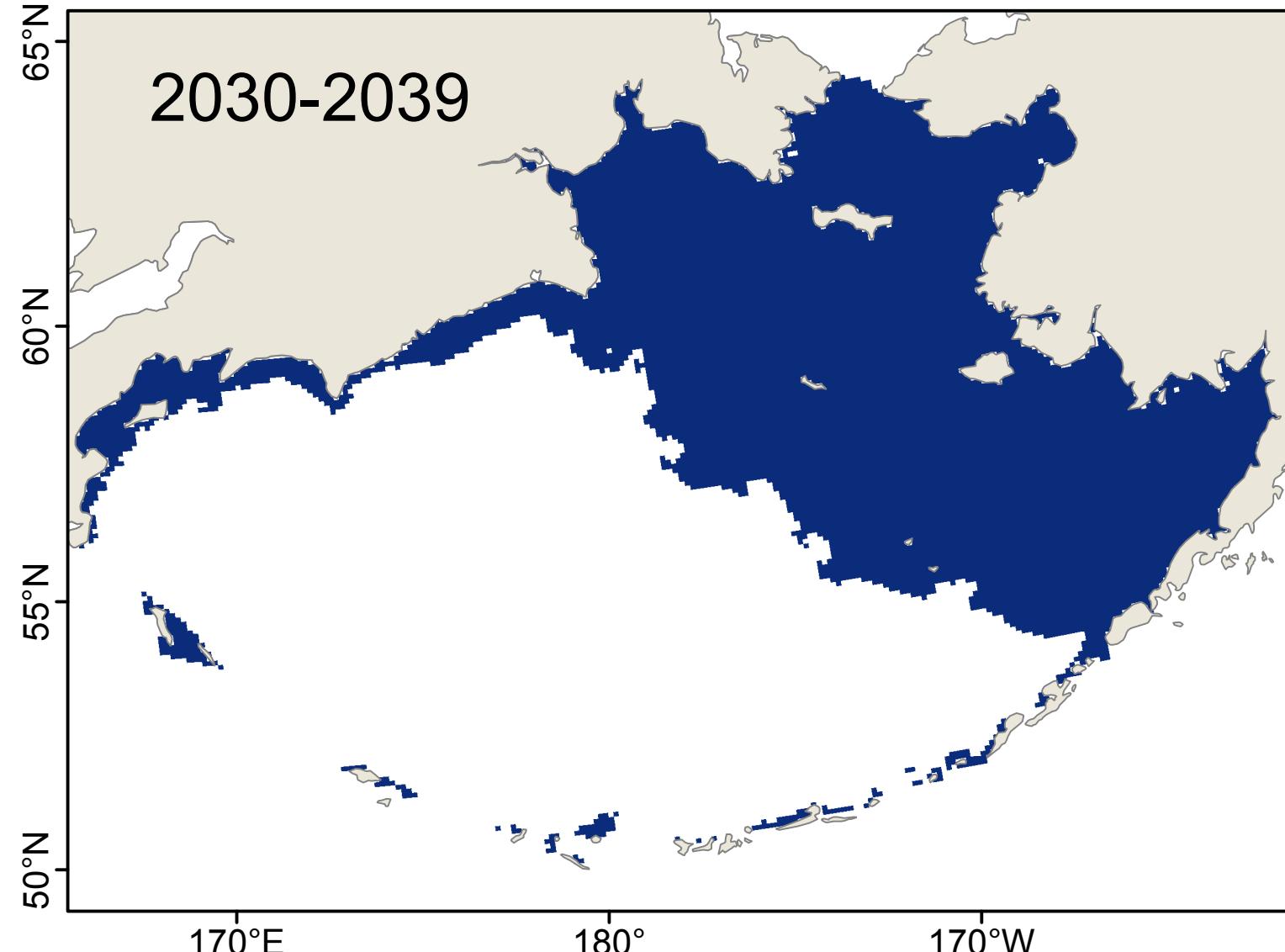
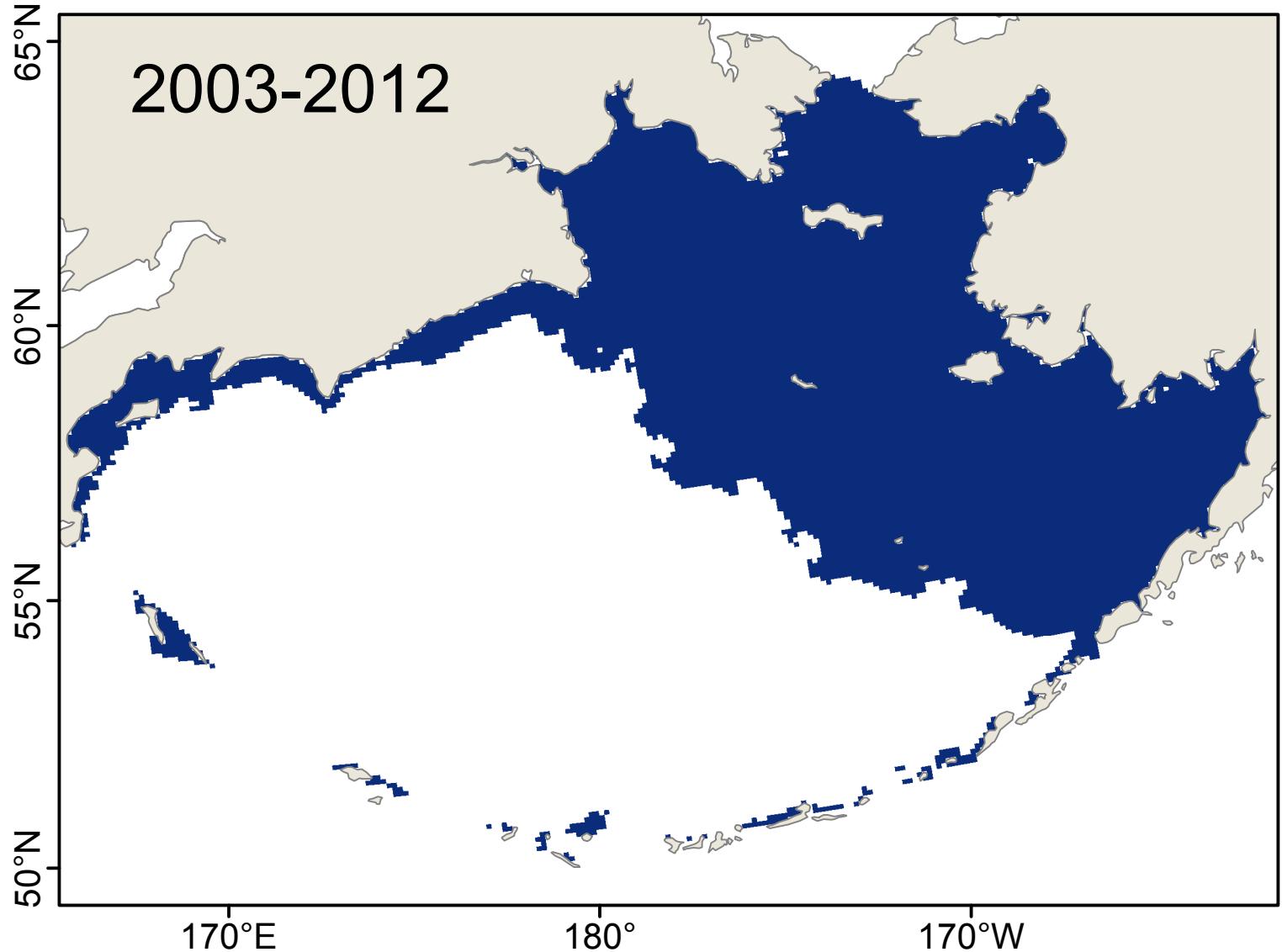


# *Salmo salar: Reproduction*

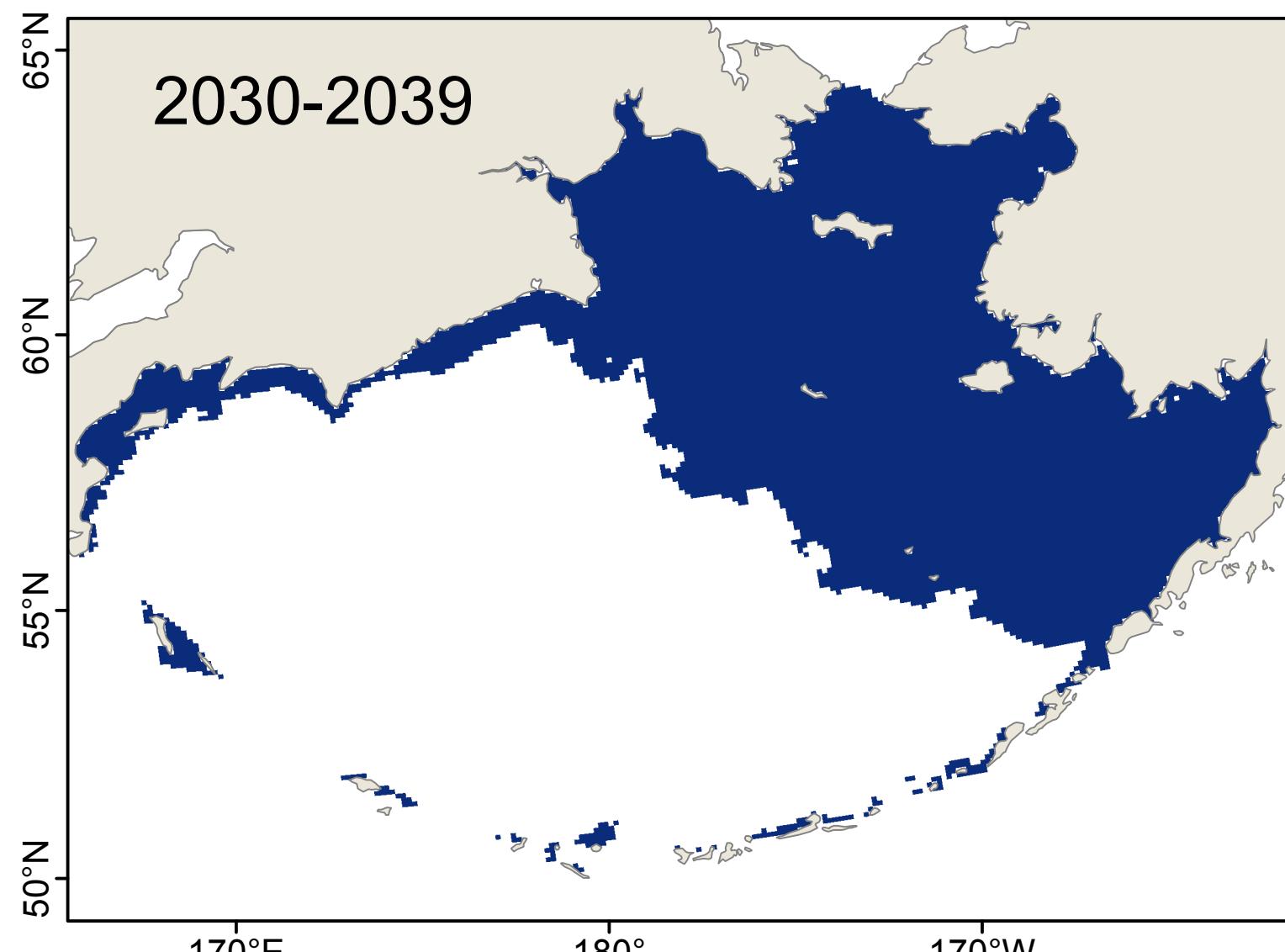
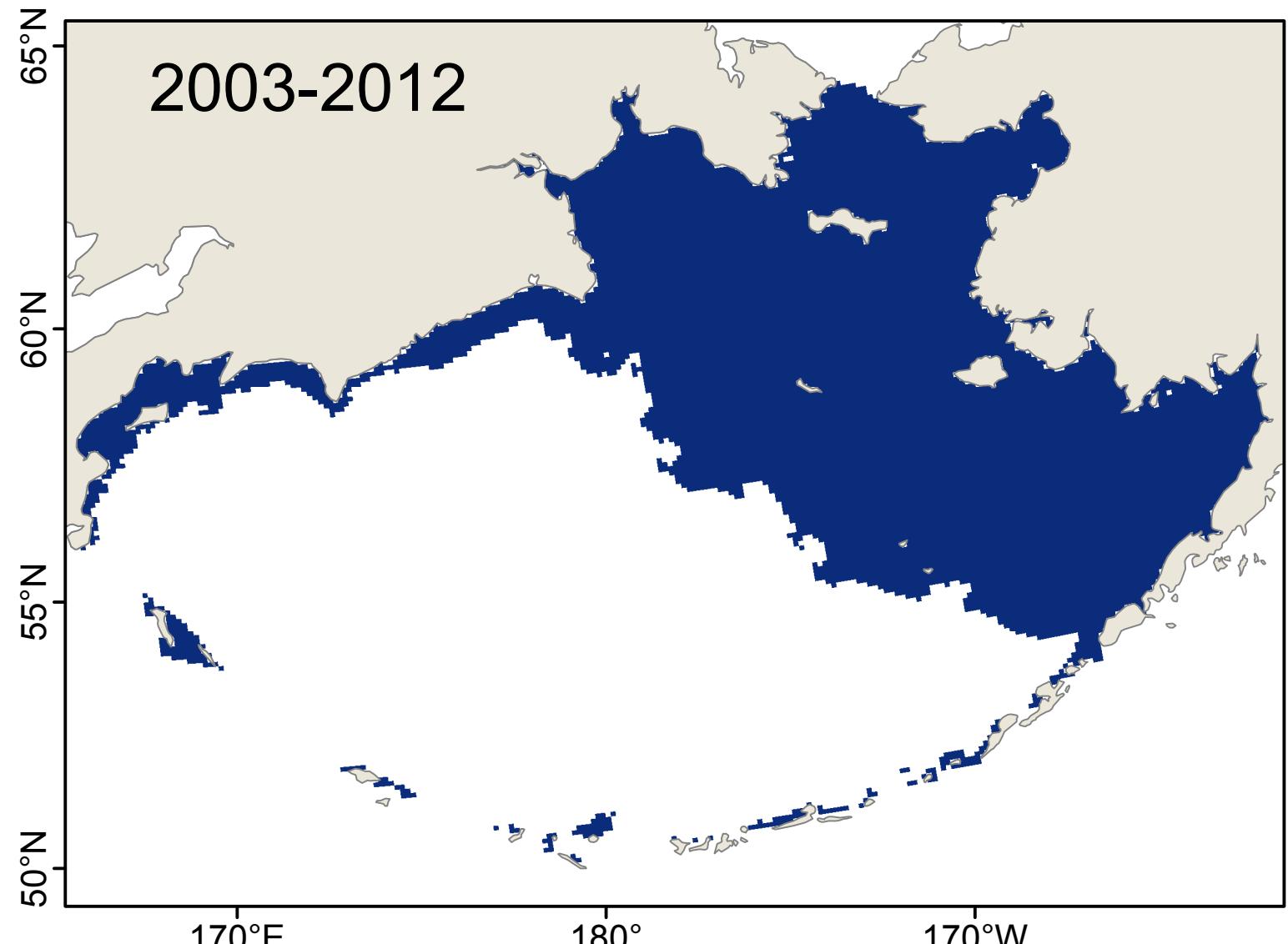
Average number of consecutive weeks of suitable habitat



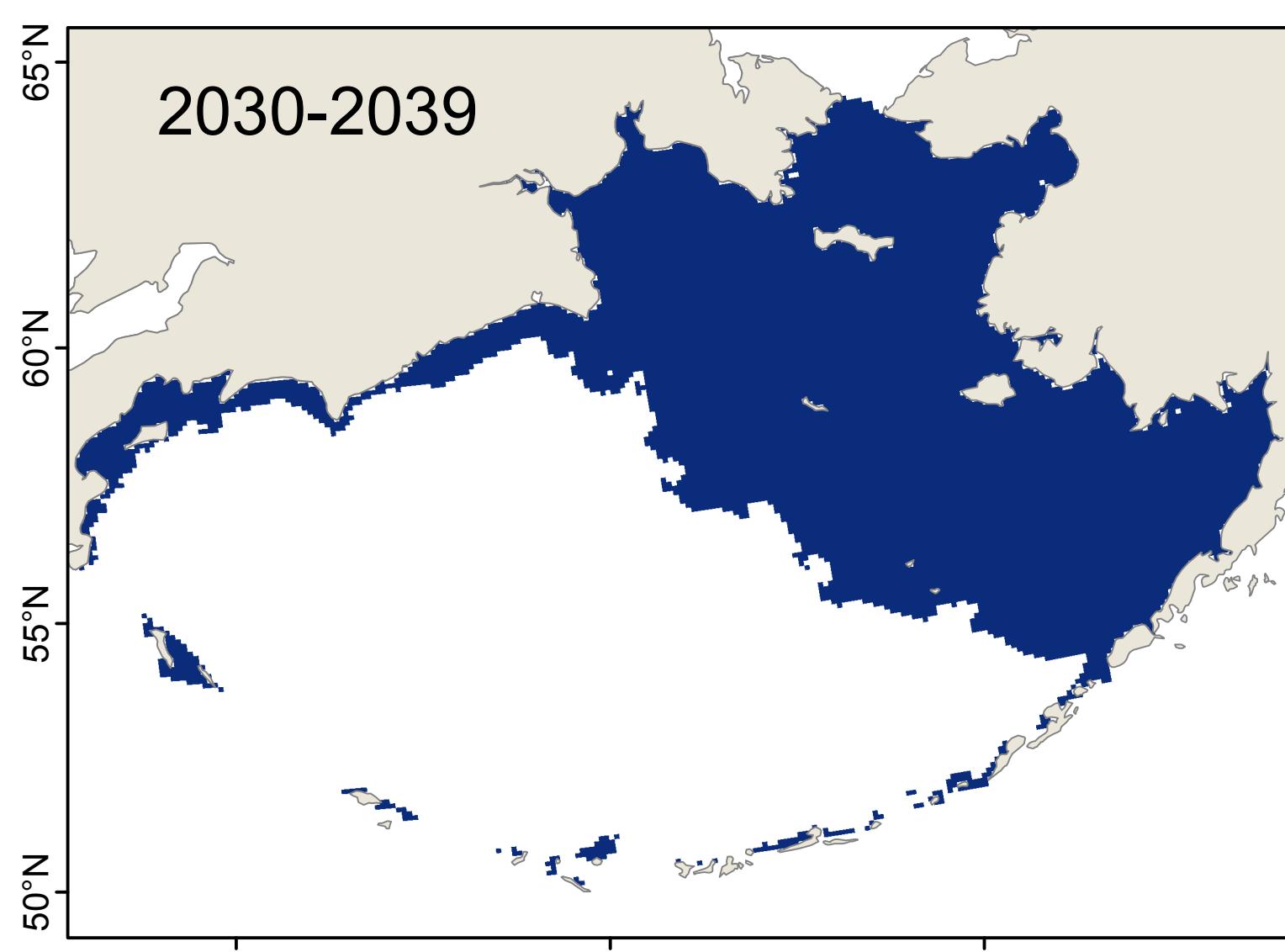
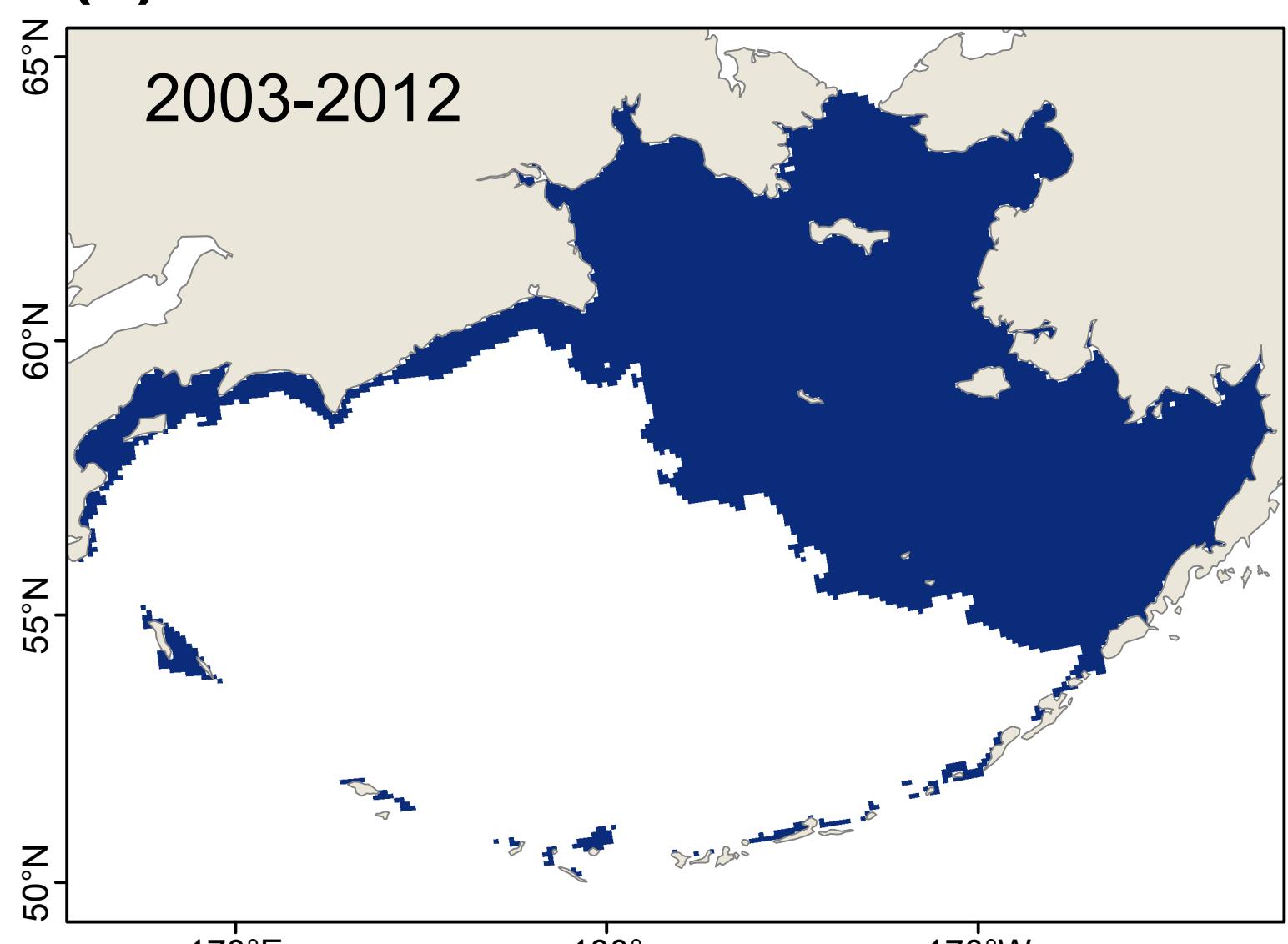
(a) Model: CGCM3-t47



(b) Model: ECHO-G

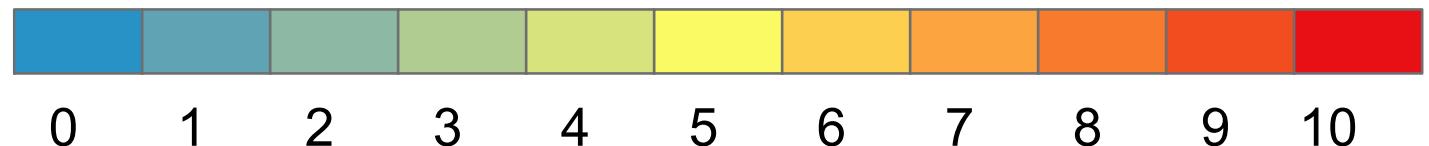


(c) Model: MIROC3.2

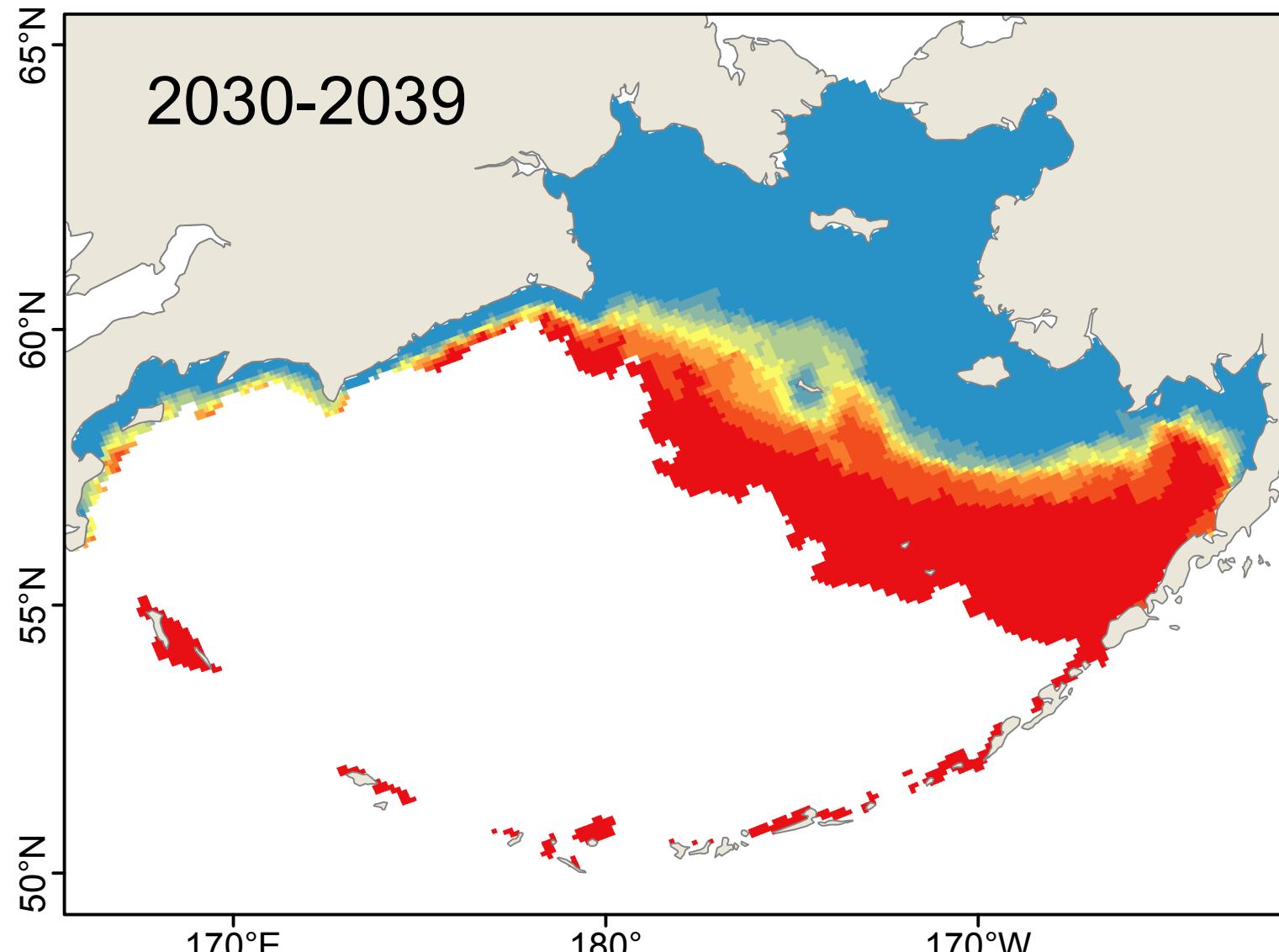
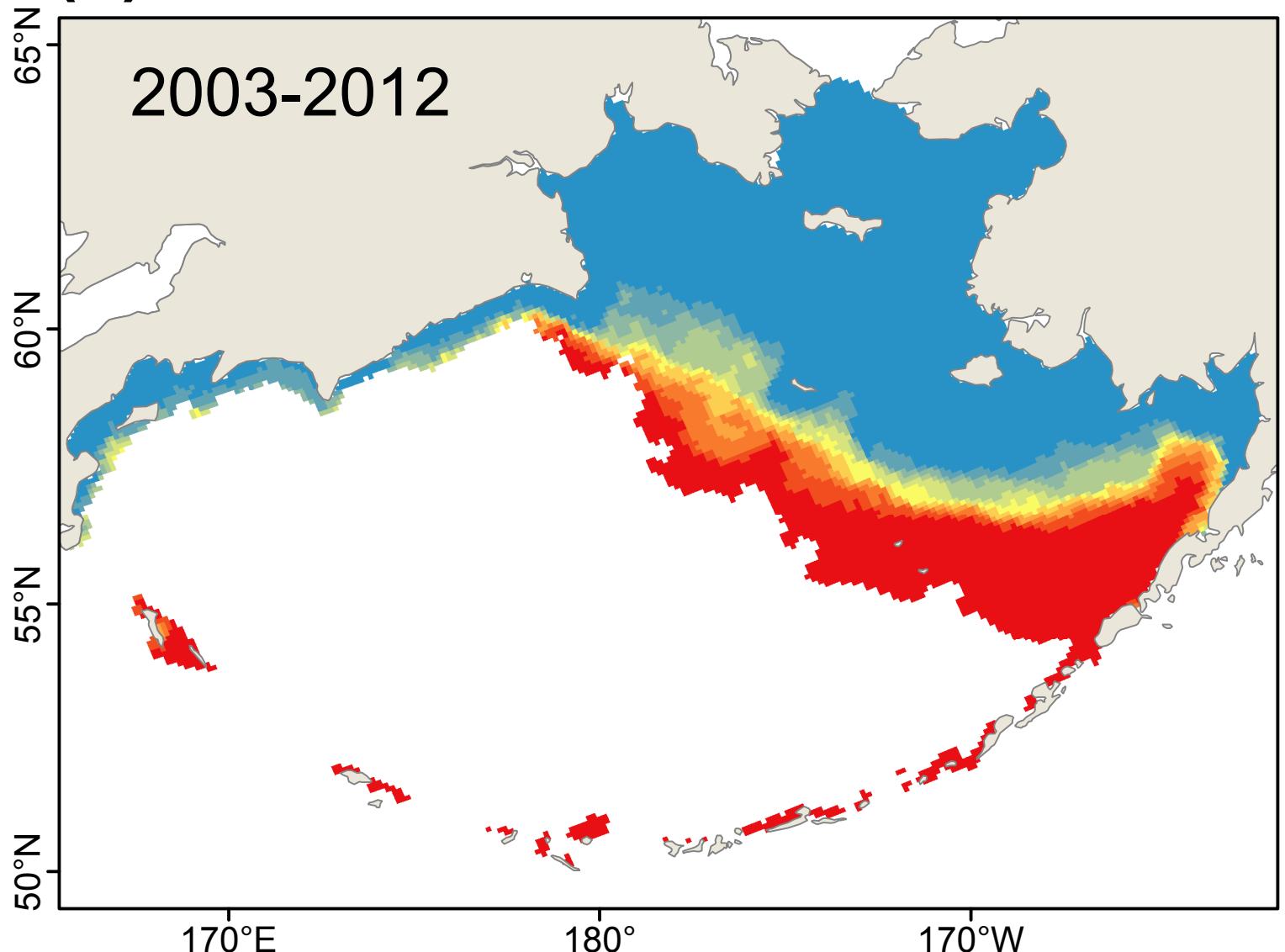


# *Botrylloides violaceus*: Year-round Survival

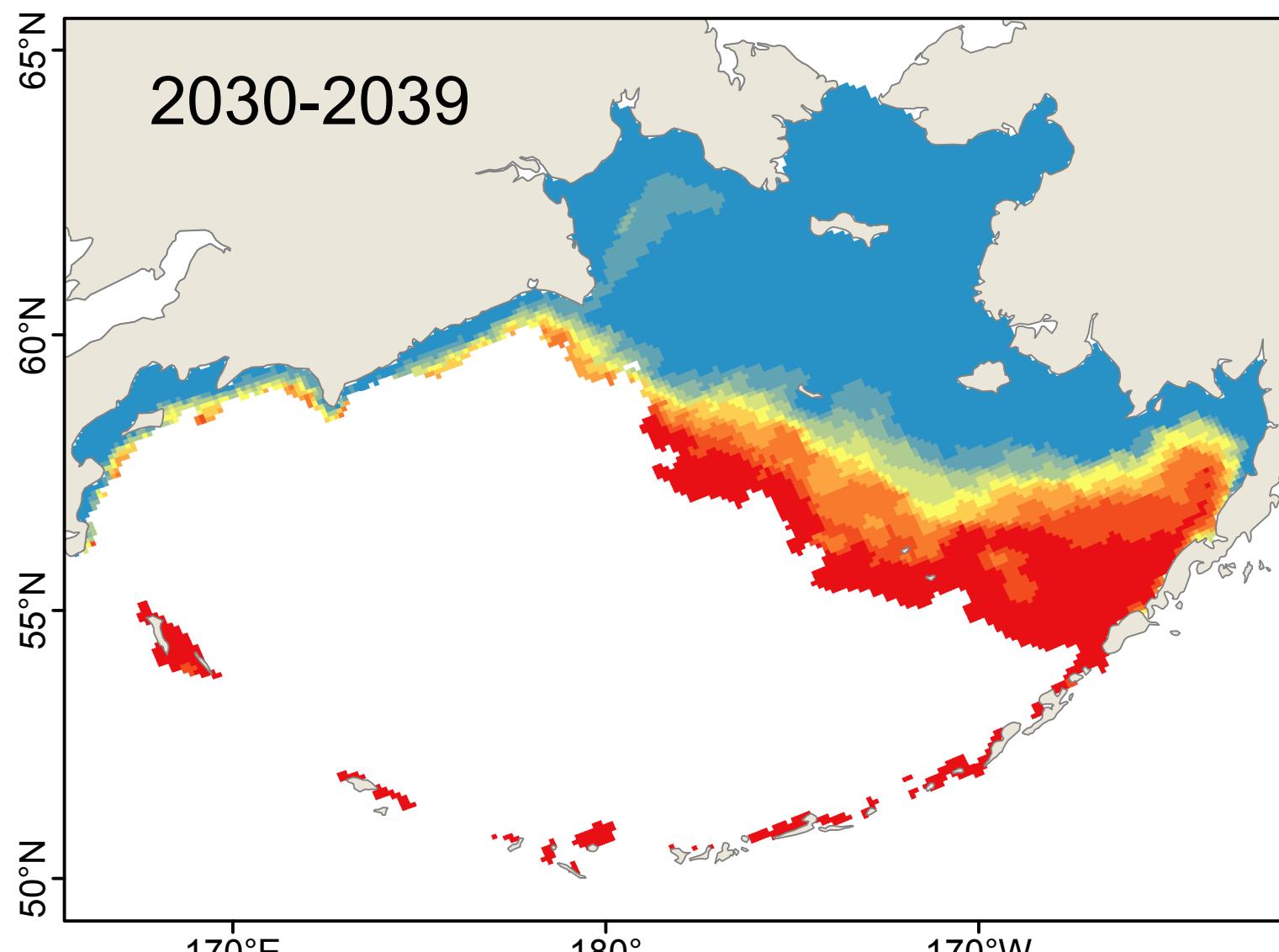
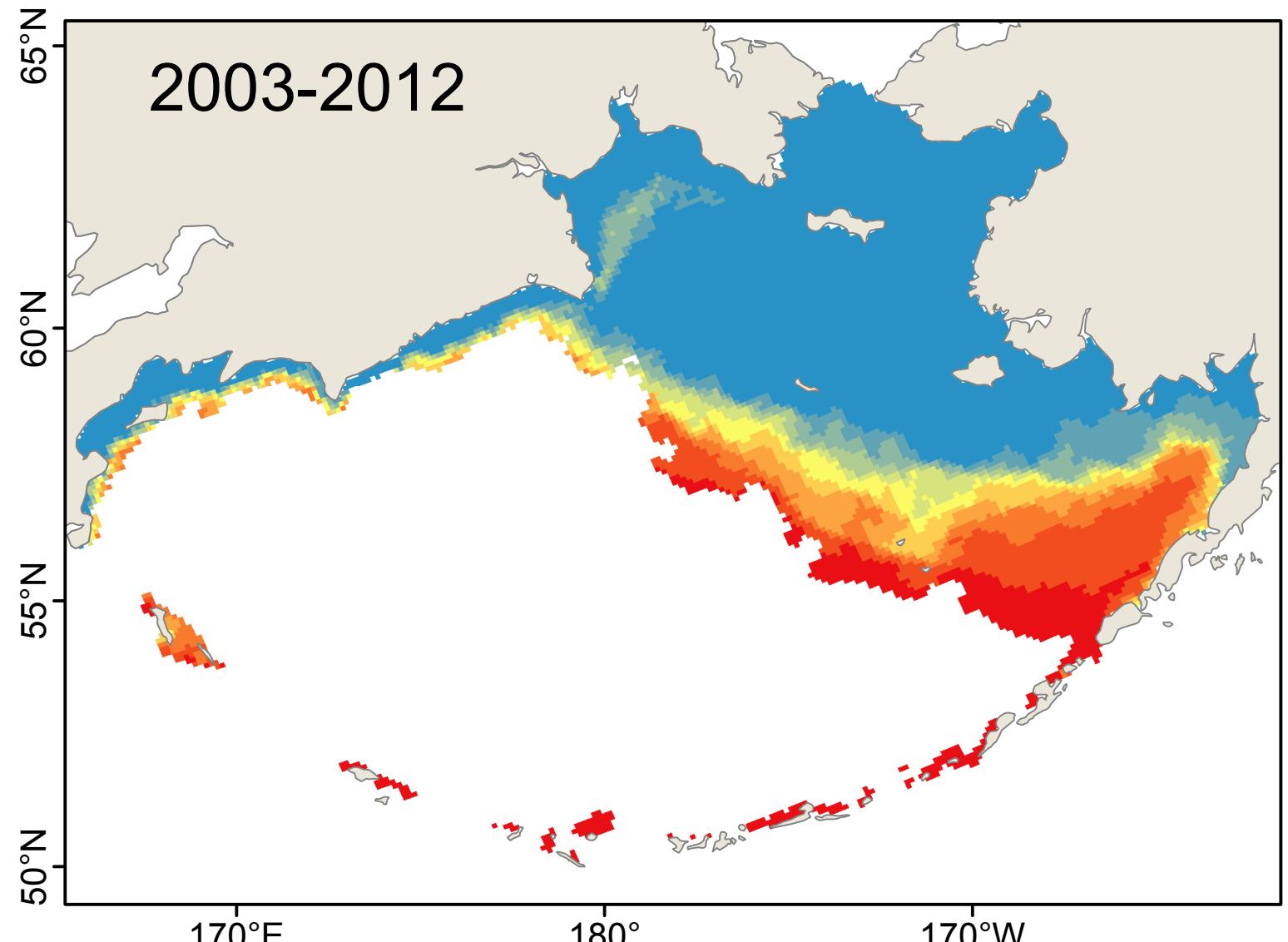
Number of years with suitable habitat



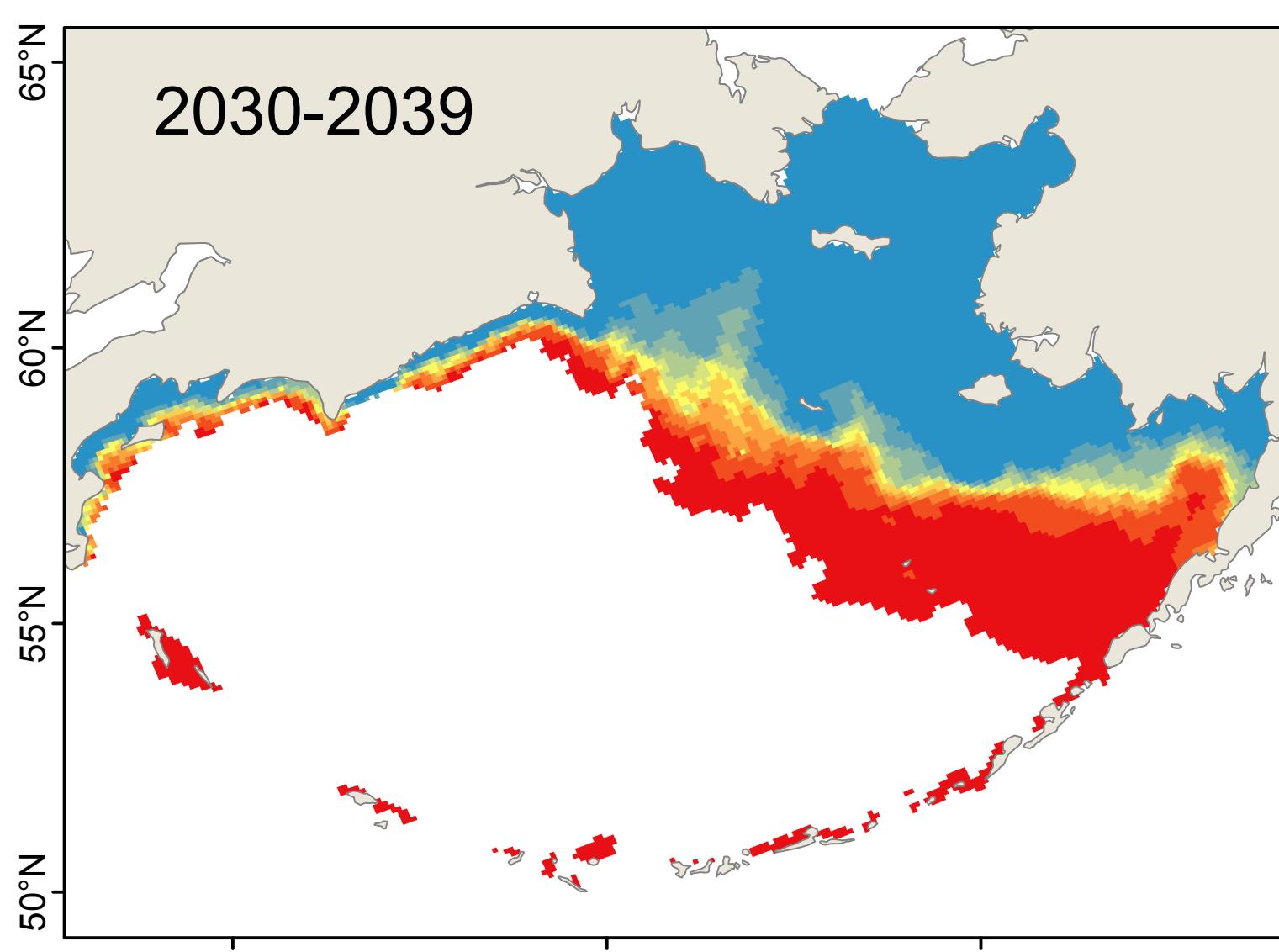
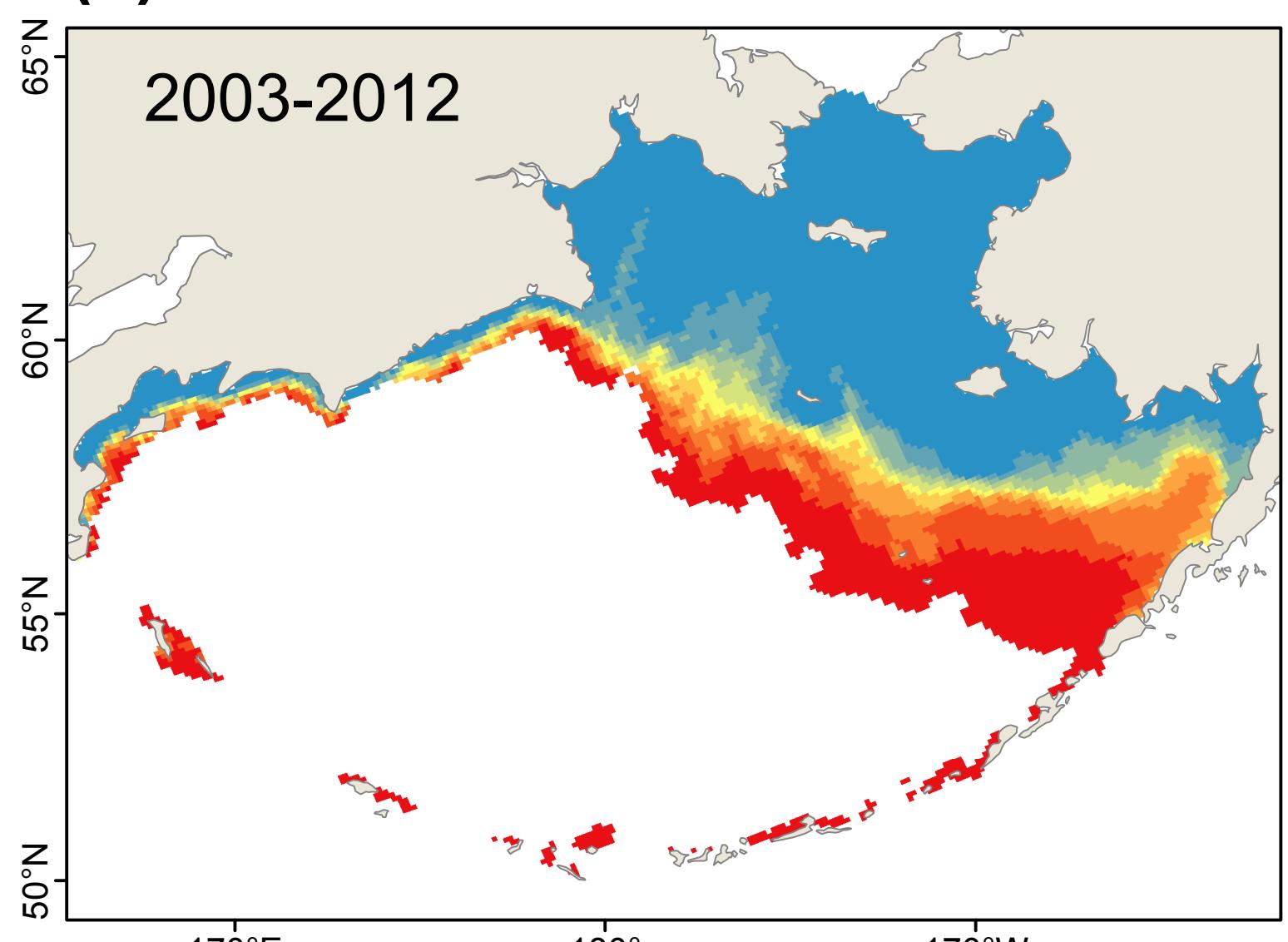
(a) Model: CGCM3-t47



(b) Model: ECHO-G

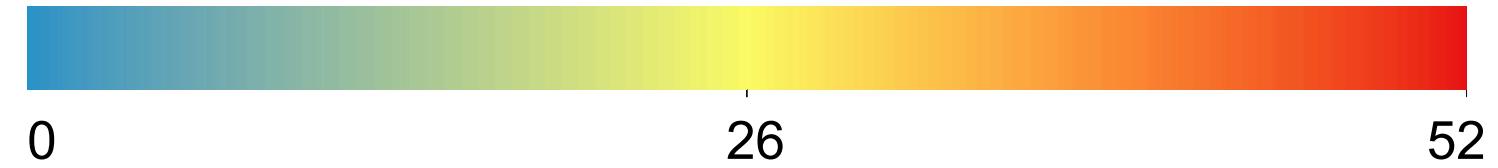


(c) Model: MIROC3.2

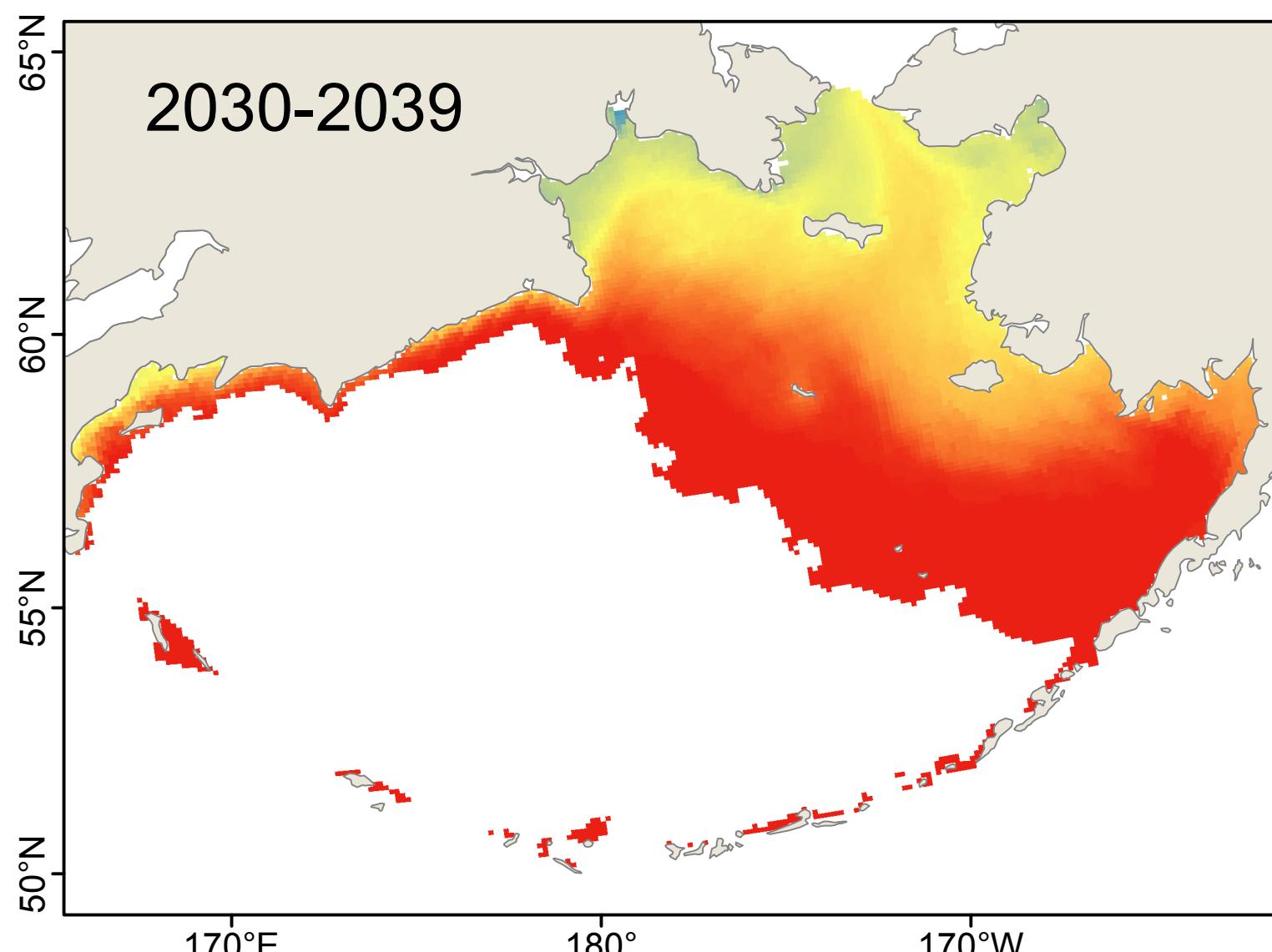
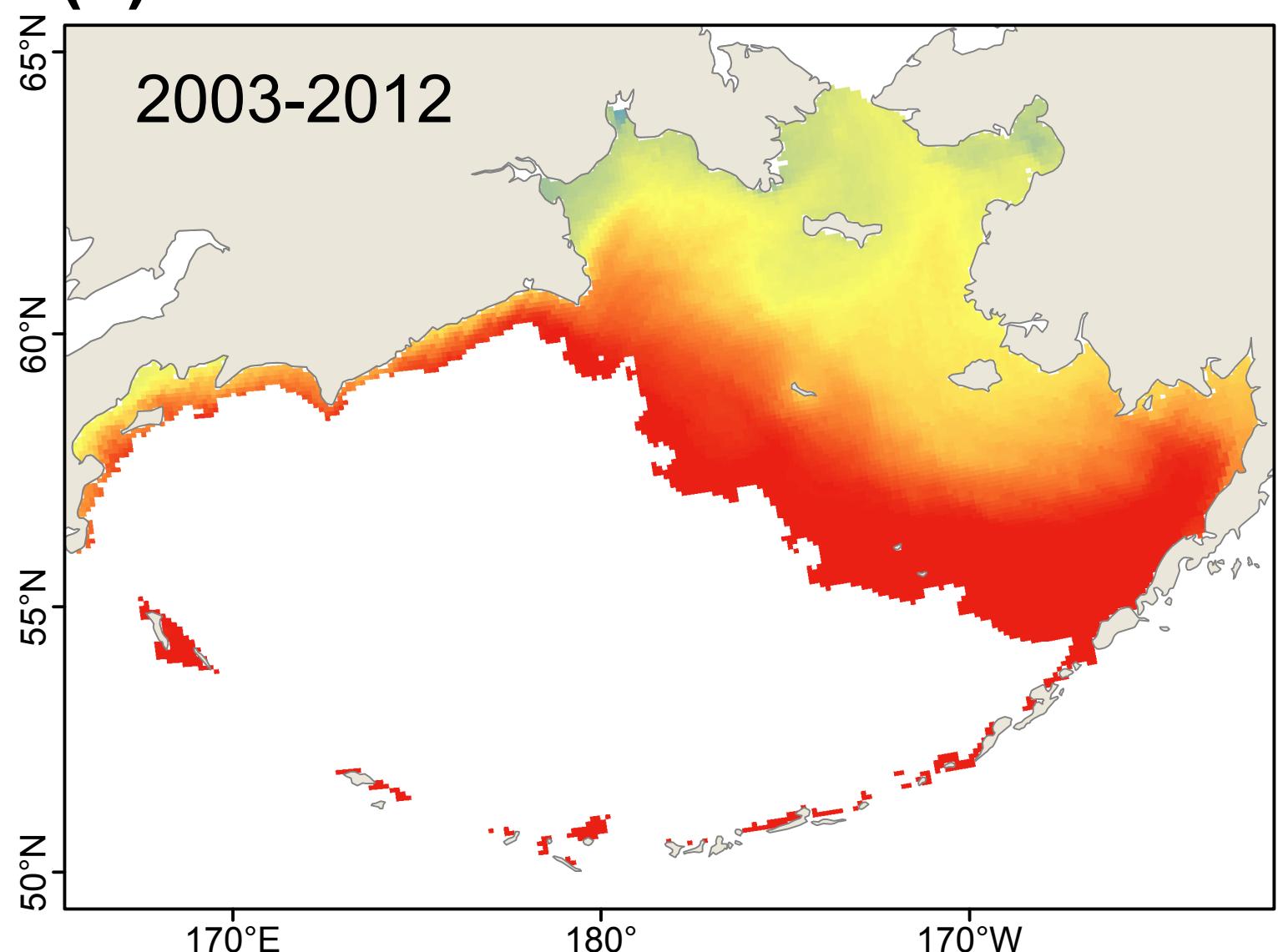


# *Botrylloides violaceus: Weekly Survival*

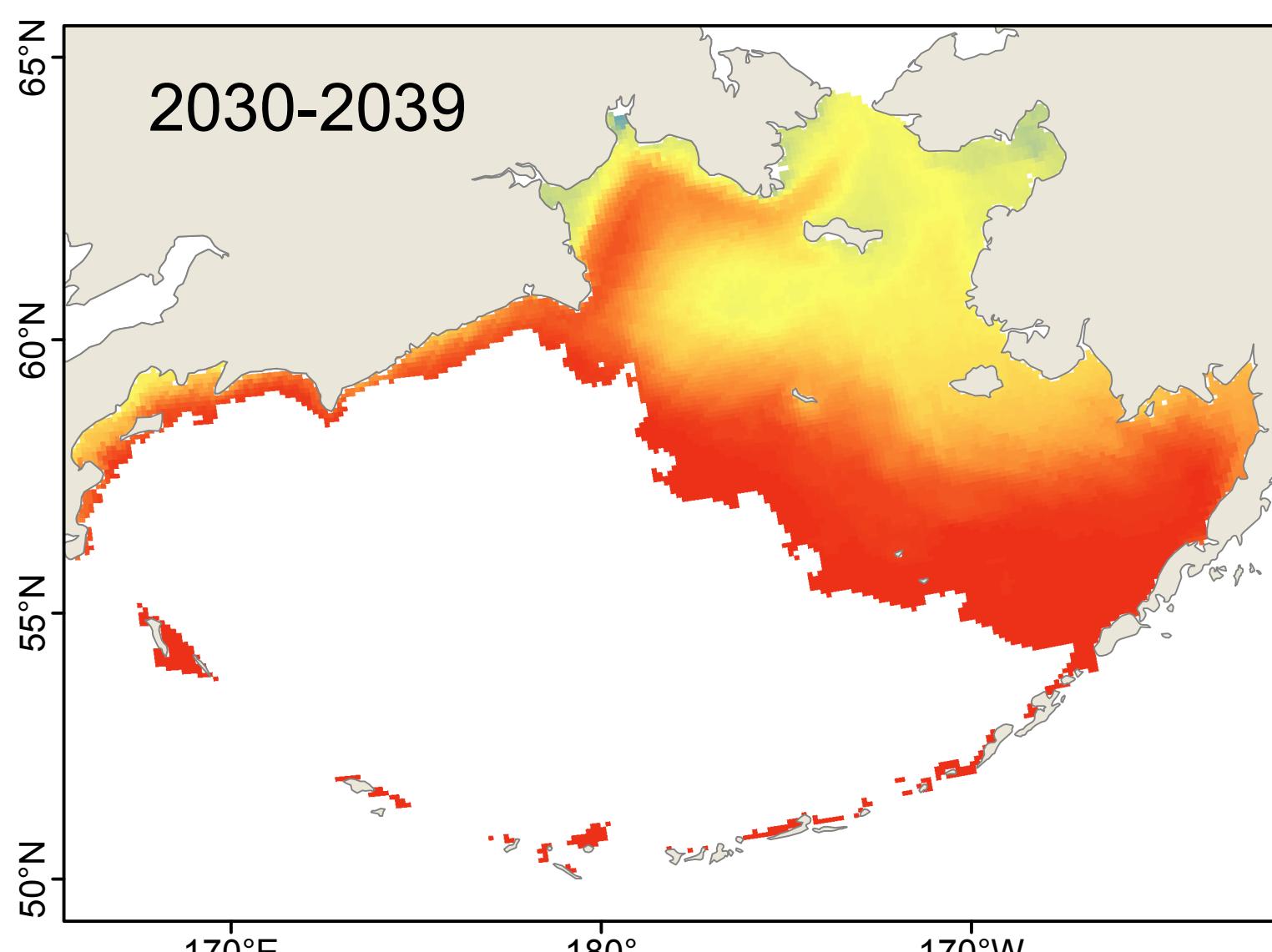
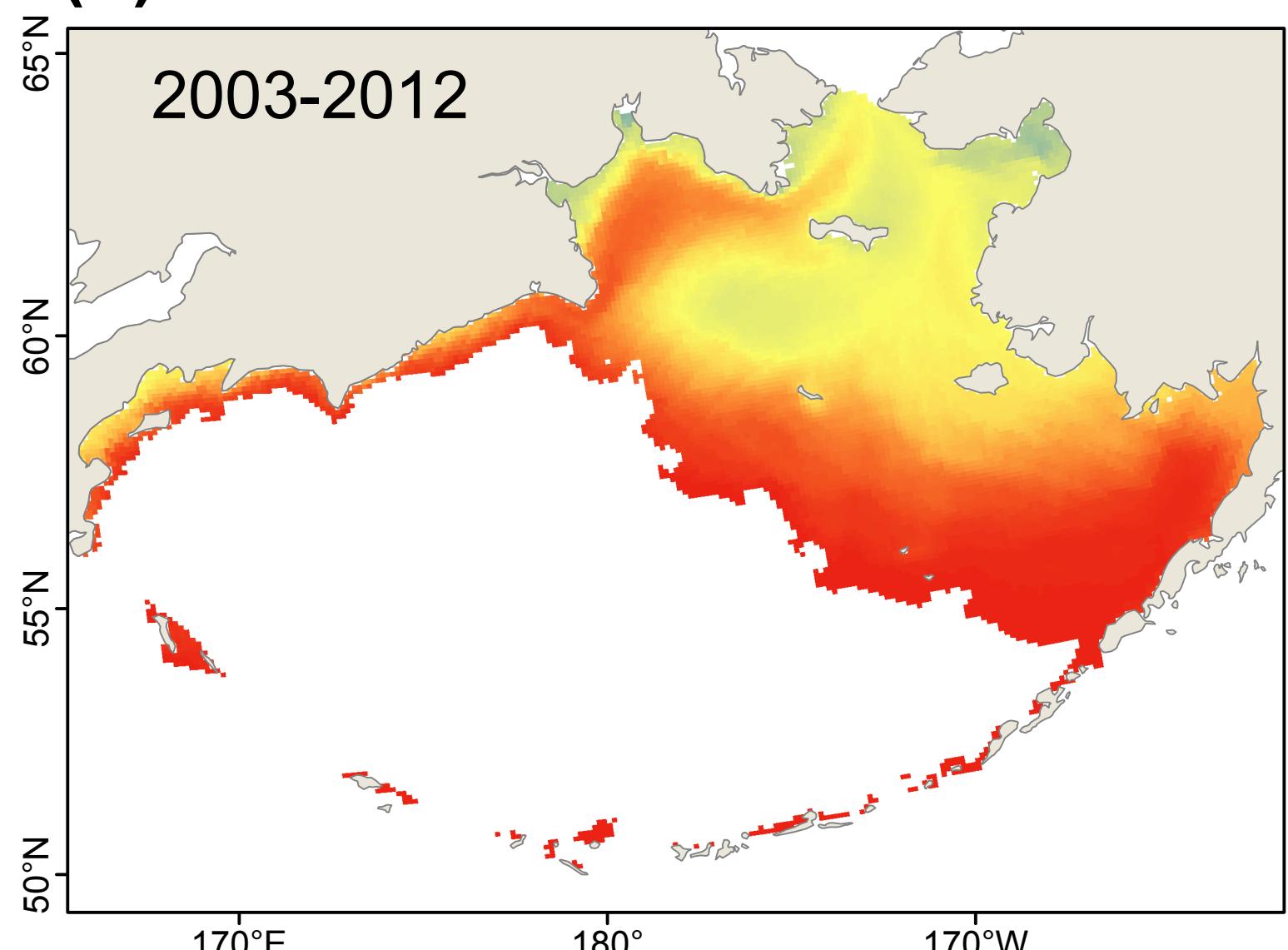
Average number of weeks of suitable habitat



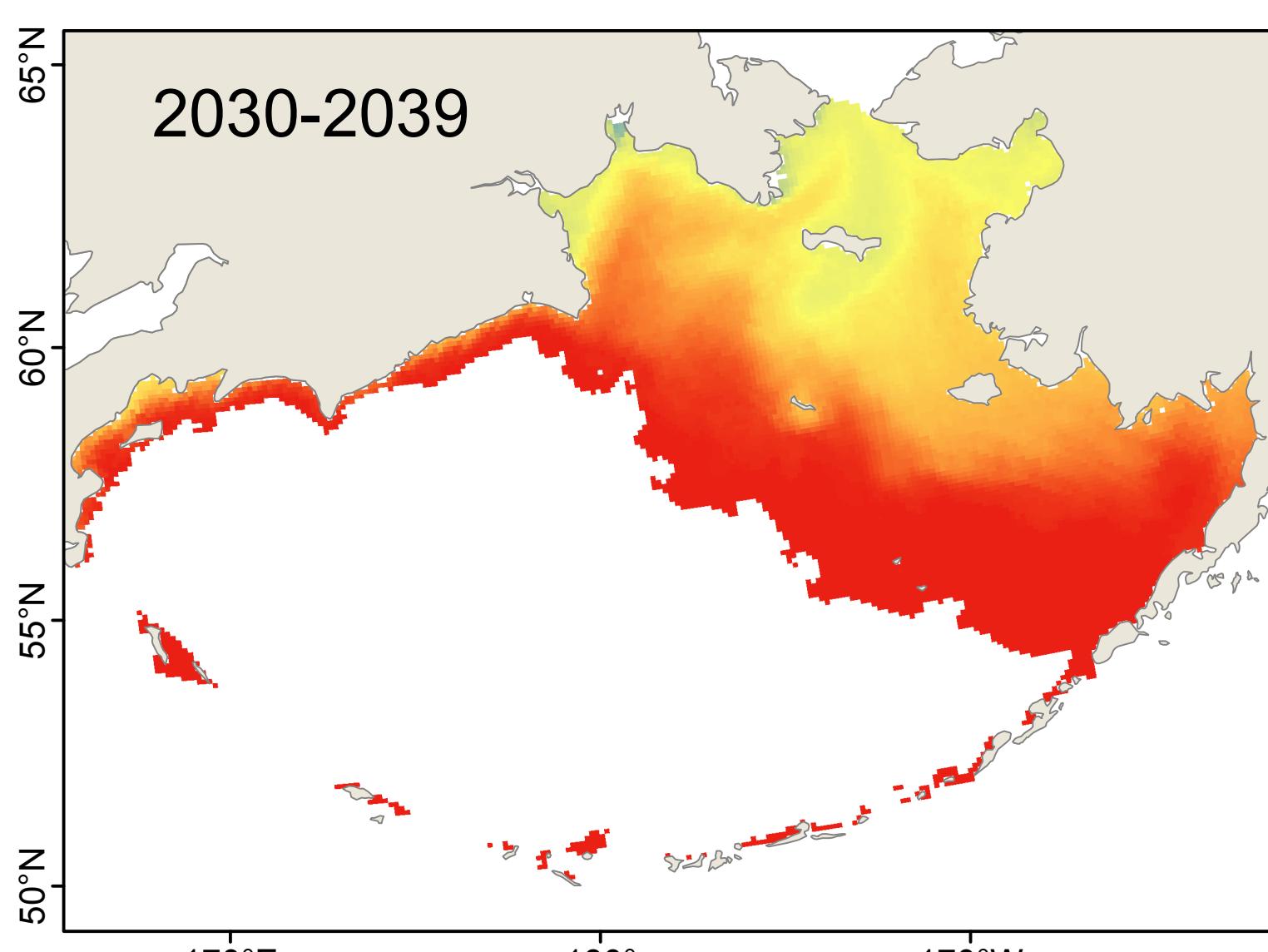
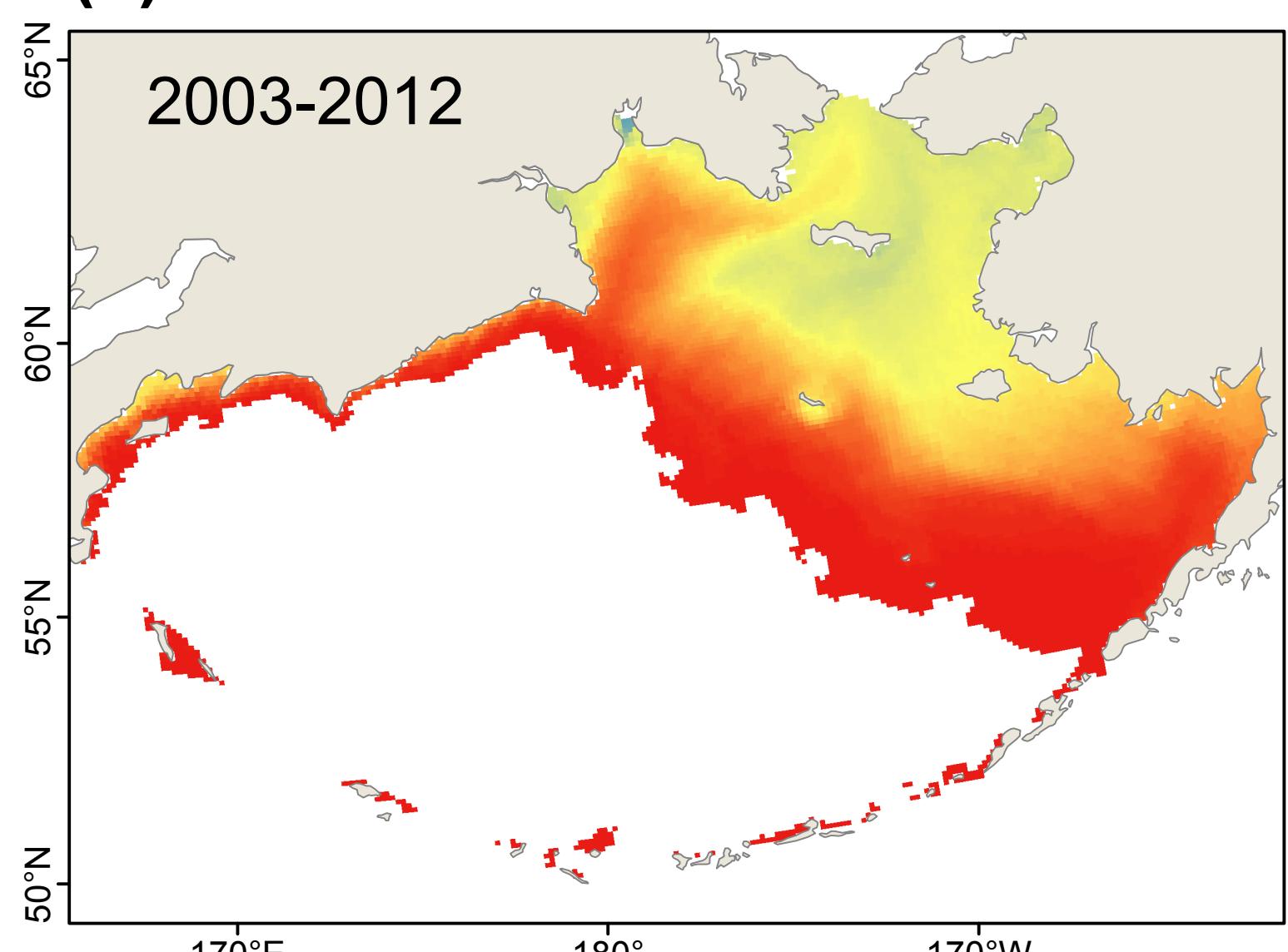
(a) Model: CGCM3-t47



(b) Model: ECHO-G

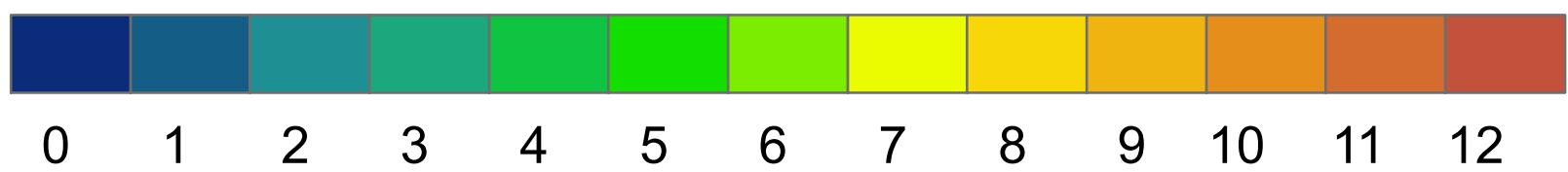


(c) Model: MIROC3.2

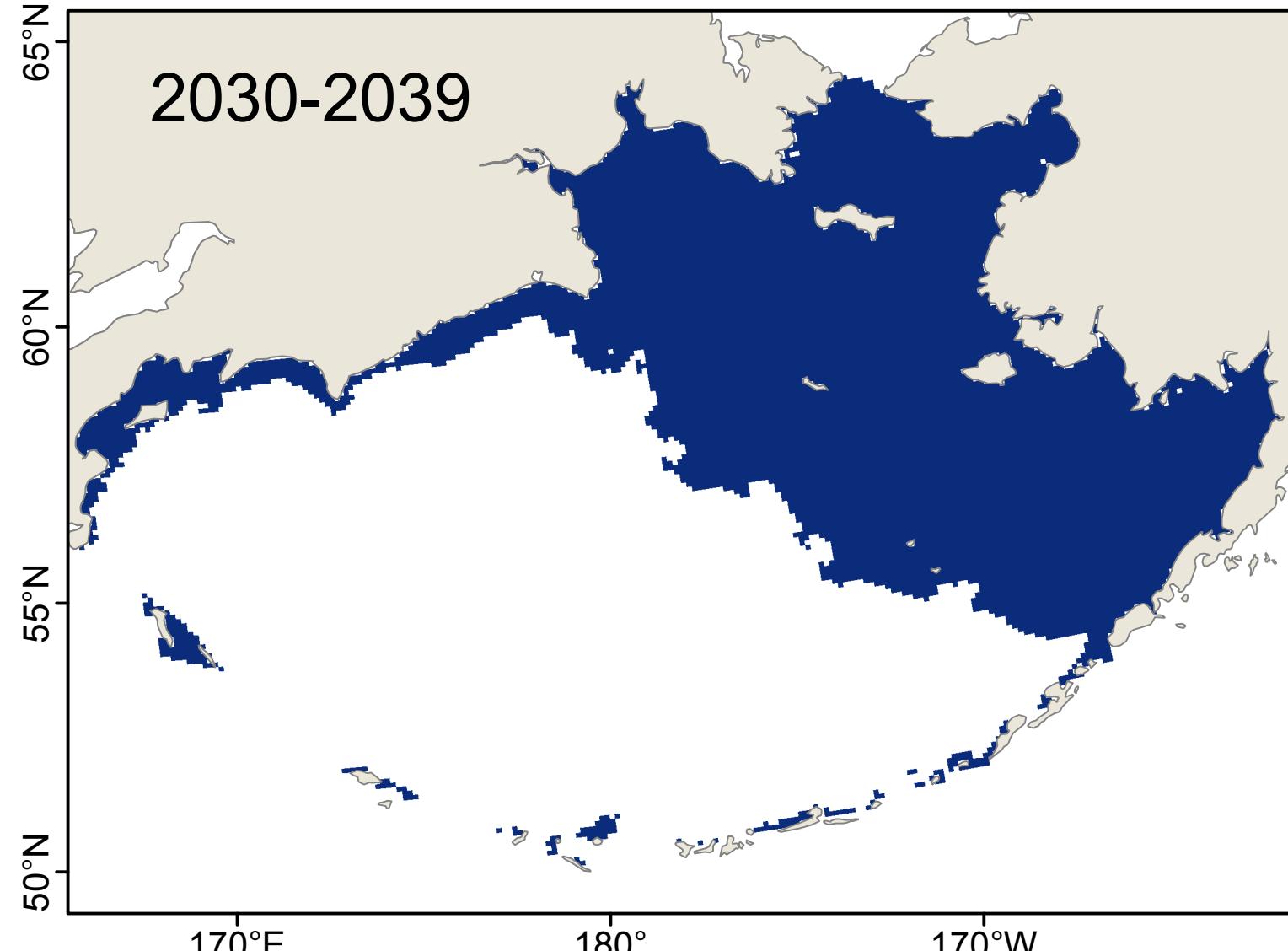
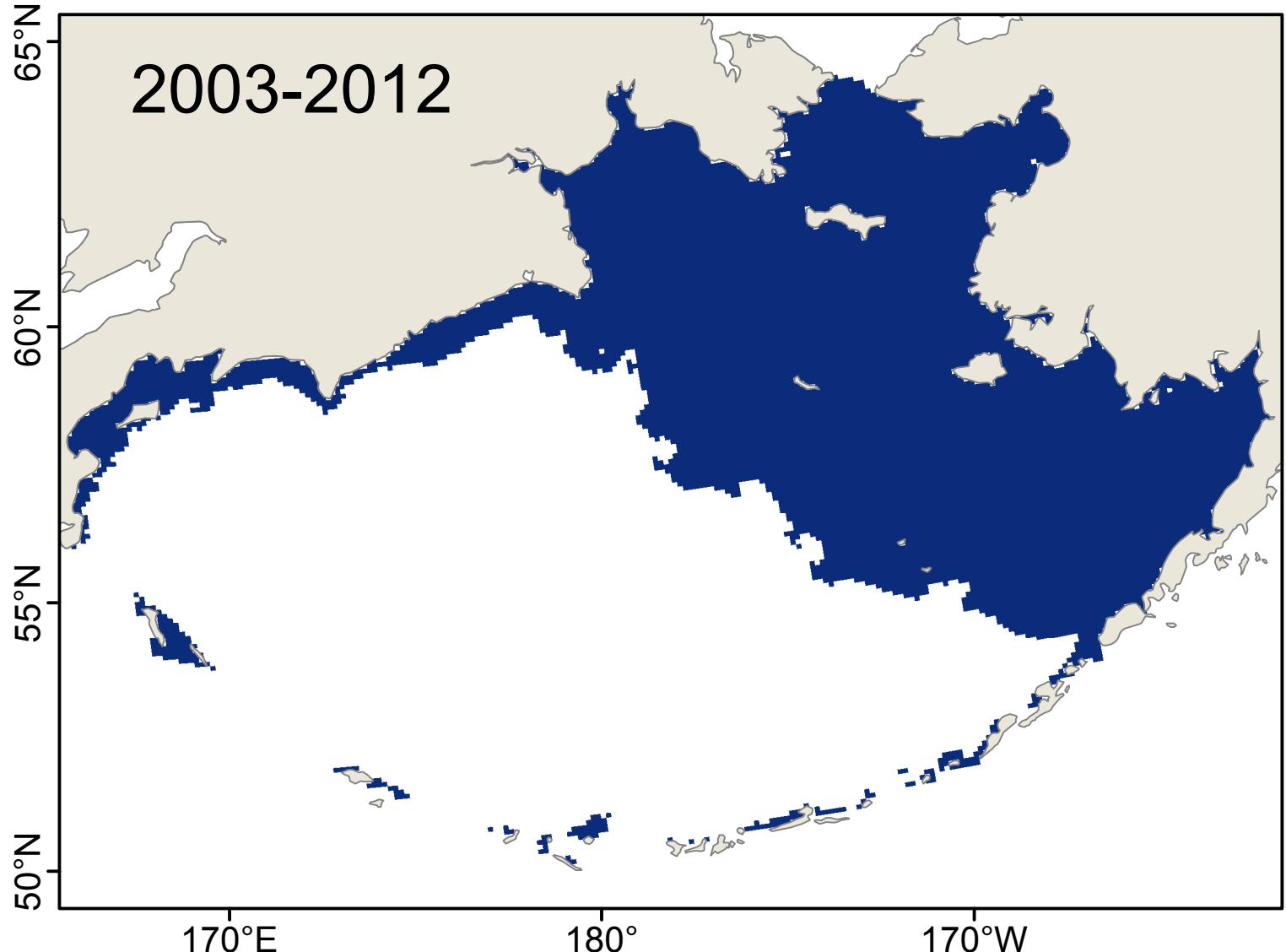


# *Botrylloides violaceus: Reproduction*

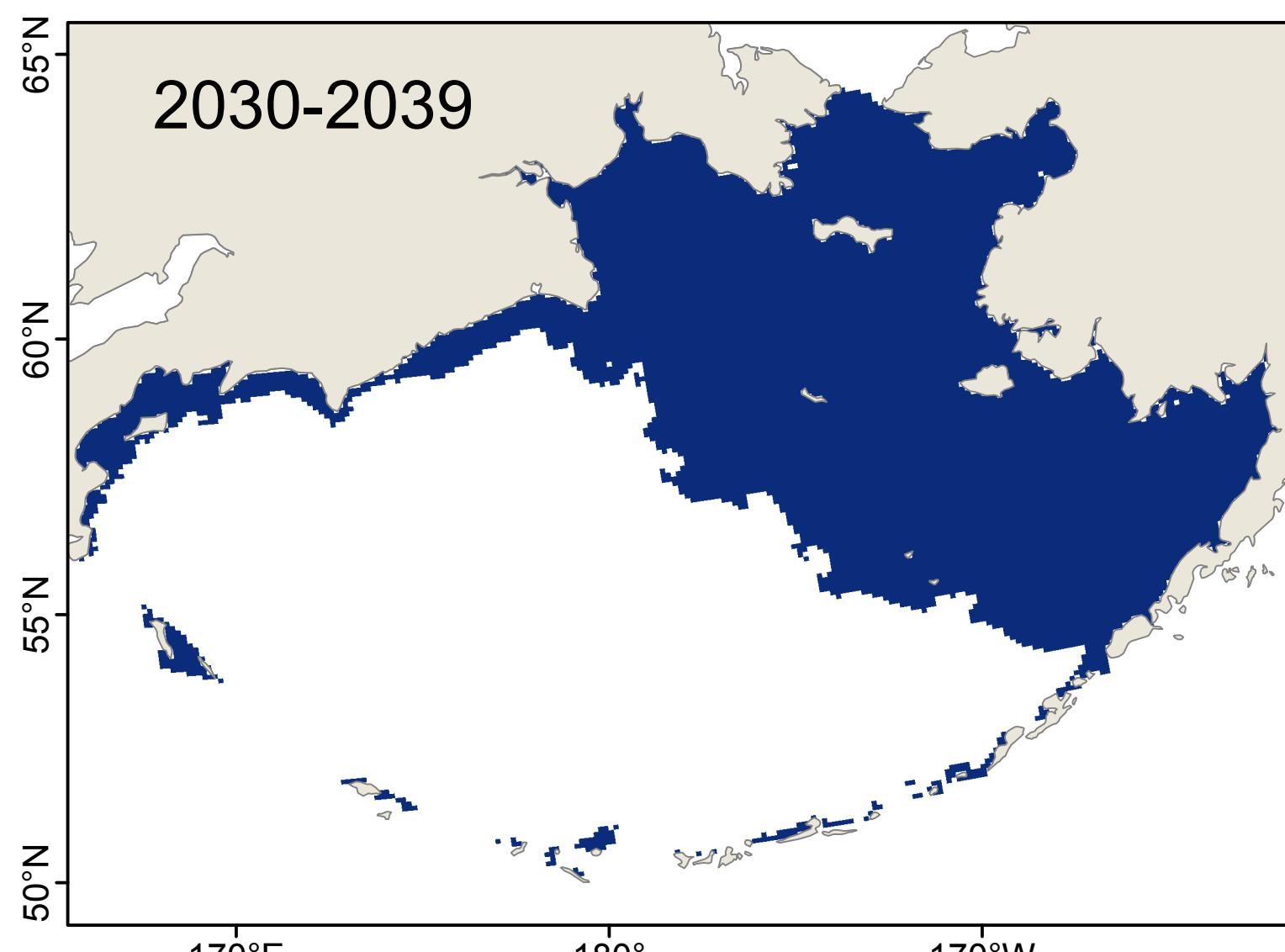
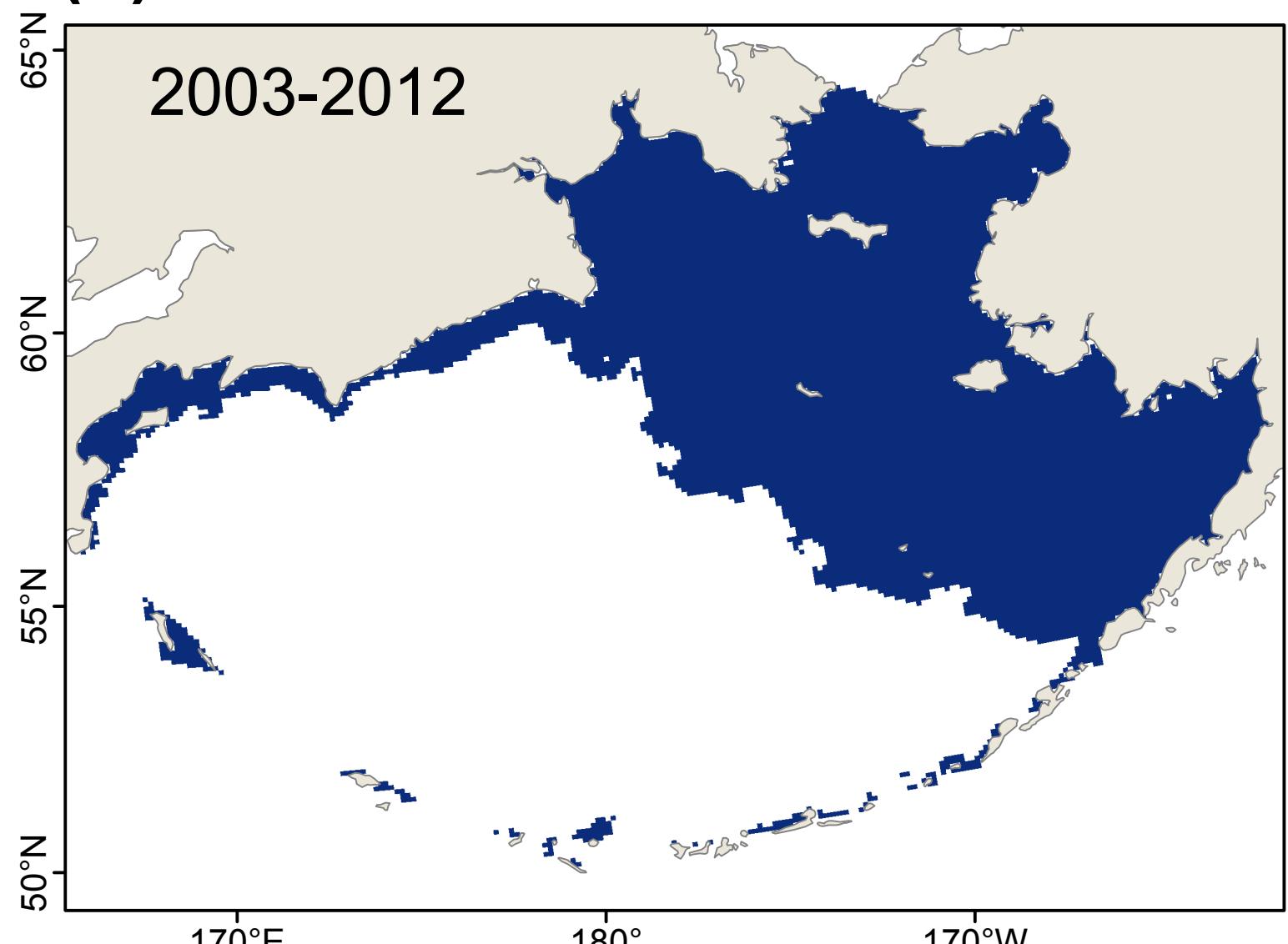
Average number of consecutive weeks of suitable habitat



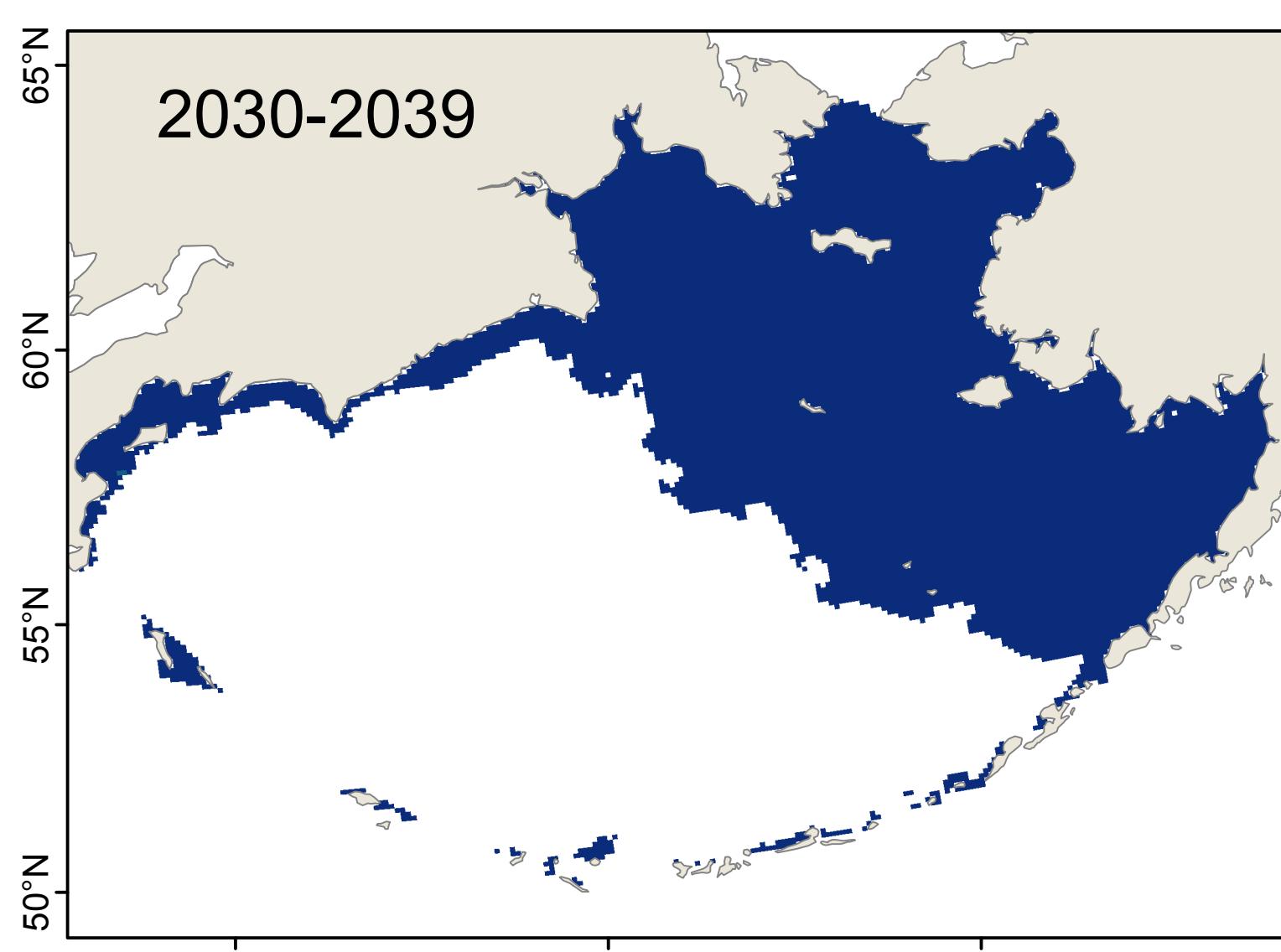
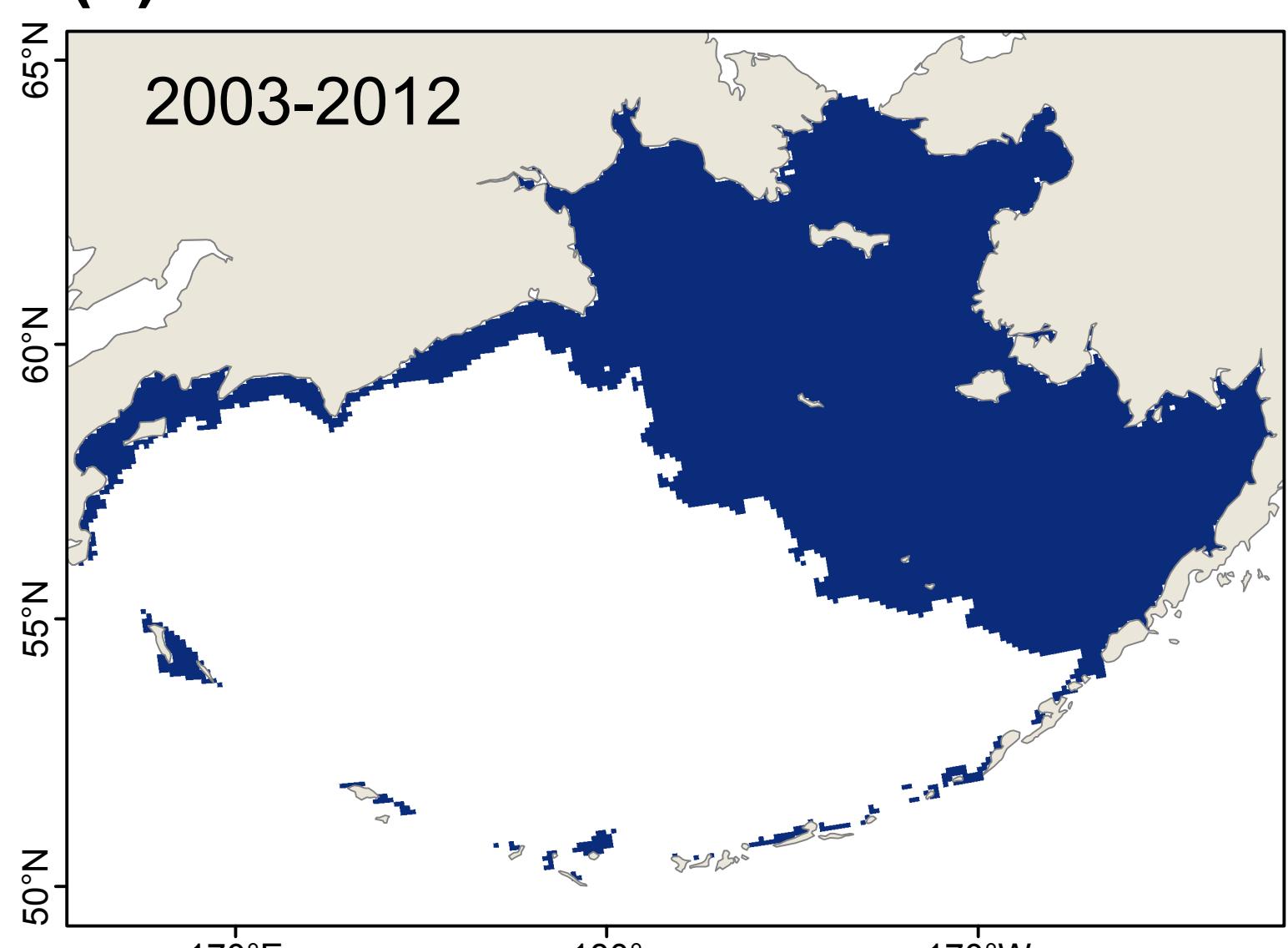
(a) Model: CGCM3-t47



(b) Model: ECHO-G

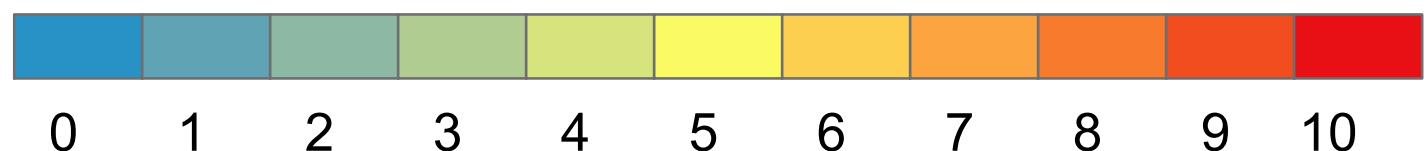


(c) Model: MIROC3.2

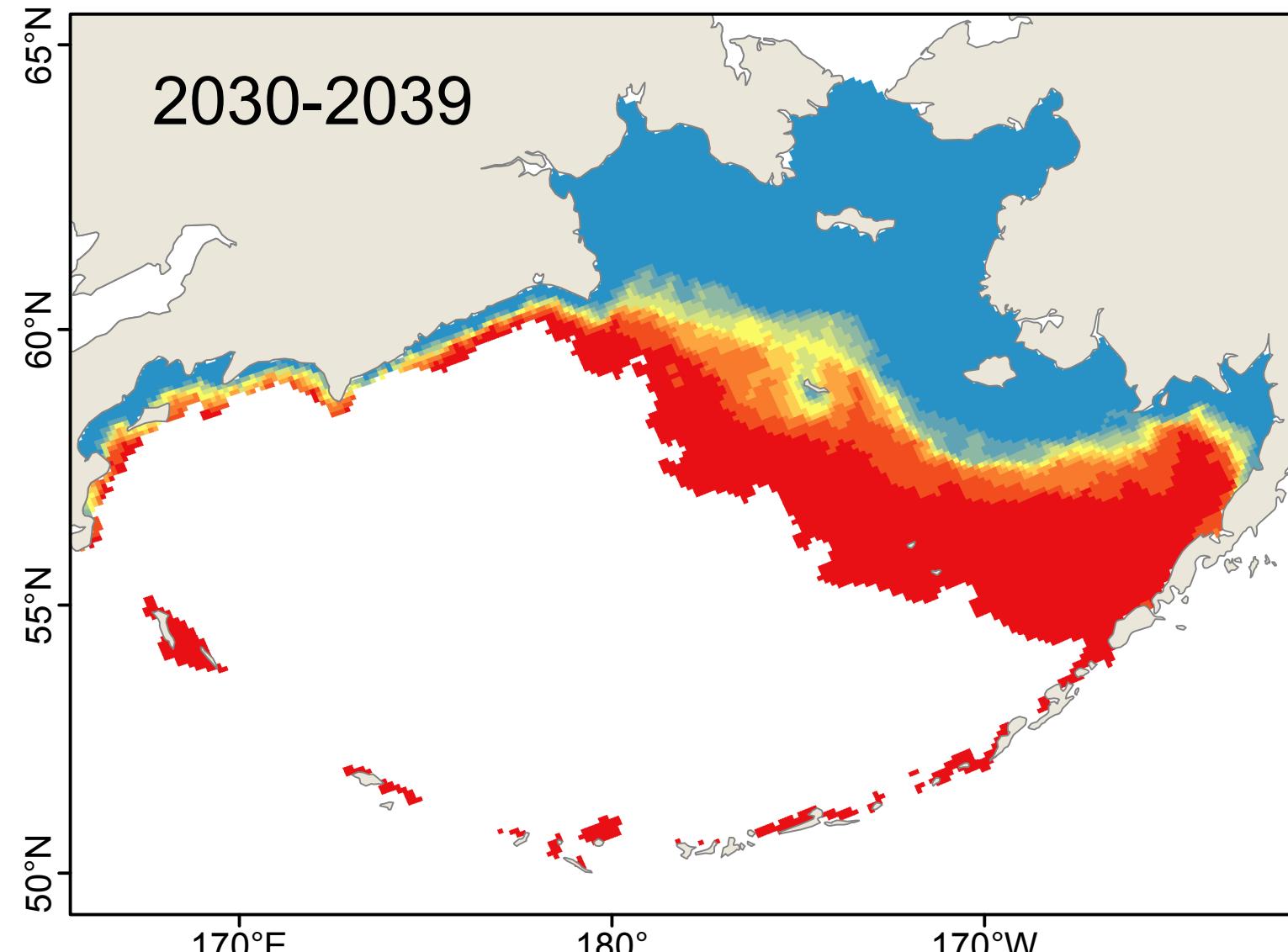
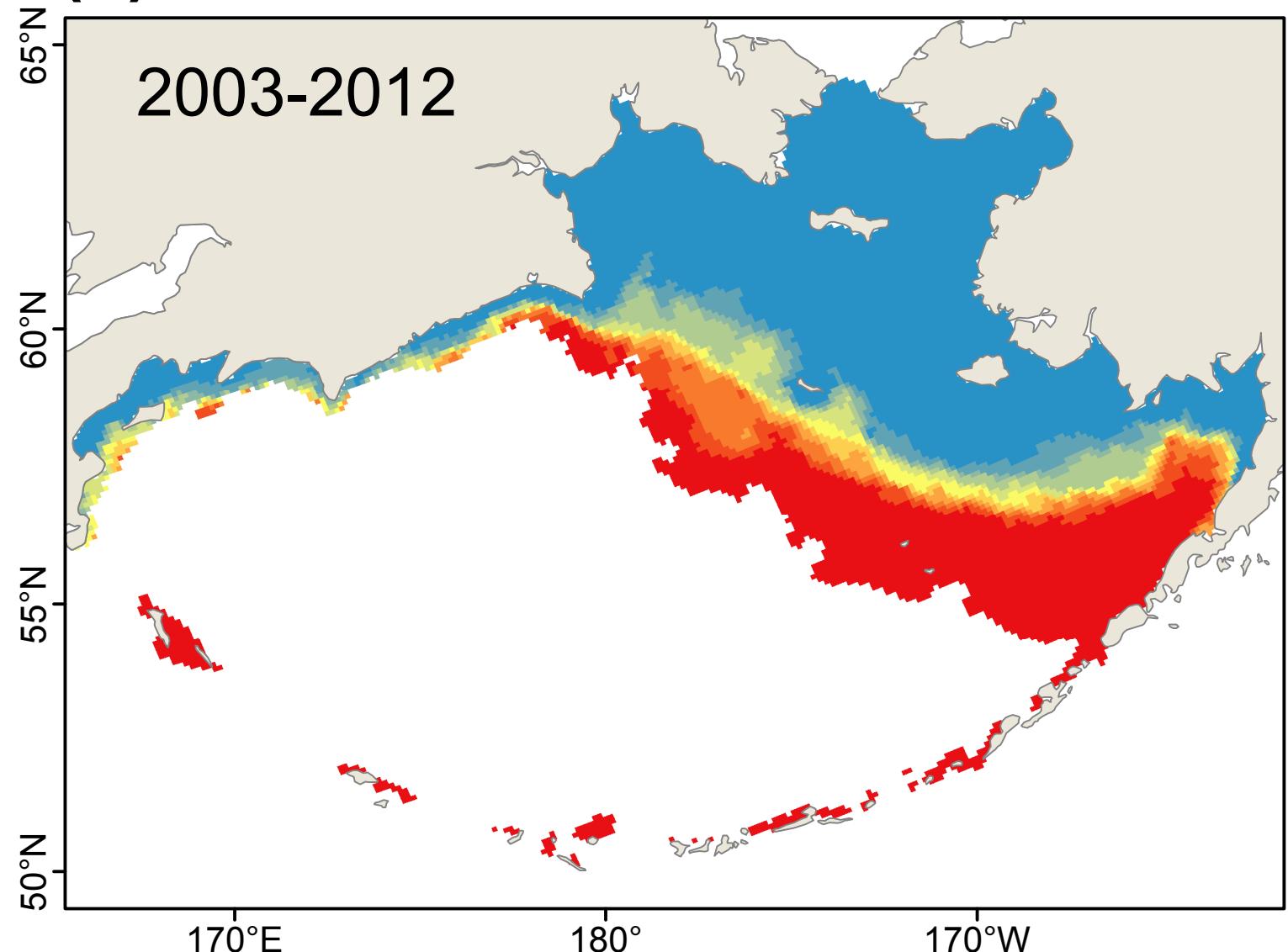


# *Botryllus schlosseri*: Year-round Survival

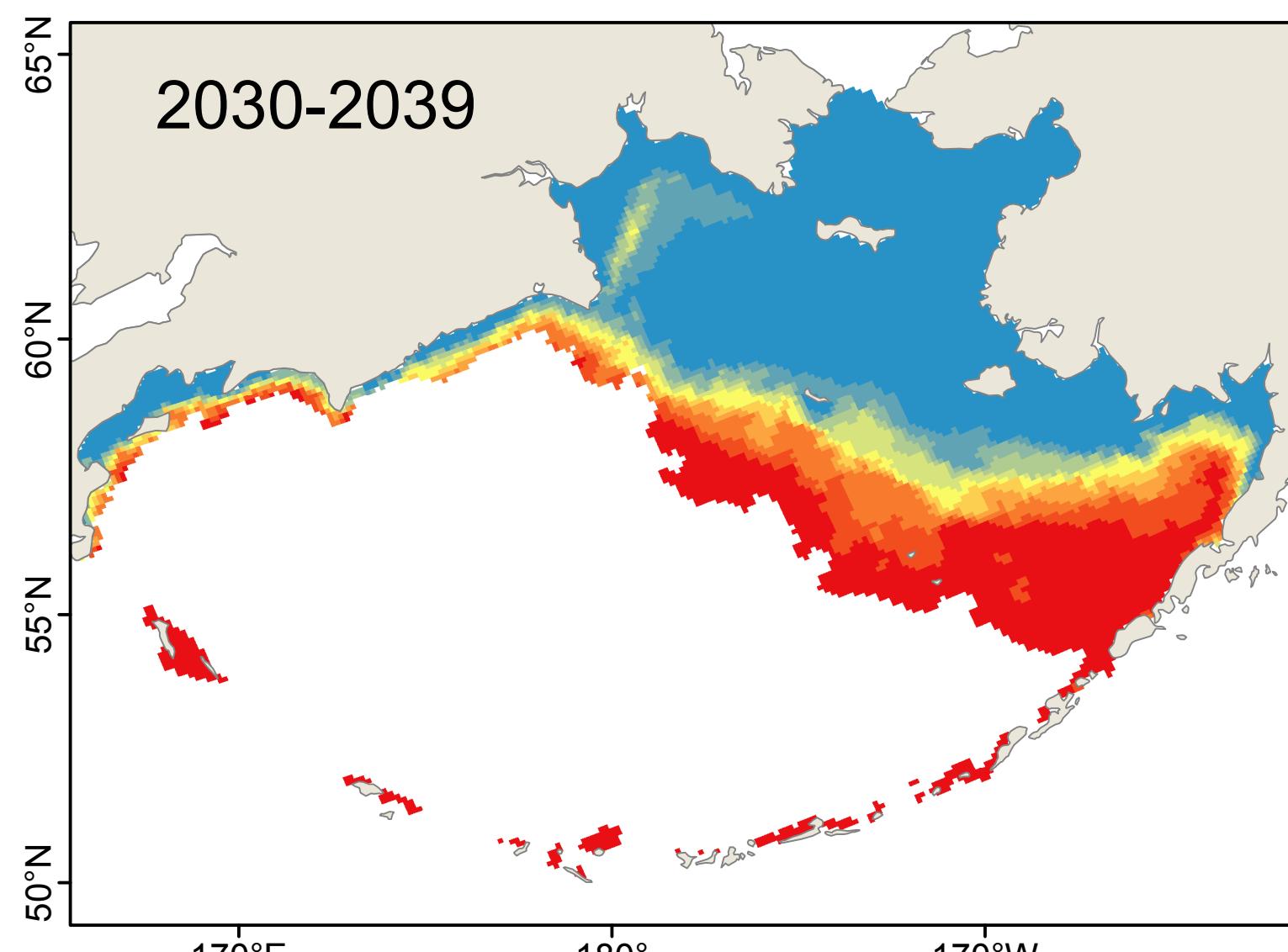
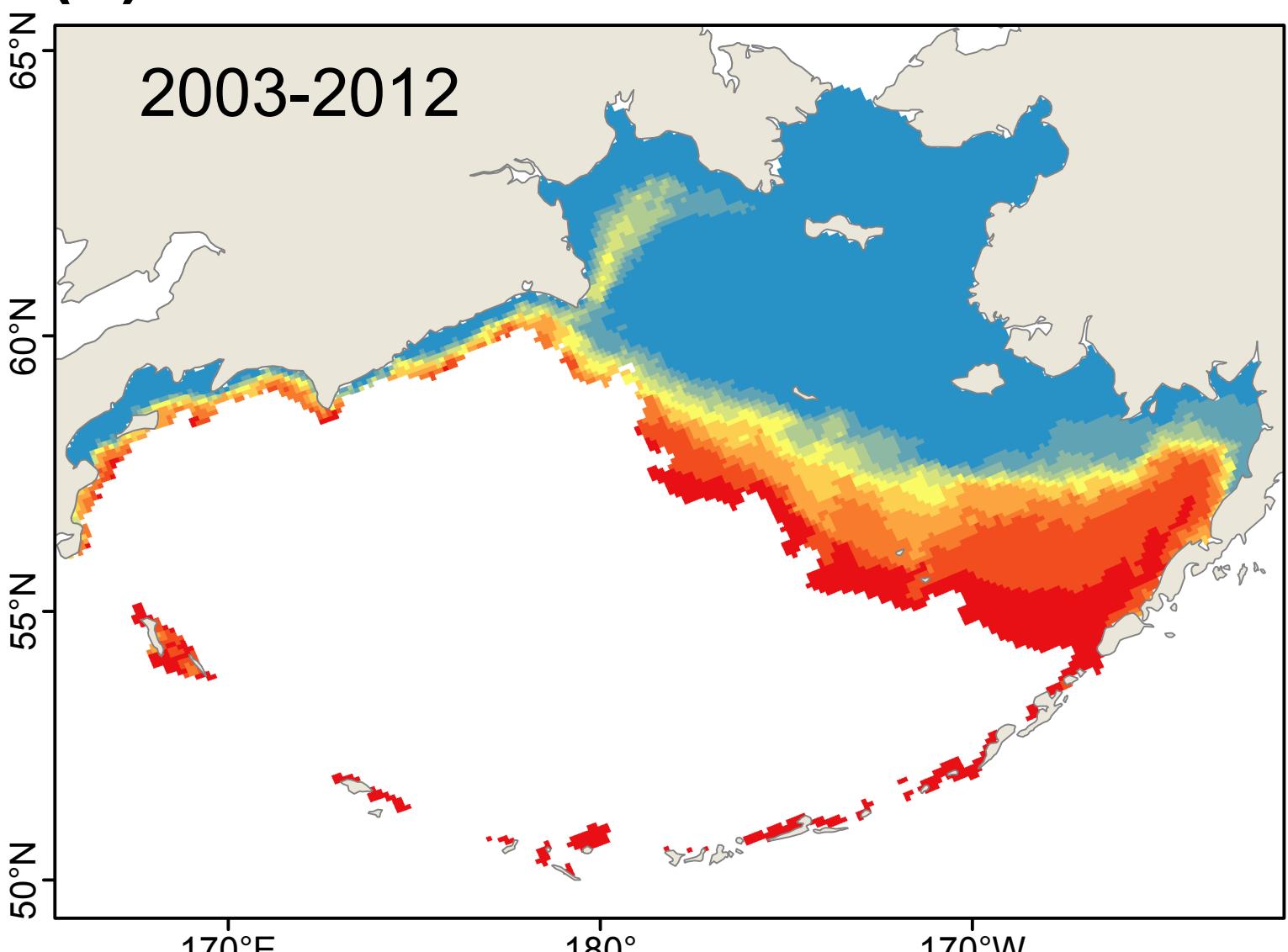
Number of years with suitable habitat



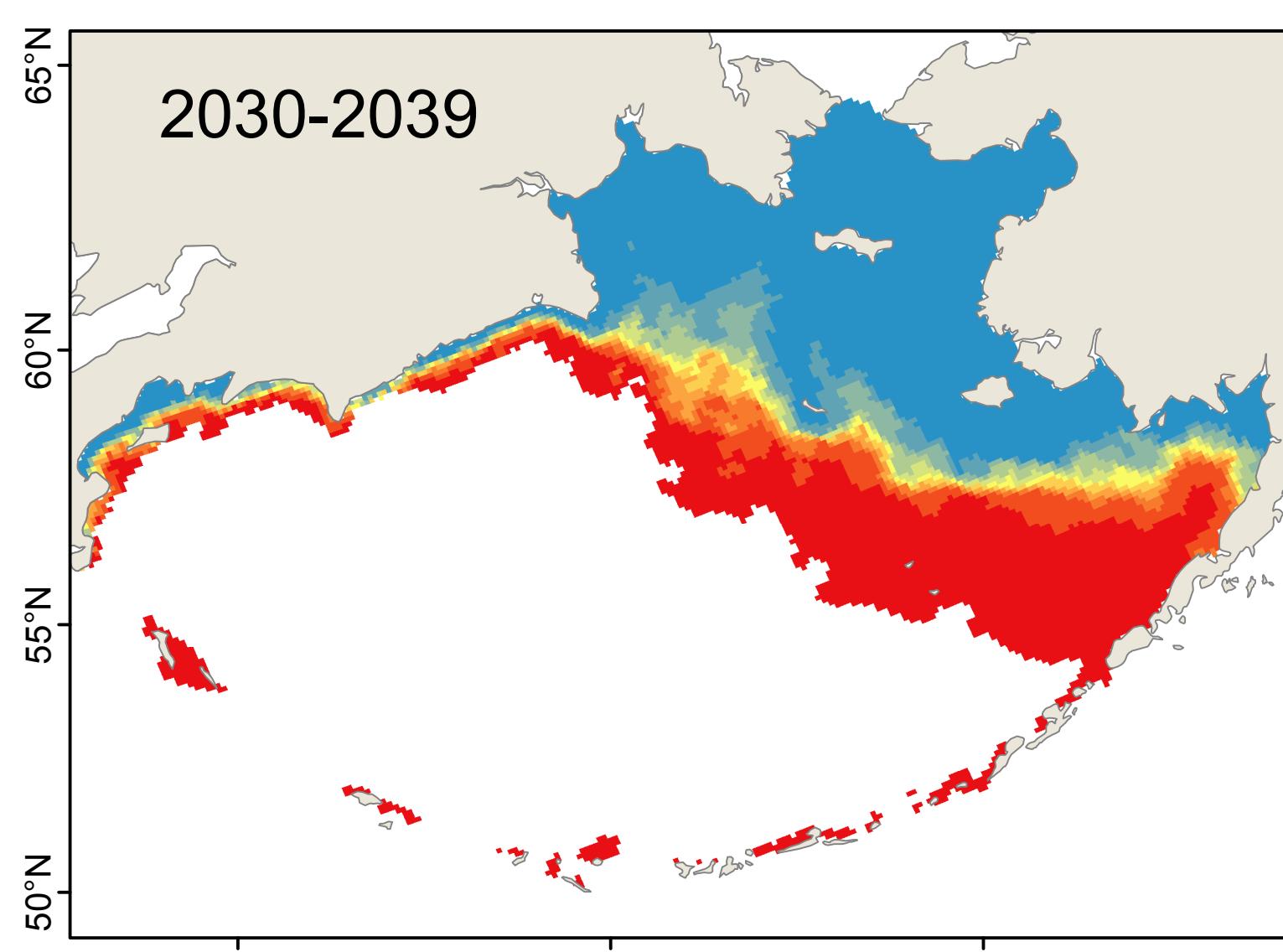
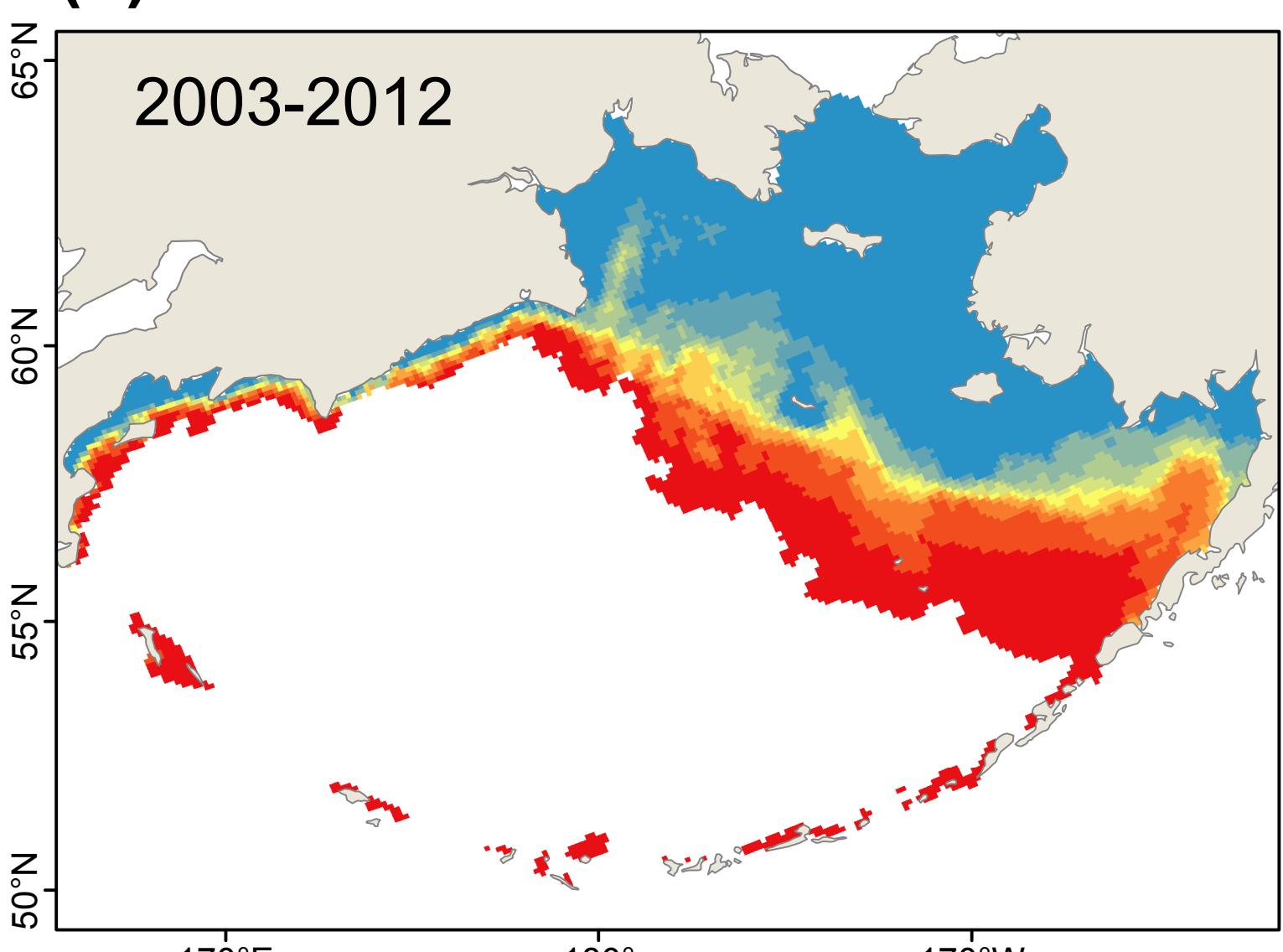
(a) Model: CGCM3-t47



(b) Model: ECHO-G

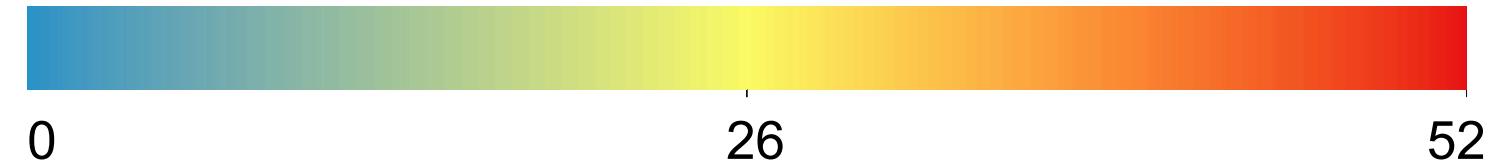


(c) Model: MIROC3.2

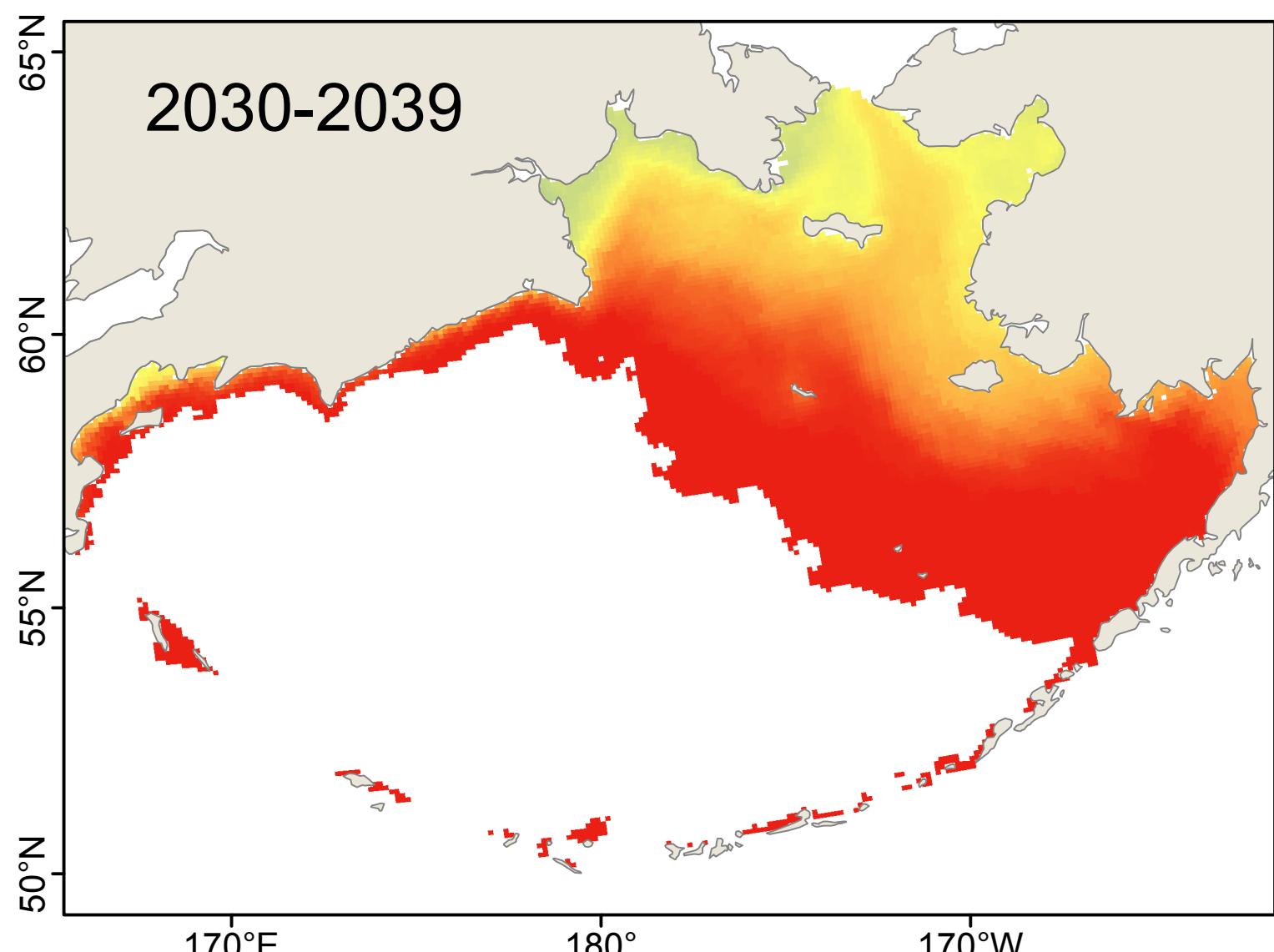
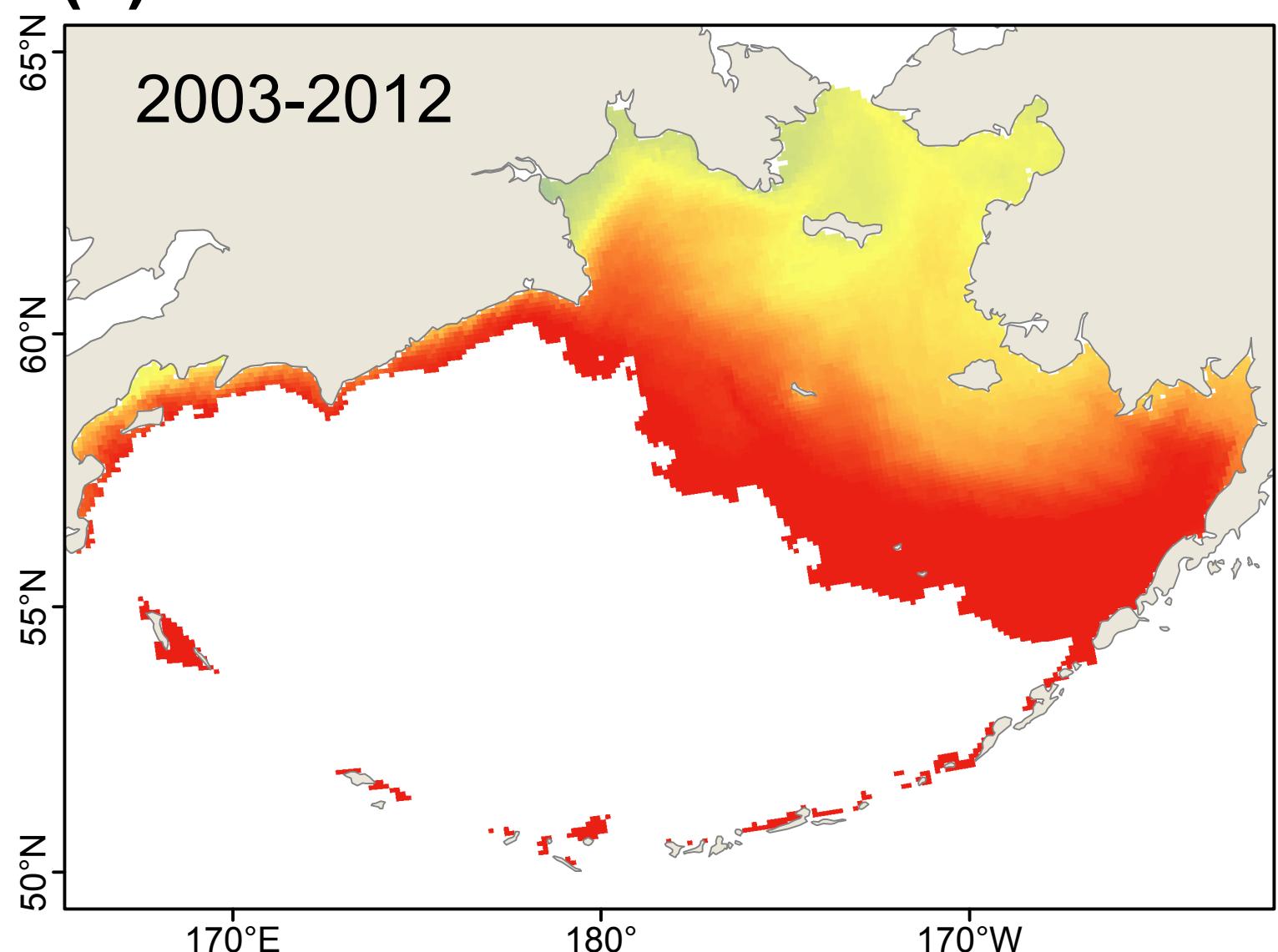


# *Botryllus schlosseri: Weekly Survival*

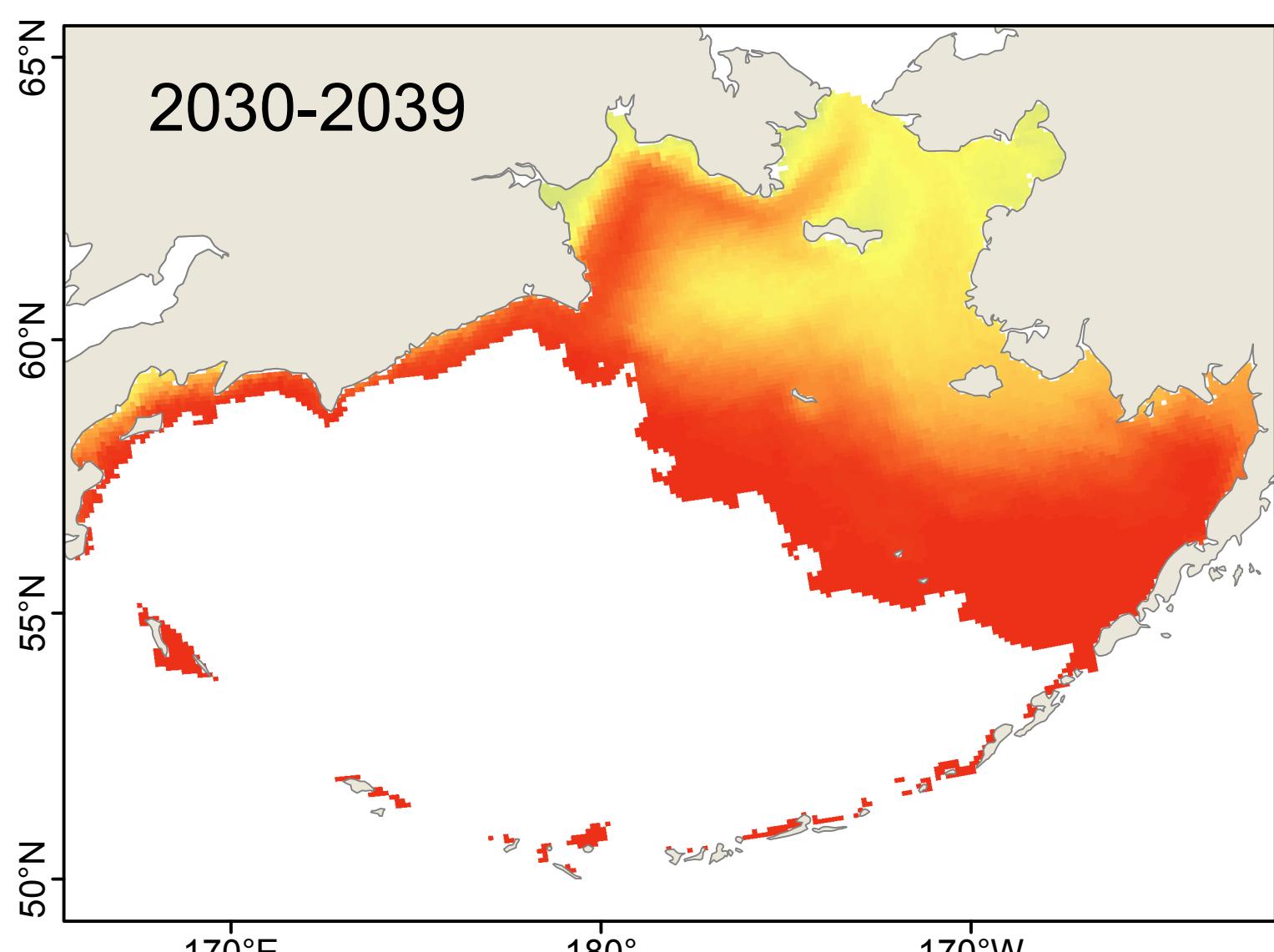
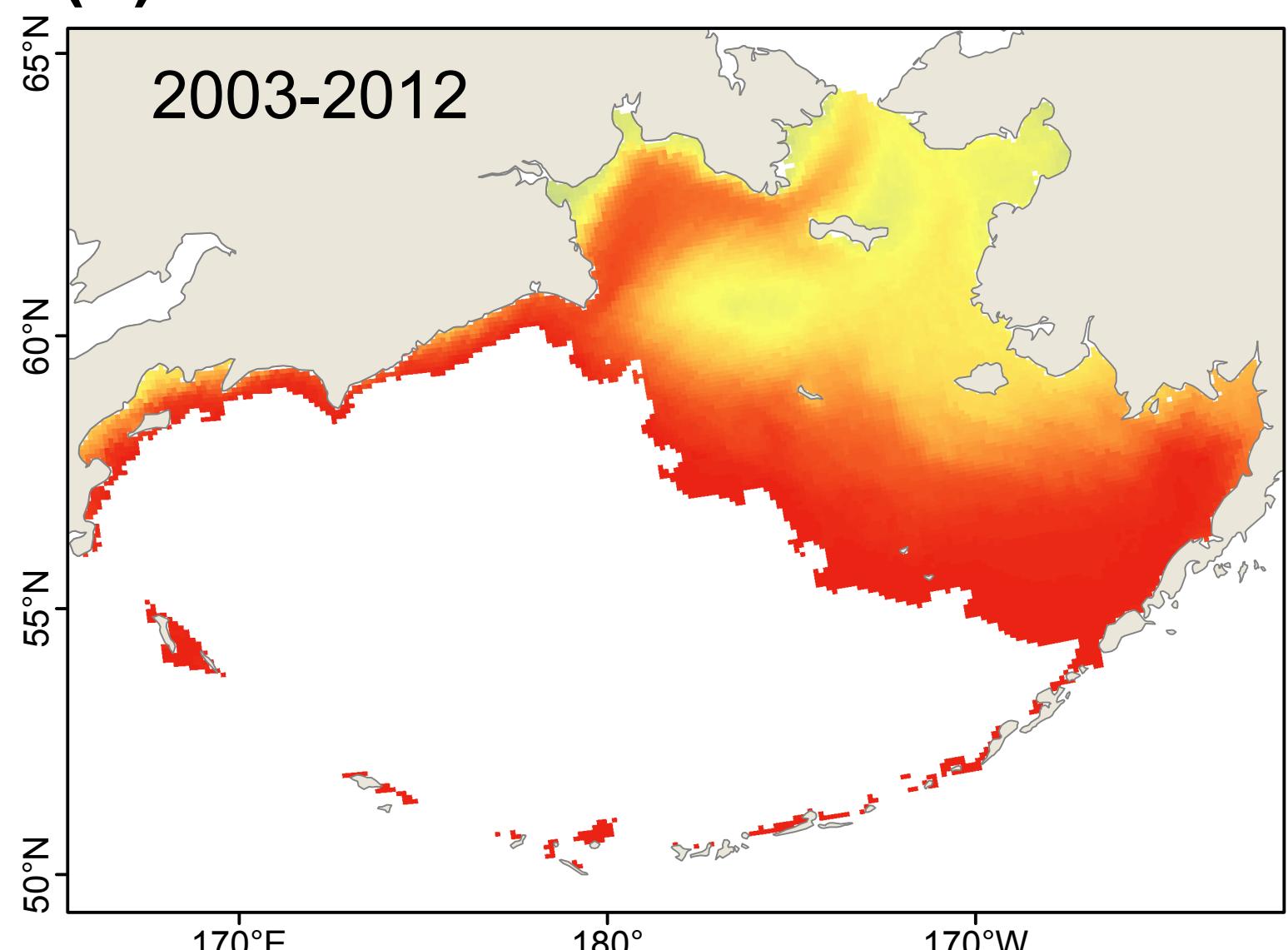
Average number of weeks of suitable habitat



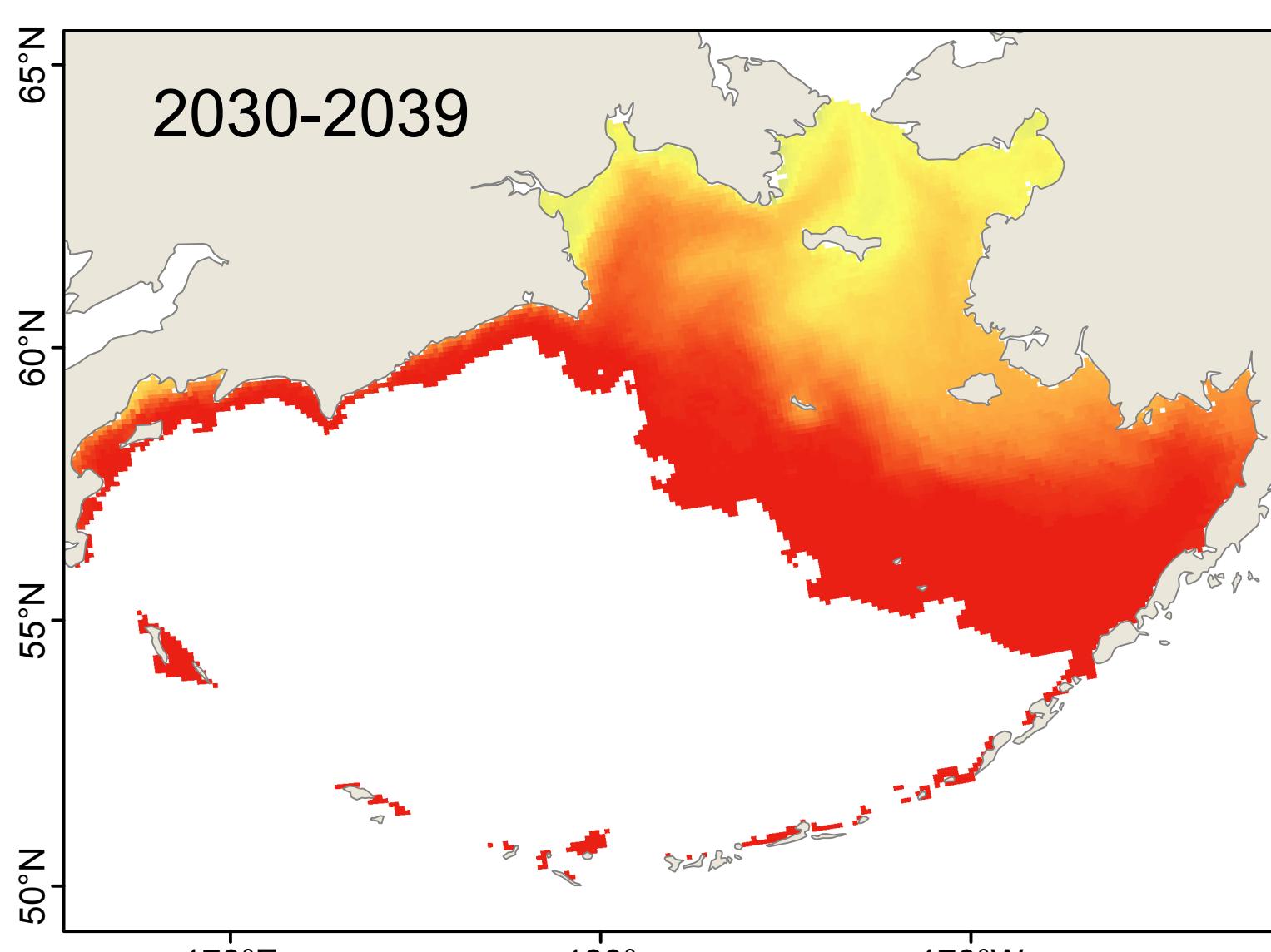
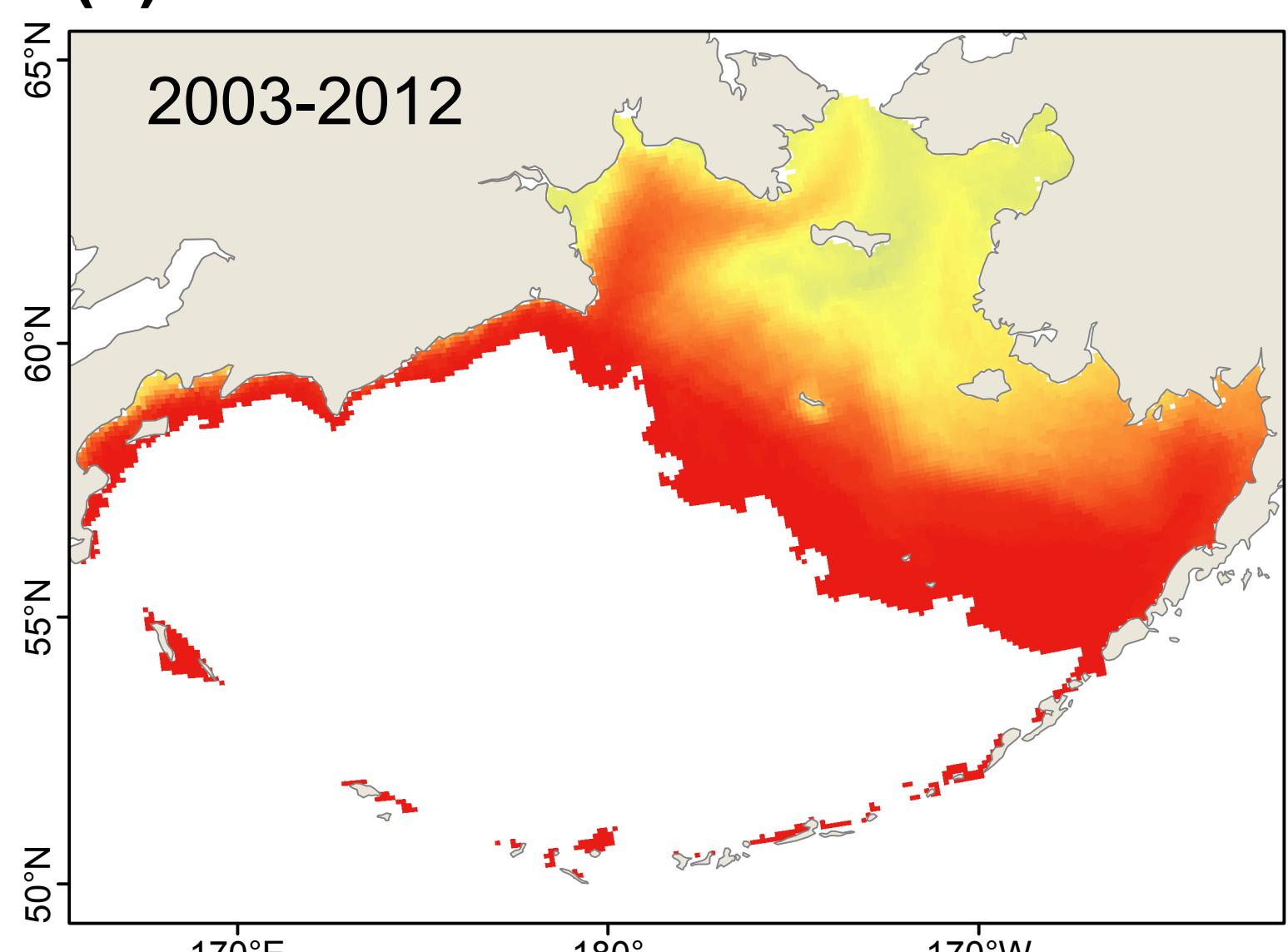
(a) Model: CGCM3-t47



(b) Model: ECHO-G

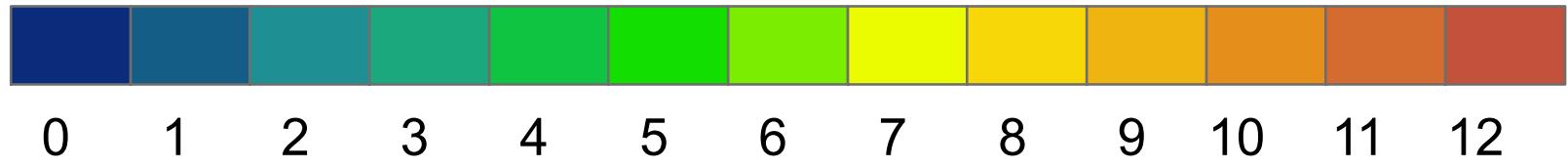


(c) Model: MIROC3.2

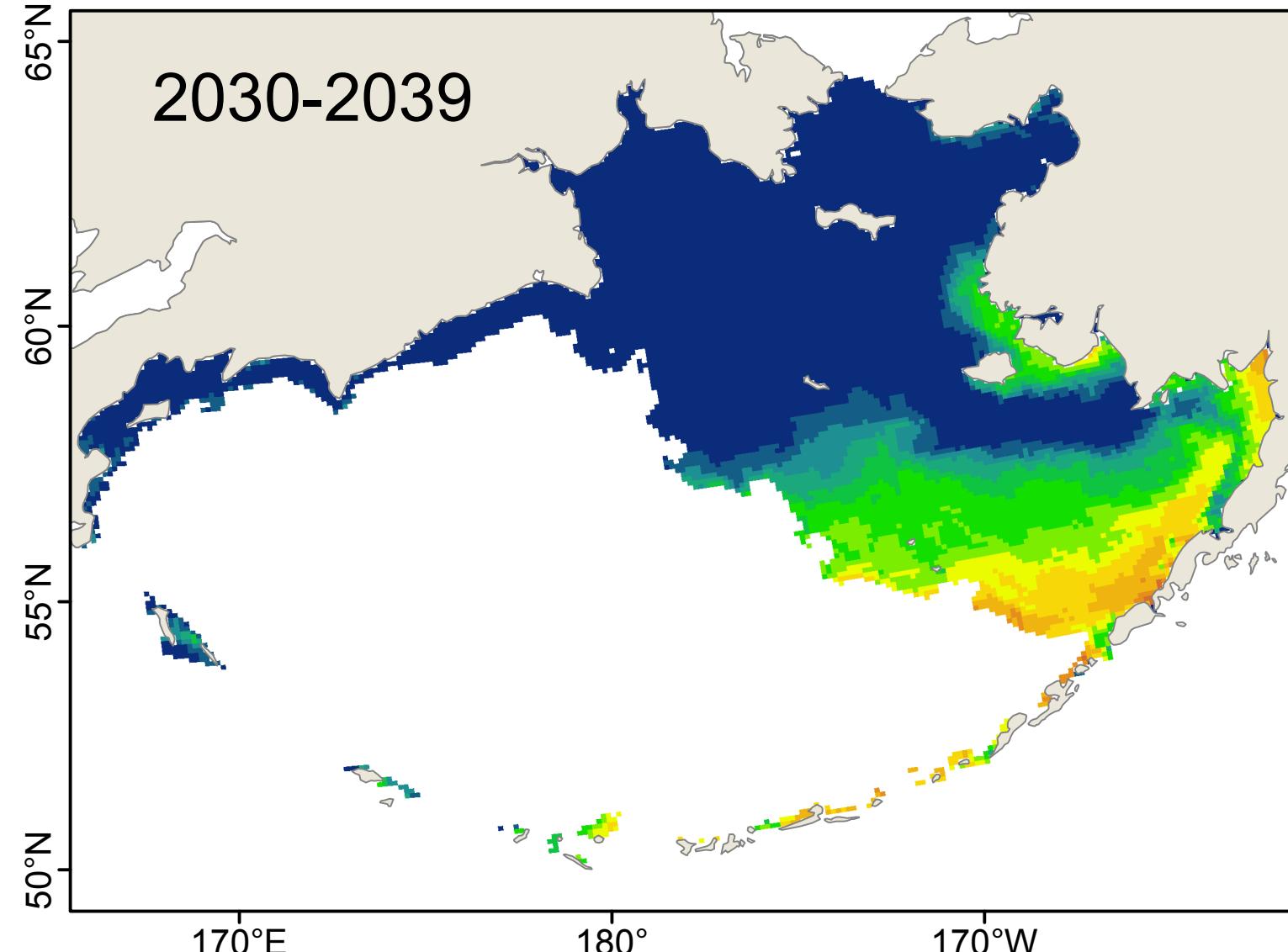
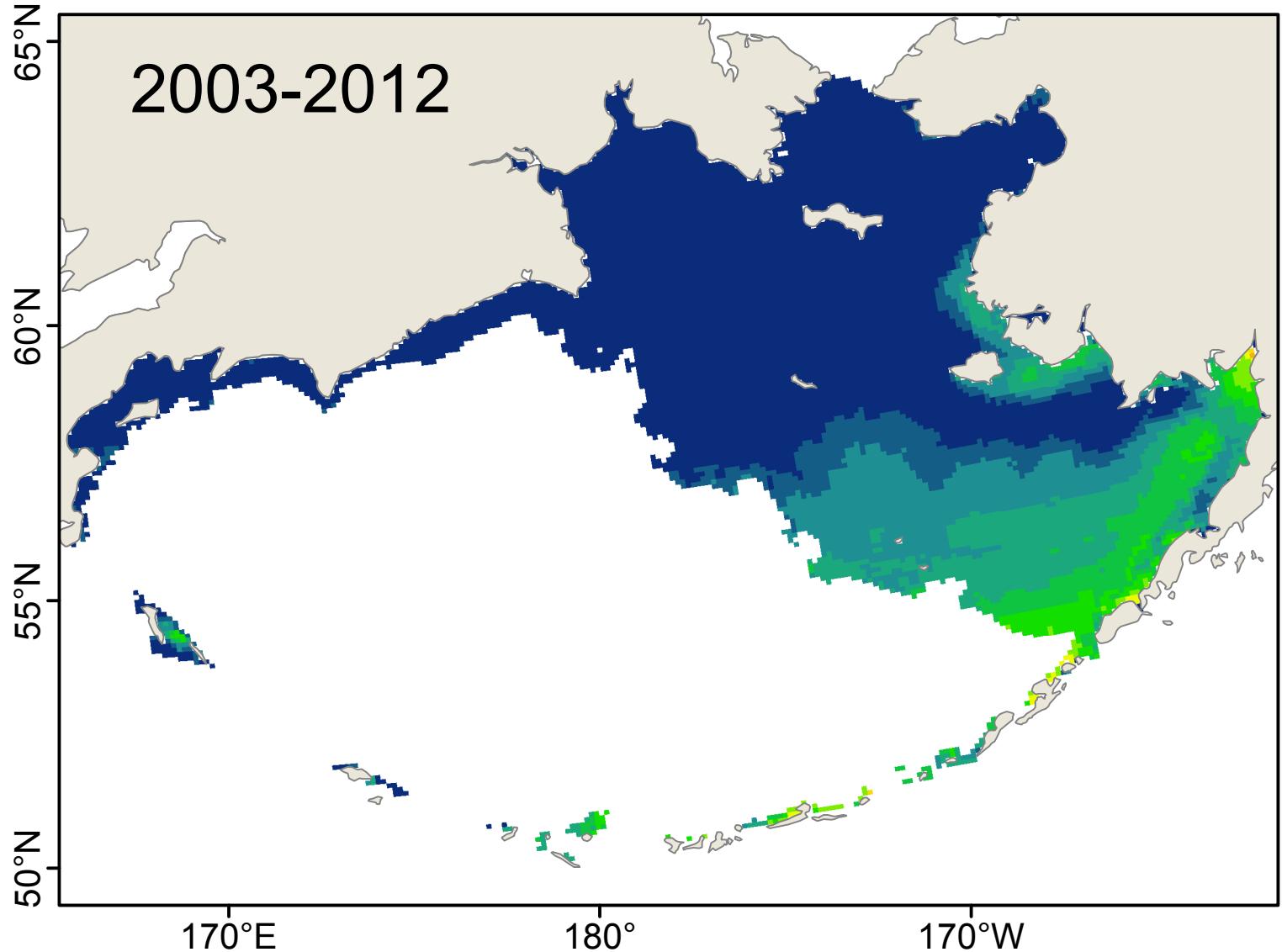


# *Botryllus schlosseri: Reproduction*

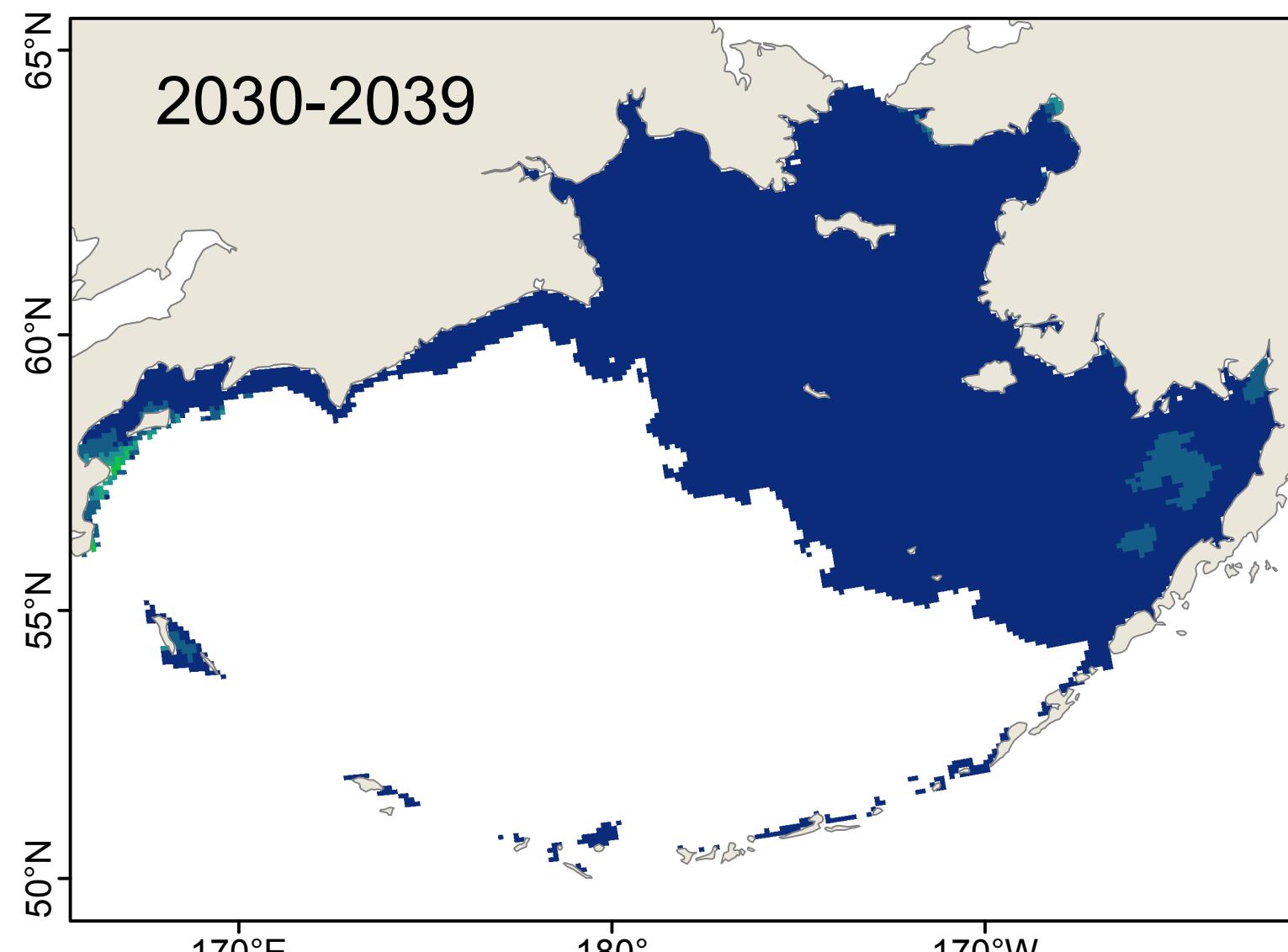
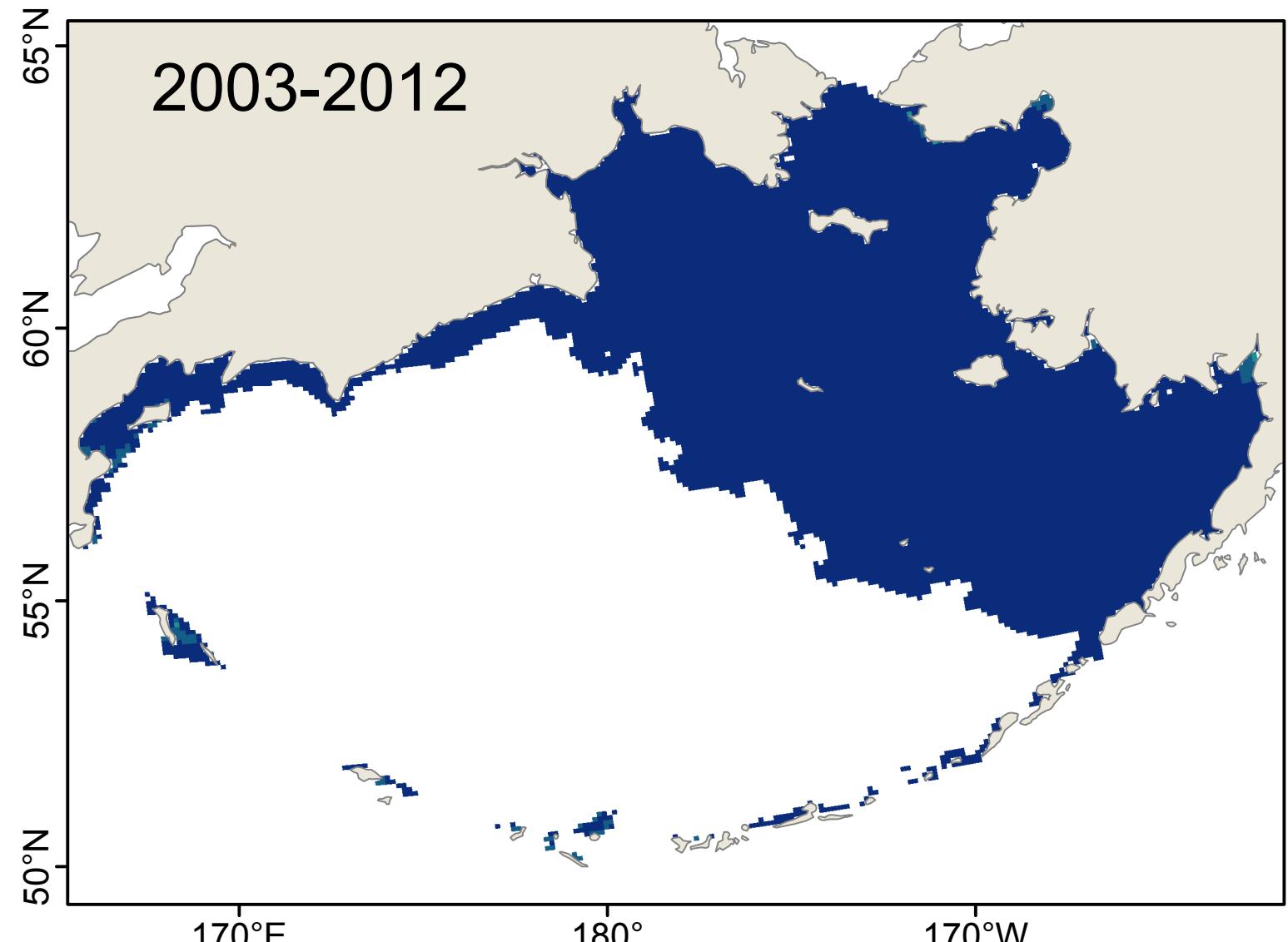
Average number of consecutive weeks of suitable habitat



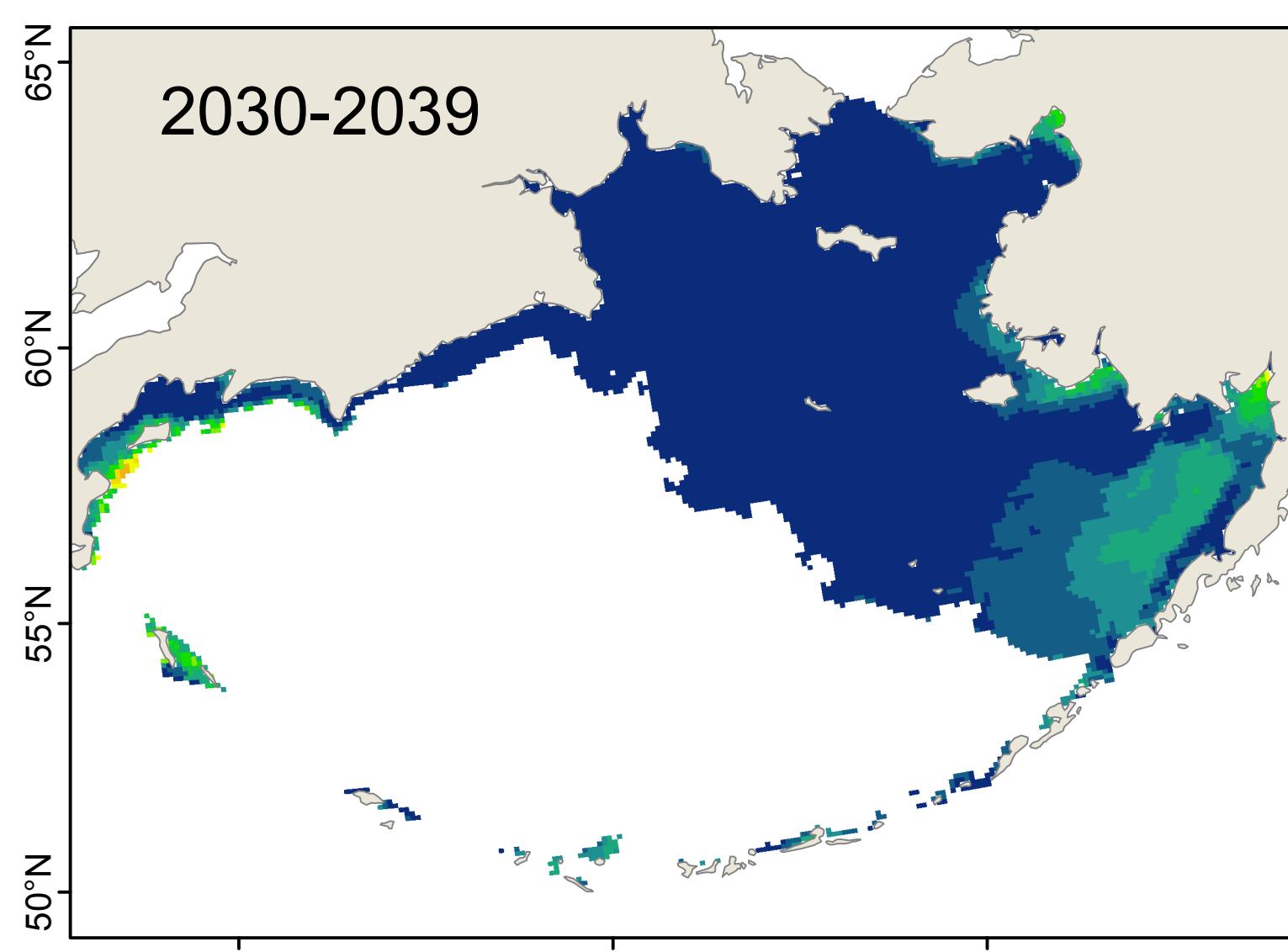
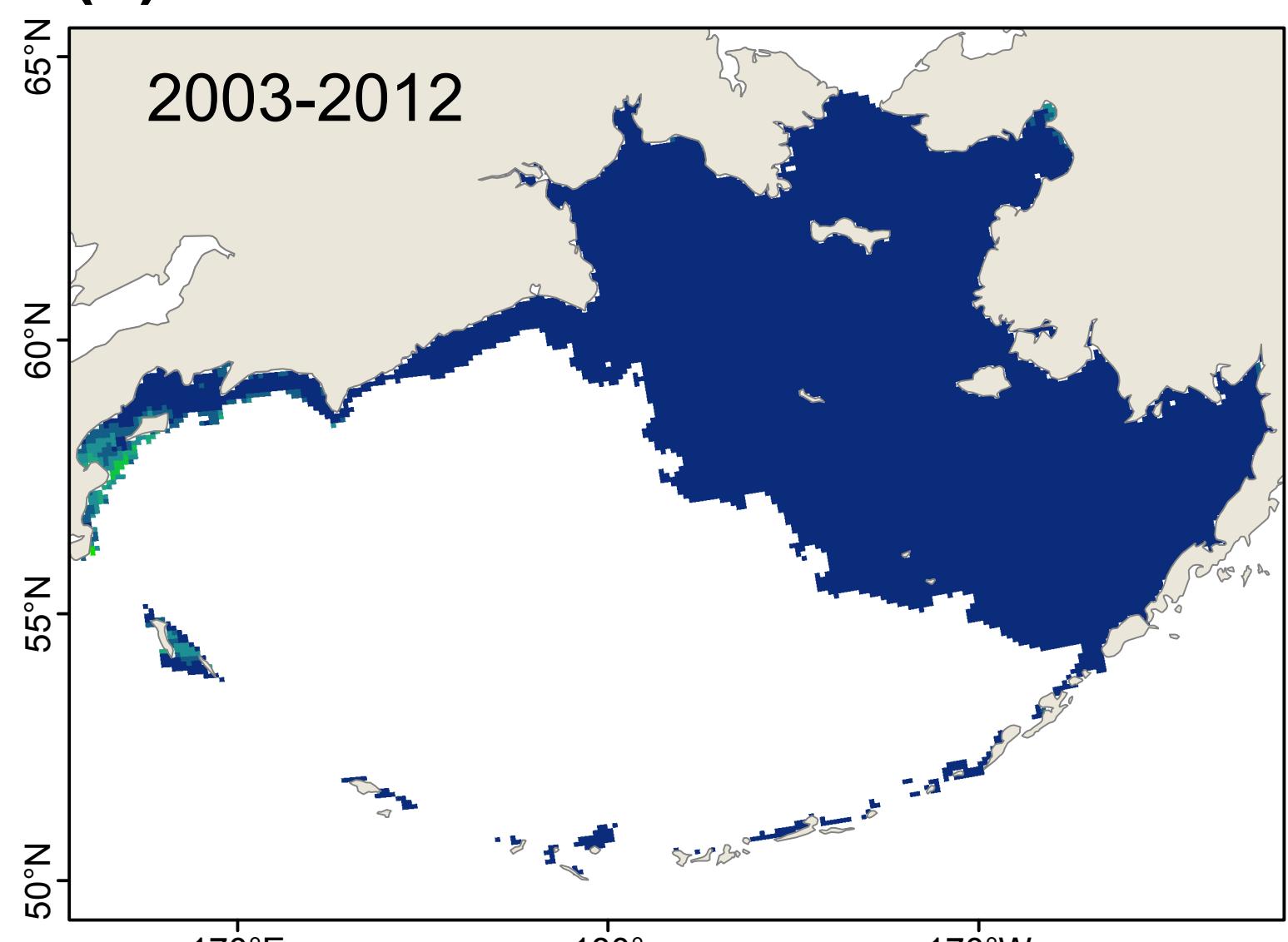
(a) Model: CGCM3-t47



(b) Model: ECHO-G

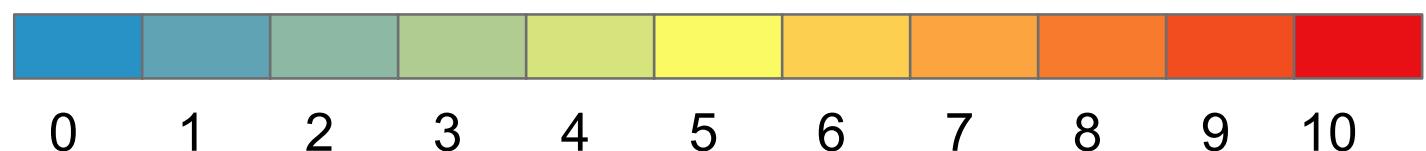


(c) Model: MIROC3.2

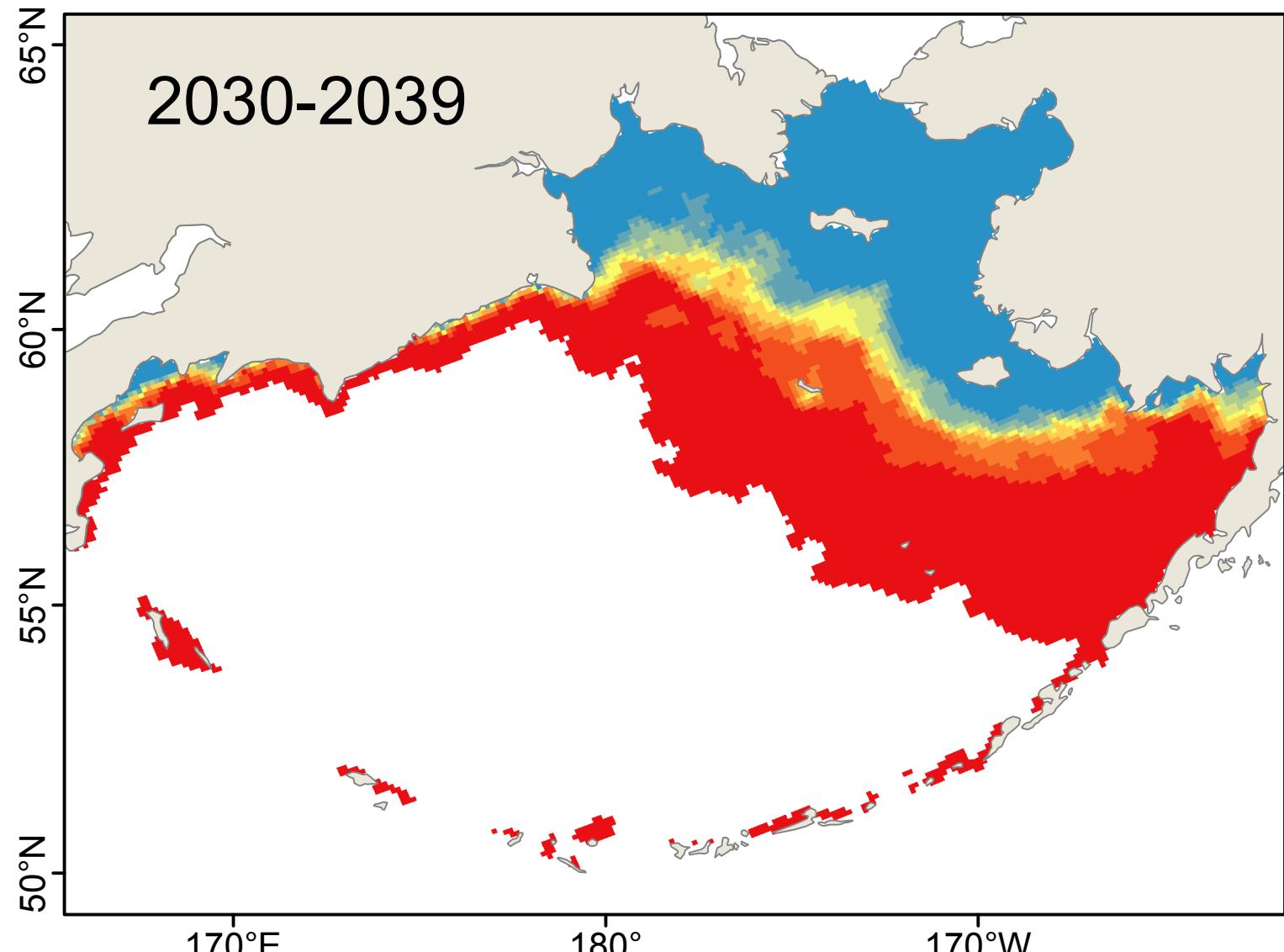
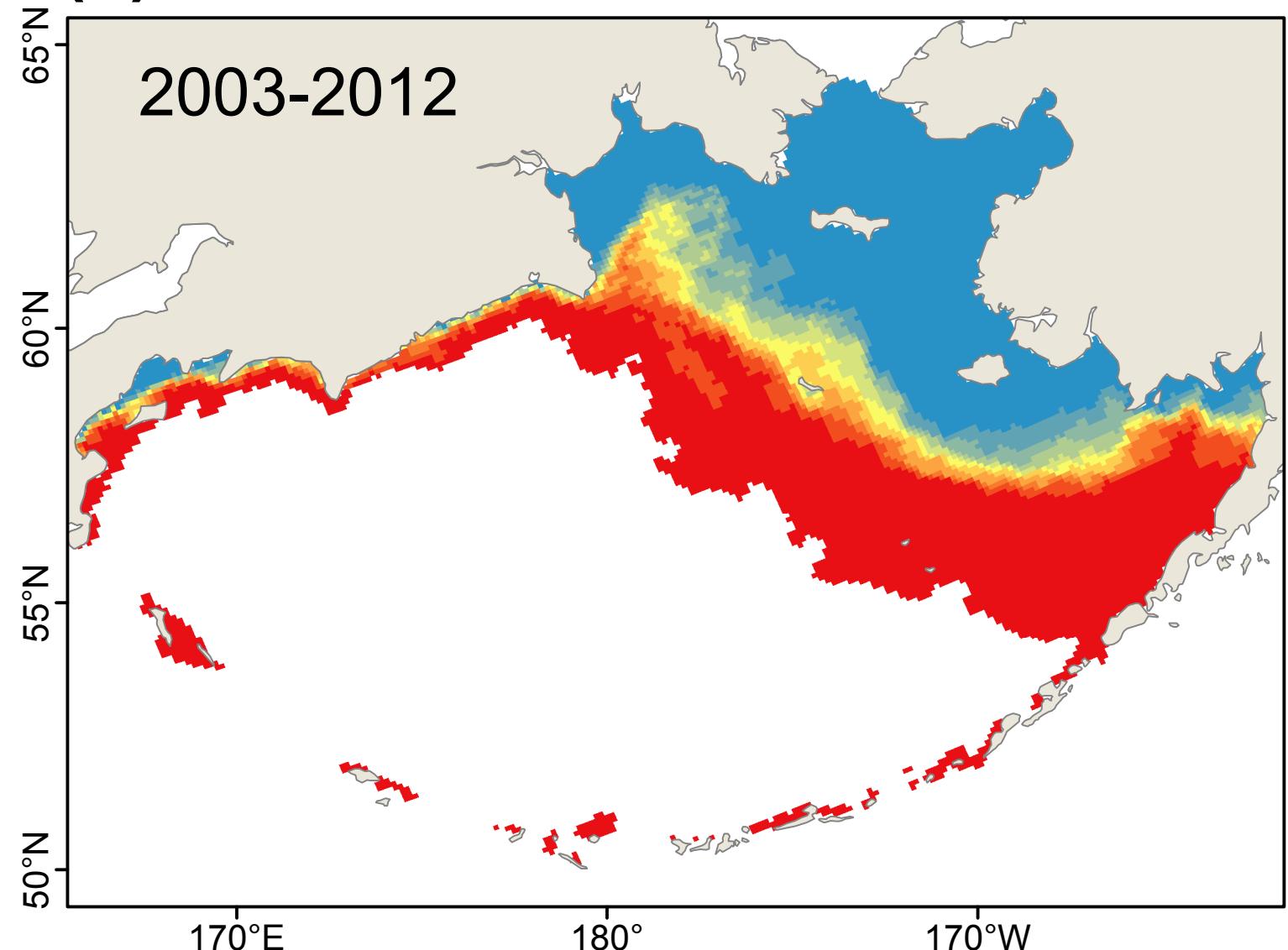


# *Ciona savignyi*: Year-round Survival

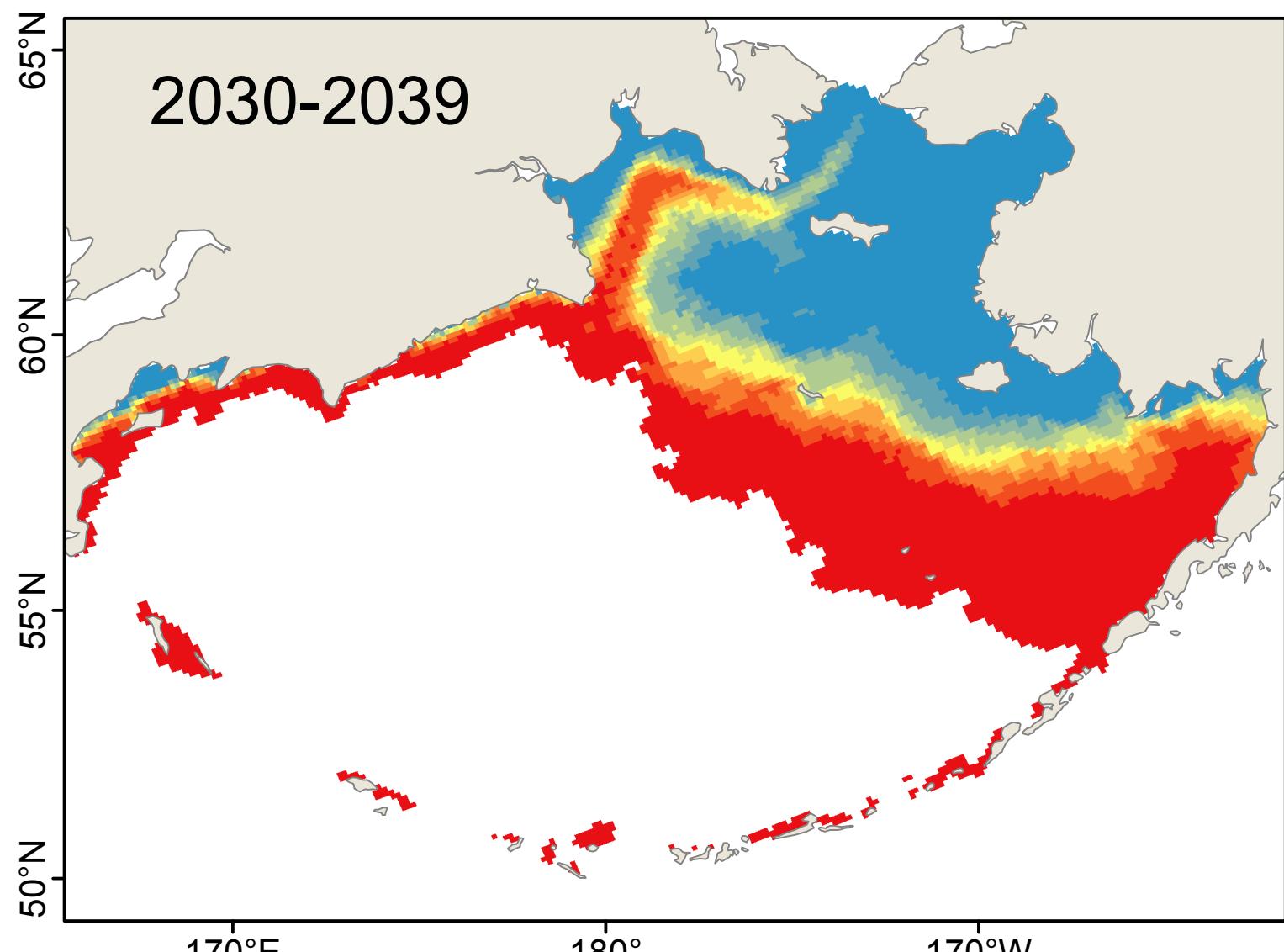
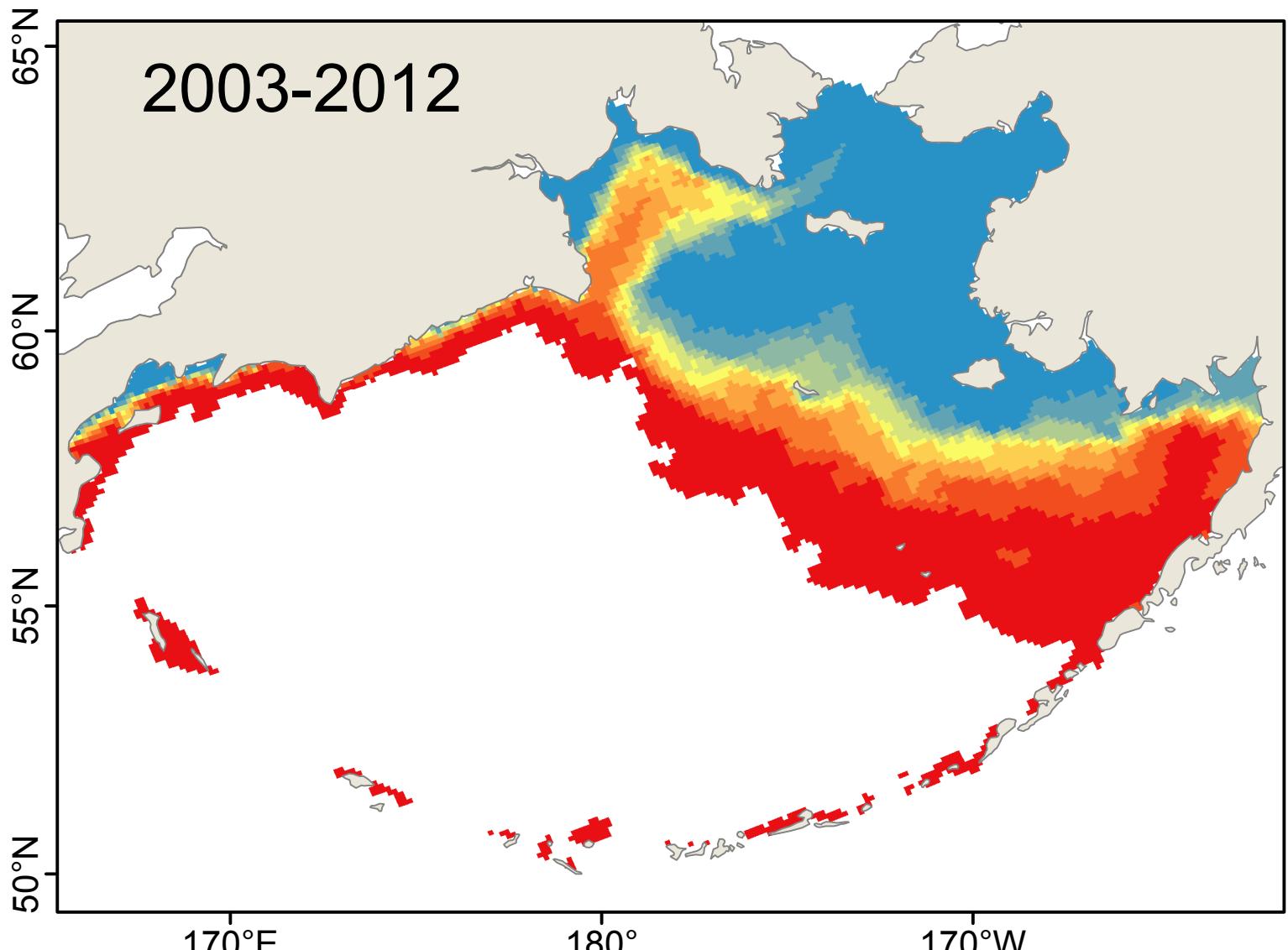
Number of years with suitable habitat



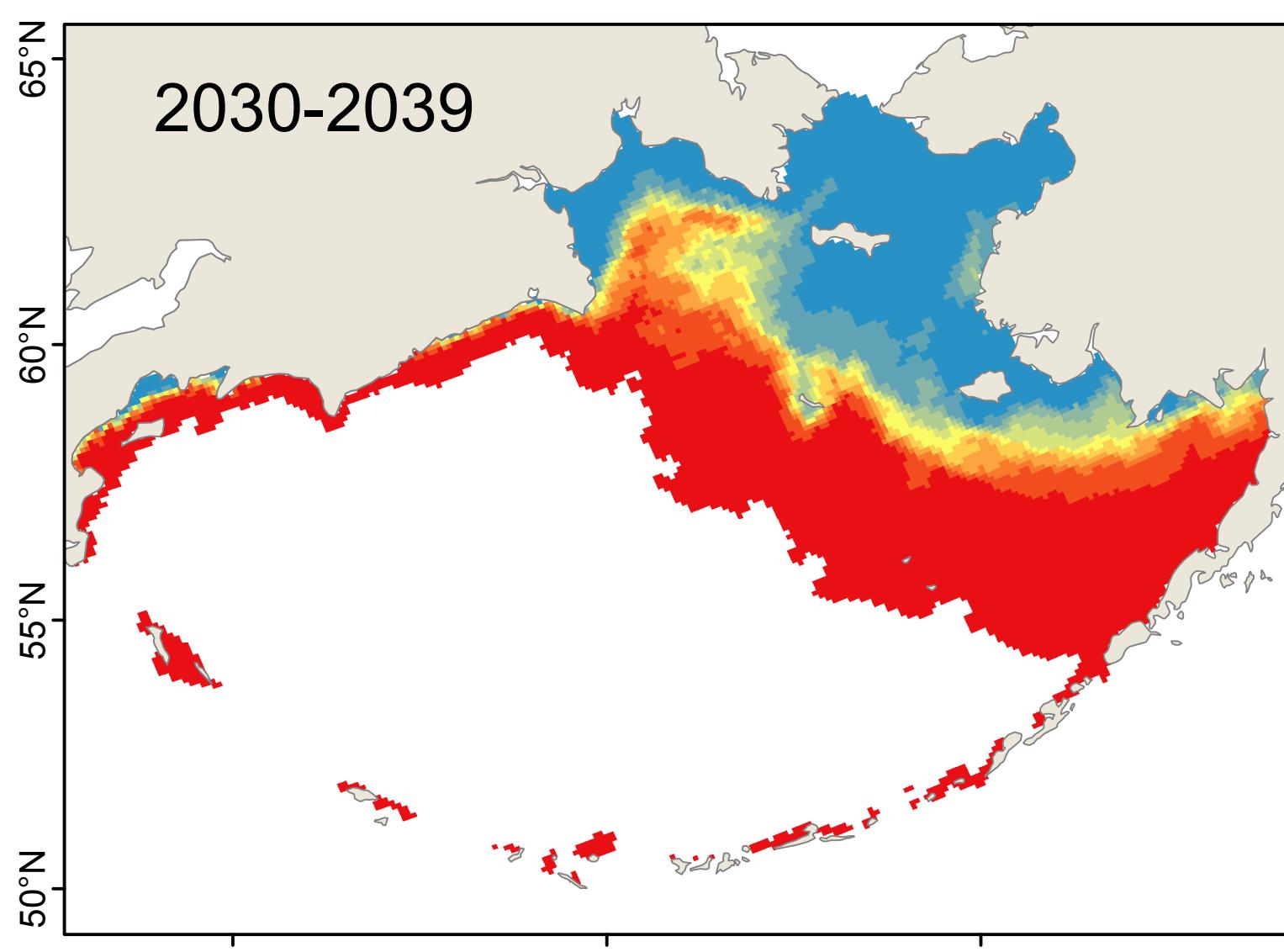
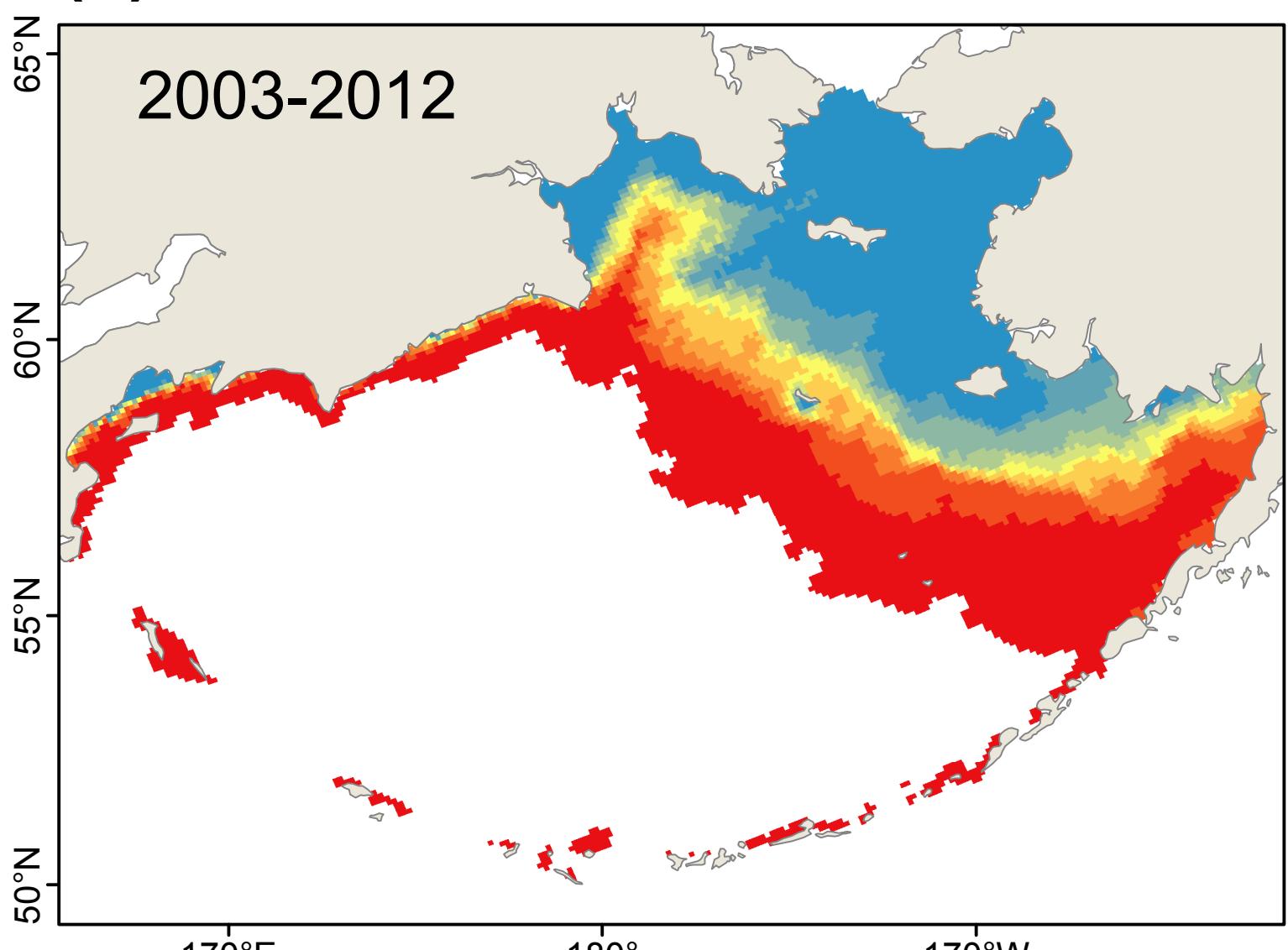
(a) Model: CGCM3-t47



(b) Model: ECHO-G

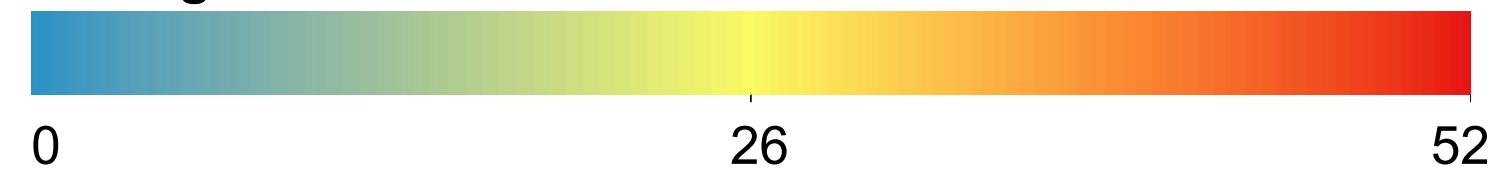


(c) Model: MIROC3.2

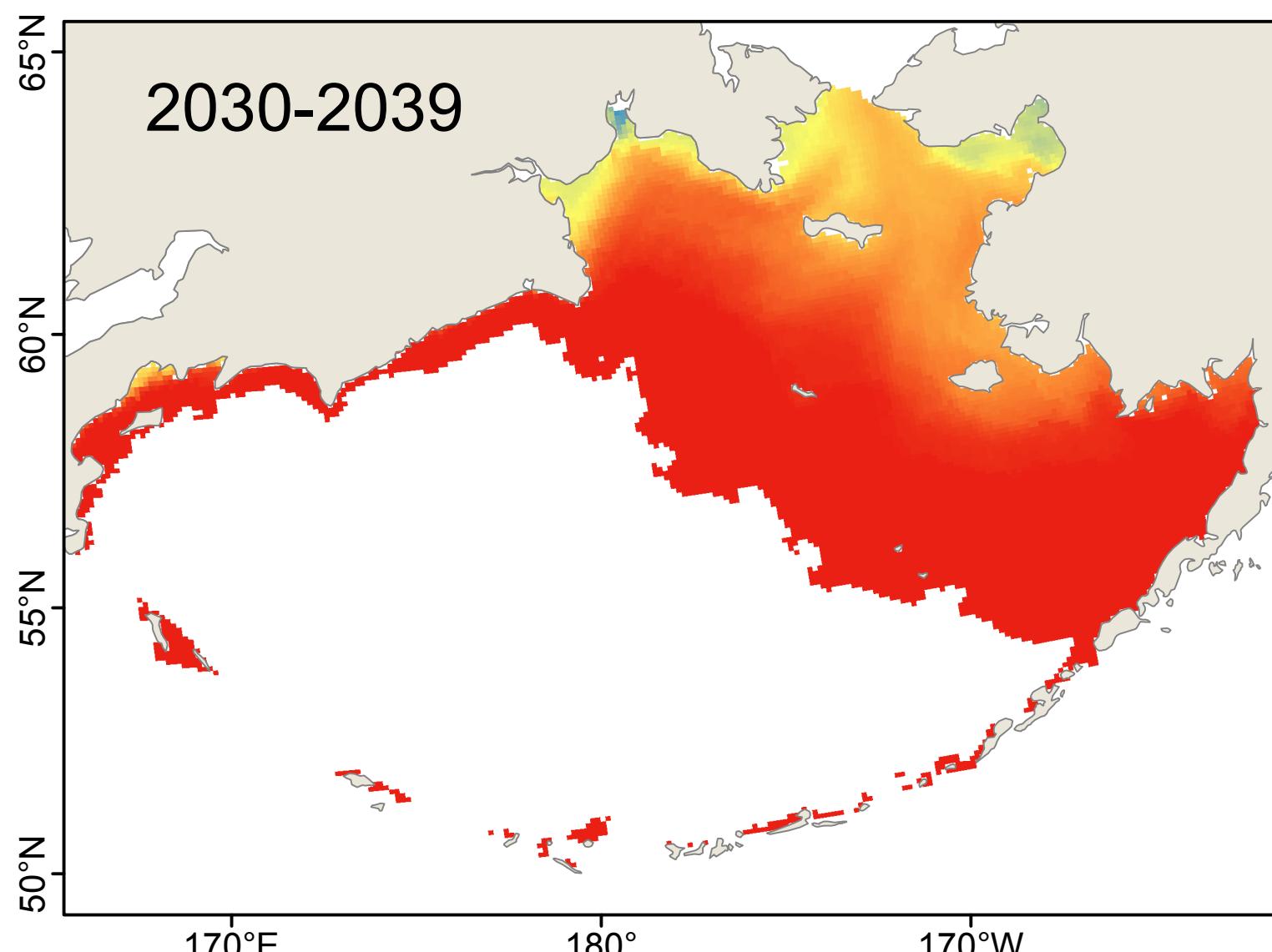
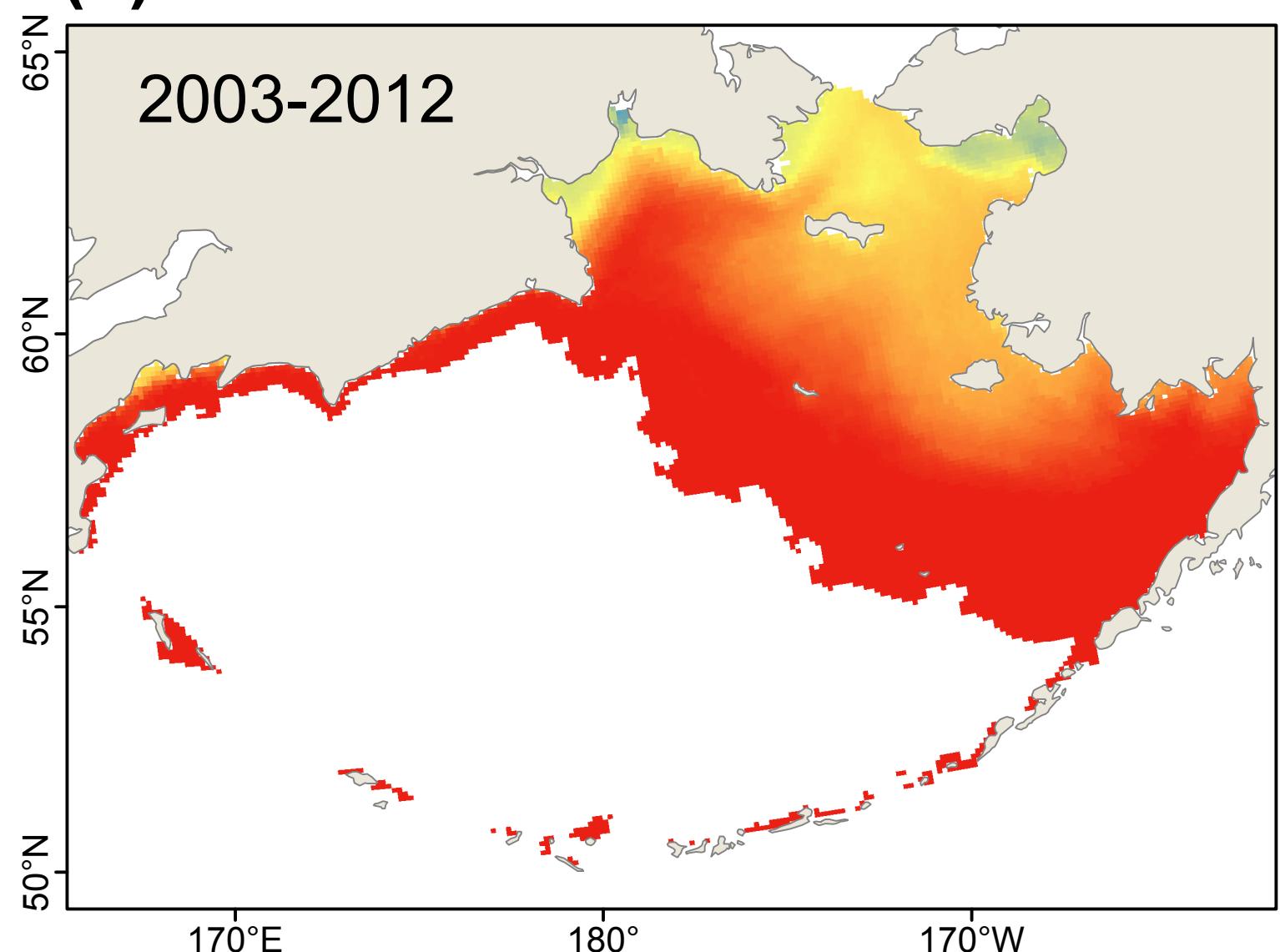


# *Ciona savignyi: Weekly Survival*

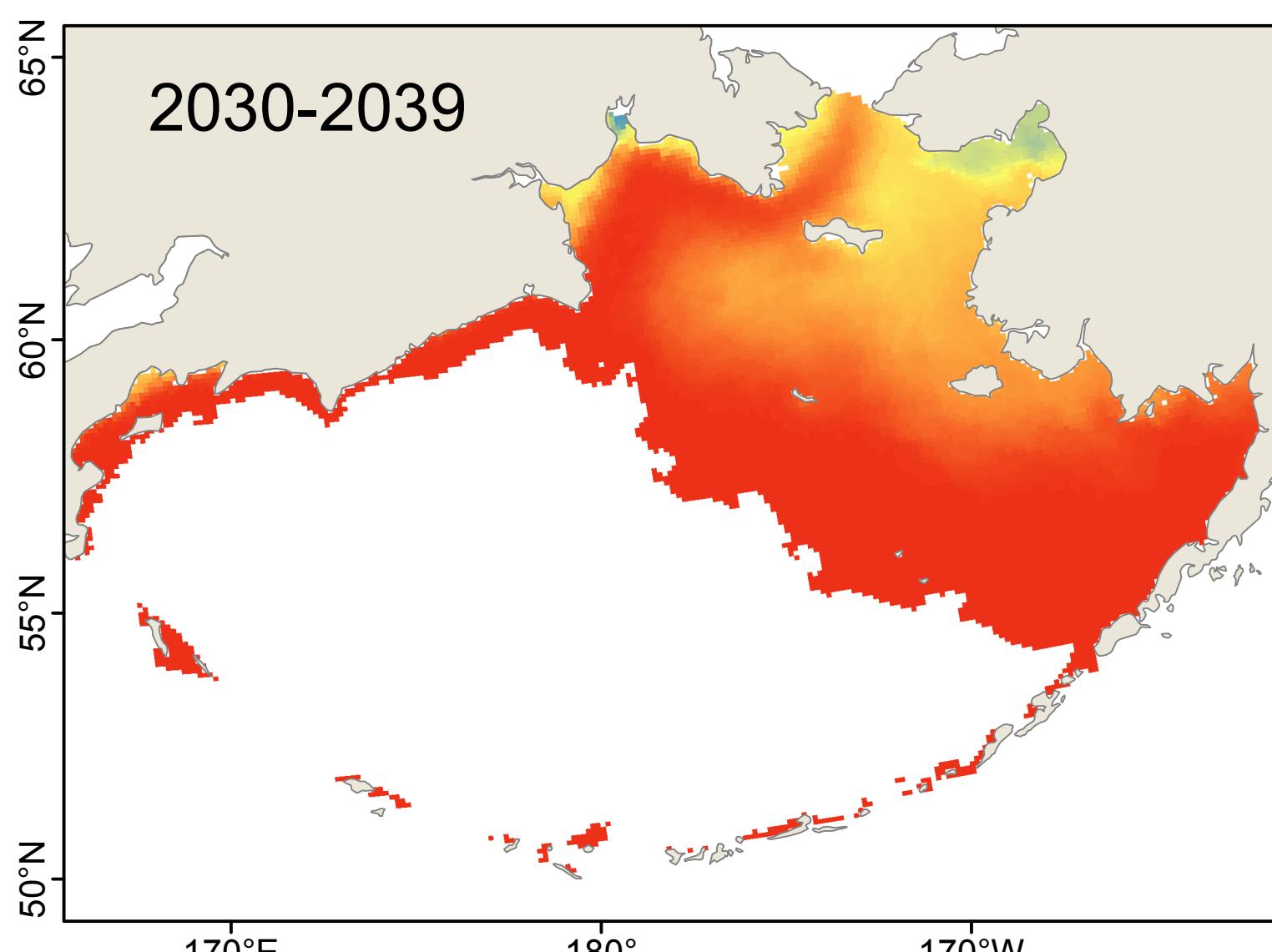
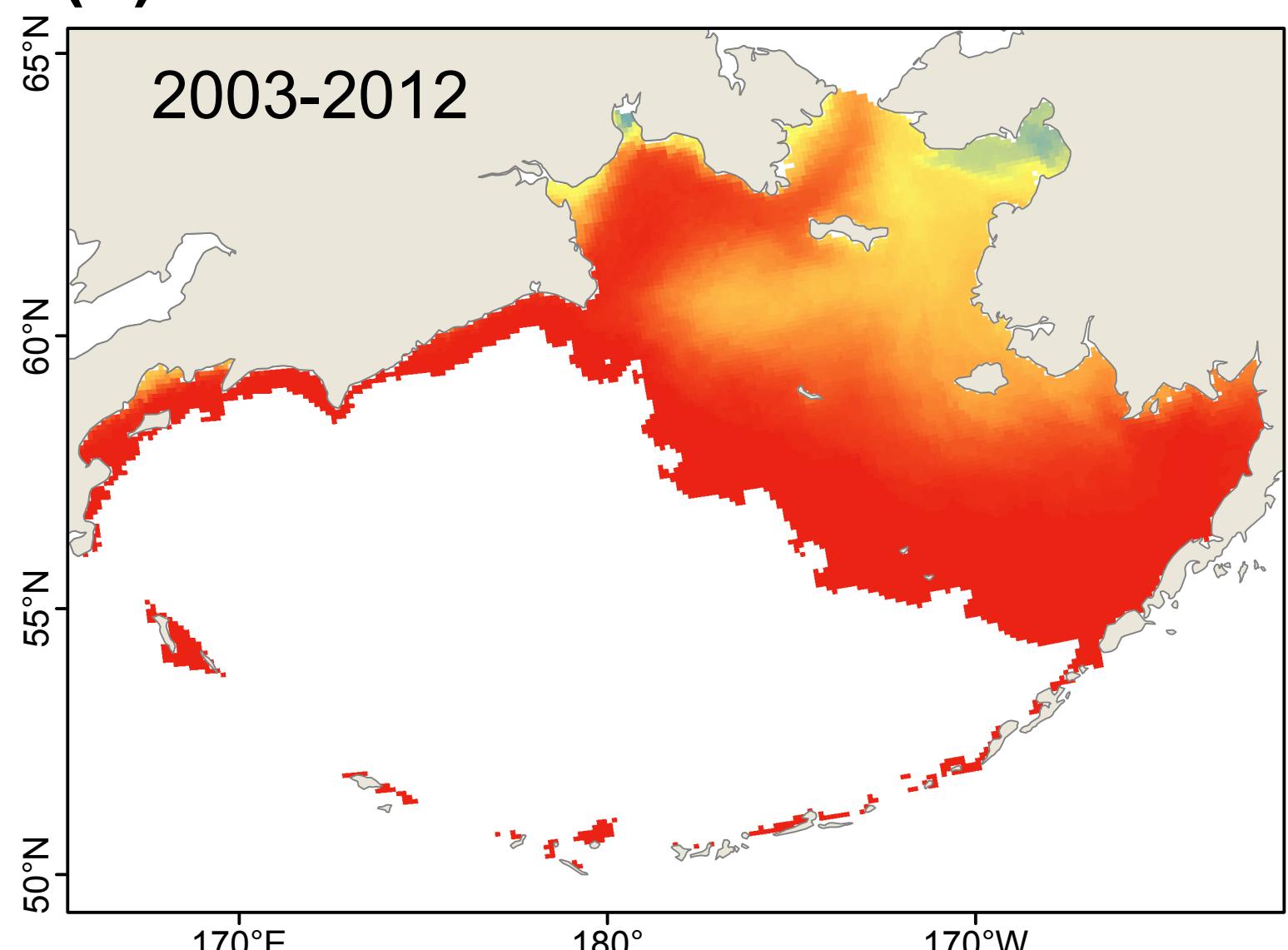
Average number of weeks of suitable habitat



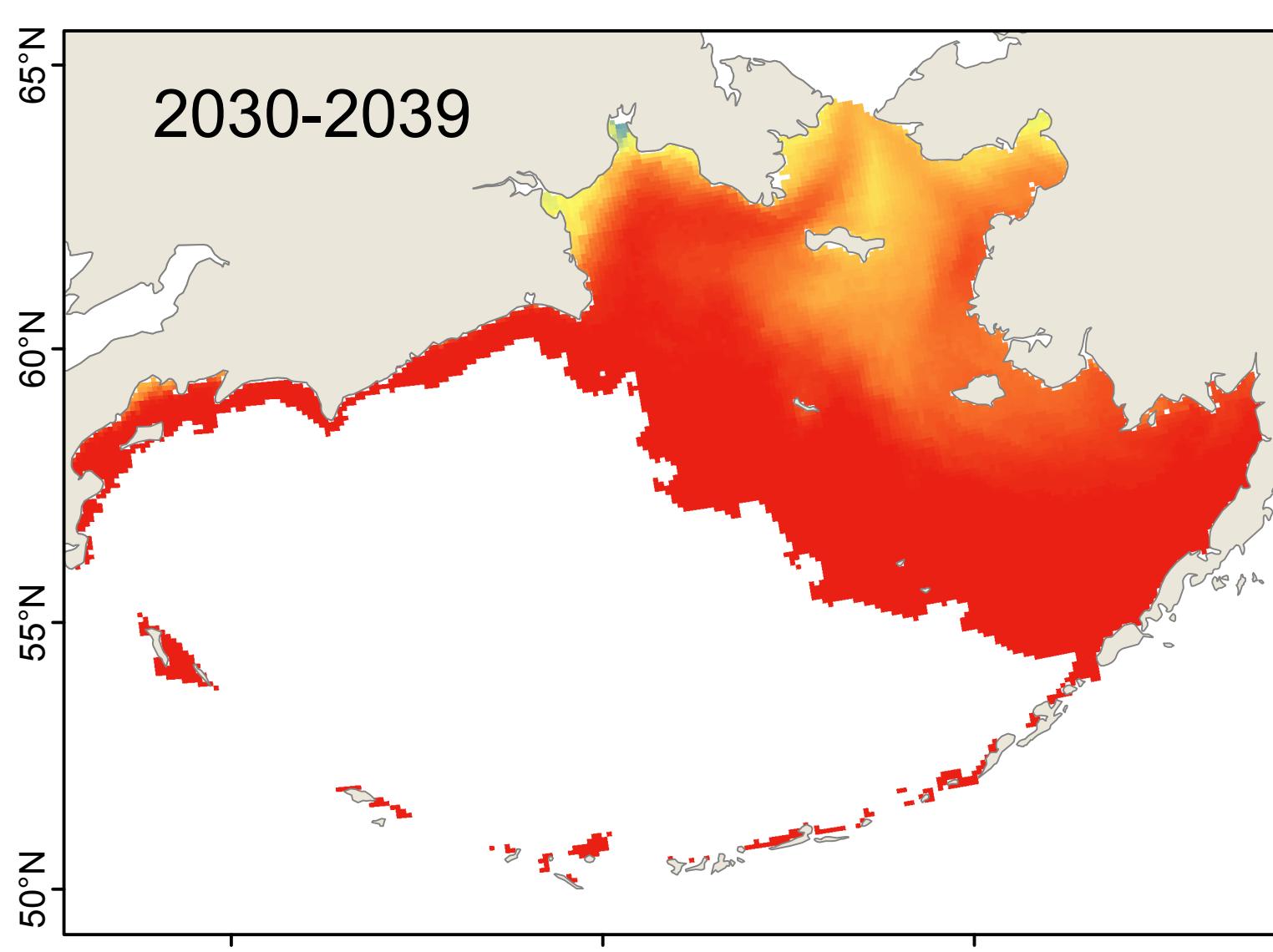
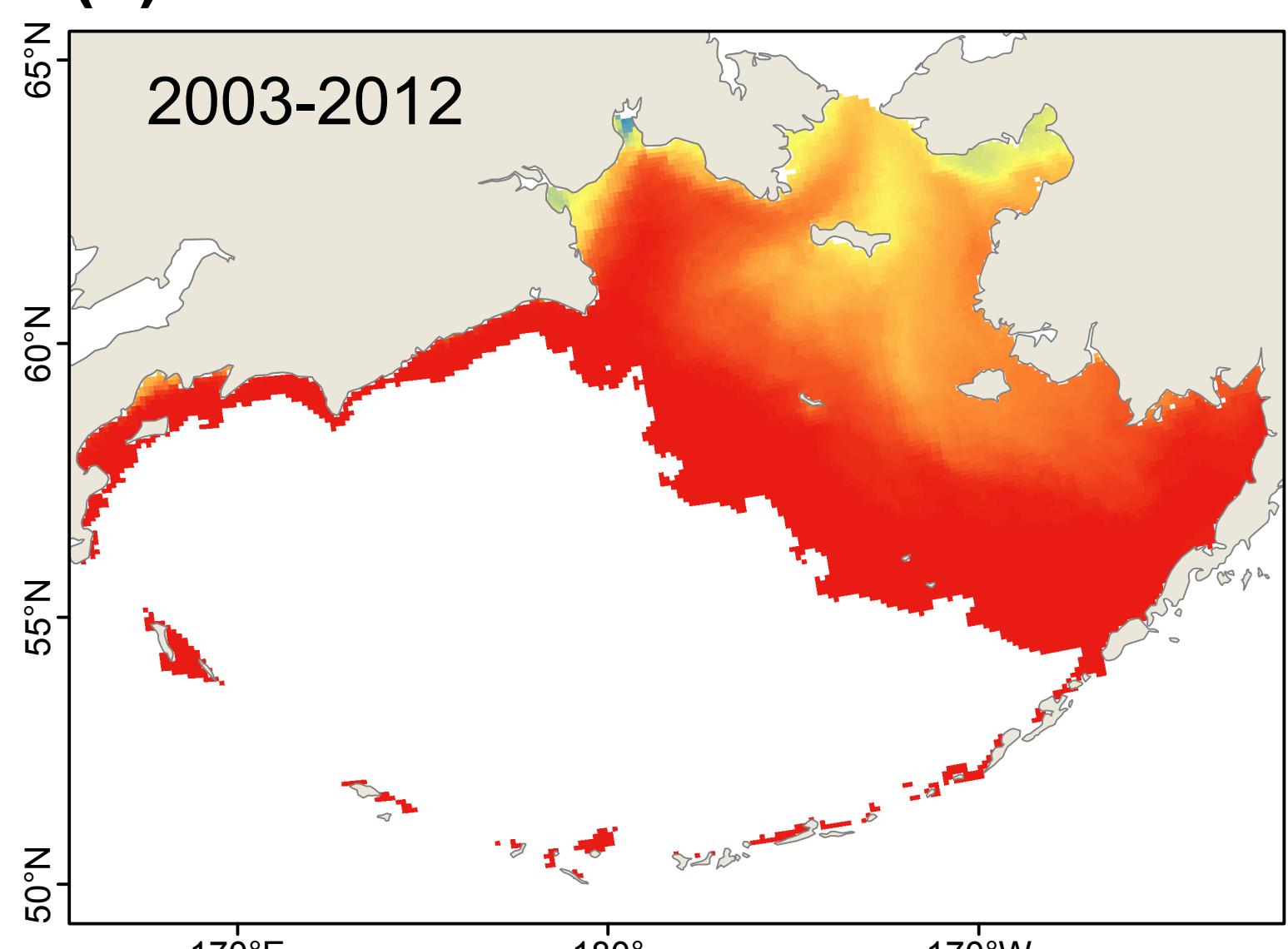
(a) Model: CGCM3-t47



(b) Model: ECHO-G

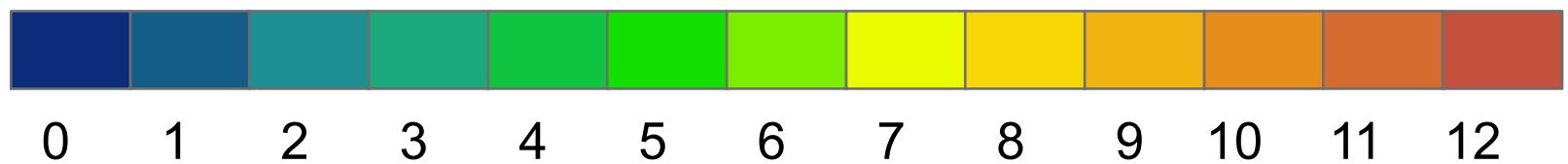


(c) Model: MIROC3.2

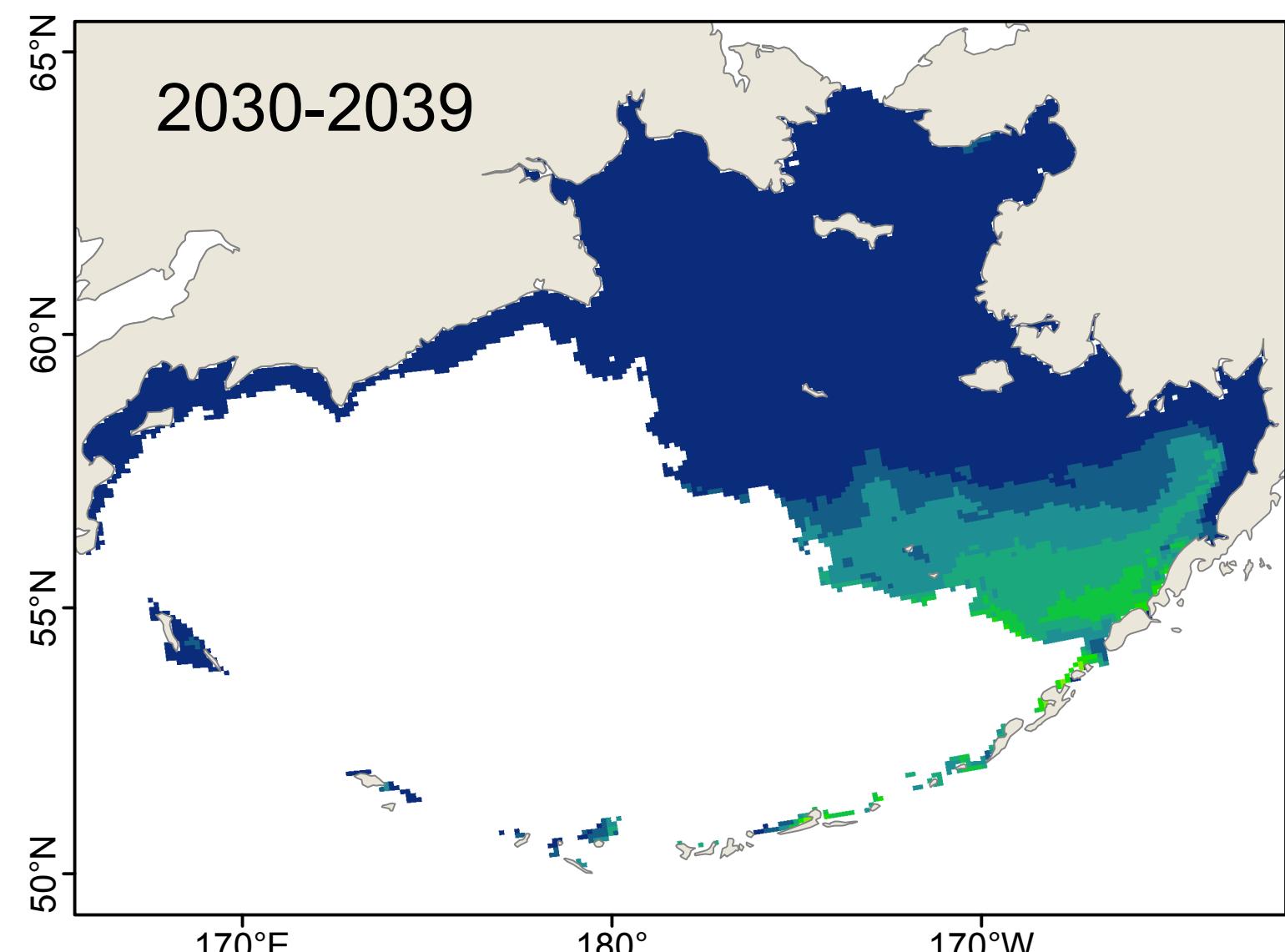
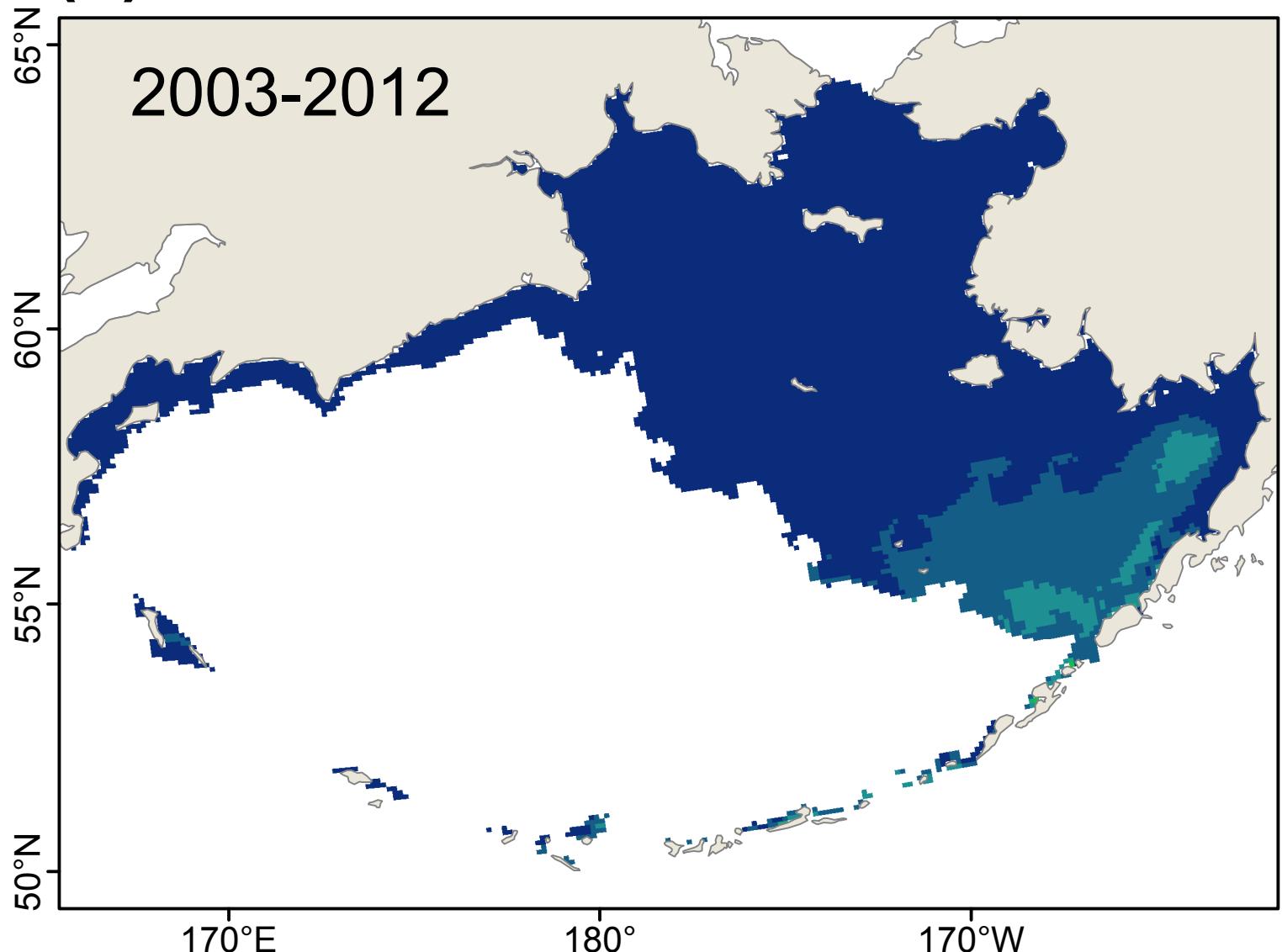


# *Ciona savignyi: Reproduction*

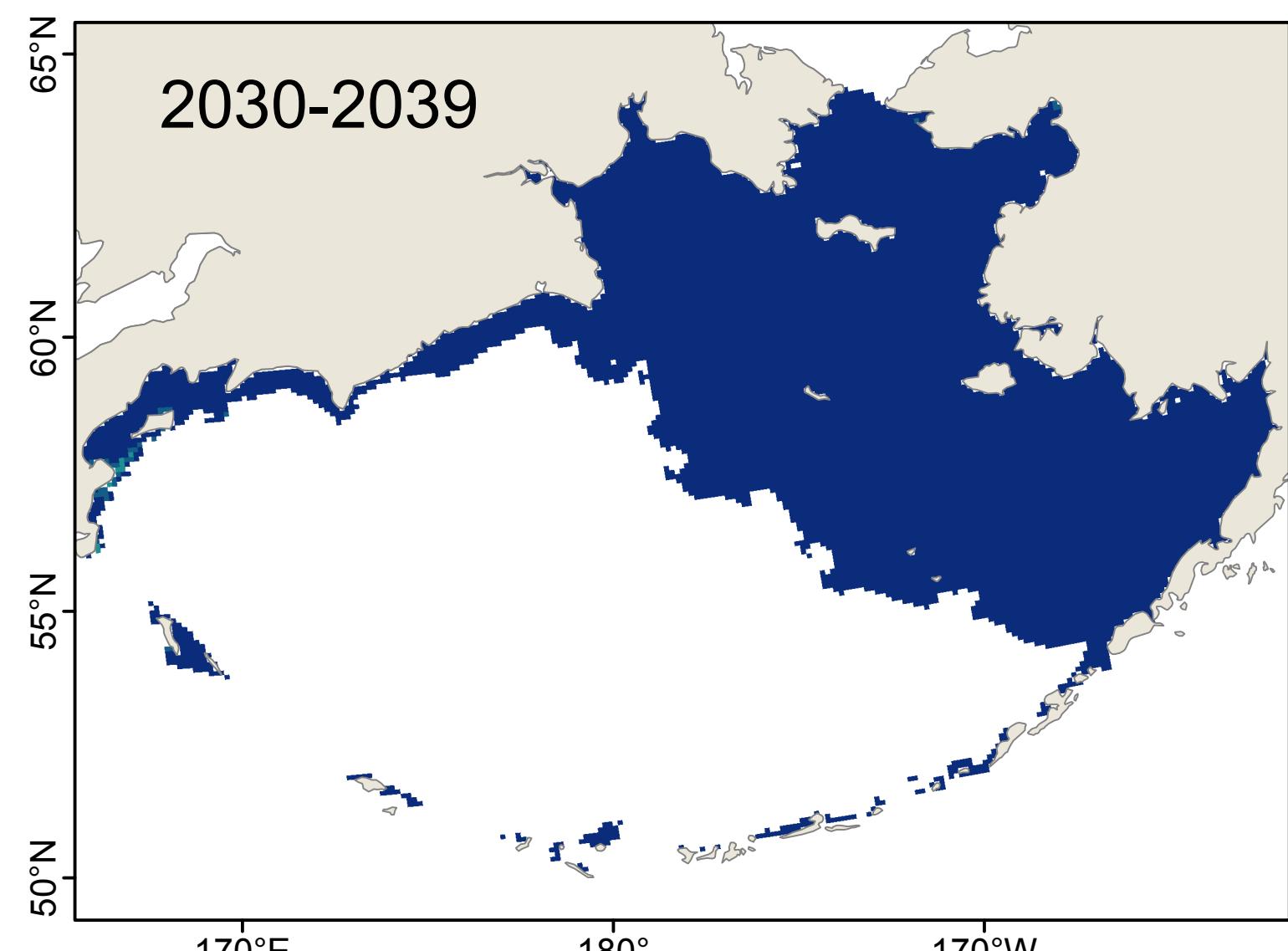
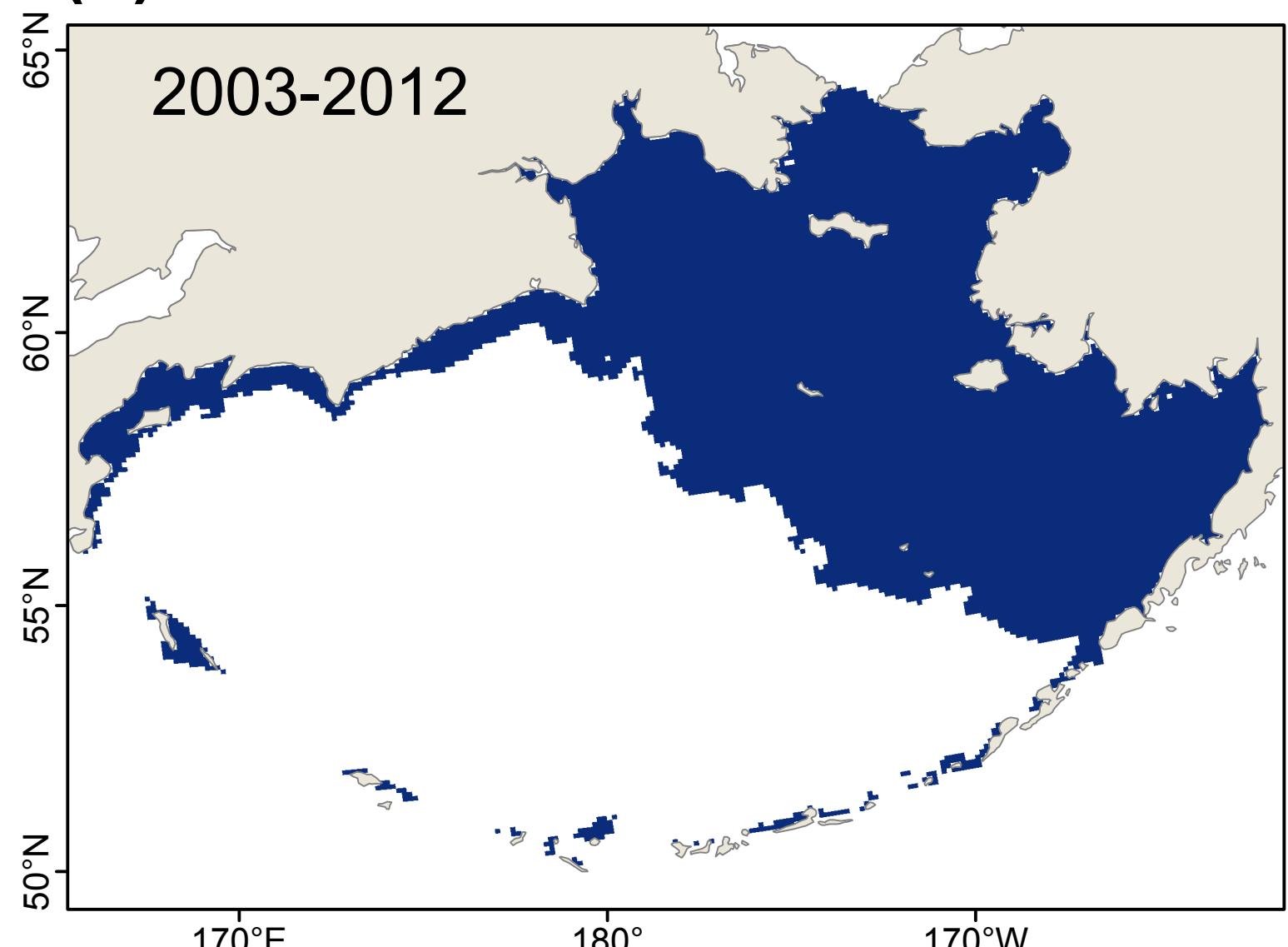
Average number of consecutive weeks of suitable habitat



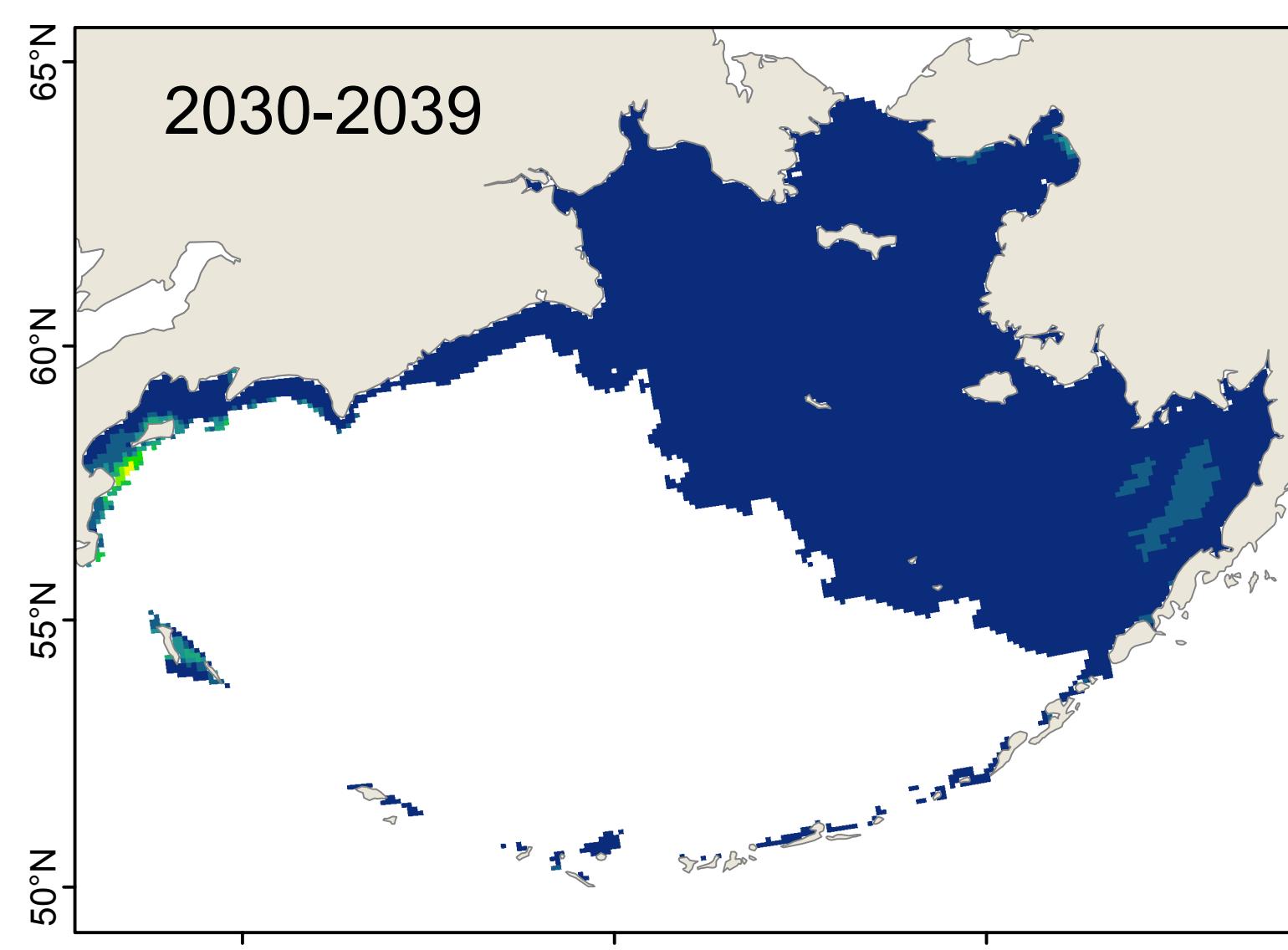
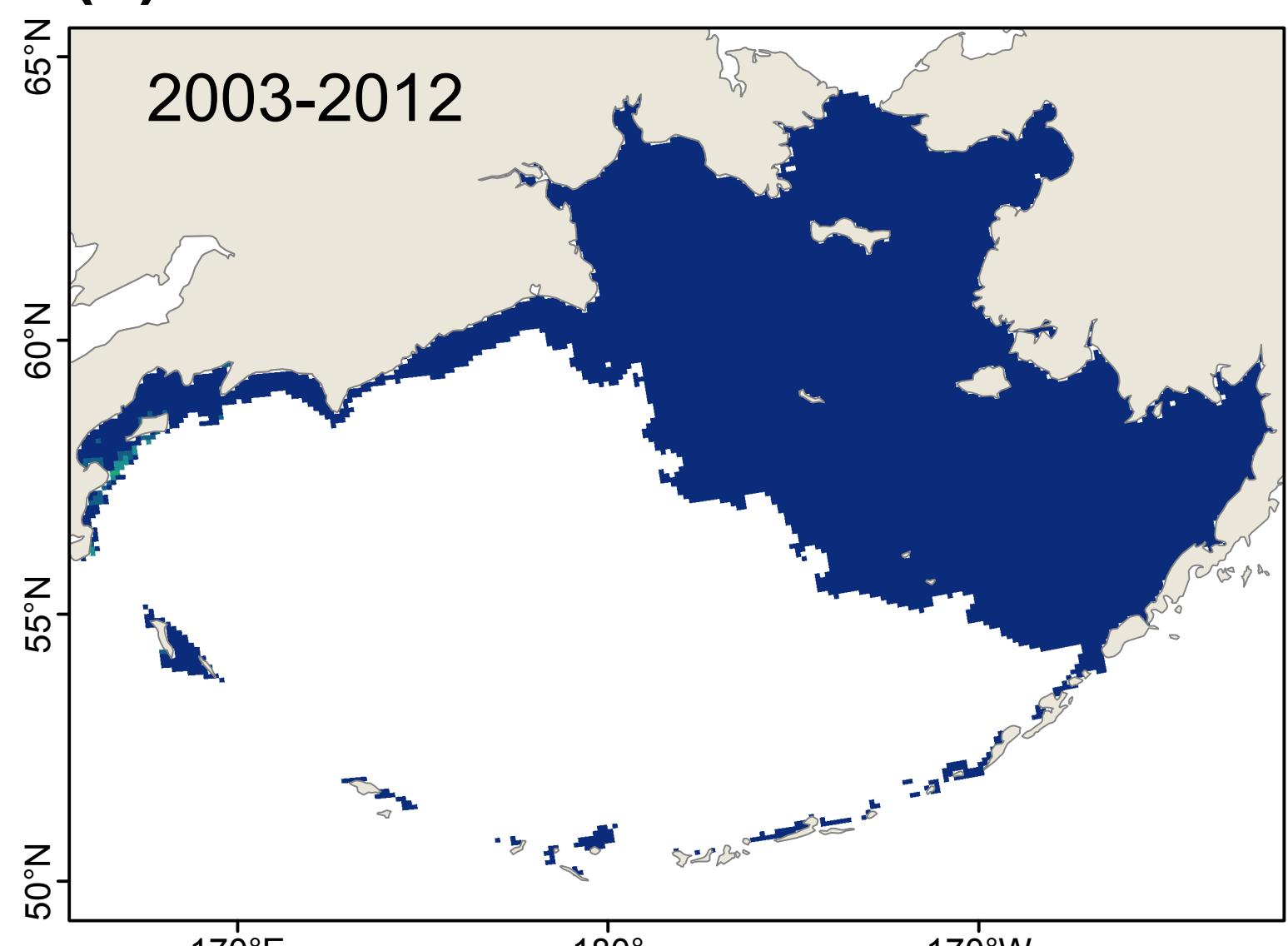
(a) Model: CGCM3-t47



(b) Model: ECHO-G

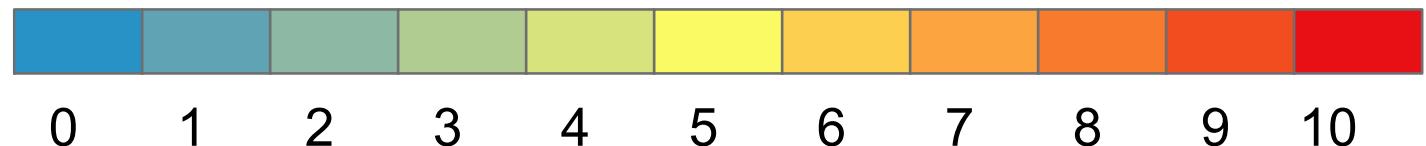


(c) Model: MIROC3.2

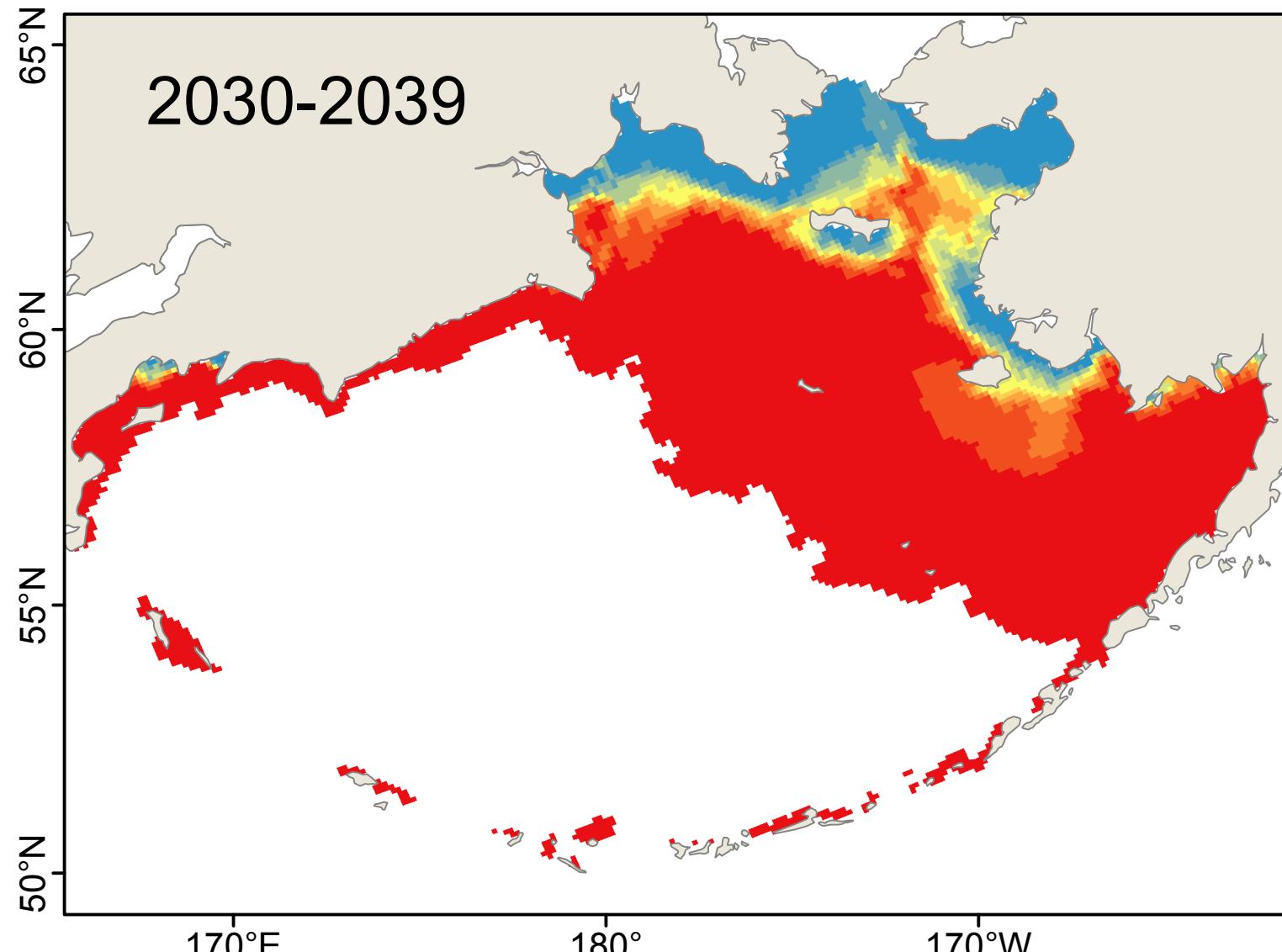
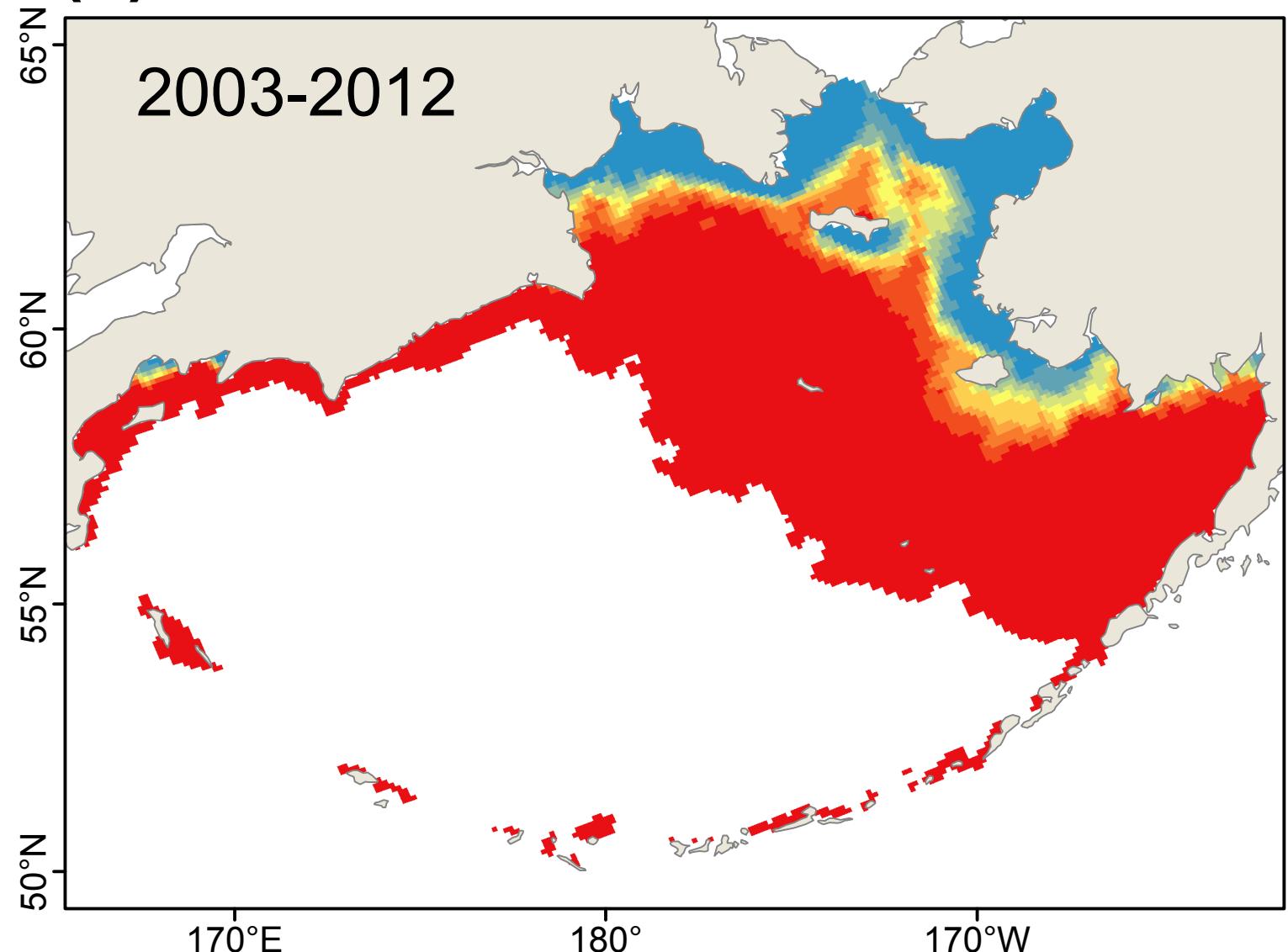


# *Didemnum vexillum*: Year-round Survival

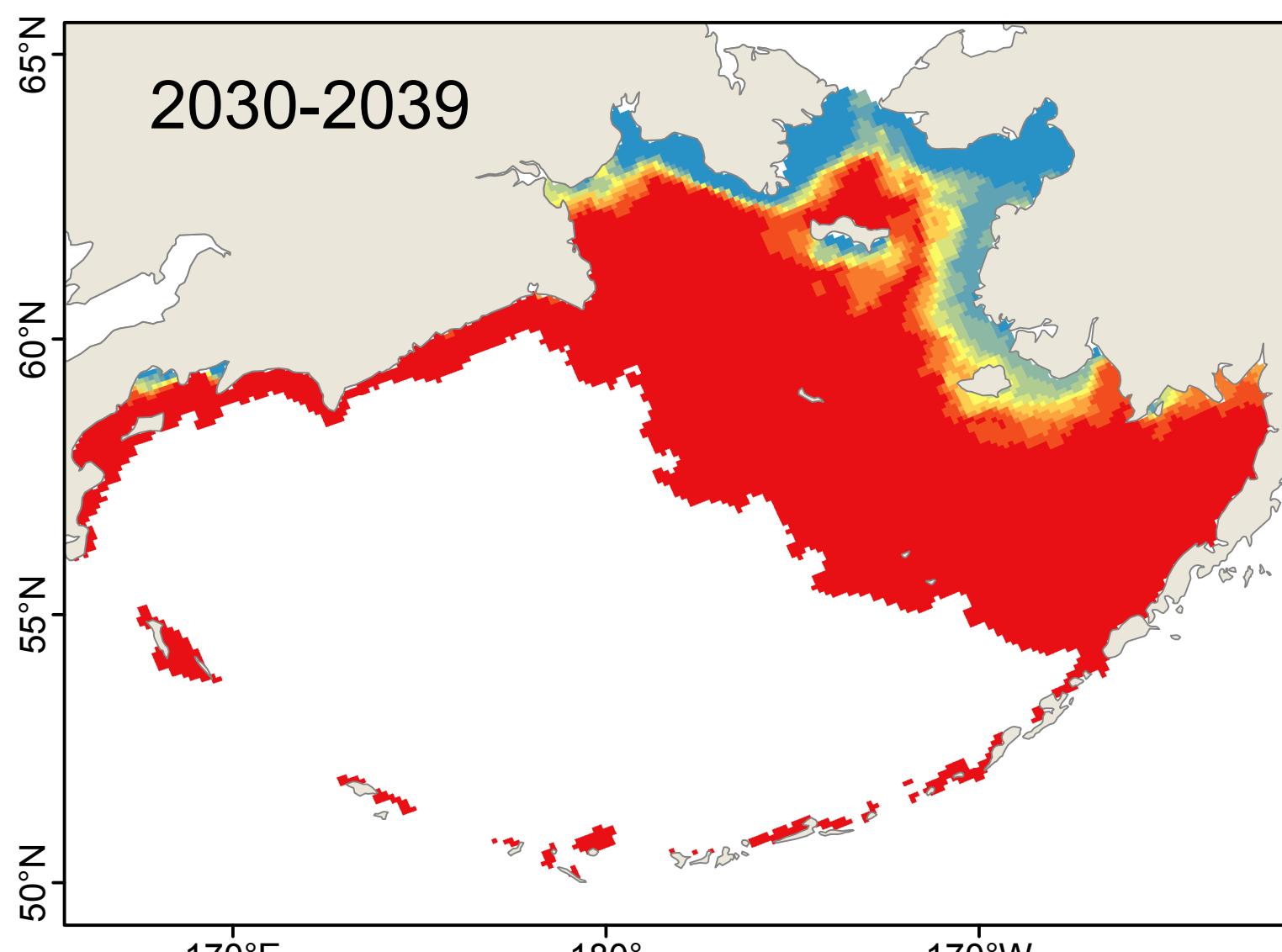
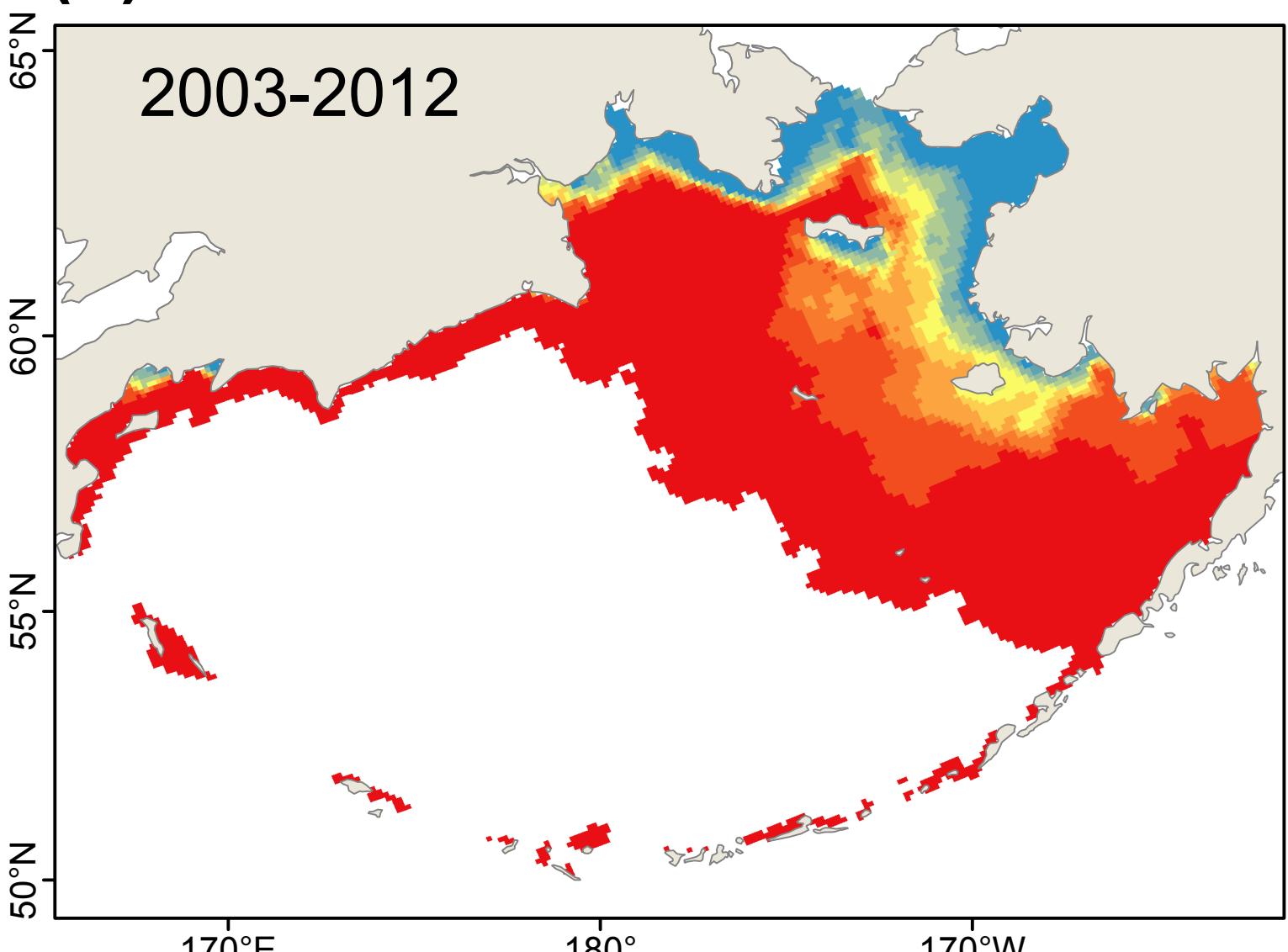
Number of years with suitable habitat



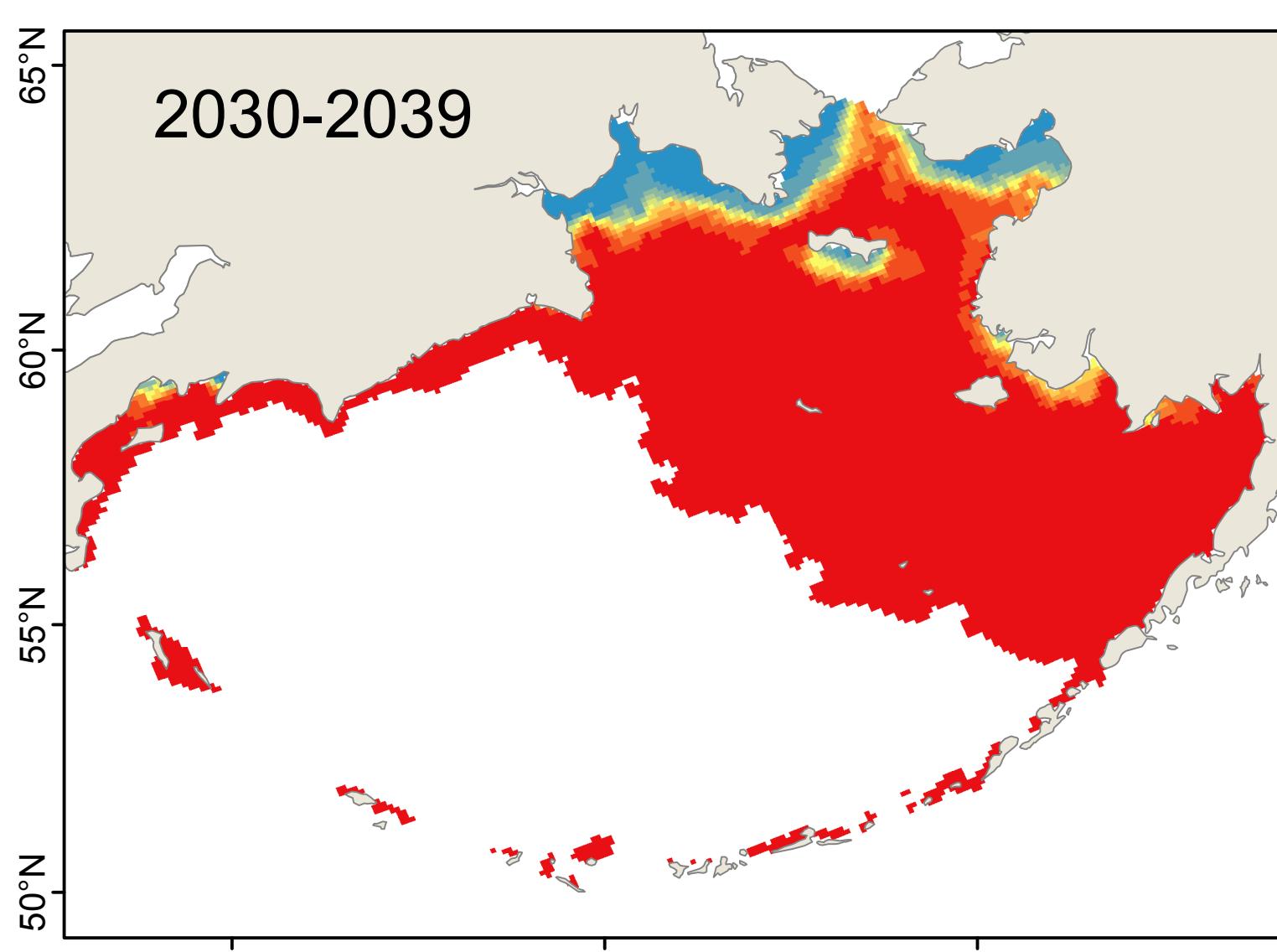
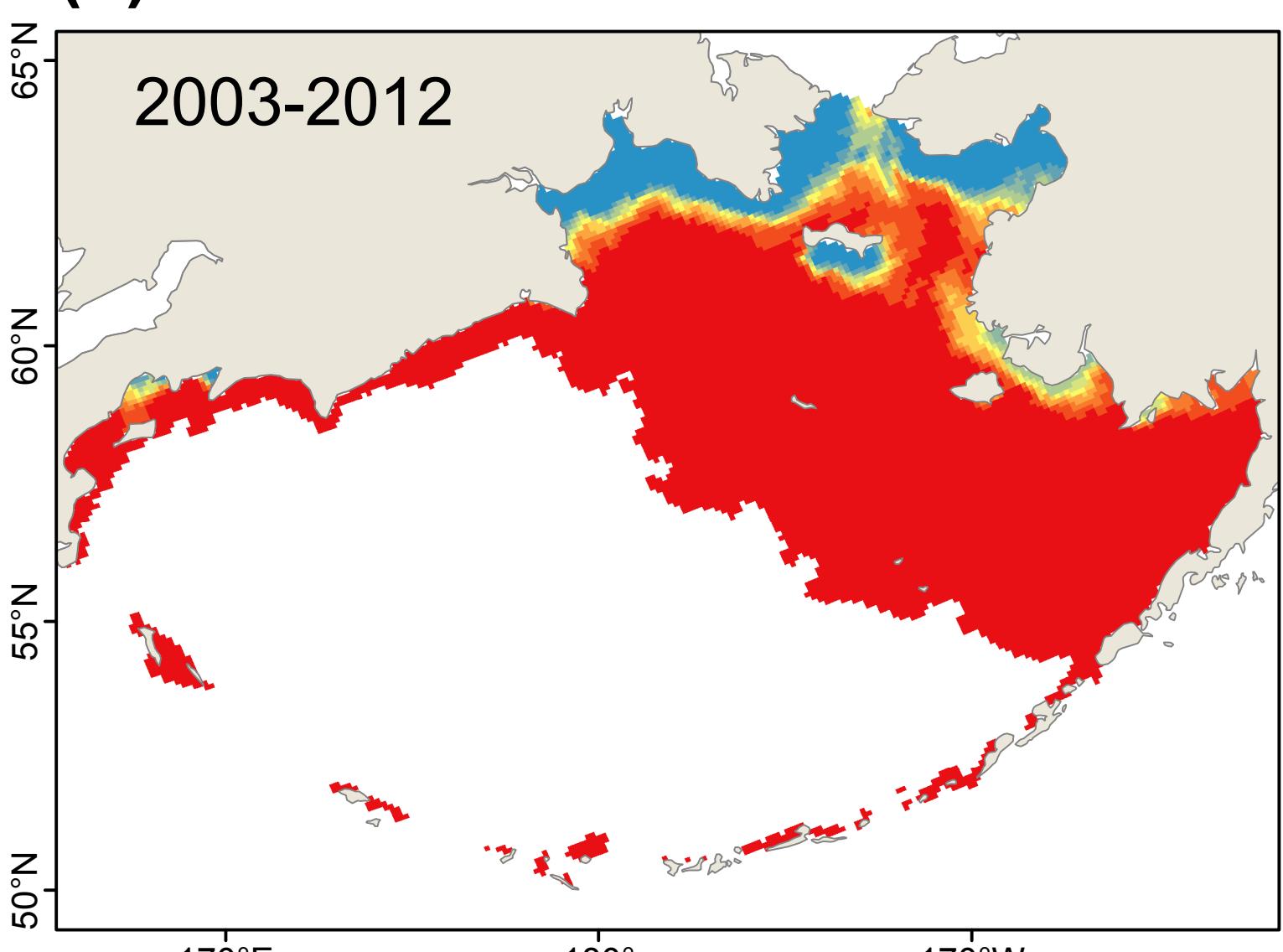
(a) Model: CGCM3-t47



(b) Model: ECHO-G

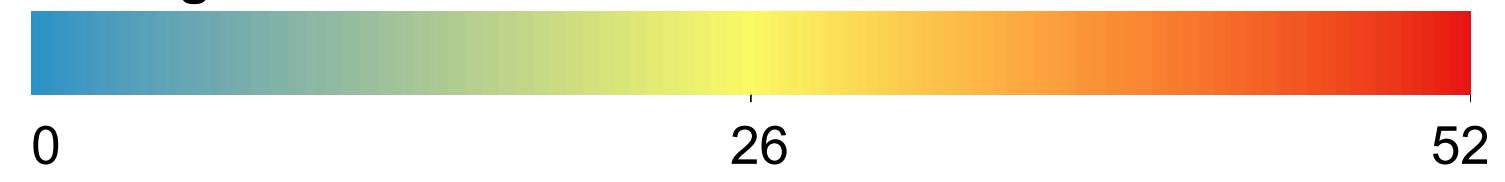


(c) Model: MIROC3.2

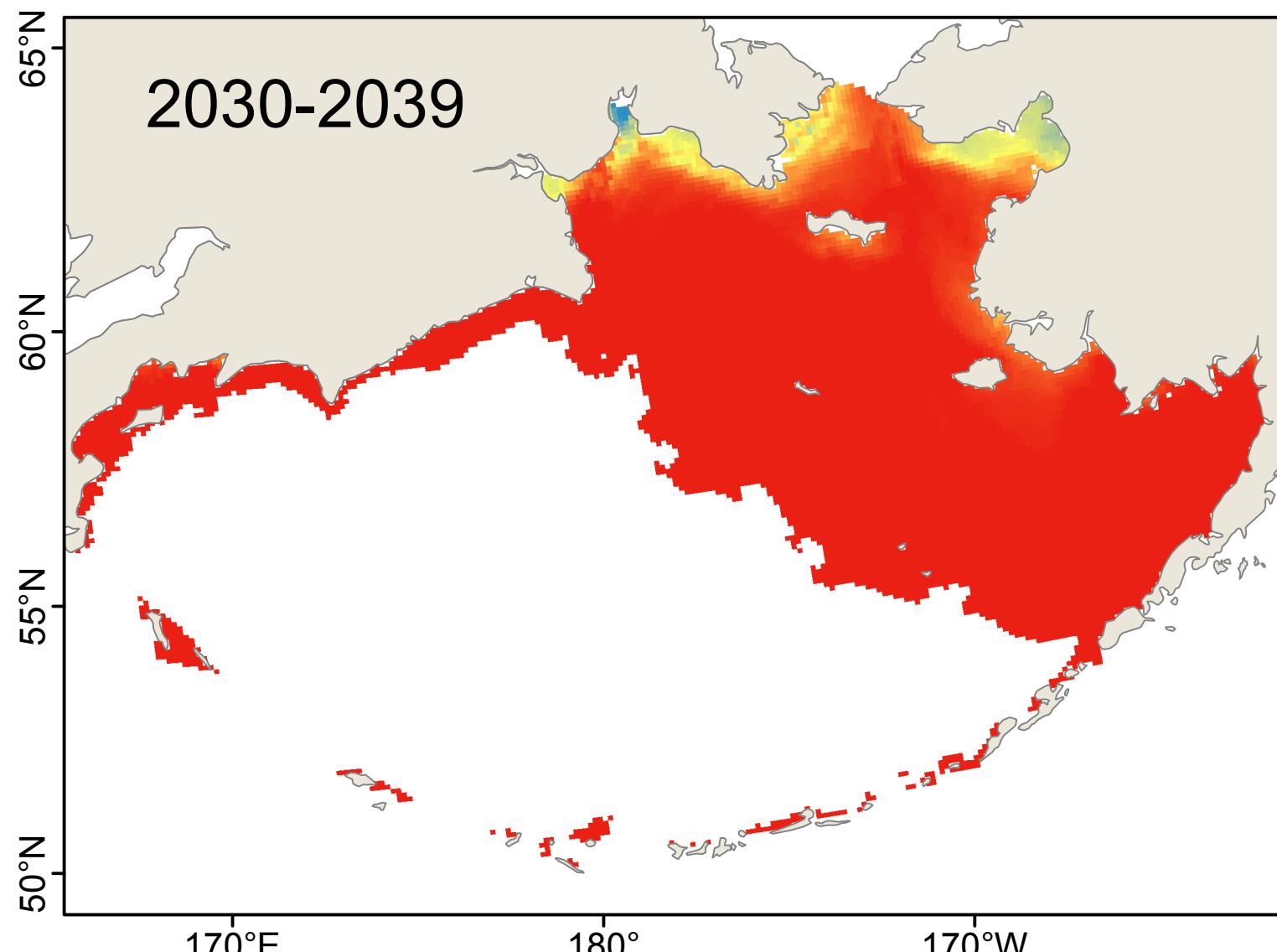
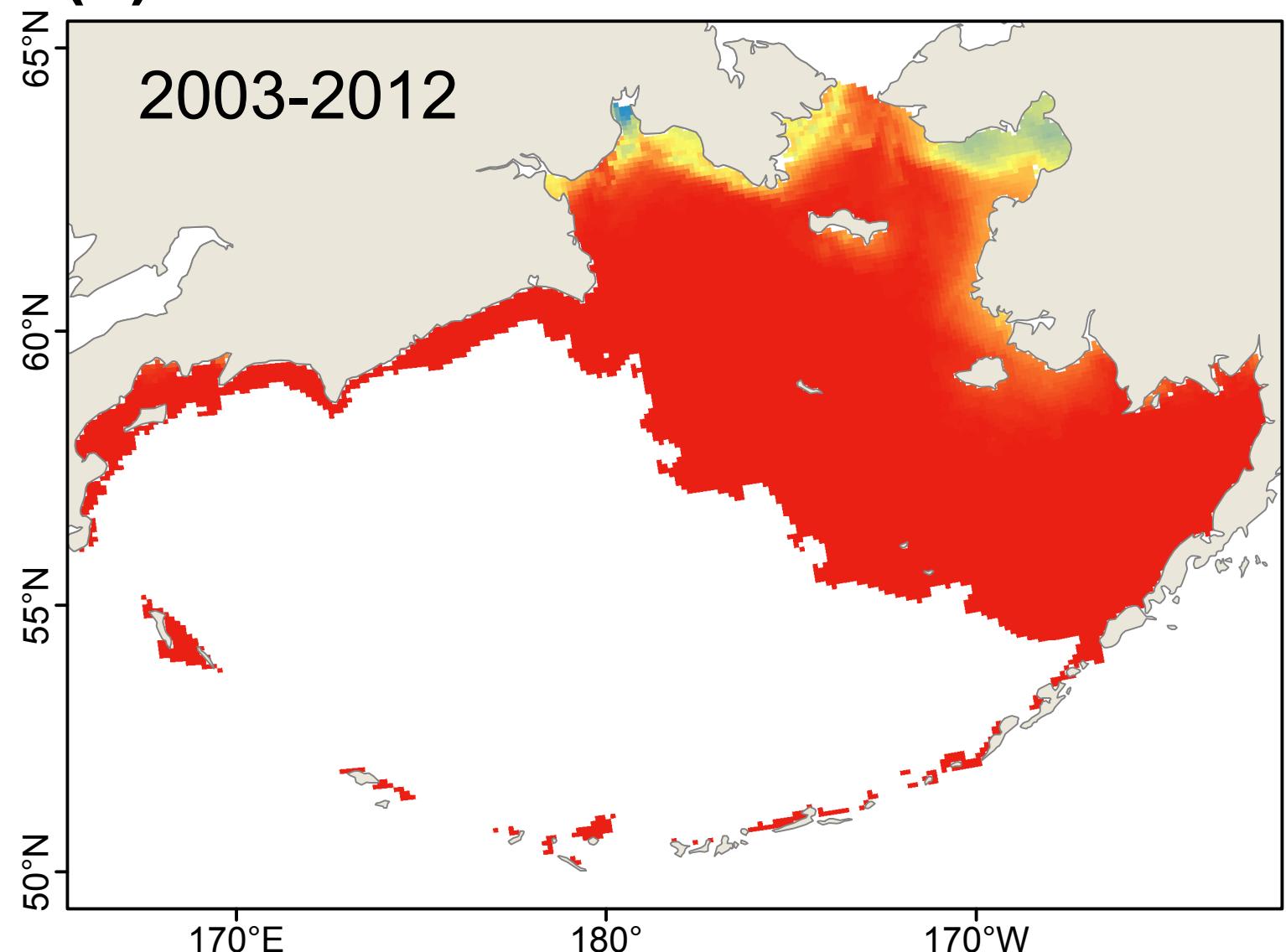


# *Didemnum vexillum*: Weekly Survival

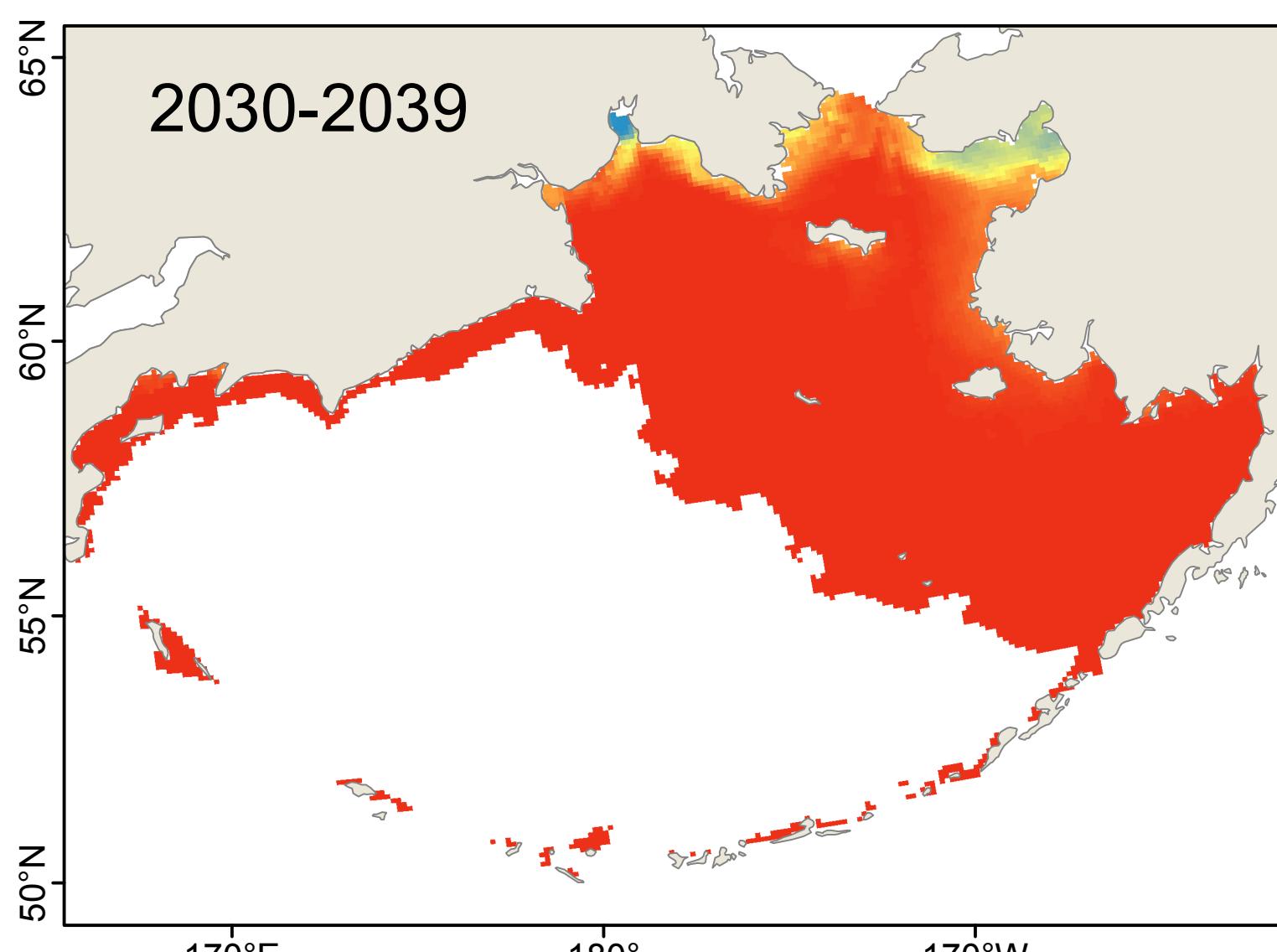
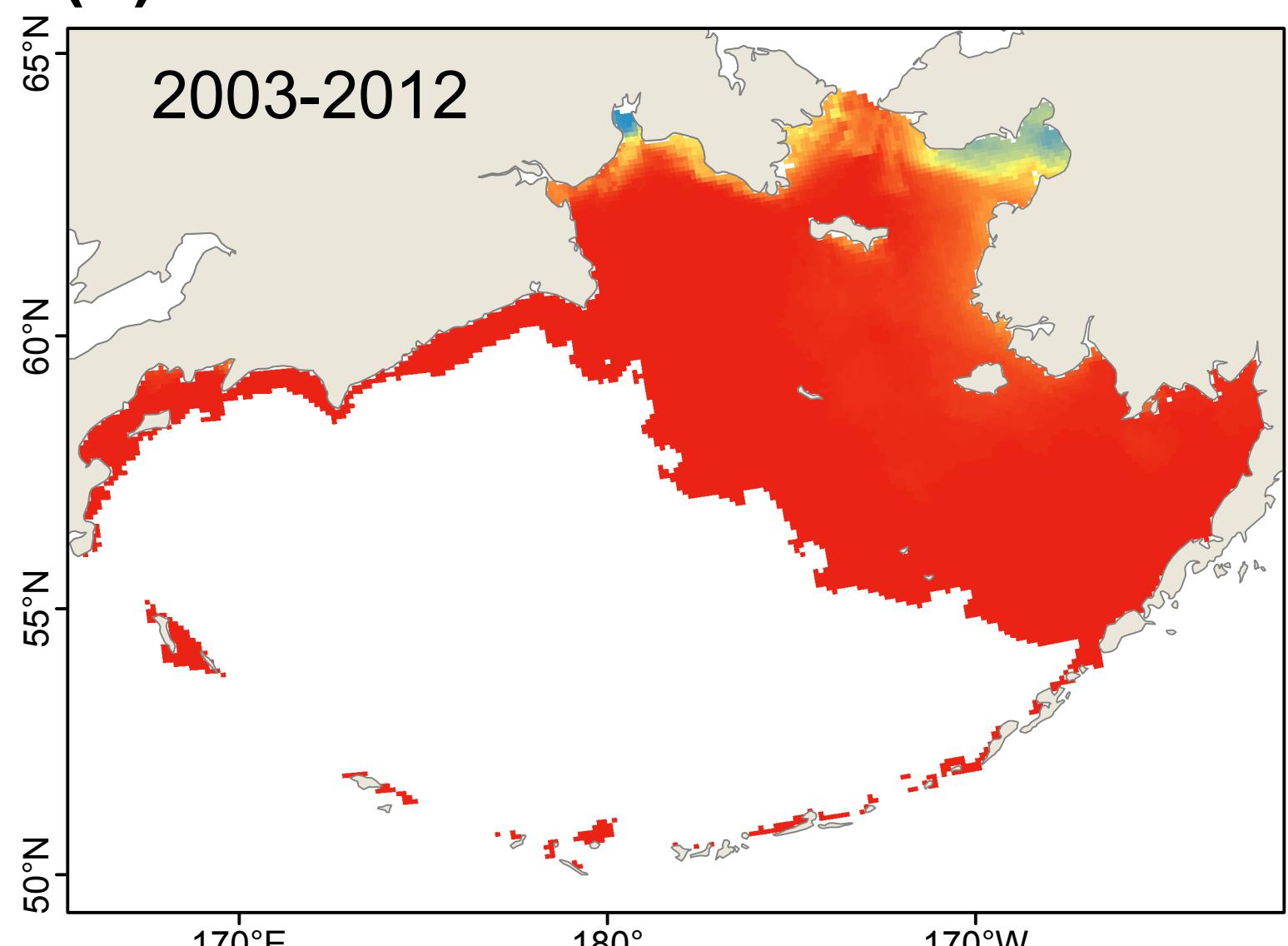
Average number of weeks of suitable habitat



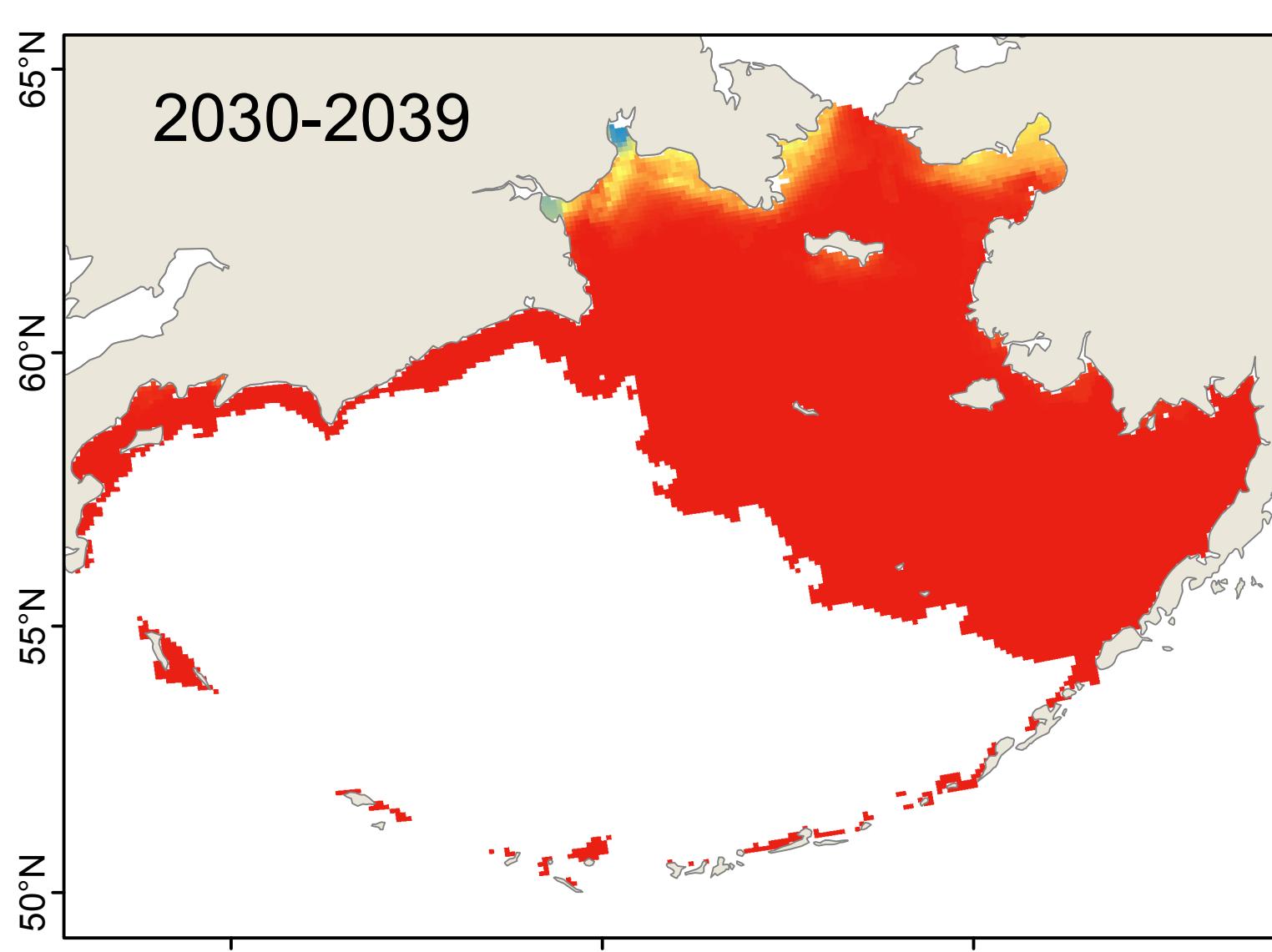
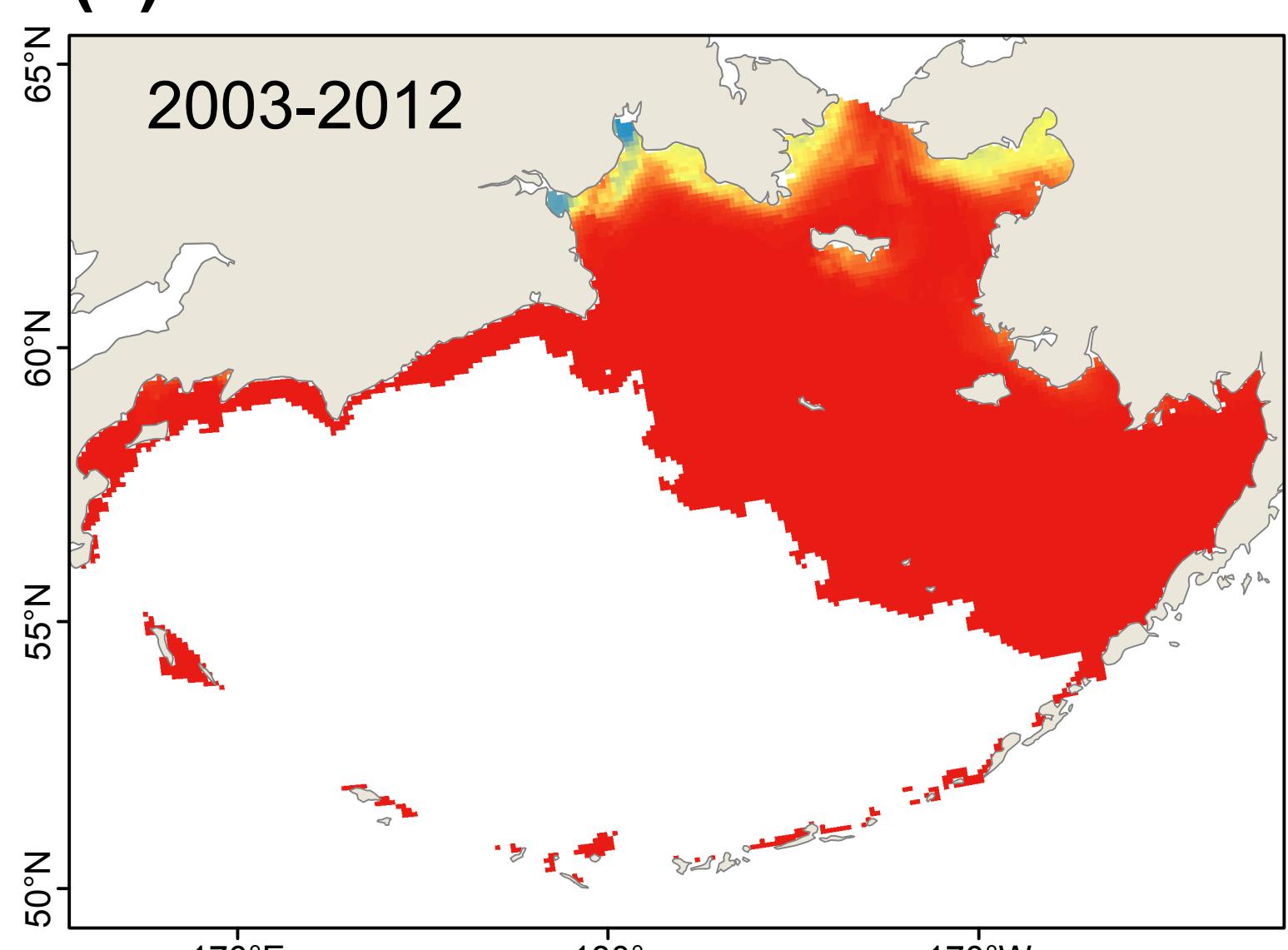
(a) Model: CGCM3-t47



(b) Model: ECHO-G

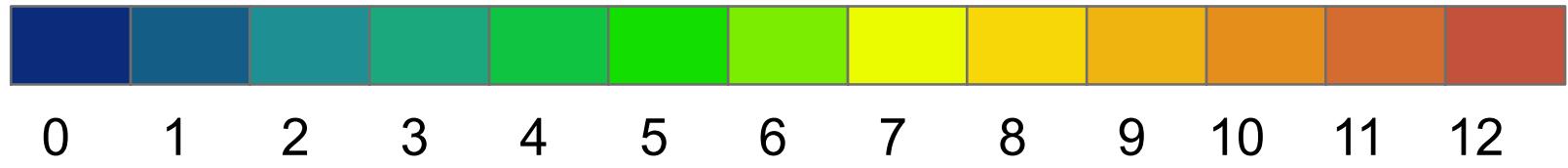


(c) Model: MIROC3.2

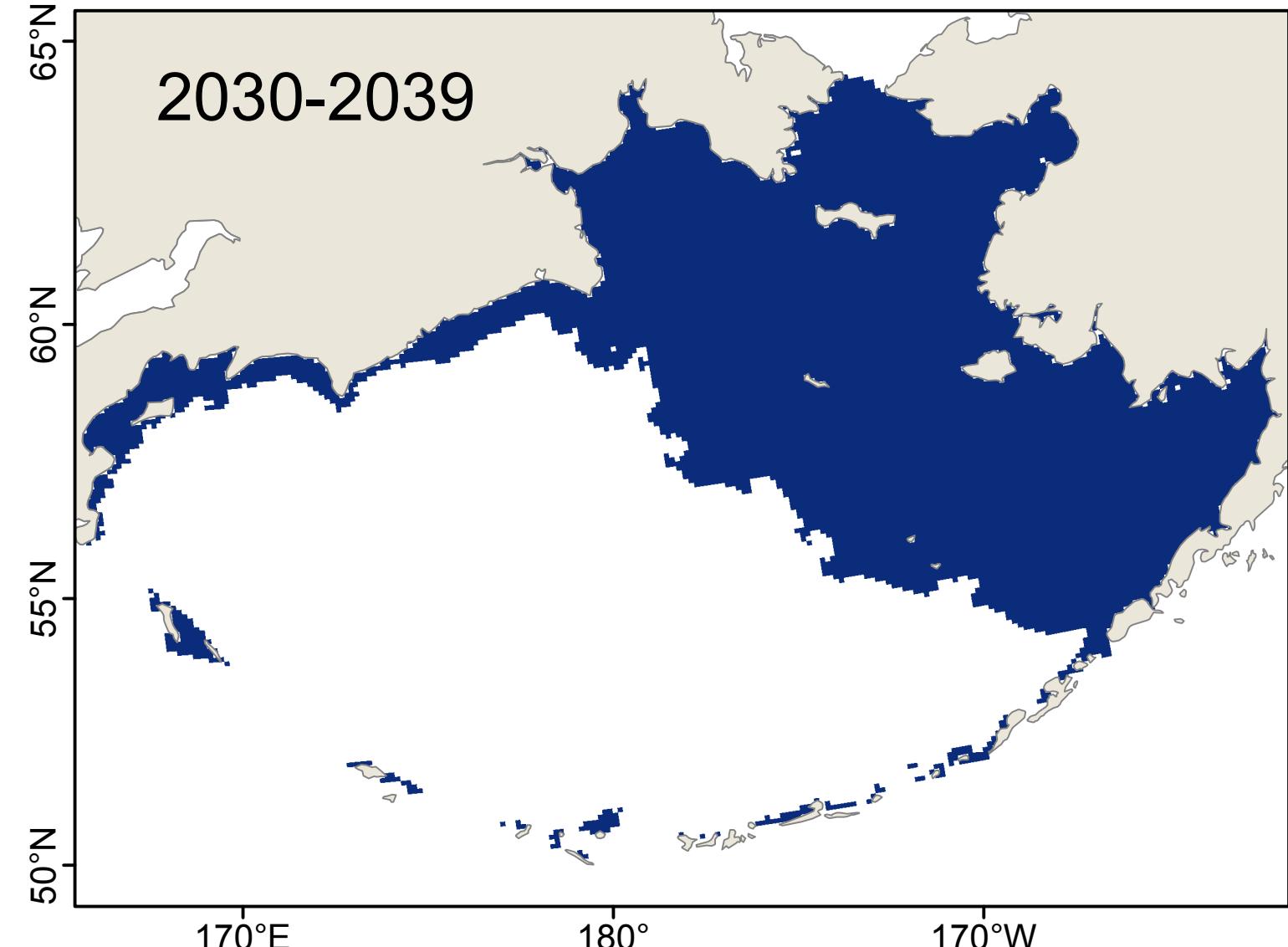
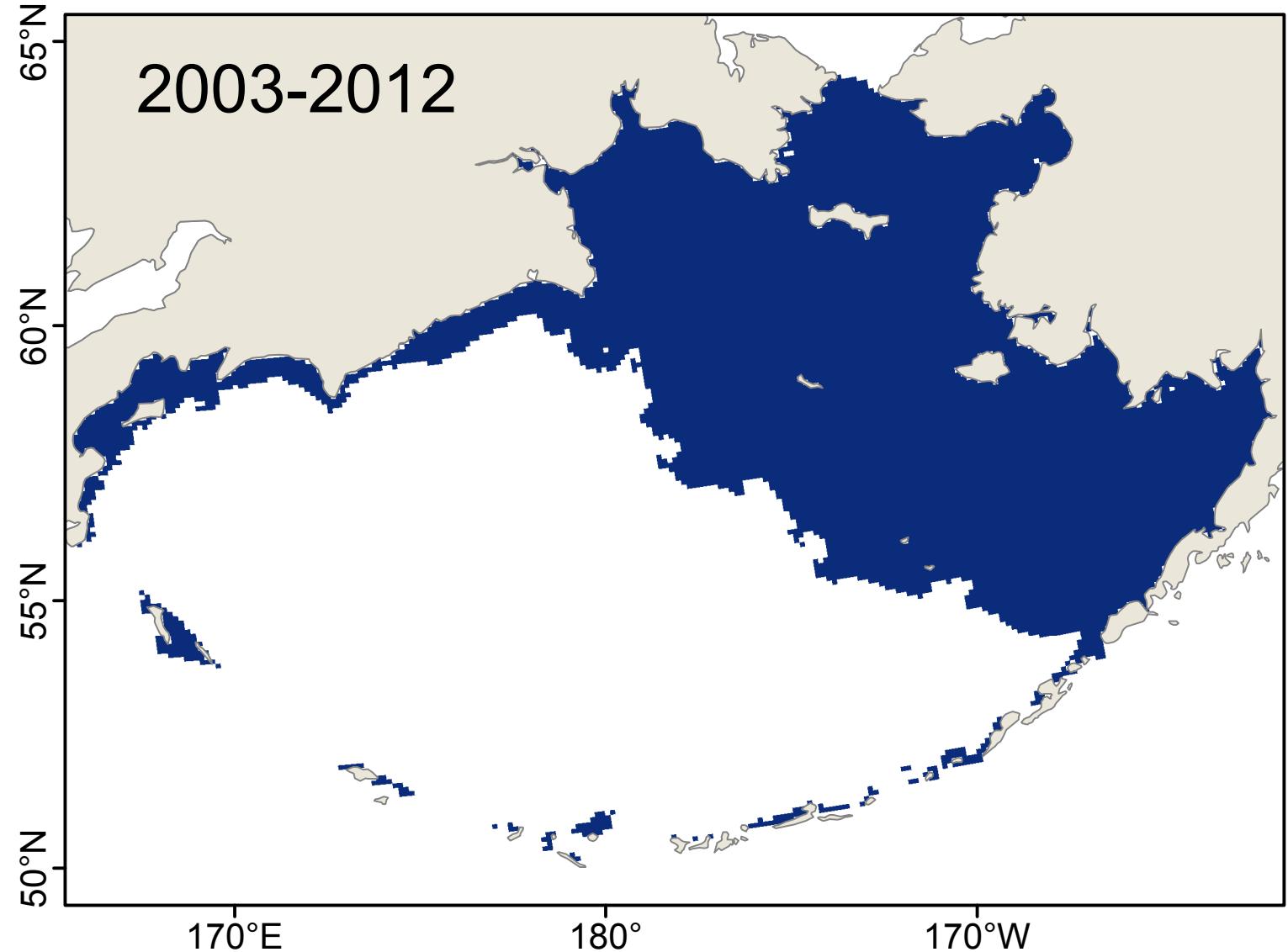


# *Didemnum vexillum: Reproduction*

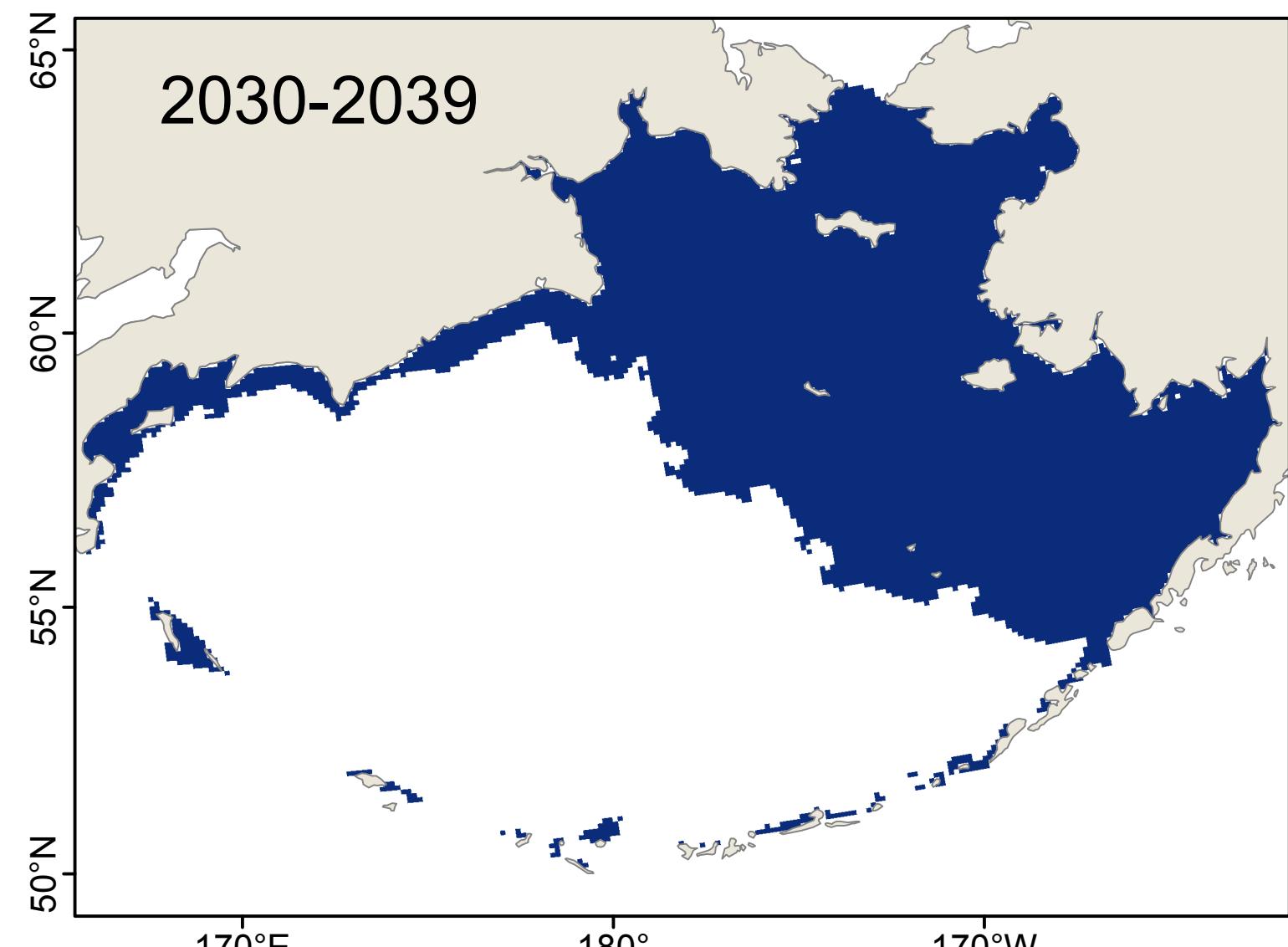
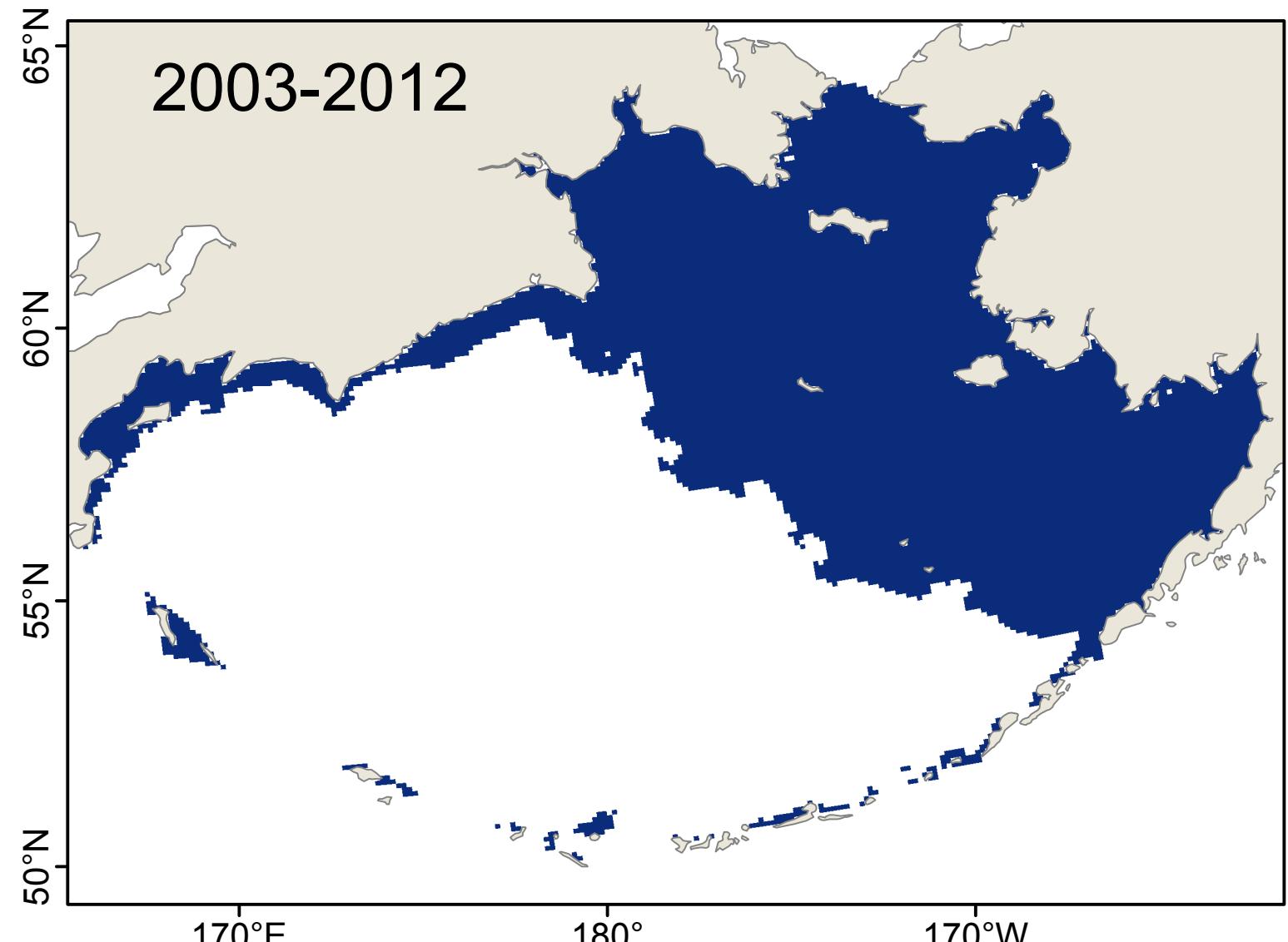
Average number of consecutive weeks of suitable habitat



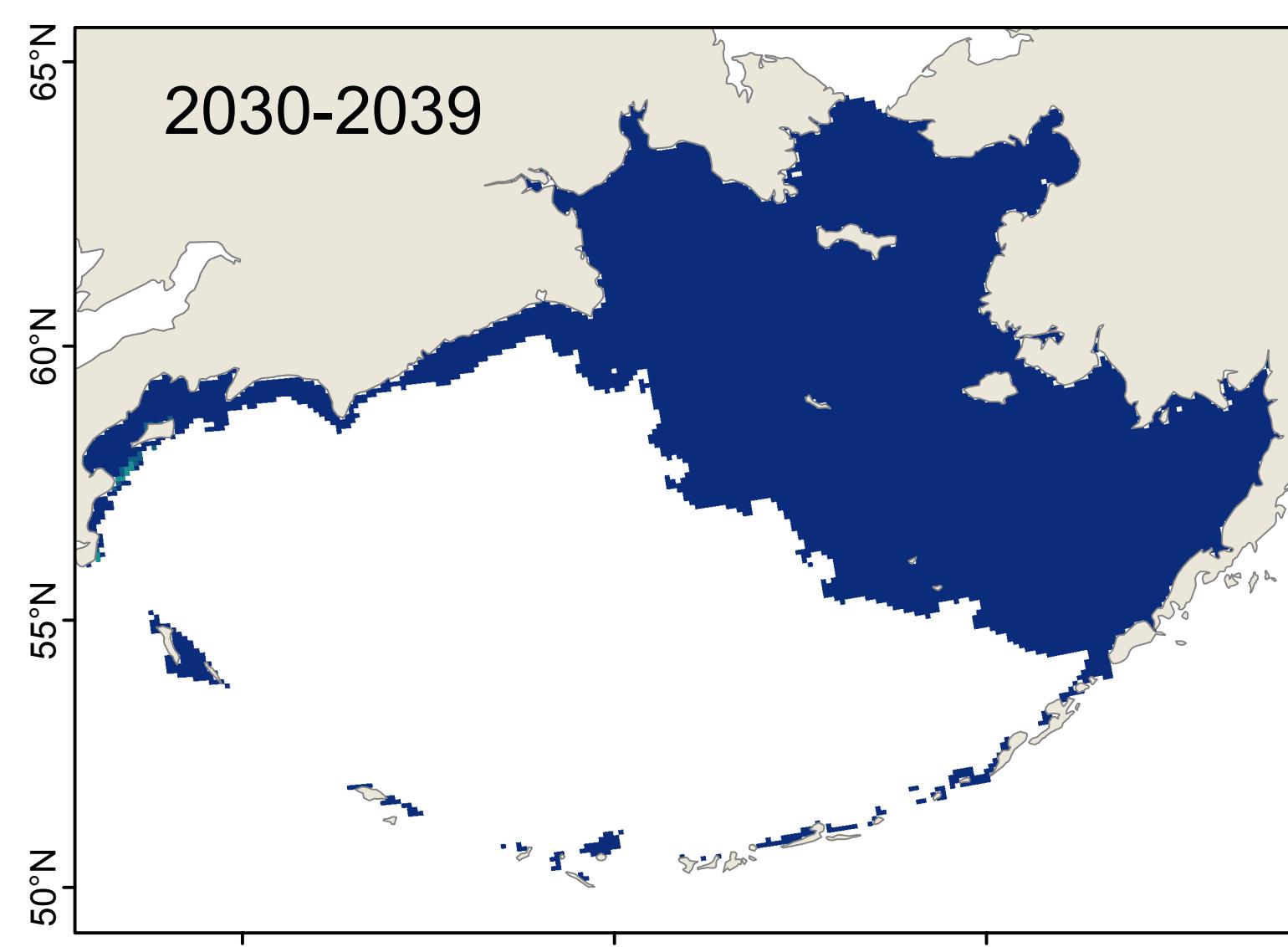
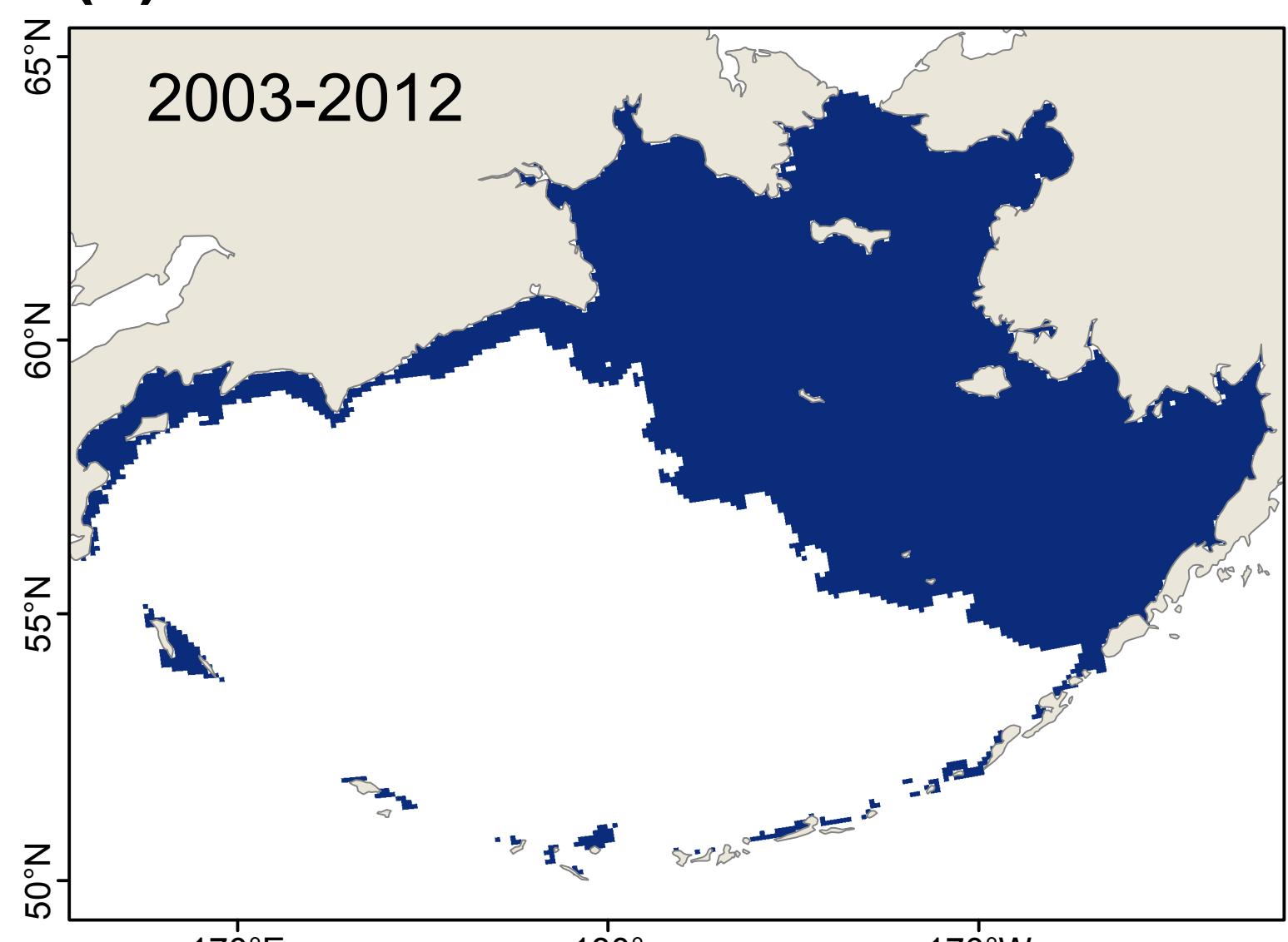
(a) Model: CGCM3-t47



(b) Model: ECHO-G

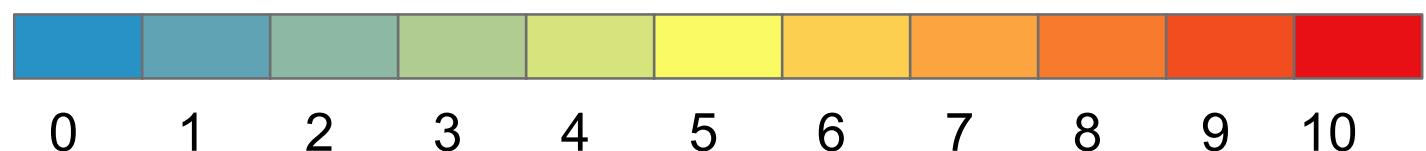


(c) Model: MIROC3.2

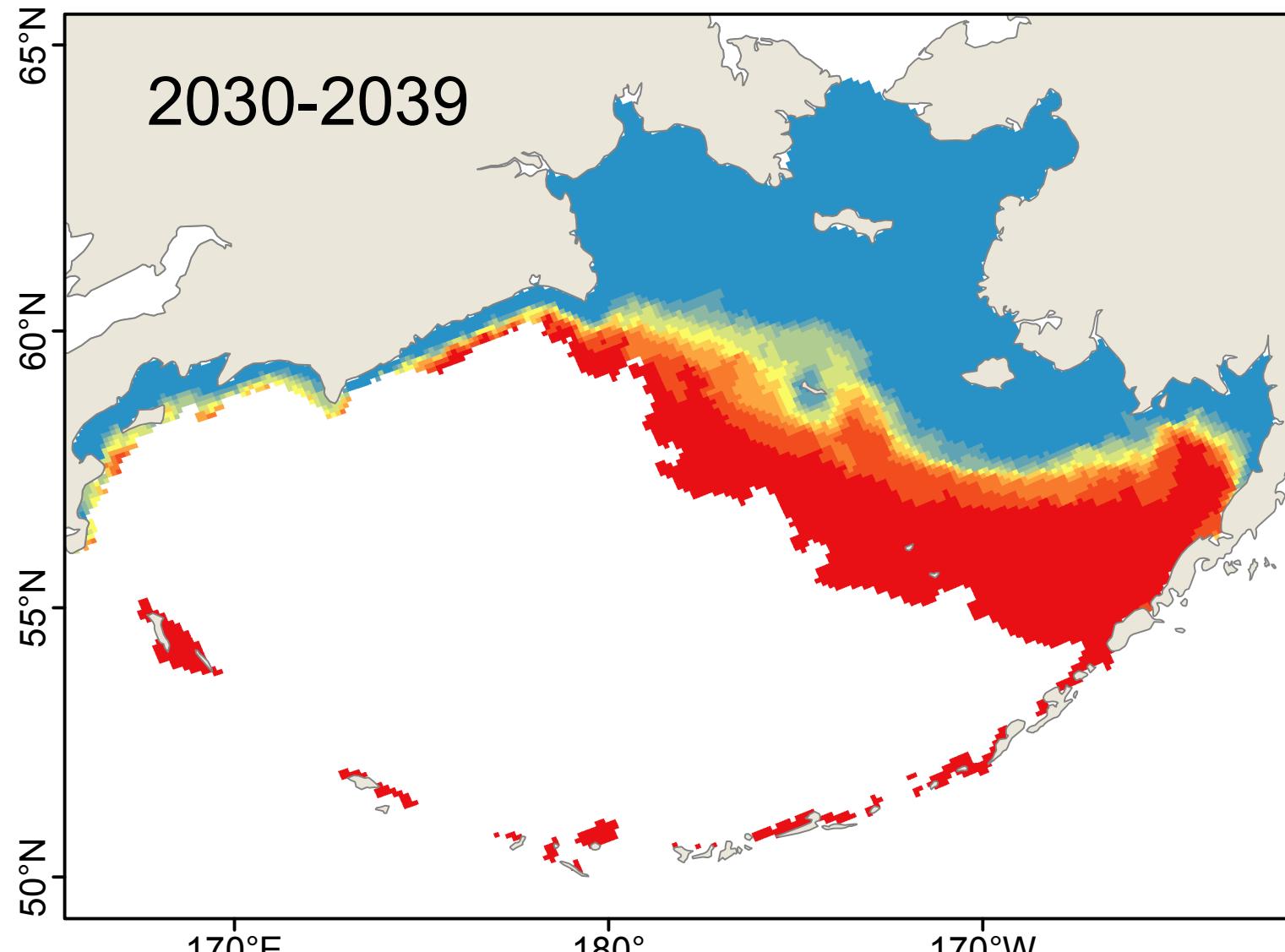
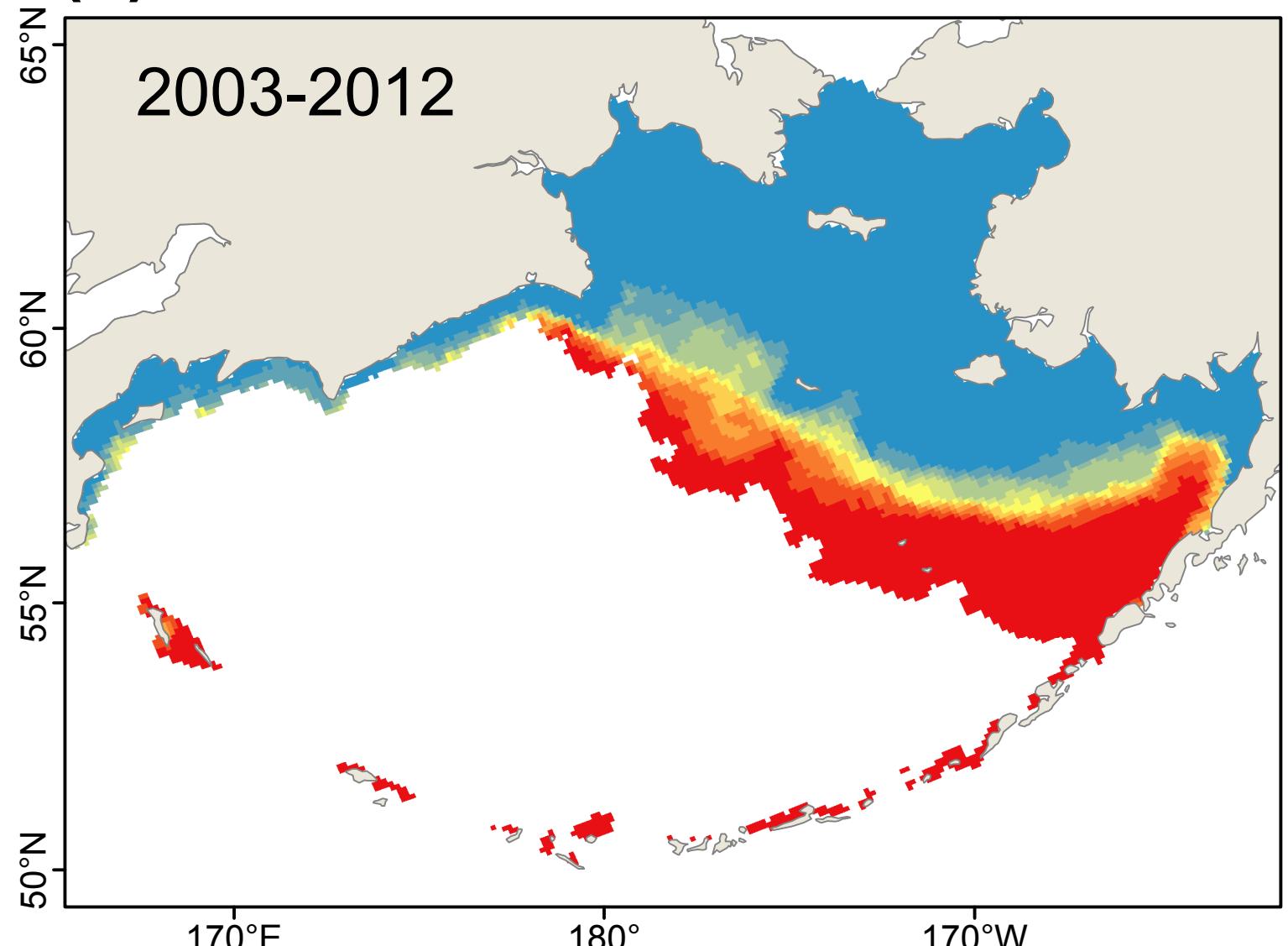


# *Diplosoma listerianum*: Year-round Survival

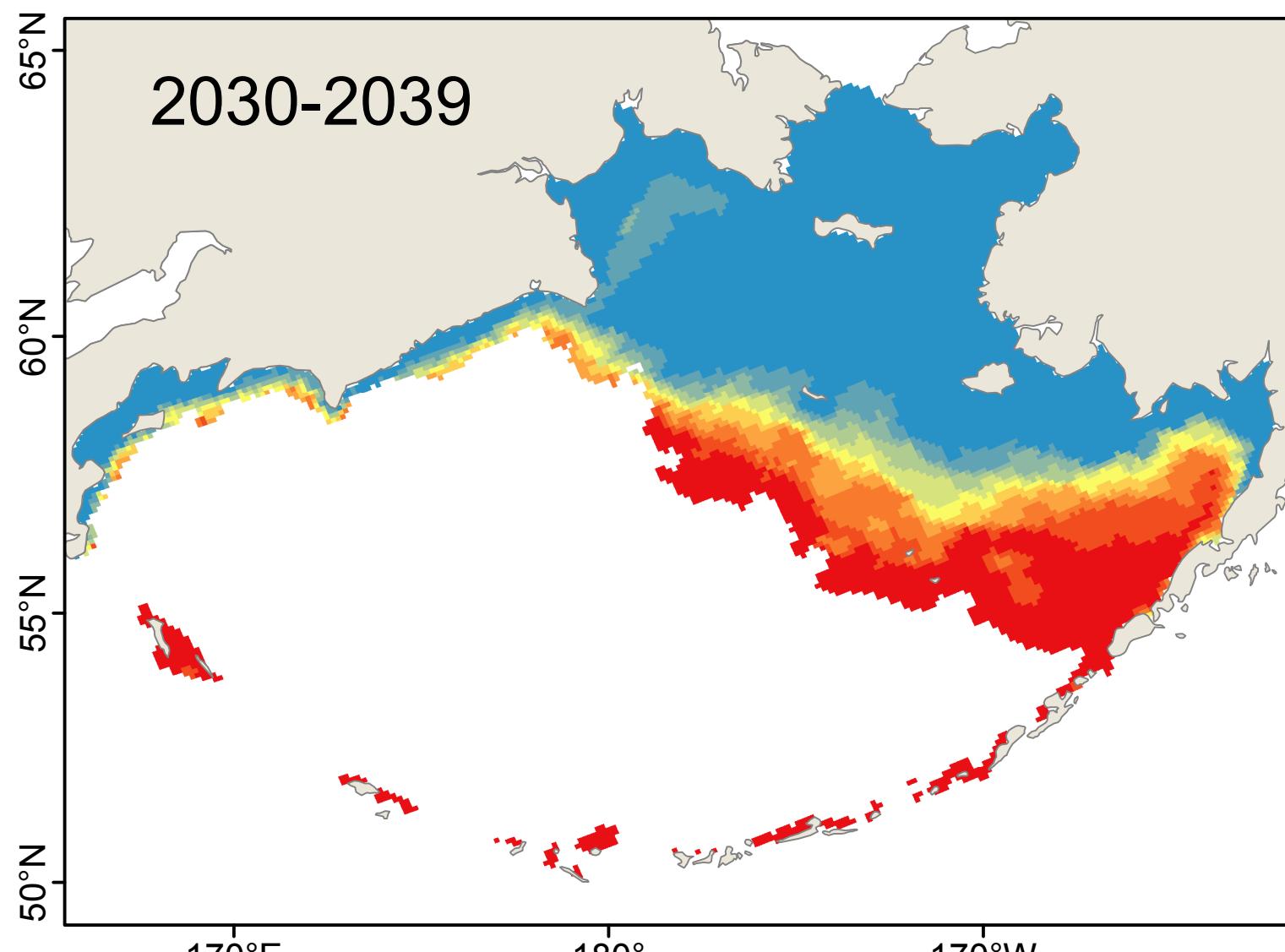
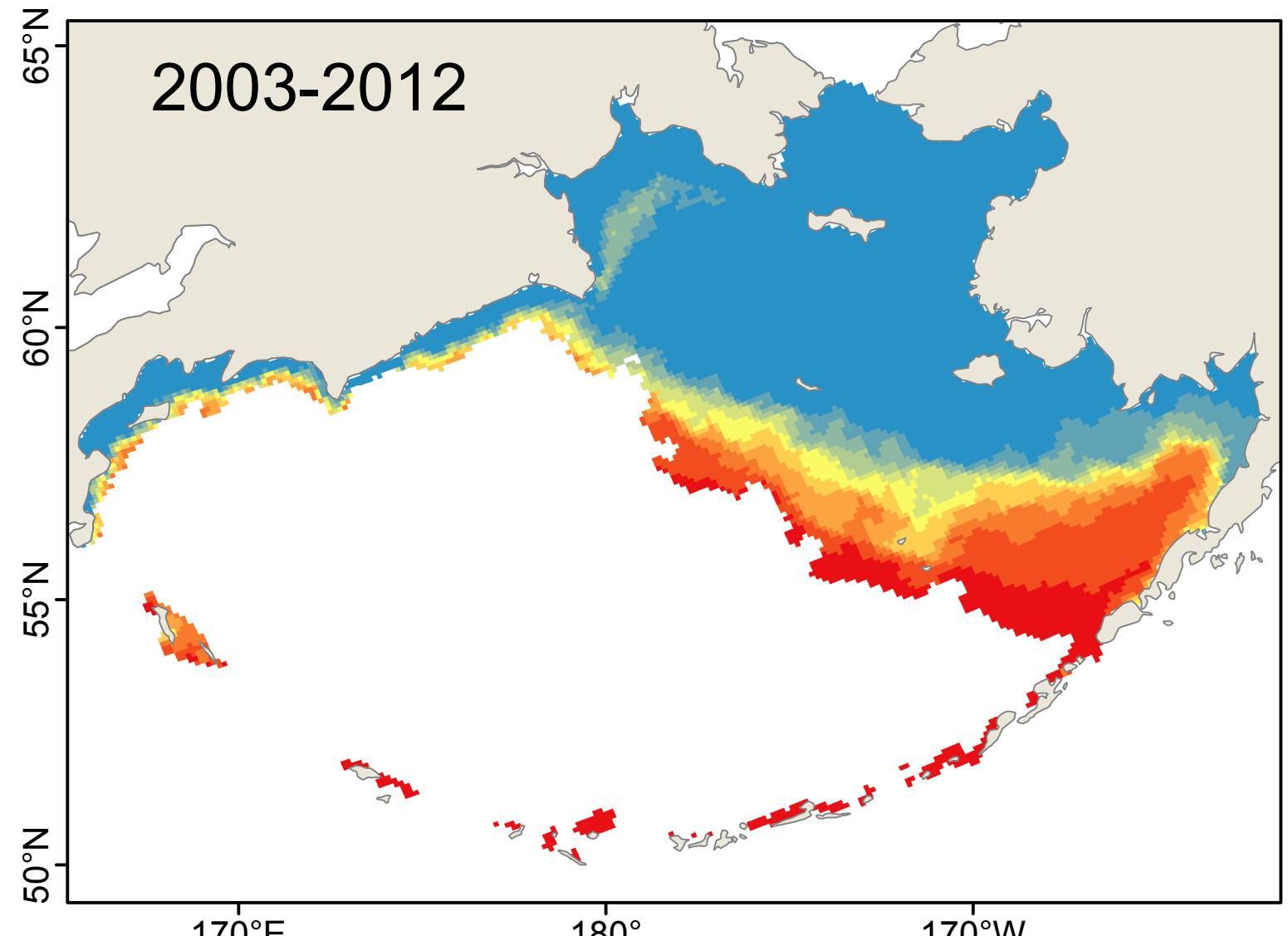
Number of years with suitable habitat



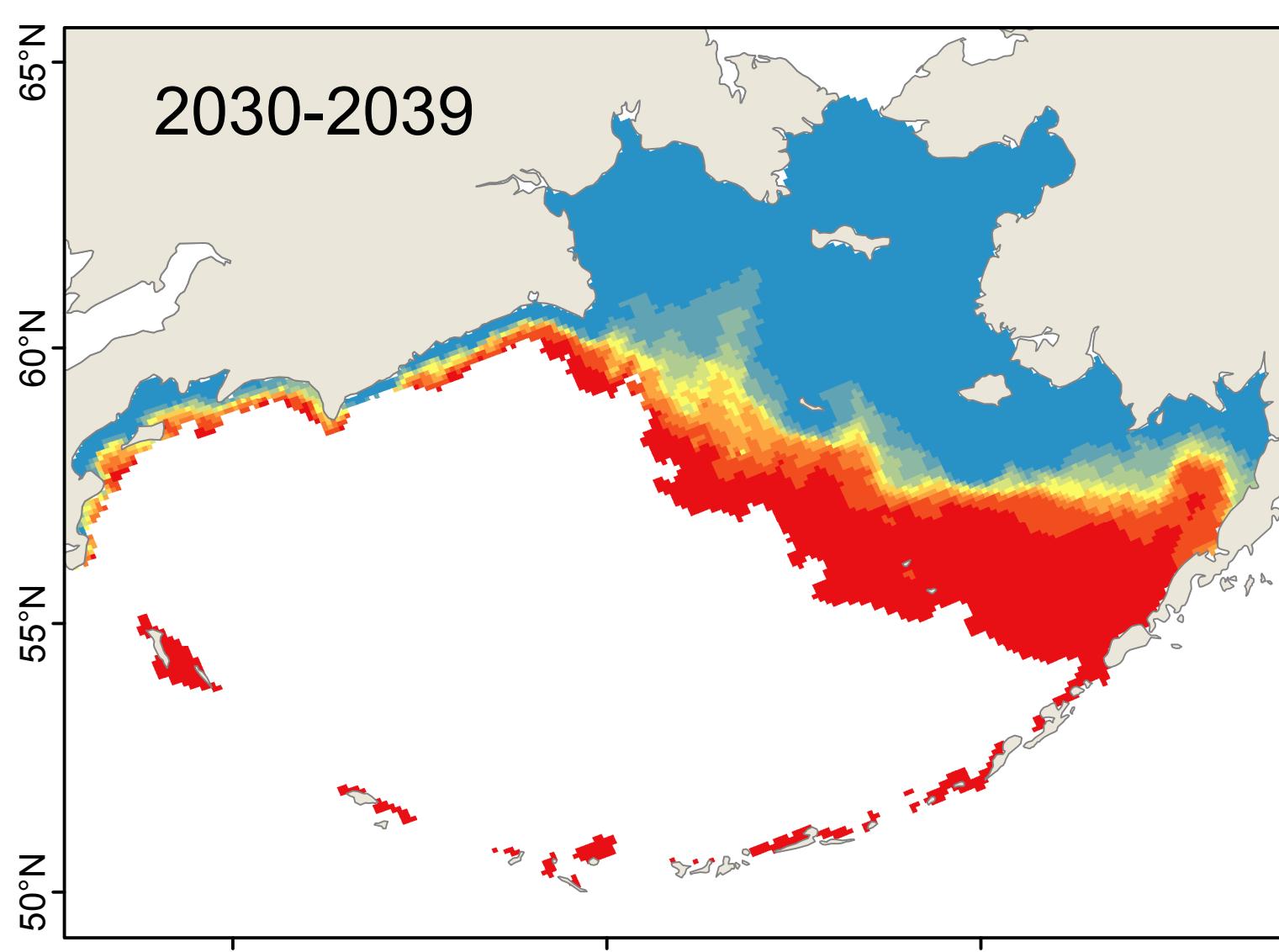
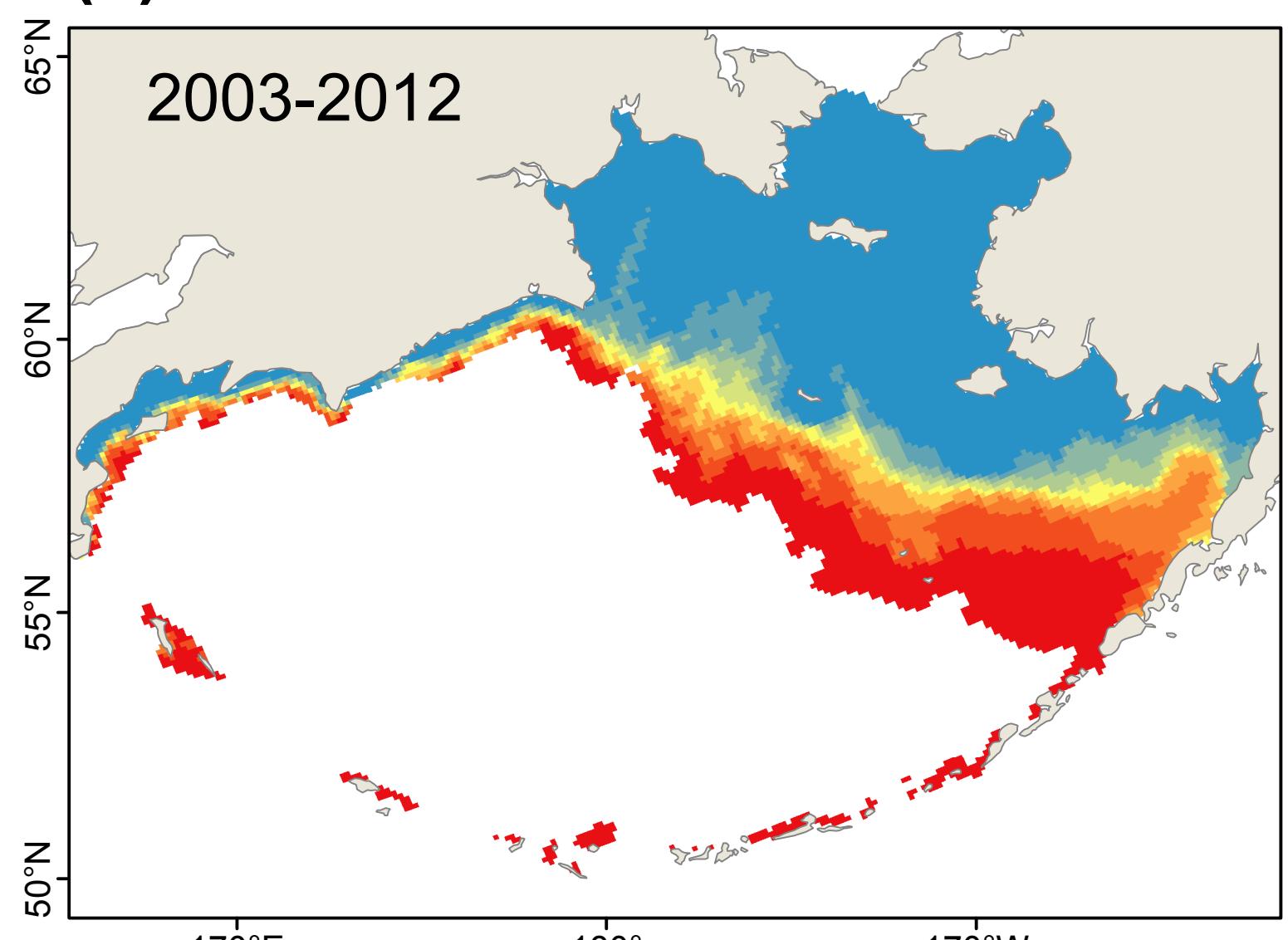
(a) Model: CGCM3-t47



(b) Model: ECHO-G

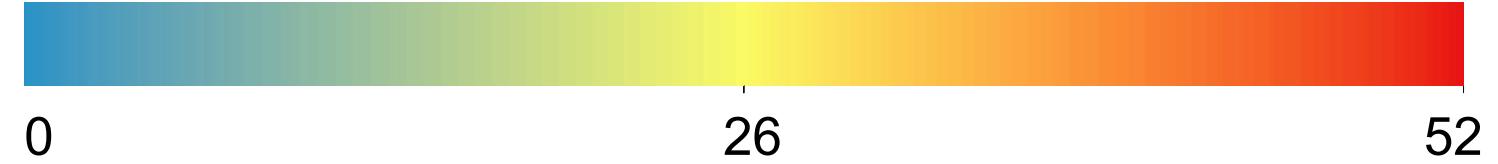


(c) Model: MIROC3.2

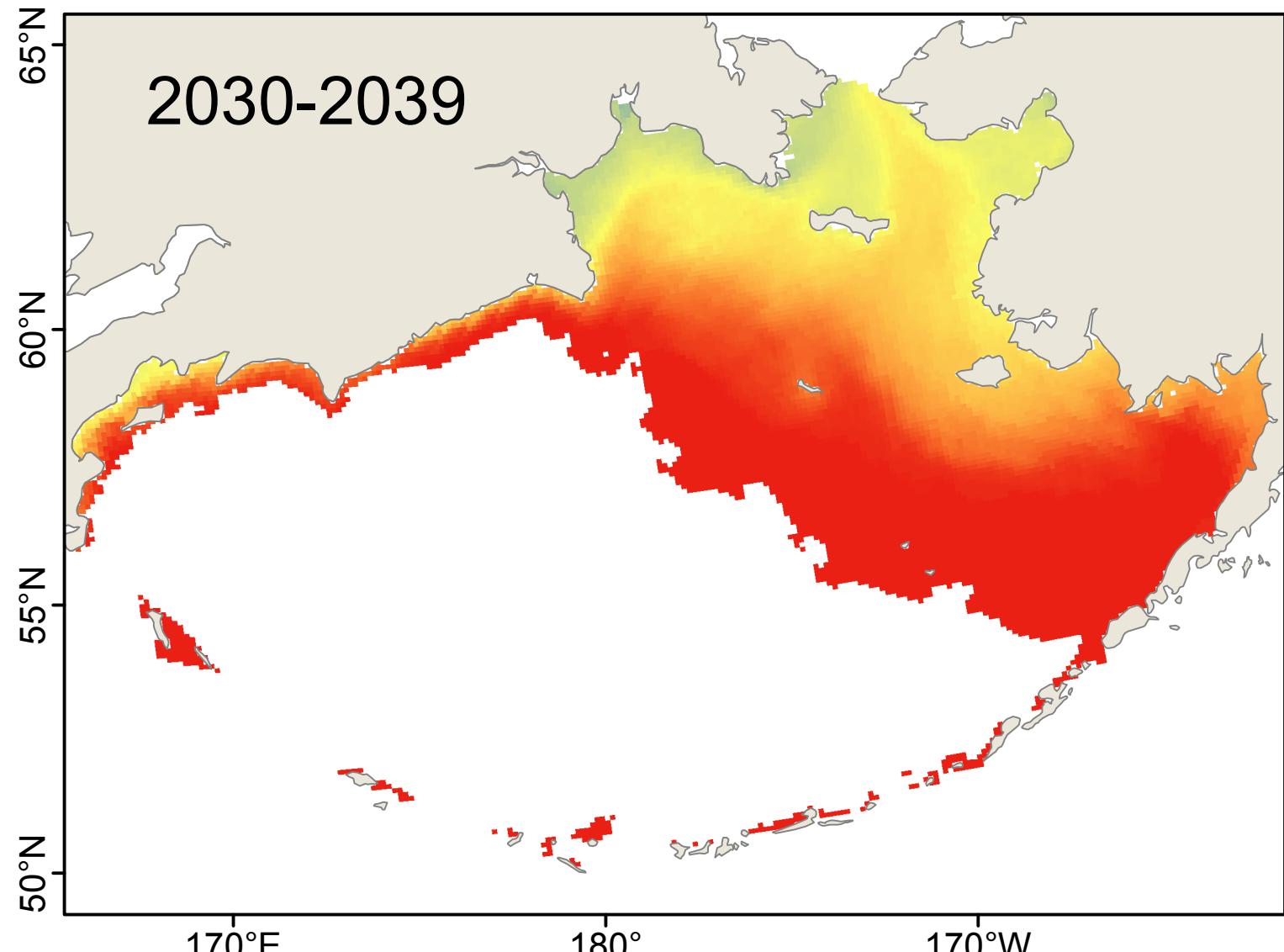
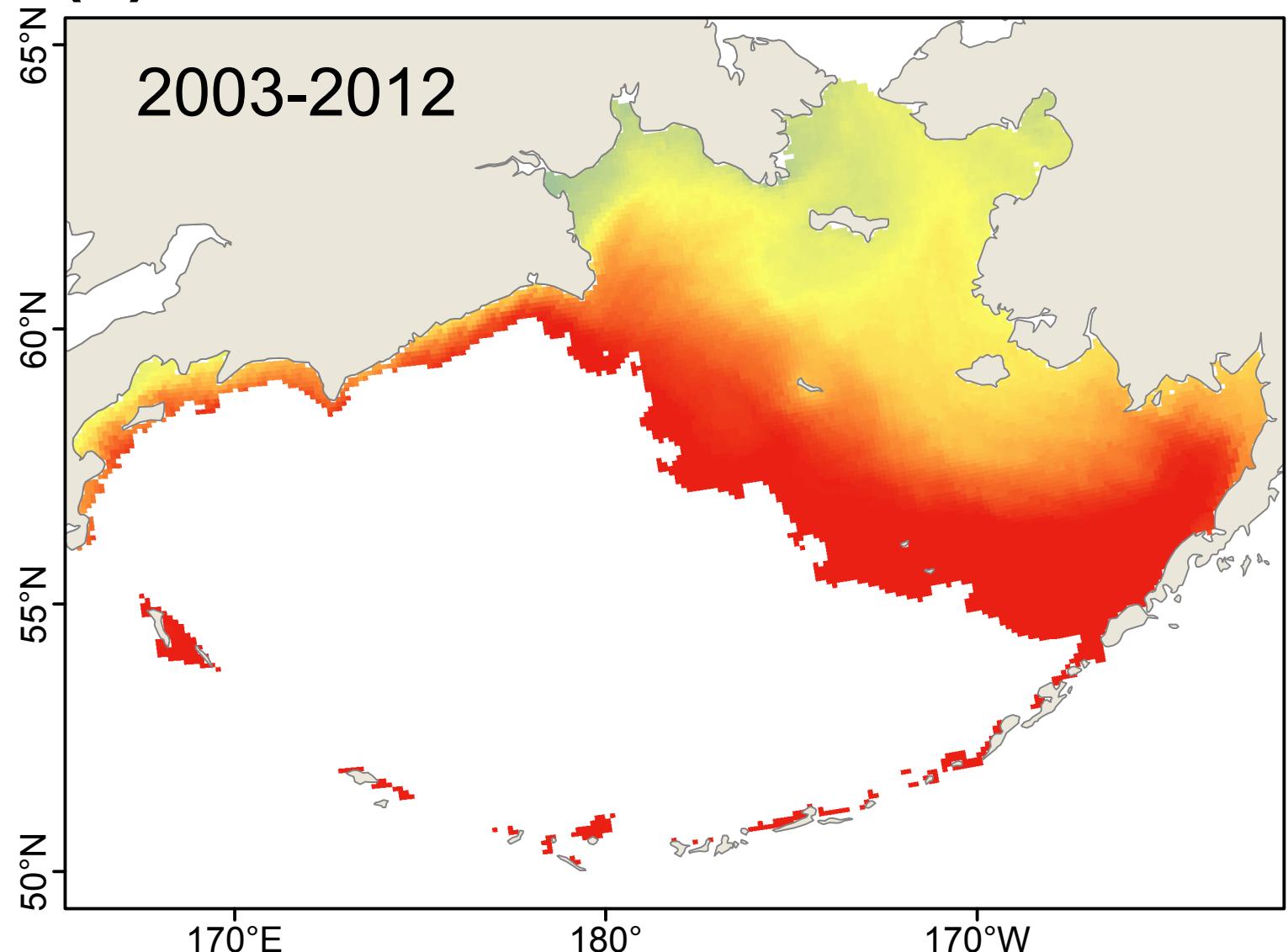


# *Diplosoma listerianum: Weekly Survival*

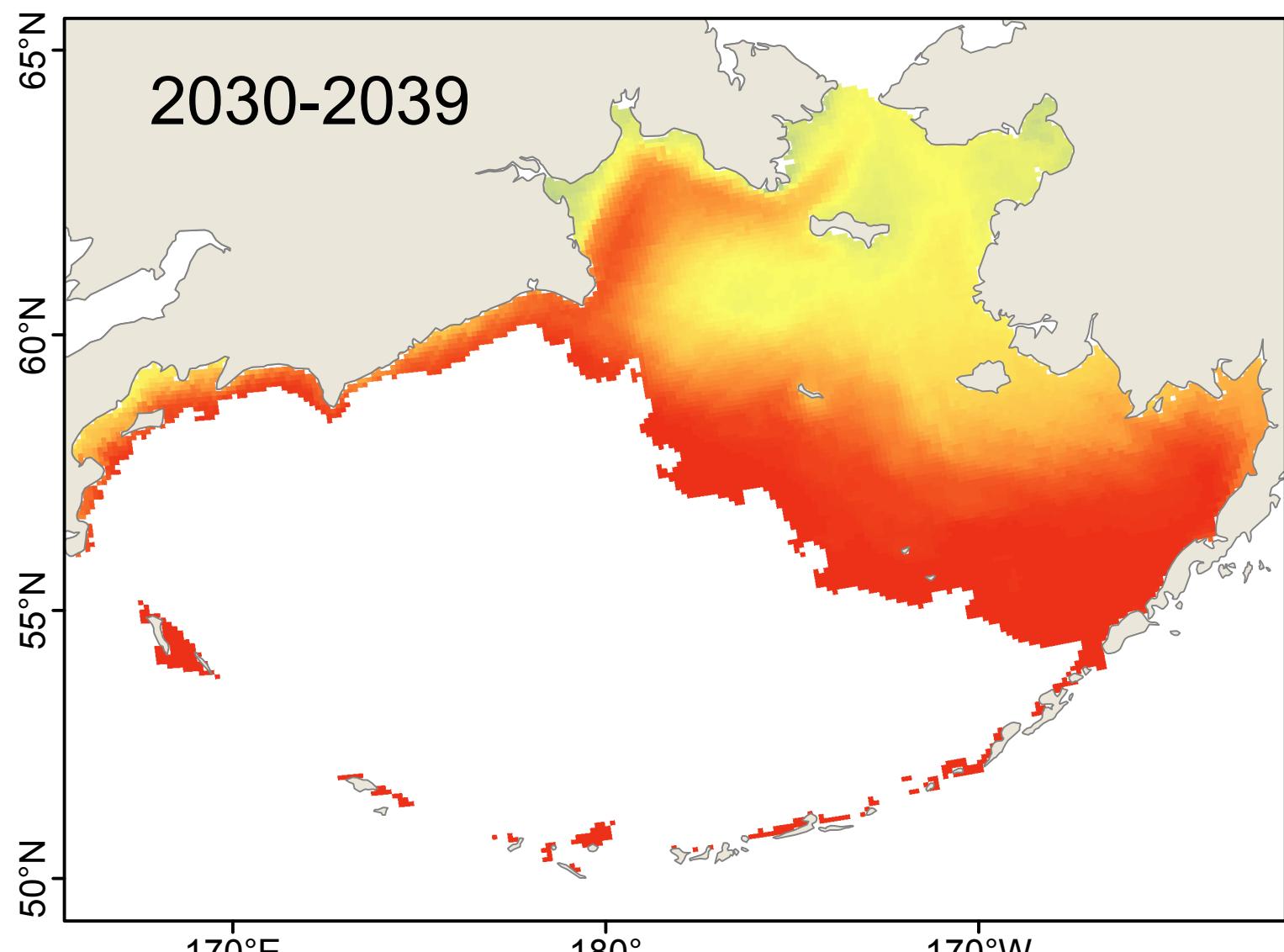
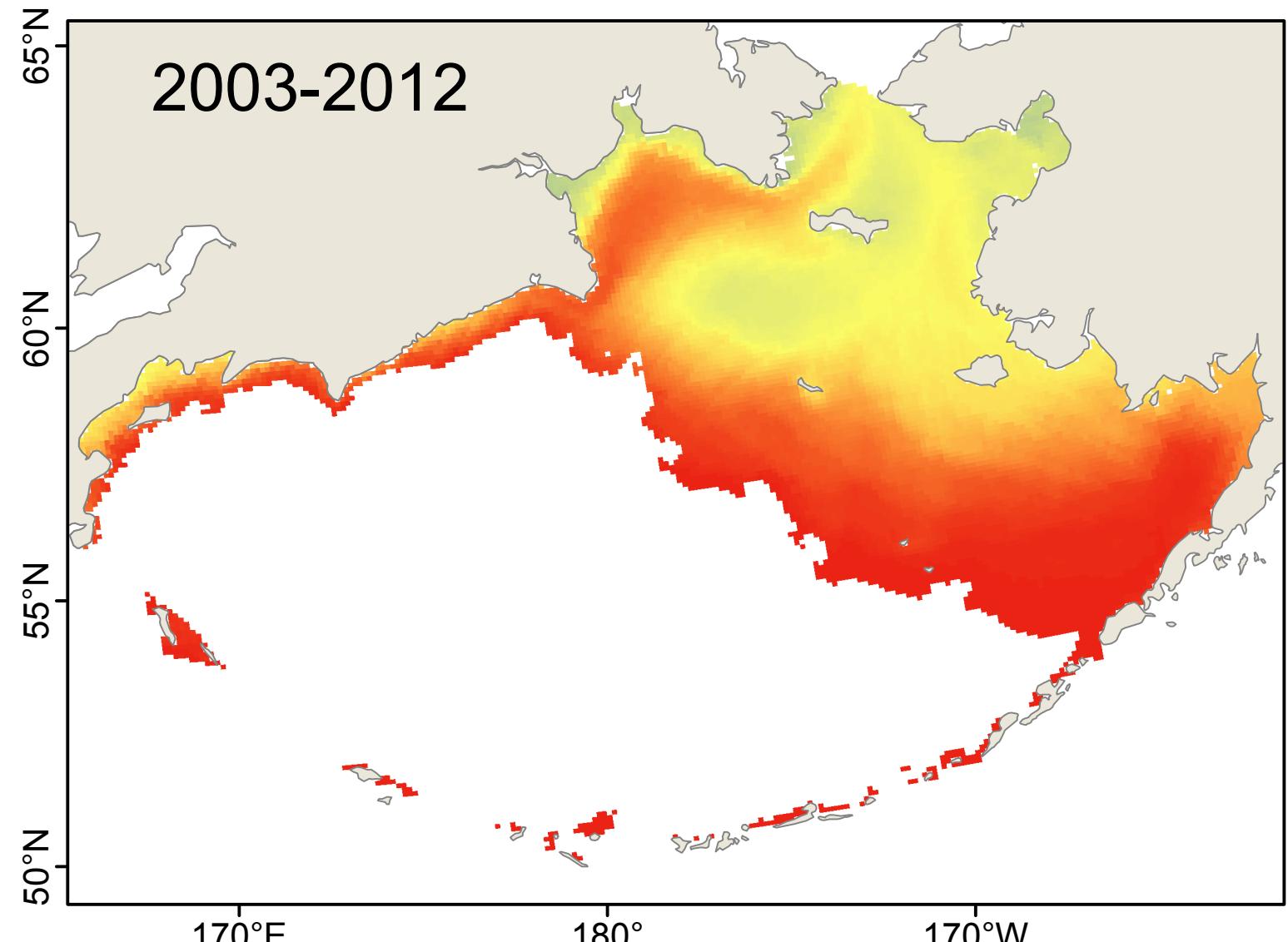
Average number of weeks of suitable habitat



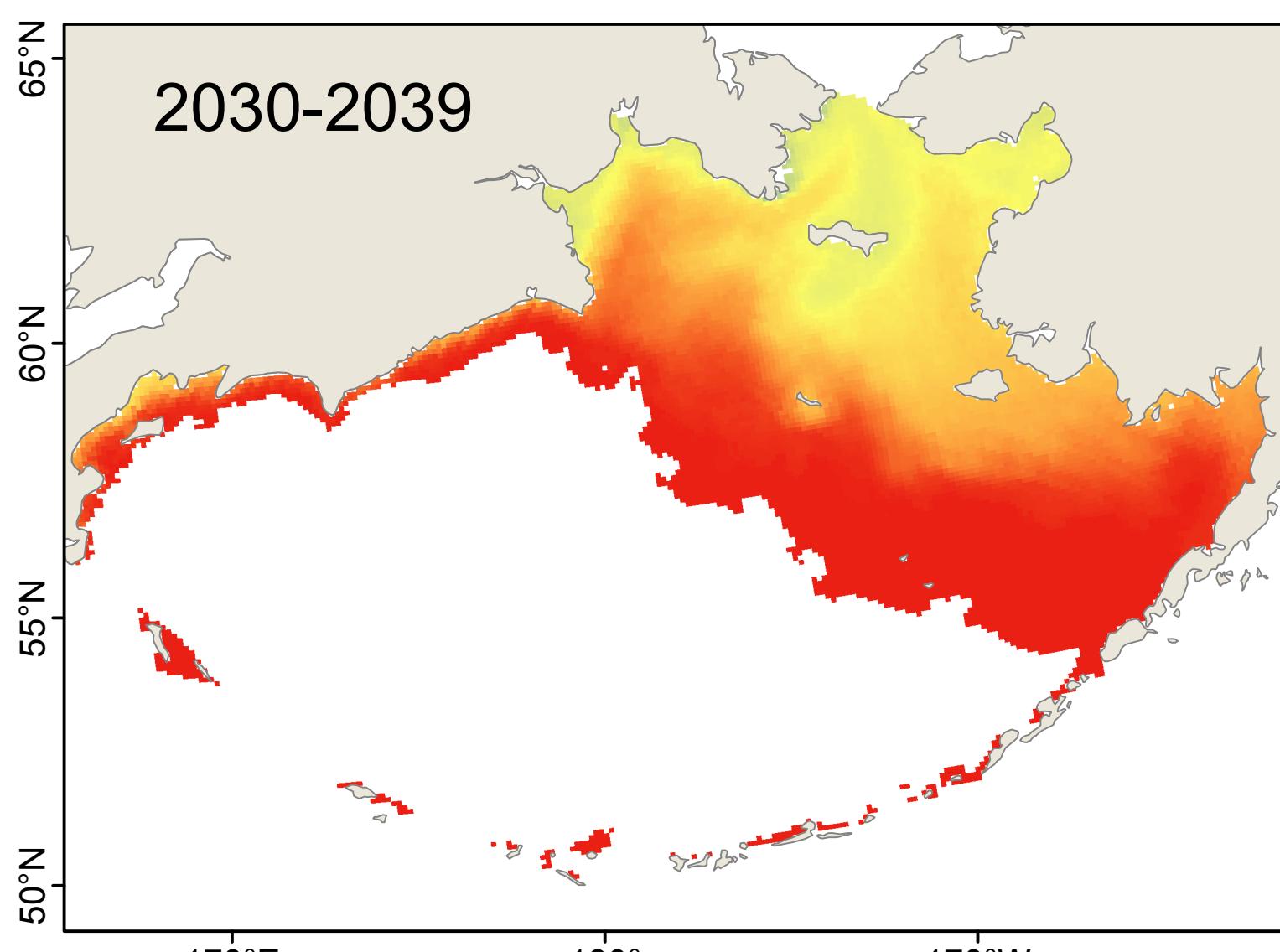
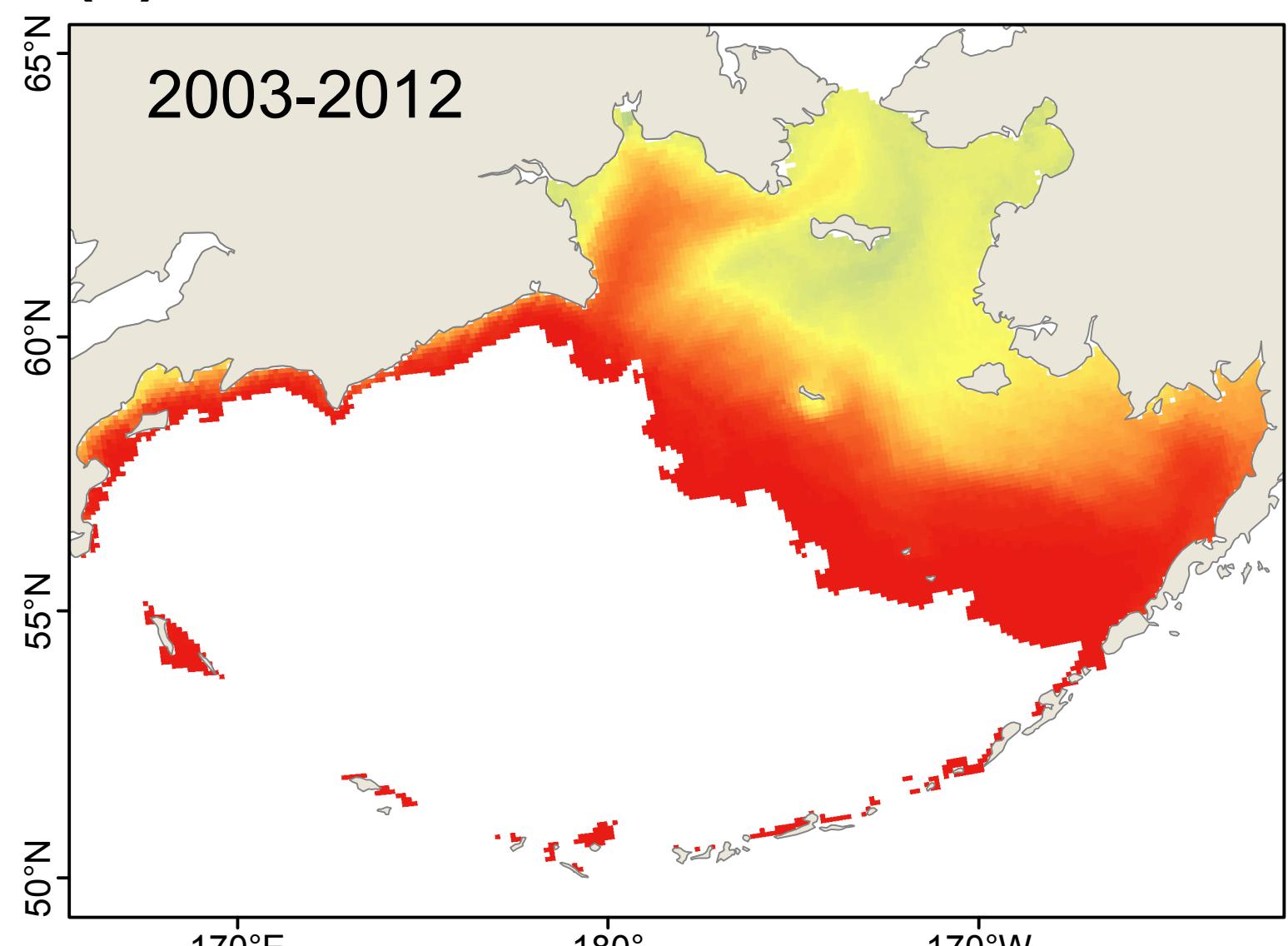
(a) Model: CGCM3-t47



(b) Model: ECHO-G

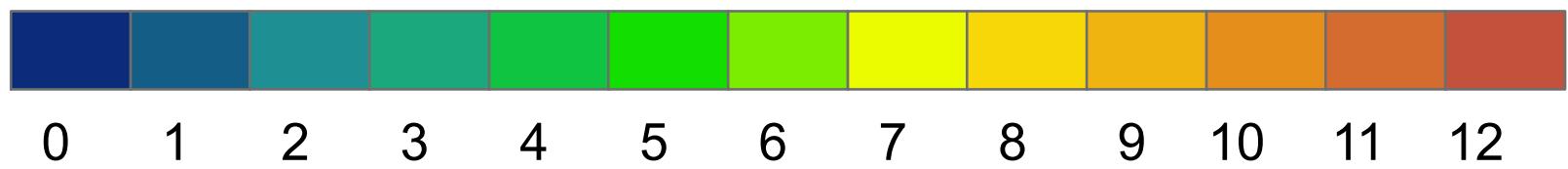


(c) Model: MIROC3.2

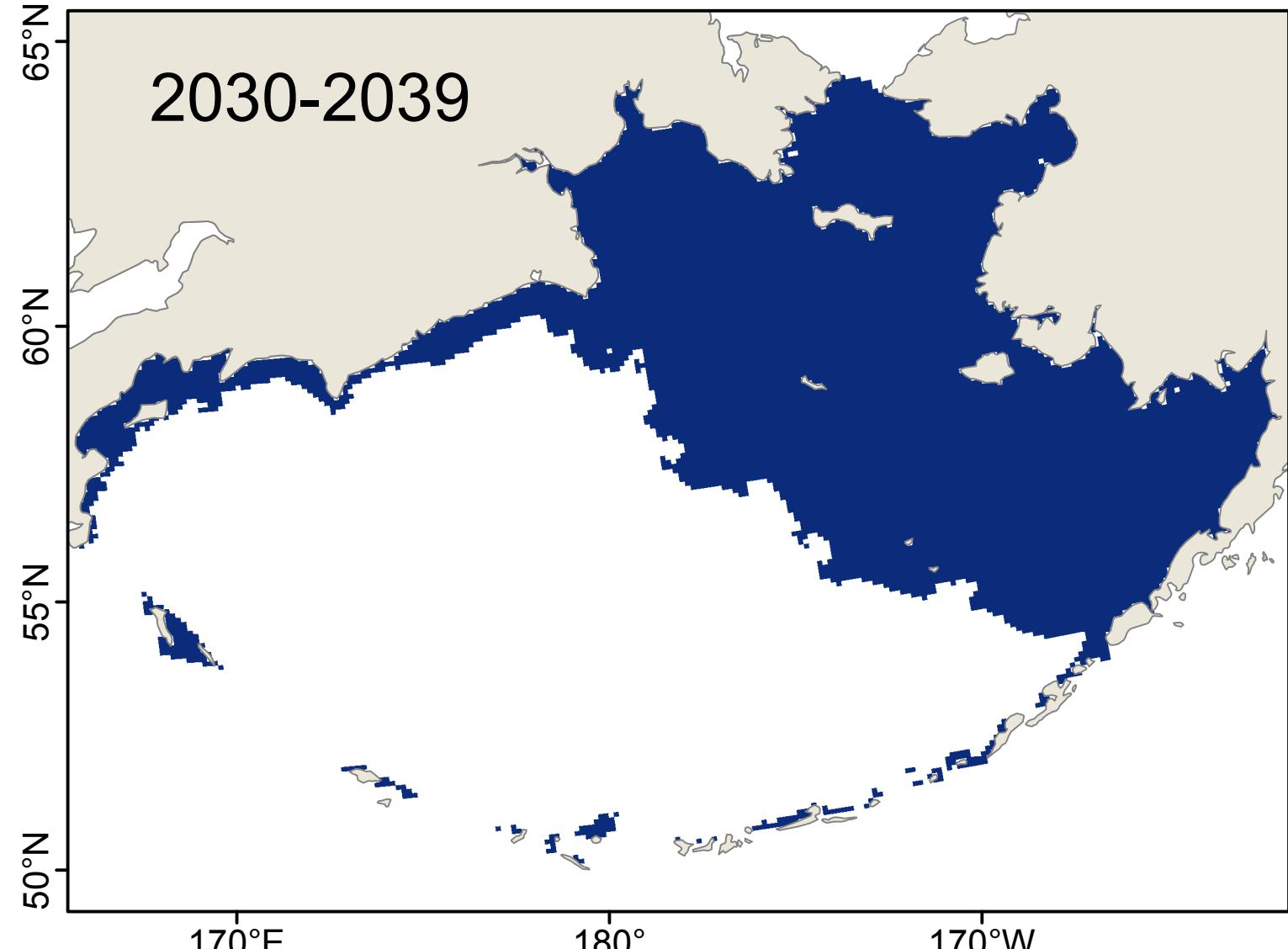
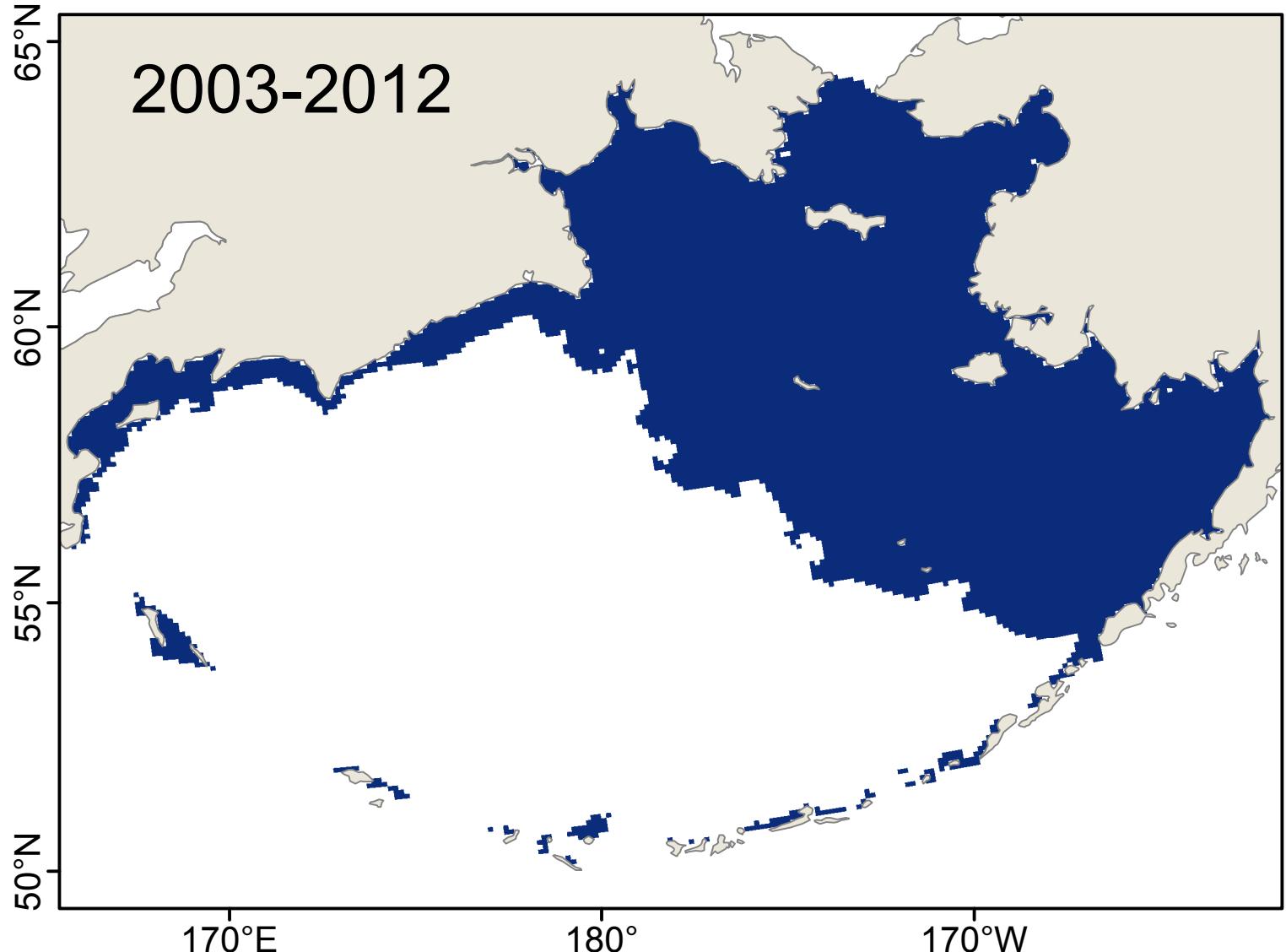


# *Diplosoma listerianum: Reproduction*

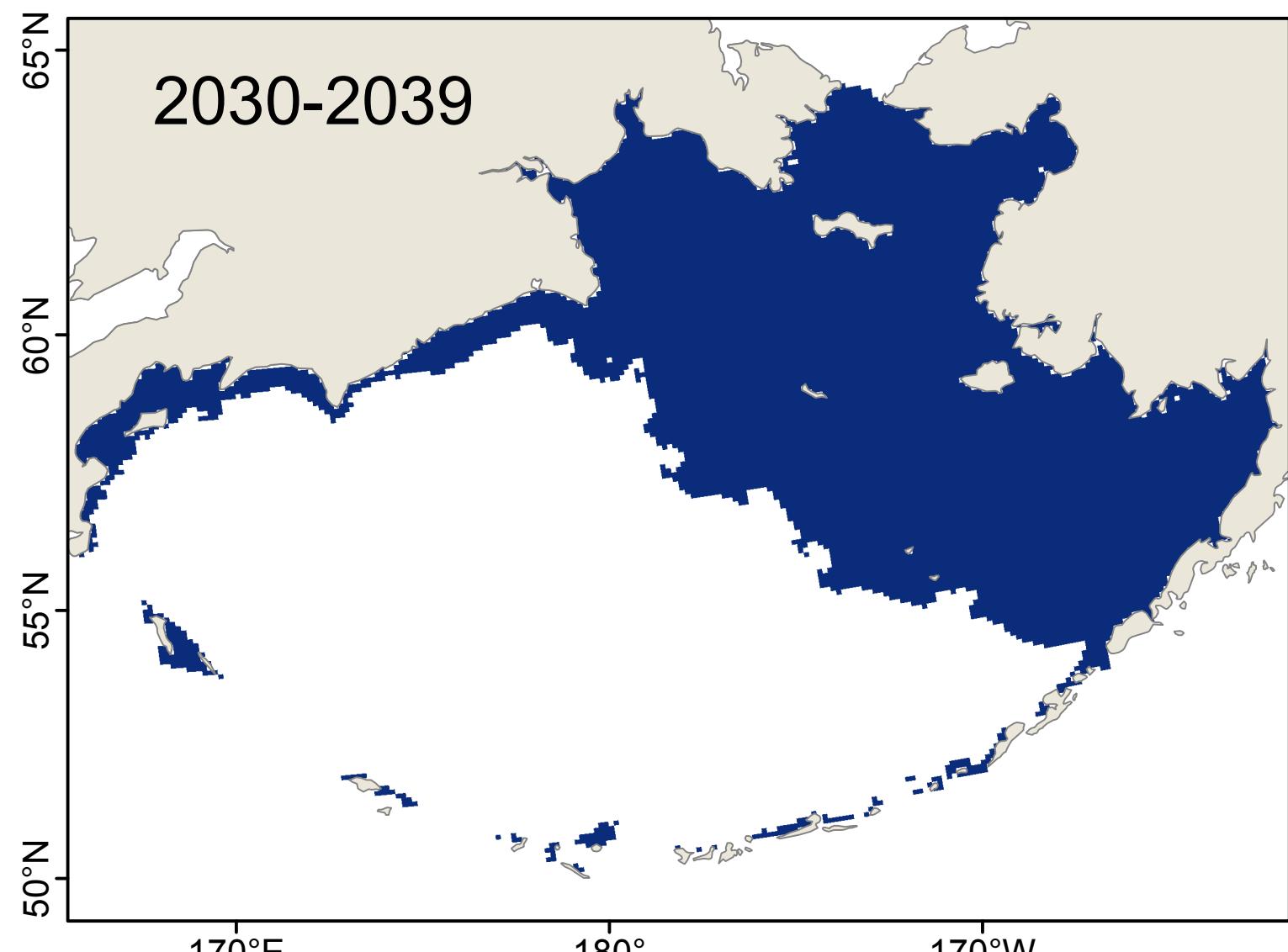
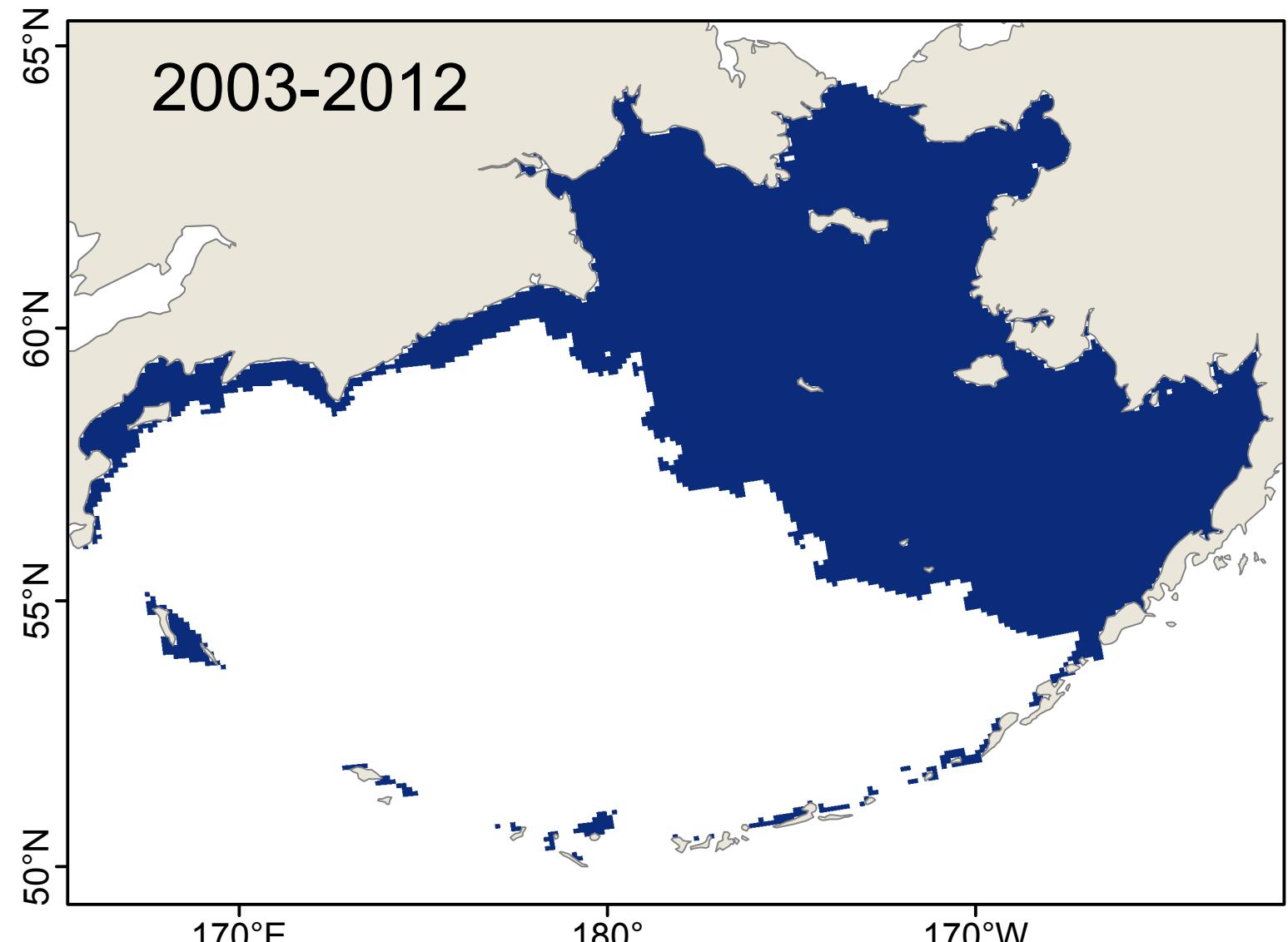
Average number of consecutive weeks of suitable habitat



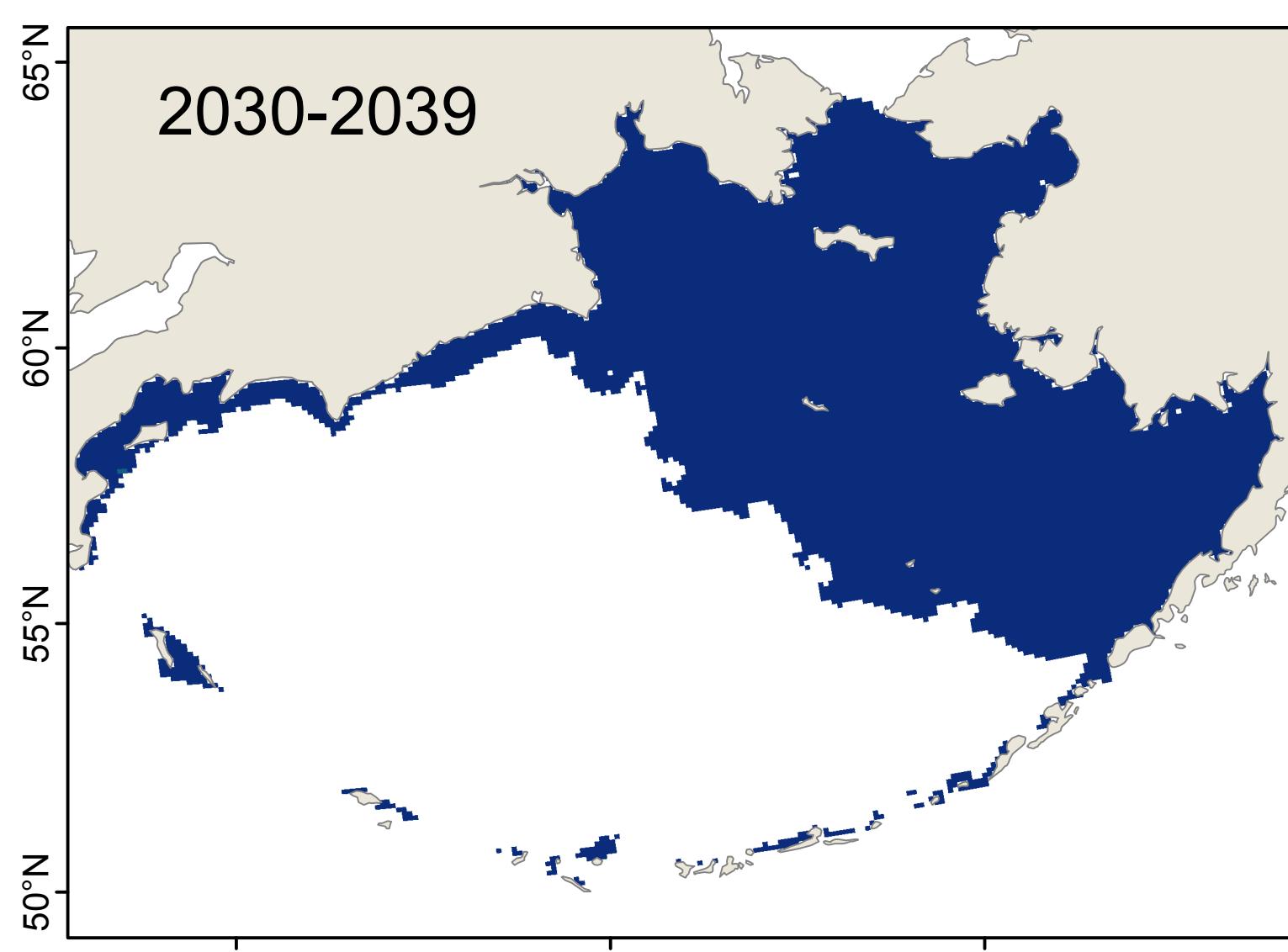
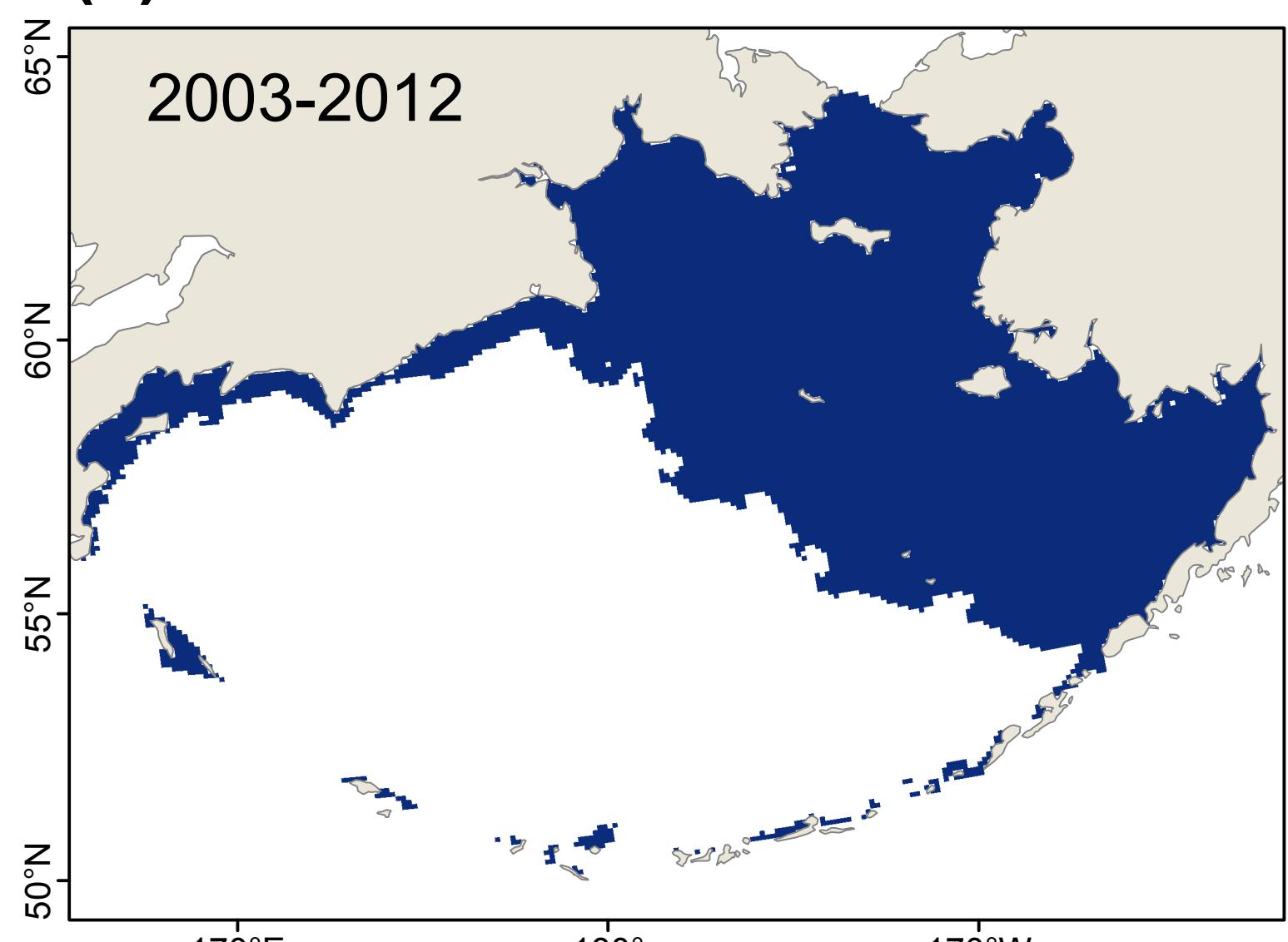
(a) Model: CGCM3-t47



(b) Model: ECHO-G

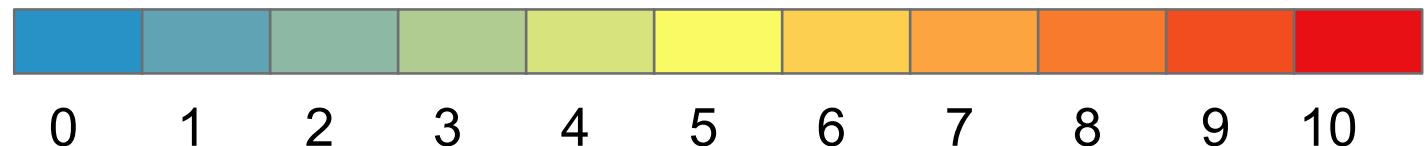


(c) Model: MIROC3.2

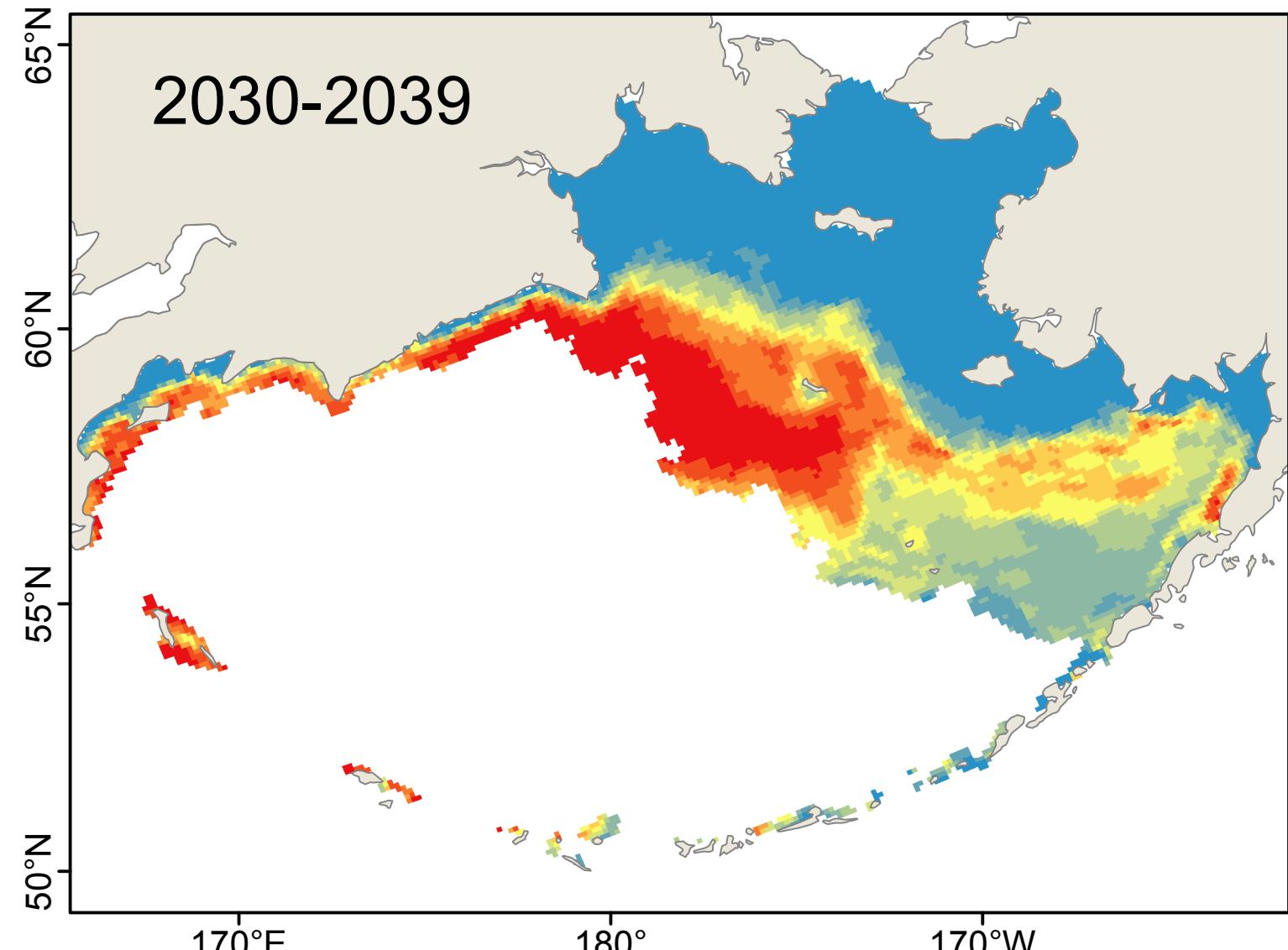
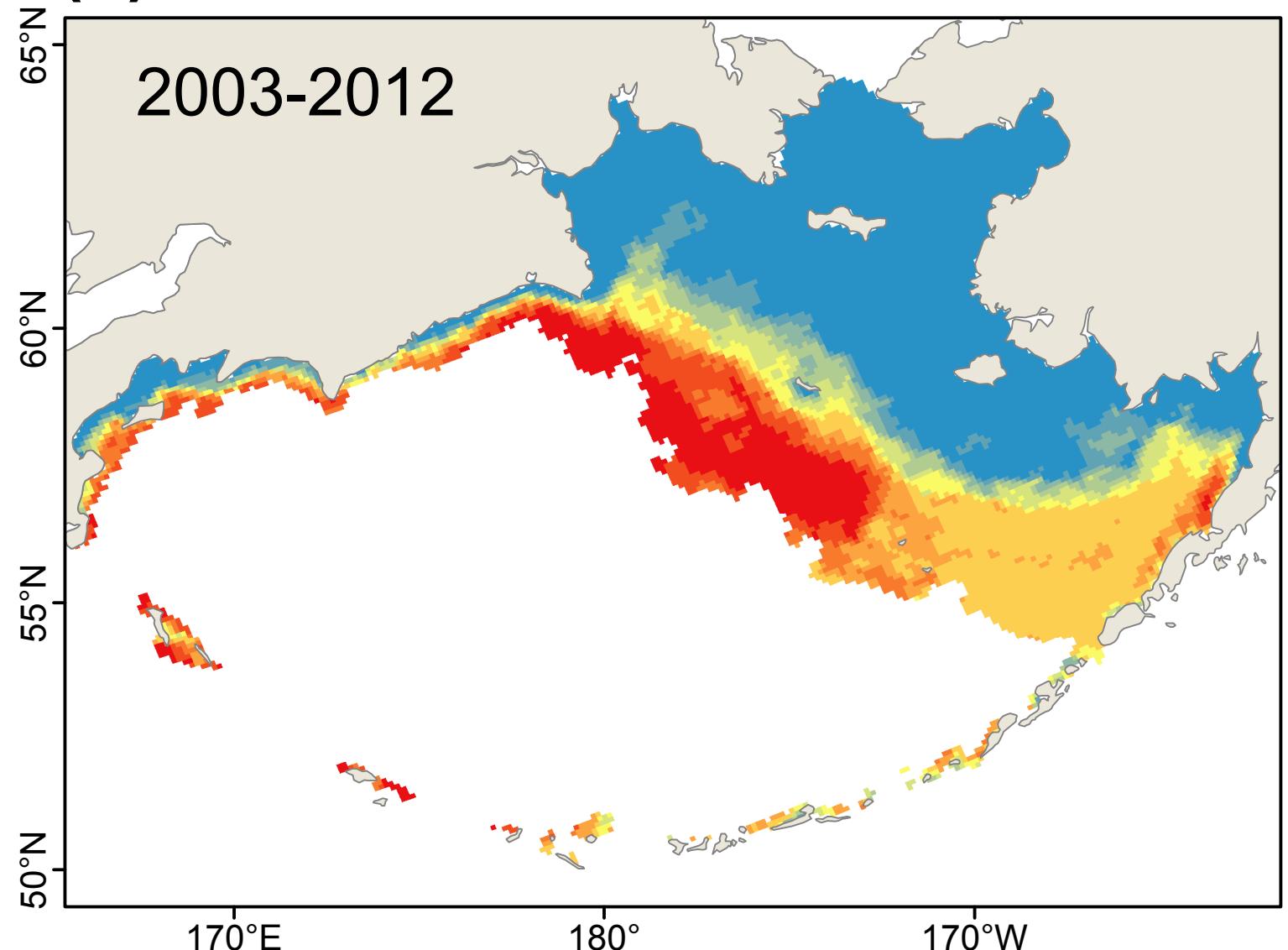


# *Molgula citrina*: Year-round Survival

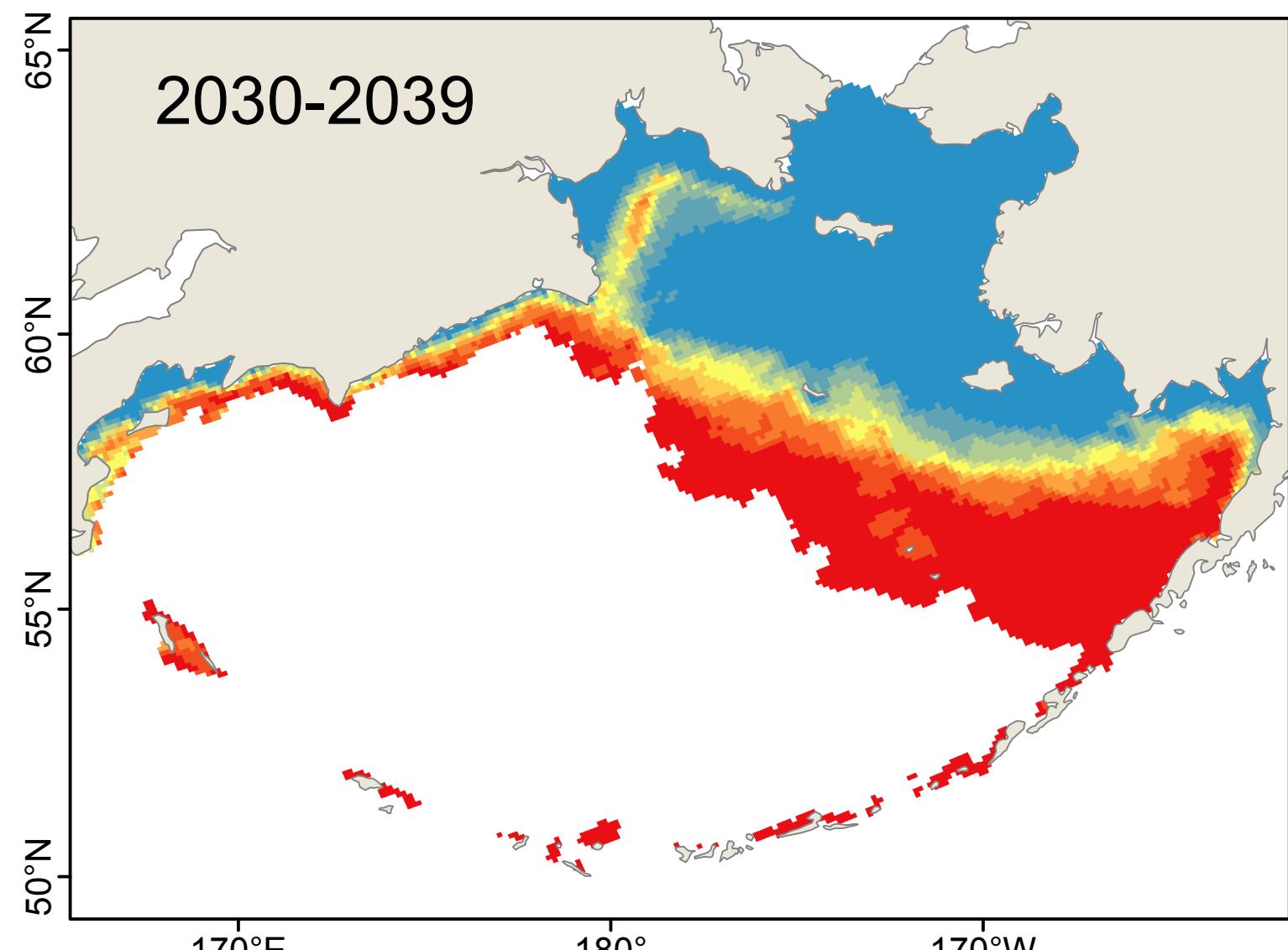
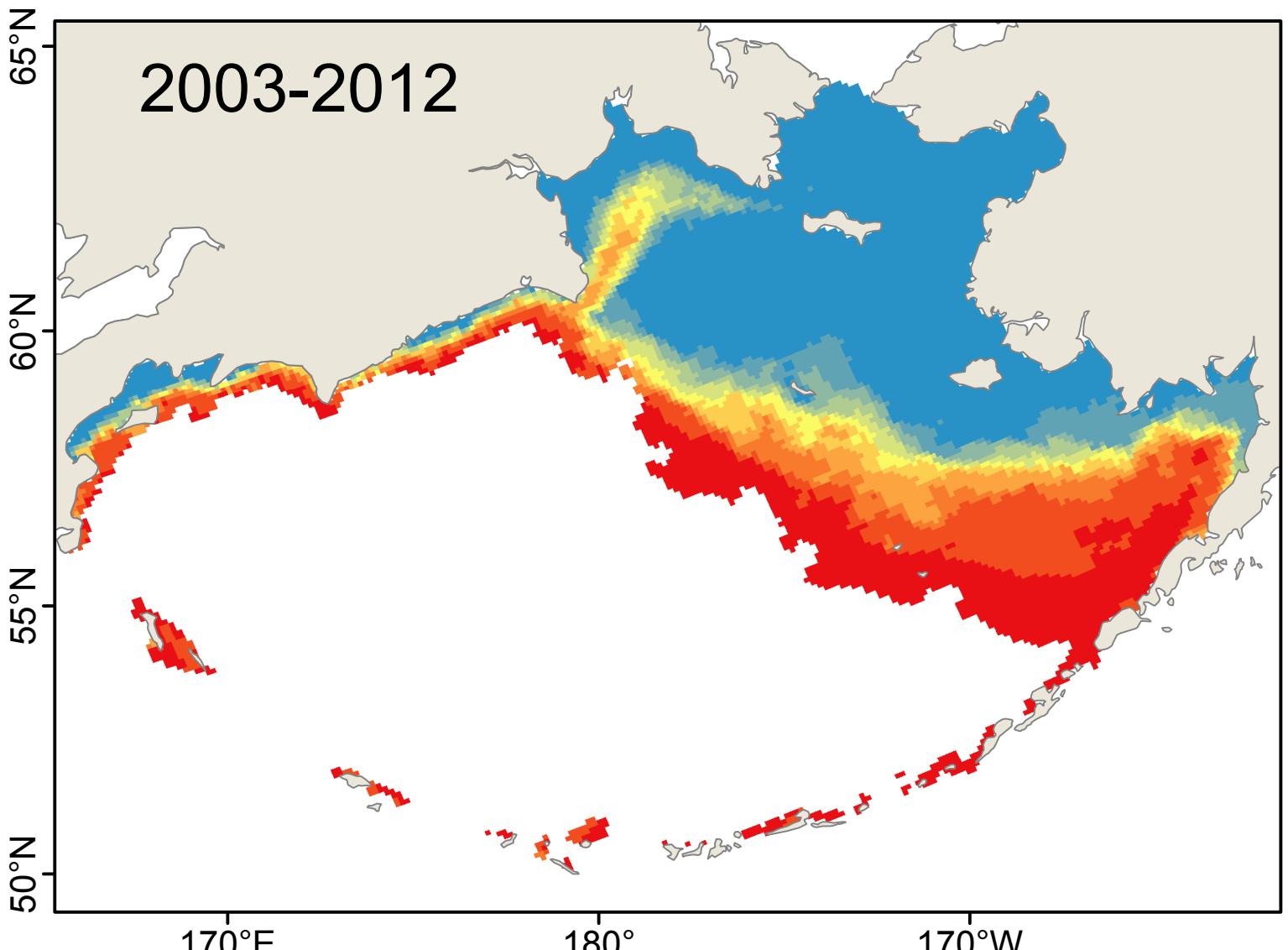
Number of years with suitable habitat



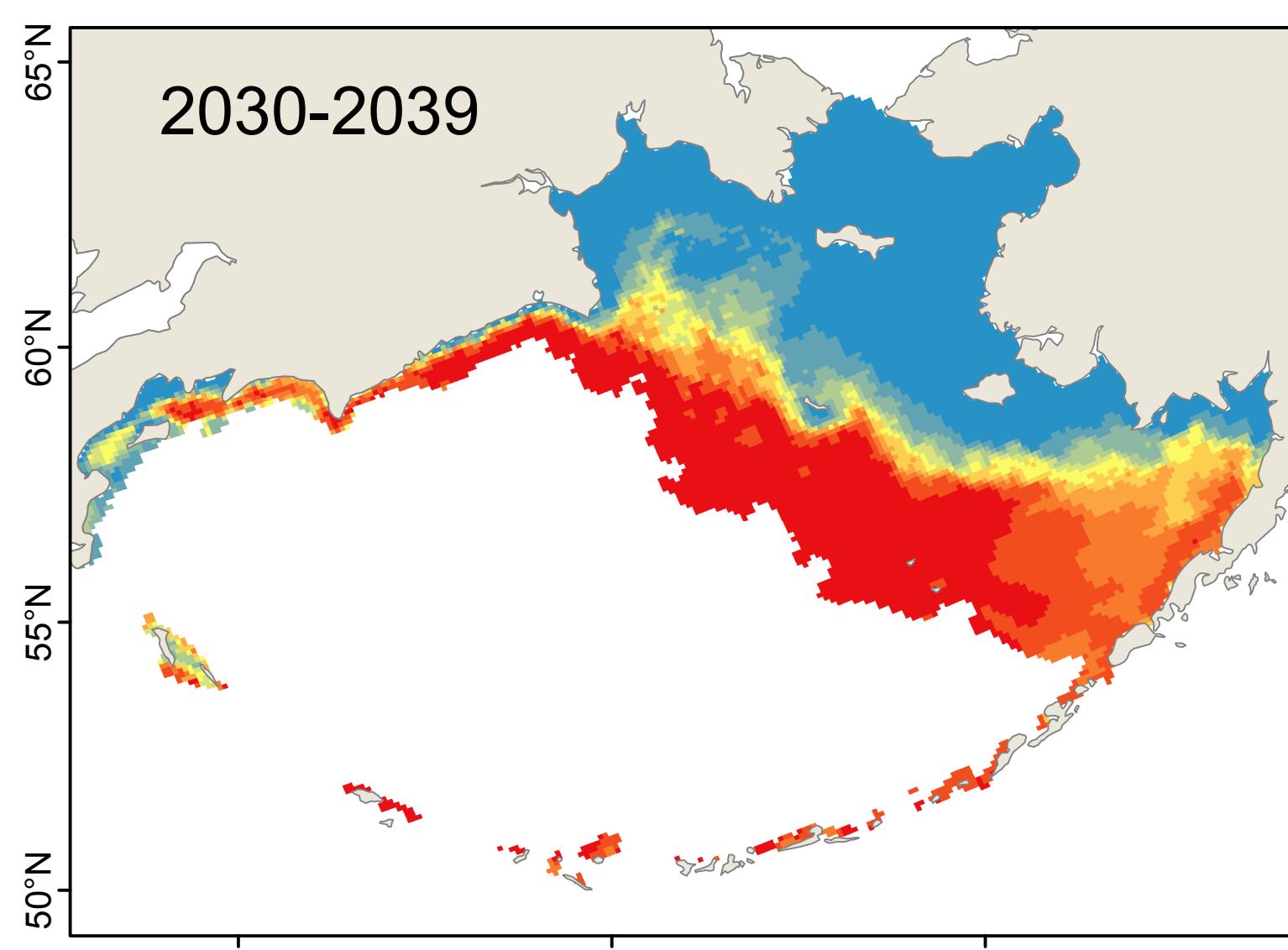
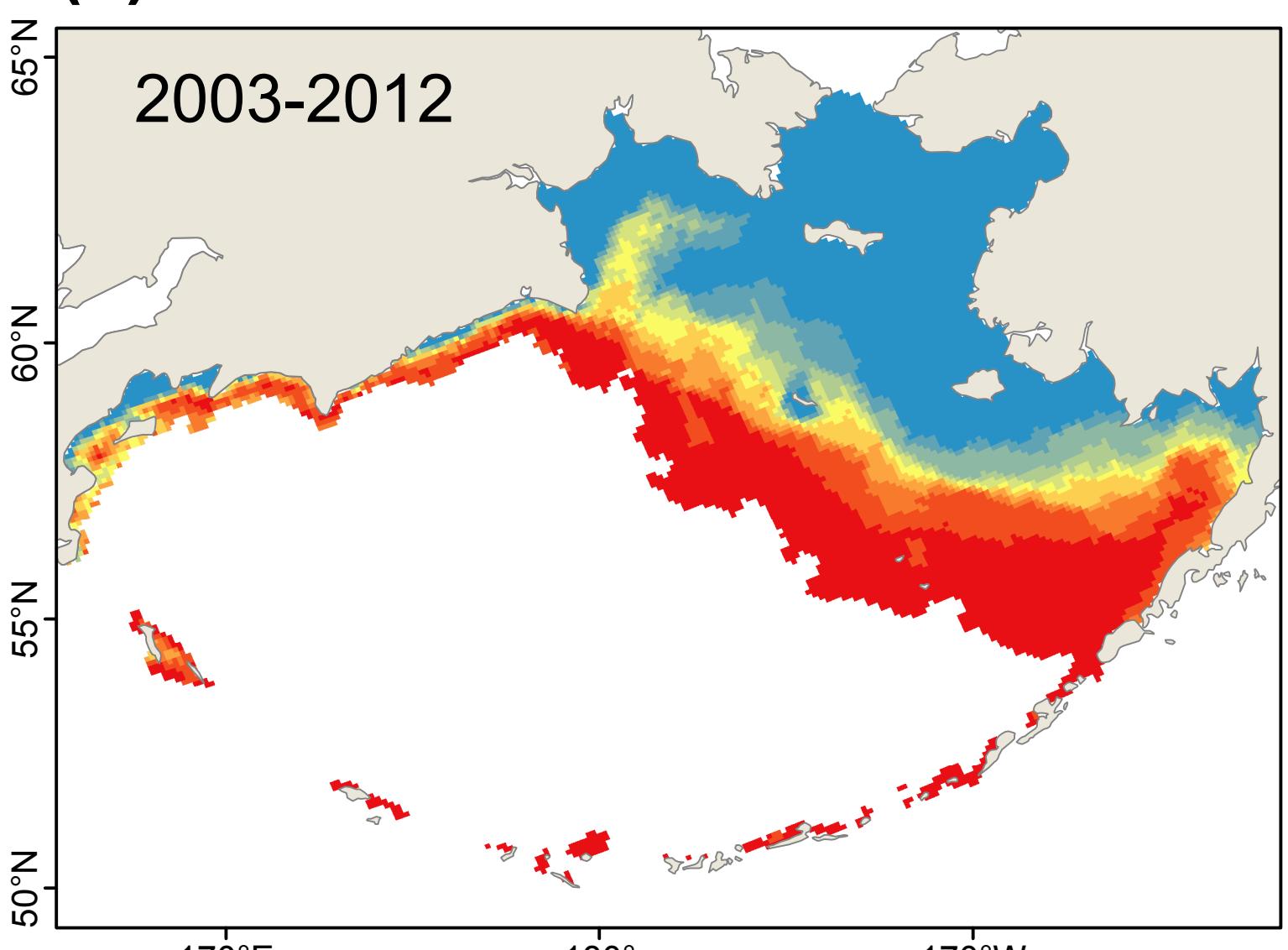
(a) Model: CGCM3-t47



(b) Model: ECHO-G

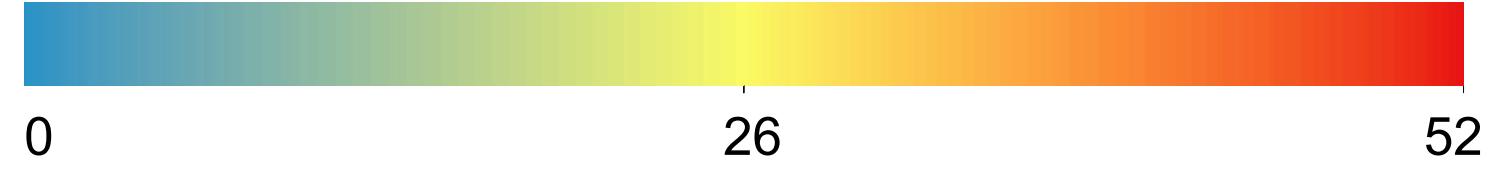


(c) Model: MIROC3.2

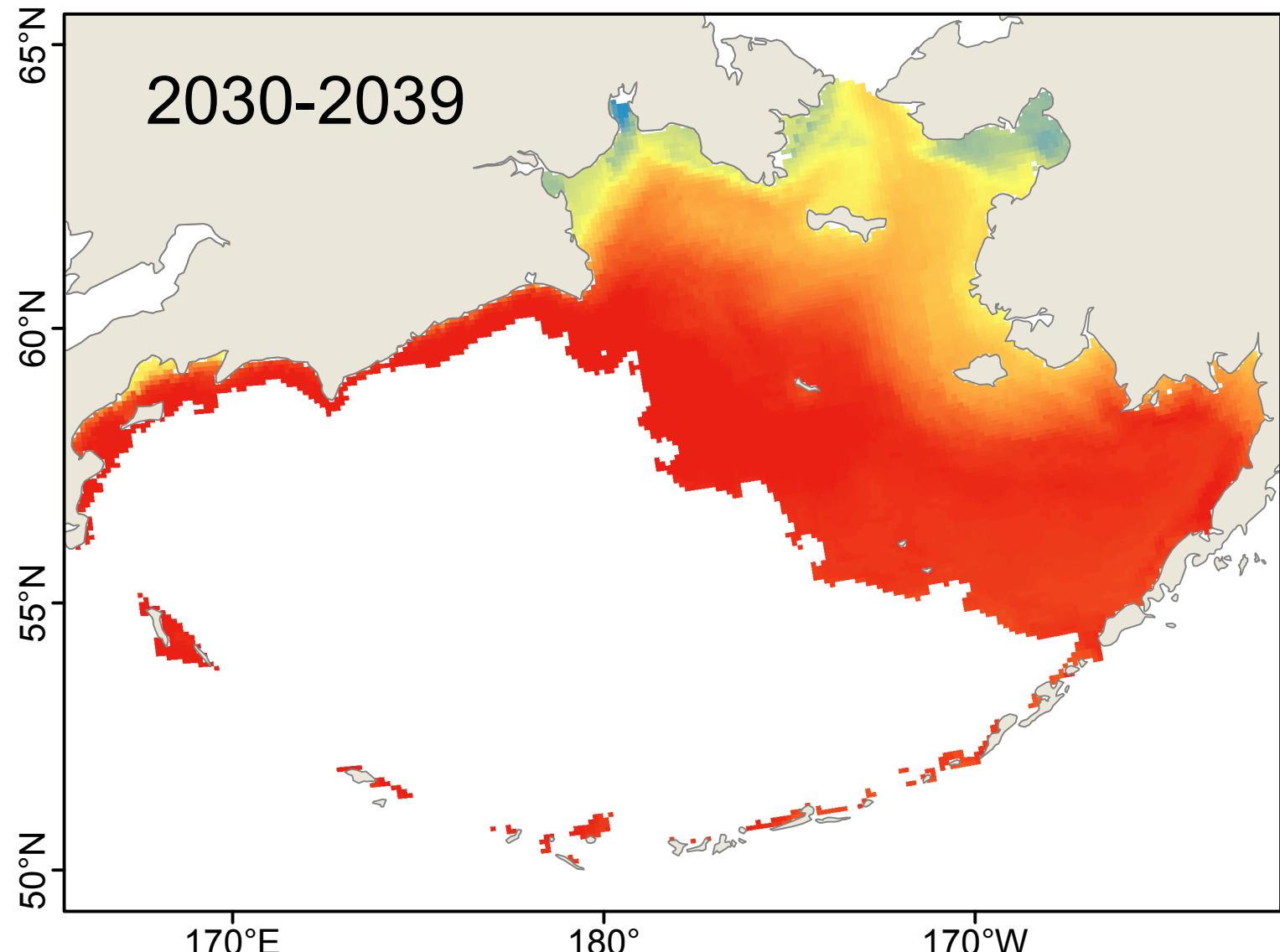
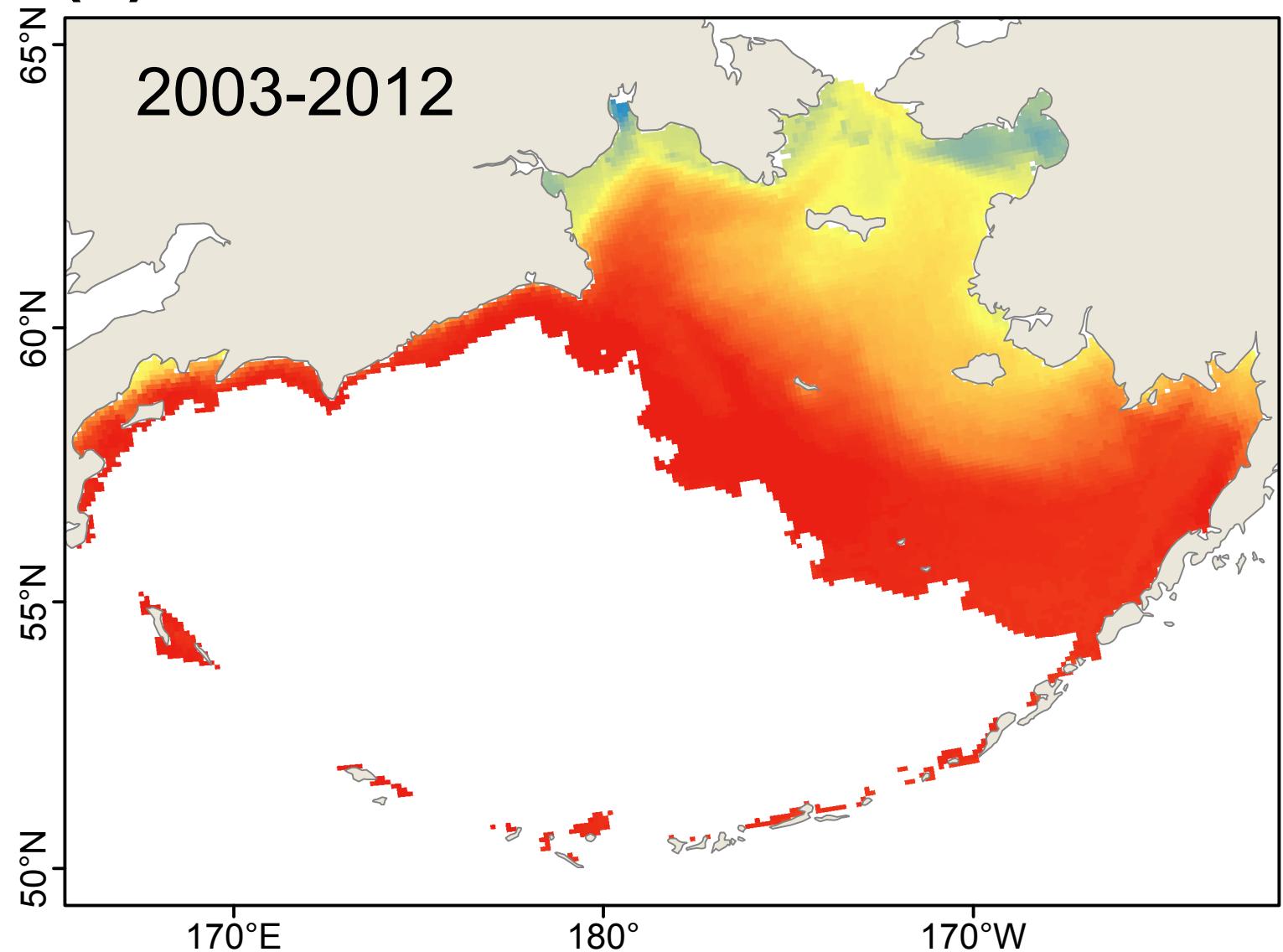


# *Molgula citrina*: Weekly Survival

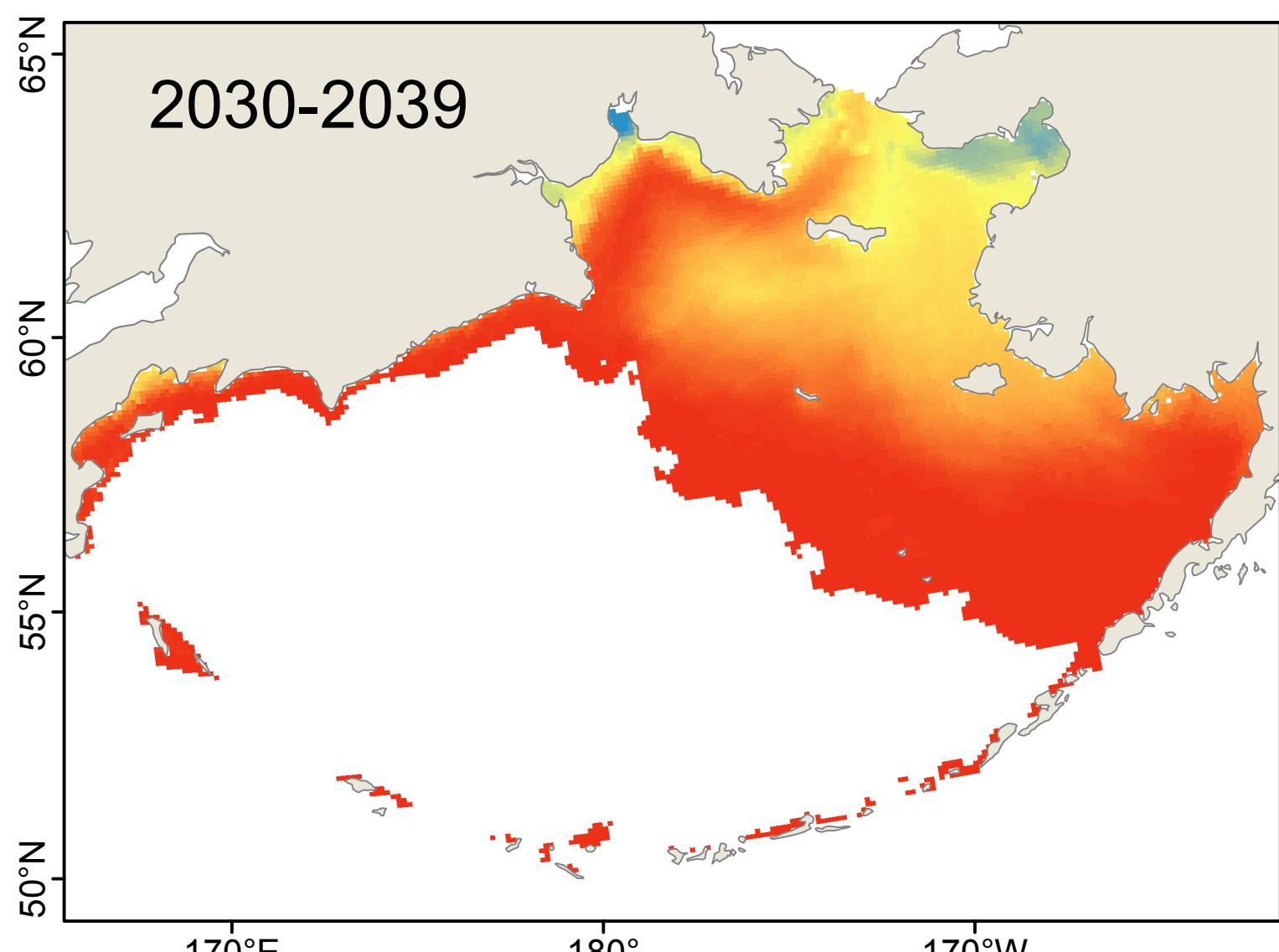
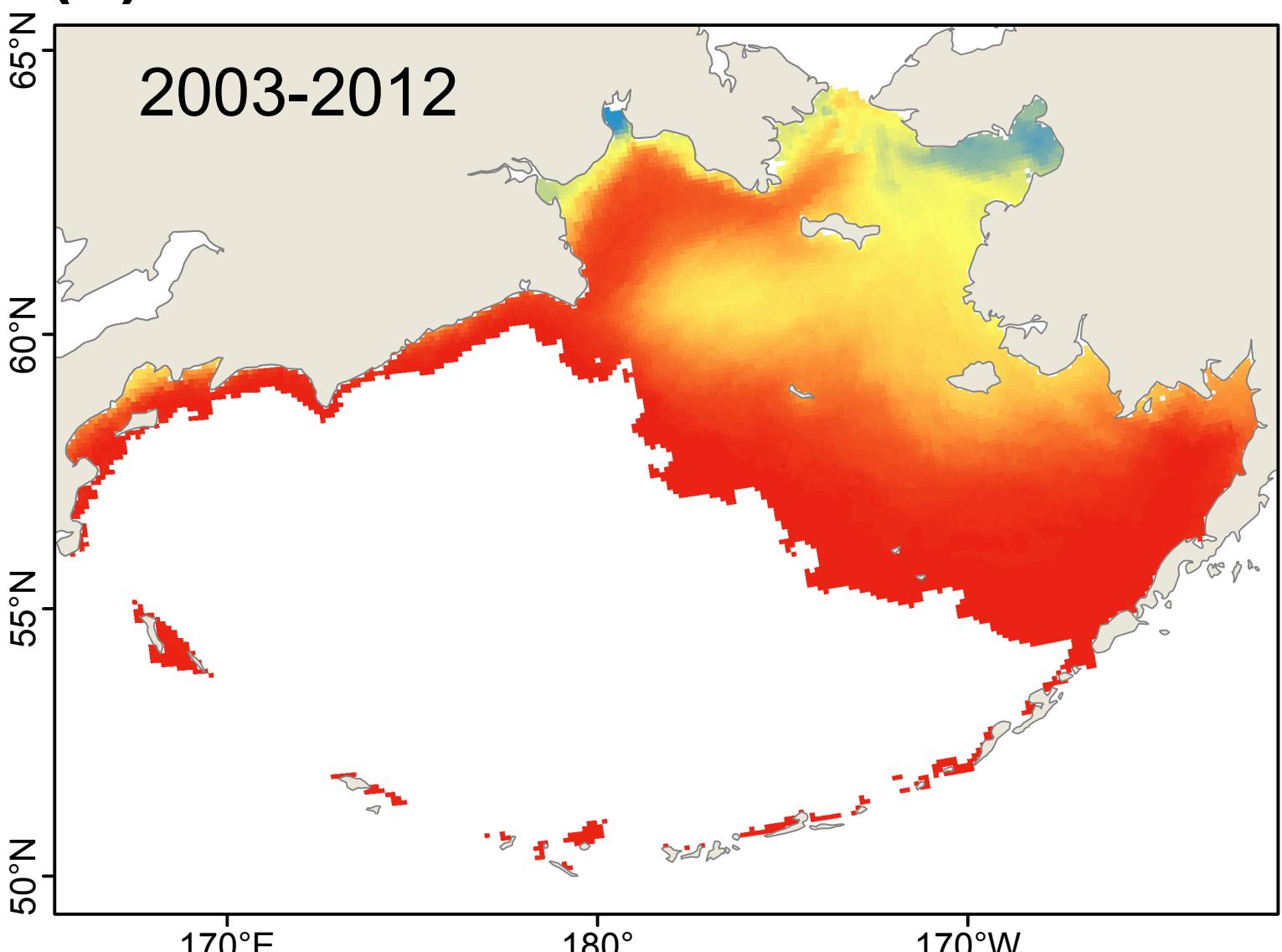
Average number of weeks of suitable habitat



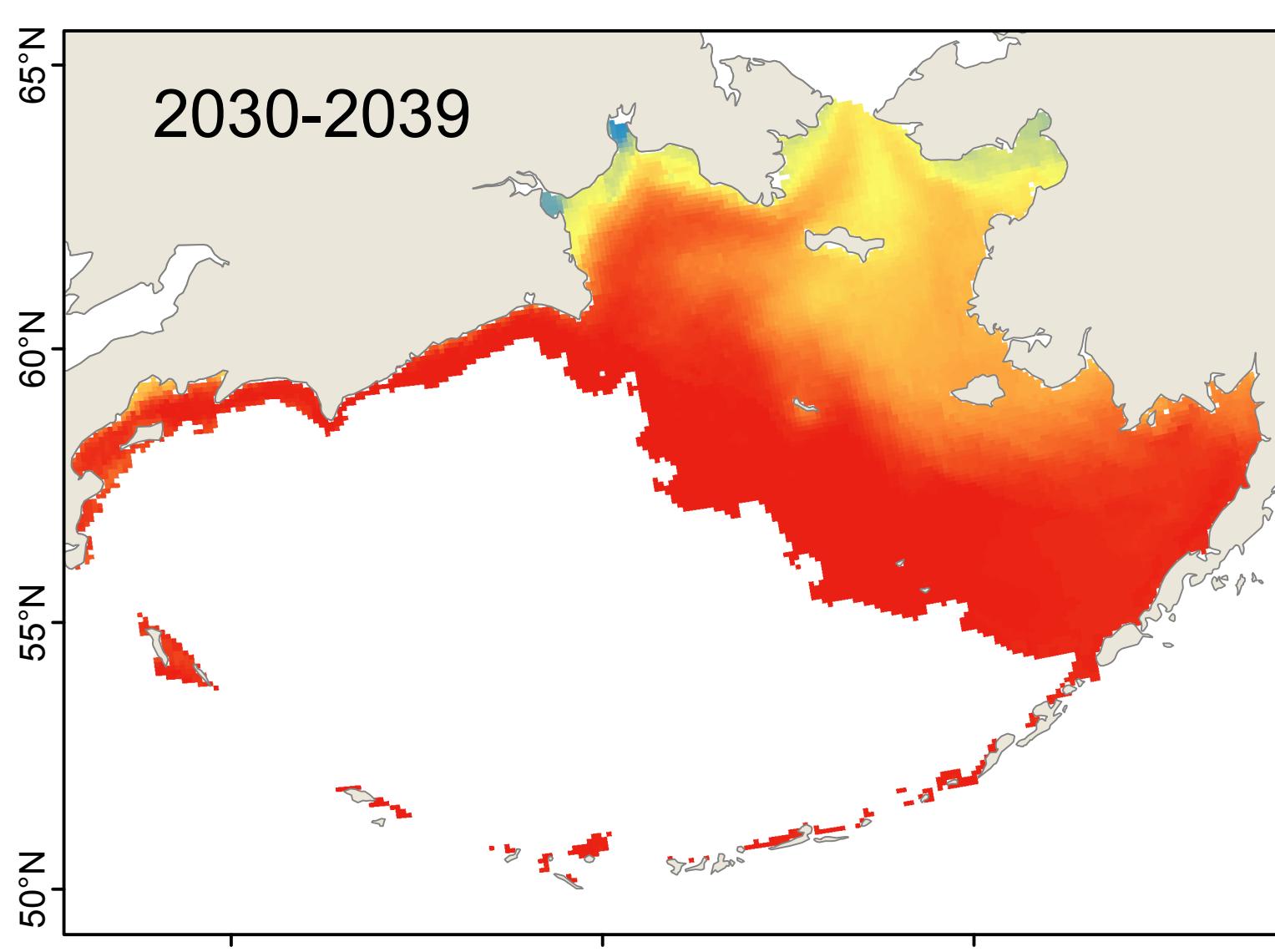
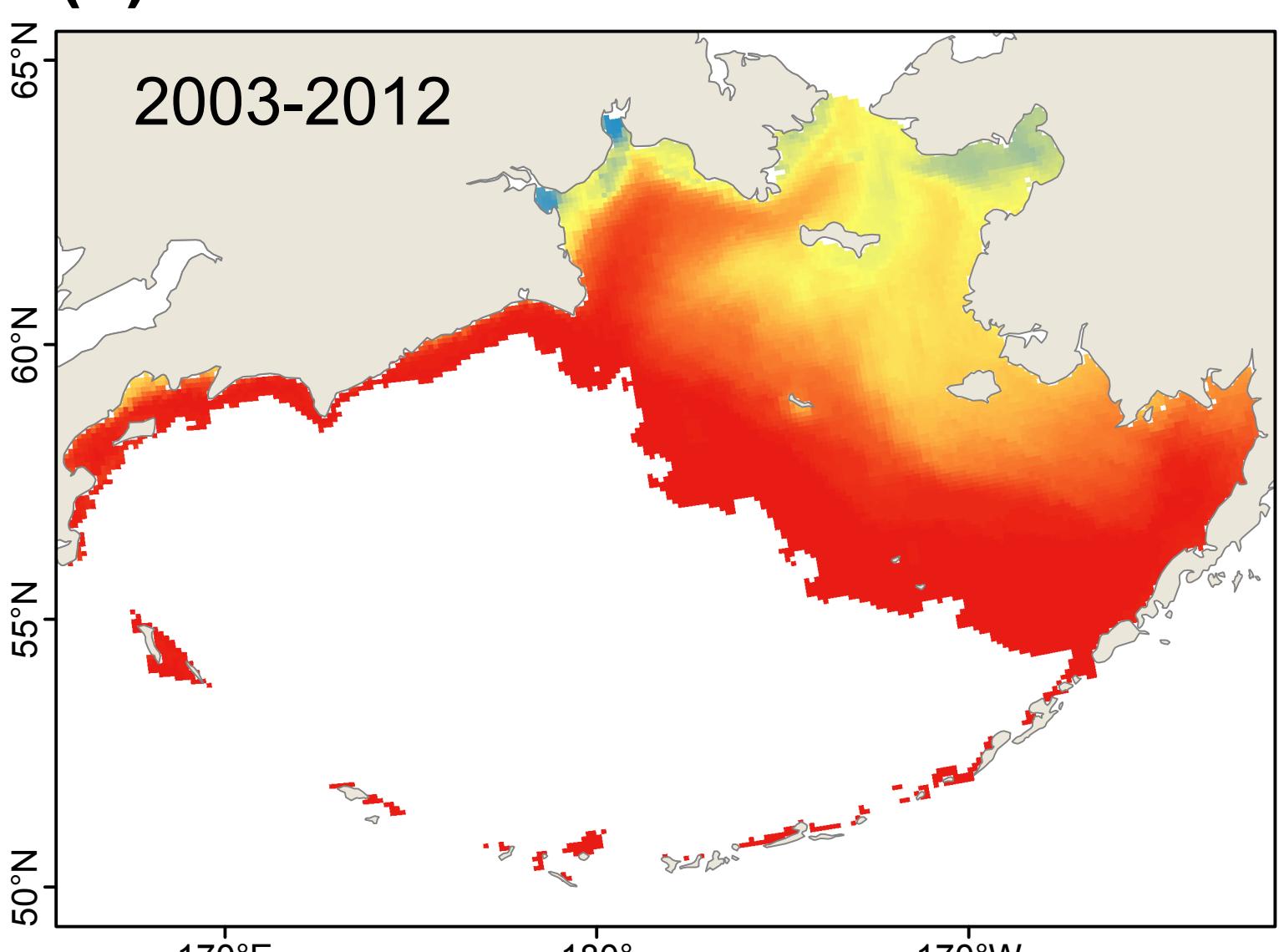
(a) Model: CGCM3-t47



(b) Model: ECHO-G

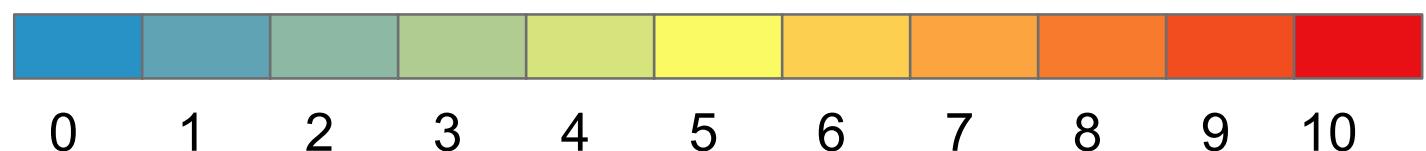


(c) Model: MIROC3.2

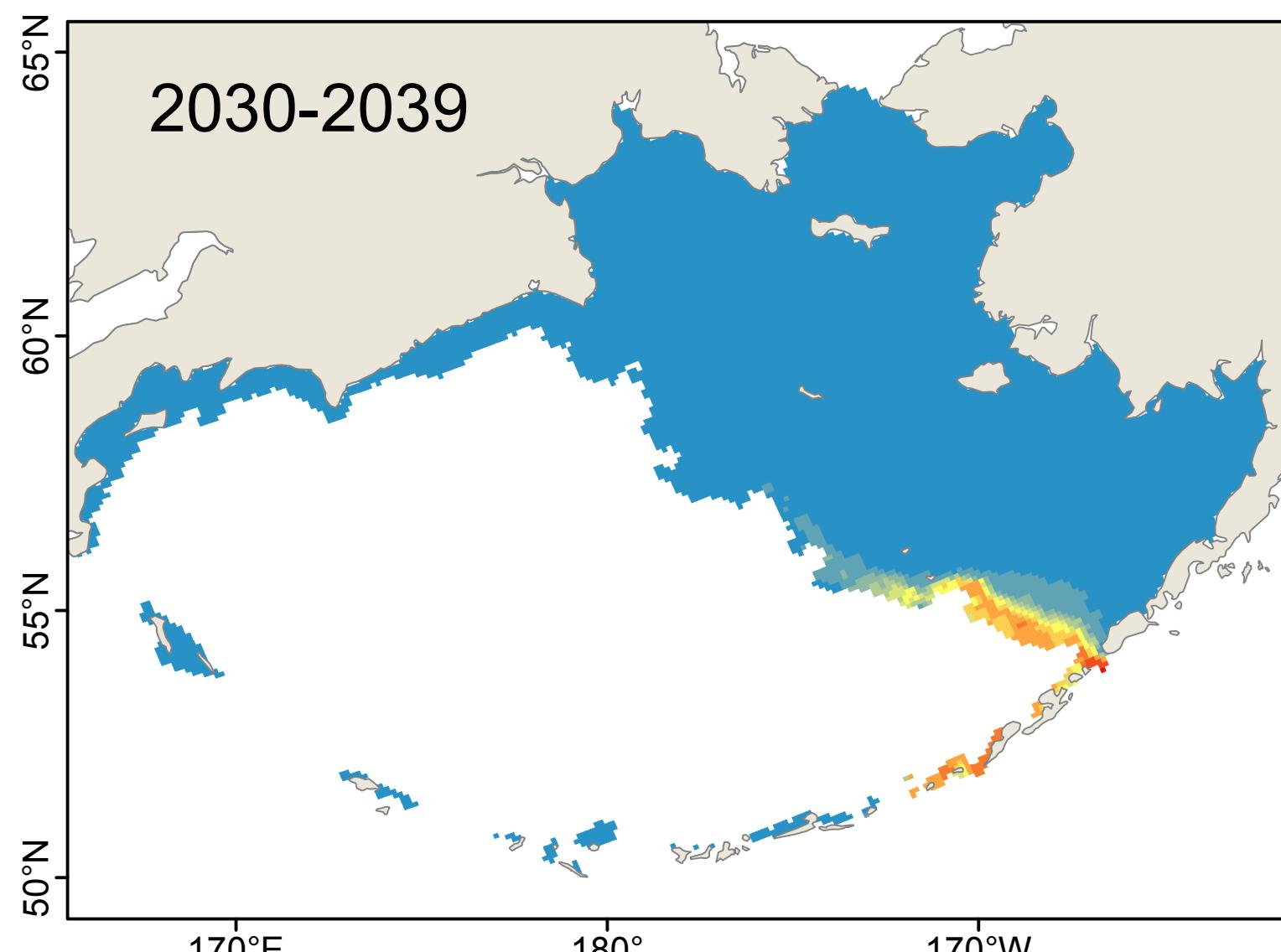
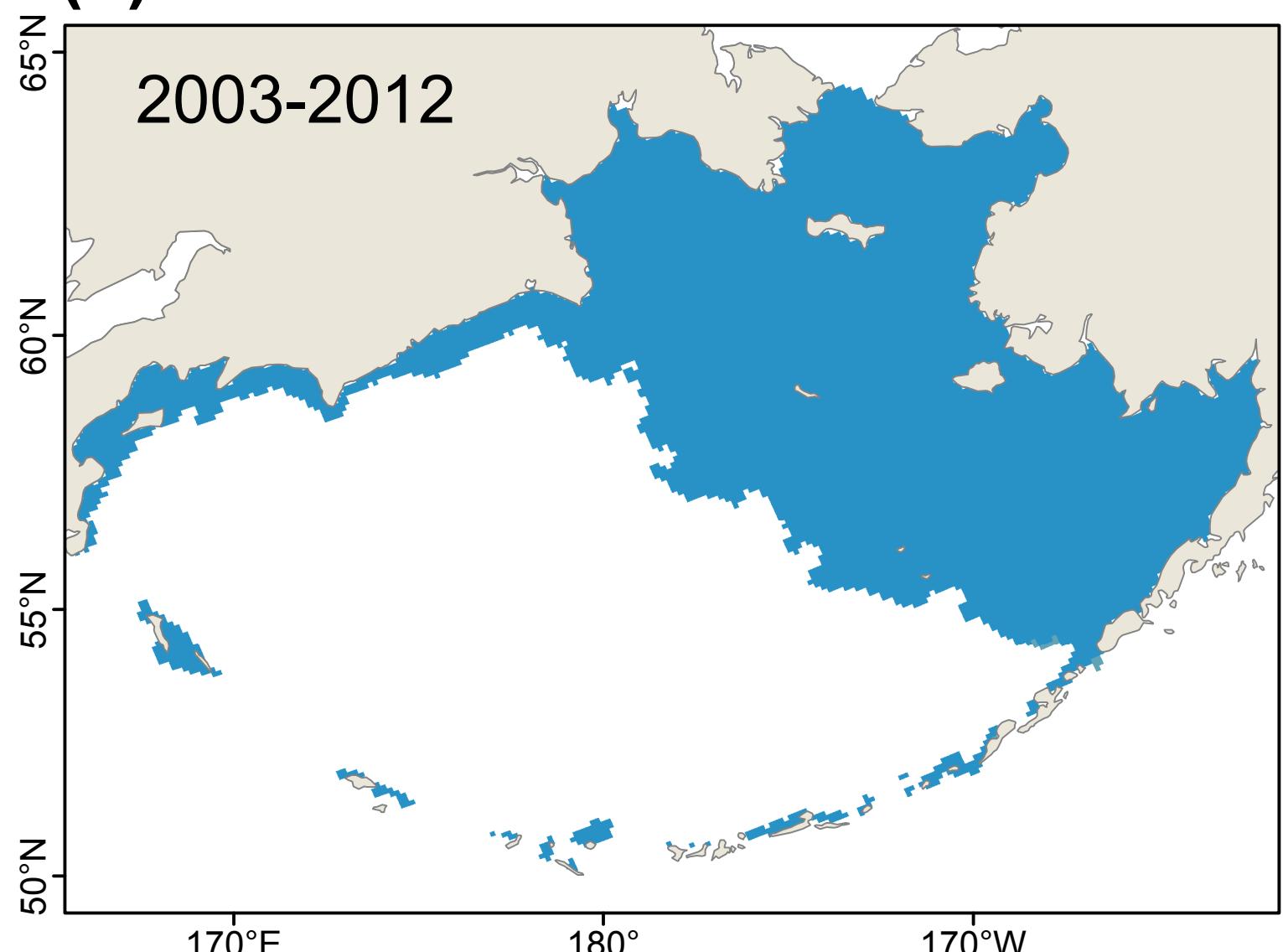


# *Molgula manhattensis*: Year-round Survival

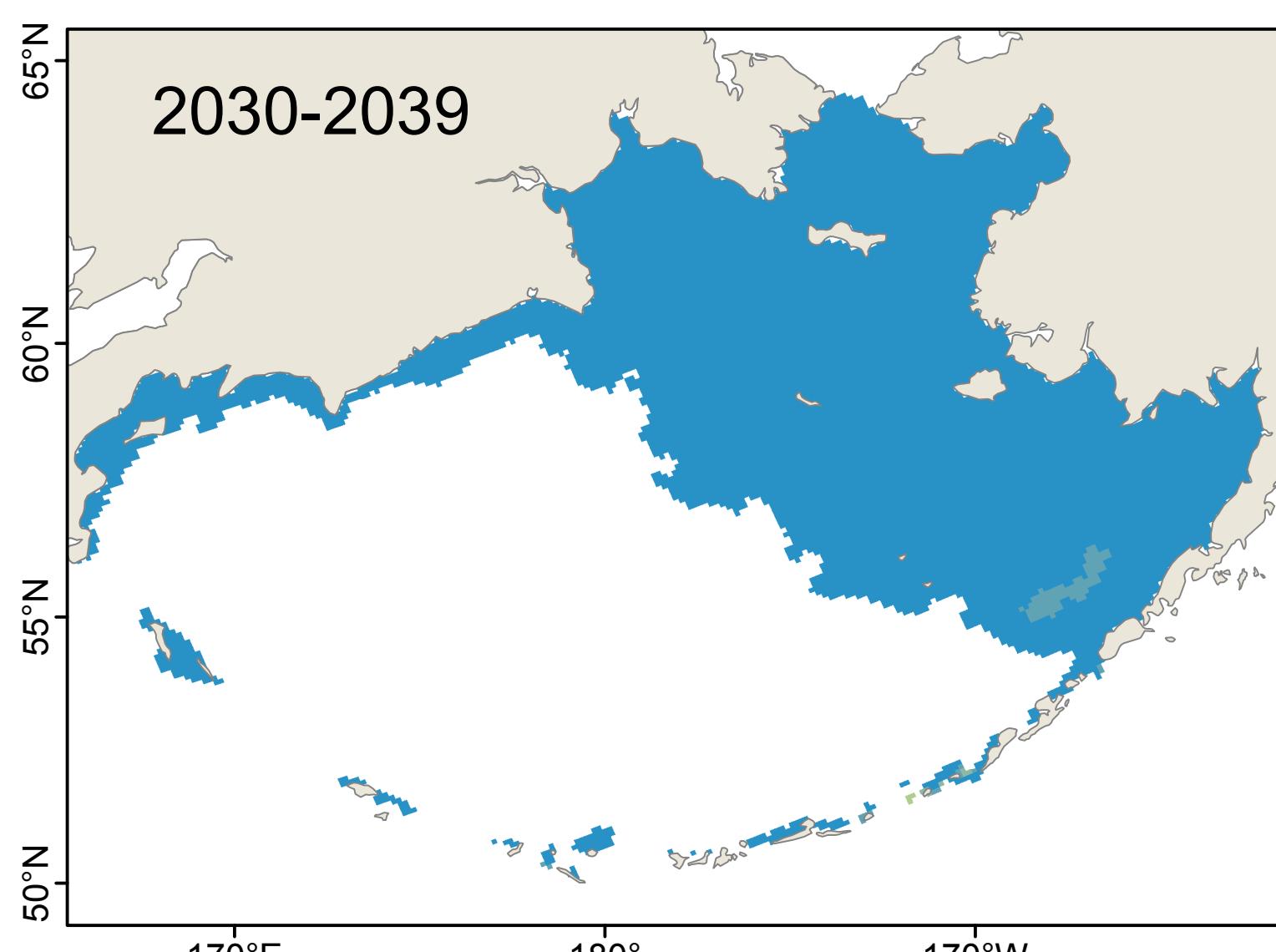
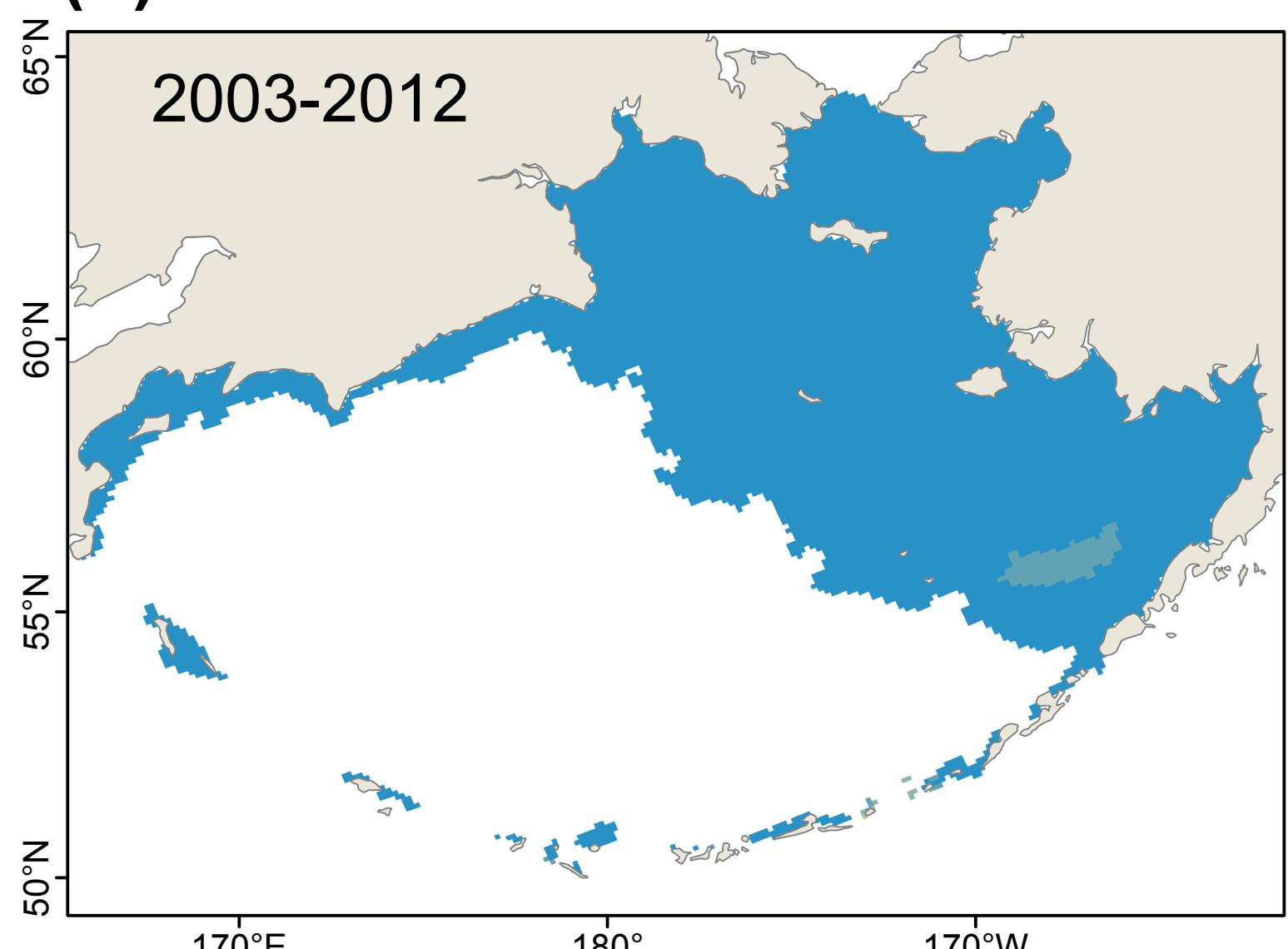
Number of years with suitable habitat



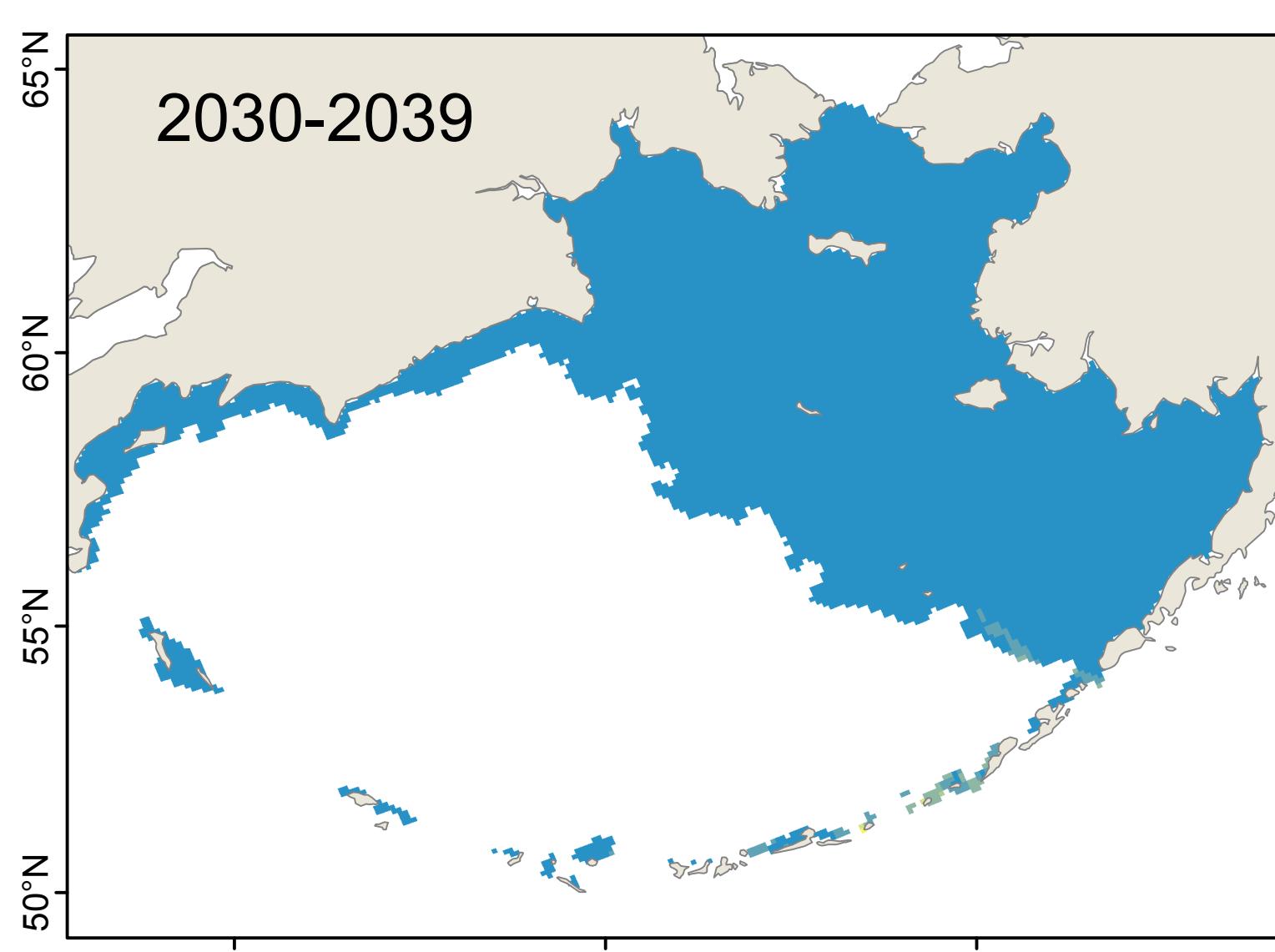
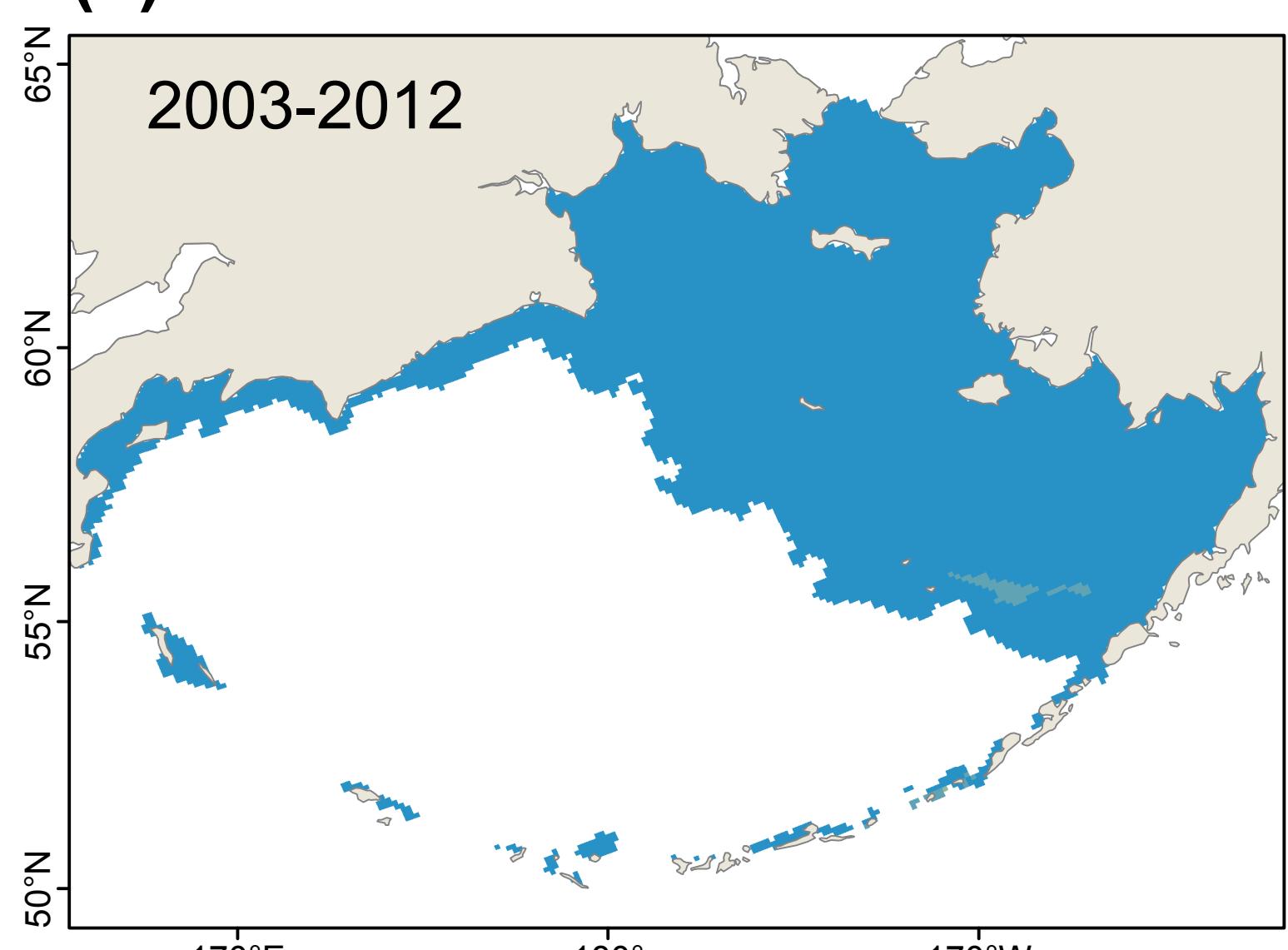
(a) Model: CGCM3-t47



(b) Model: ECHO-G

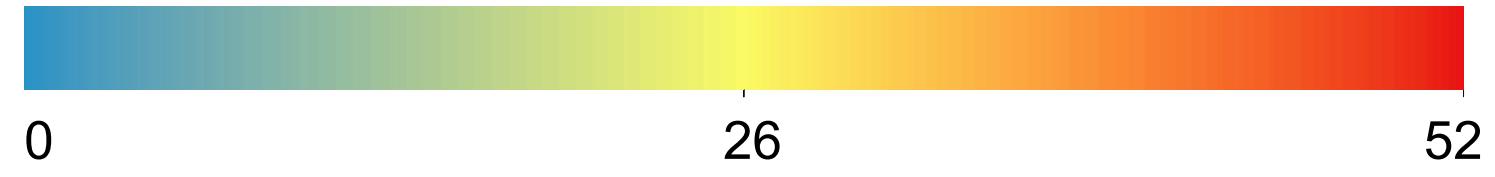


(c) Model: MIROC3.2

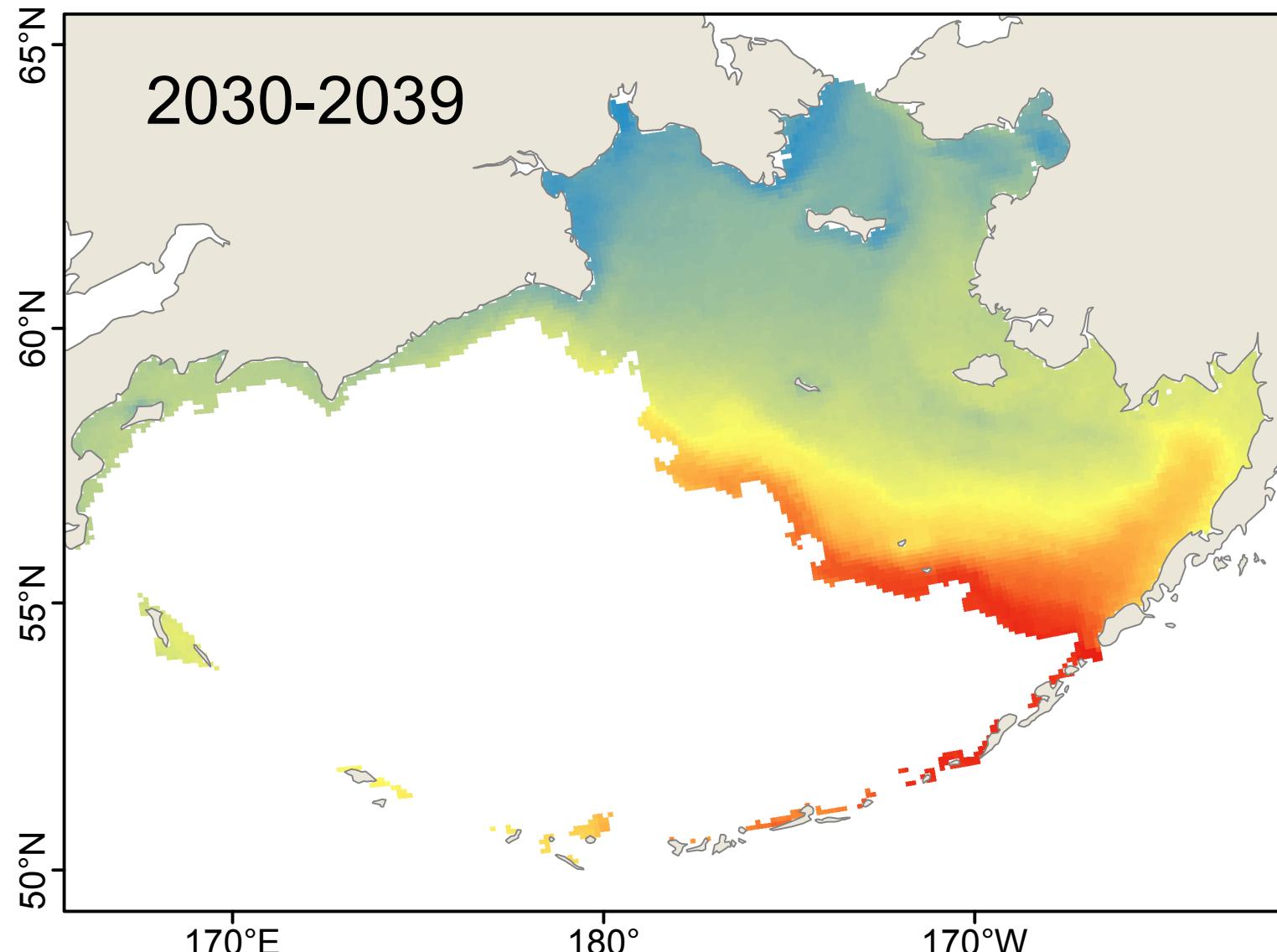
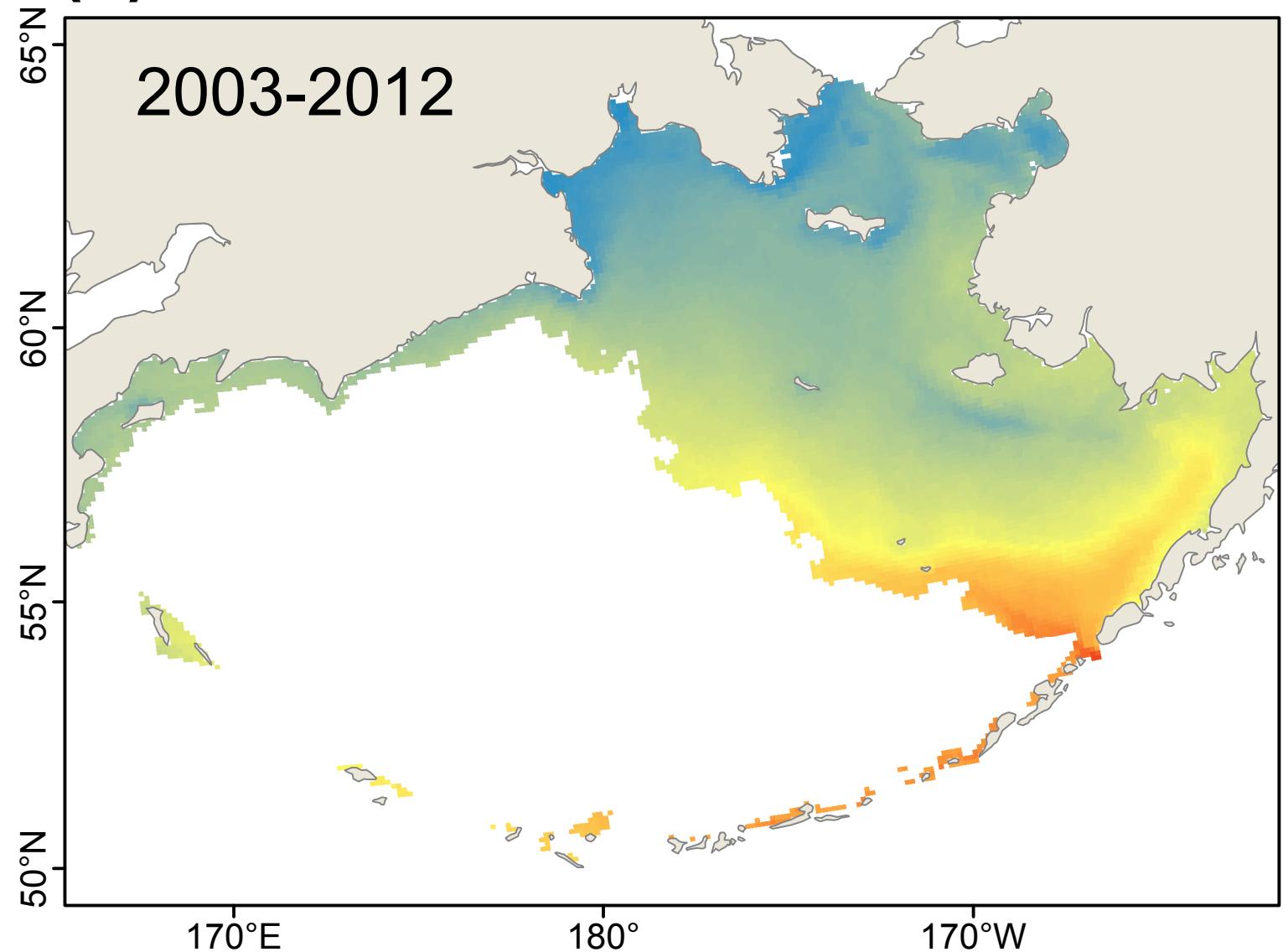


# *Molgula manhattensis*: Weekly Survival

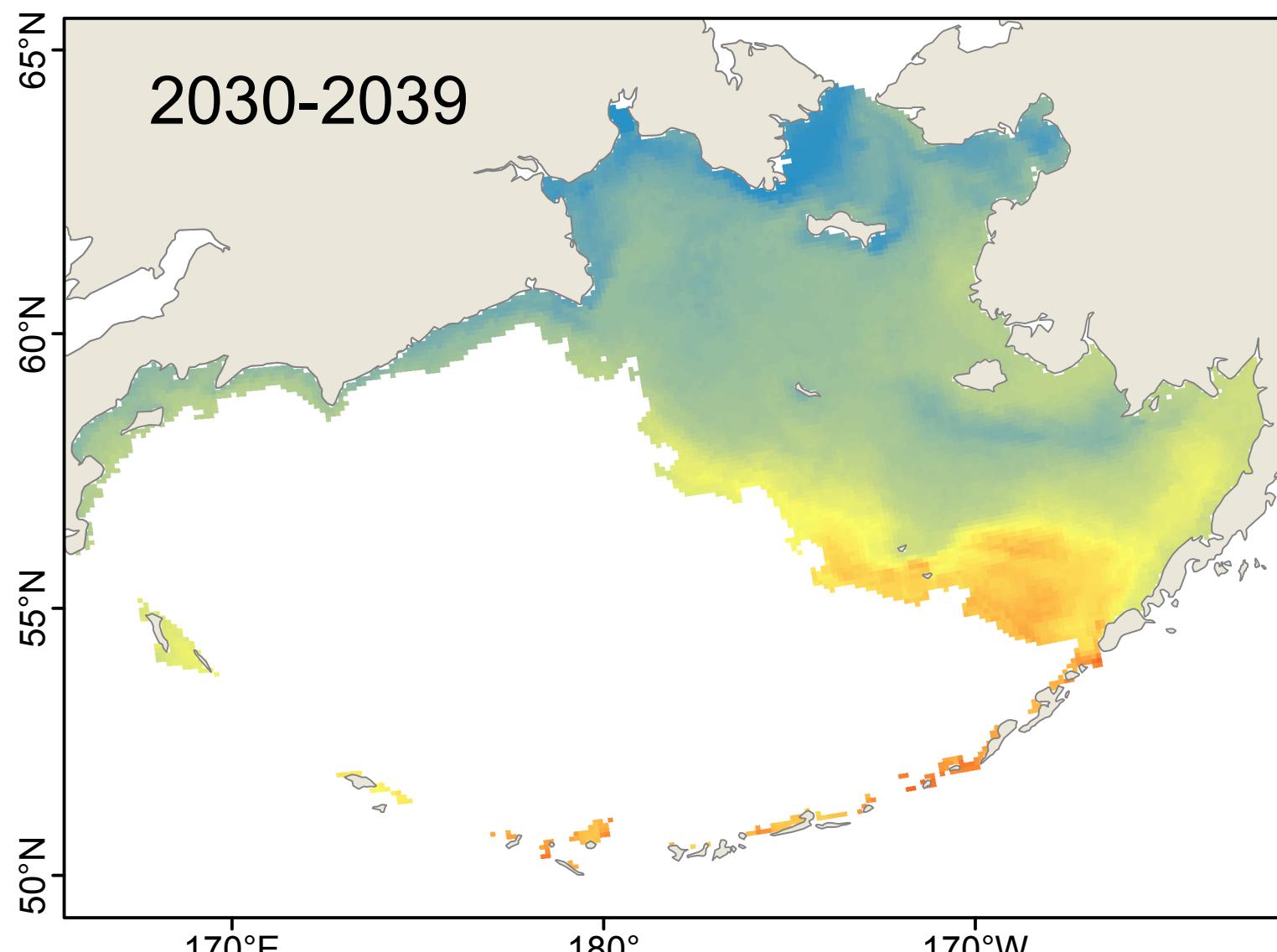
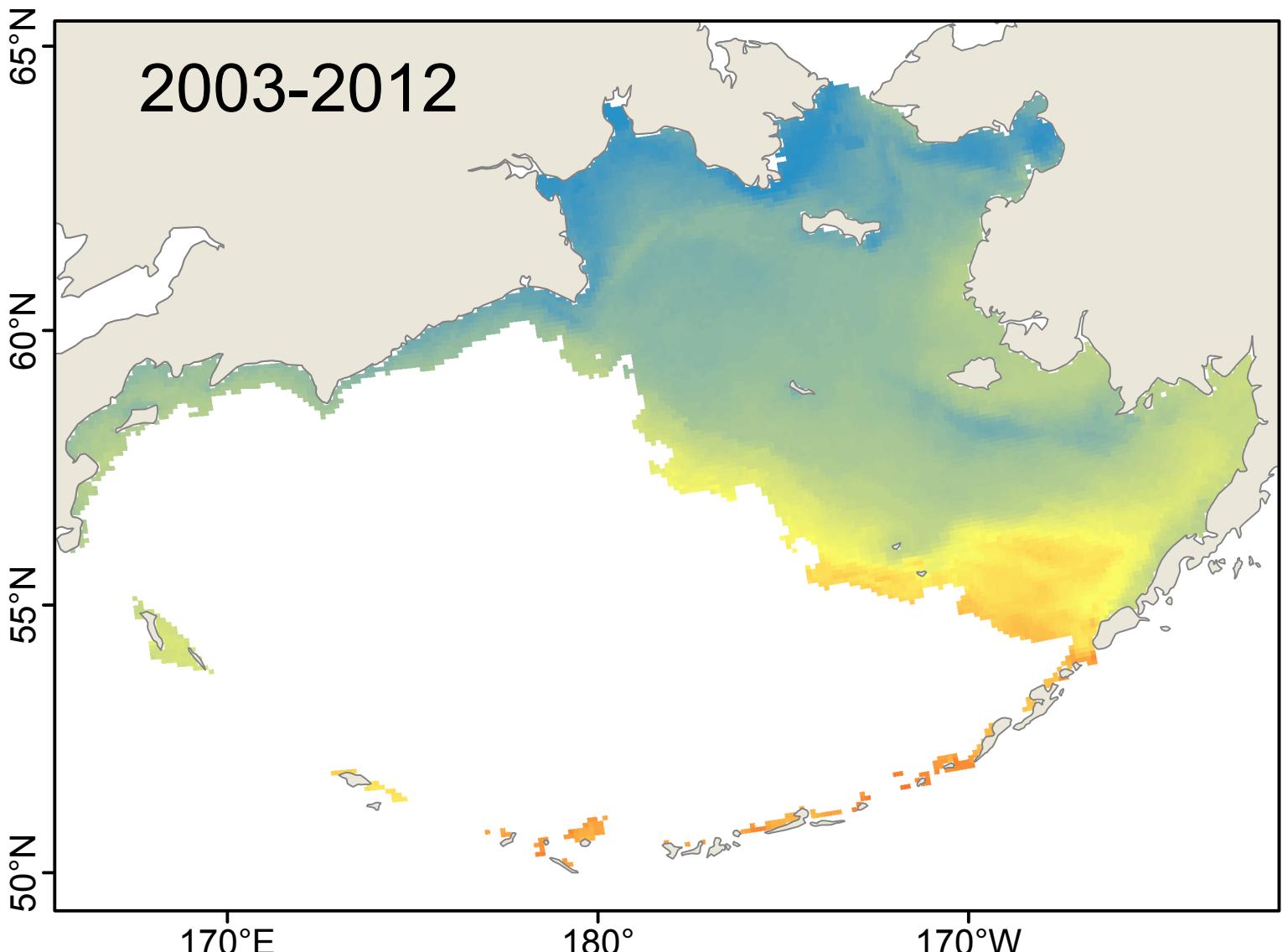
Average number of weeks of suitable habitat



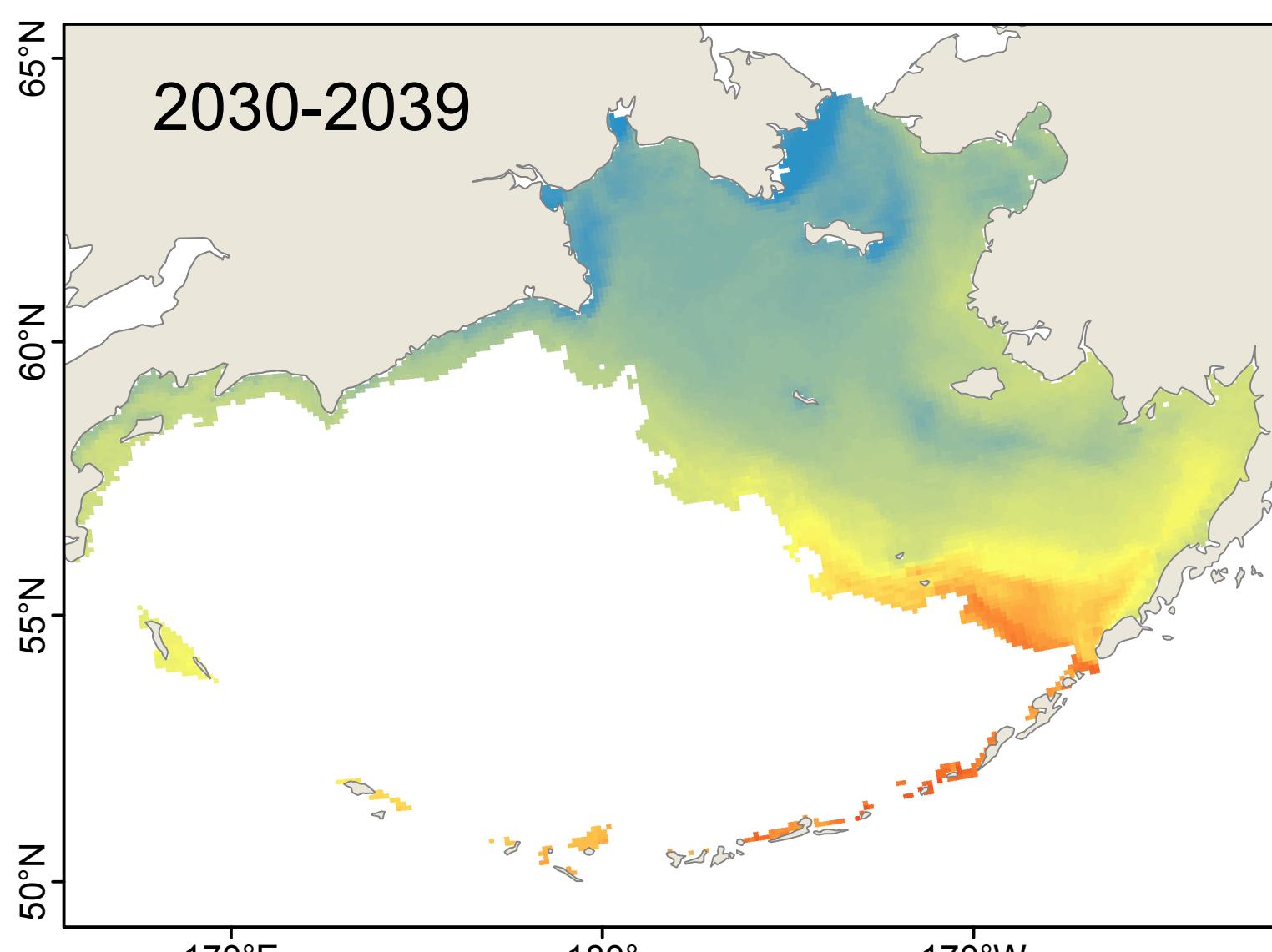
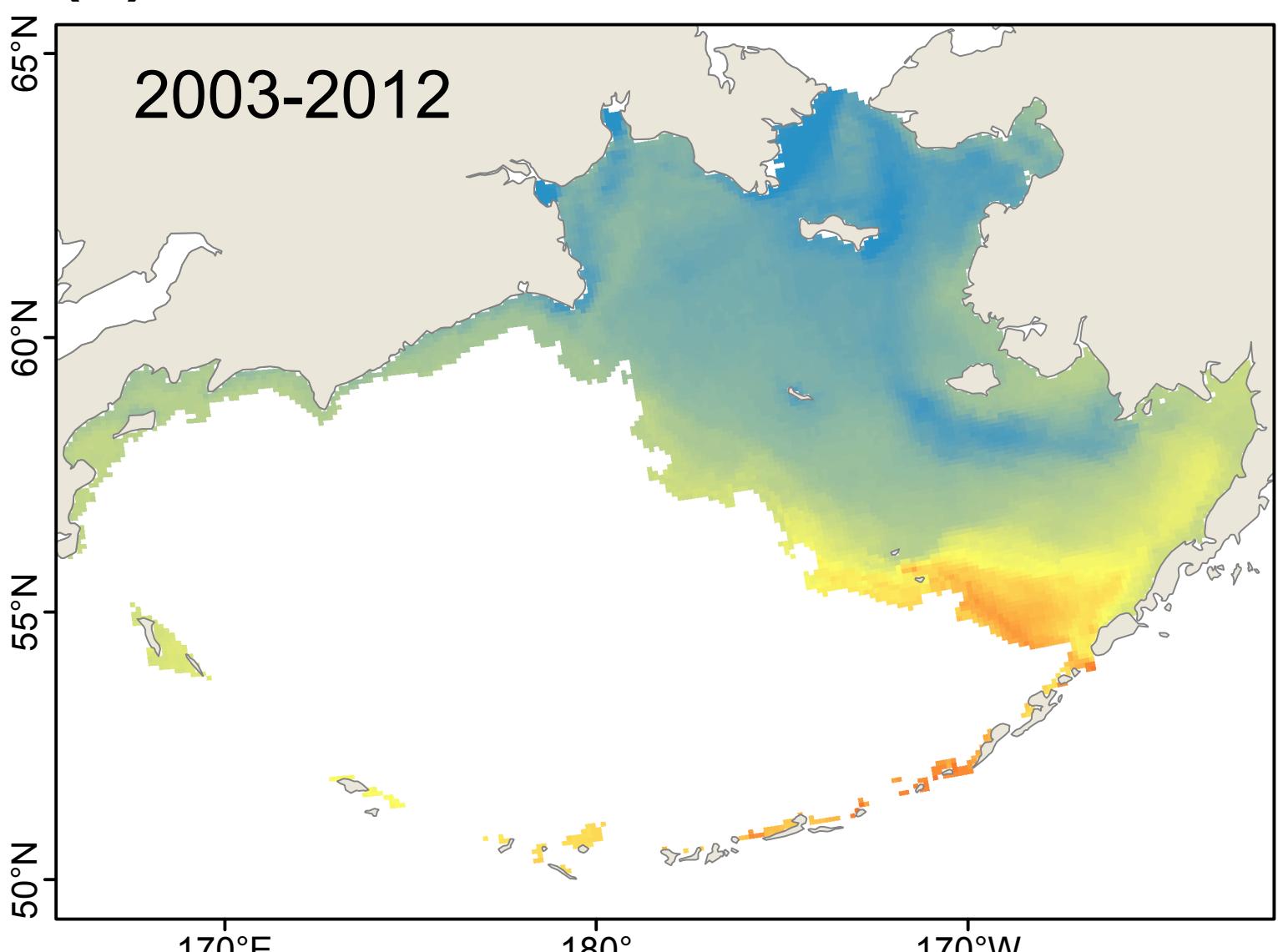
(a) Model: CGCM3-t47



(b) Model: ECHO-G

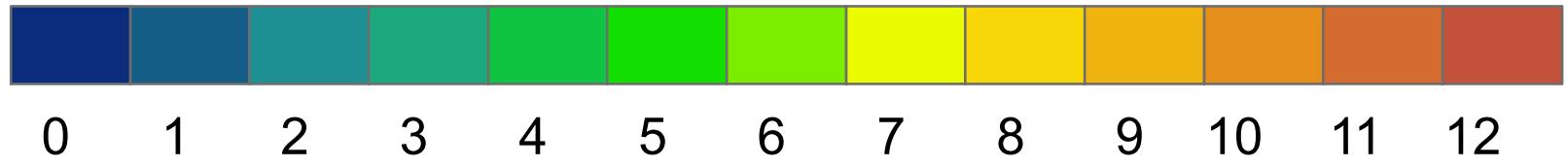


(c) Model: MIROC3.2

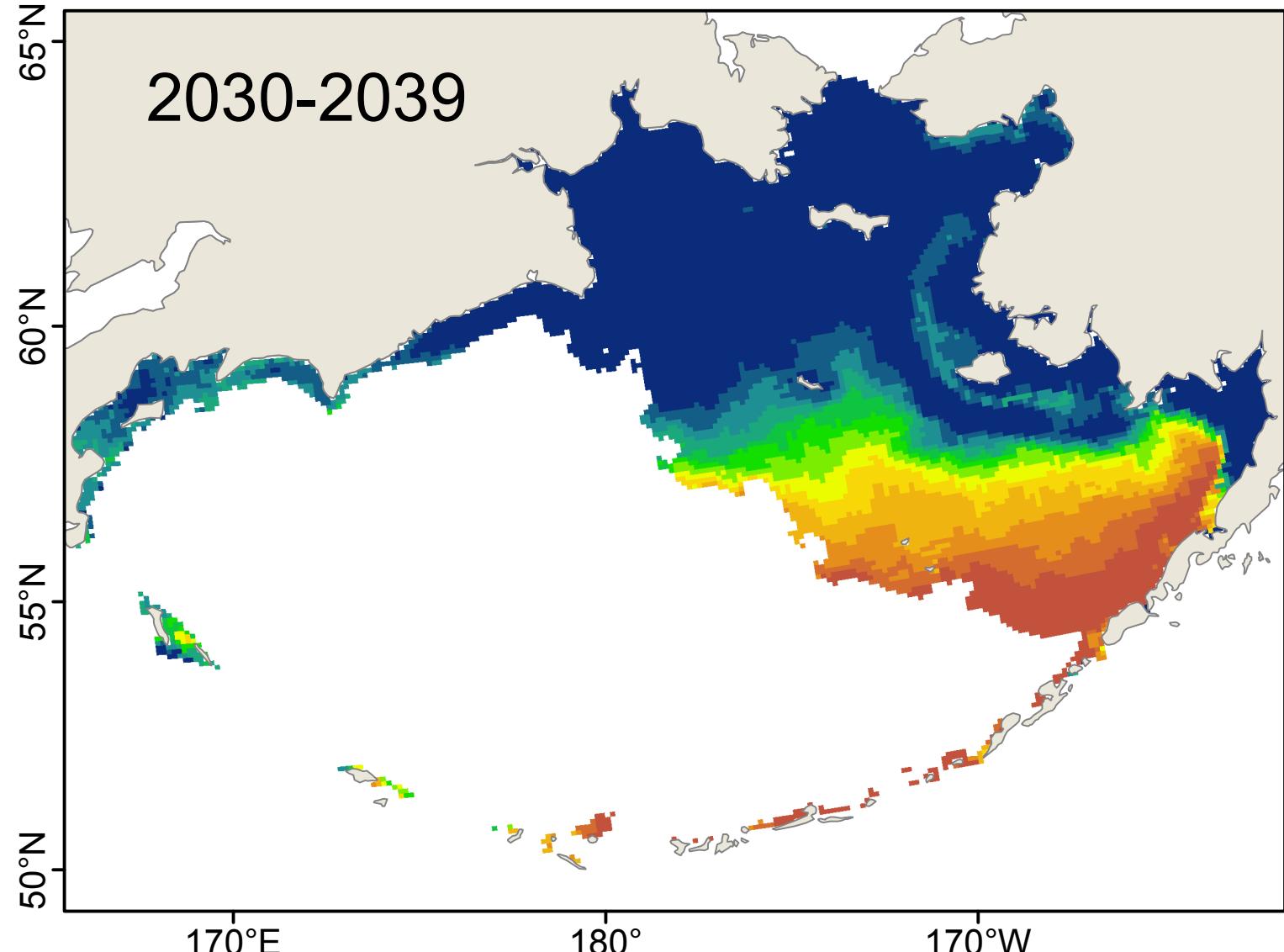
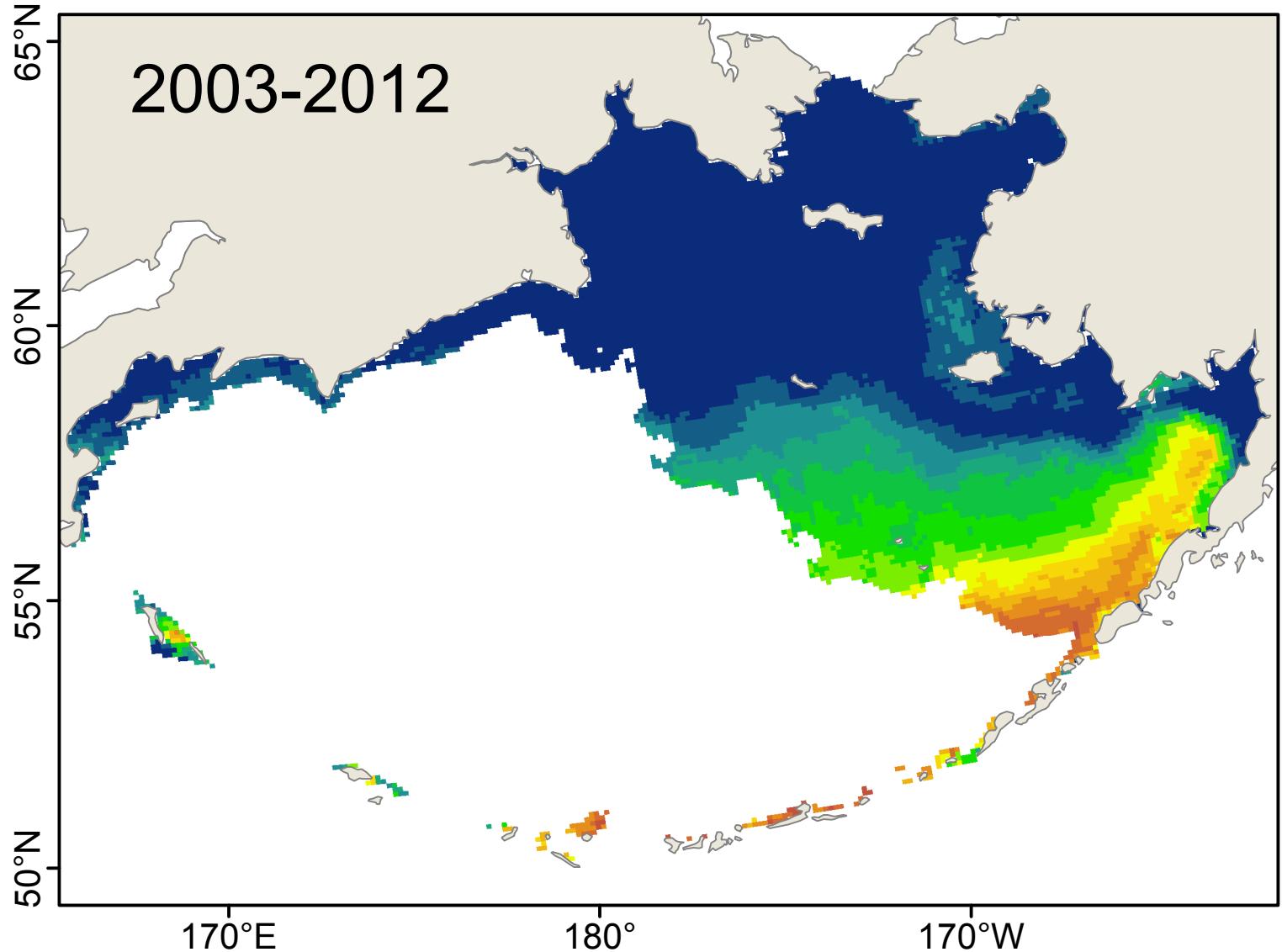


# *Molgula manhattensis: Reproduction*

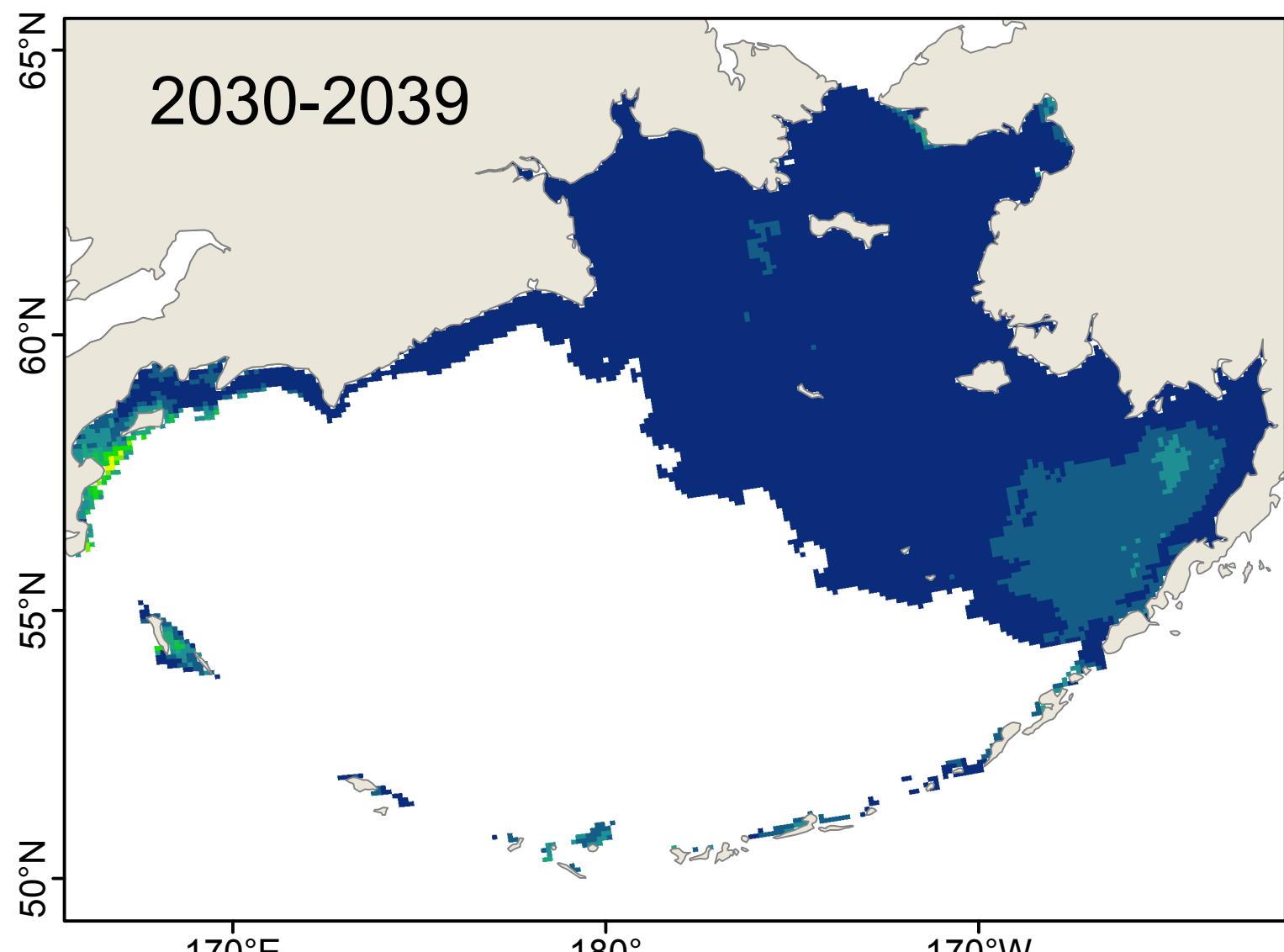
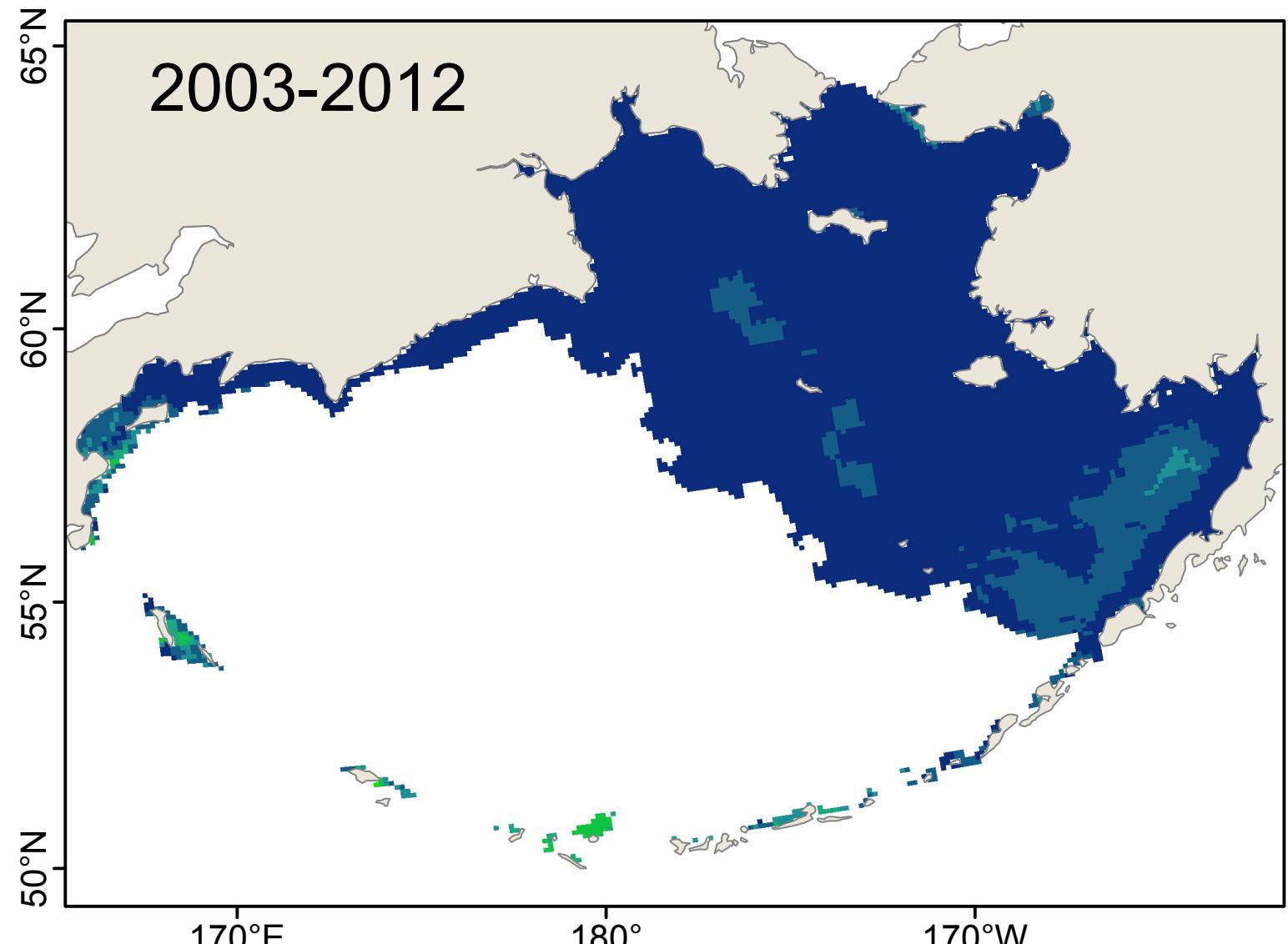
Average number of consecutive weeks of suitable habitat



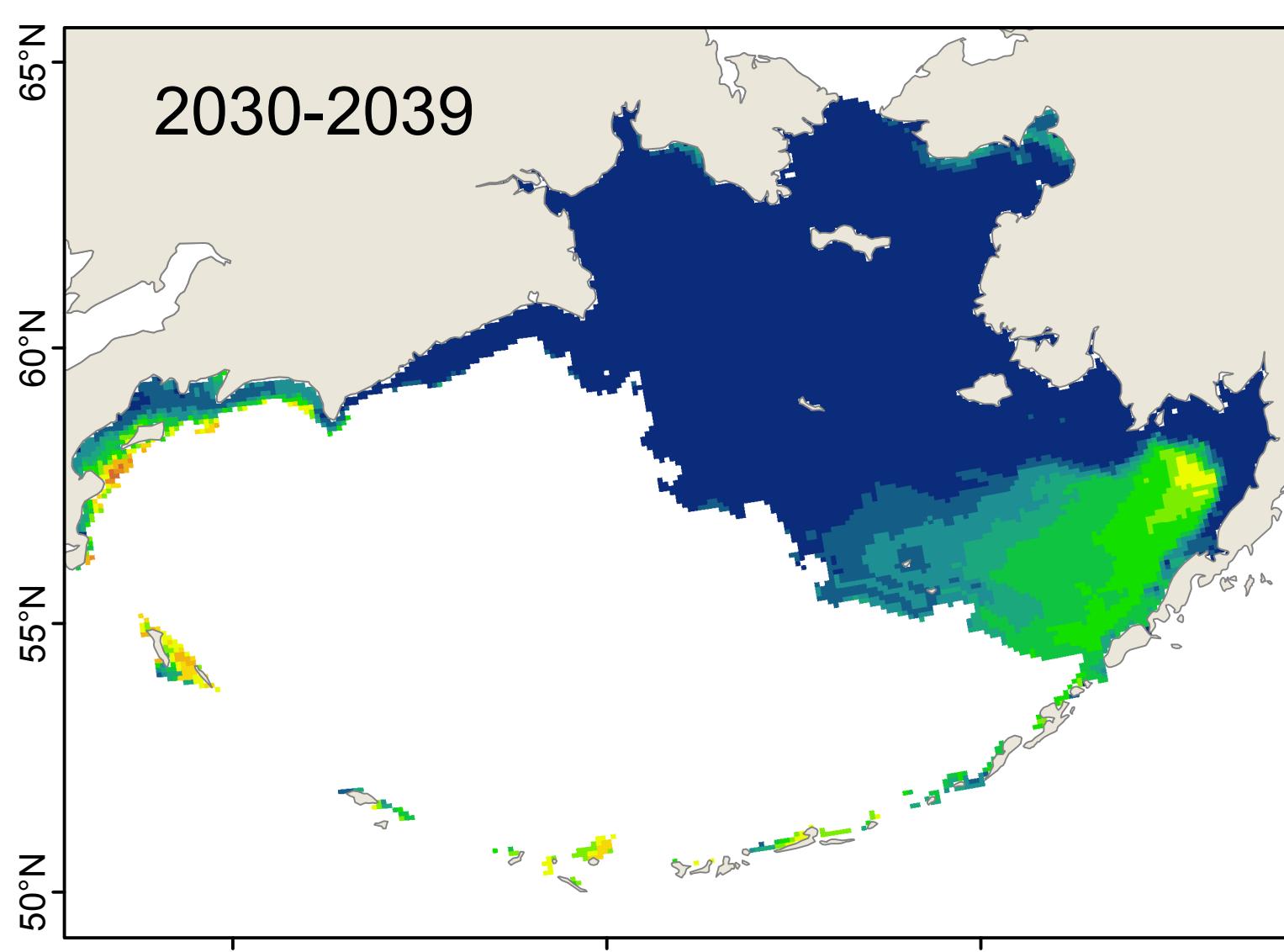
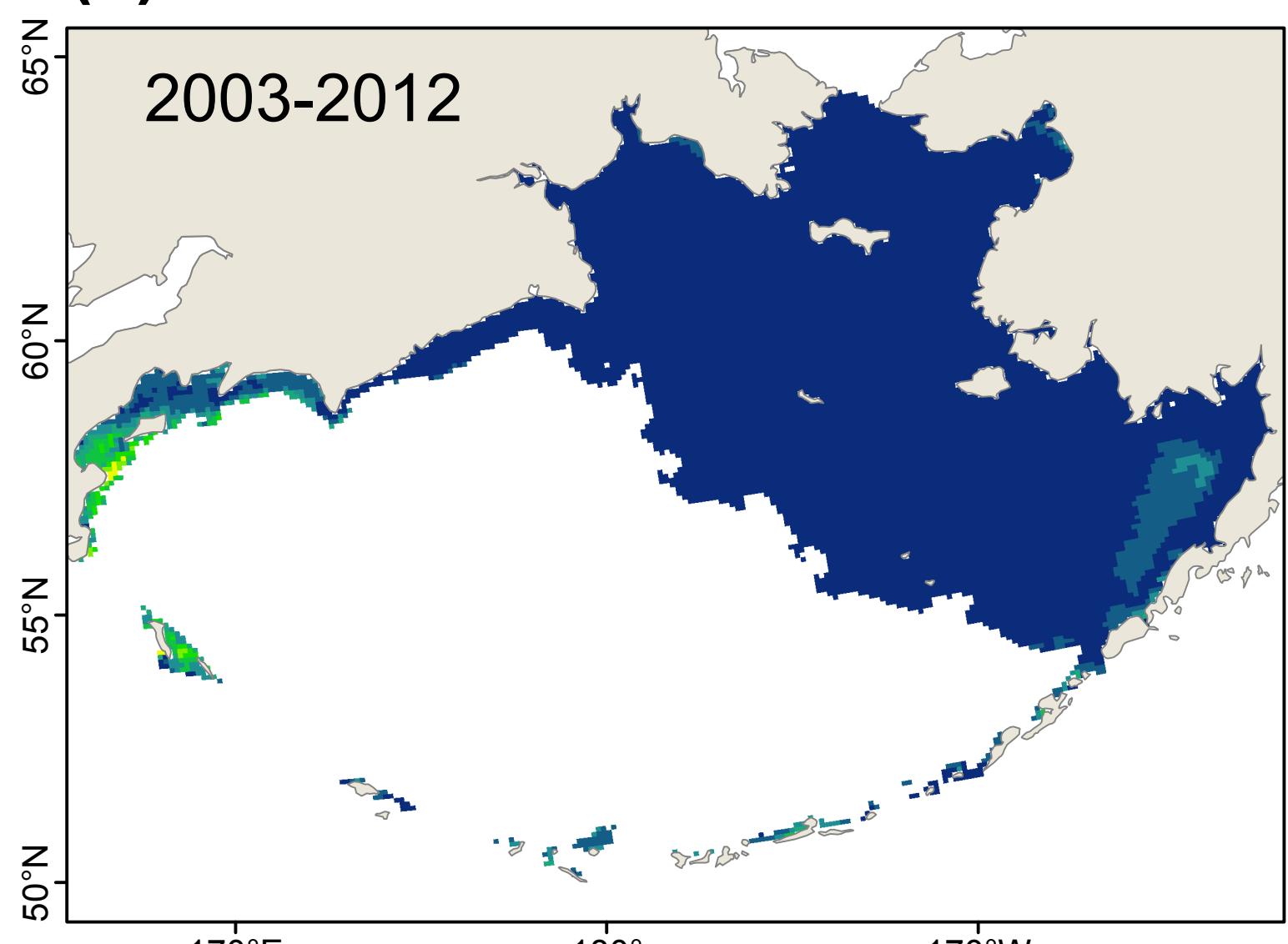
(a) Model: CGCM3-t47



(b) Model: ECHO-G

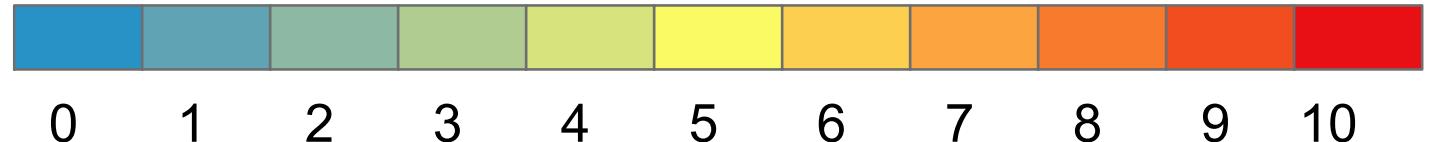


(c) Model: MIROC3.2

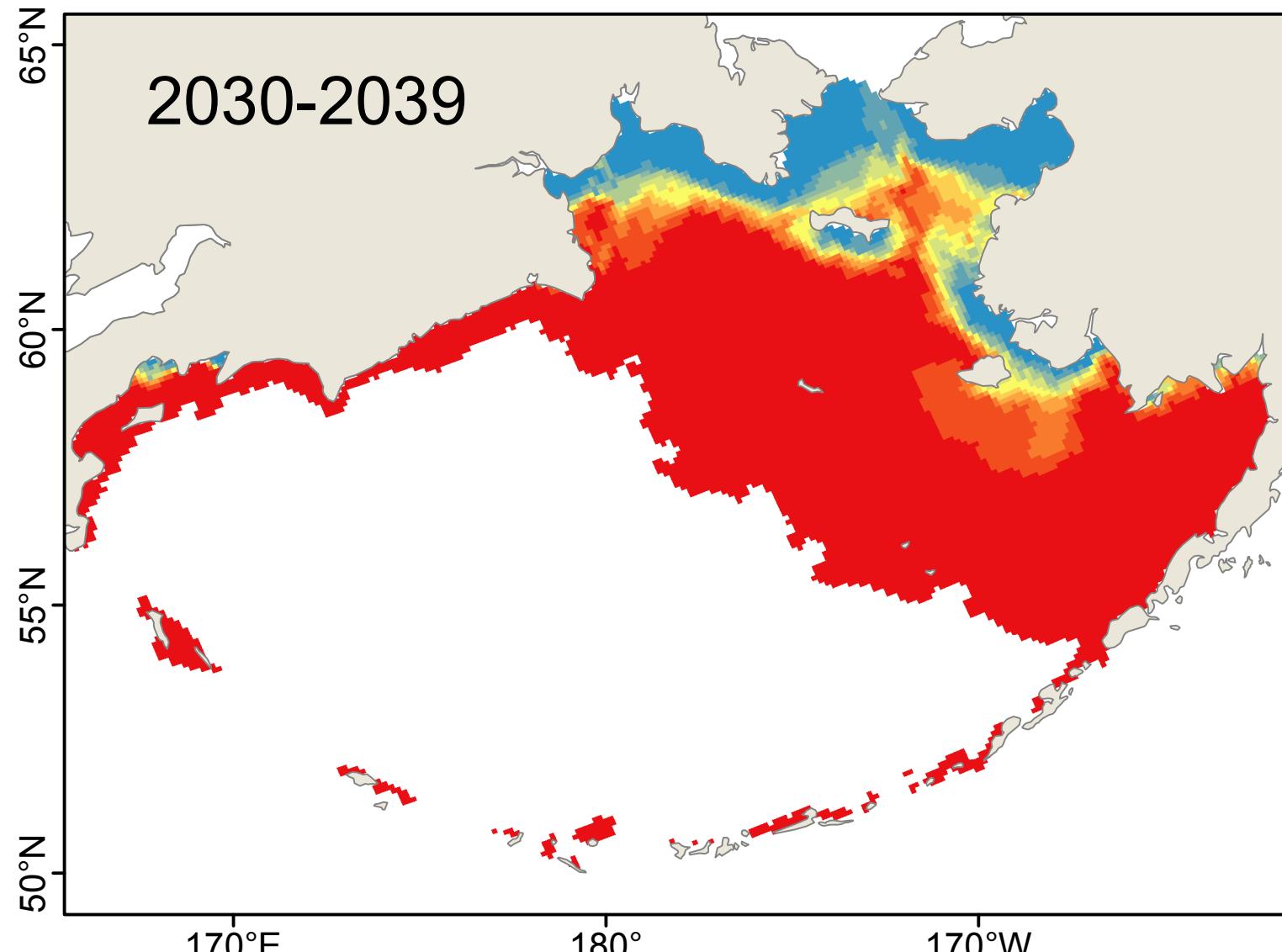
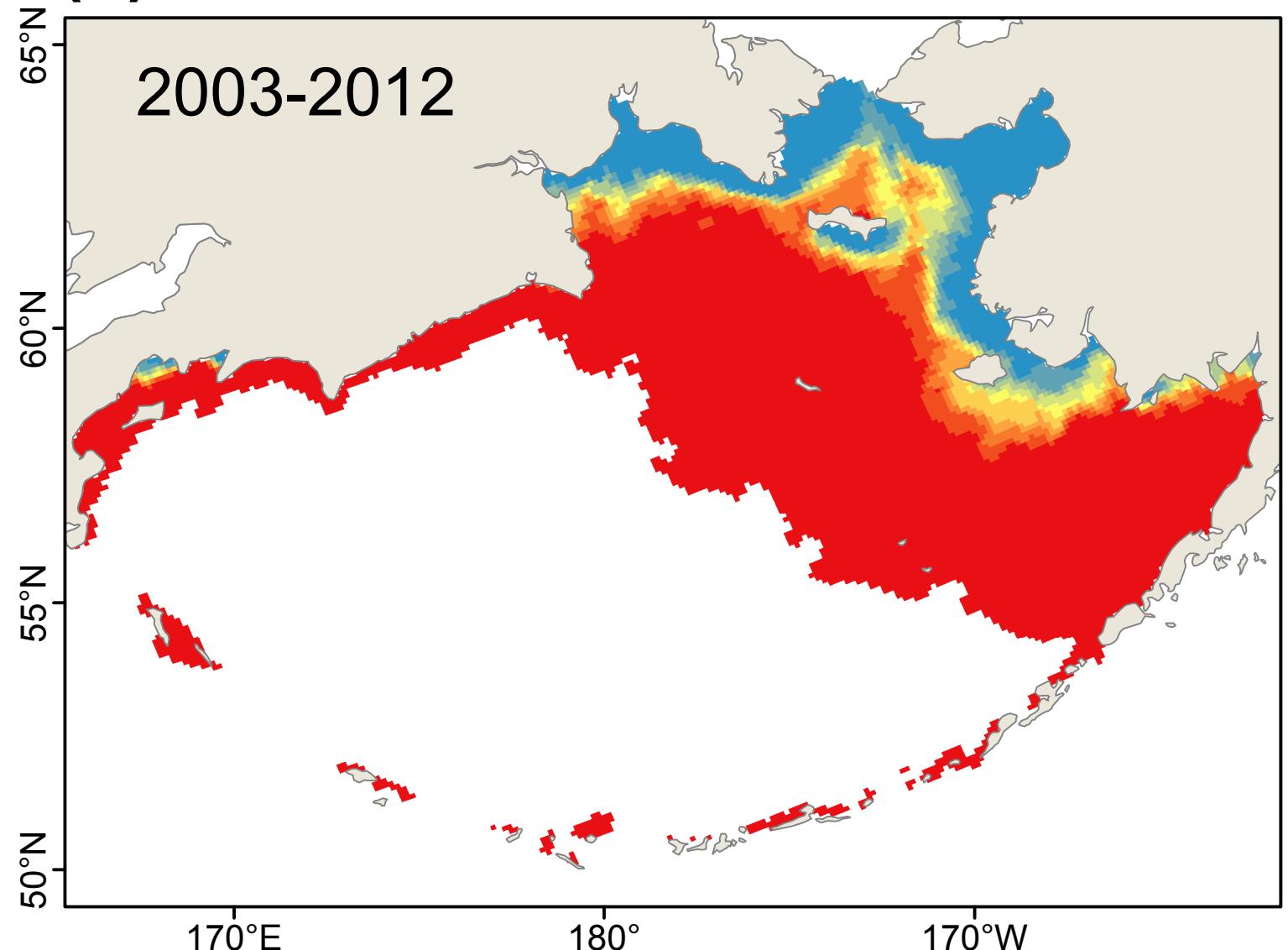


# *Styela clava: Year-round Survival*

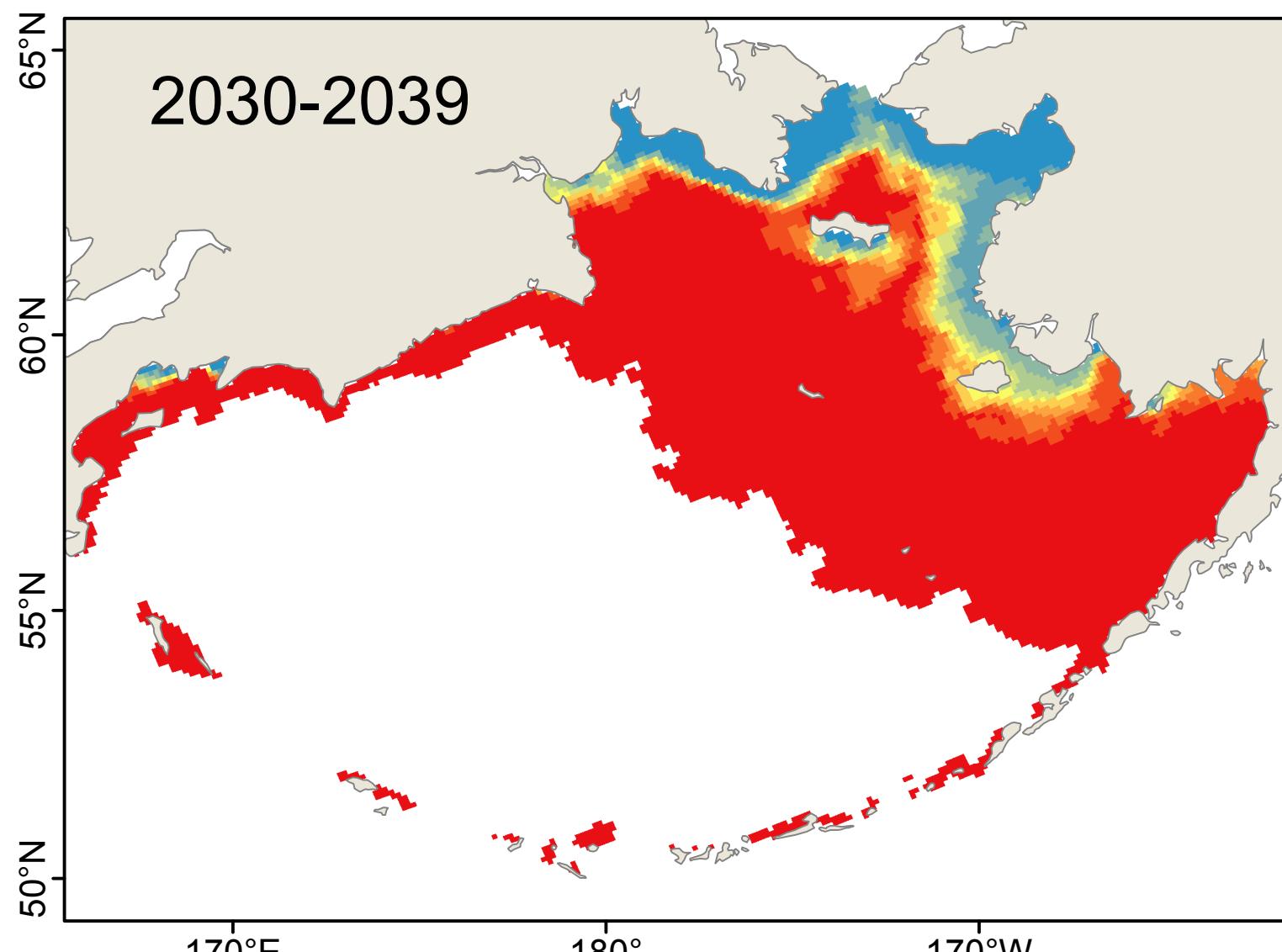
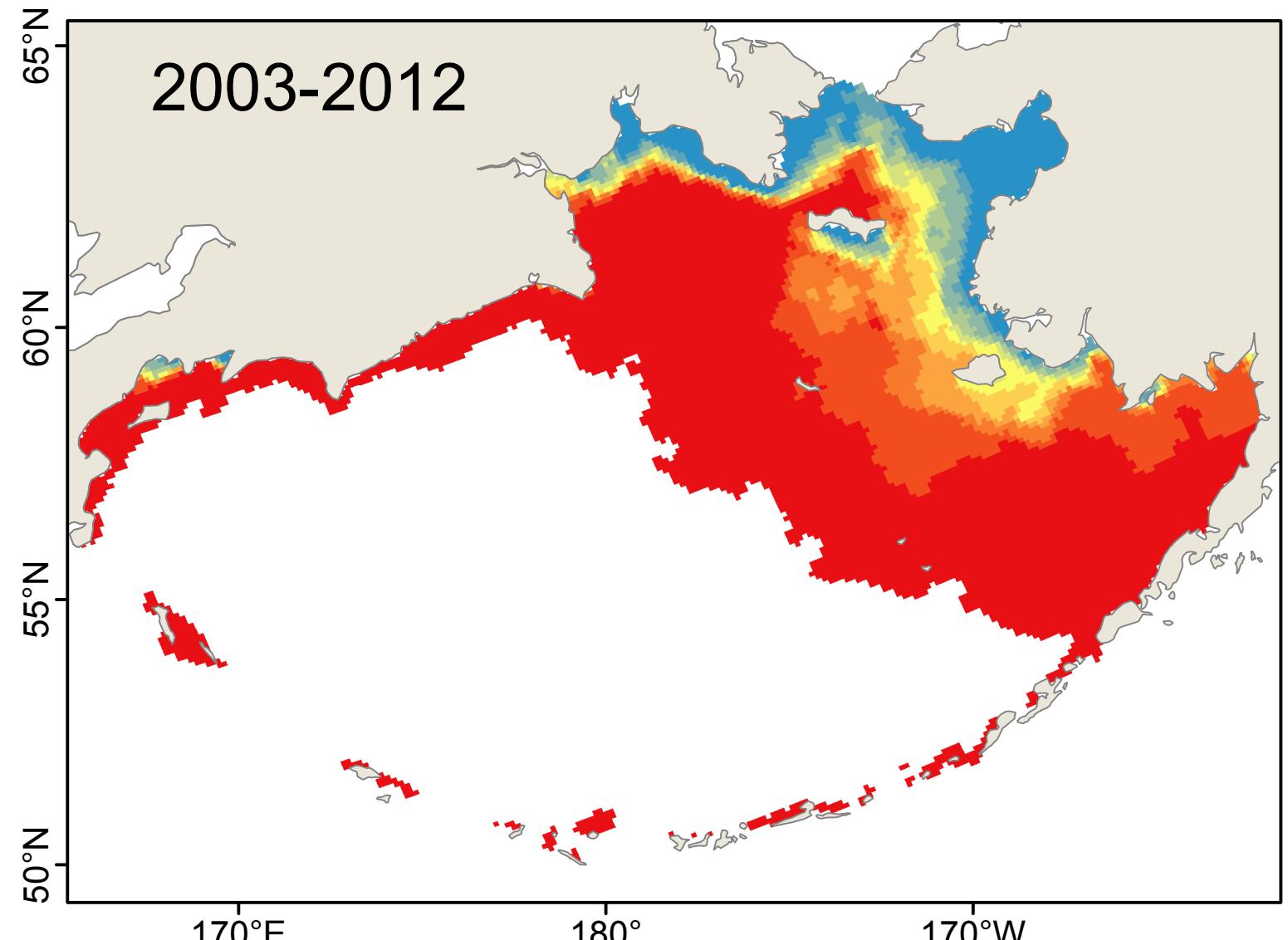
Number of years with suitable habitat



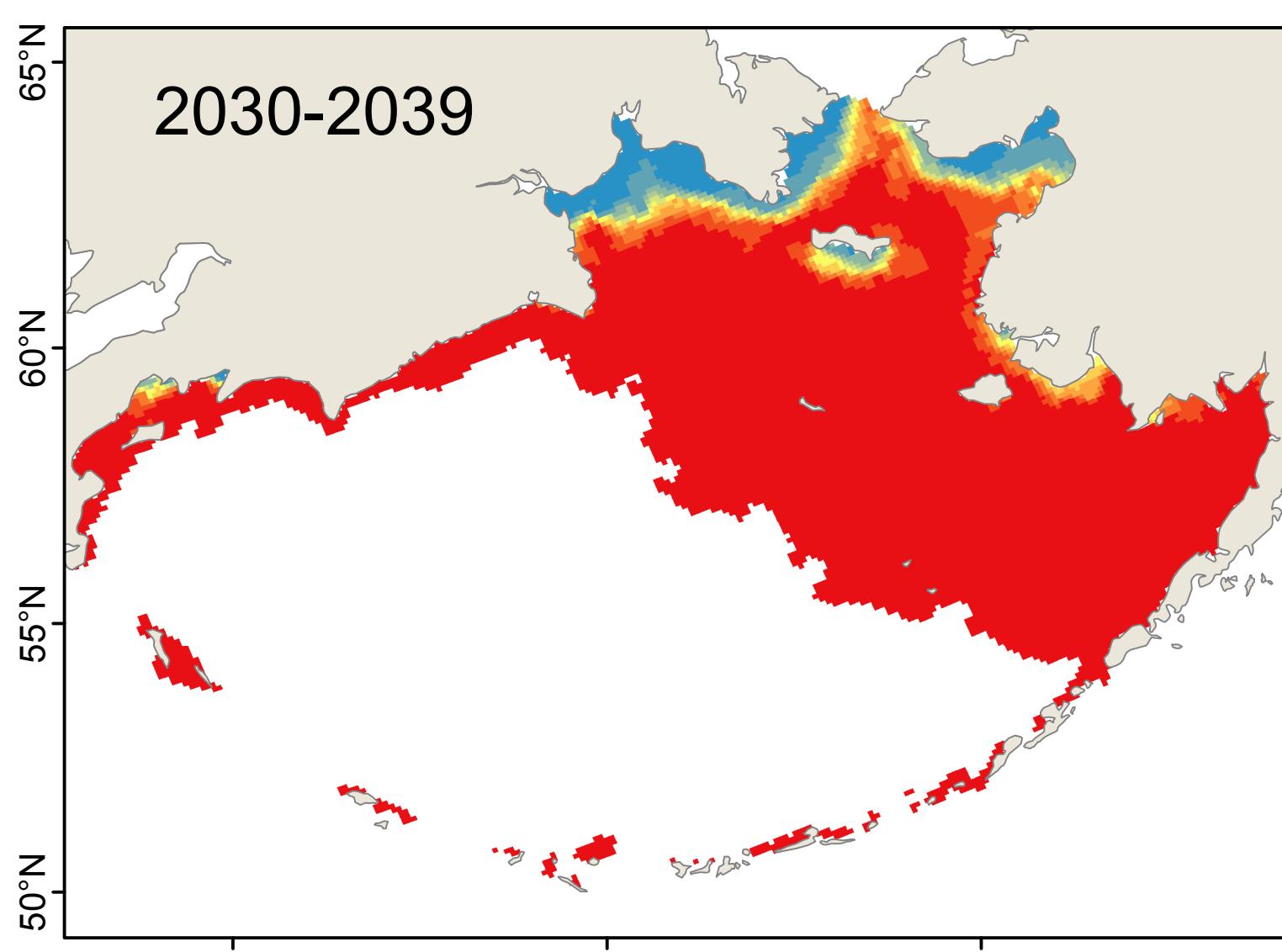
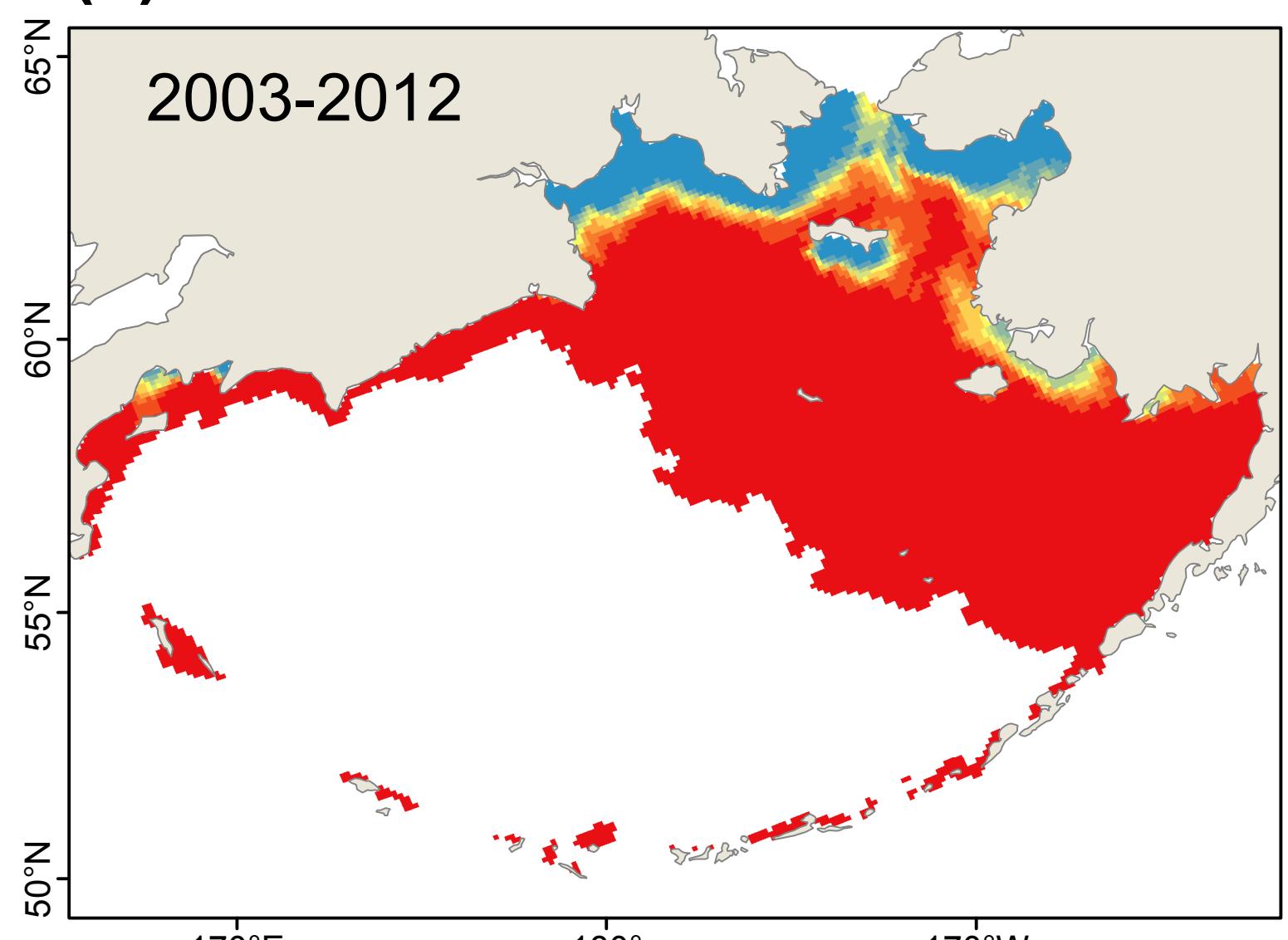
(a) Model: CGCM3-t47



(b) Model: ECHO-G

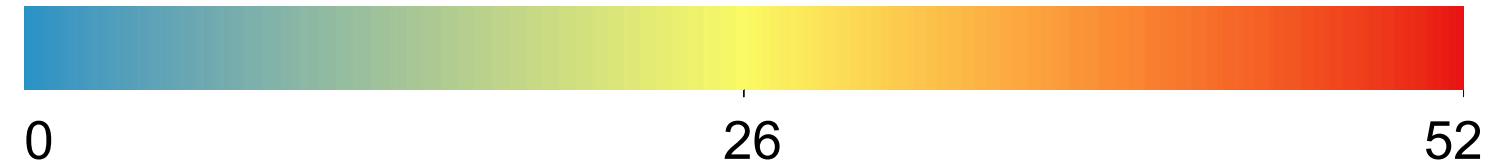


(c) Model: MIROC3.2

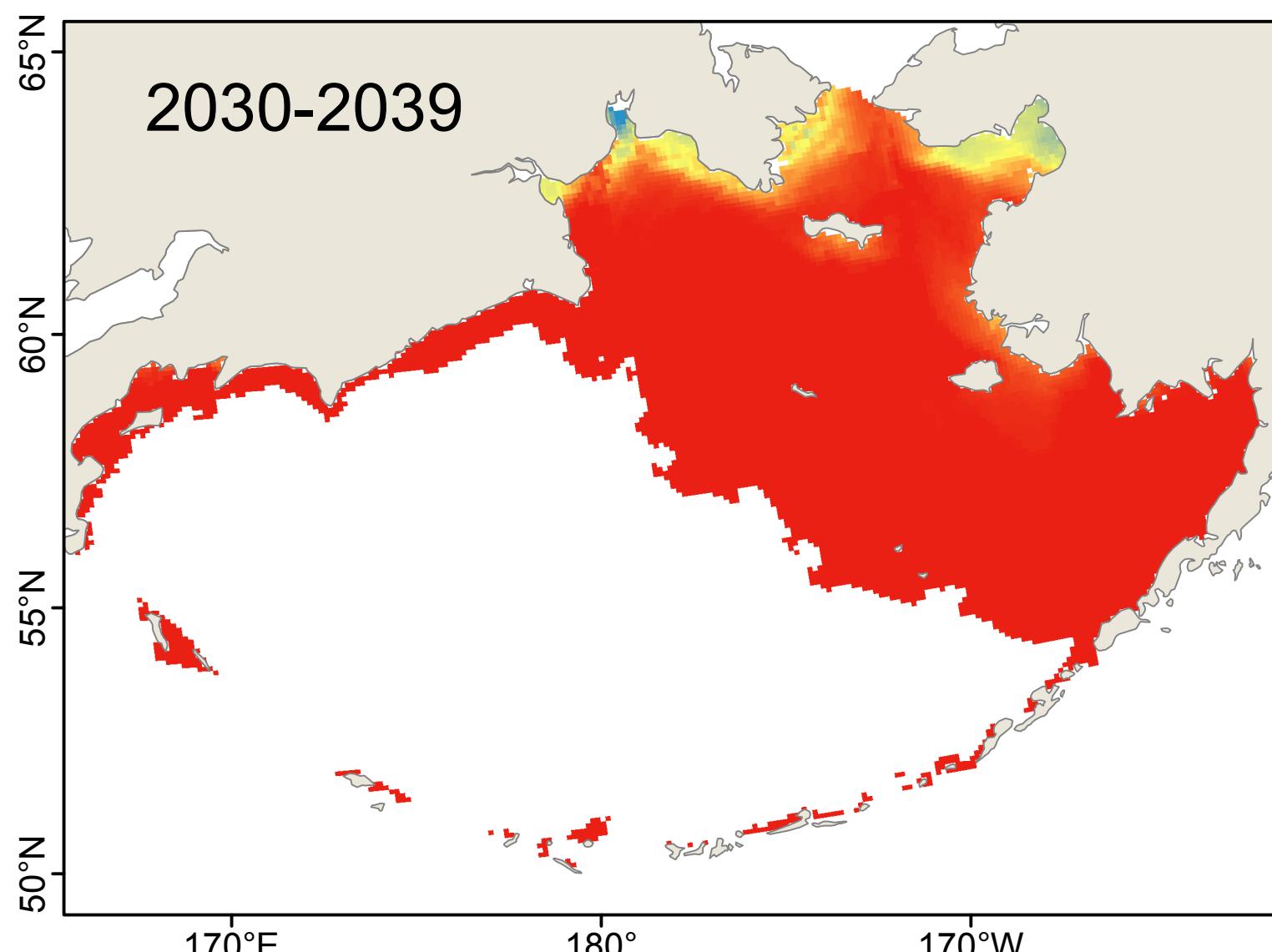
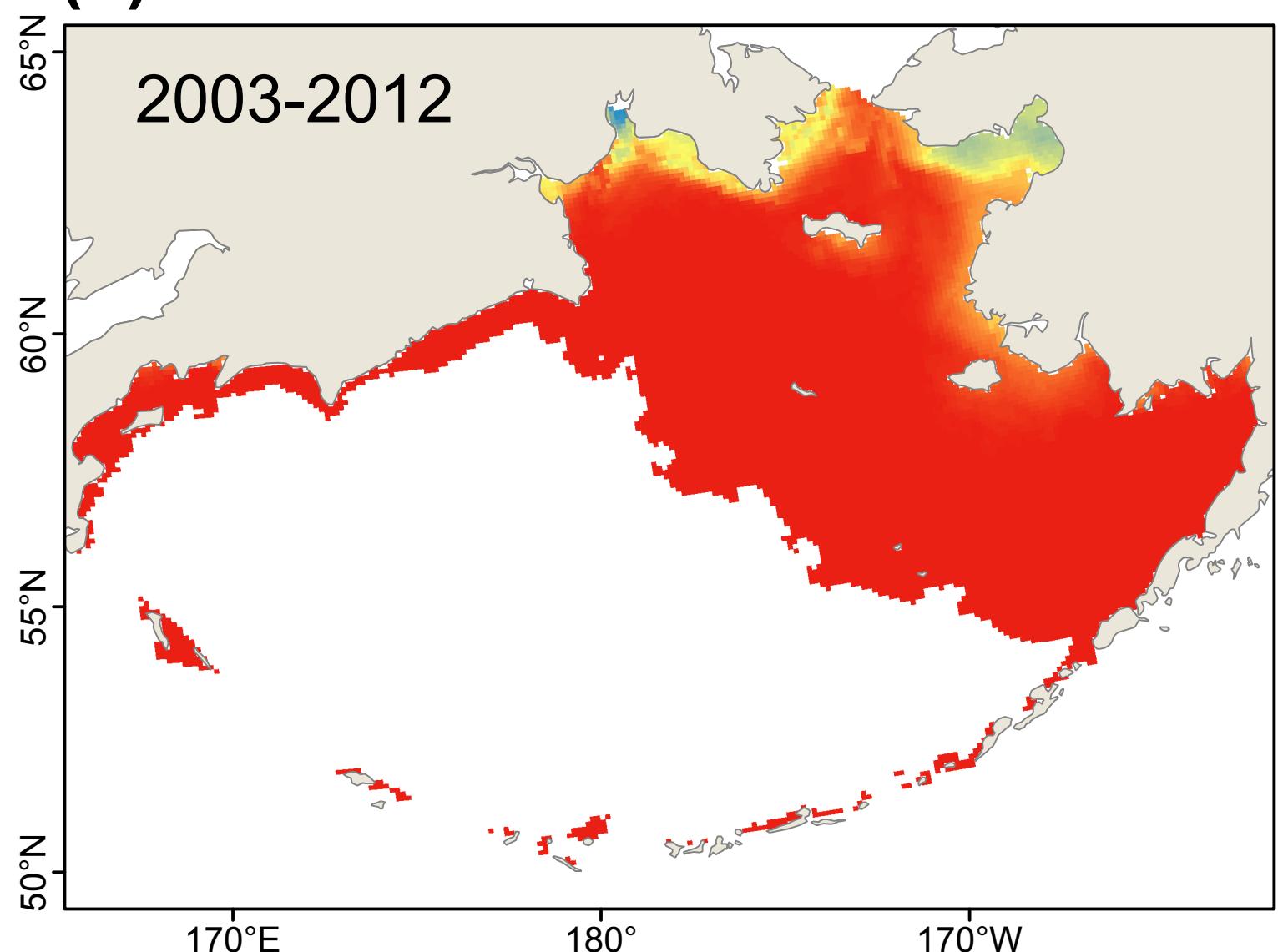


# *Styela clava: Weekly Survival*

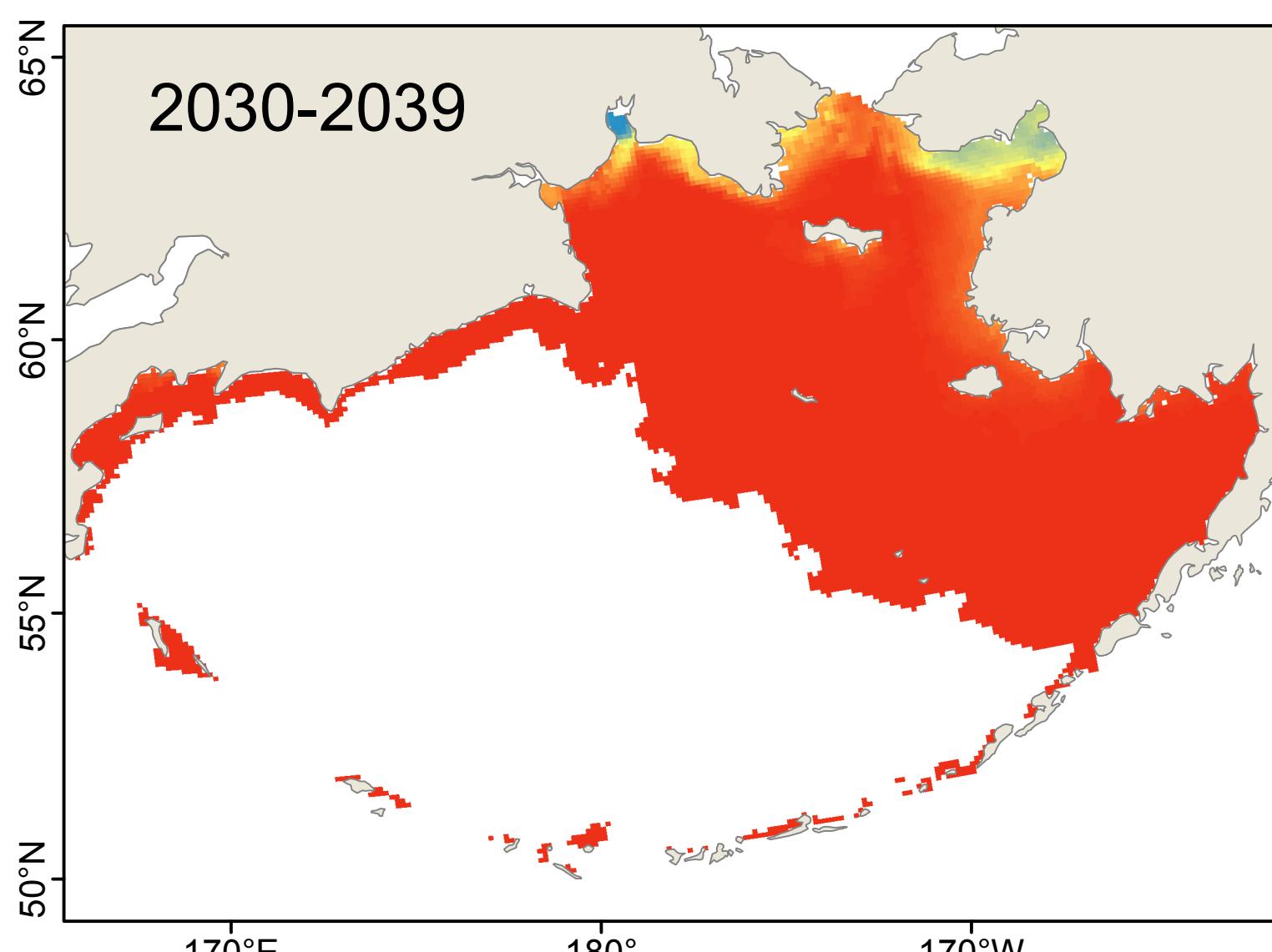
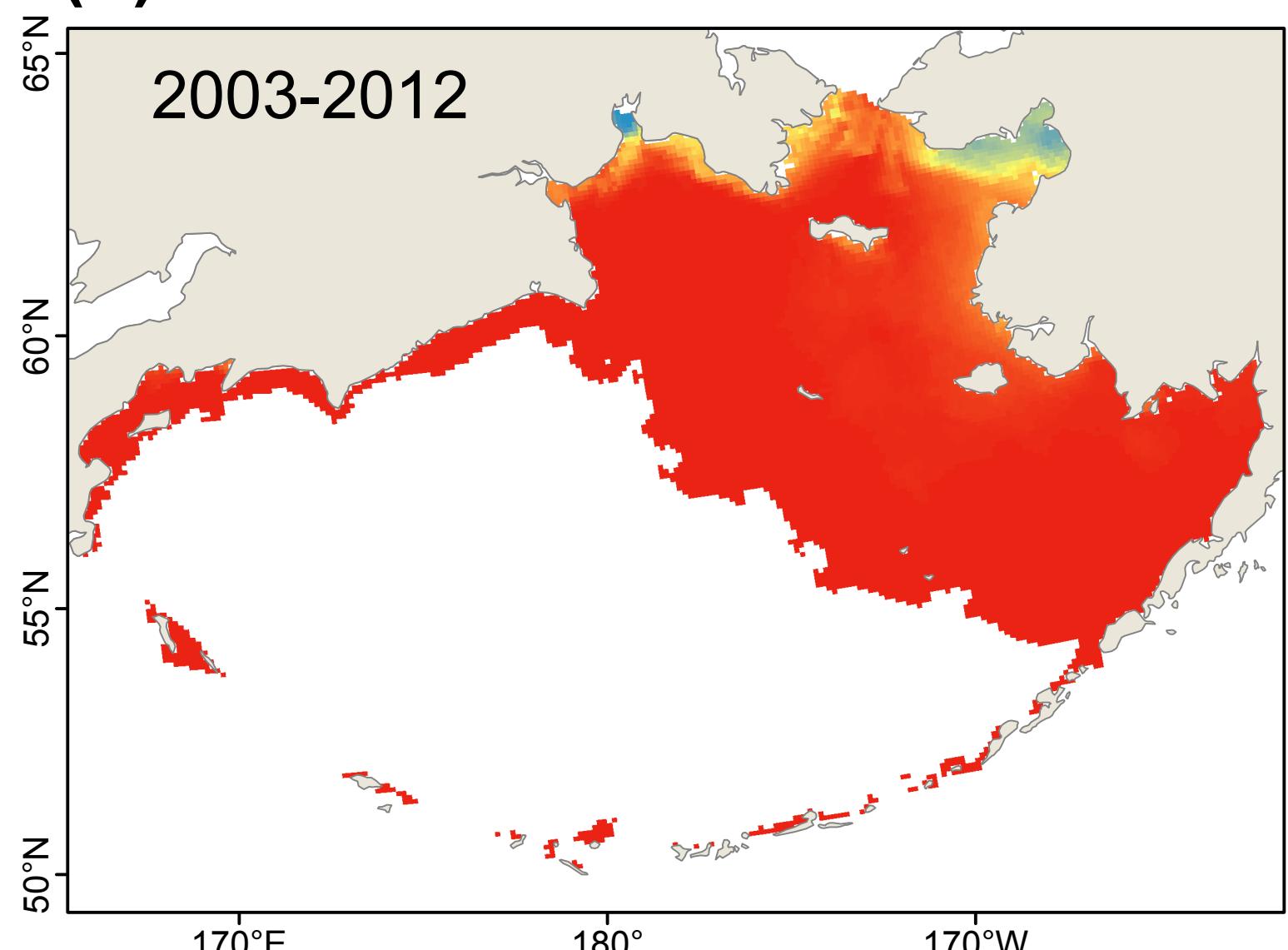
Average number of weeks of suitable habitat



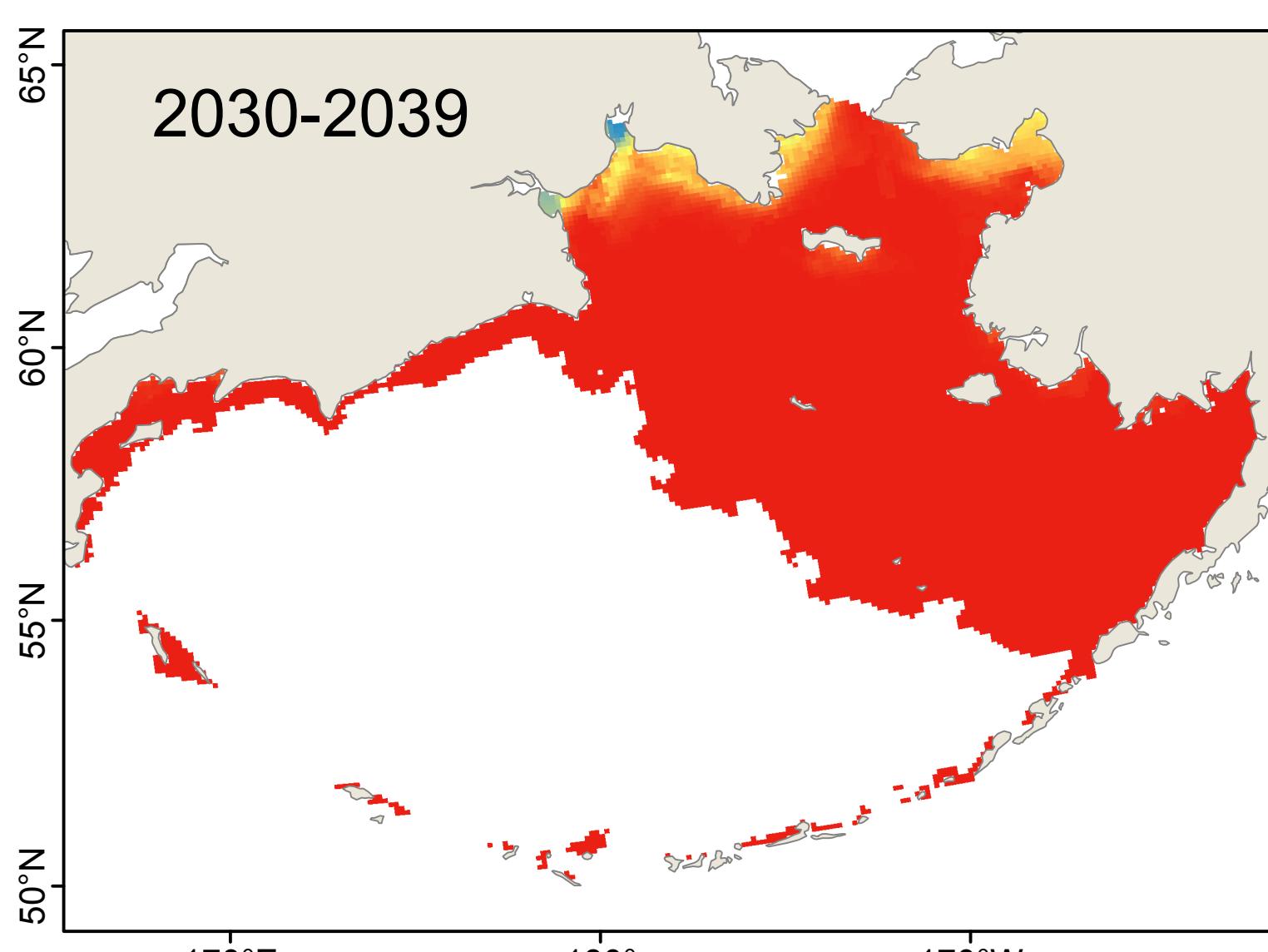
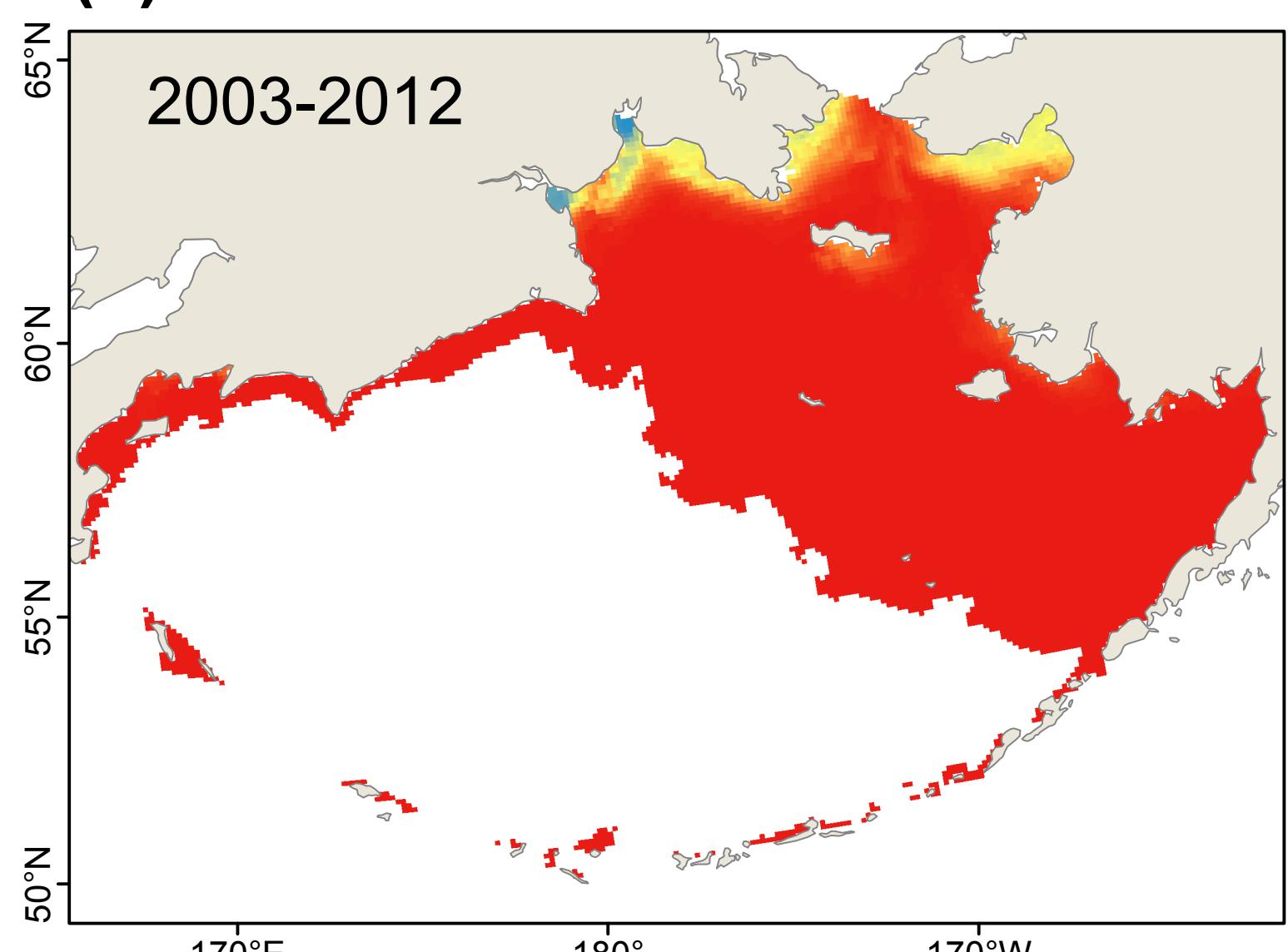
(a) Model: CGCM3-t47



(b) Model: ECHO-G

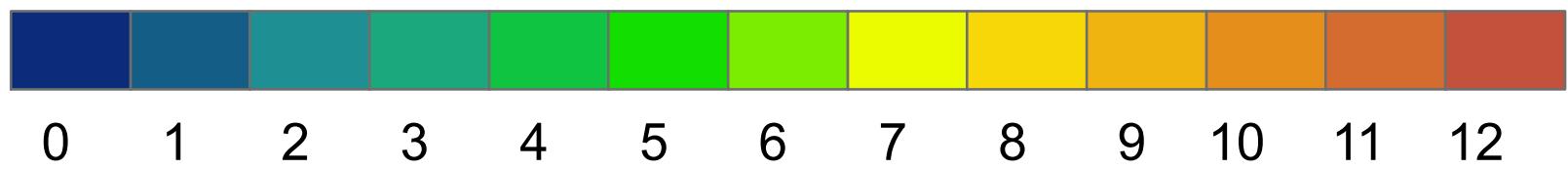


(c) Model: MIROC3.2

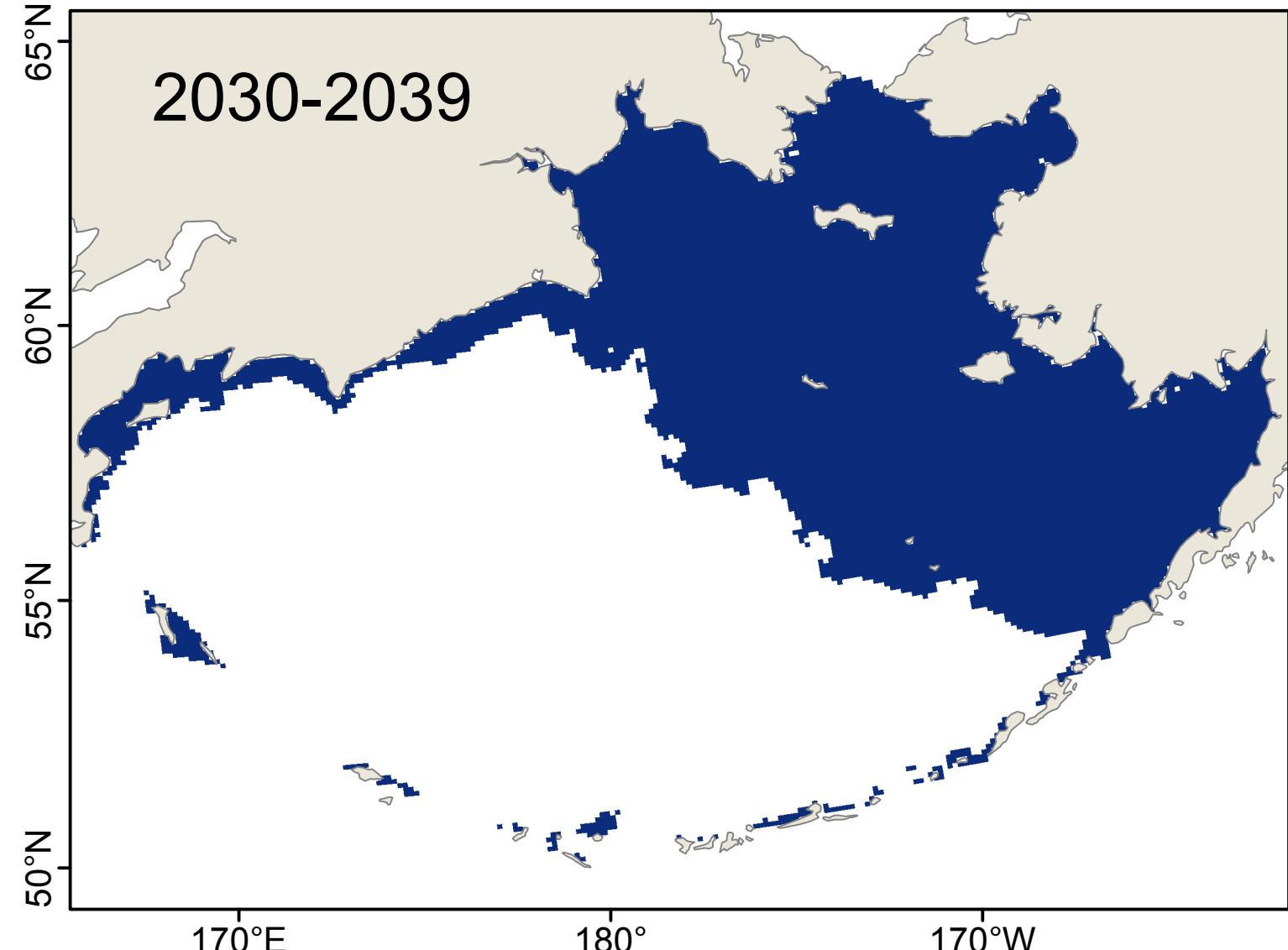
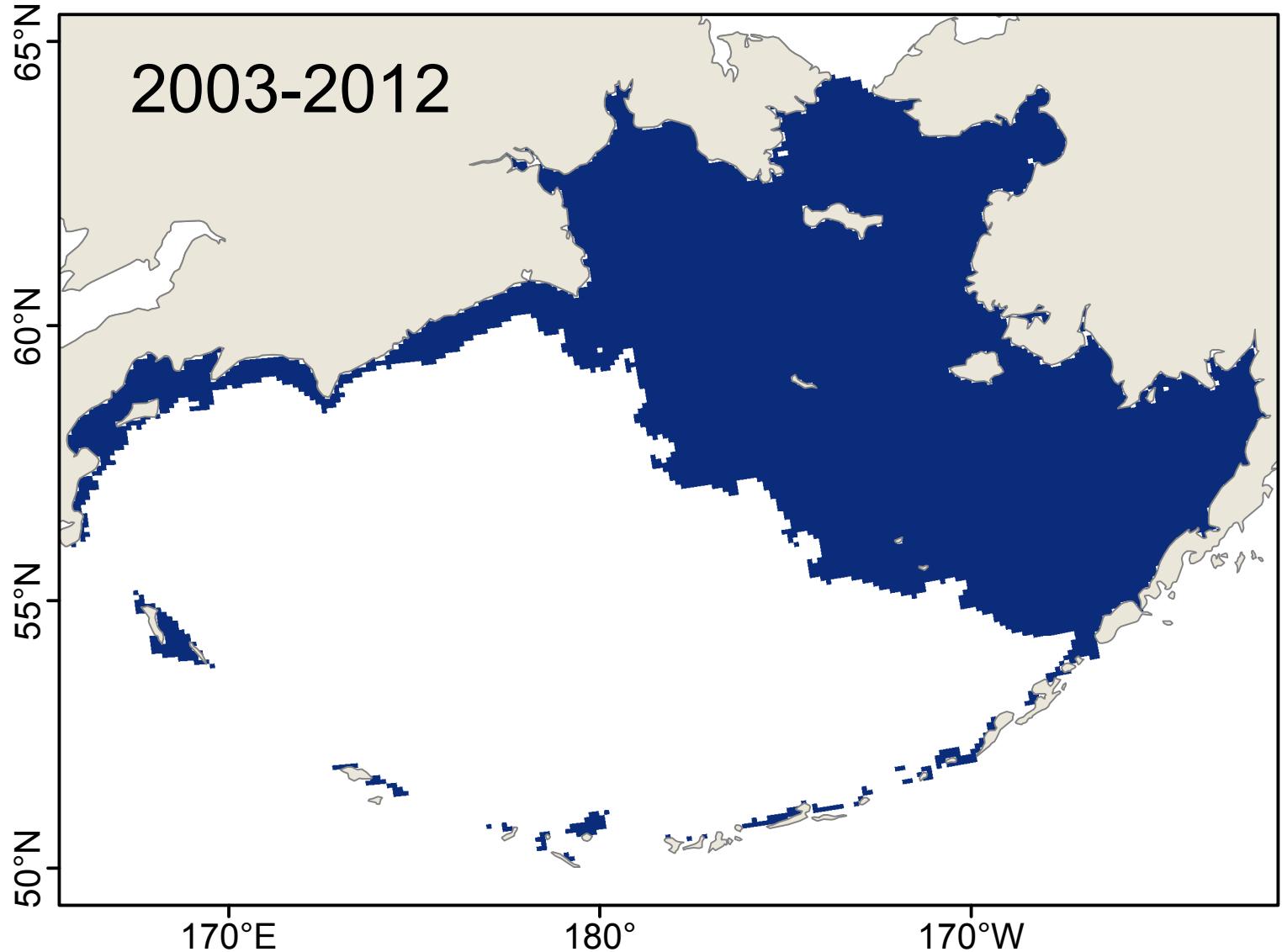


# *Styela clava: Reproduction*

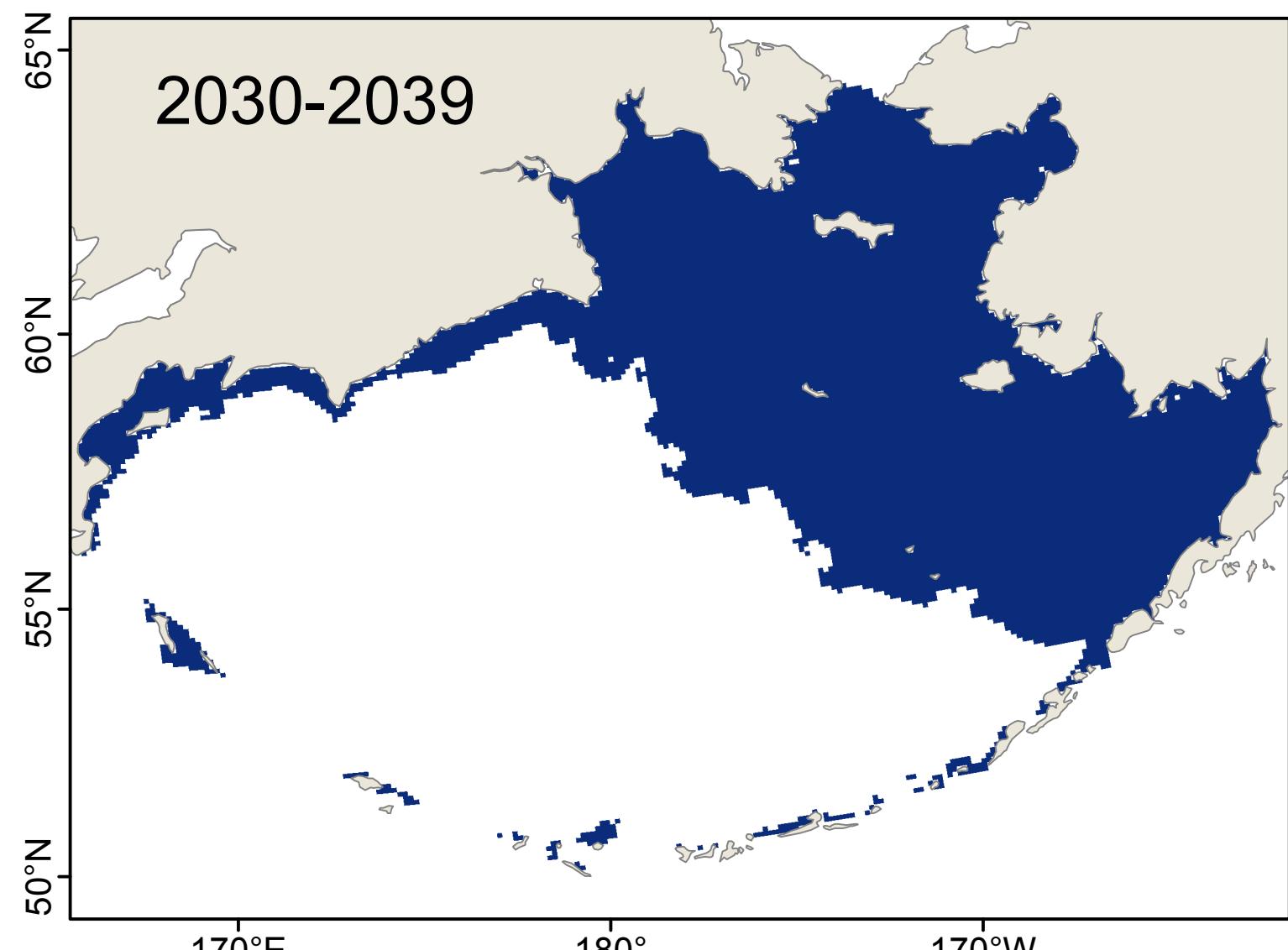
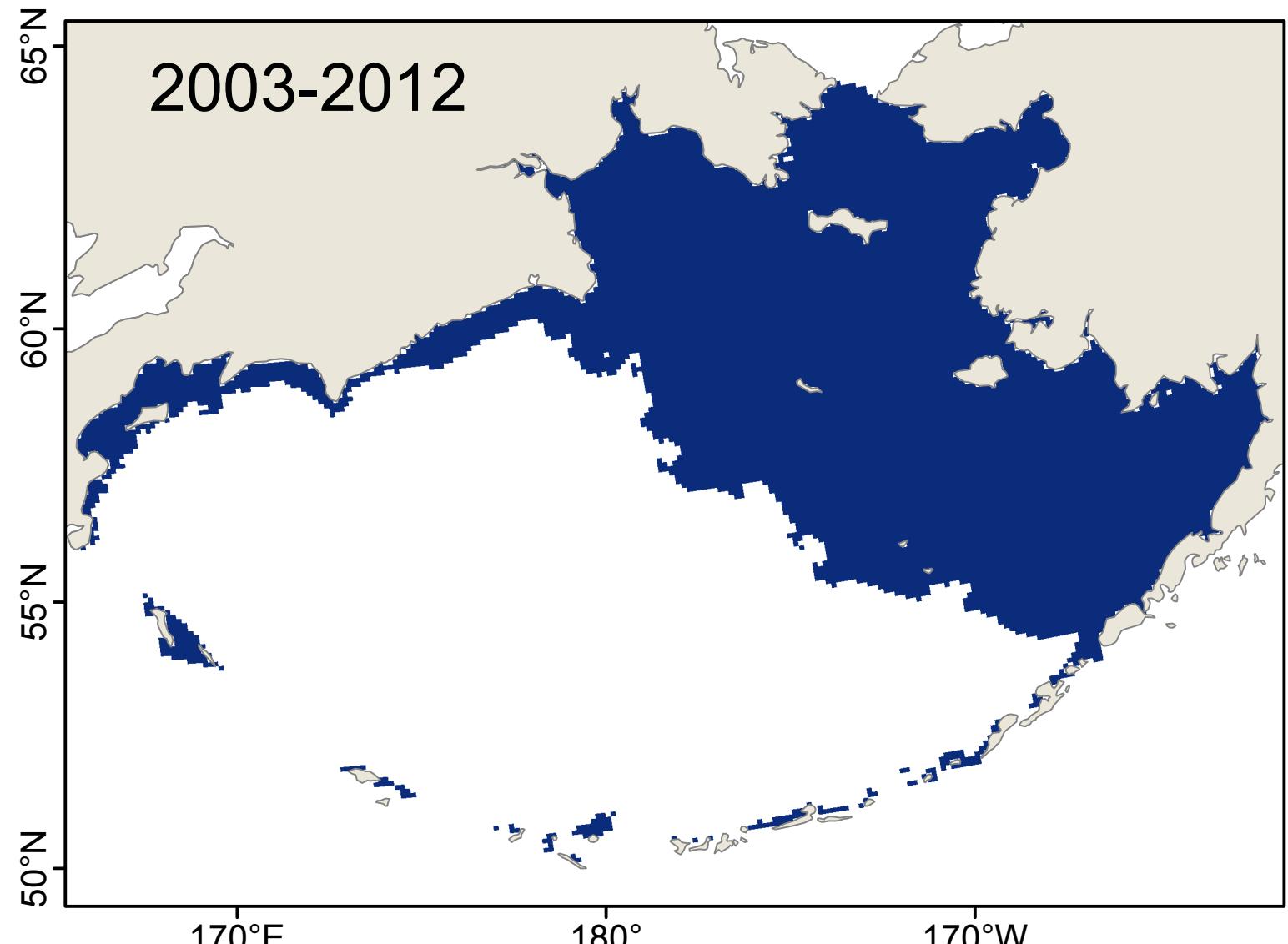
Average number of consecutive weeks of suitable habitat



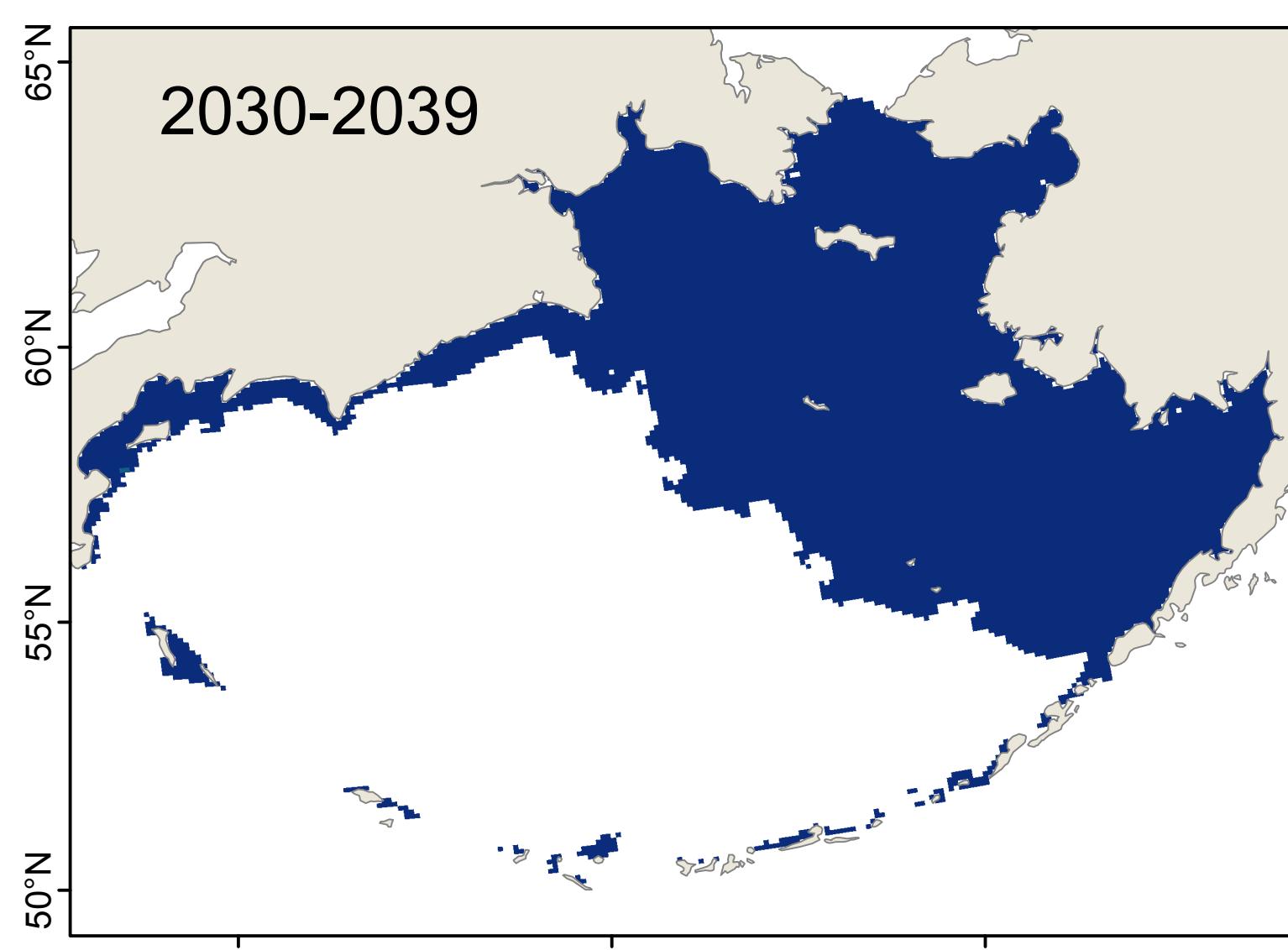
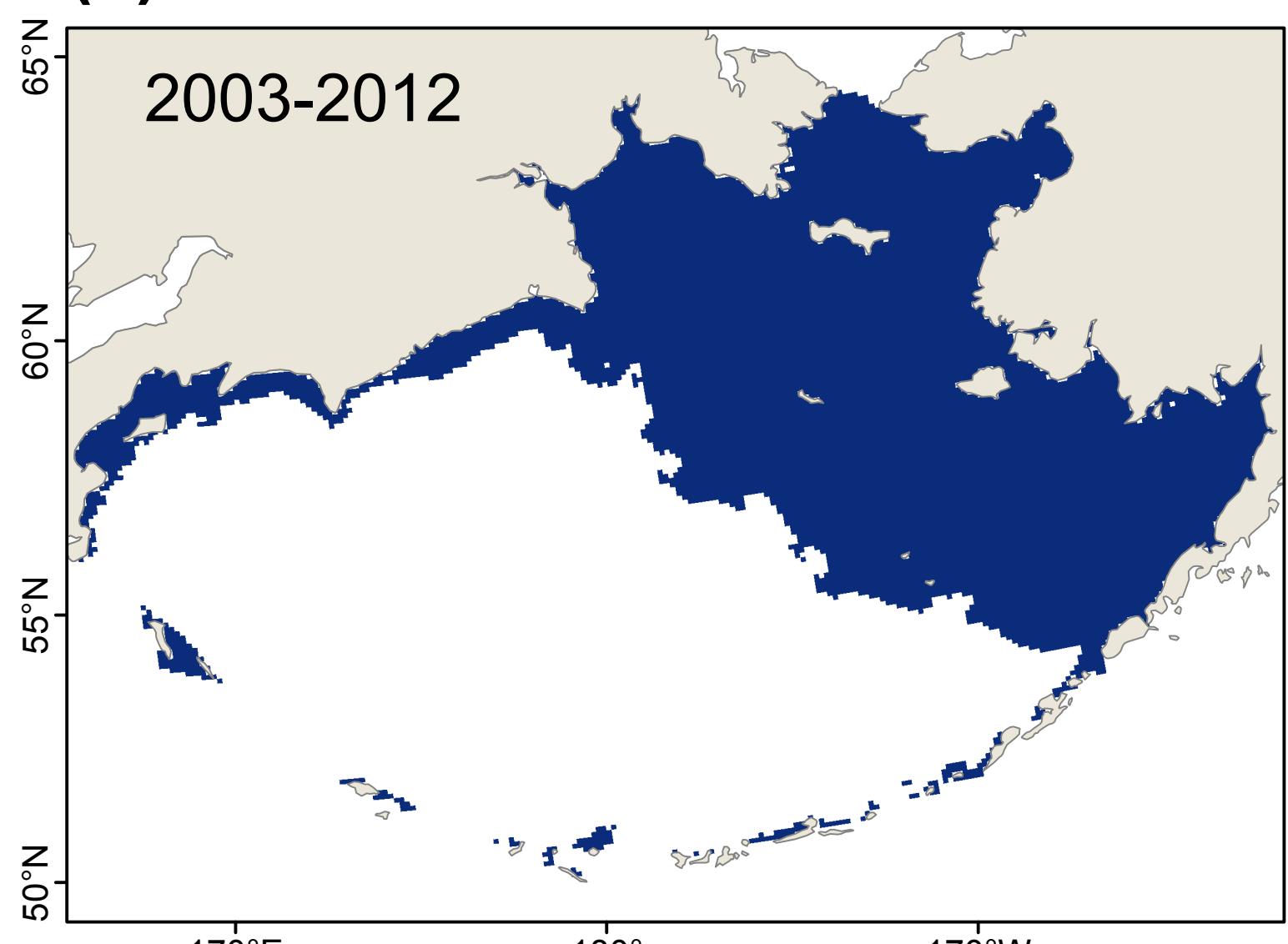
(a) Model: CGCM3-t47



(b) Model: ECHO-G

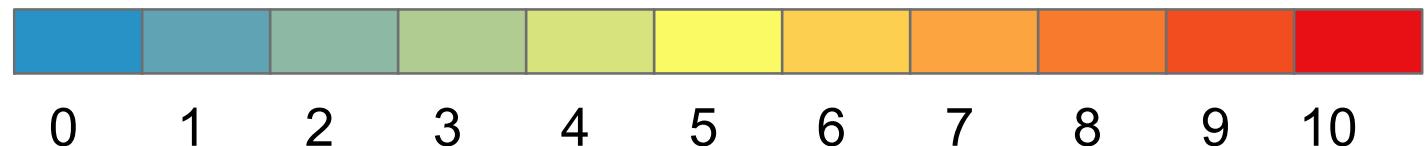


(c) Model: MIROC3.2

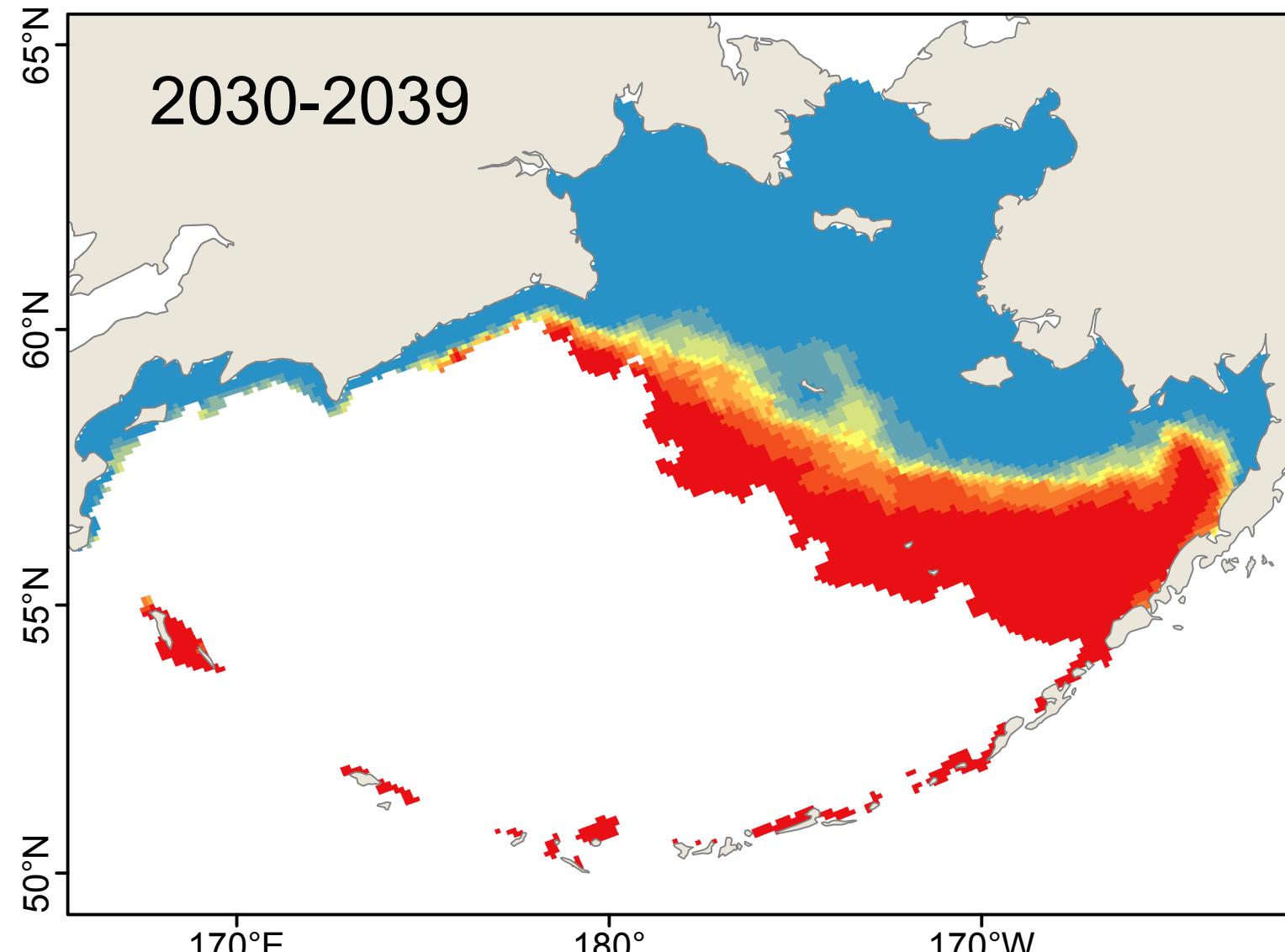
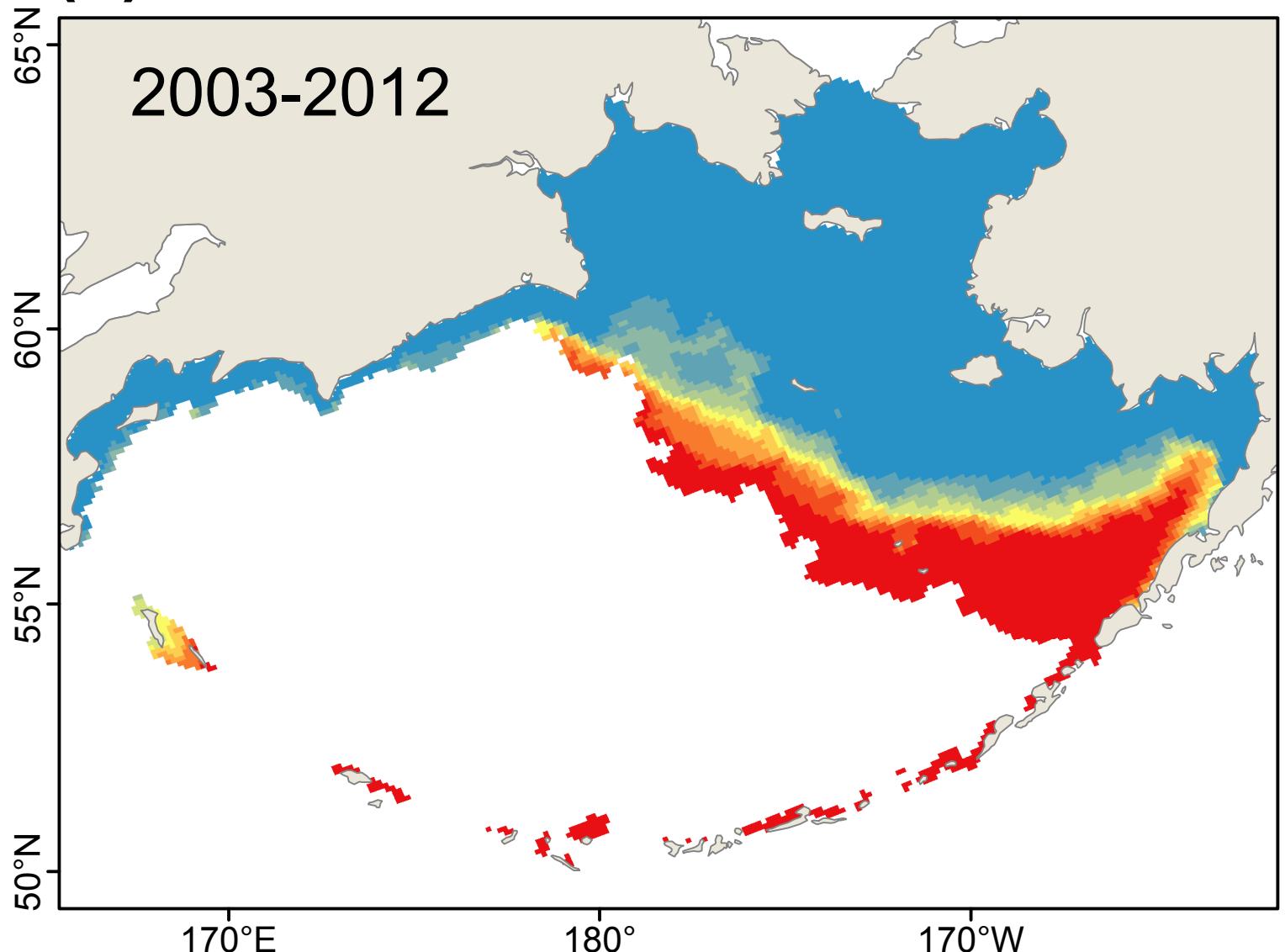


# *Diadumene lineata: Year-round Survival*

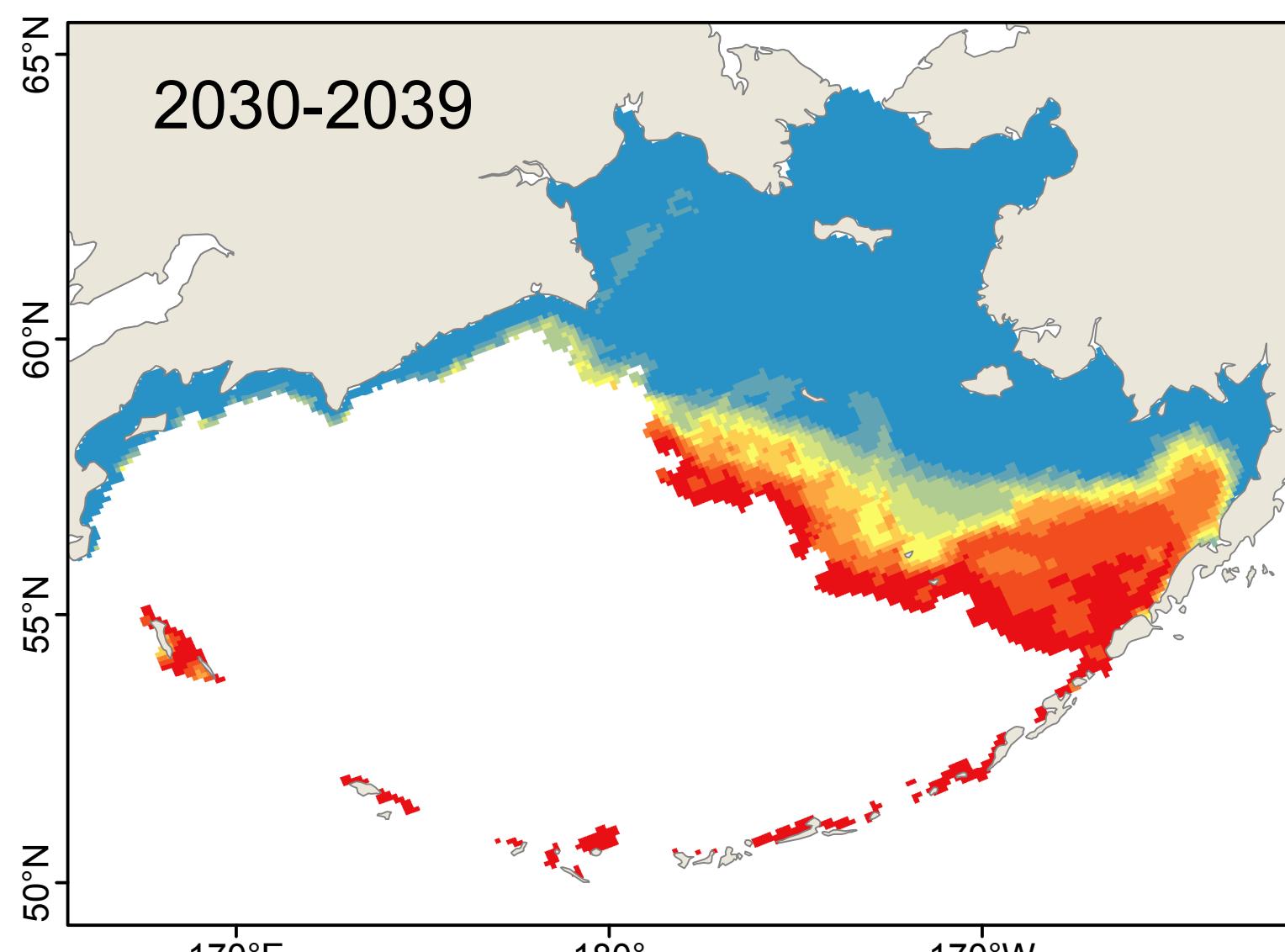
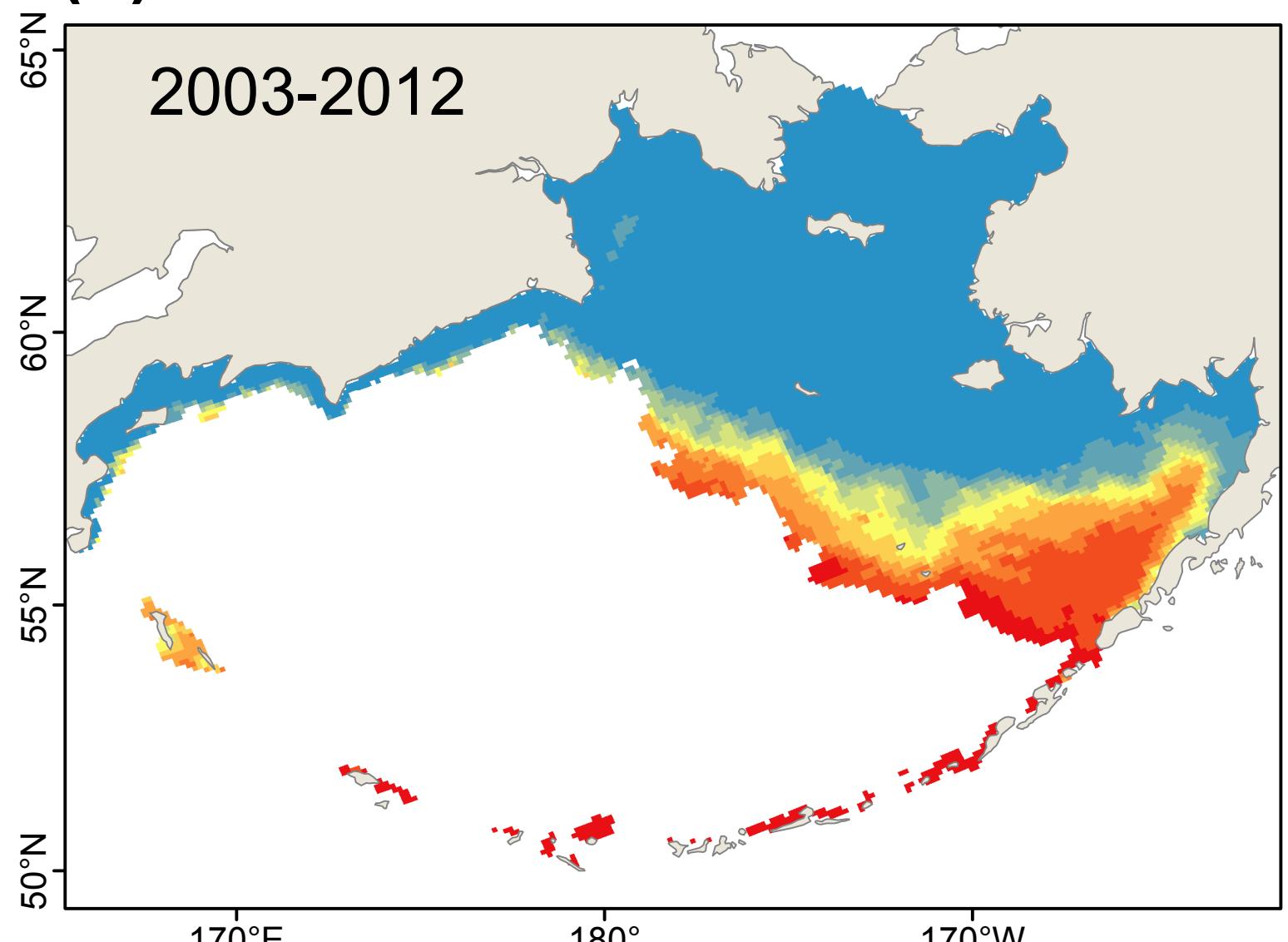
Number of years with suitable habitat



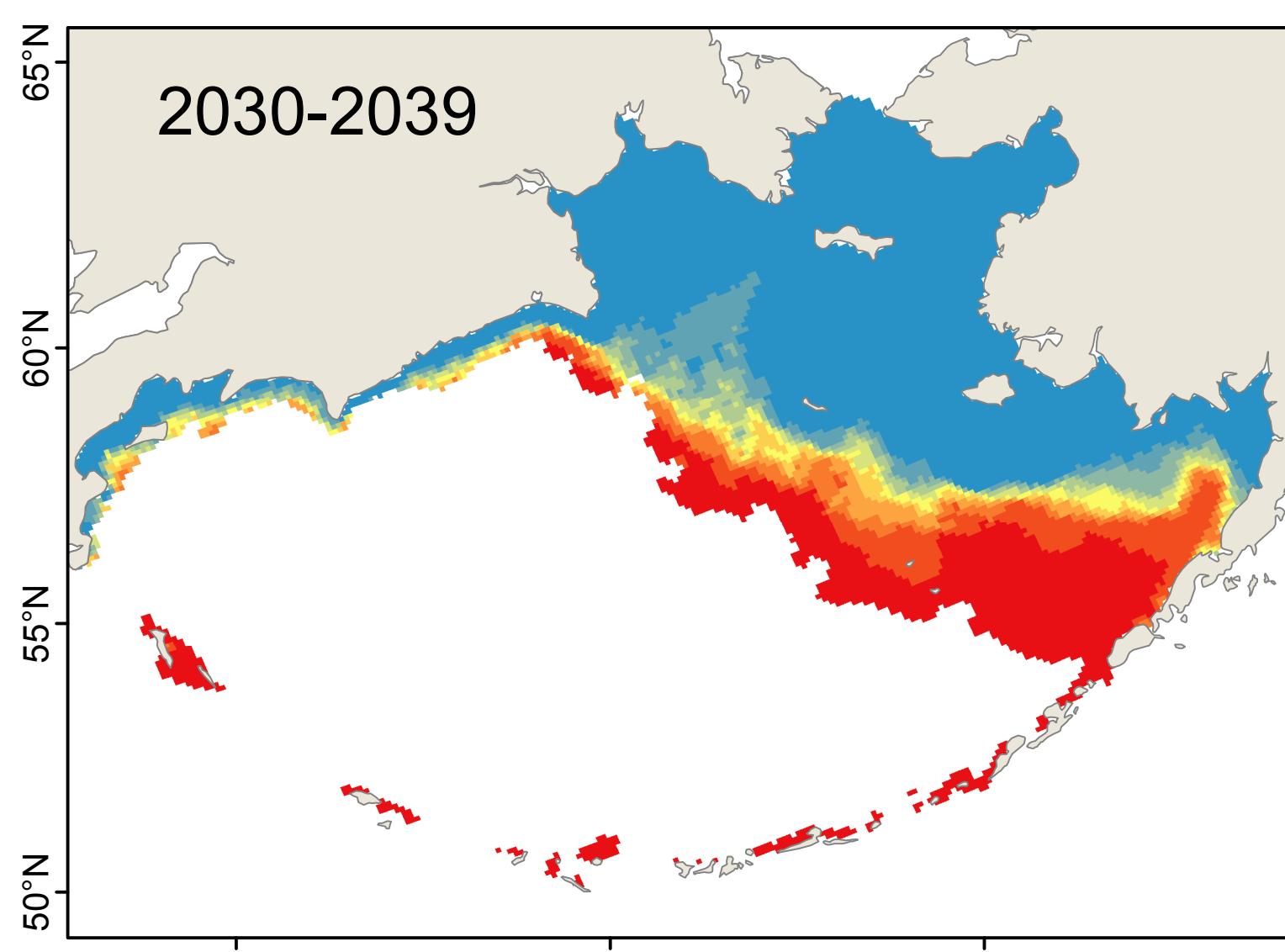
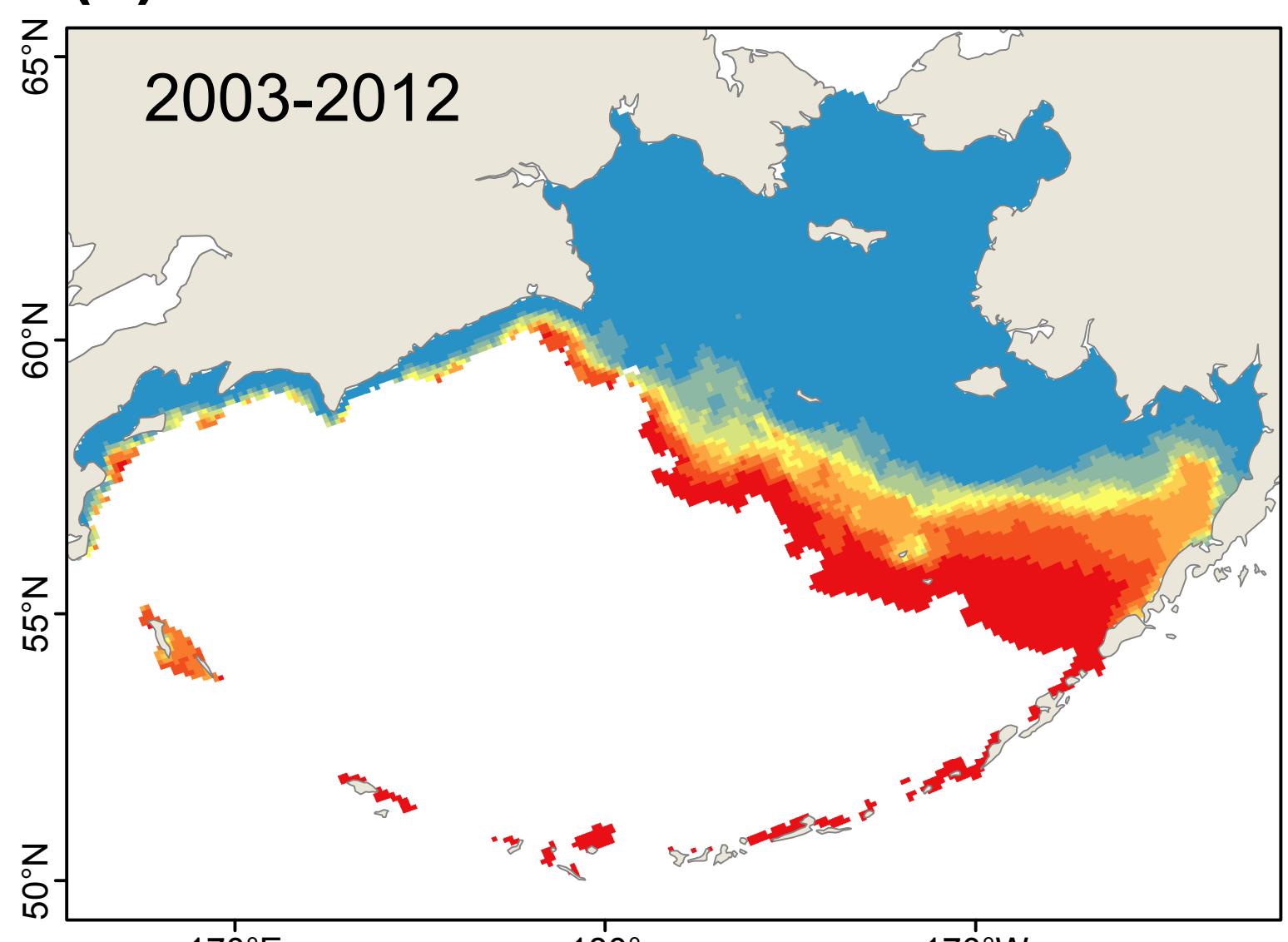
(a) Model: CGCM3-t47



(b) Model: ECHO-G

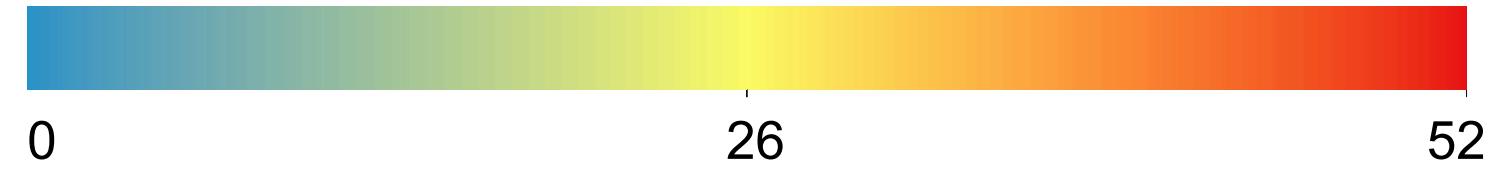


(c) Model: MIROC3.2

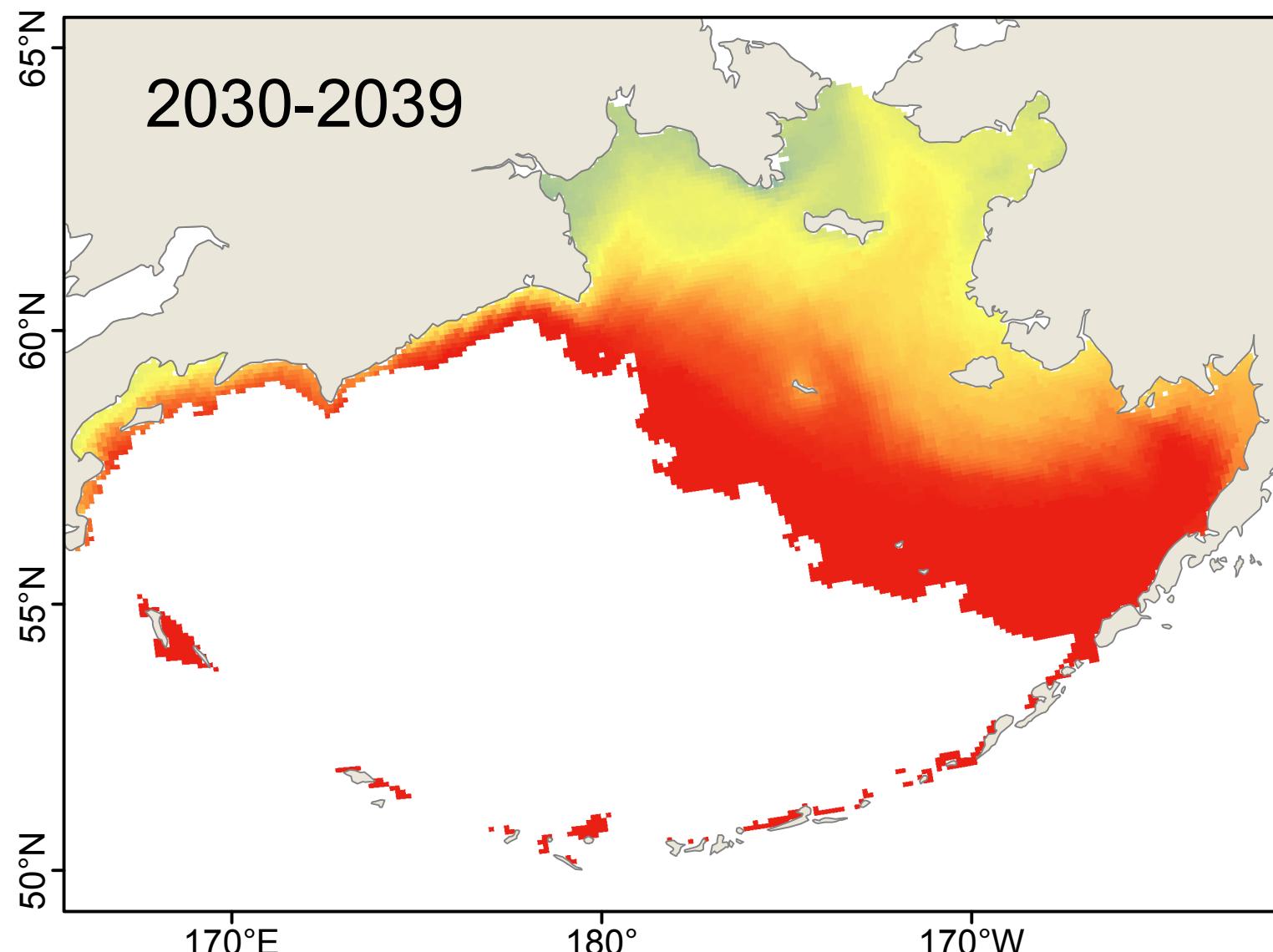
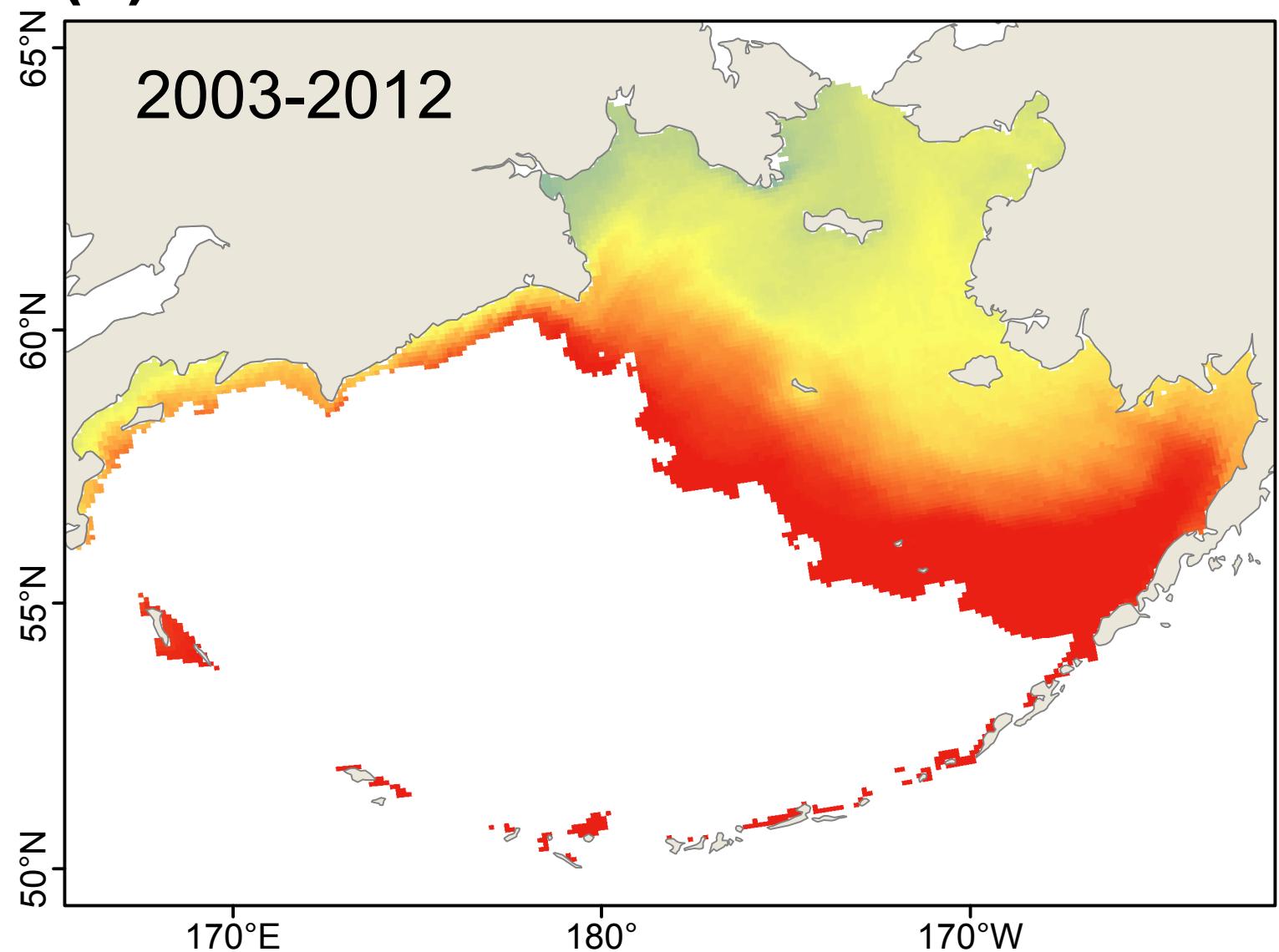


# *Diadumene lineata: Weekly Survival*

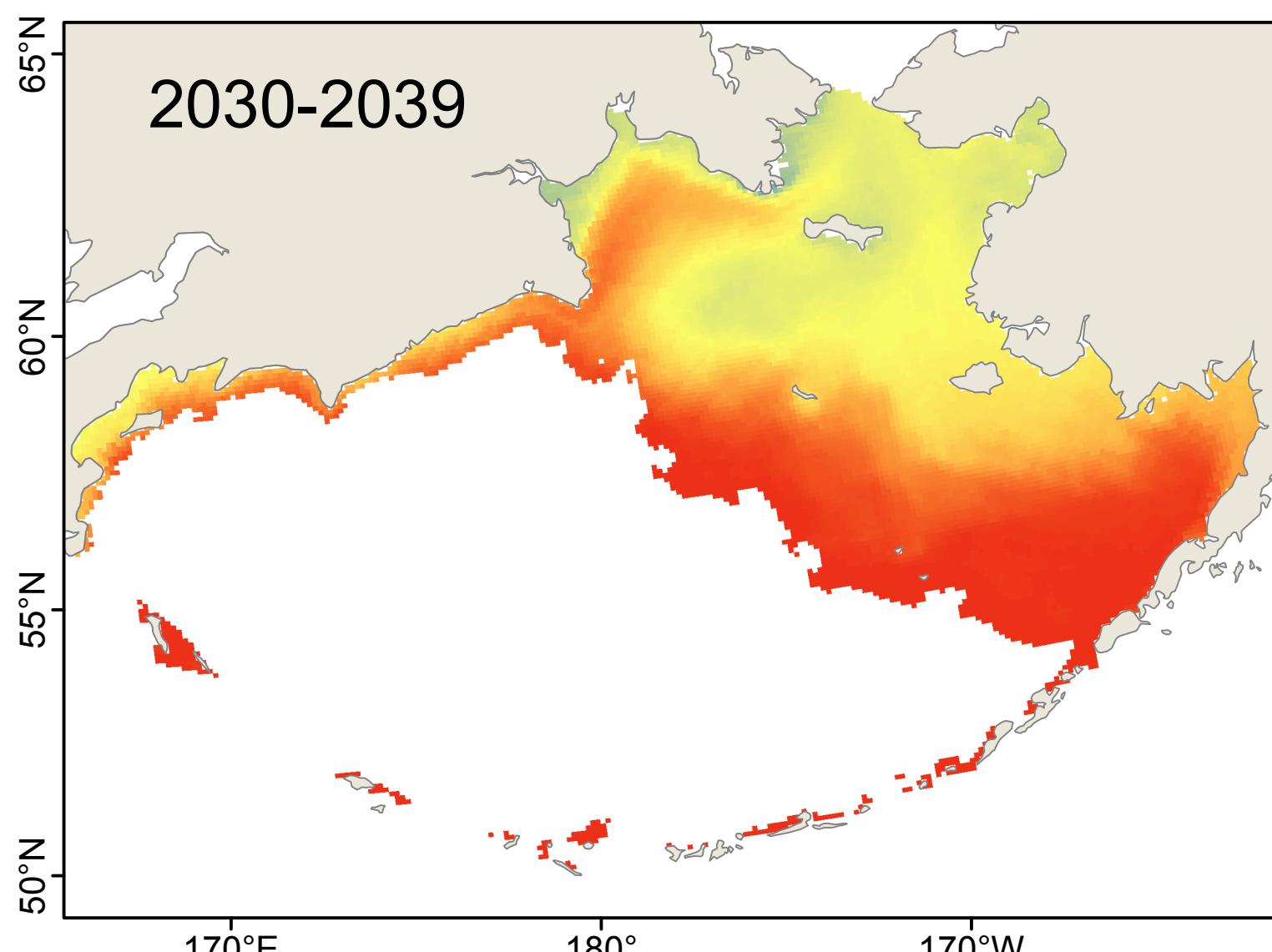
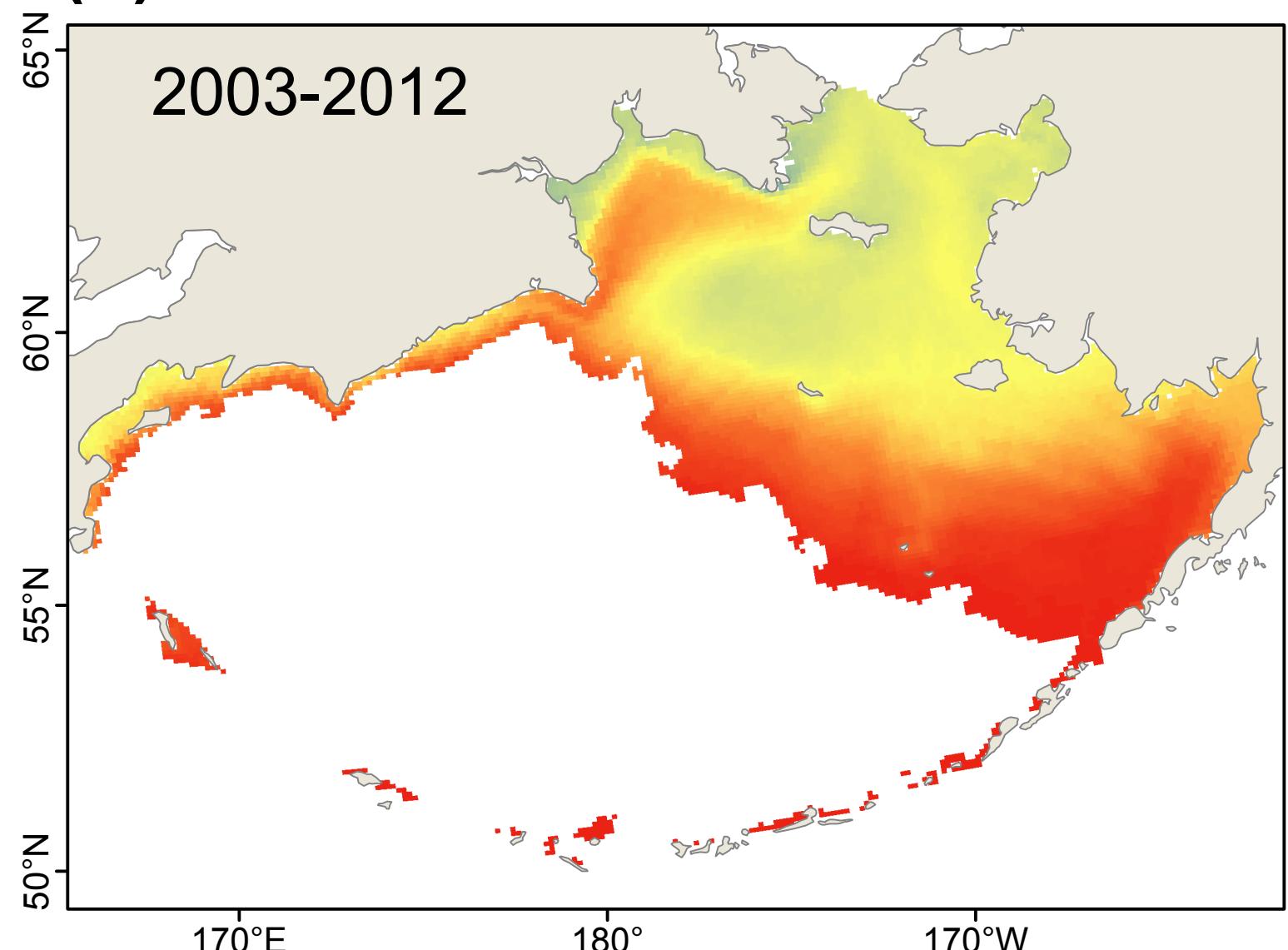
Average number of weeks of suitable habitat



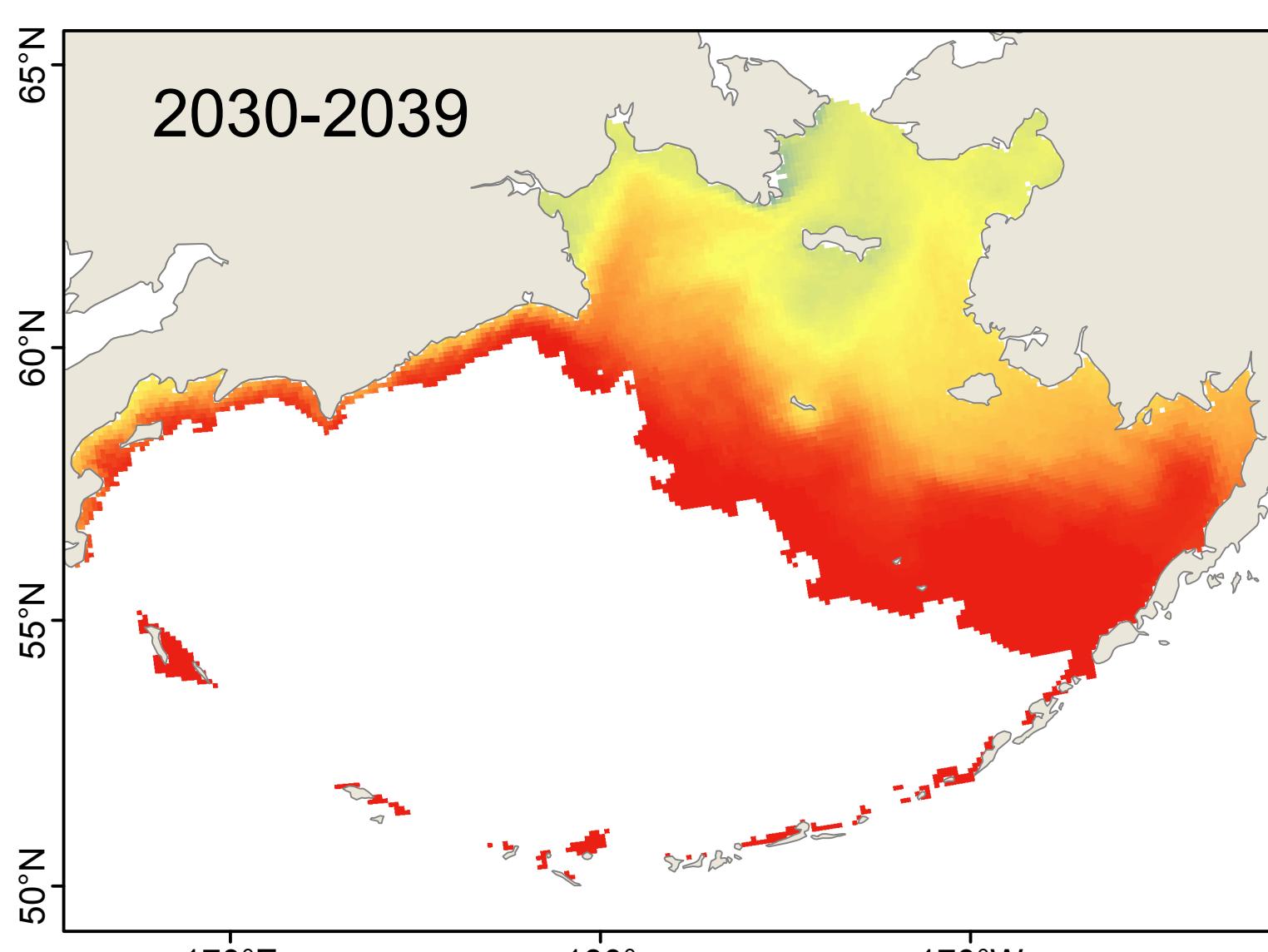
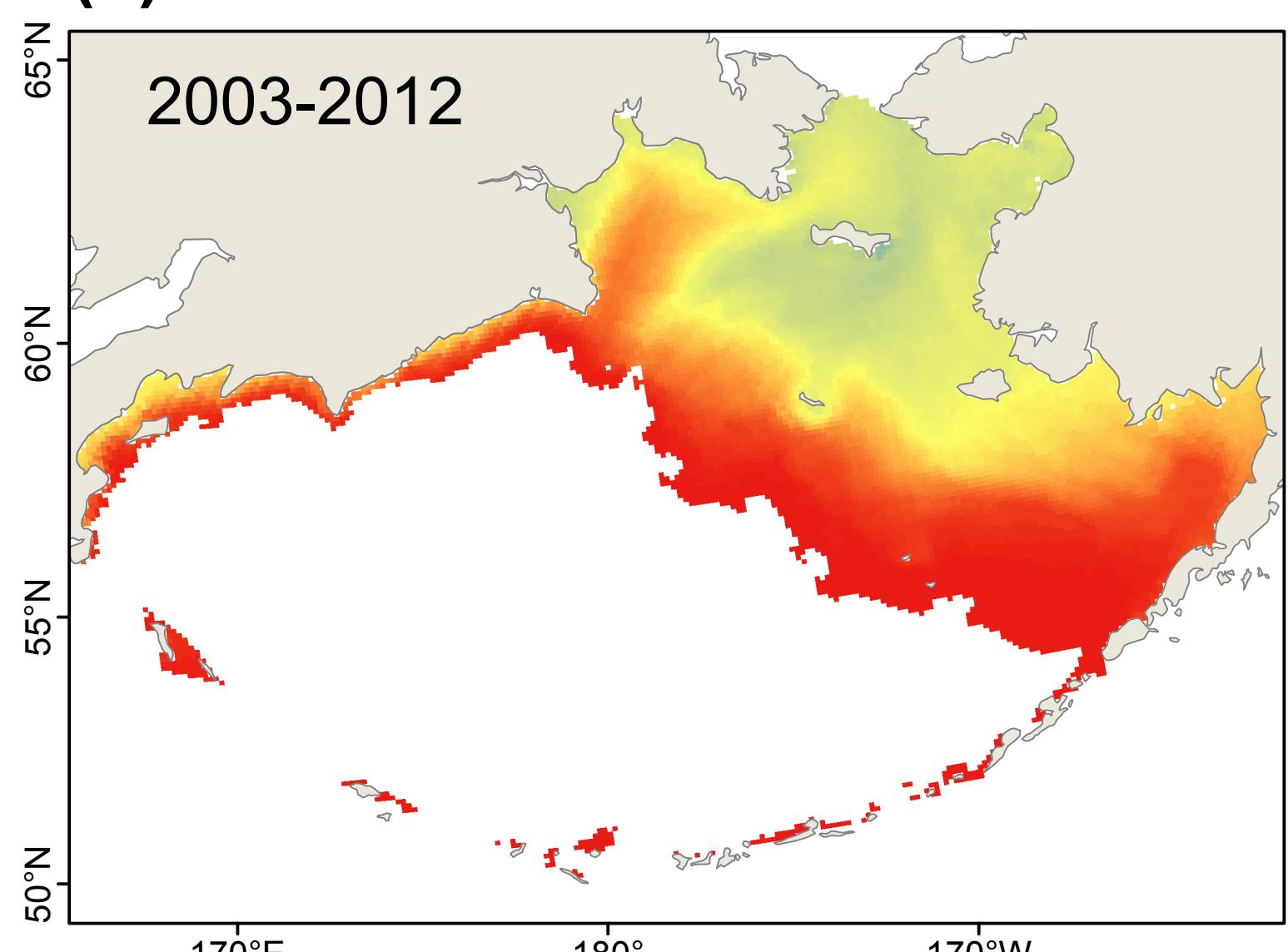
(a) Model: CGCM3-t47



(b) Model: ECHO-G

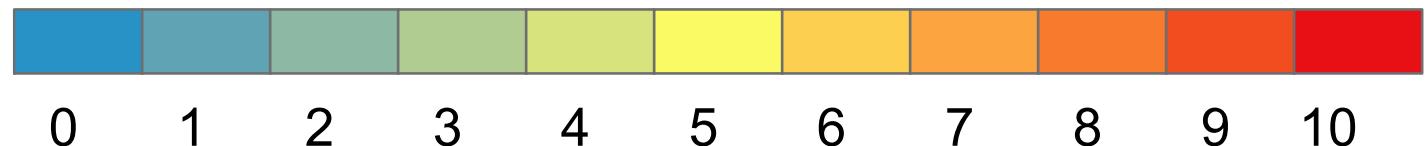


(c) Model: MIROC3.2

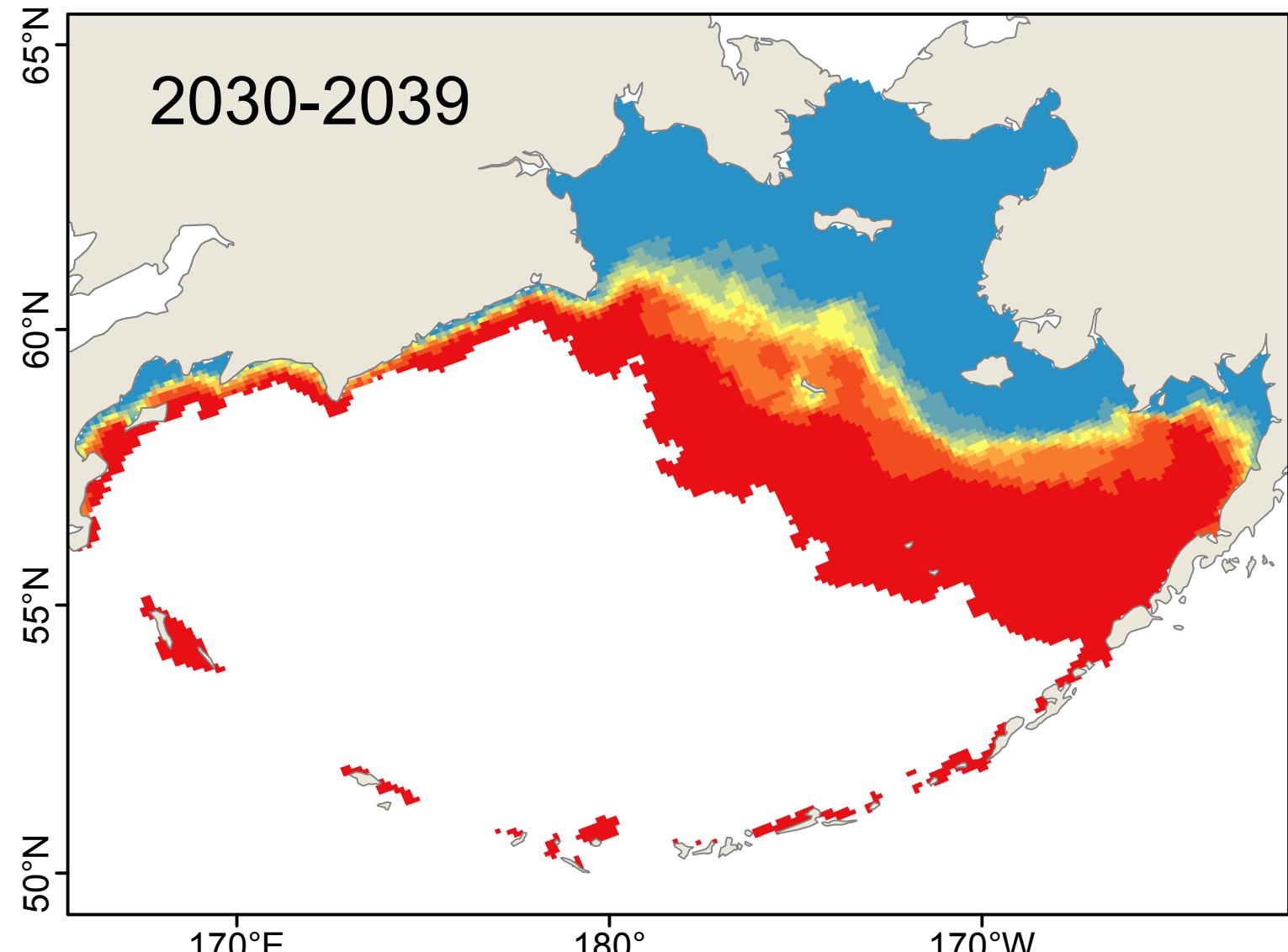
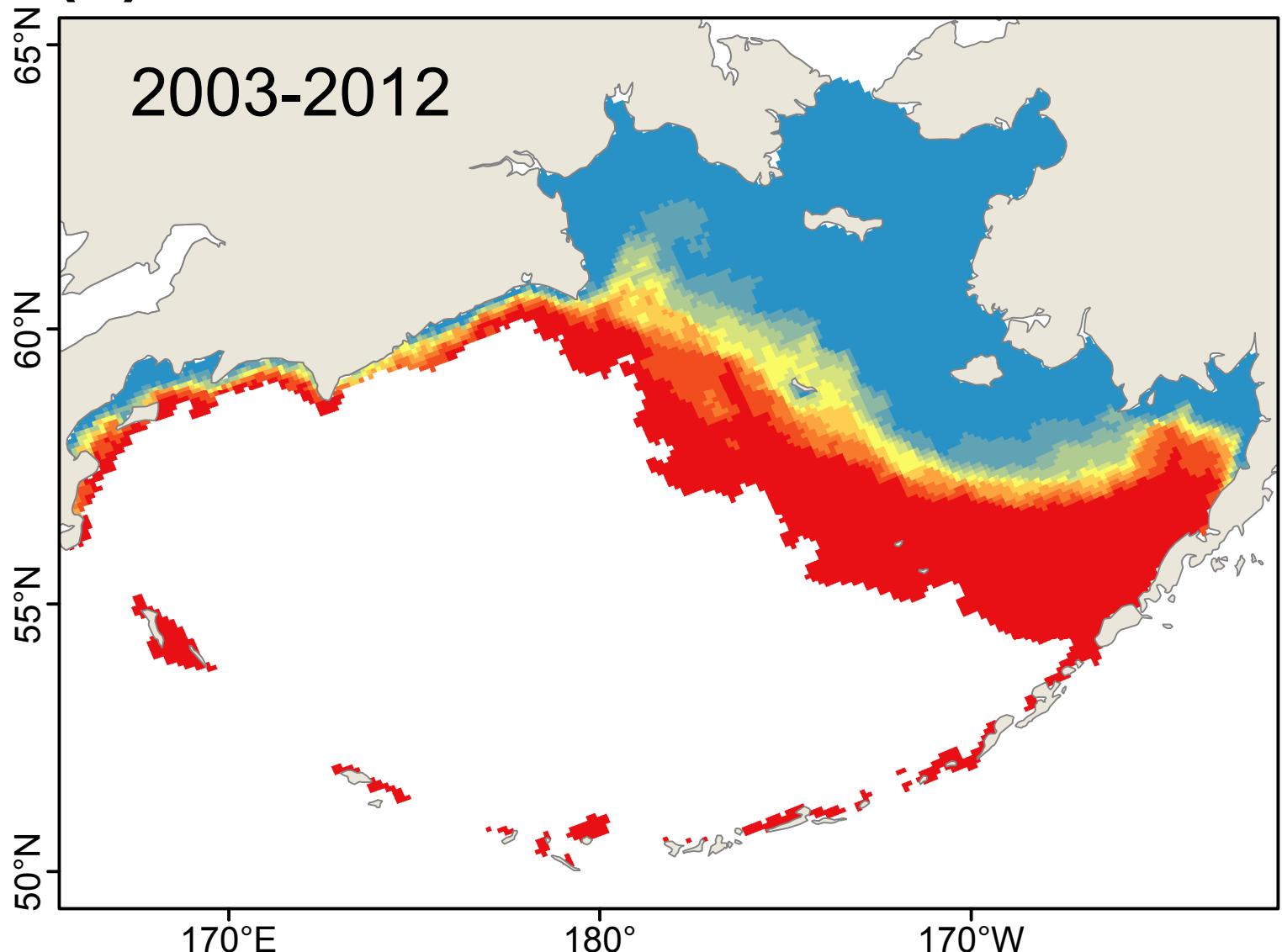


# *Nematostella vectensis*: Year-round Survival

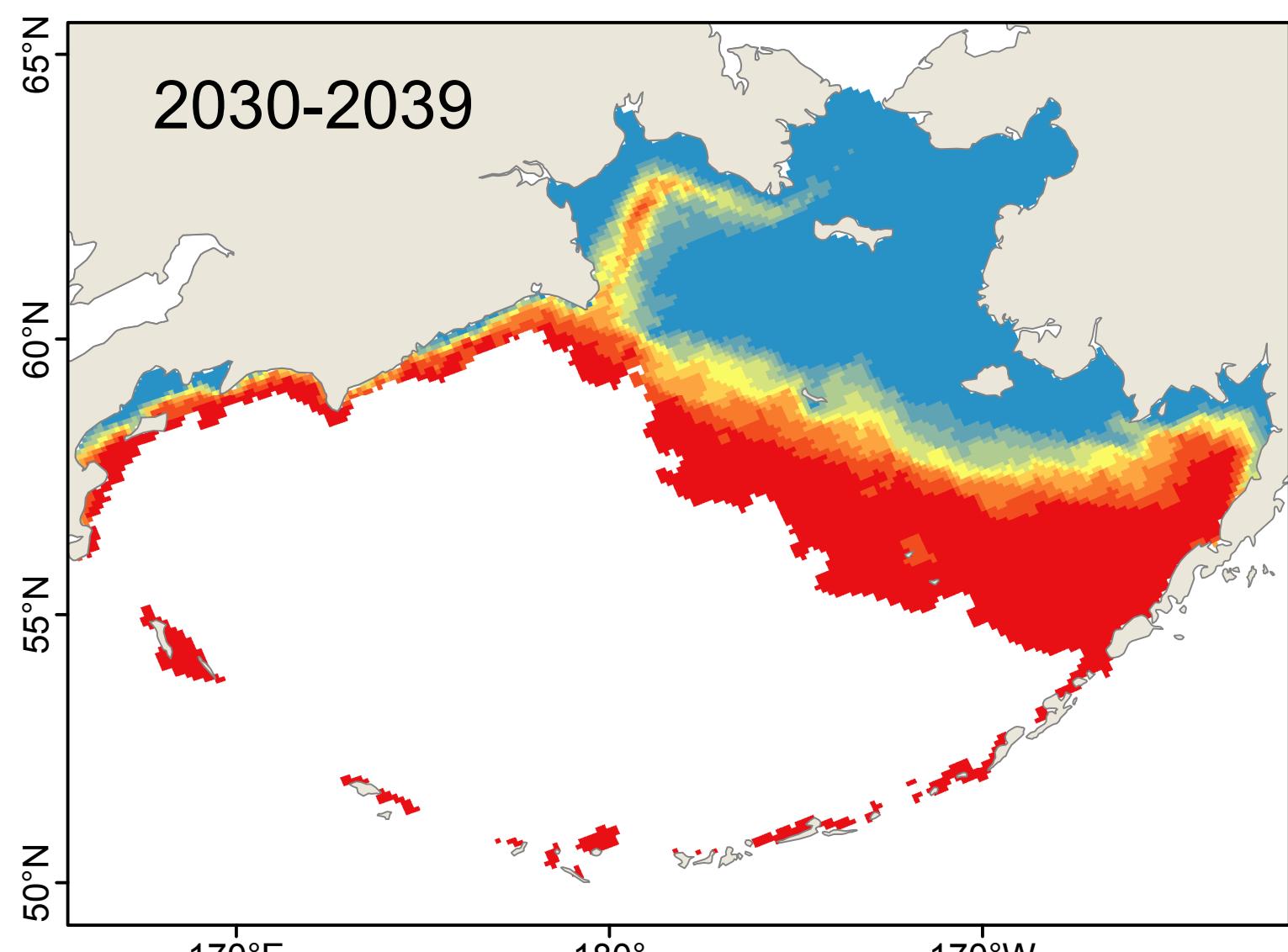
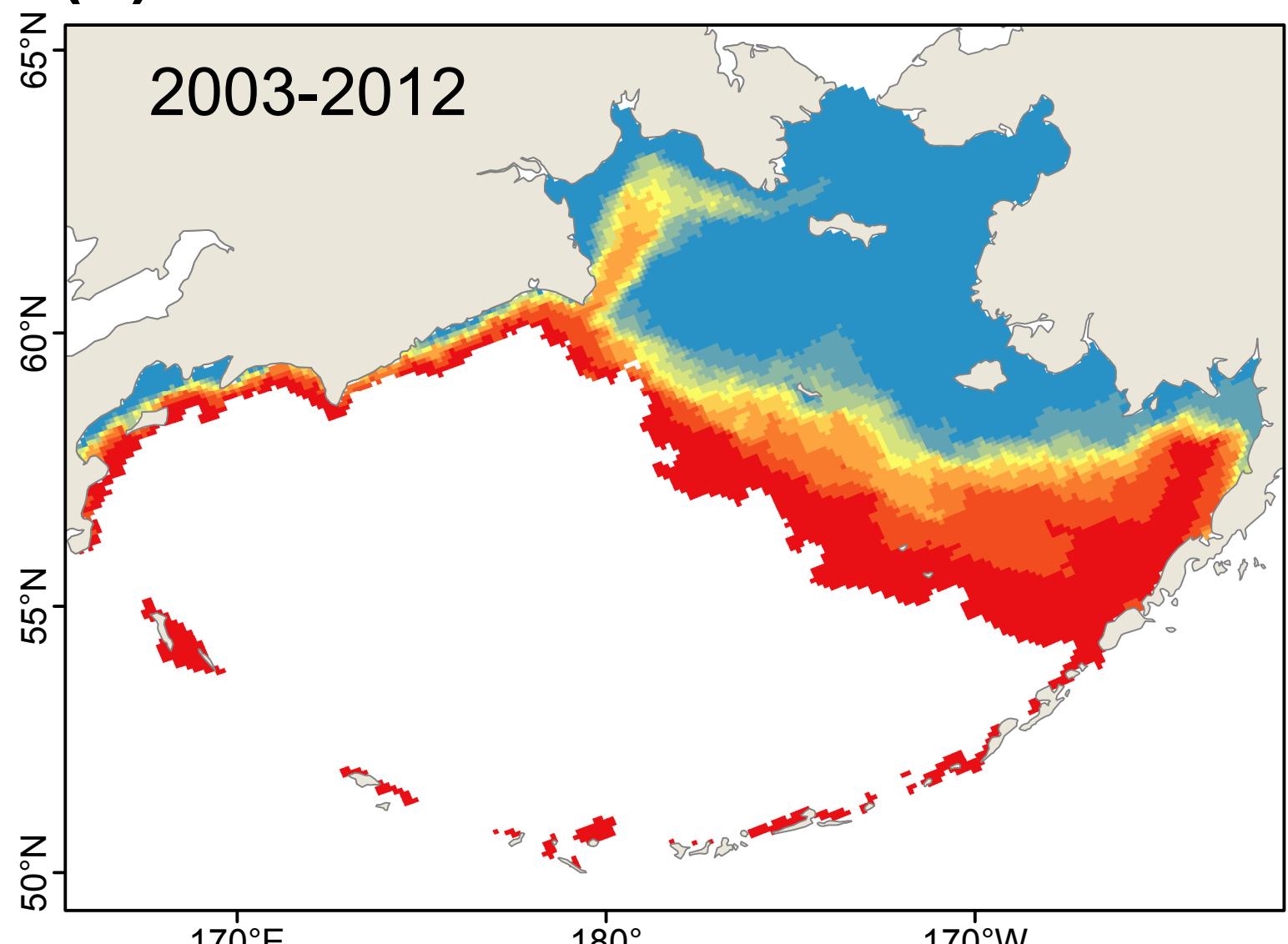
Number of years with suitable habitat



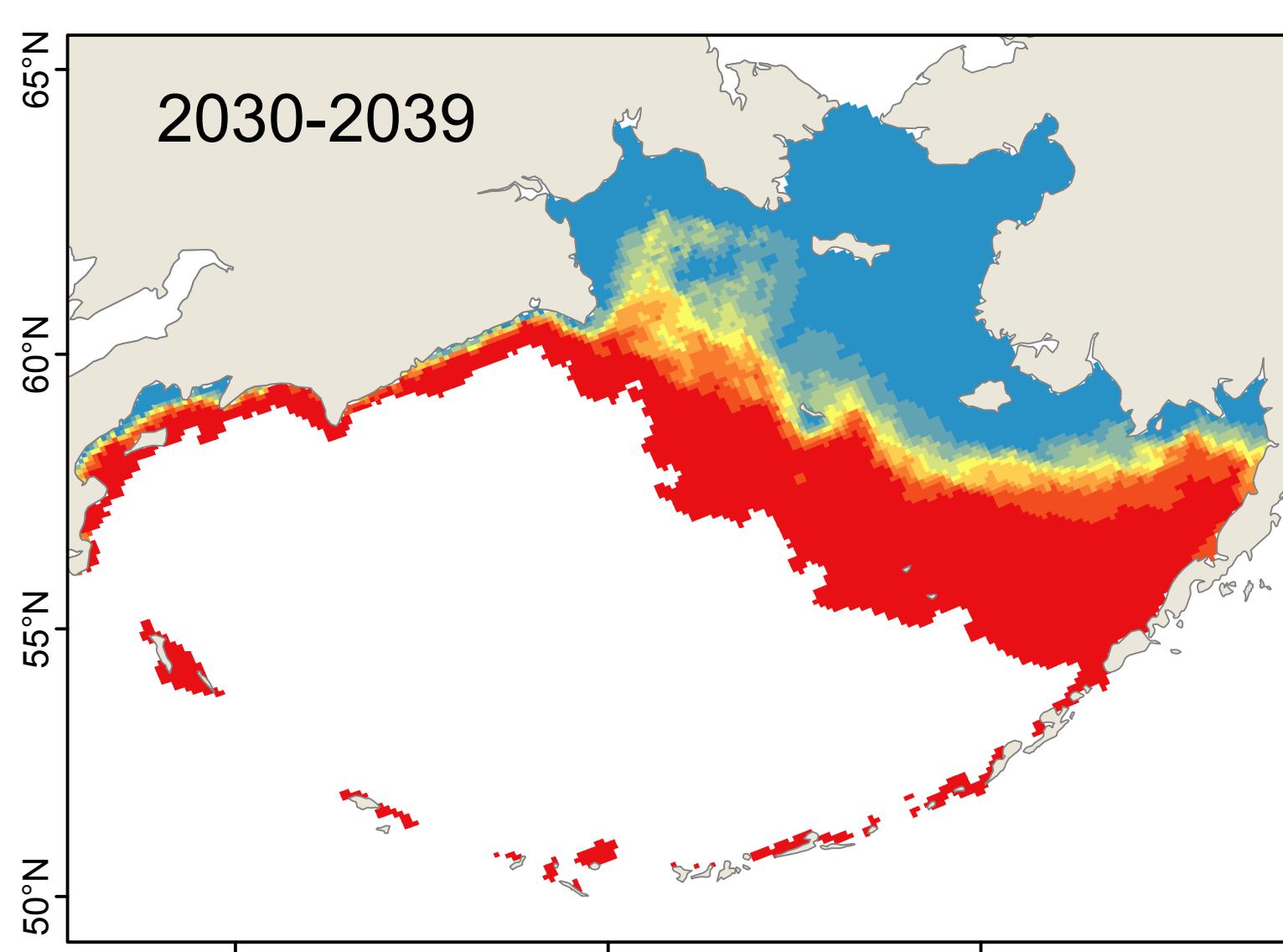
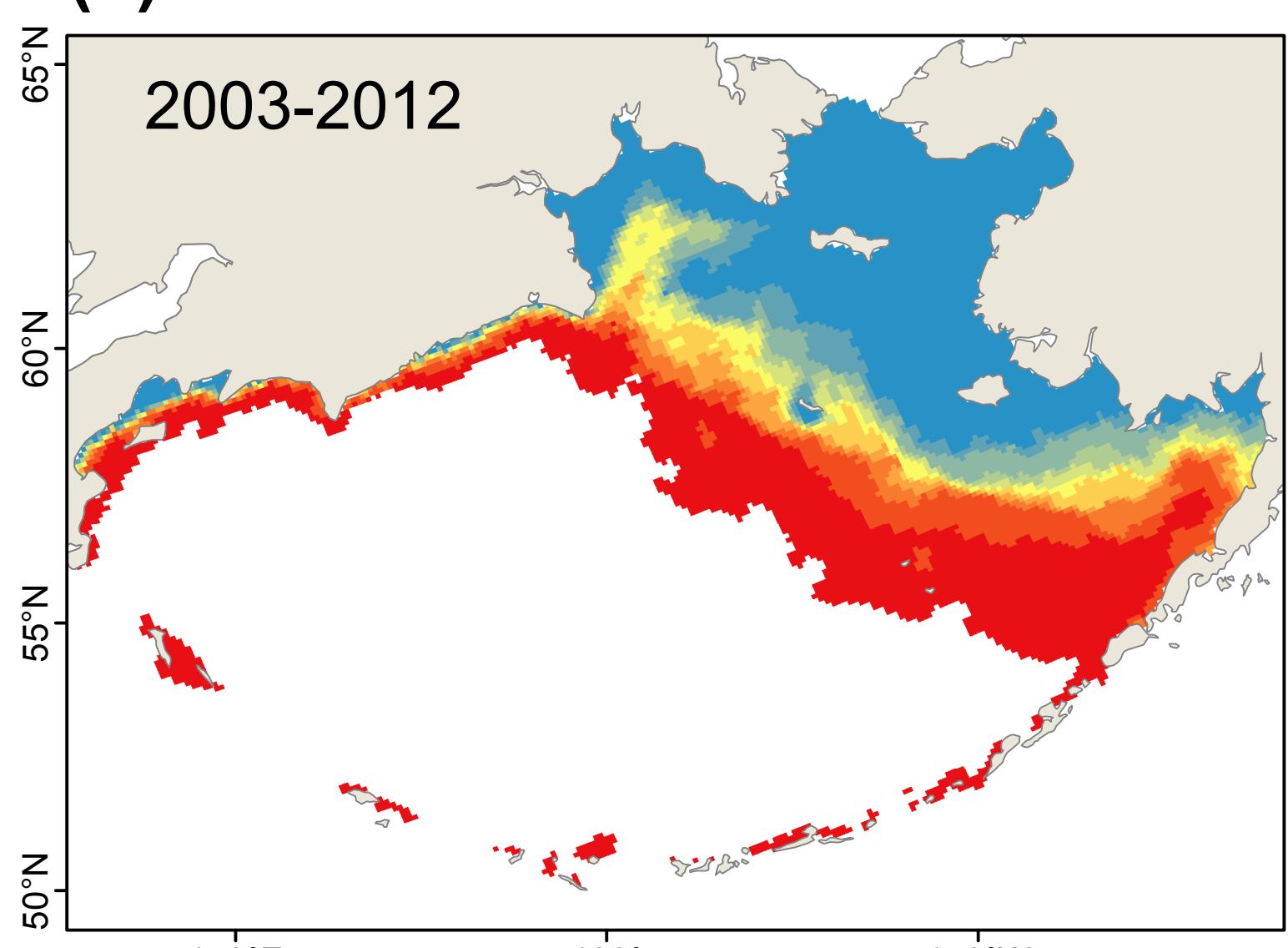
(a) Model: CGCM3-t47



(b) Model: ECHO-G

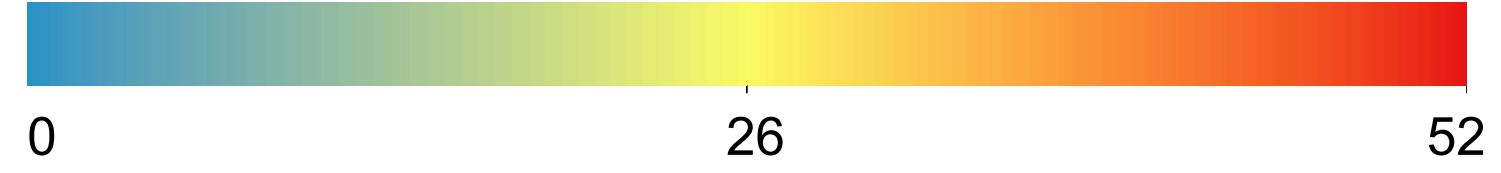


(c) Model: MIROC3.2

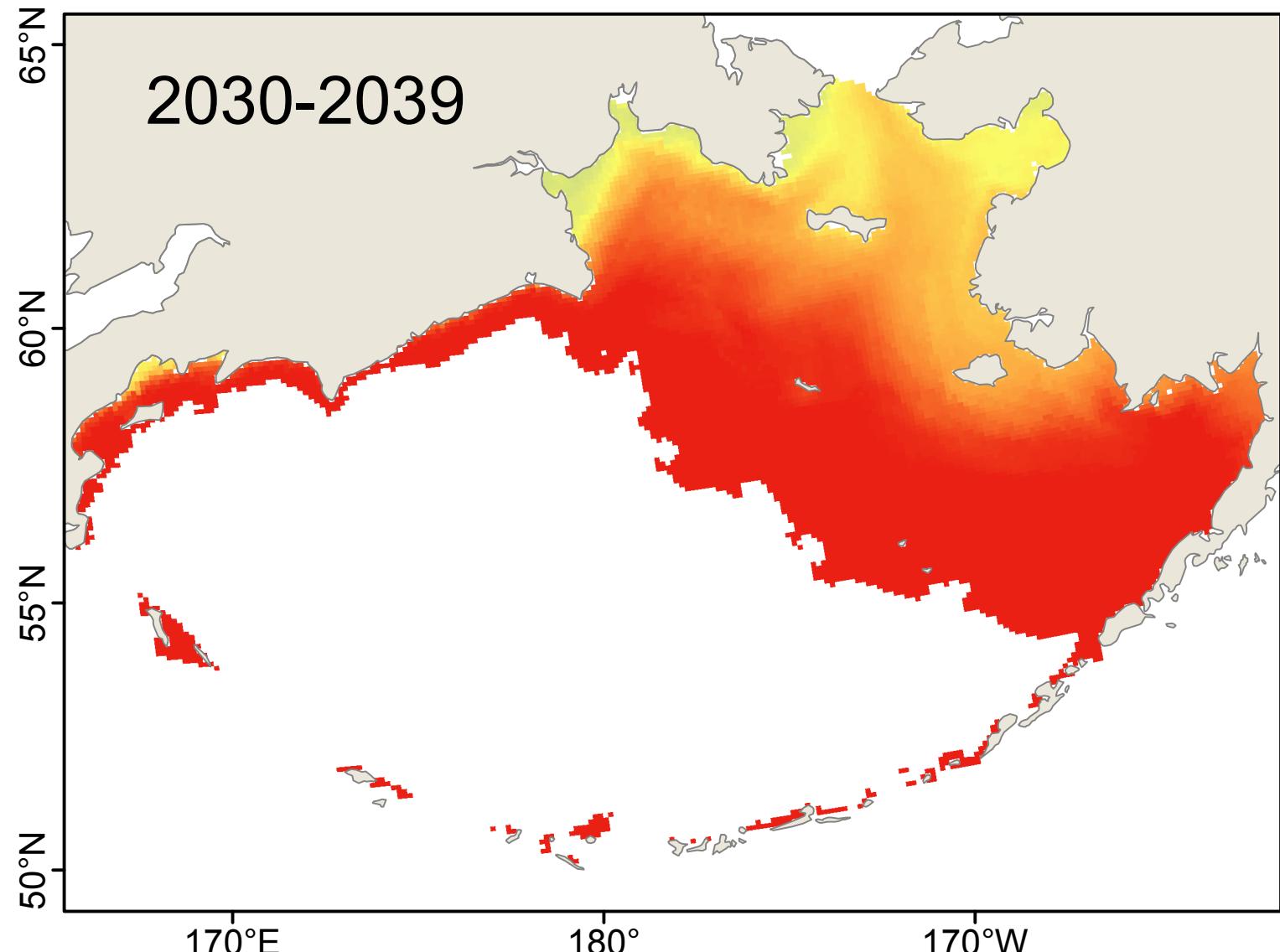
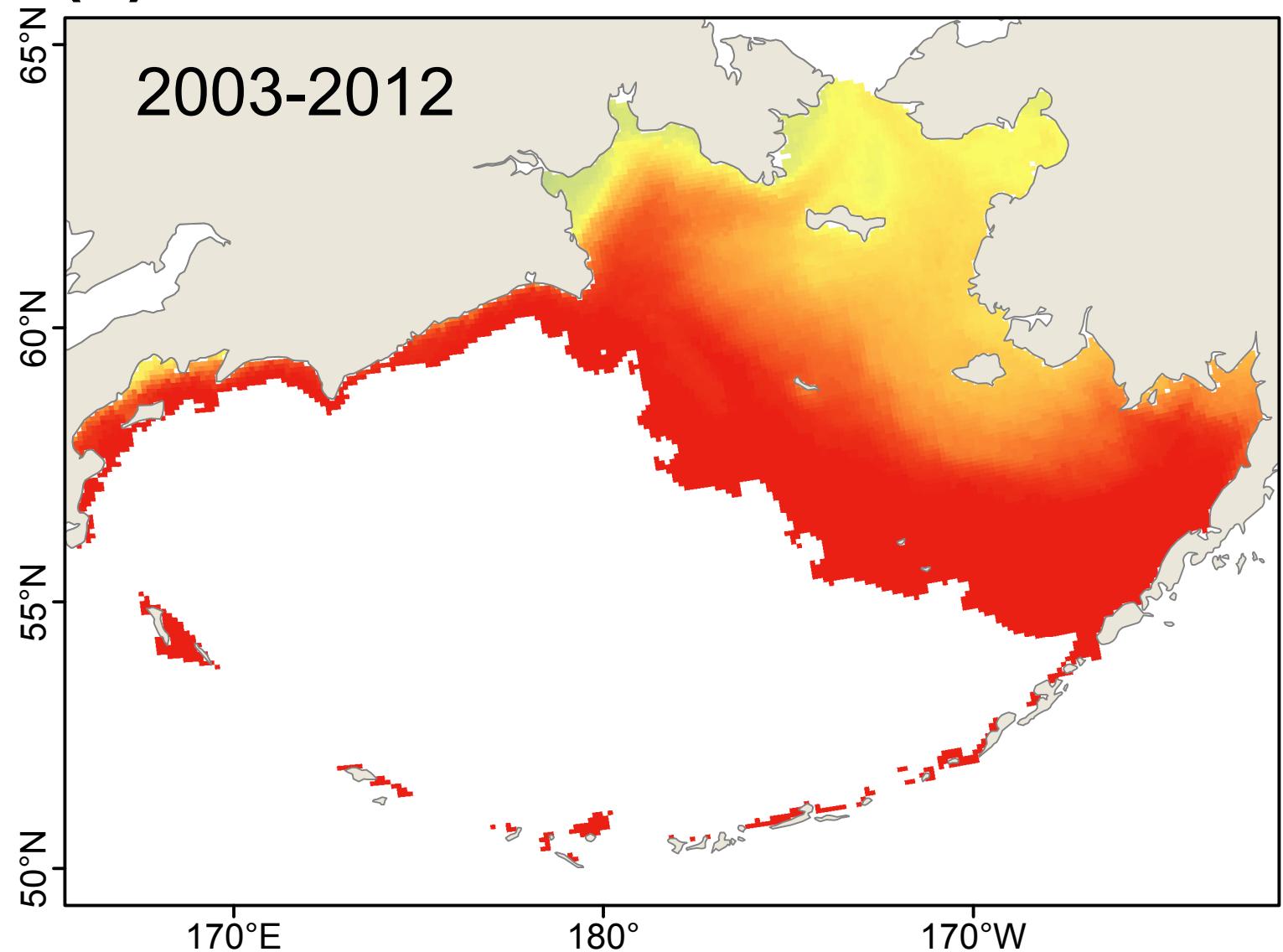


# *Nematostella vectensis*: Weekly Survival

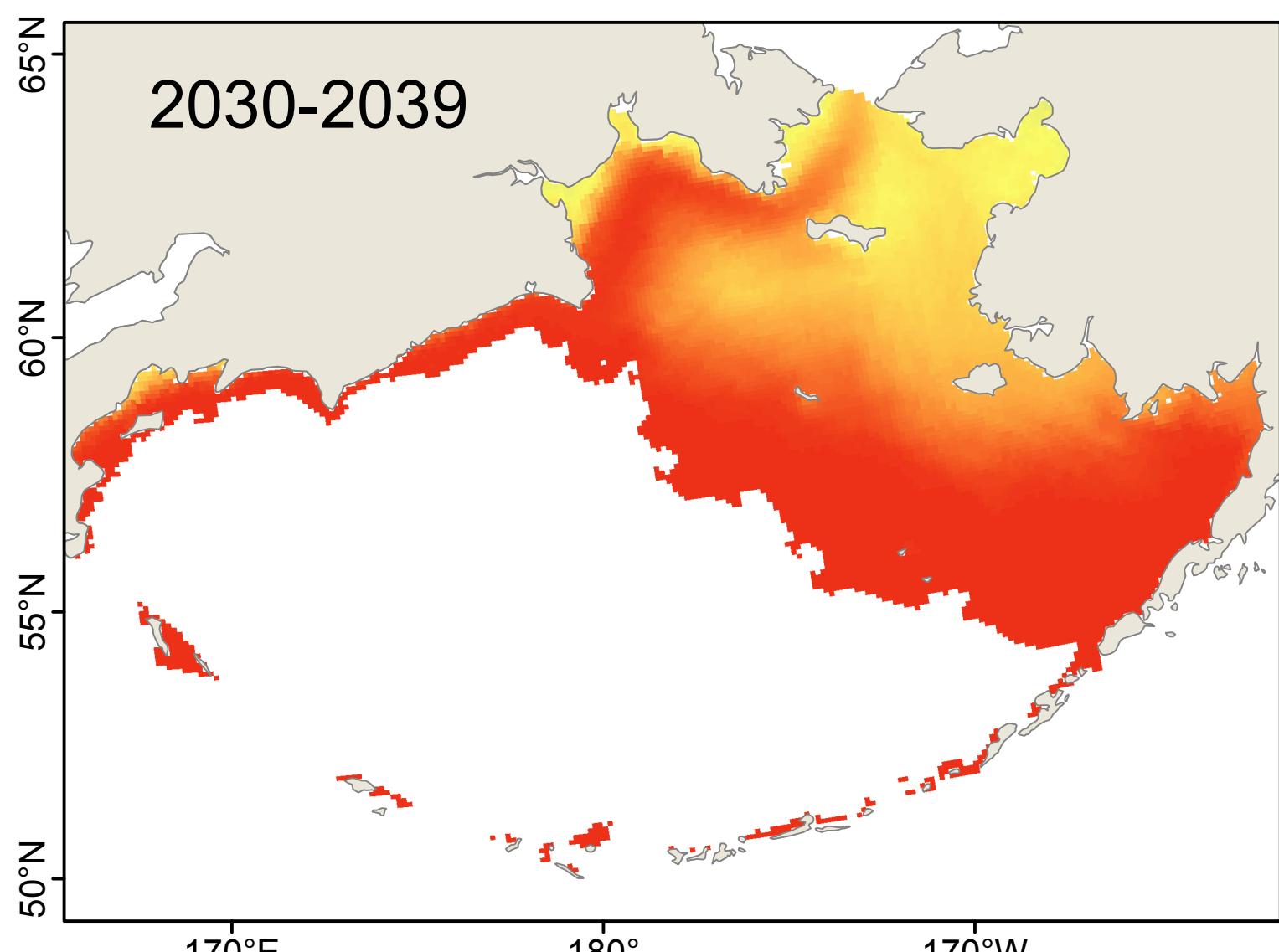
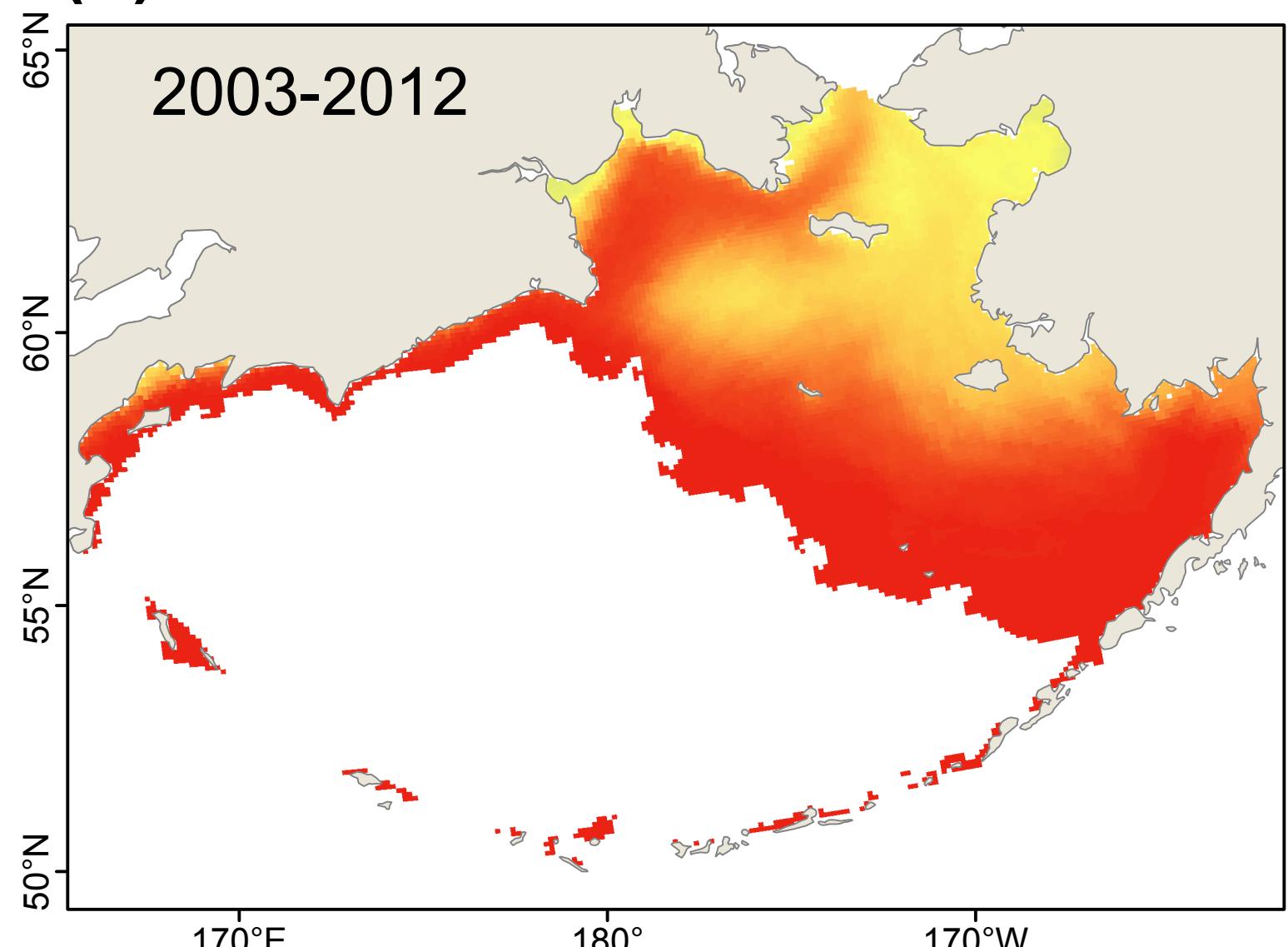
Average number of weeks of suitable habitat



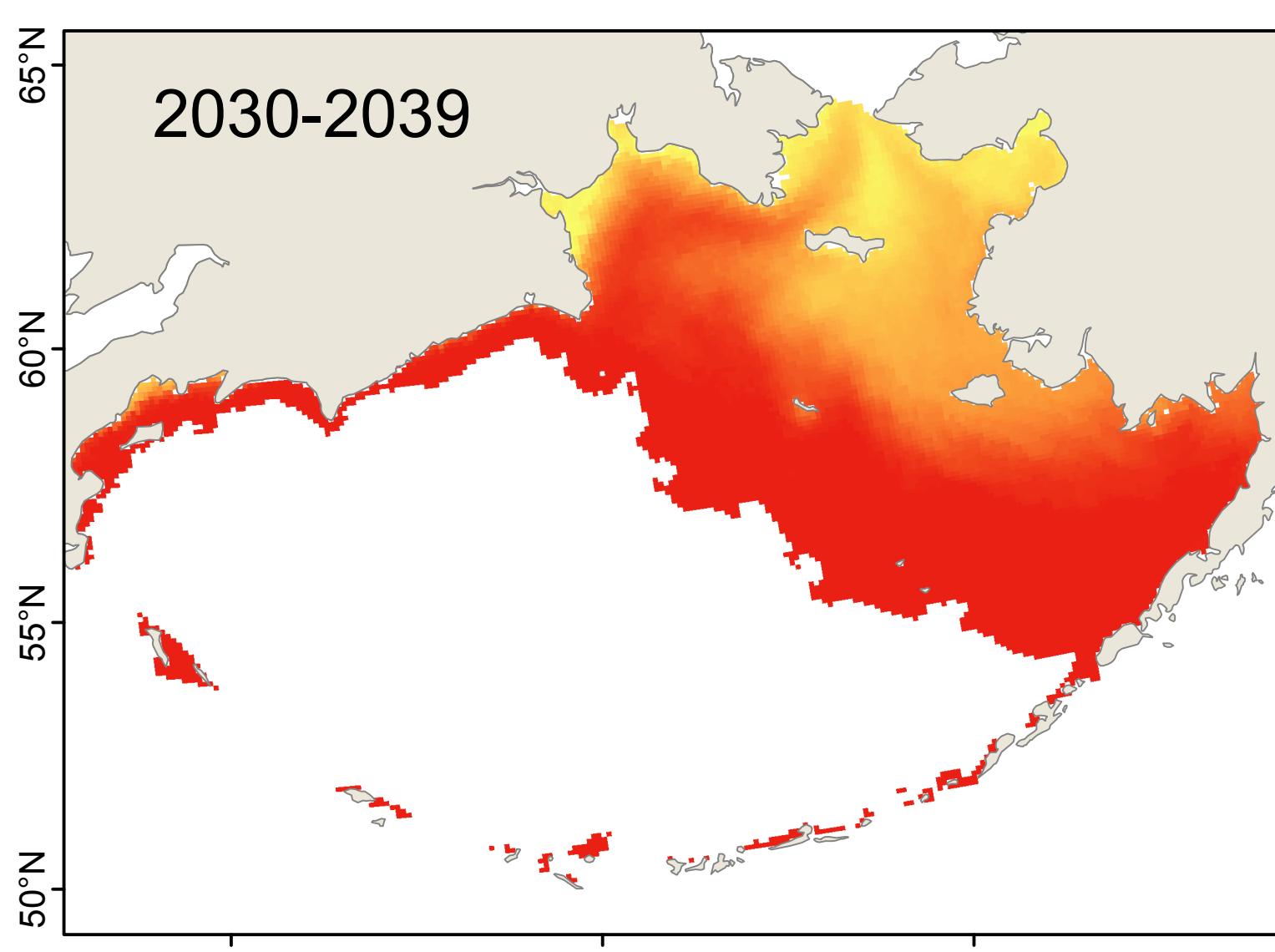
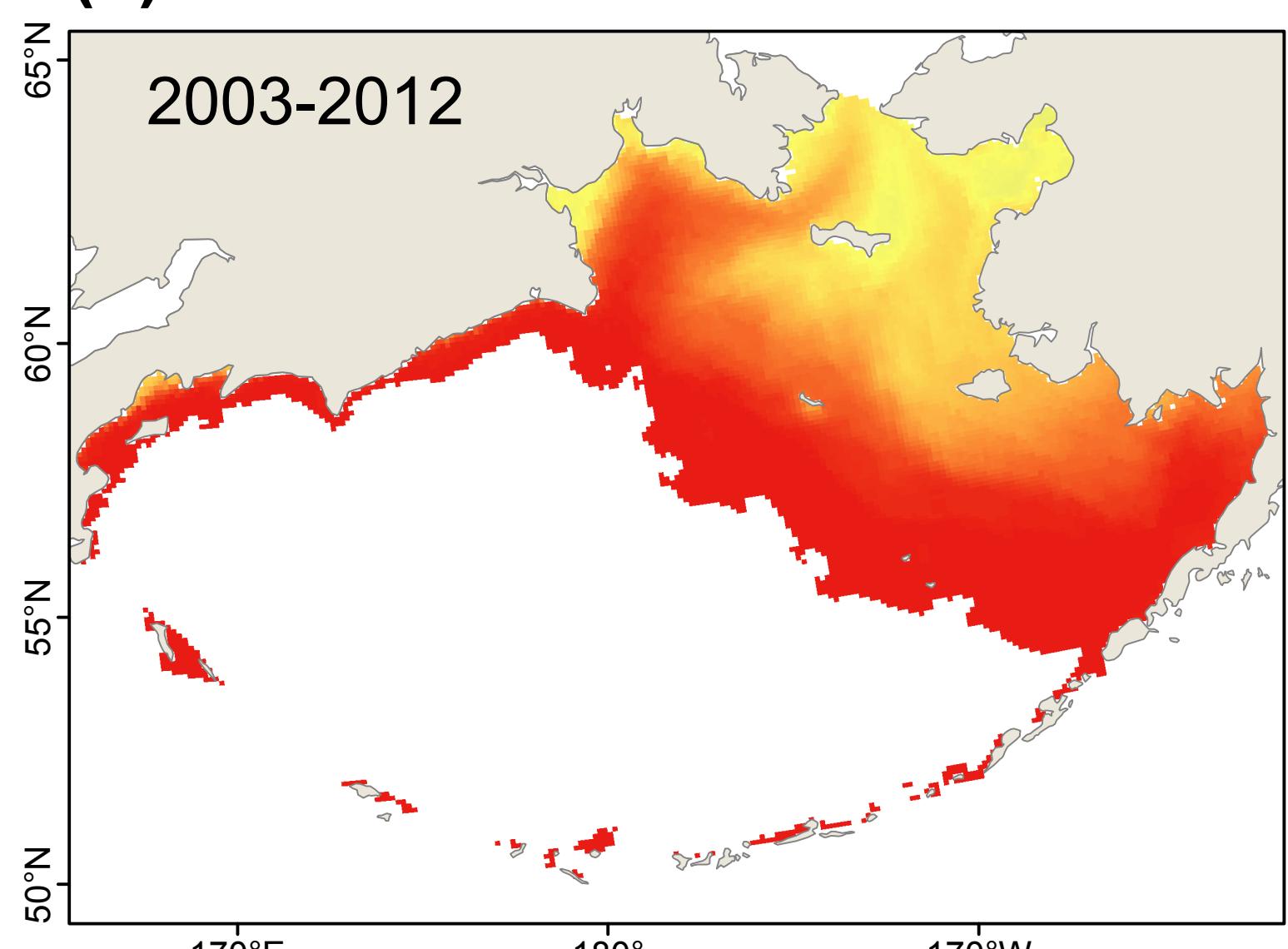
(a) Model: CGCM3-t47



(b) Model: ECHO-G

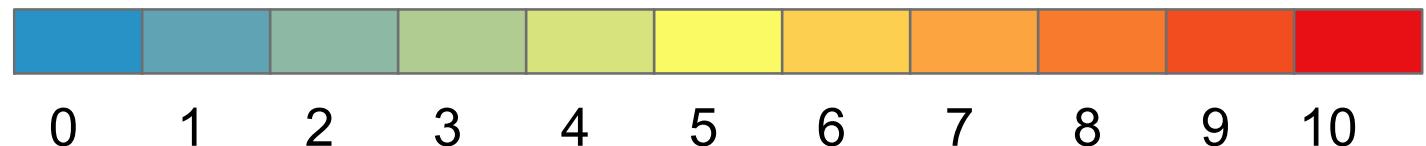


(c) Model: MIROC3.2

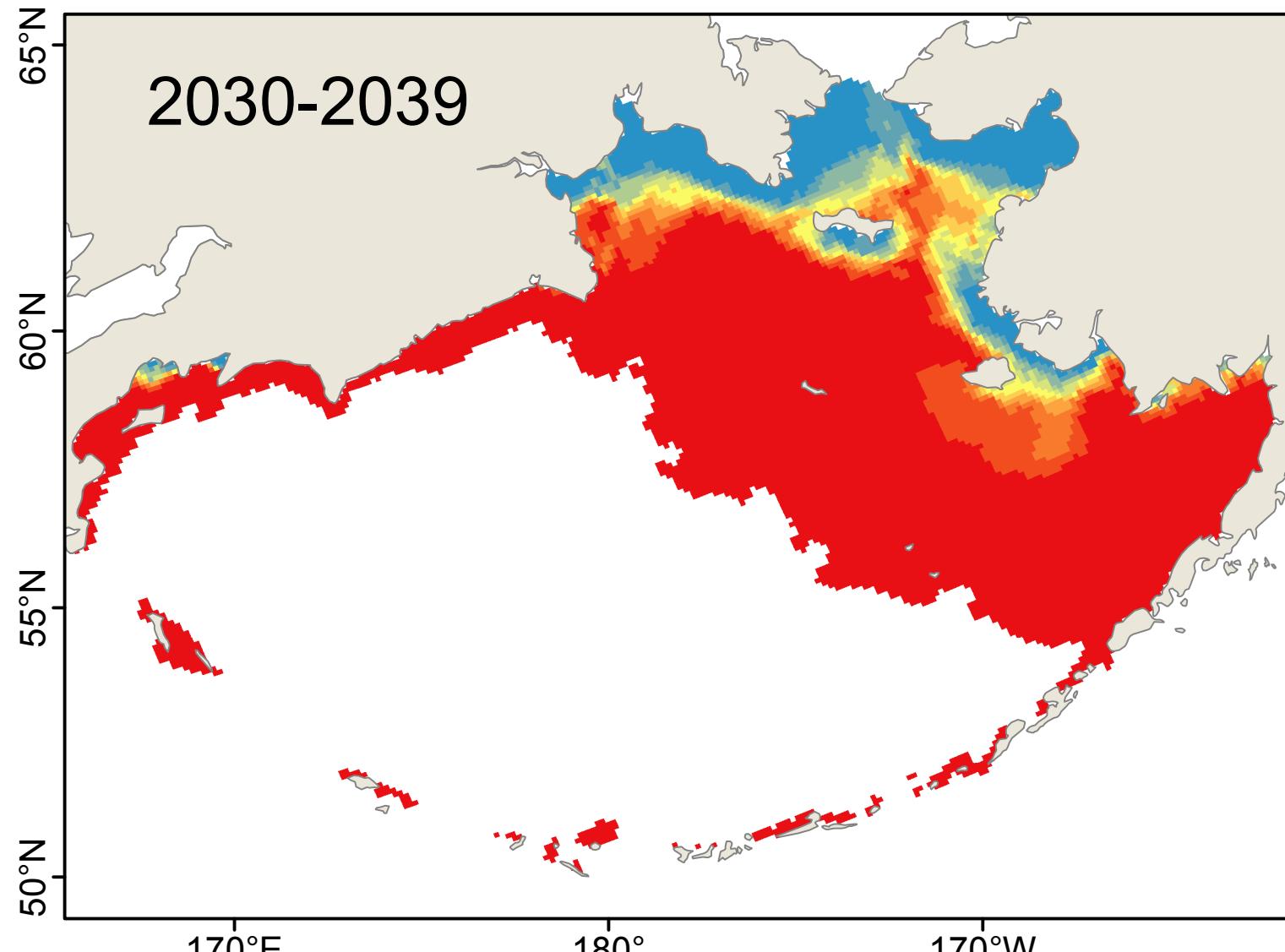
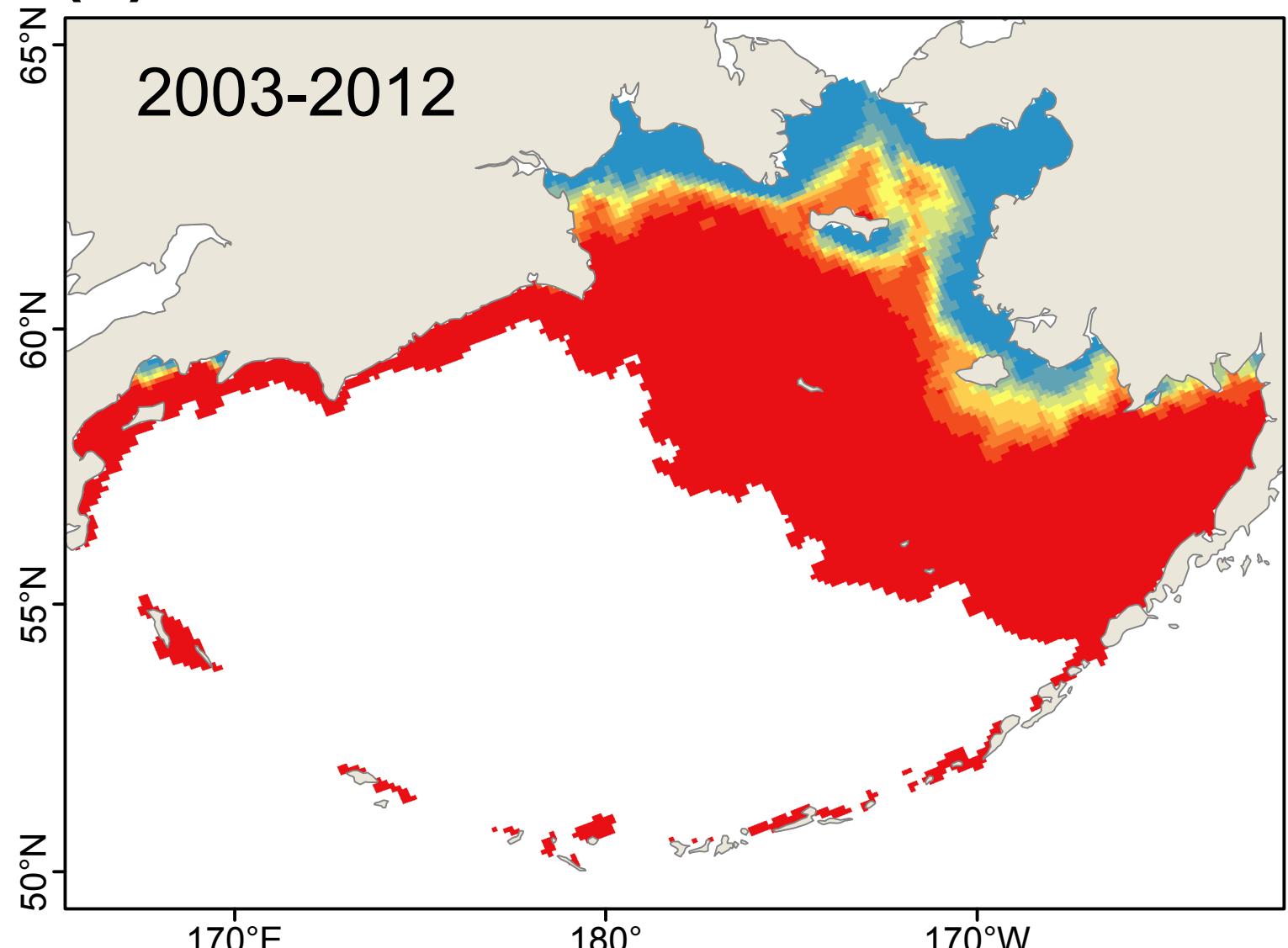


# *Cordylophora caspia: Year-round Survival*

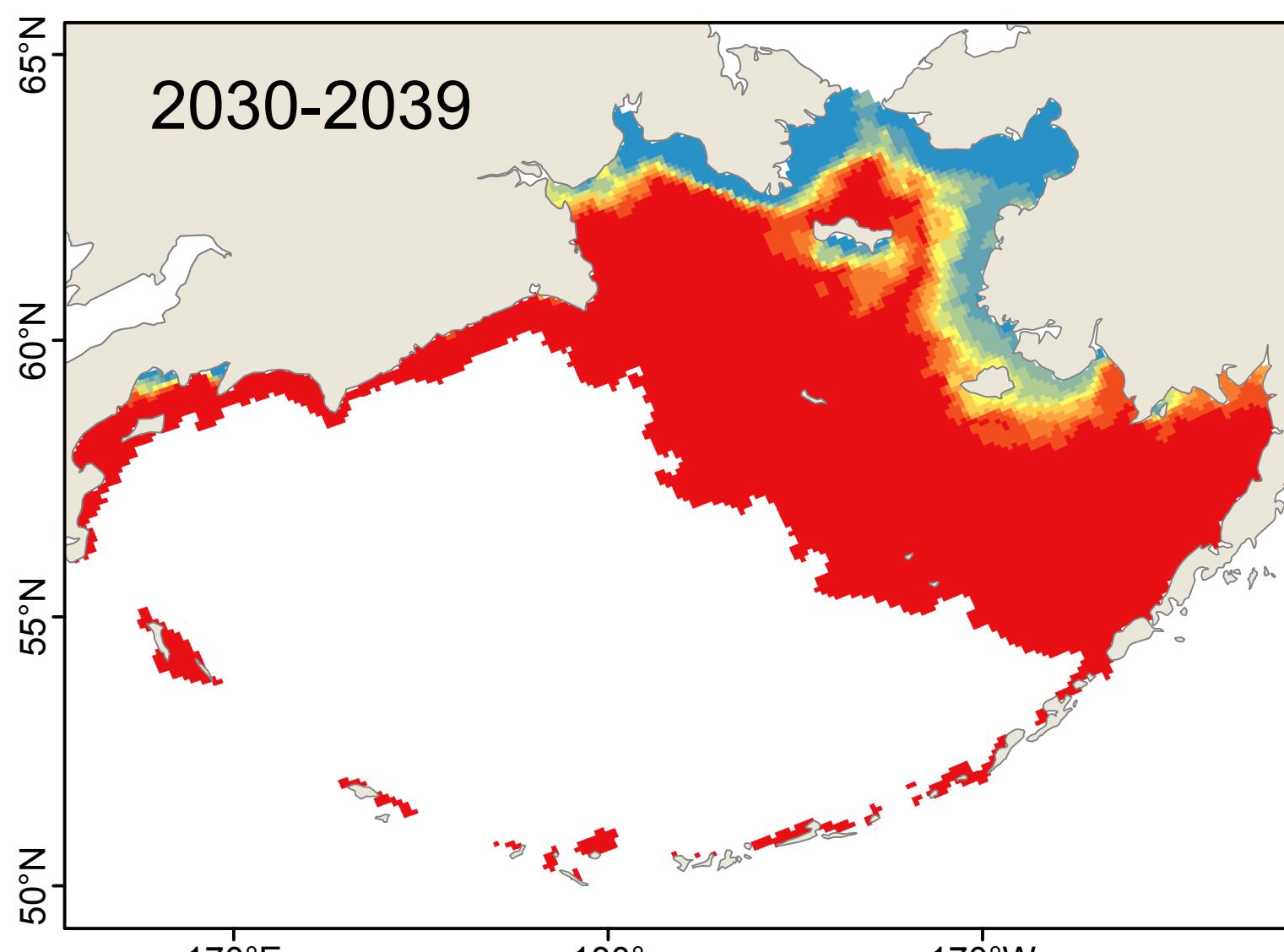
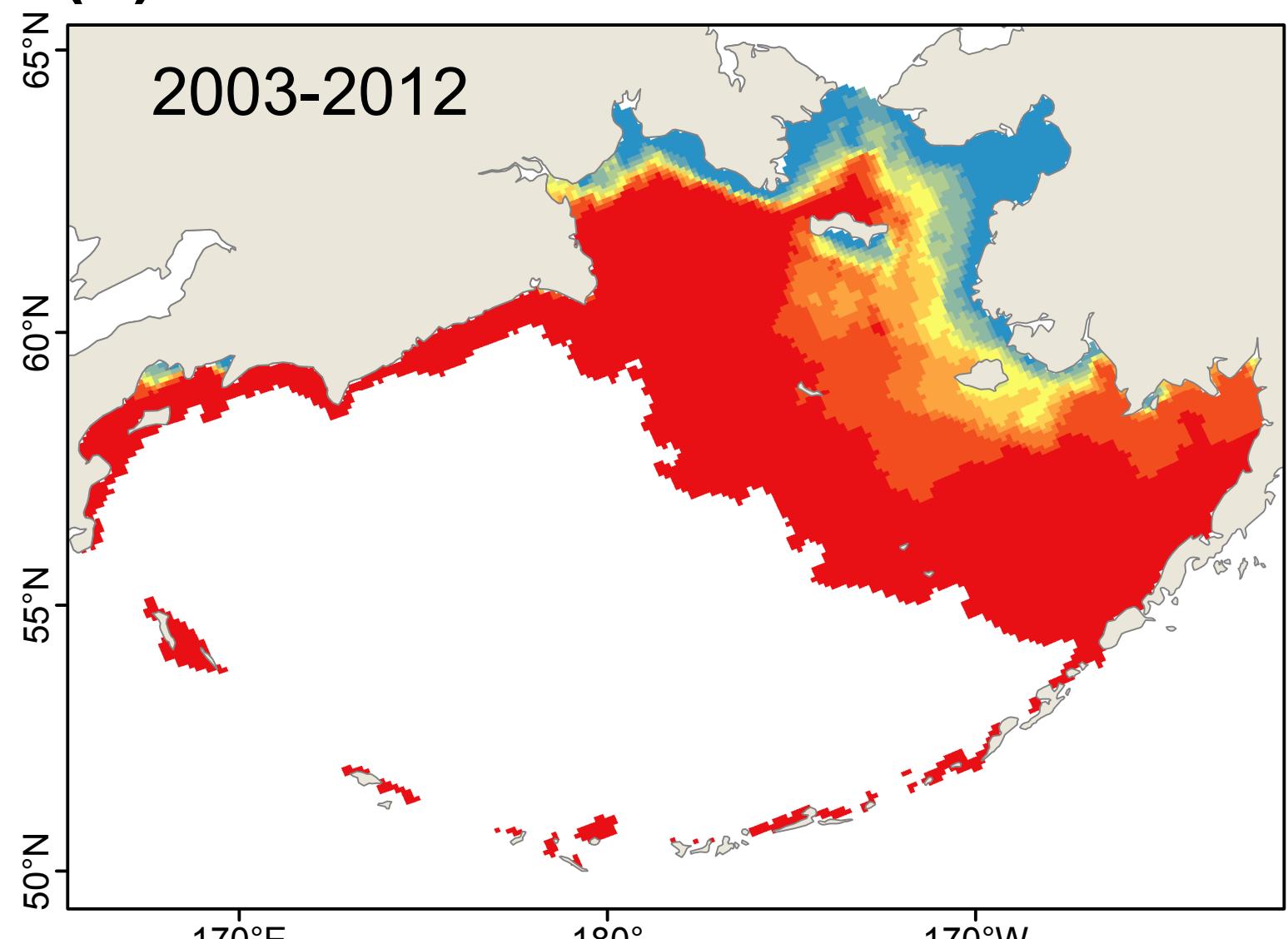
Number of years with suitable habitat



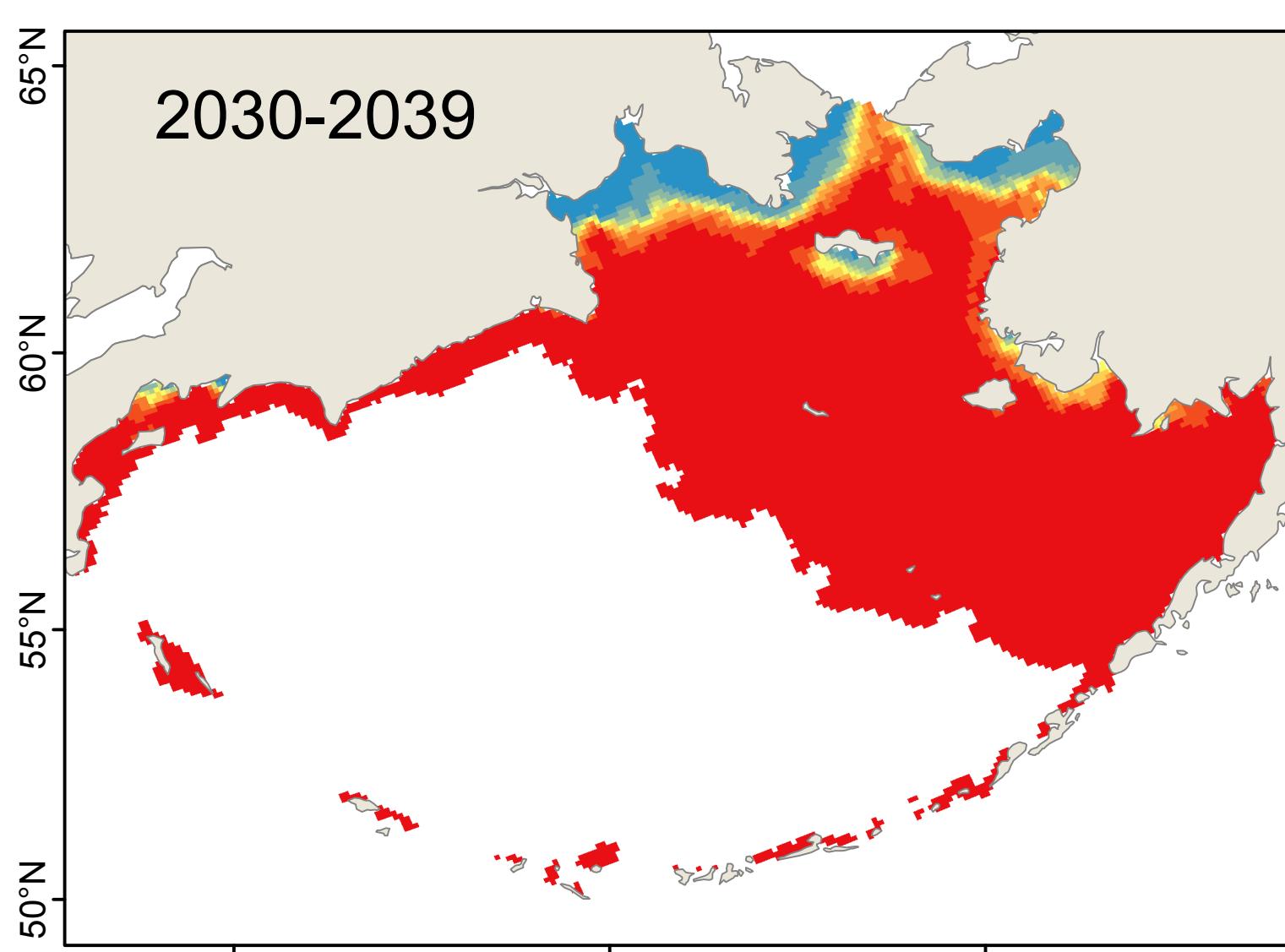
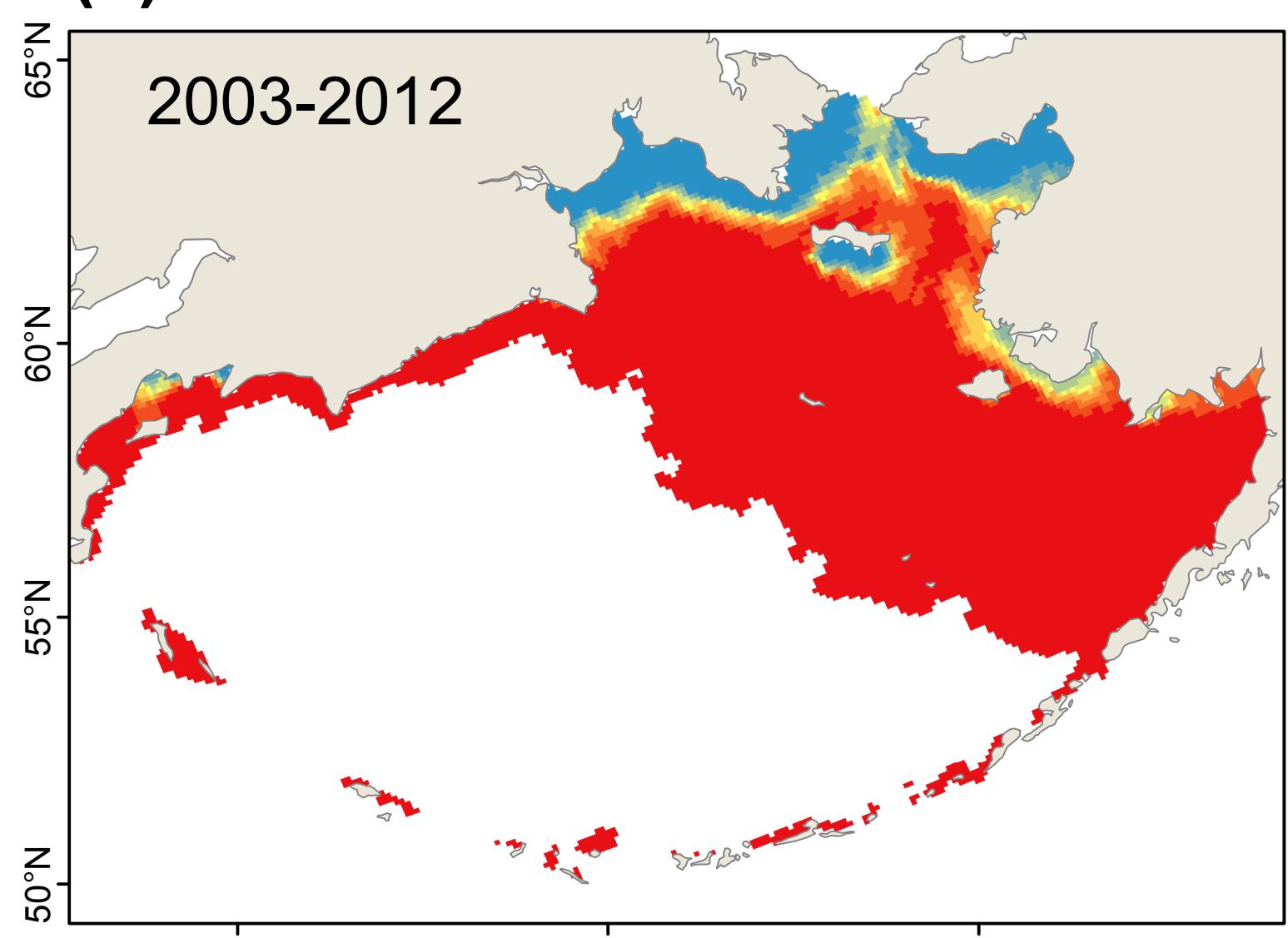
(a) Model: CGCM3-t47



(b) Model: ECHO-G

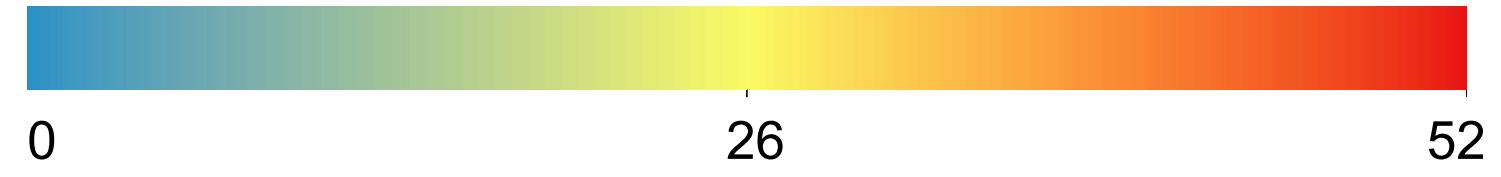


(c) Model: MIROC3.2

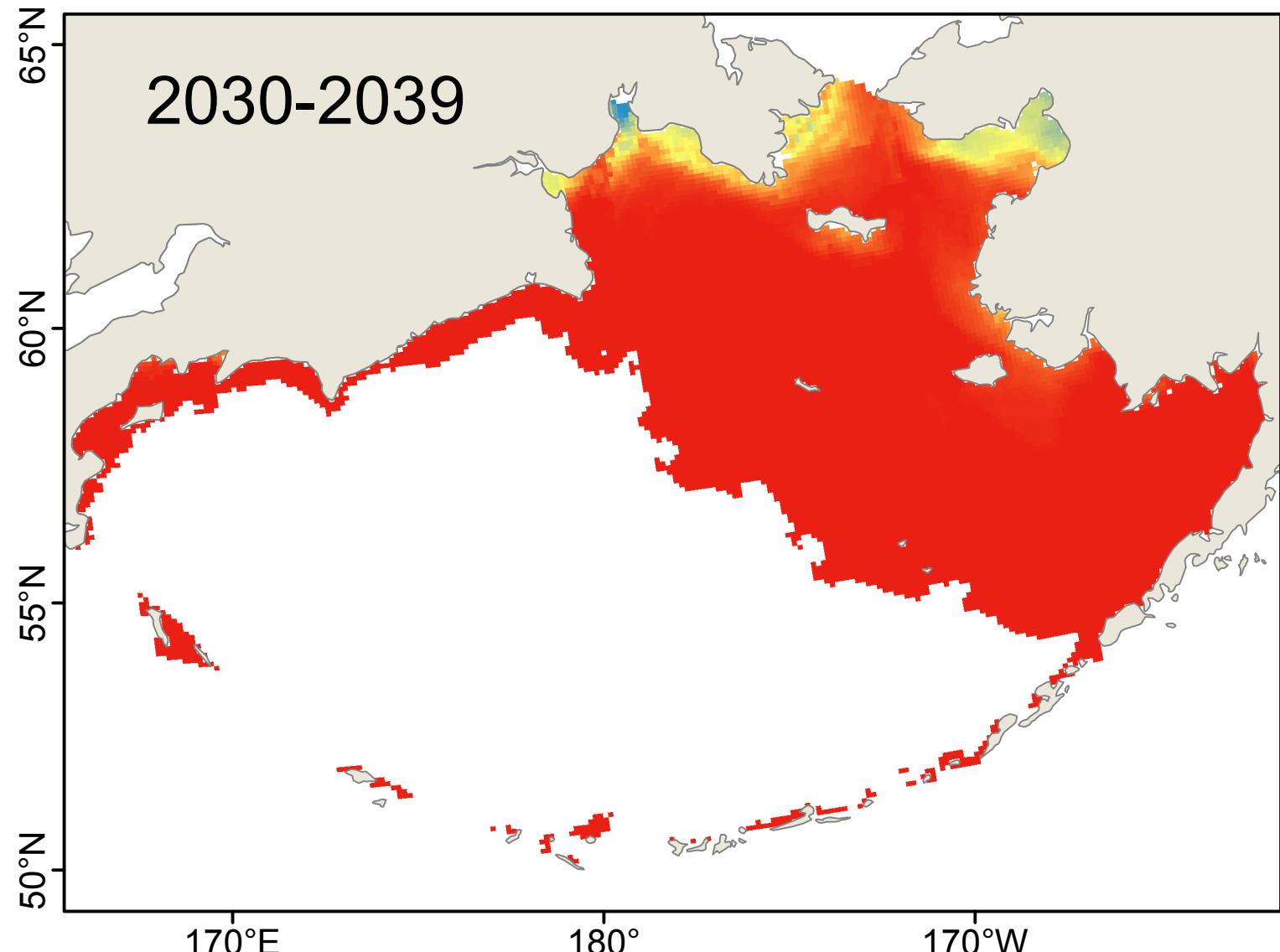
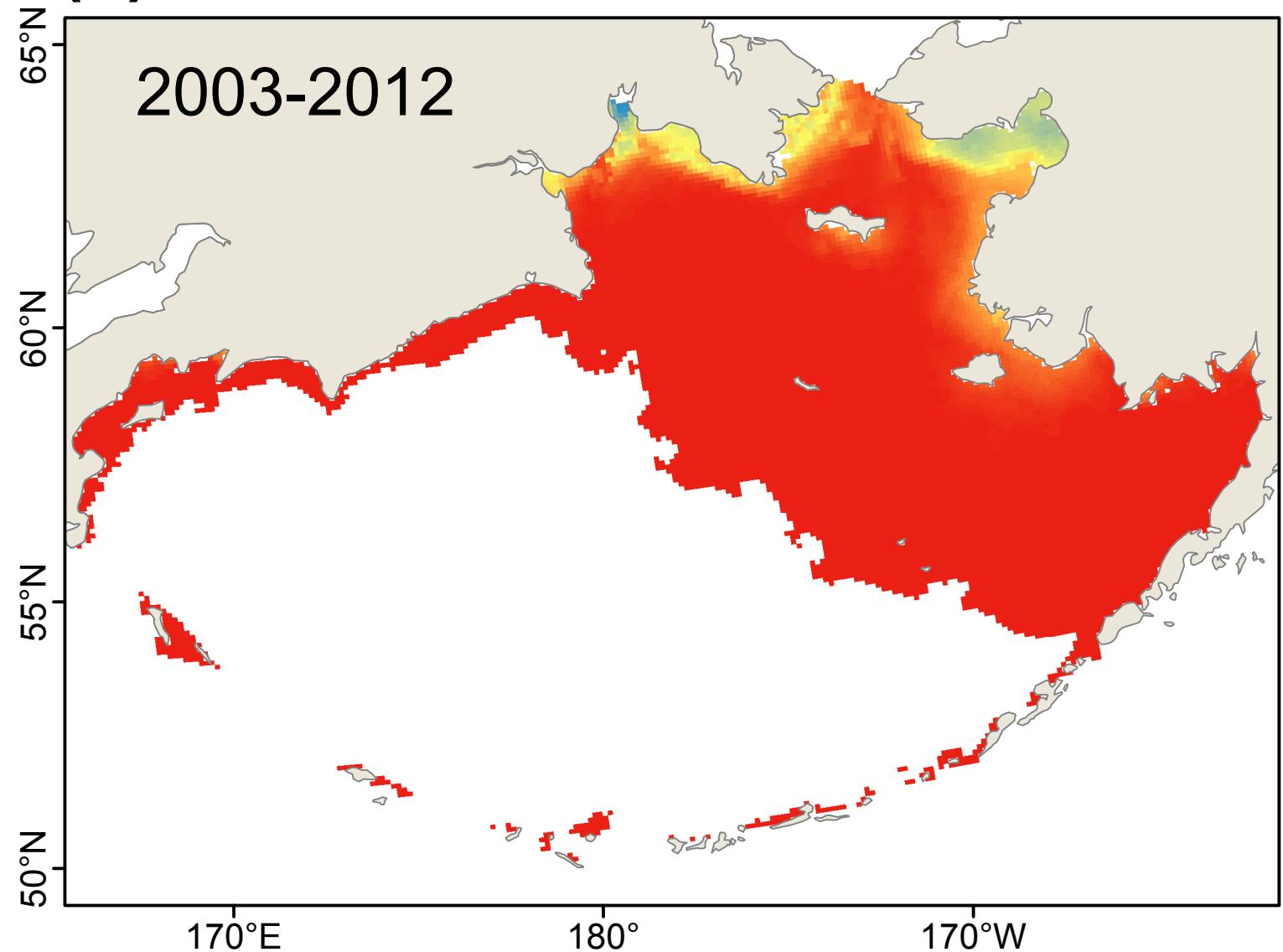


# *Cordylophora caspia: Weekly Survival*

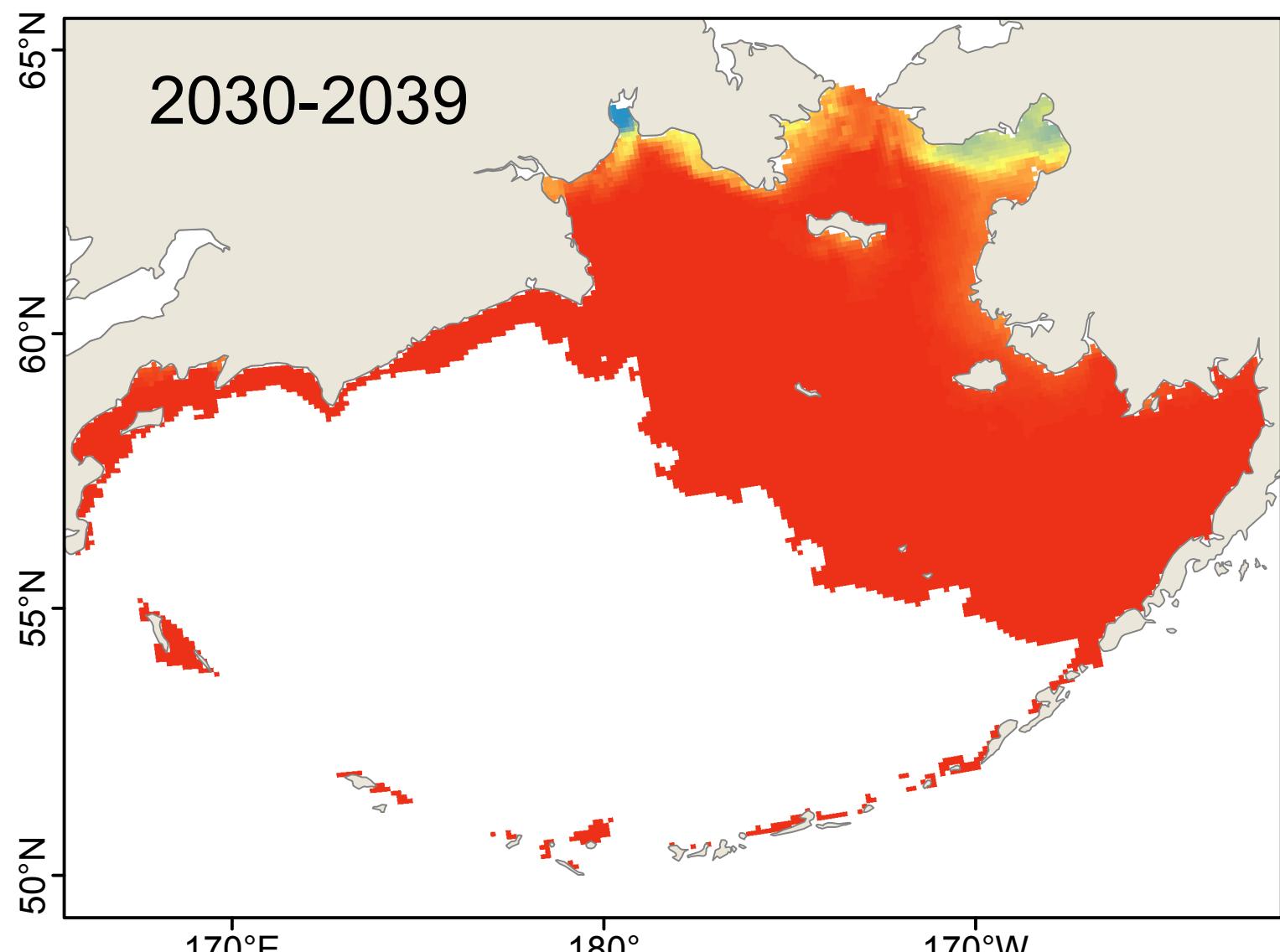
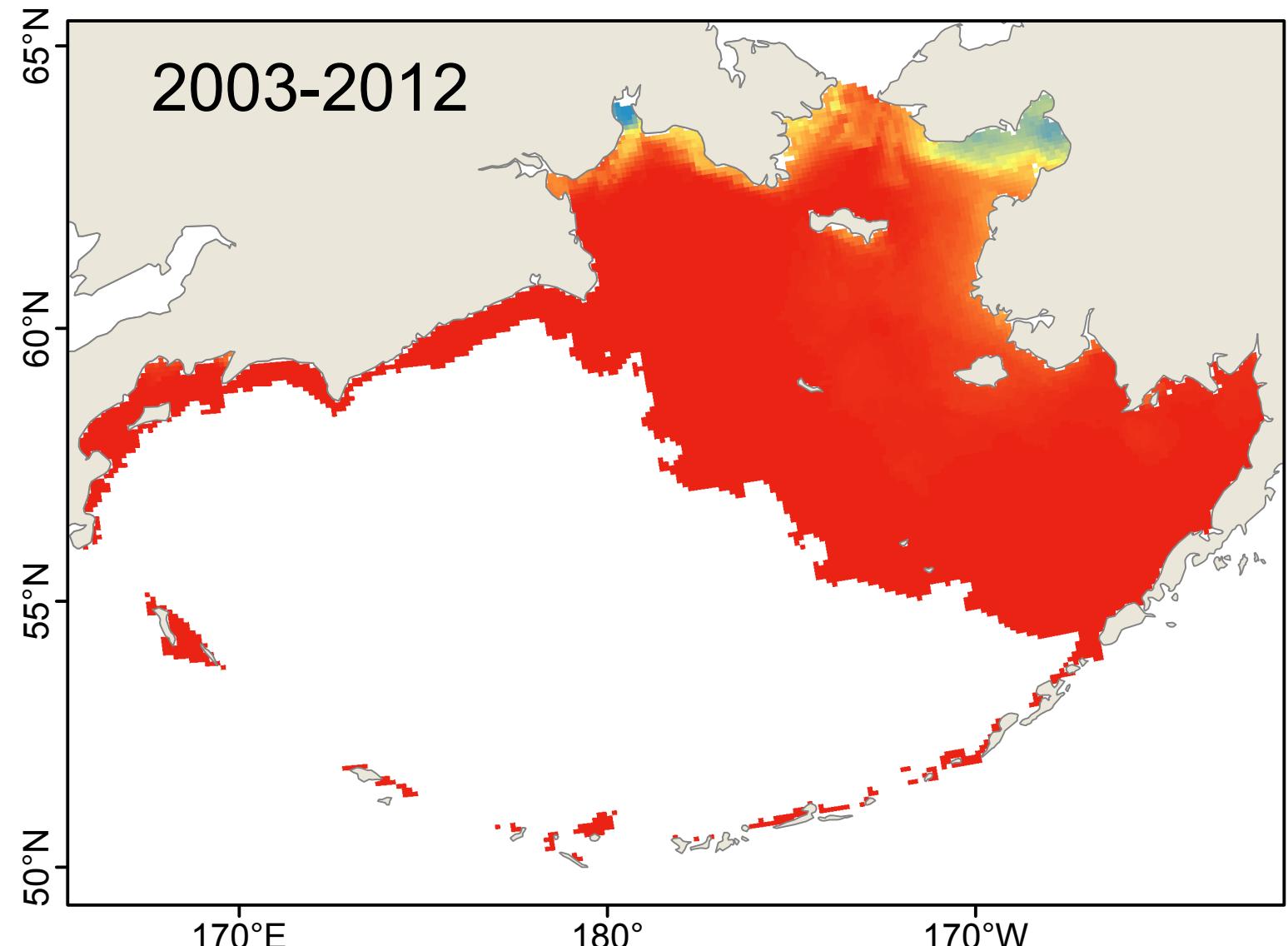
Average number of weeks of suitable habitat



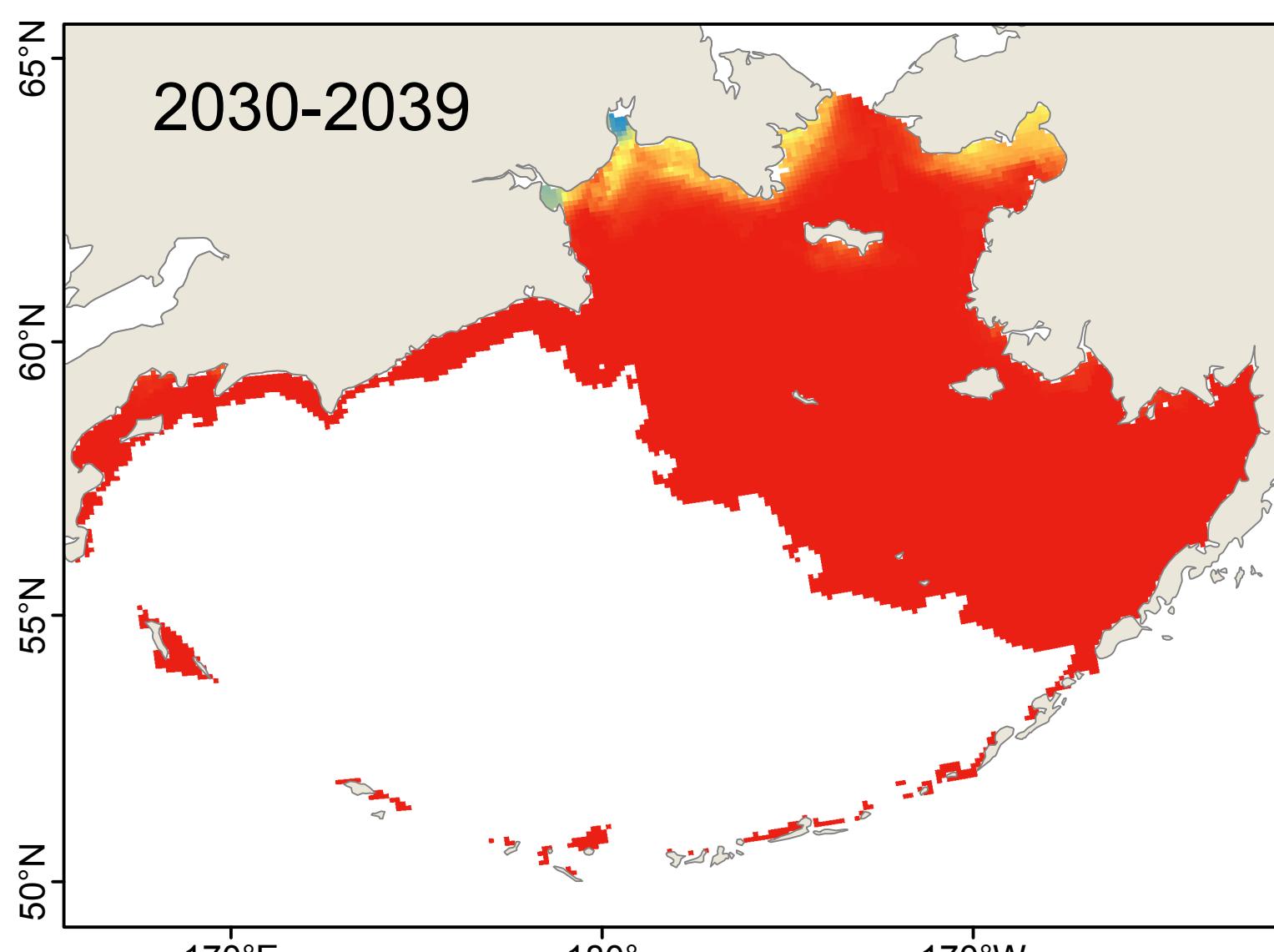
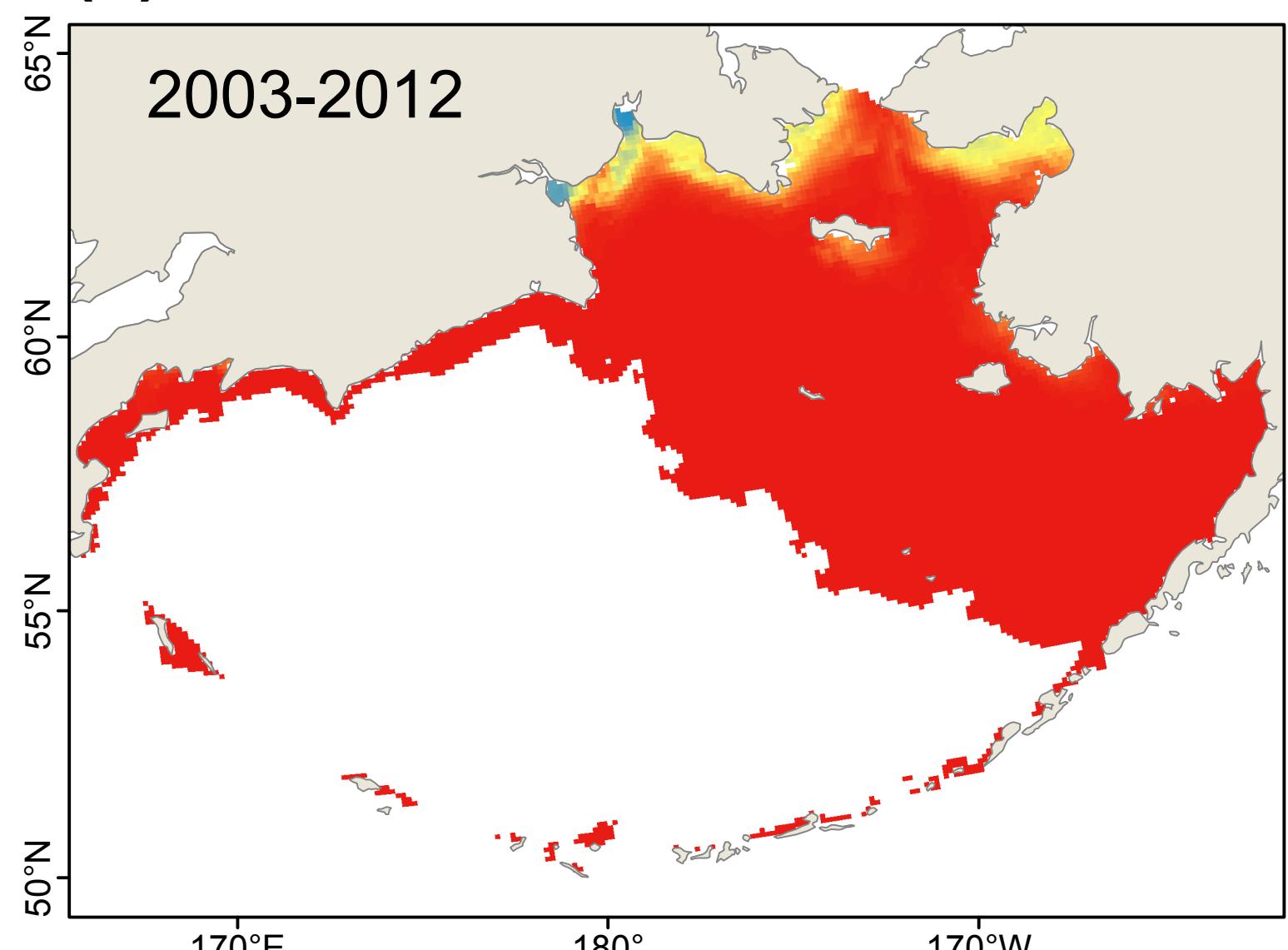
(a) Model: CGCM3-t47



(b) Model: ECHO-G

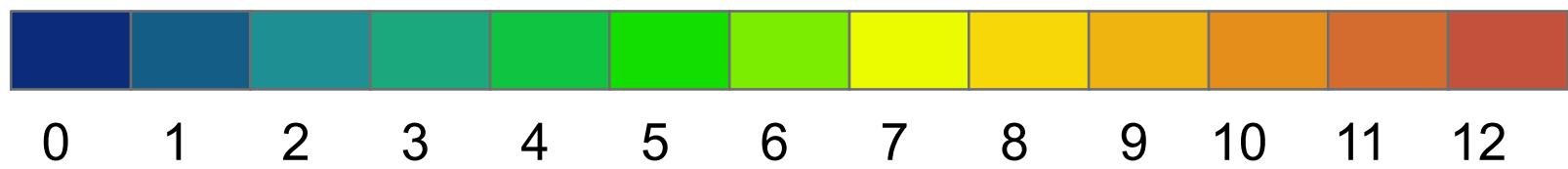


(c) Model: MIROC3.2

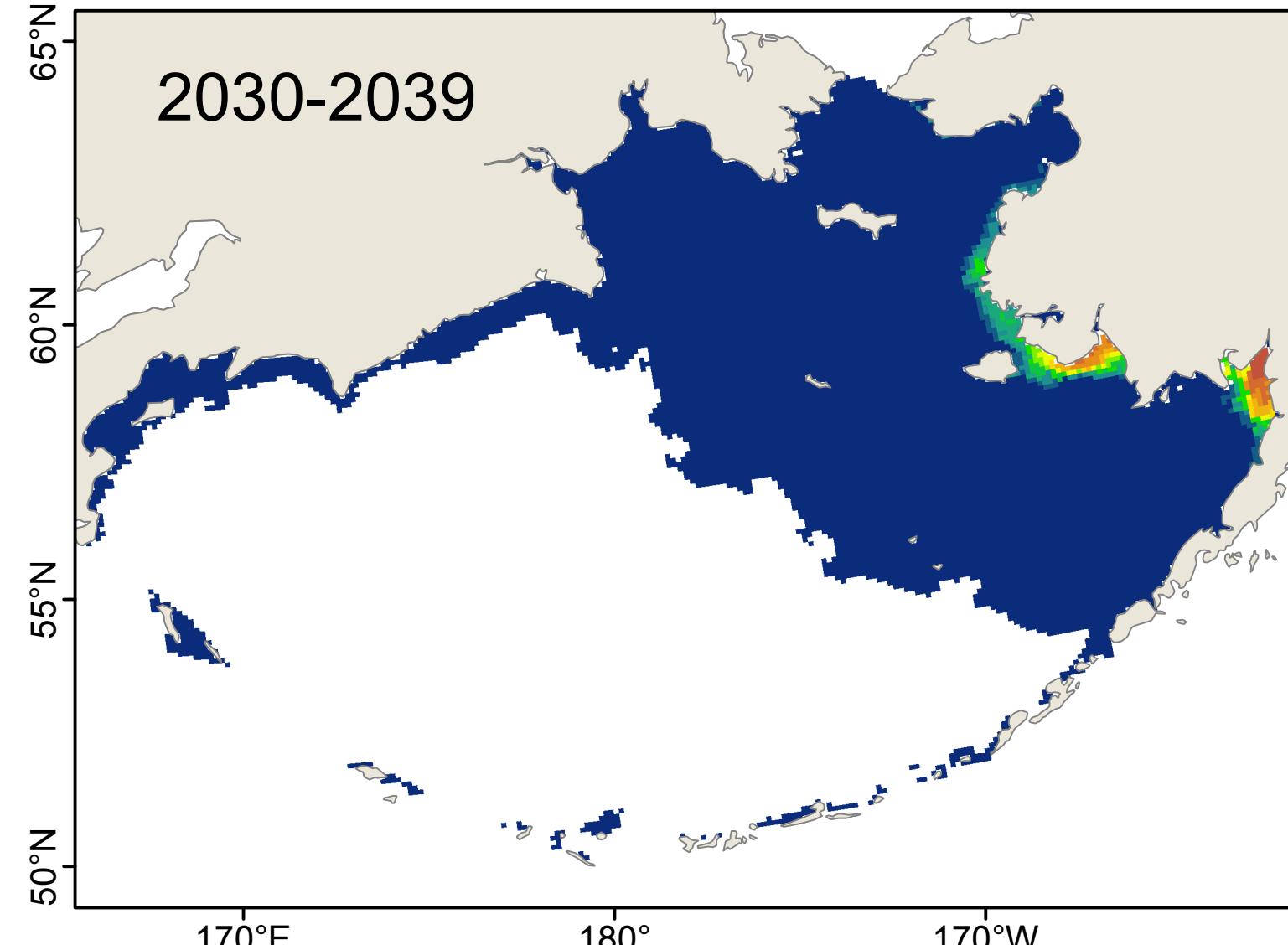
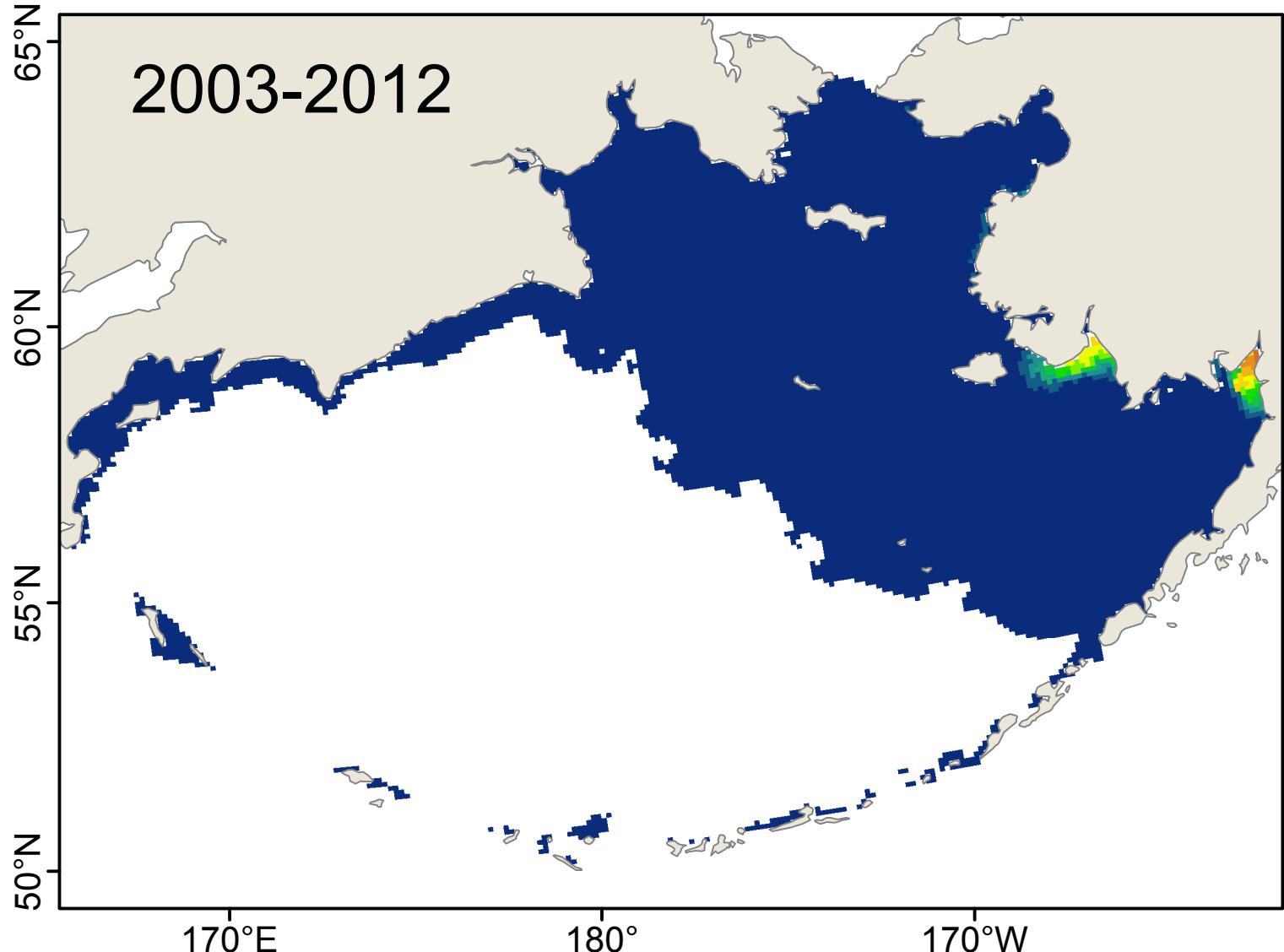


# *Cordylophora caspia: Reproduction*

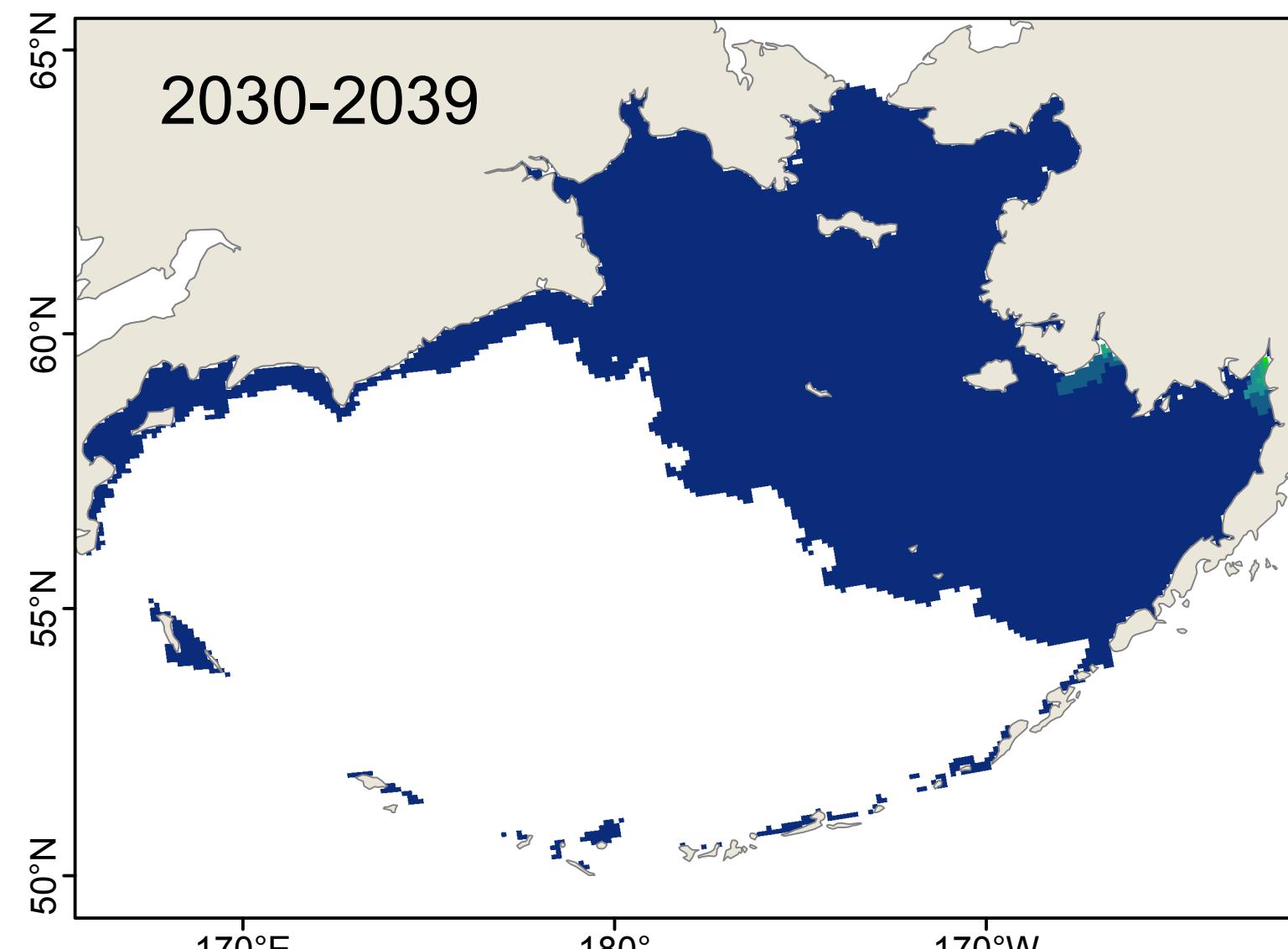
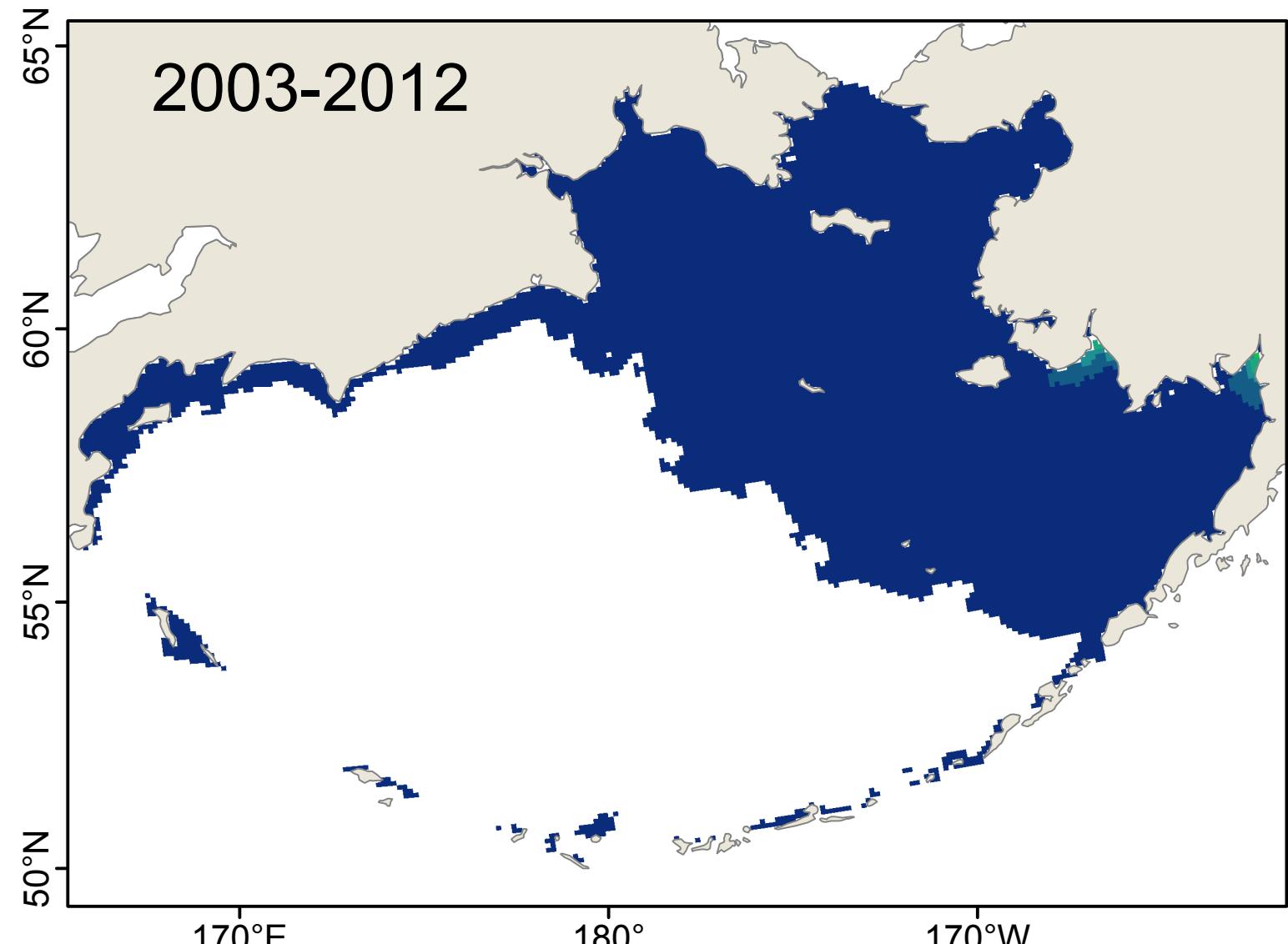
Average number of consecutive weeks of suitable habitat



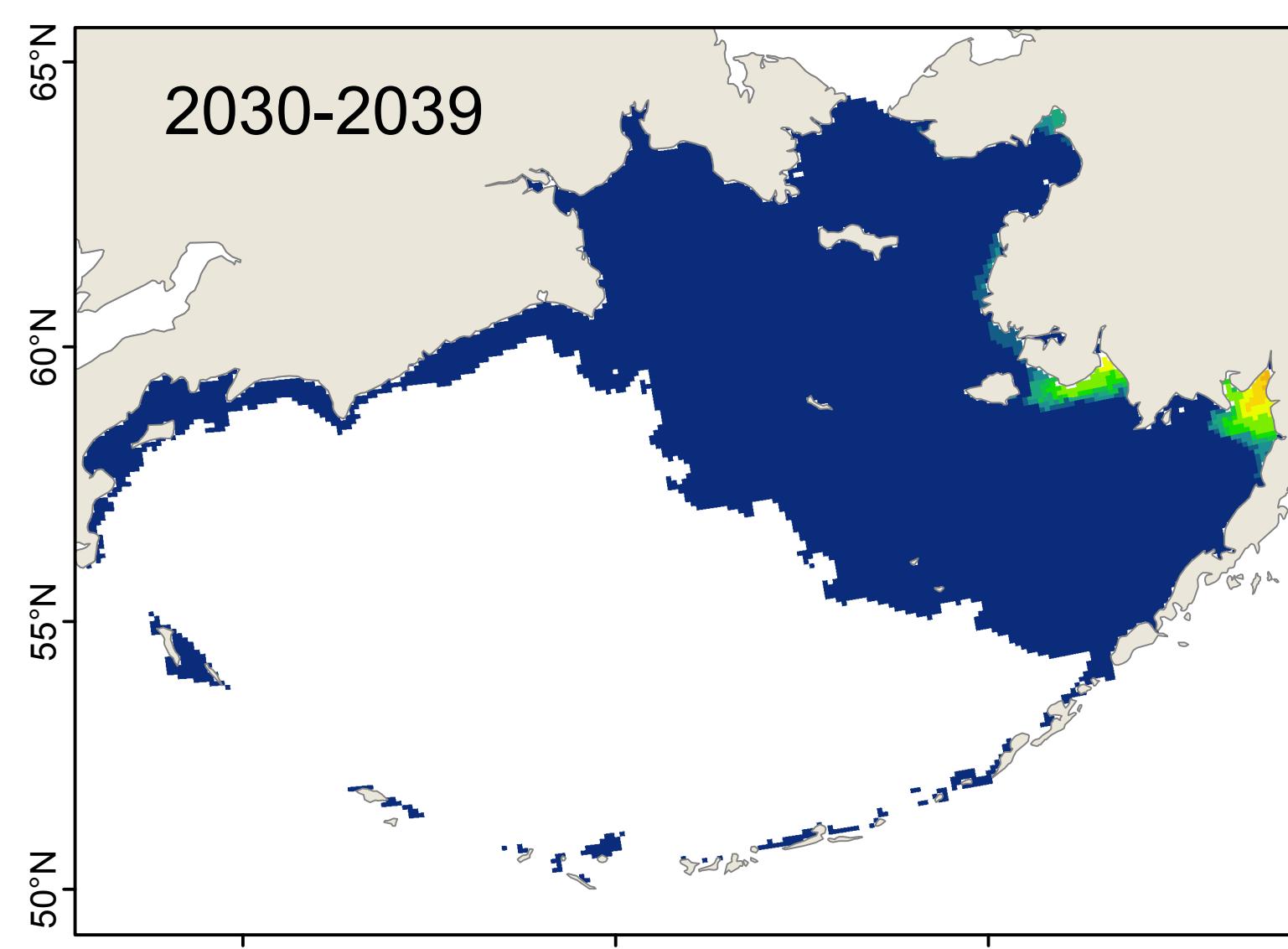
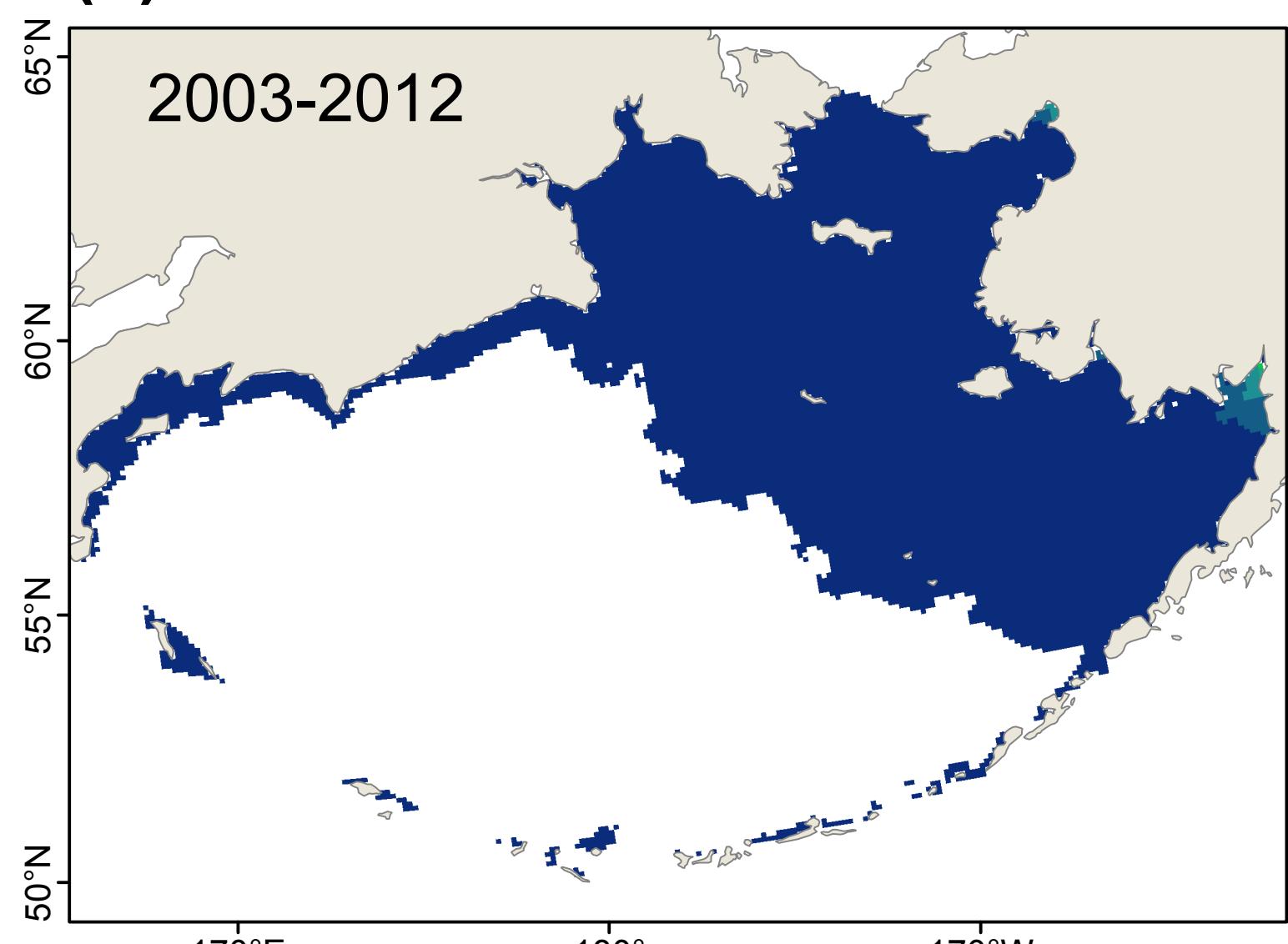
(a) Model: CGCM3-t47



(b) Model: ECHO-G

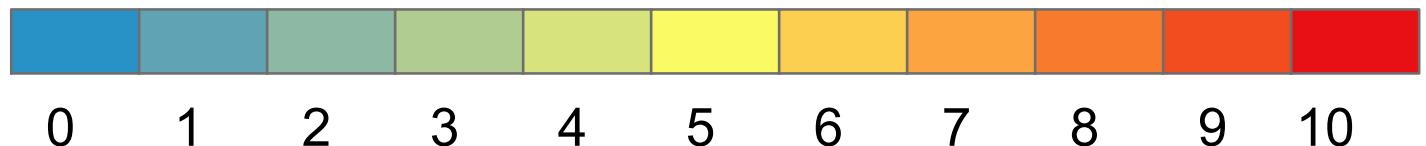


(c) Model: MIROC3.2

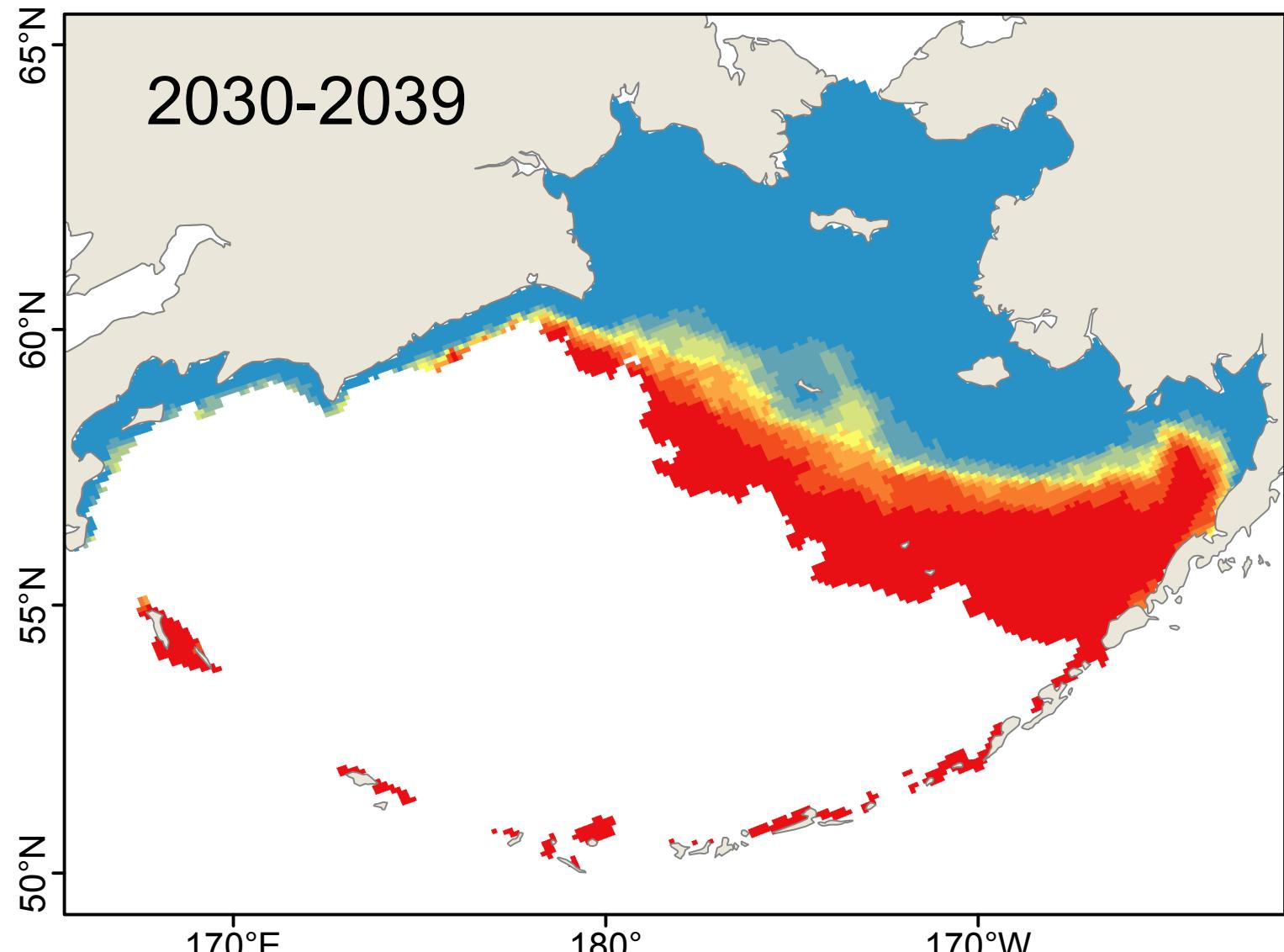
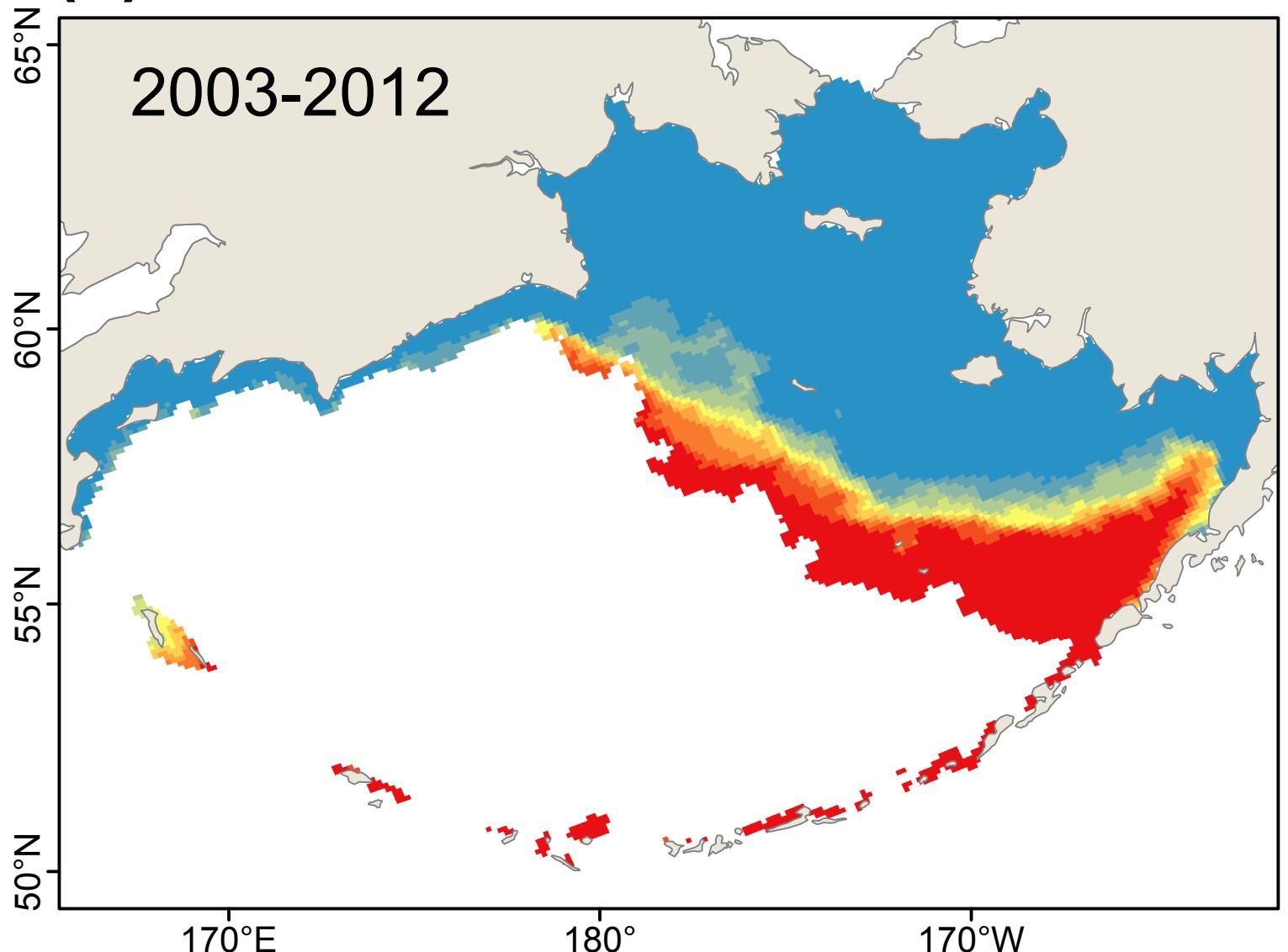


# *Ectopleura crocea: Year-round Survival*

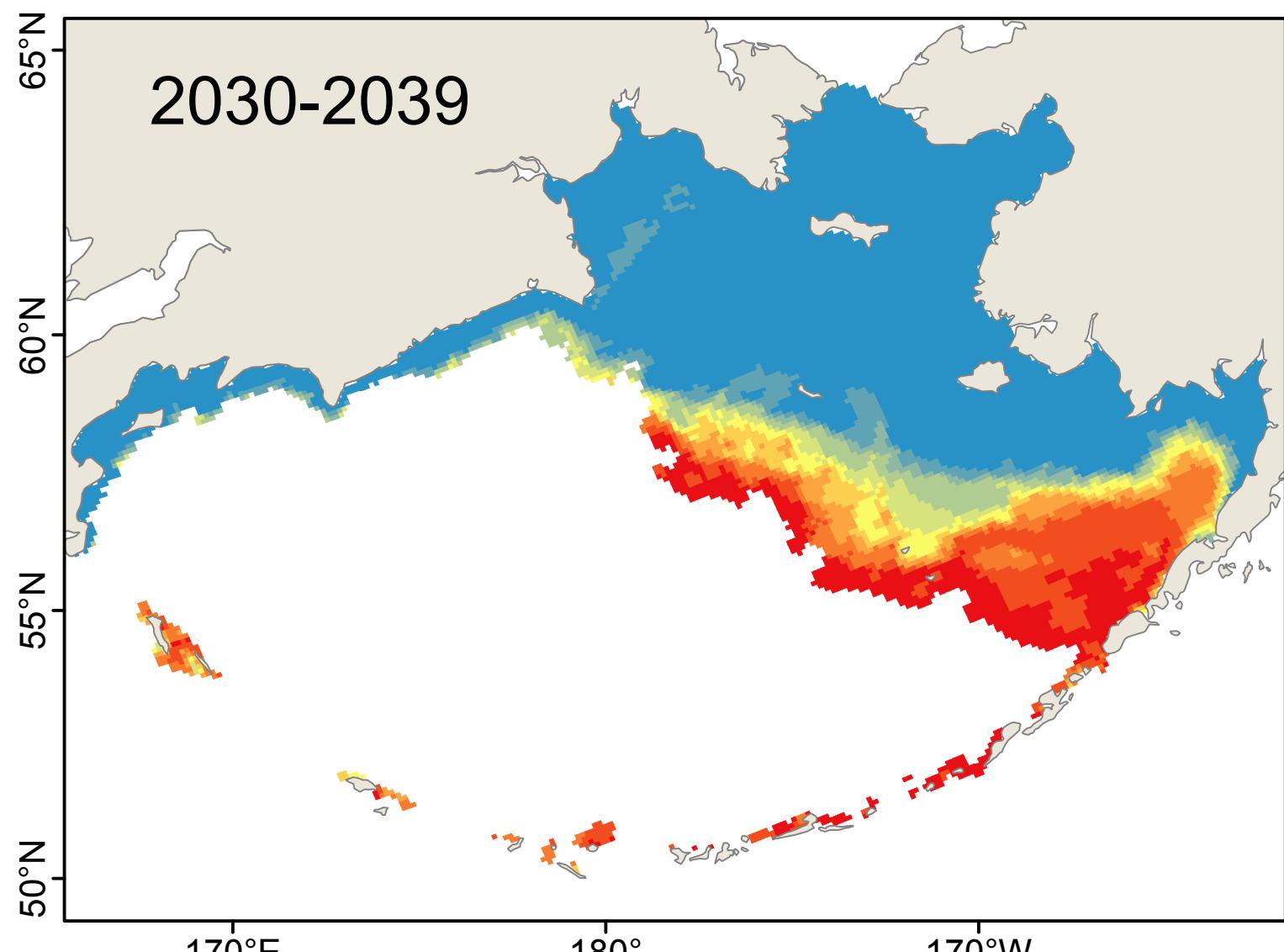
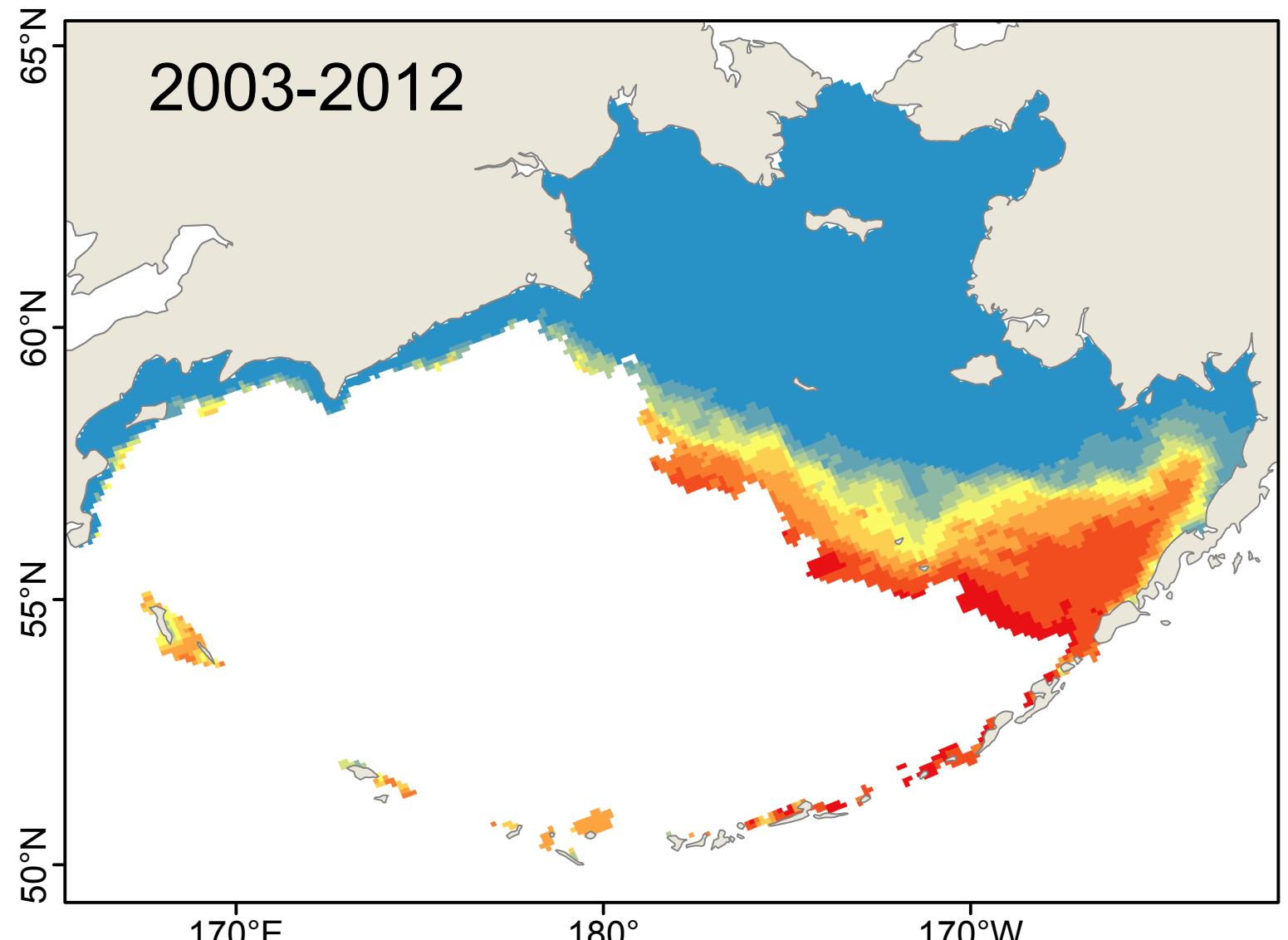
Number of years with suitable habitat



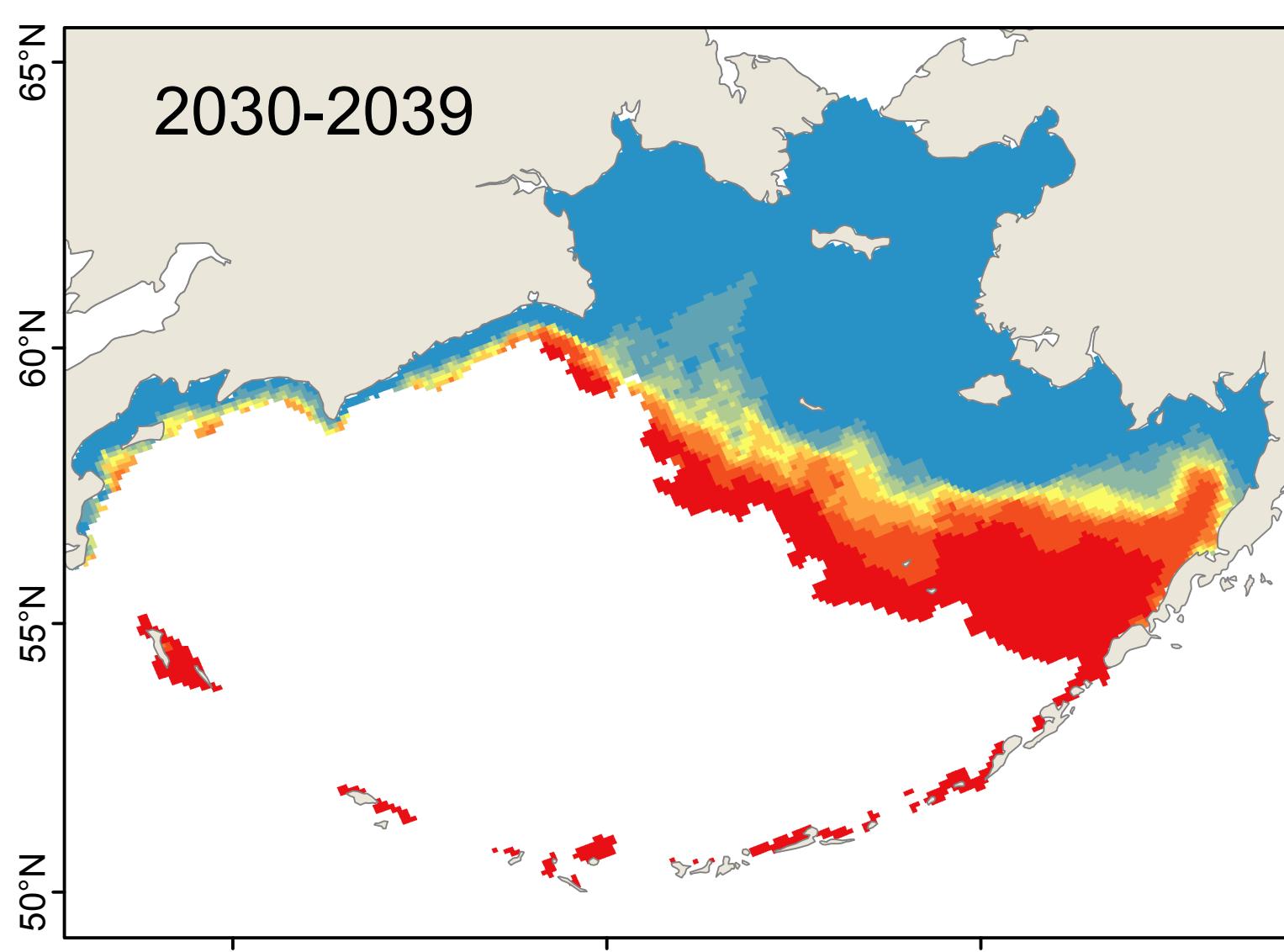
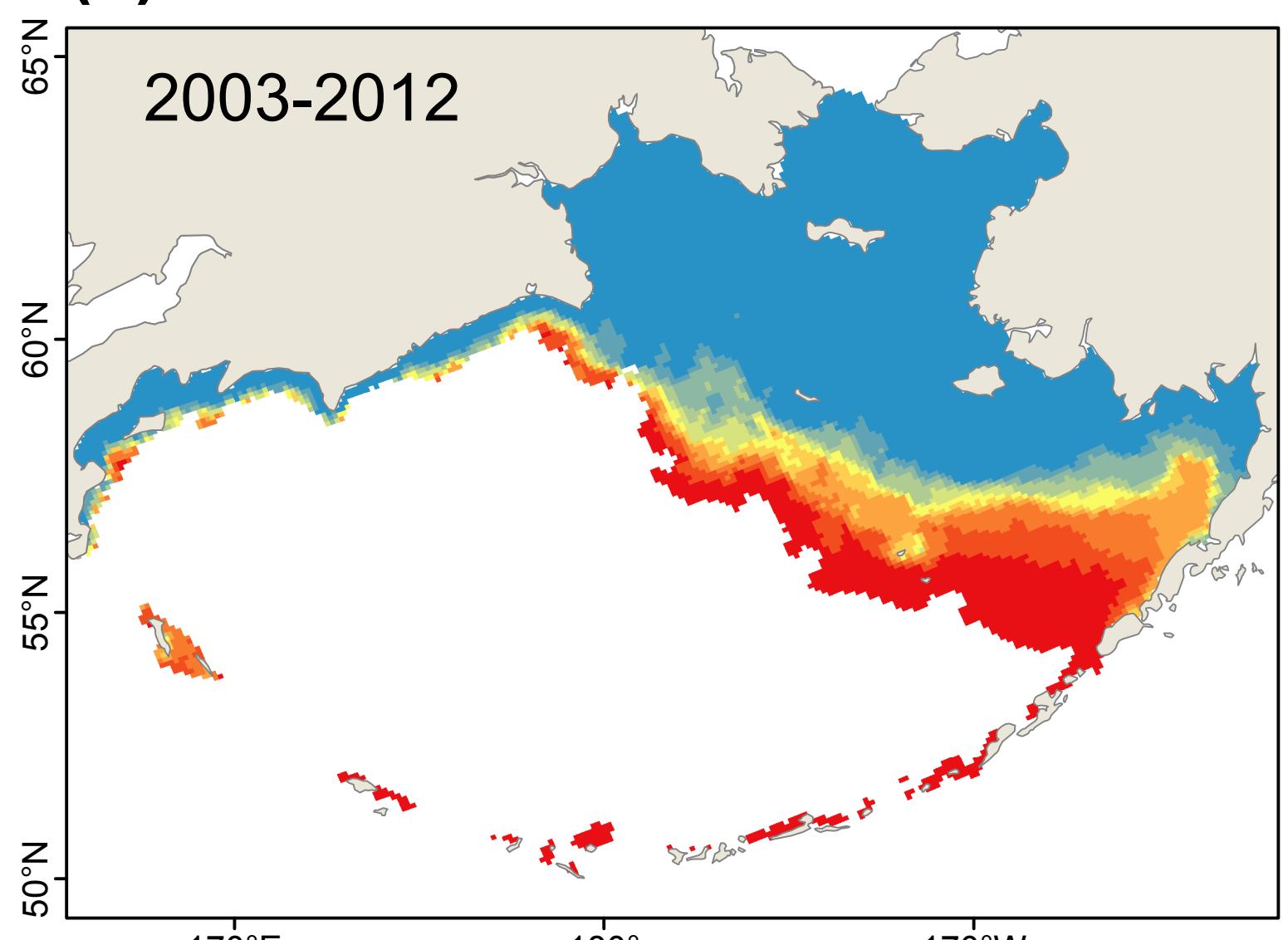
(a) Model: CGCM3-t47



(b) Model: ECHO-G

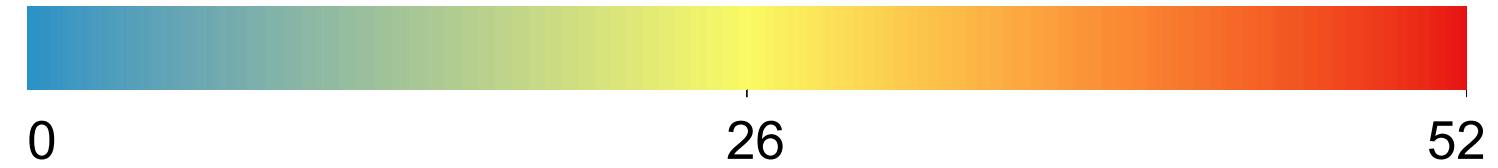


(c) Model: MIROC3.2

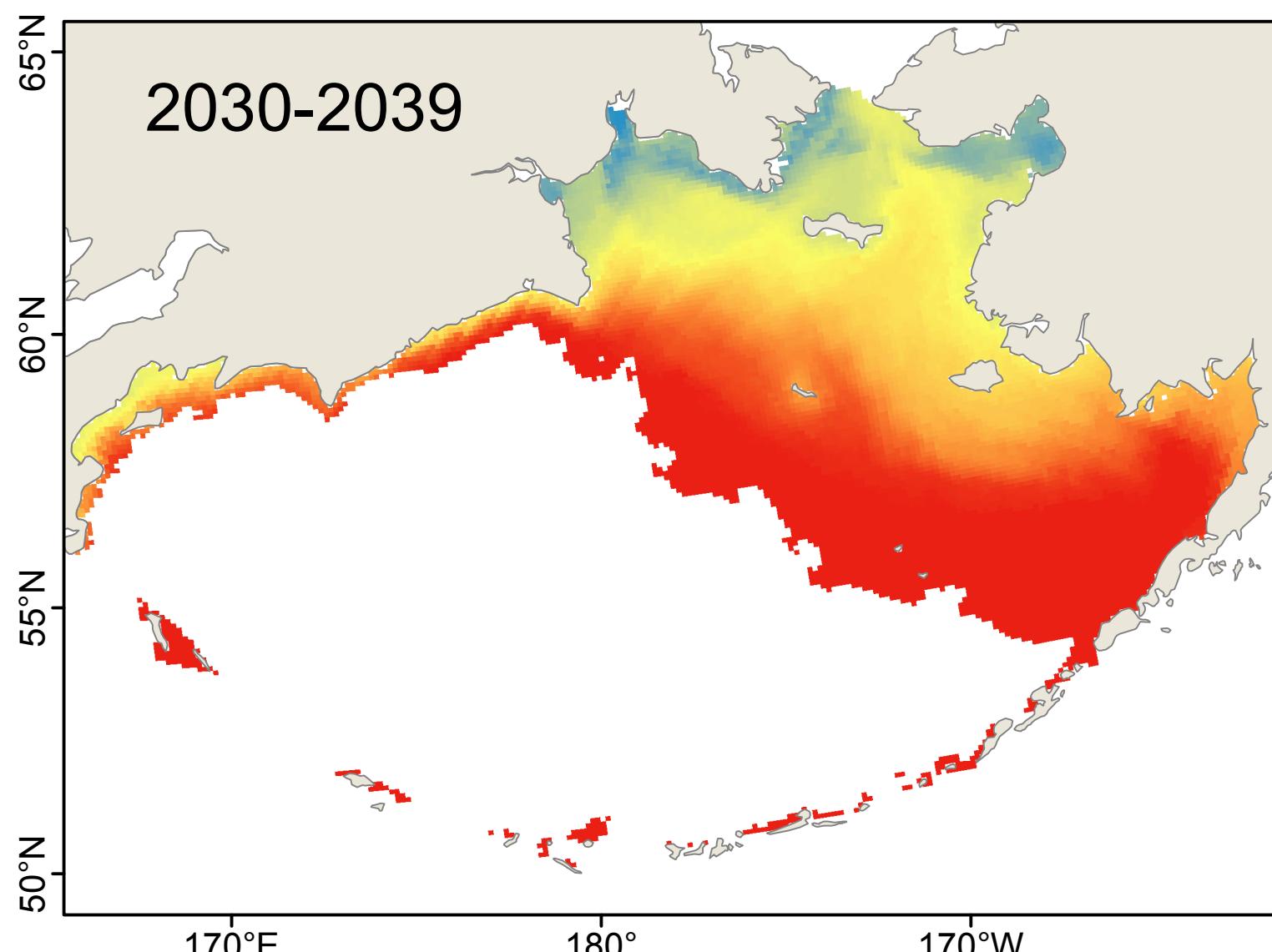
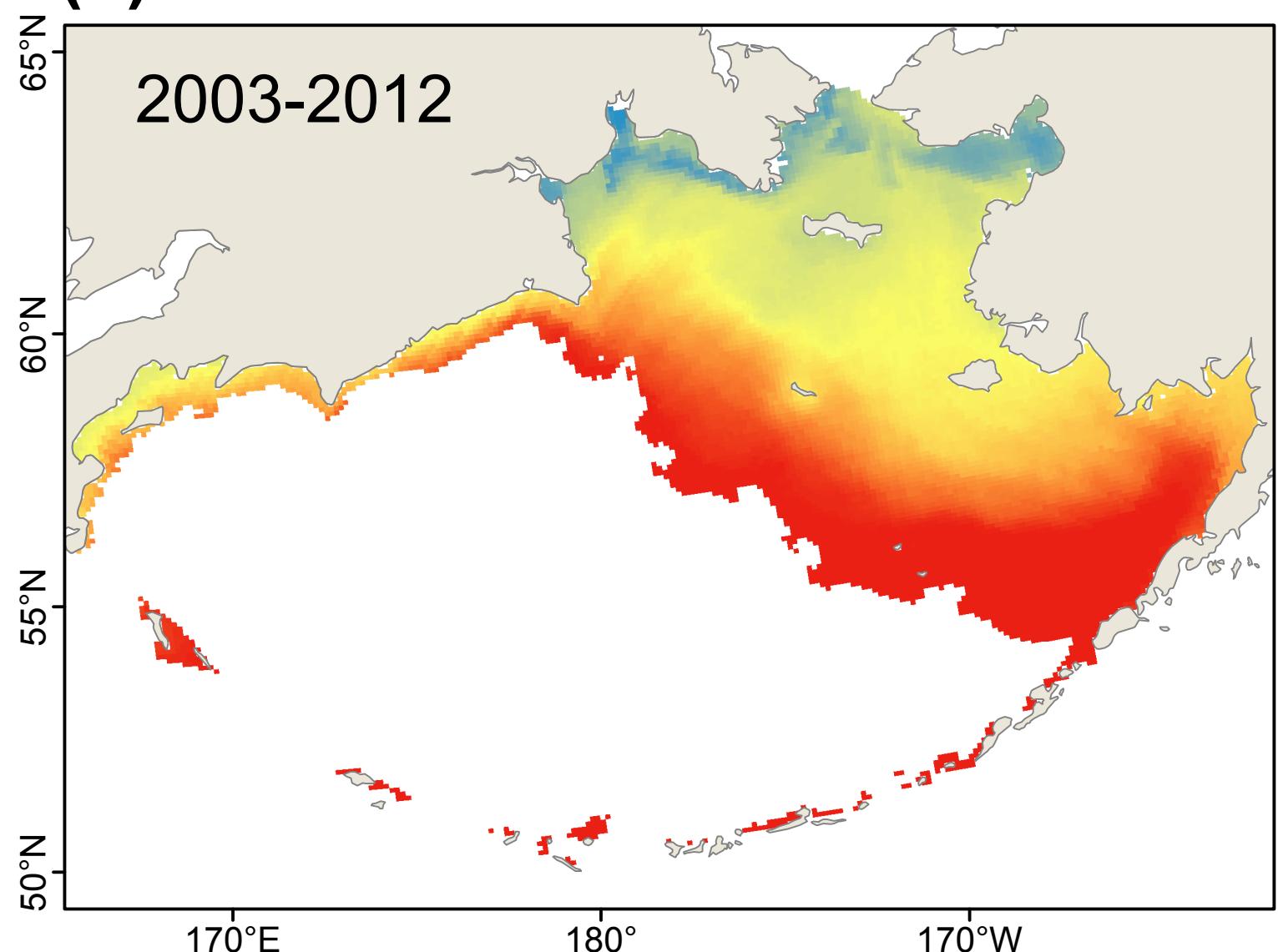


# *Ectopleura crocea: Weekly Survival*

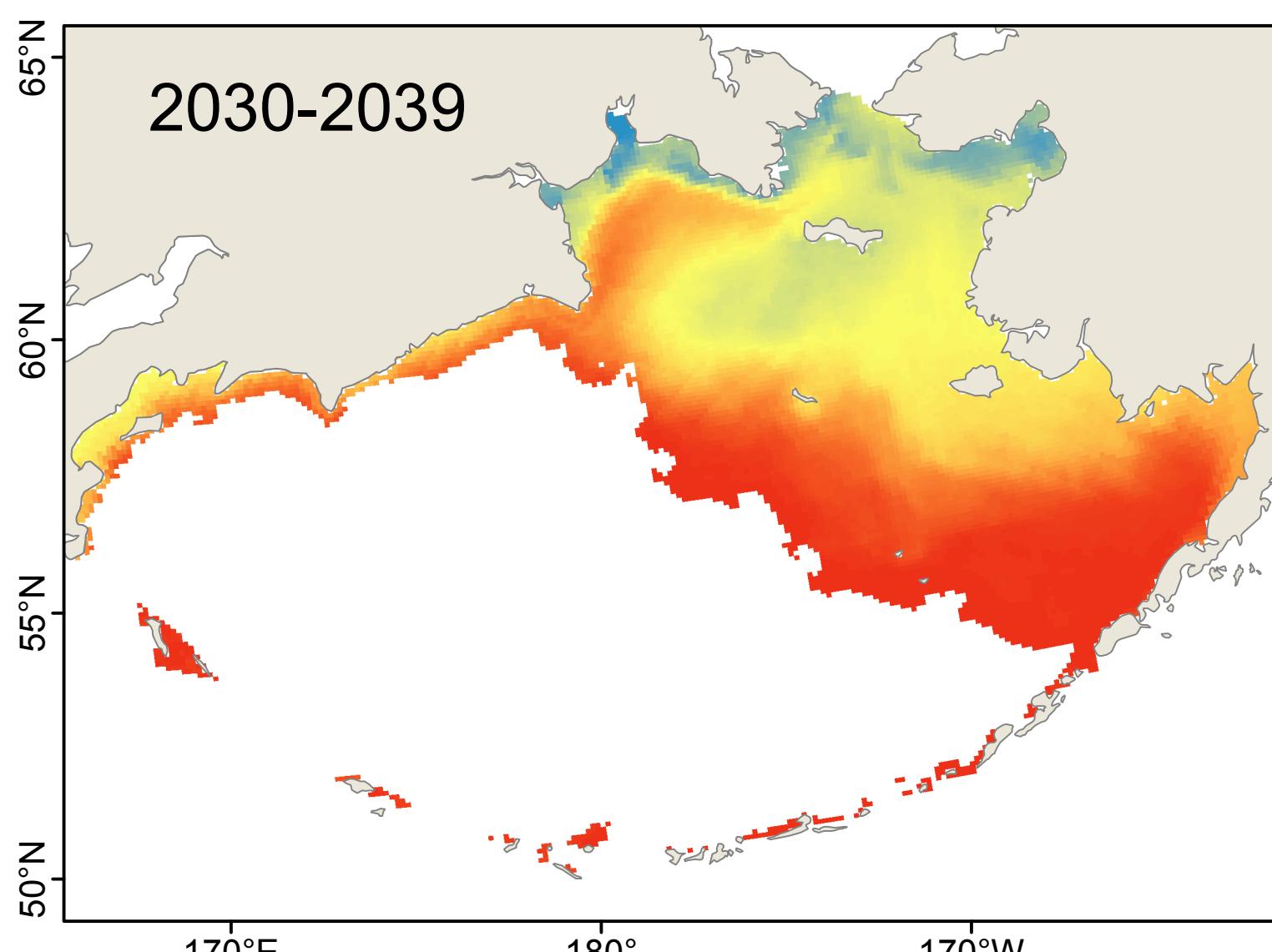
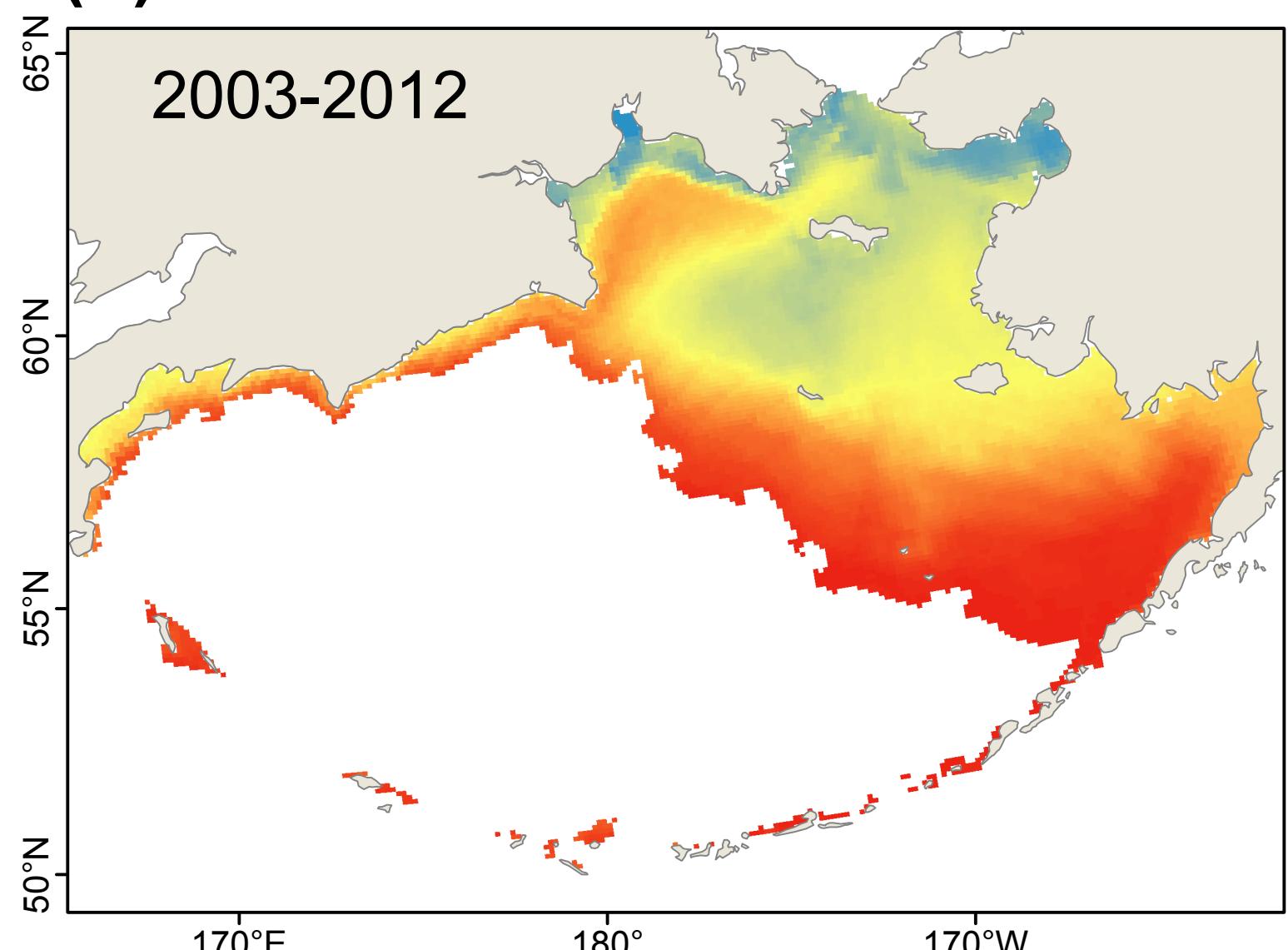
Average number of weeks of suitable habitat



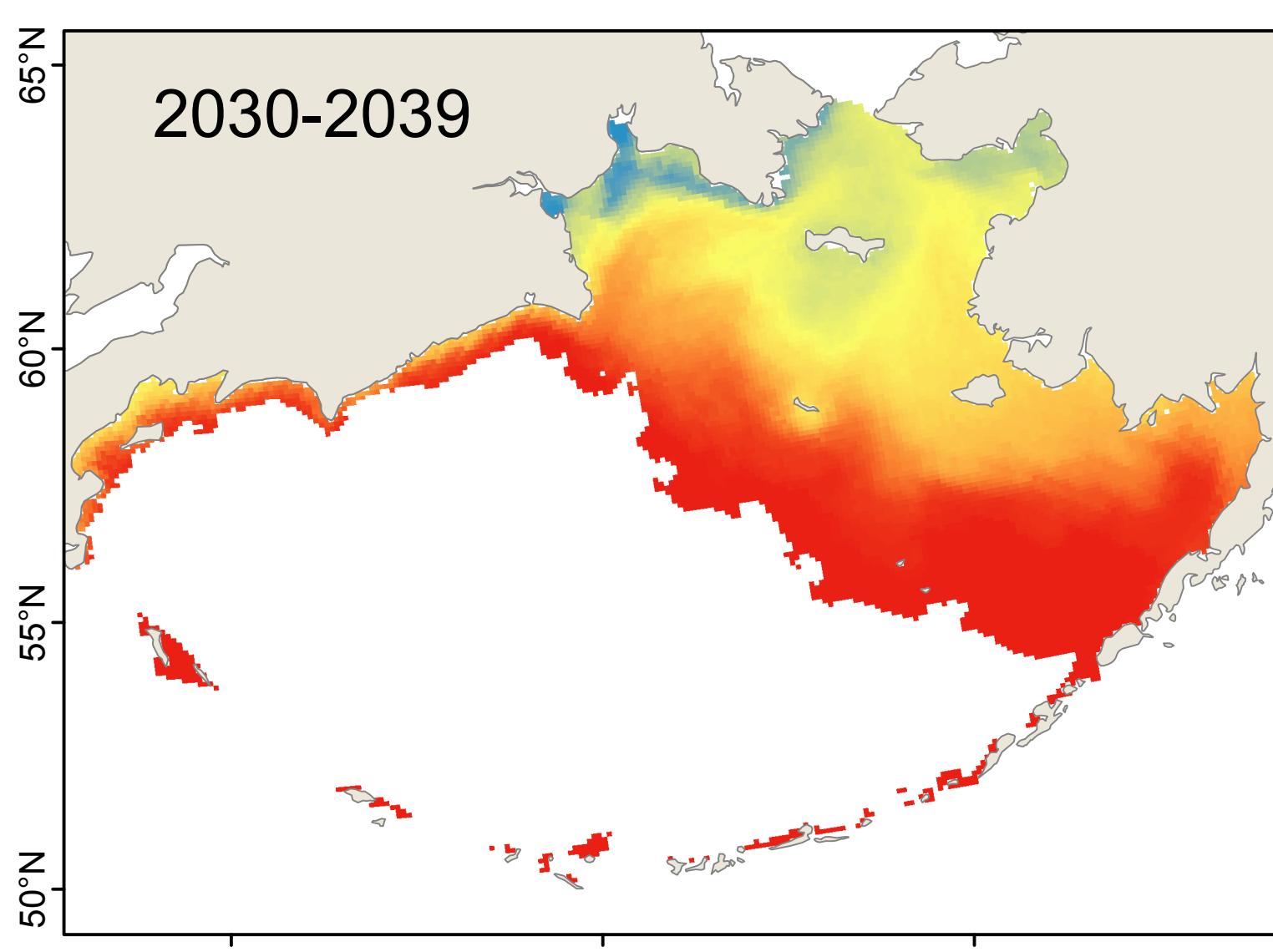
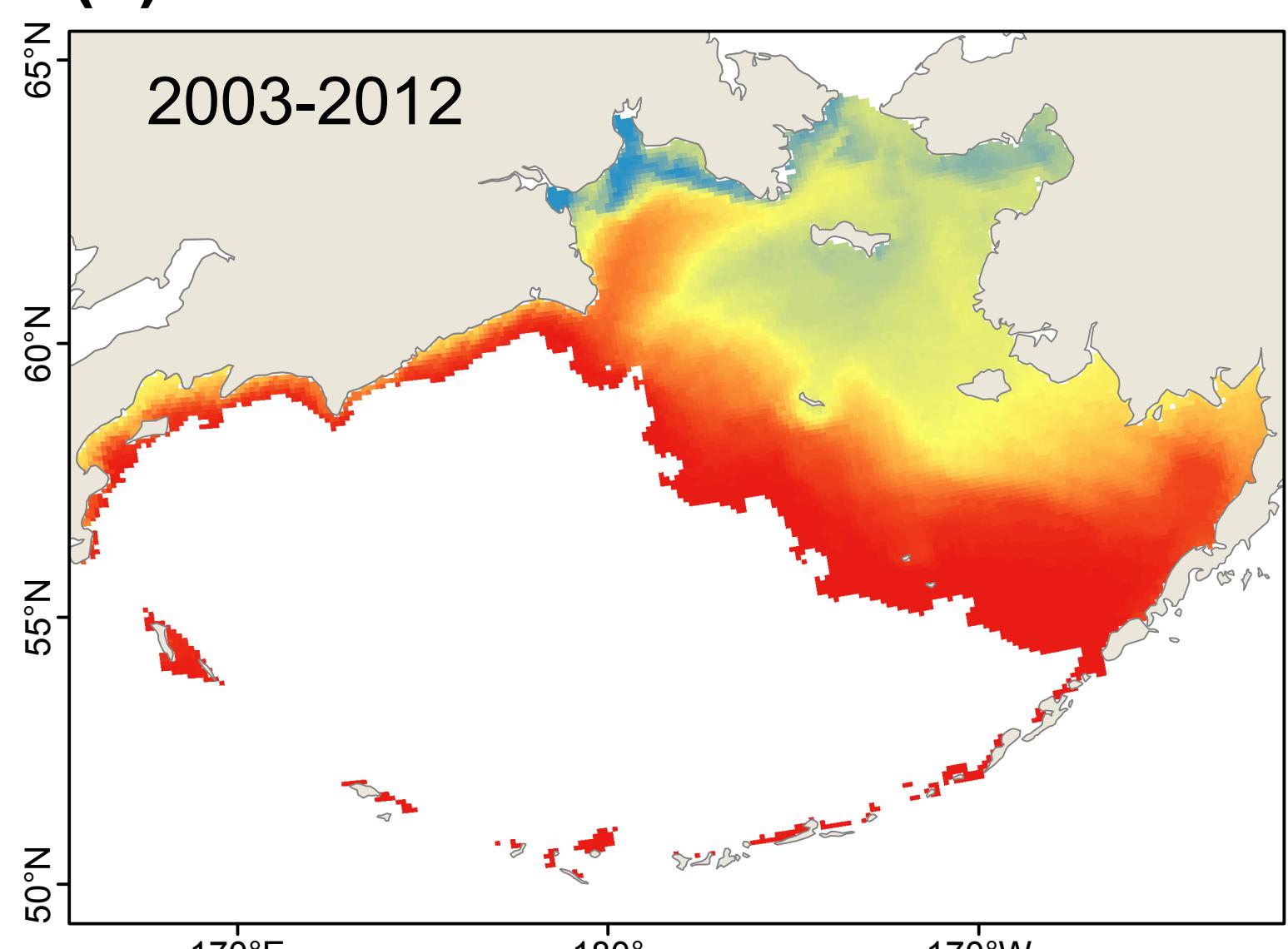
(a) Model: CGCM3-t47



(b) Model: ECHO-G

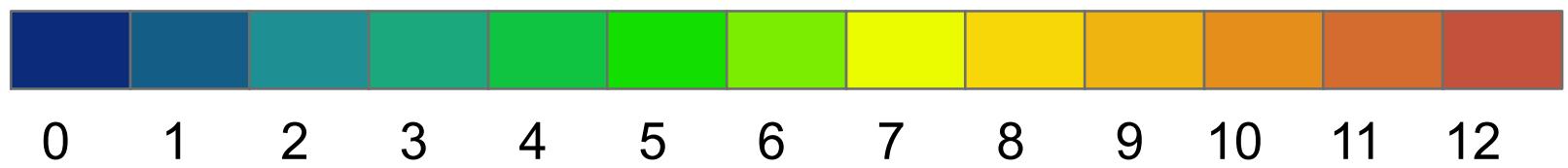


(c) Model: MIROC3.2

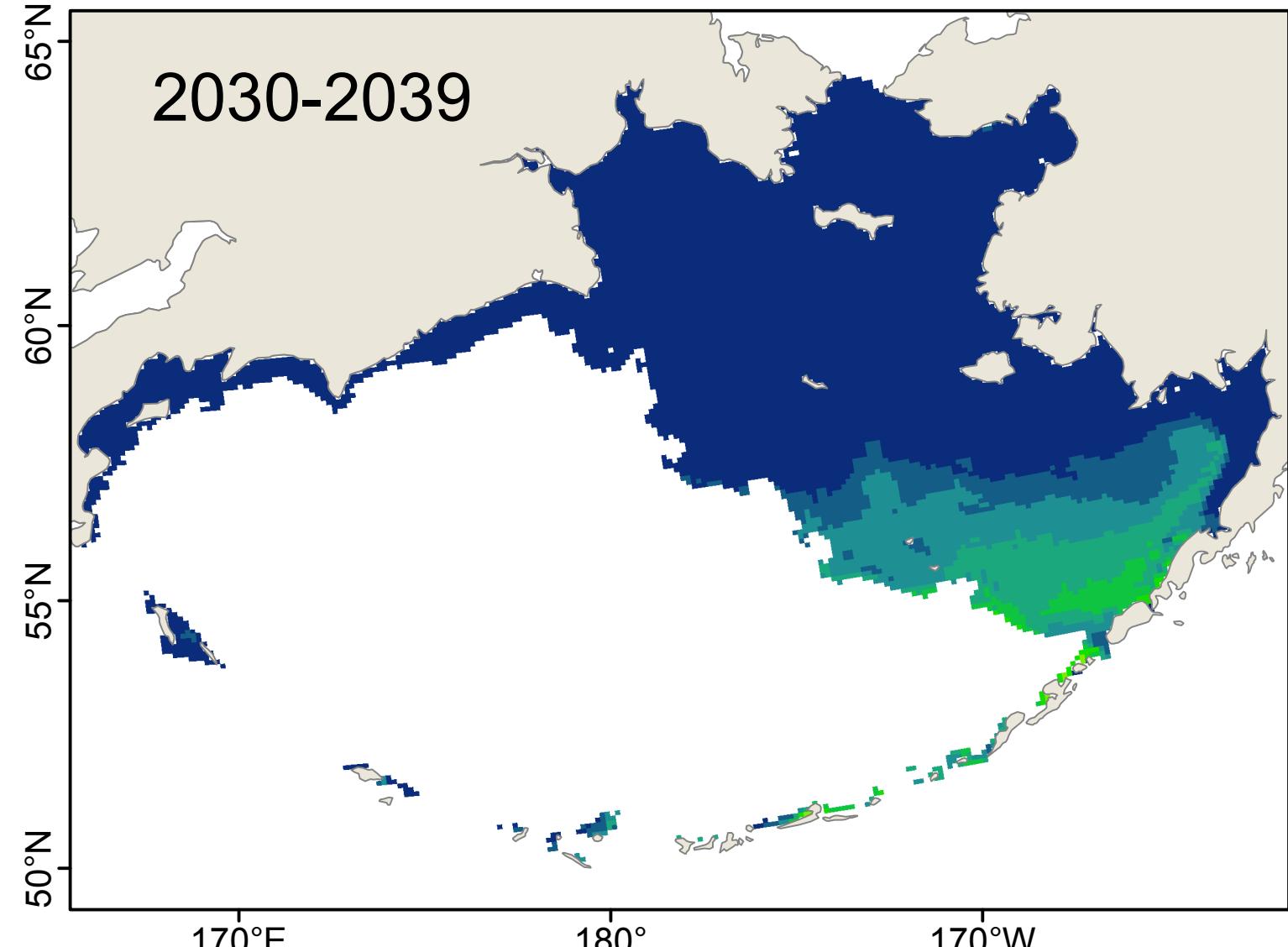
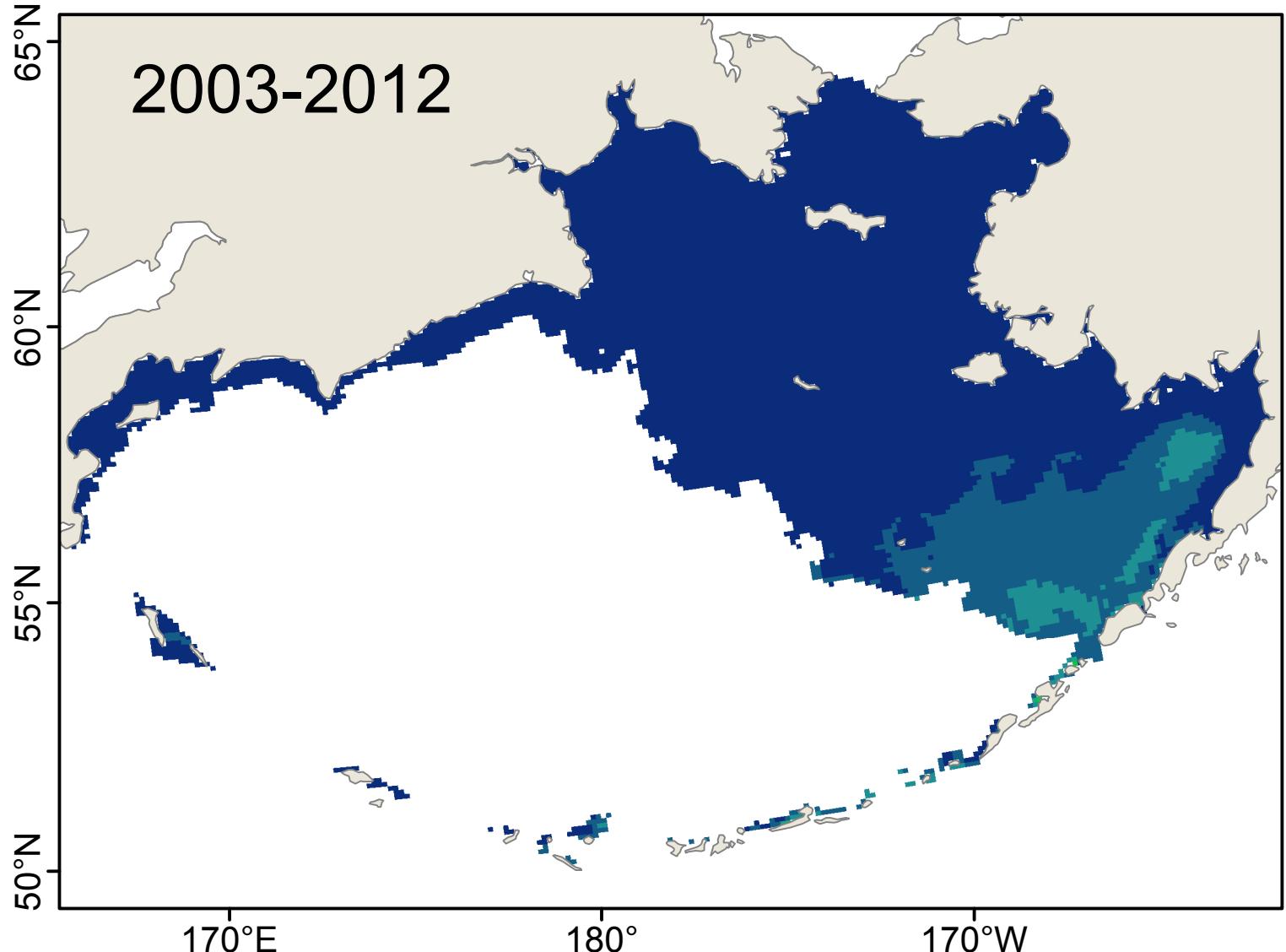


# *Ectopleura crocea: Reproduction*

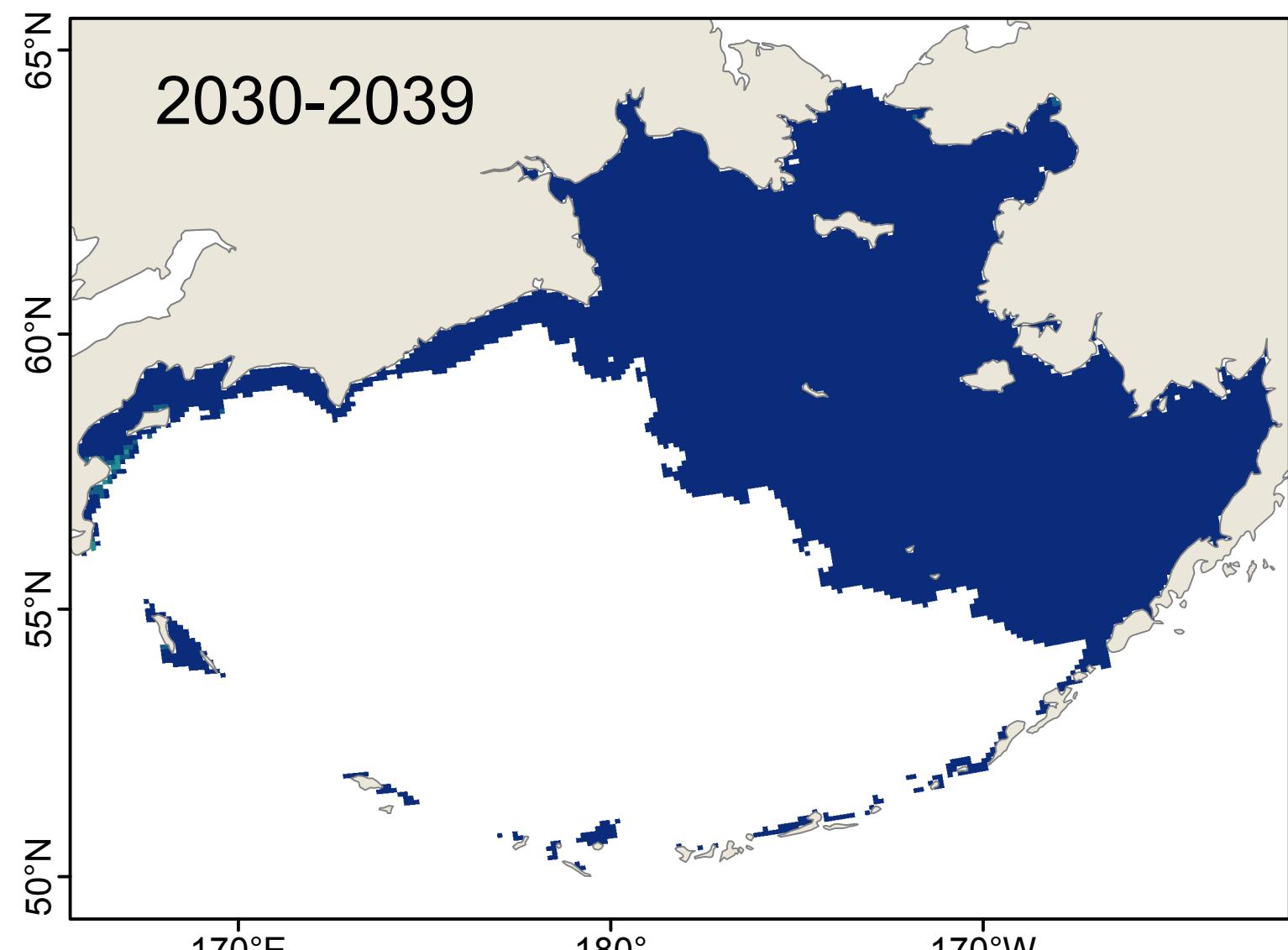
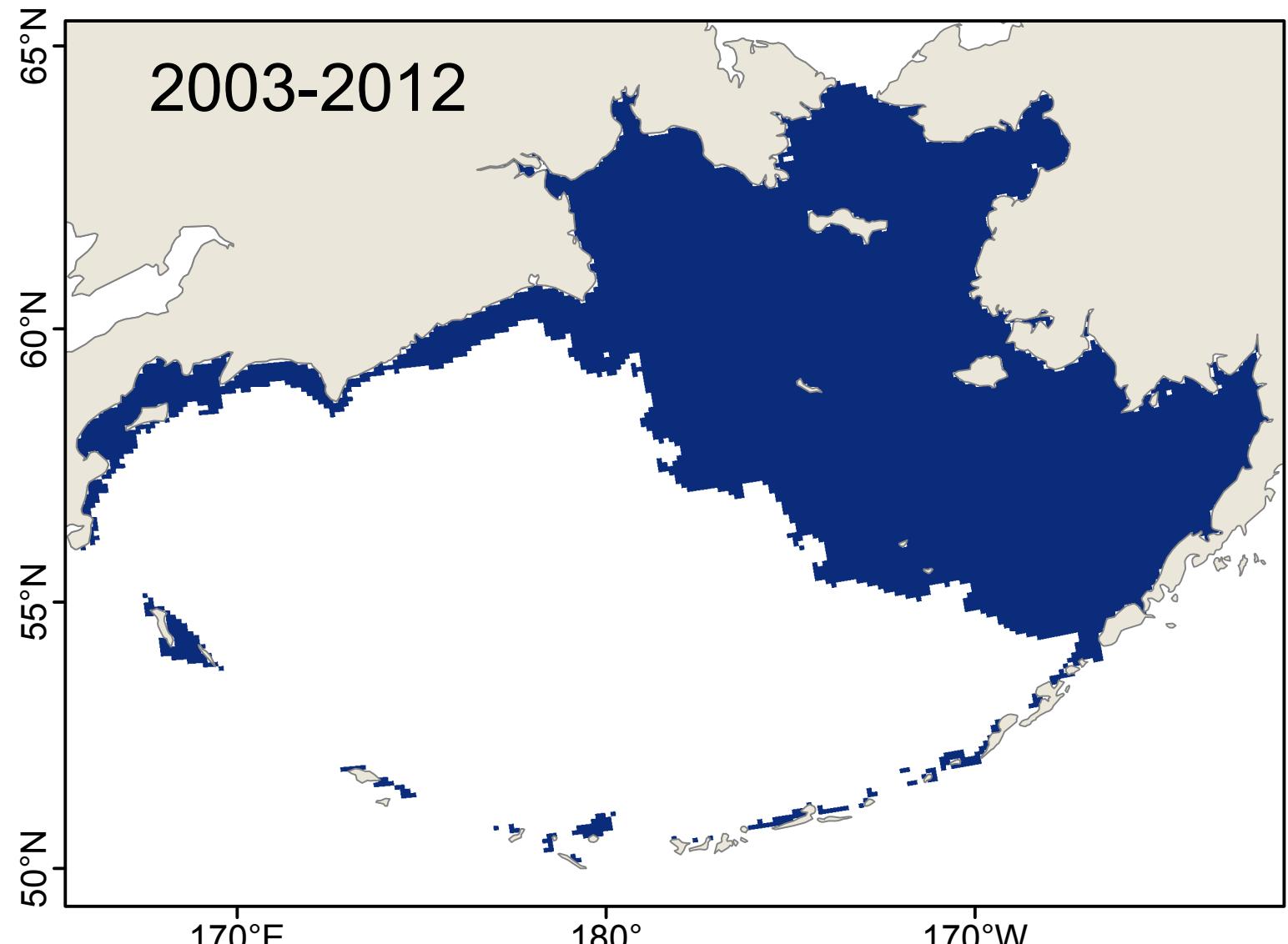
Average number of consecutive weeks of suitable habitat



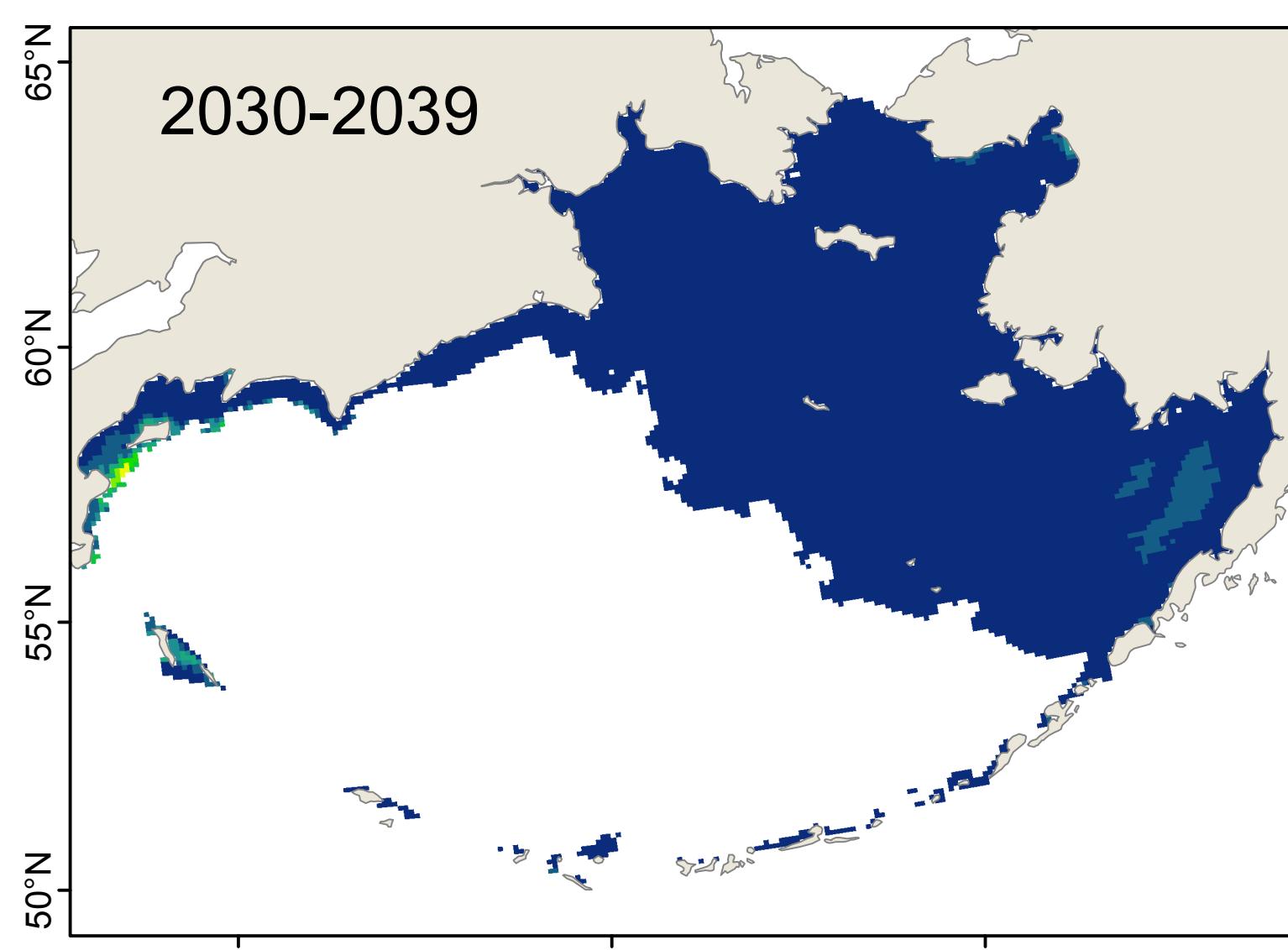
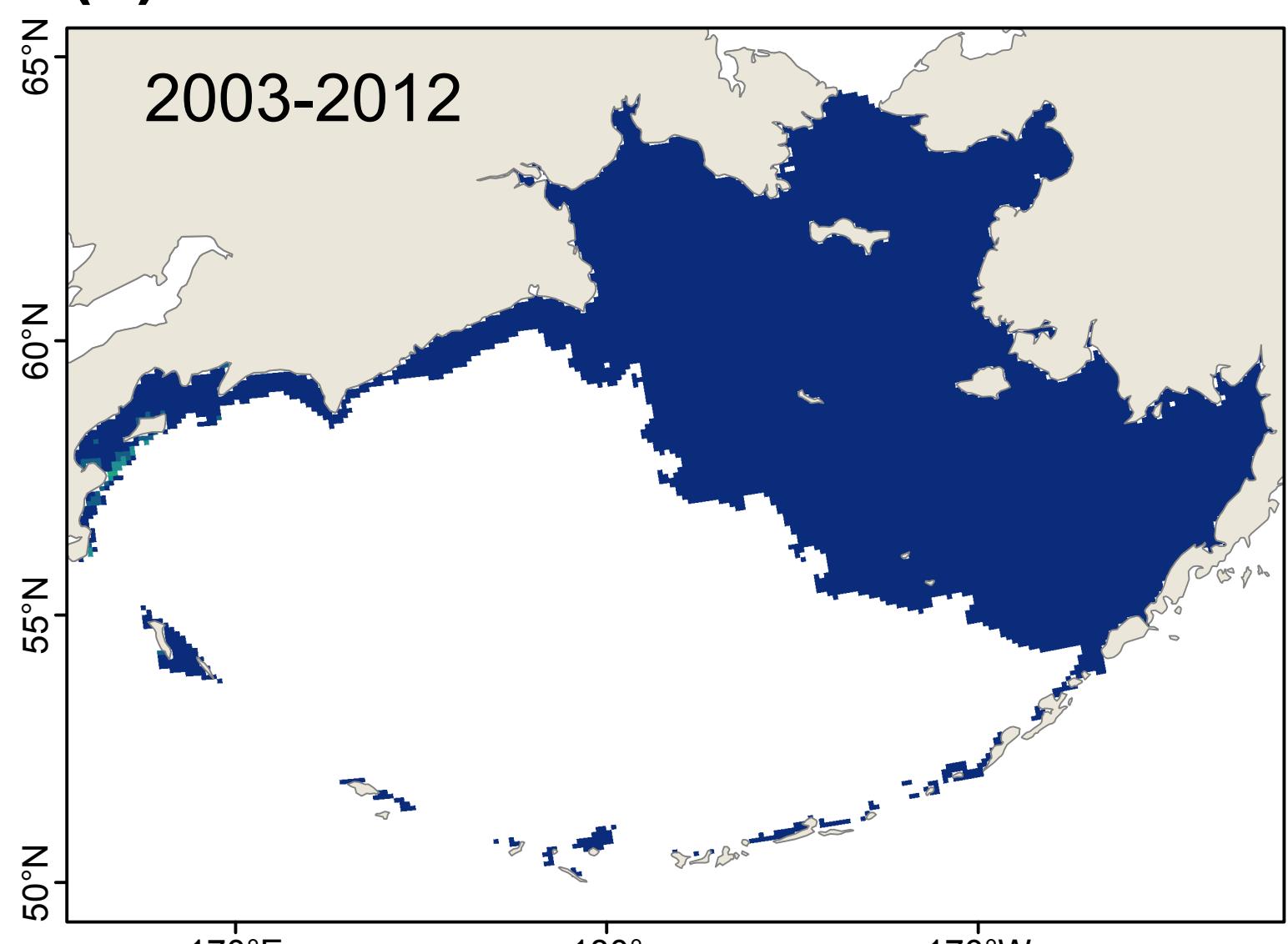
(a) Model: CGCM3-t47



(b) Model: ECHO-G

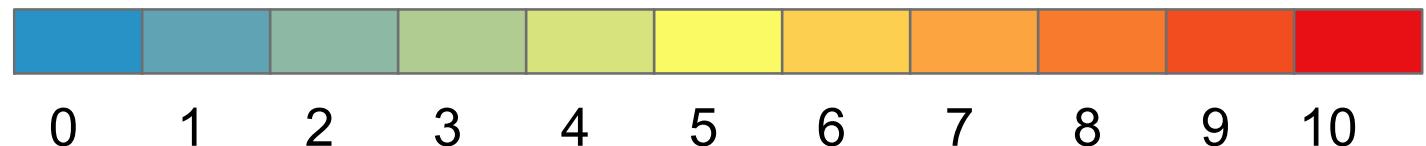


(c) Model: MIROC3.2

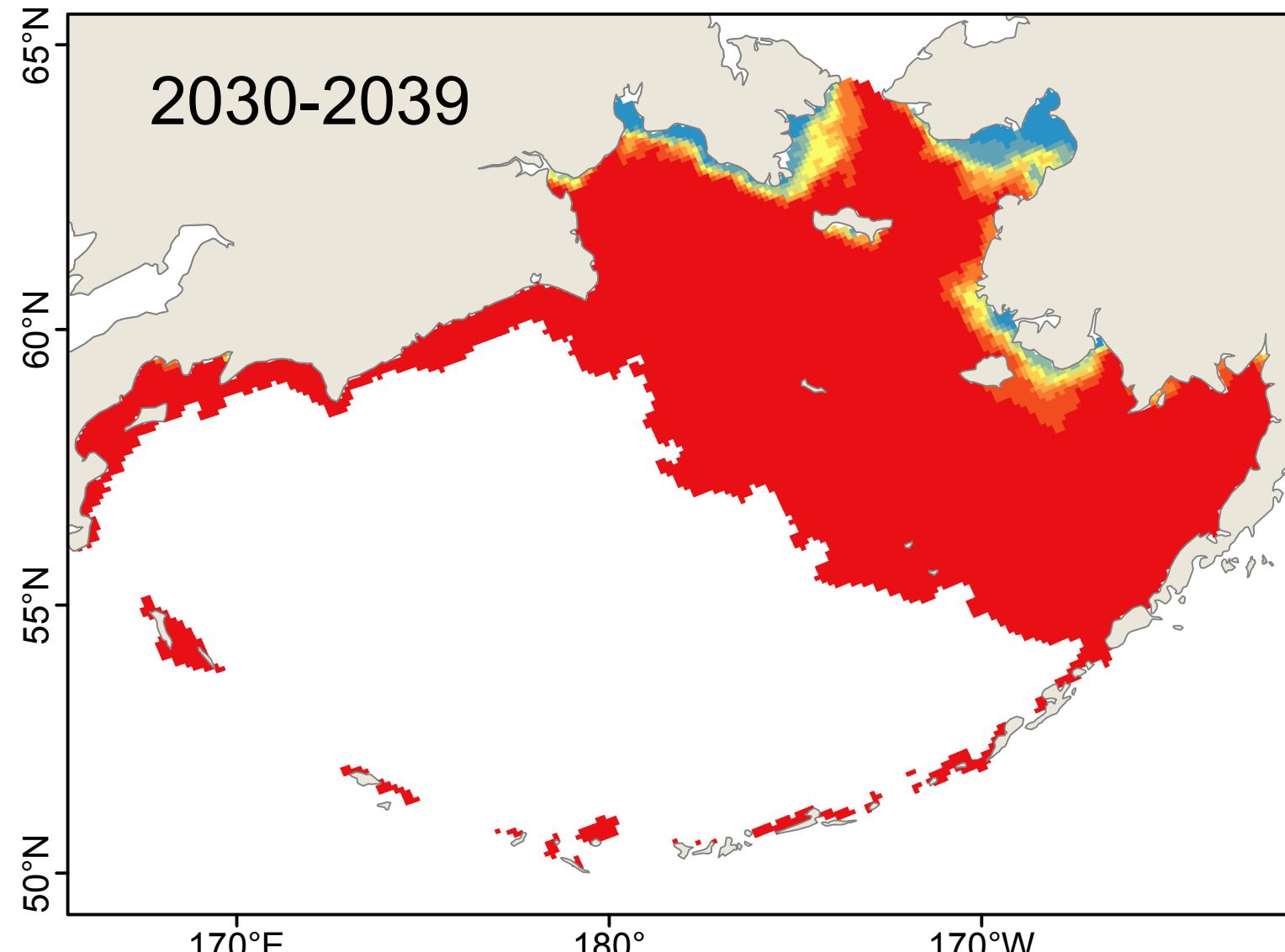
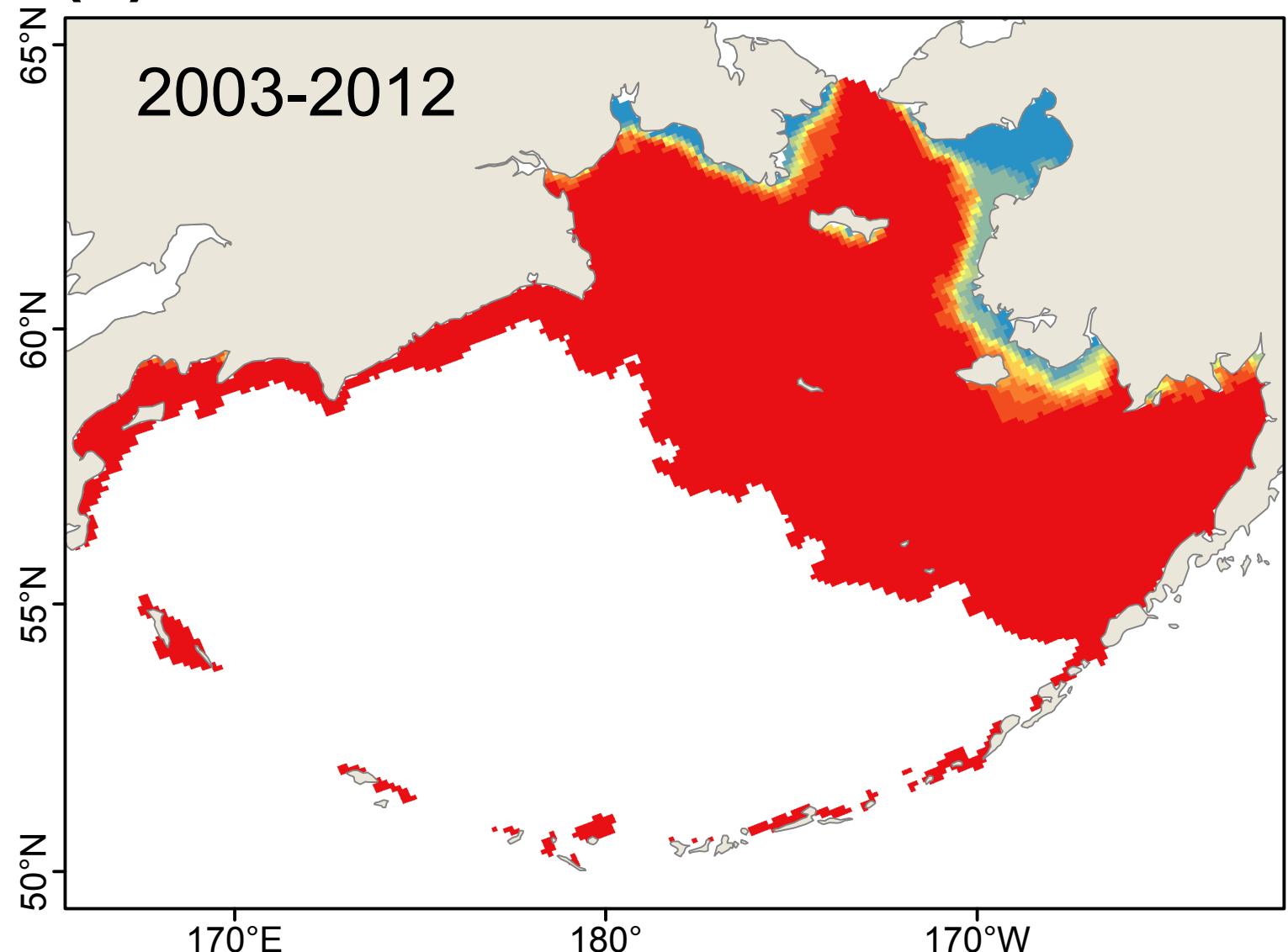


# *Caprella mutica*: Year-round Survival

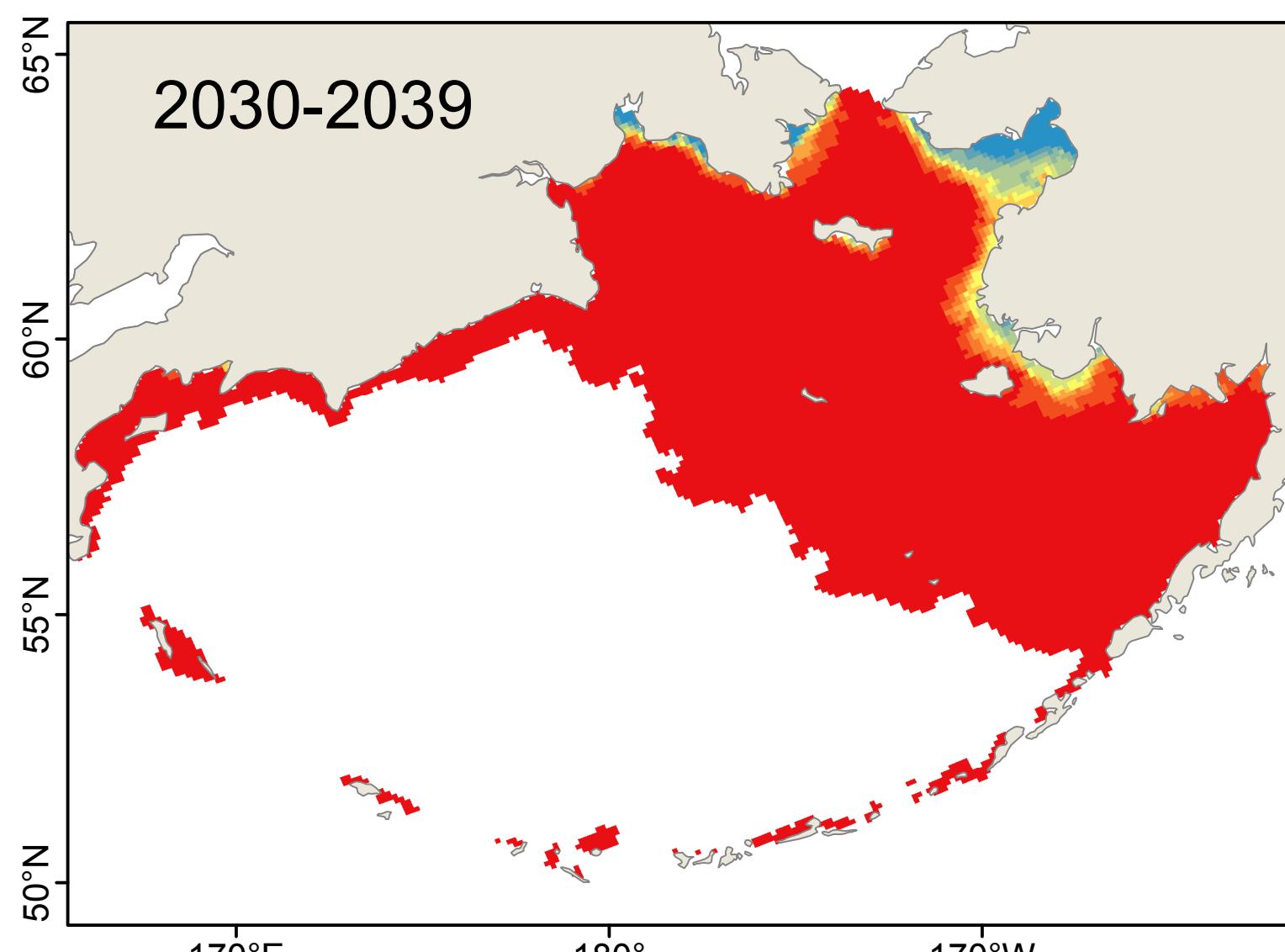
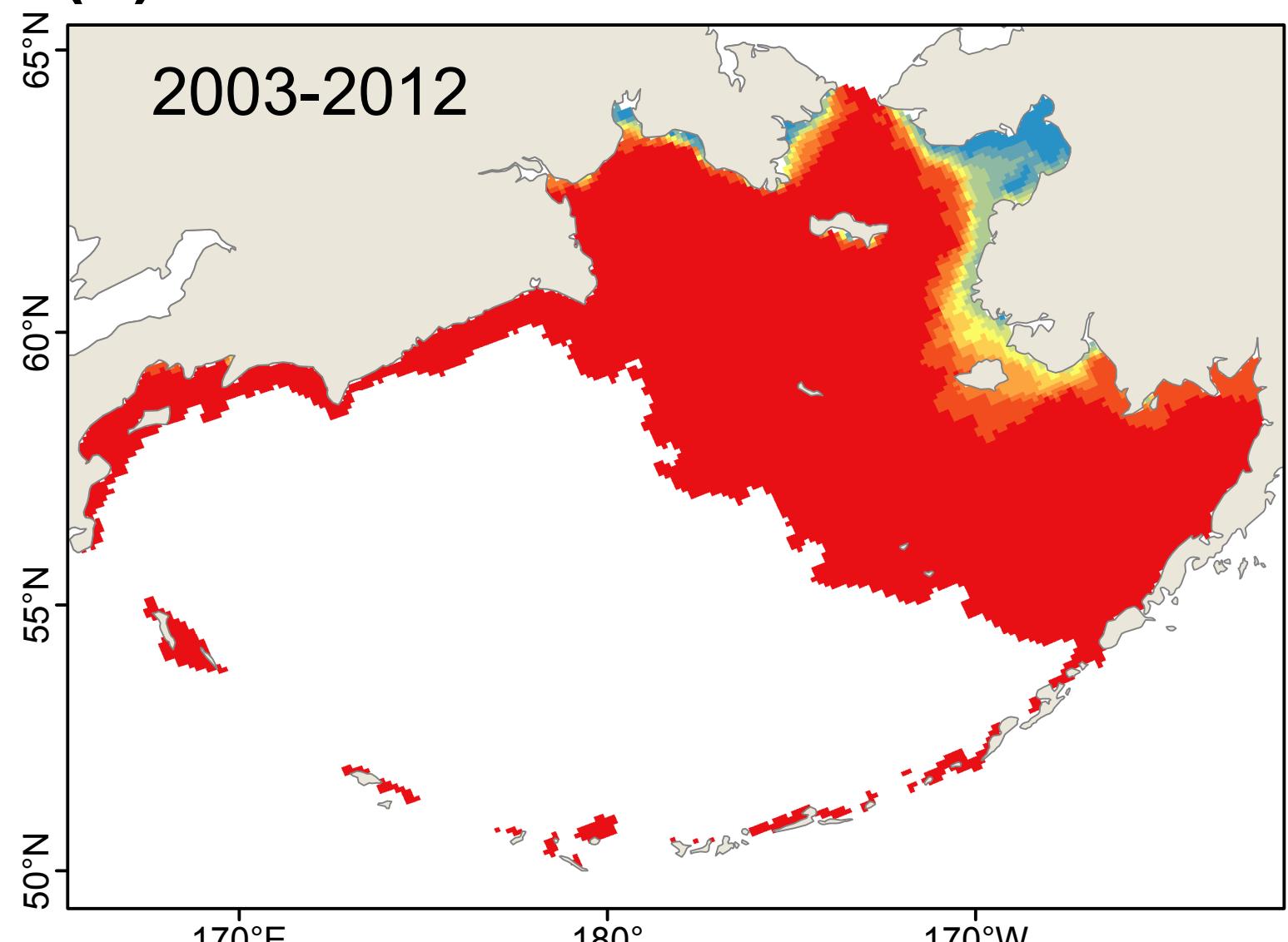
Number of years with suitable habitat



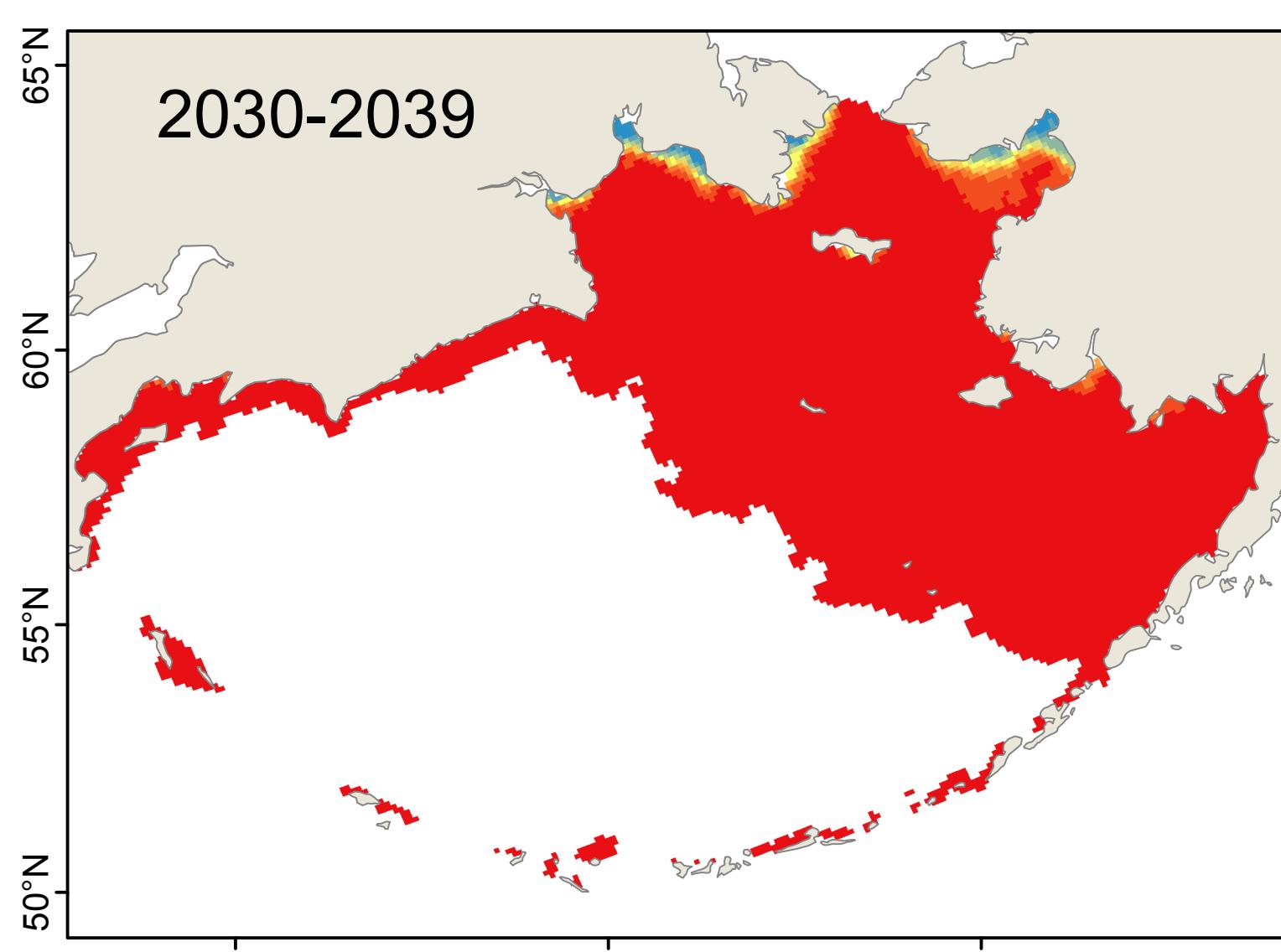
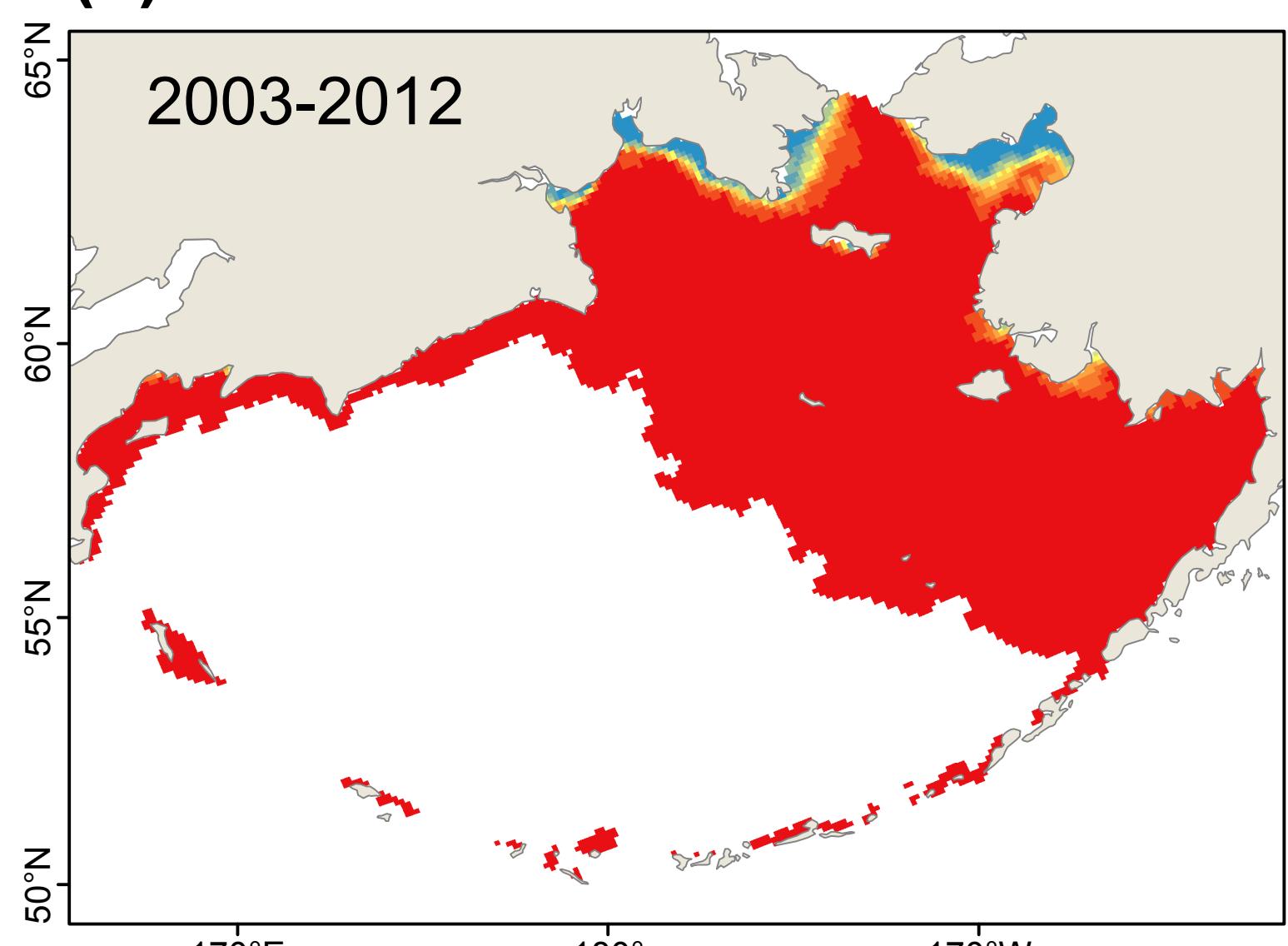
(a) Model: CGCM3-t47



(b) Model: ECHO-G

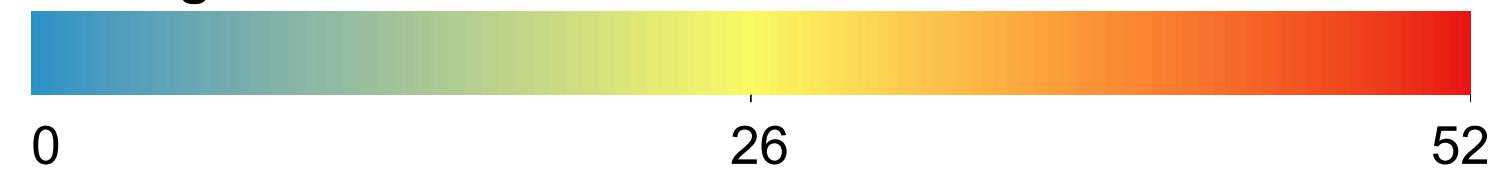


(c) Model: MIROC3.2

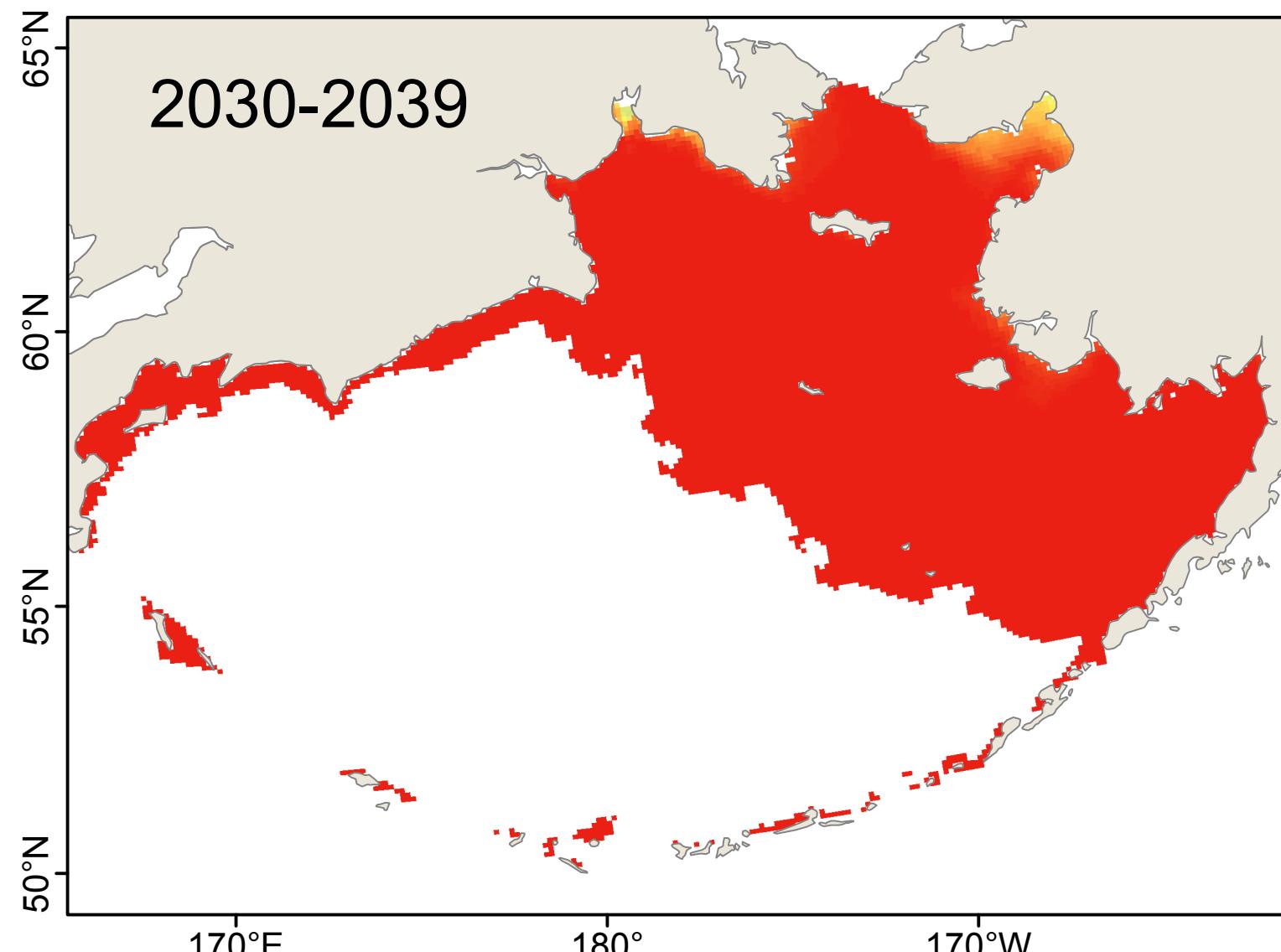
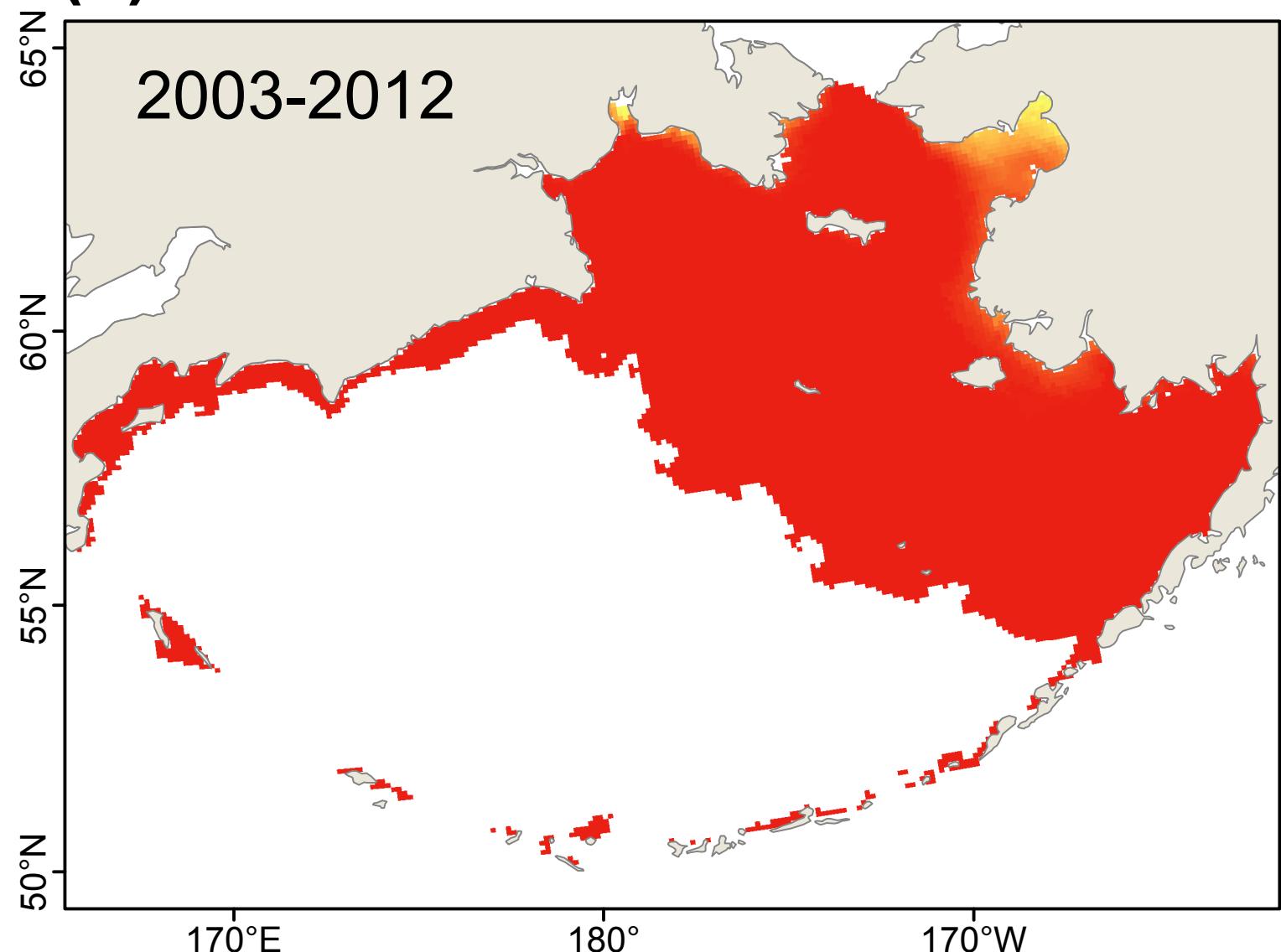


# *Caprella mutica: Weekly Survival*

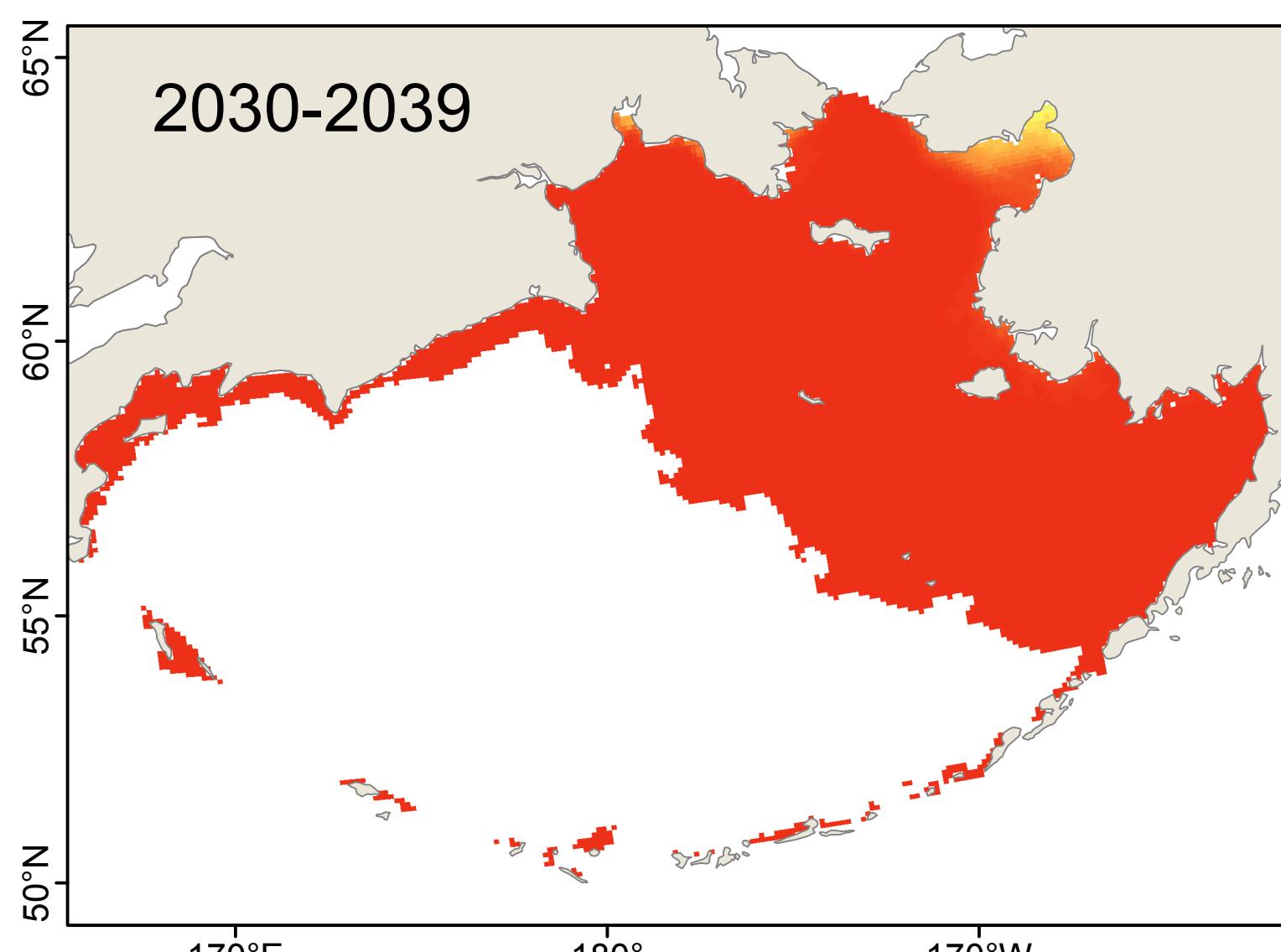
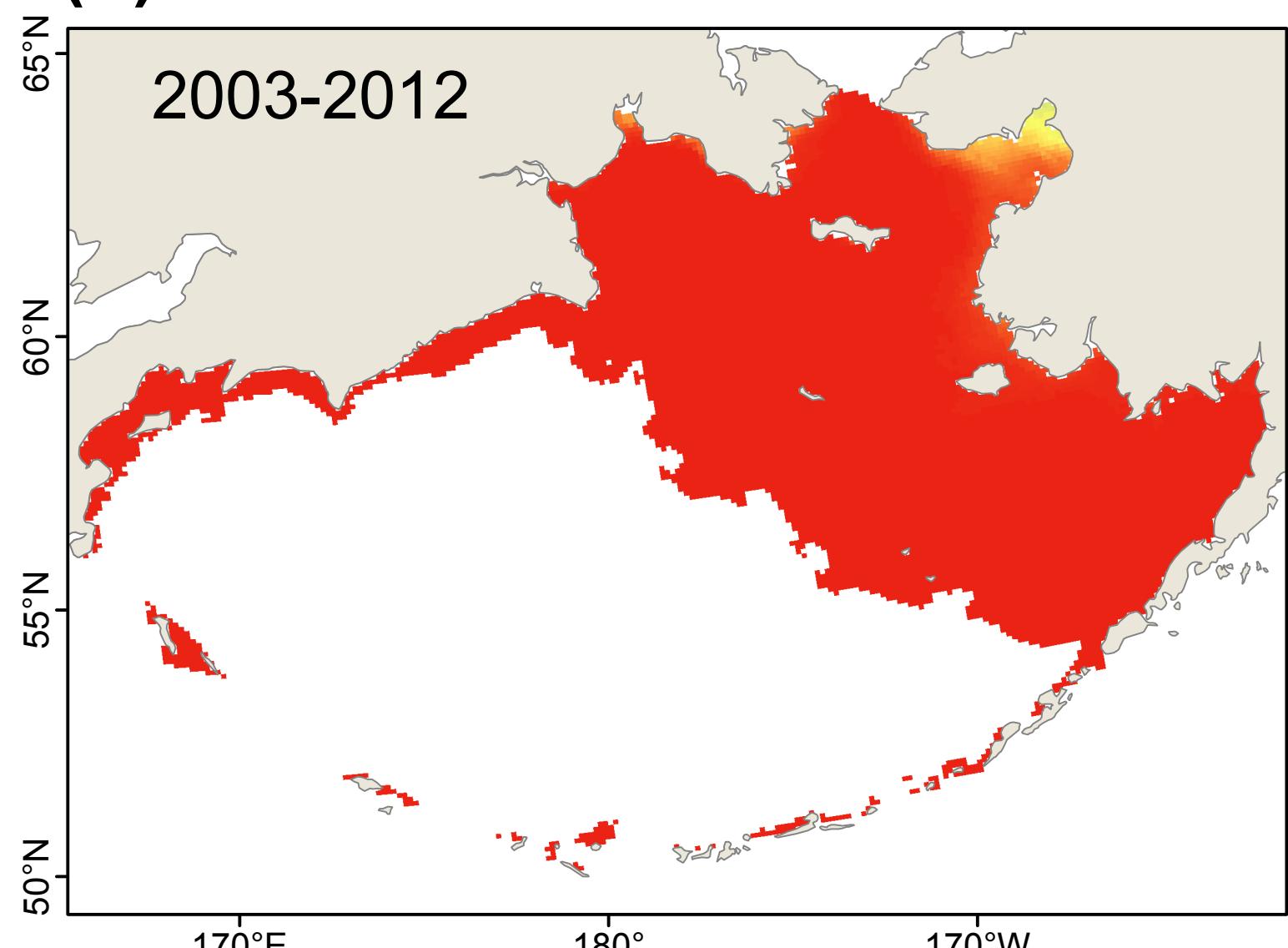
Average number of weeks of suitable habitat



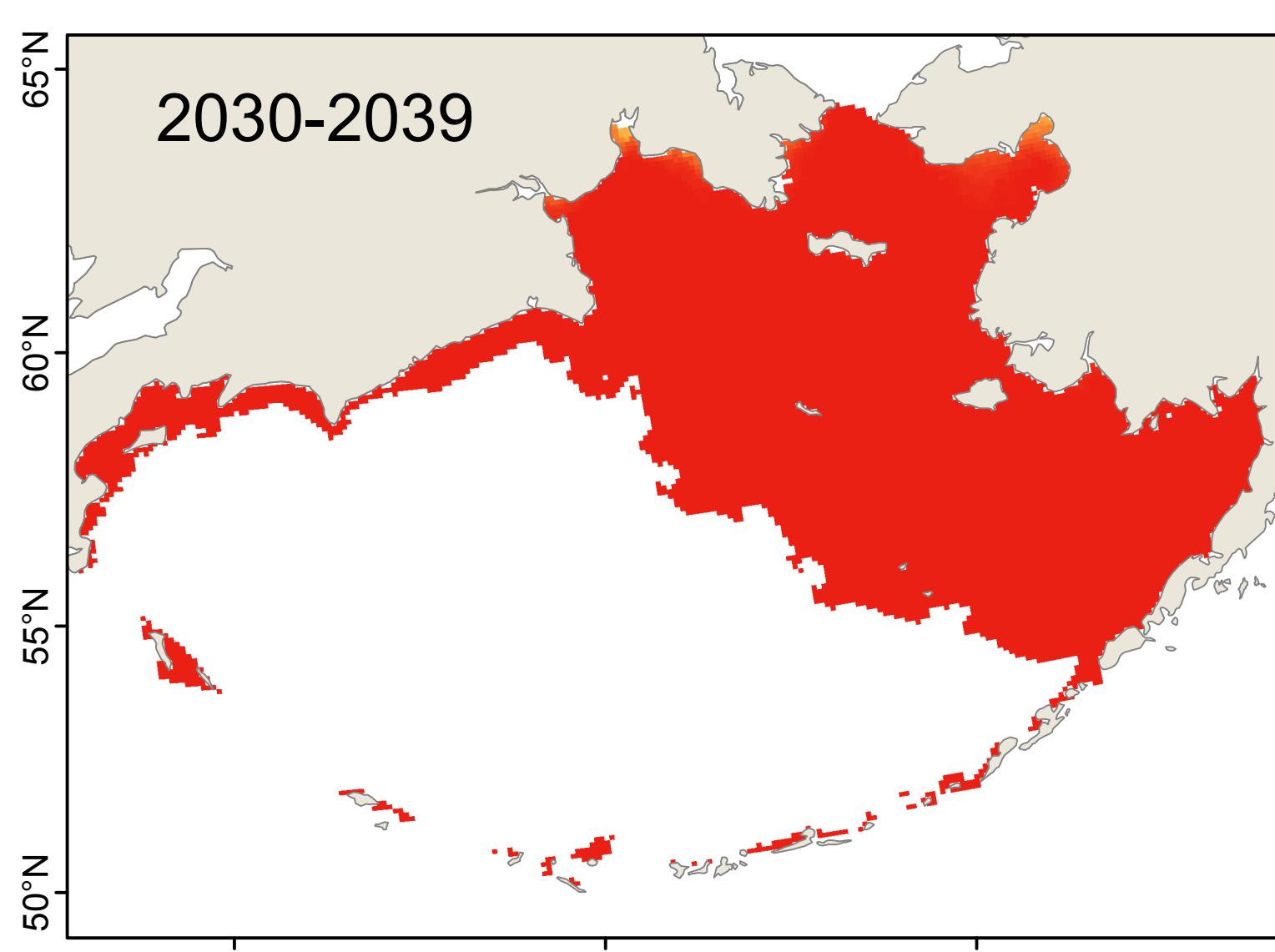
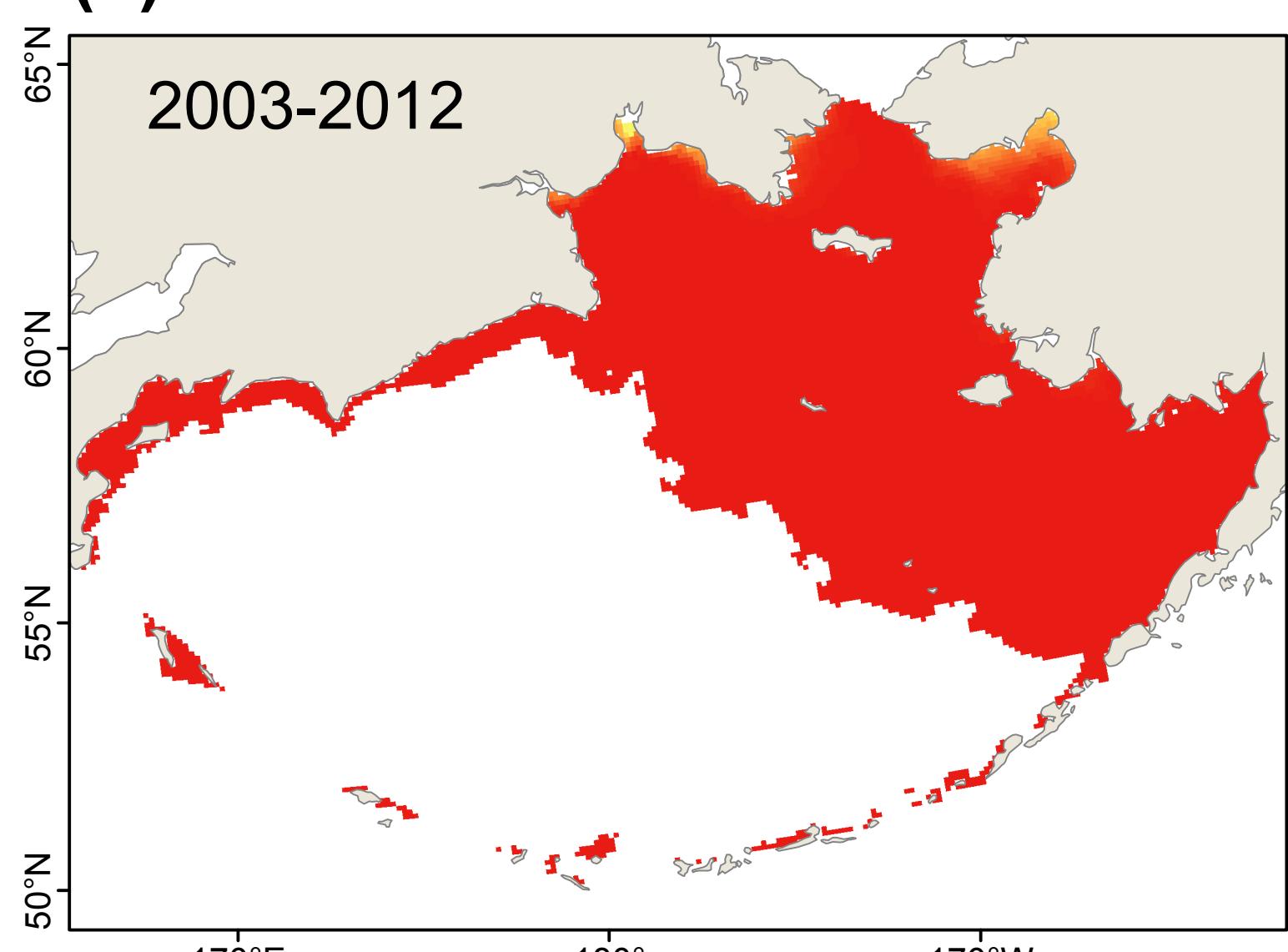
(a) Model: CGCM3-t47



(b) Model: ECHO-G

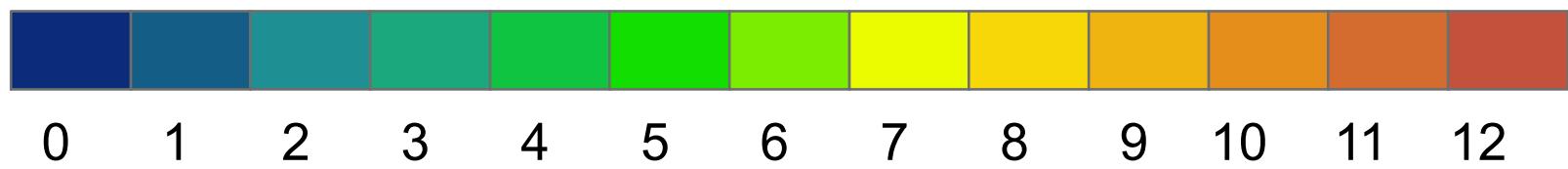


(c) Model: MIROC3.2

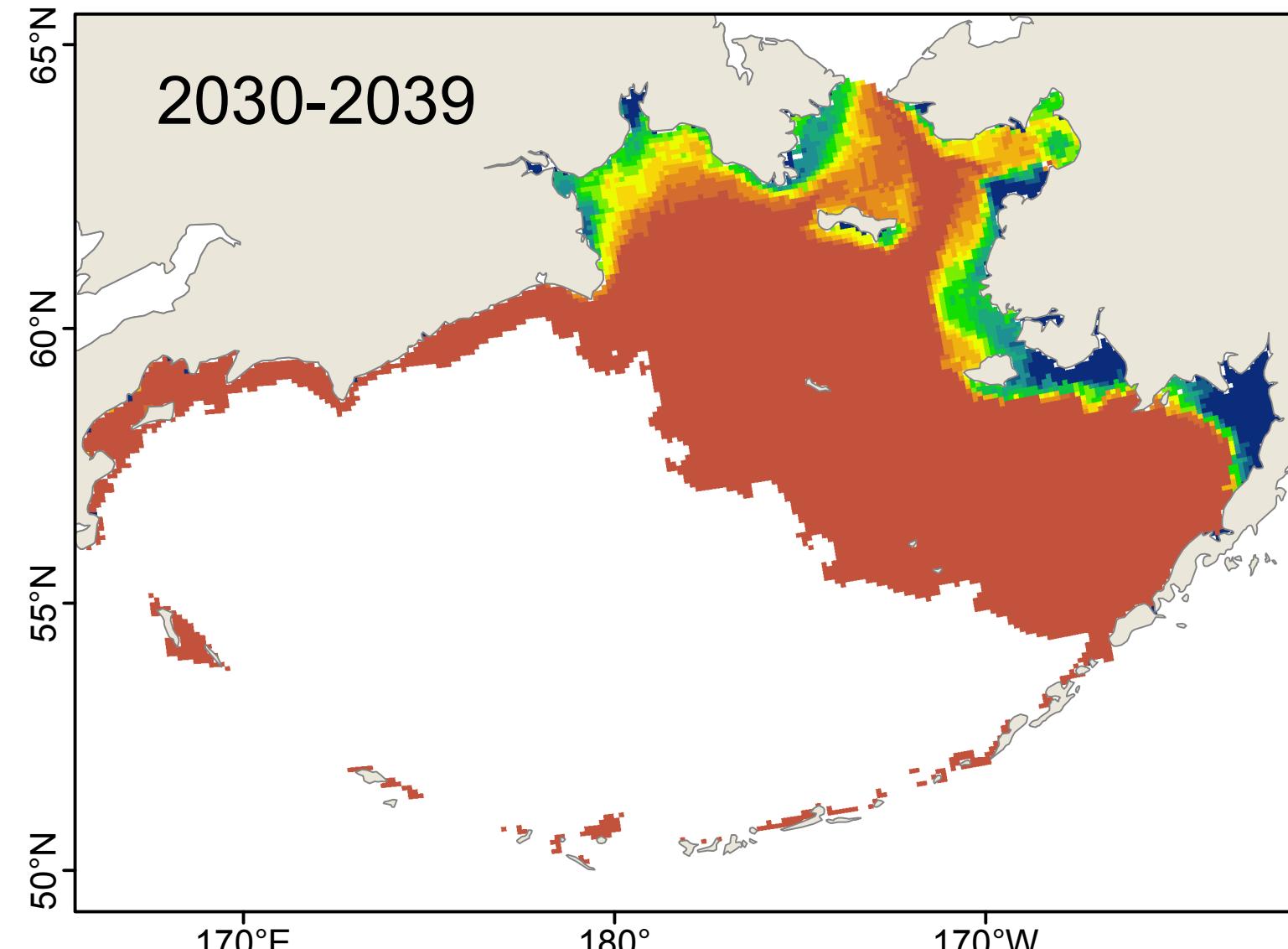
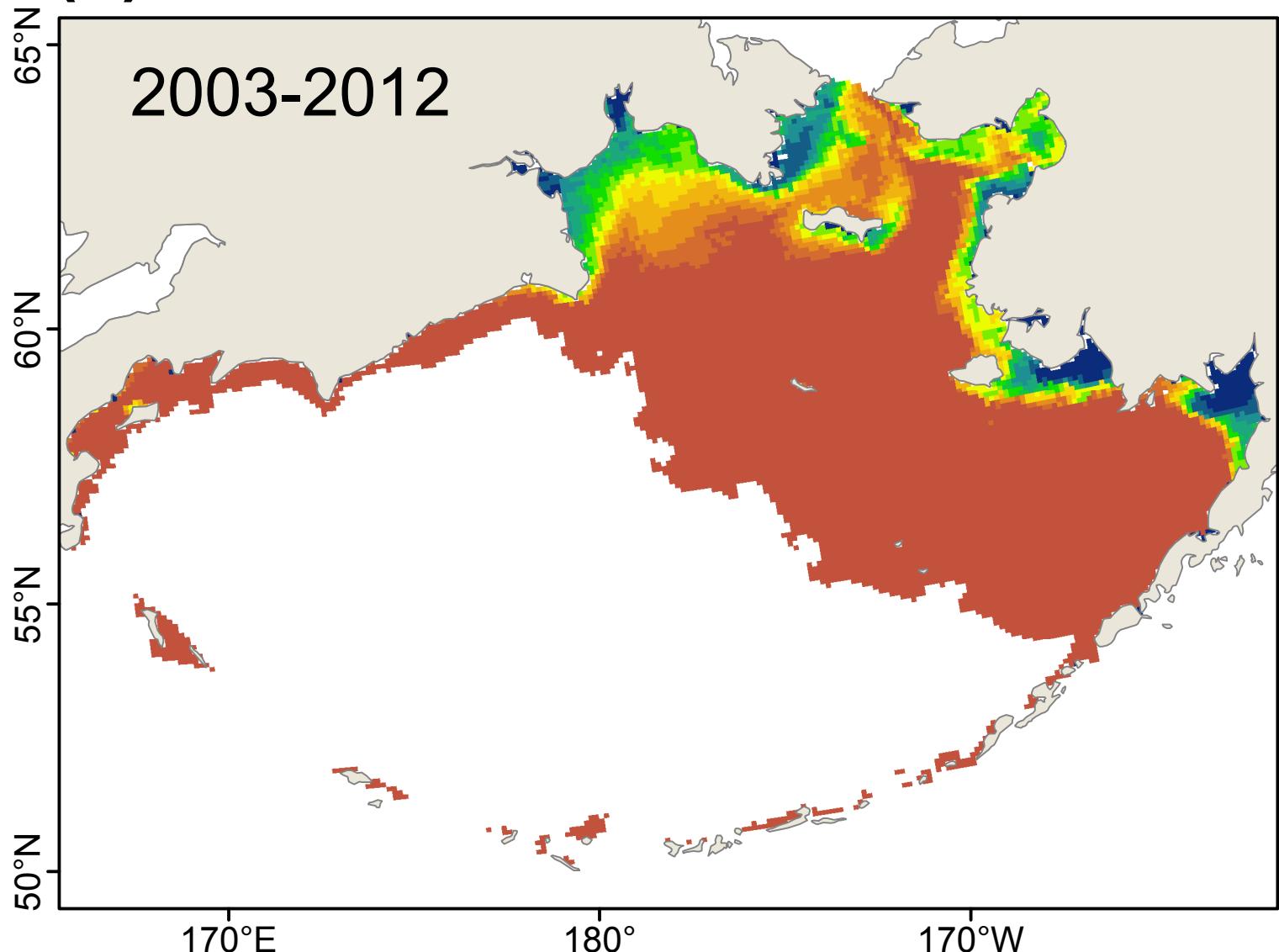


# *Caprella mutica: Reproduction*

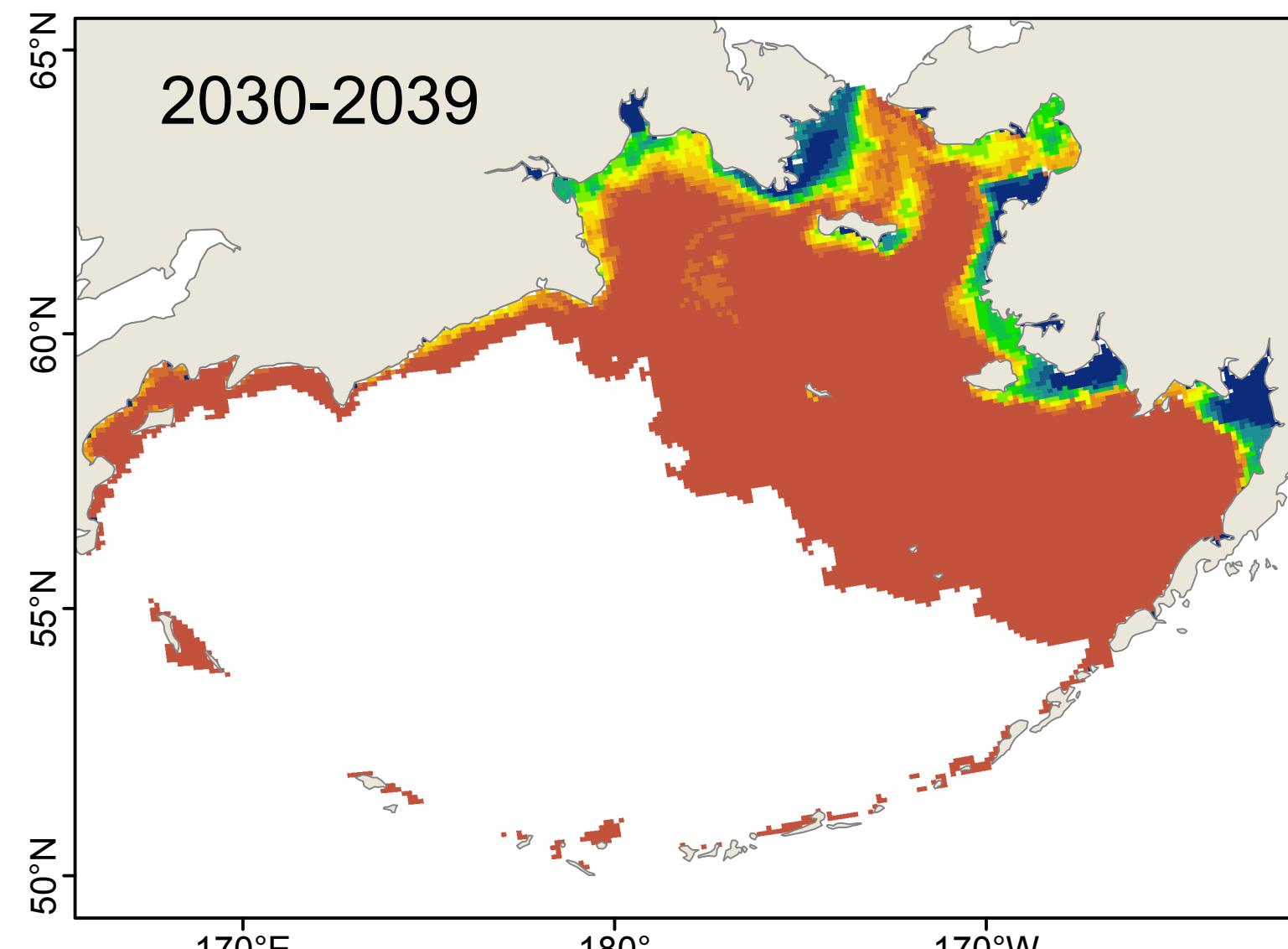
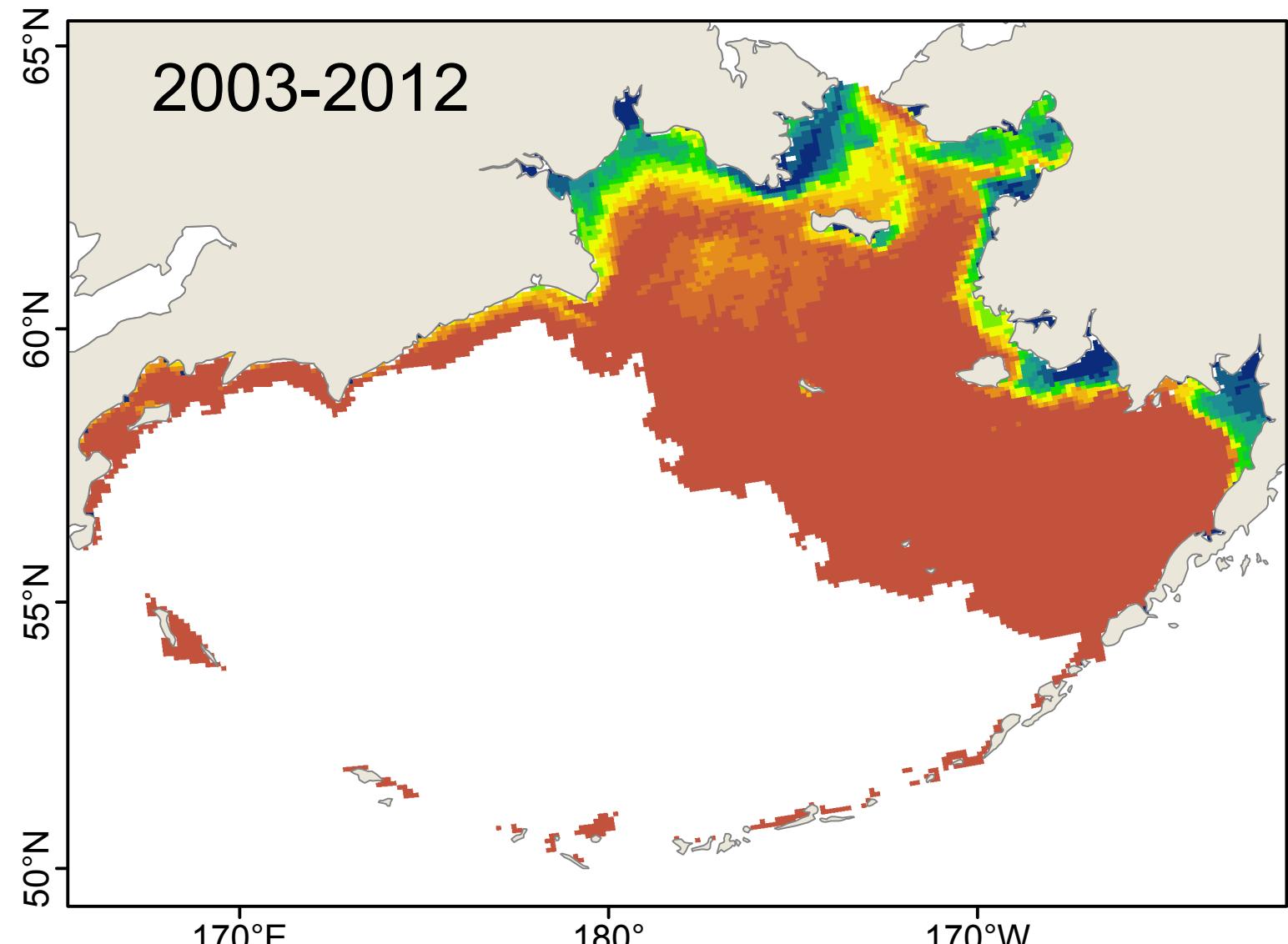
Average number of consecutive weeks of suitable habitat



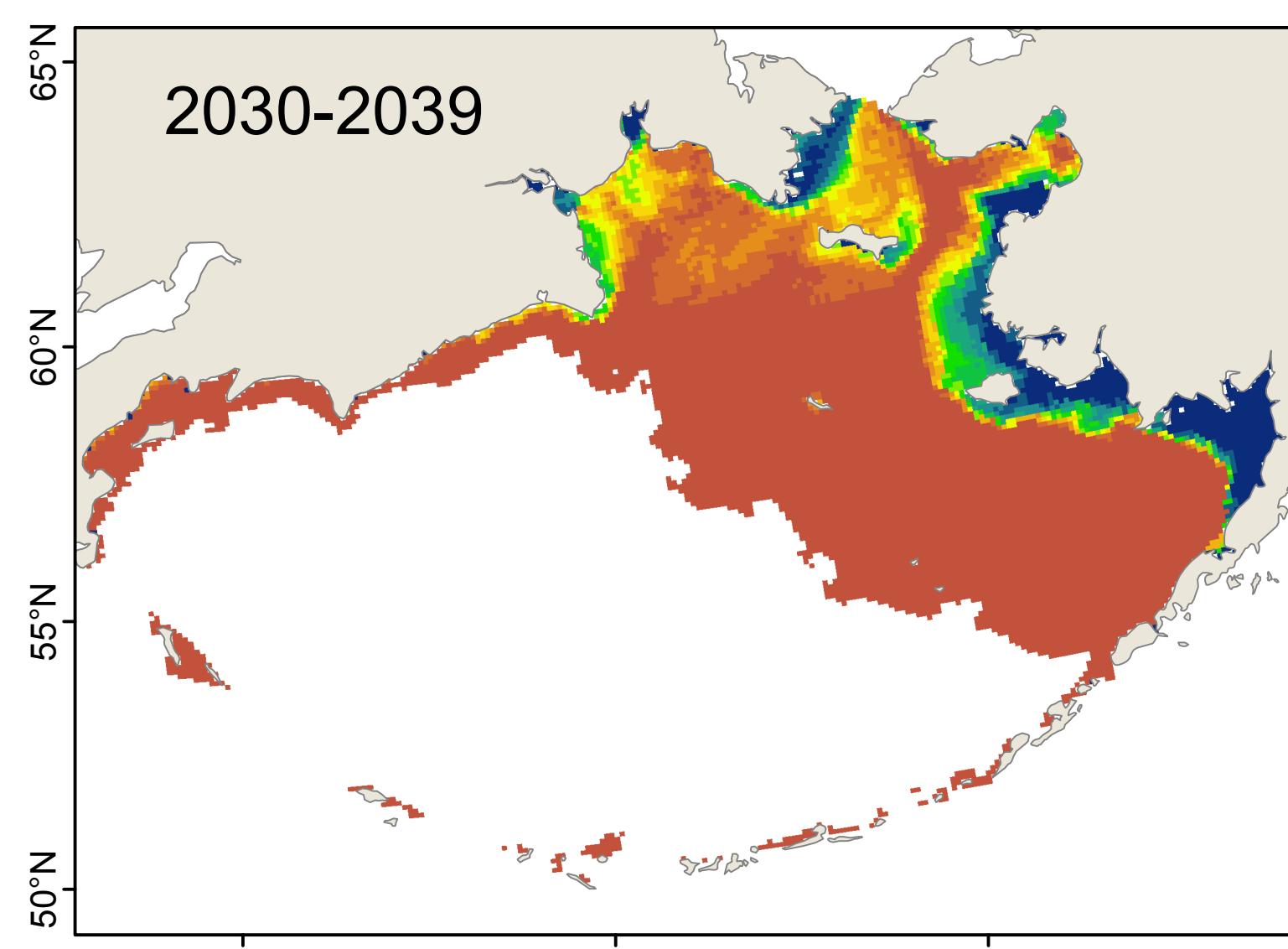
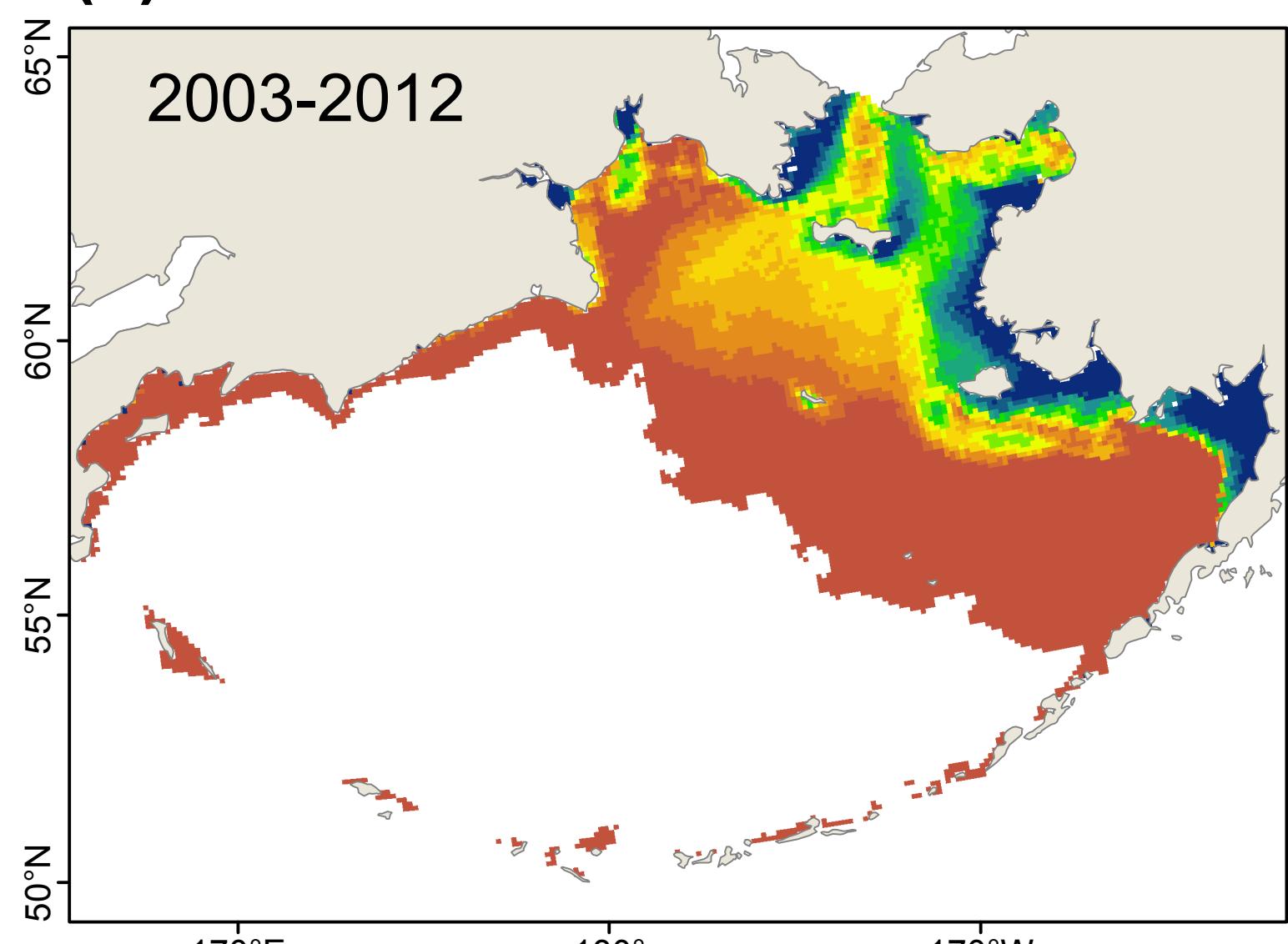
(a) Model: CGCM3-t47



(b) Model: ECHO-G

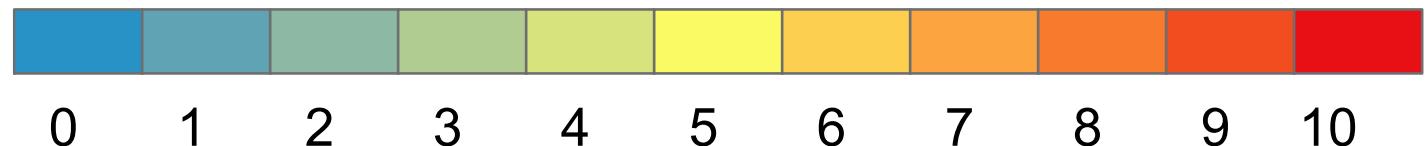


(c) Model: MIROC3.2

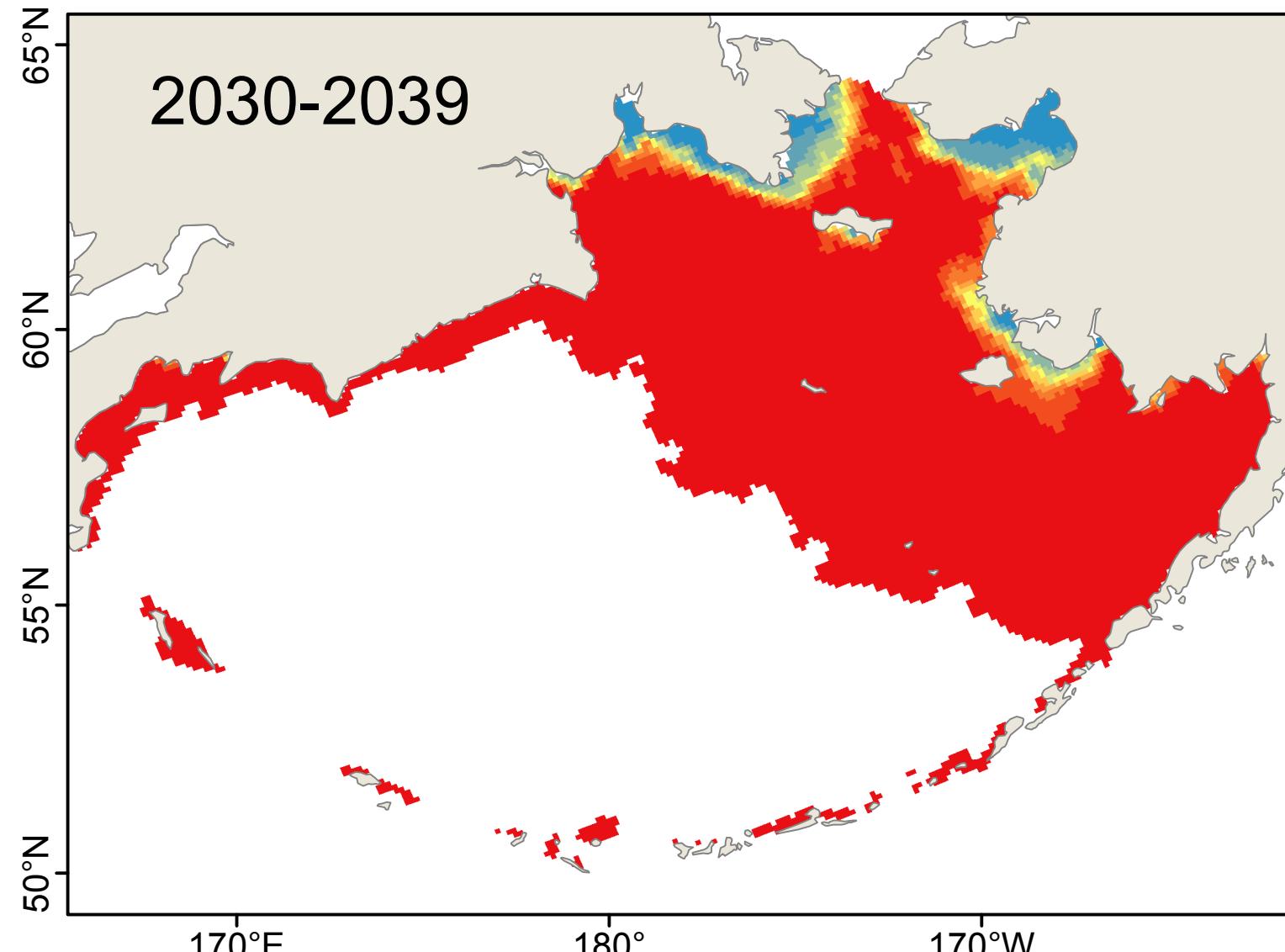
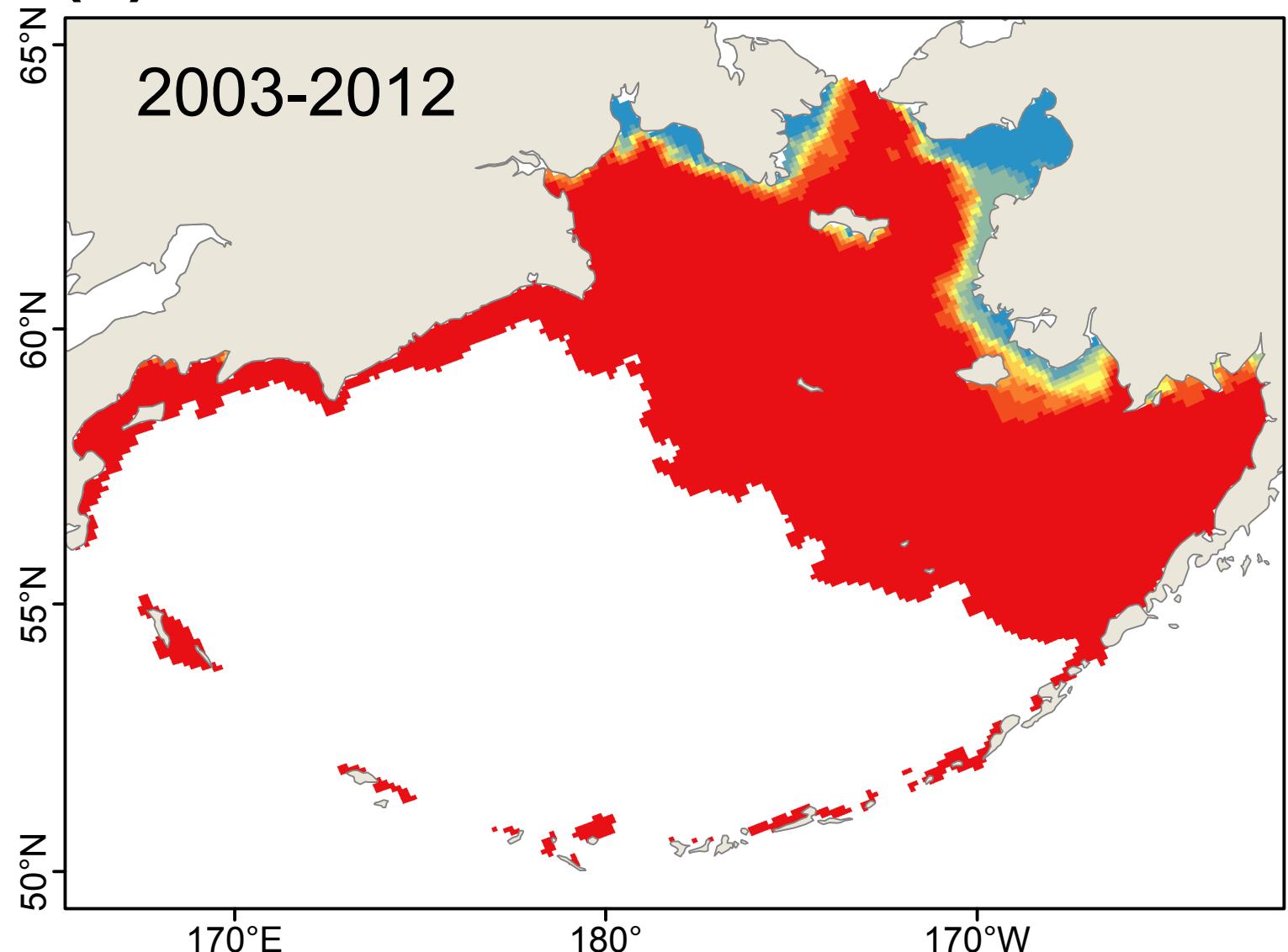


# *Jassa marmorata: Year-round Survival*

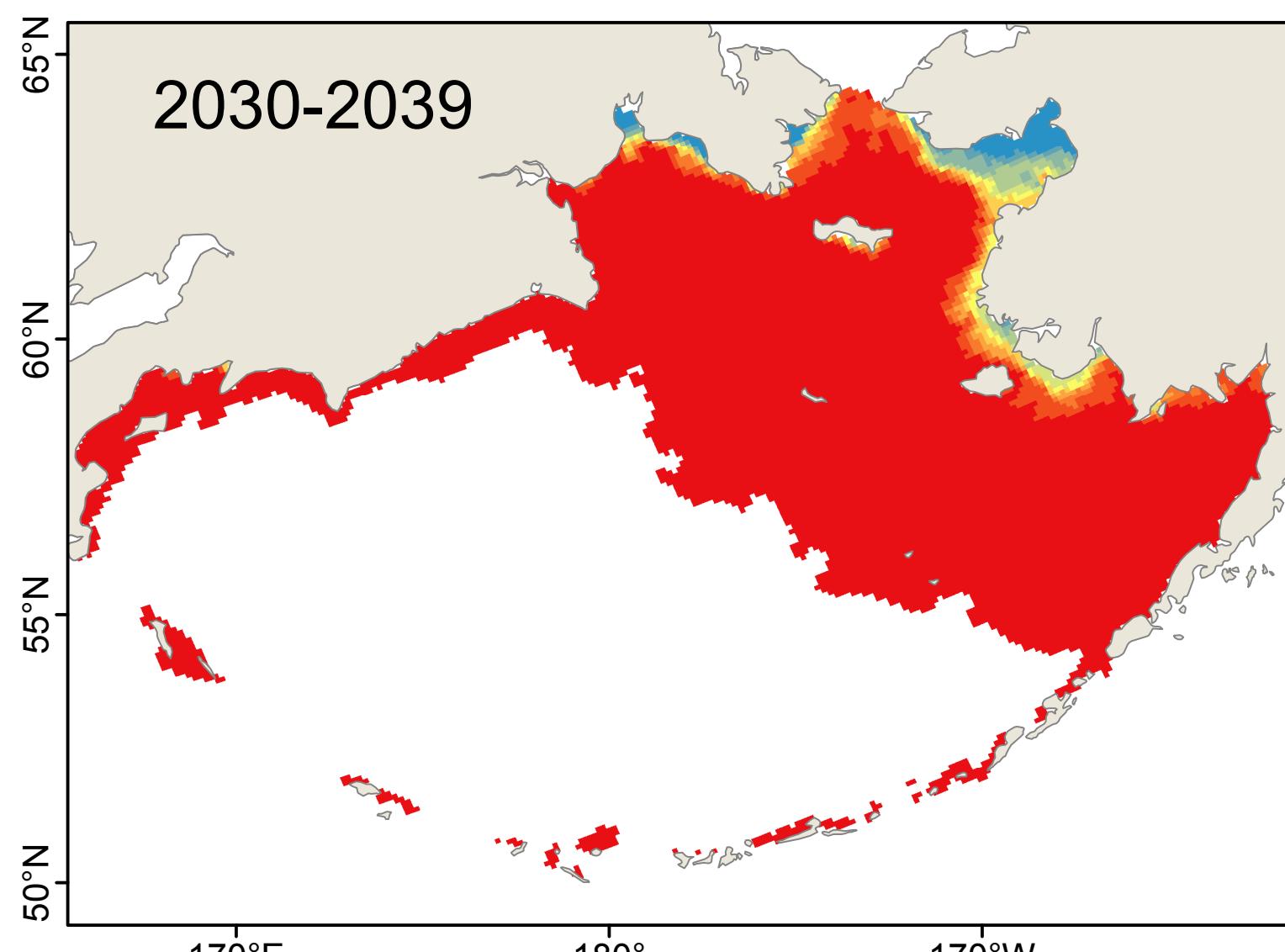
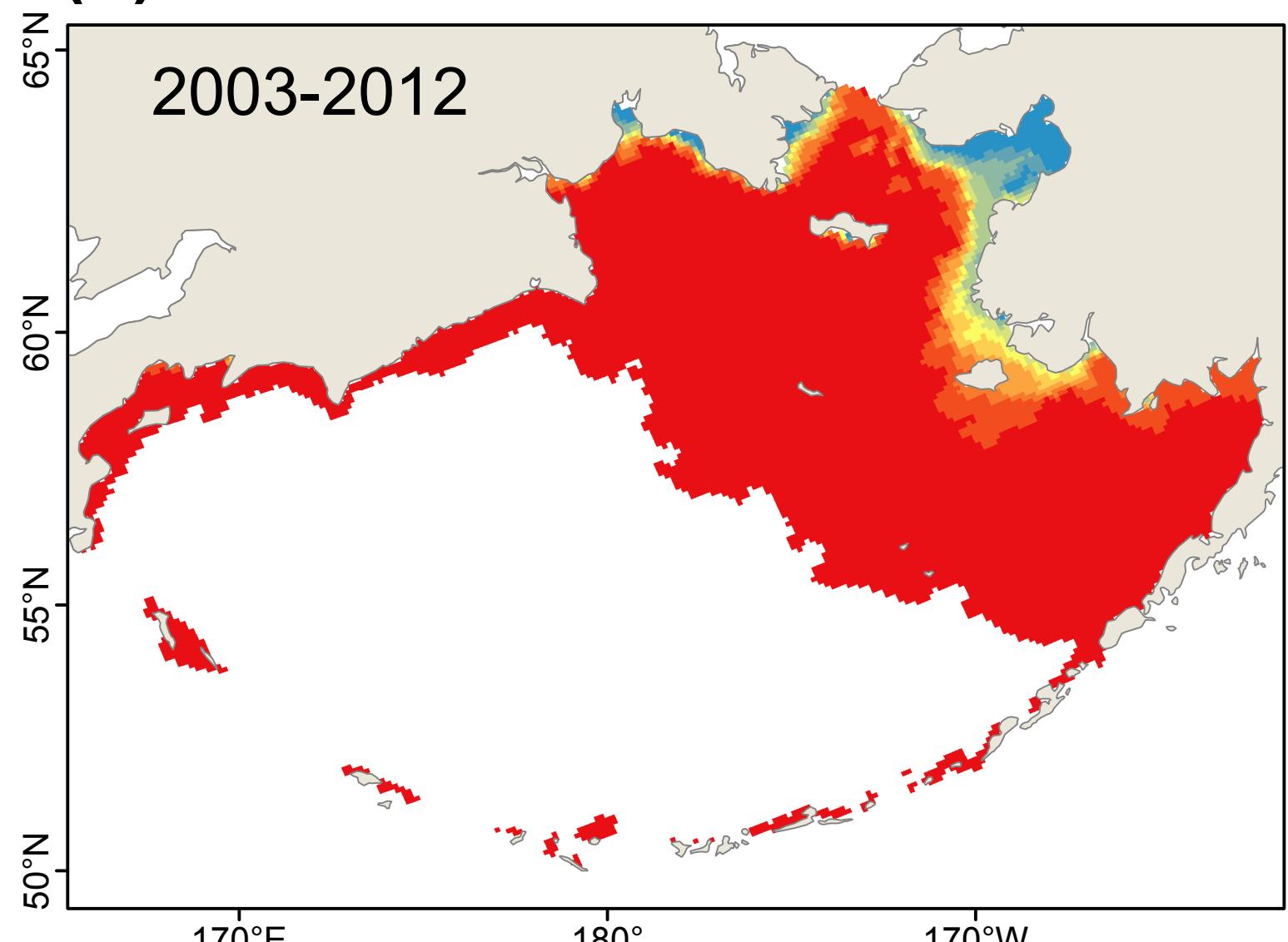
Number of years with suitable habitat



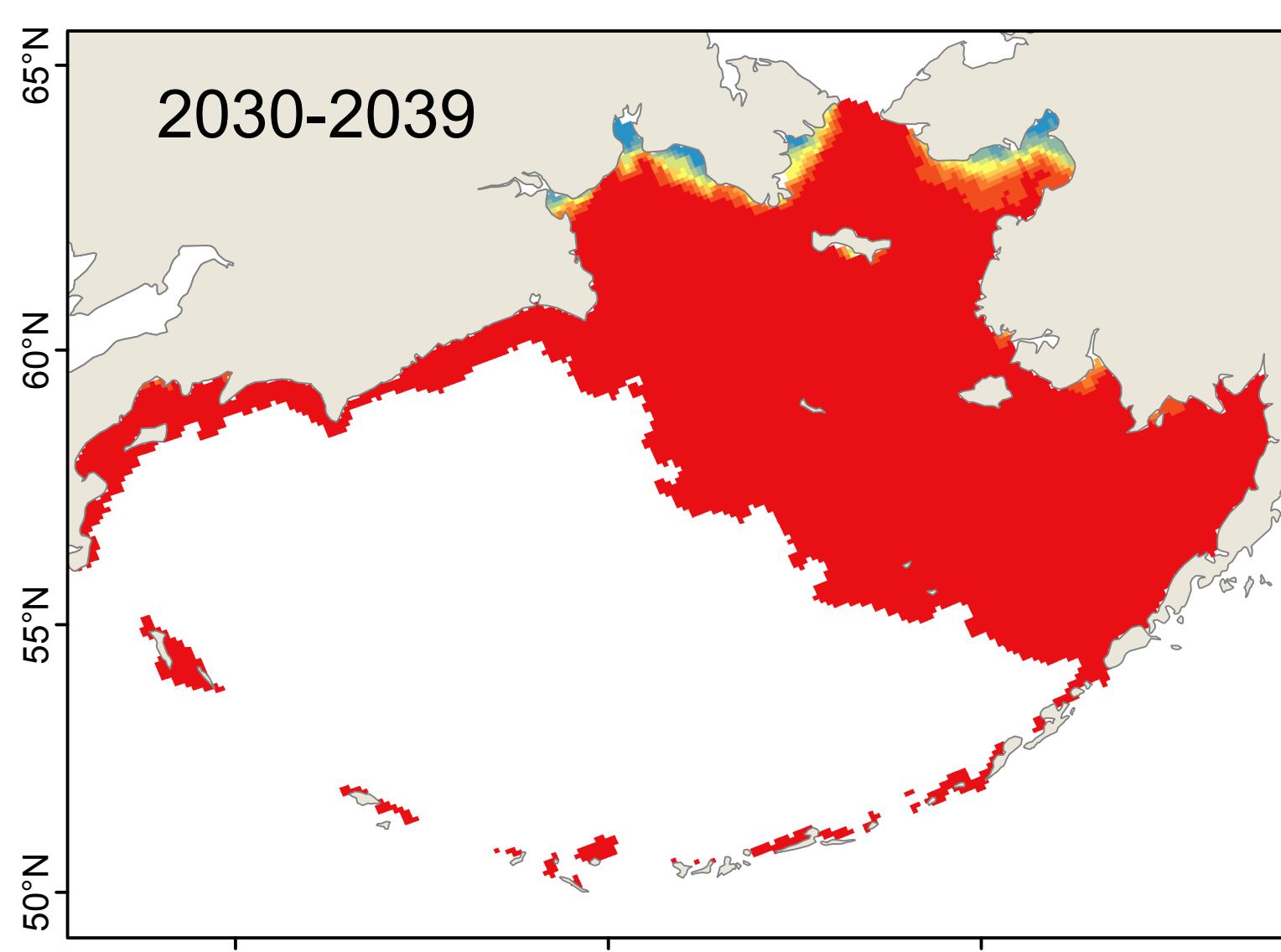
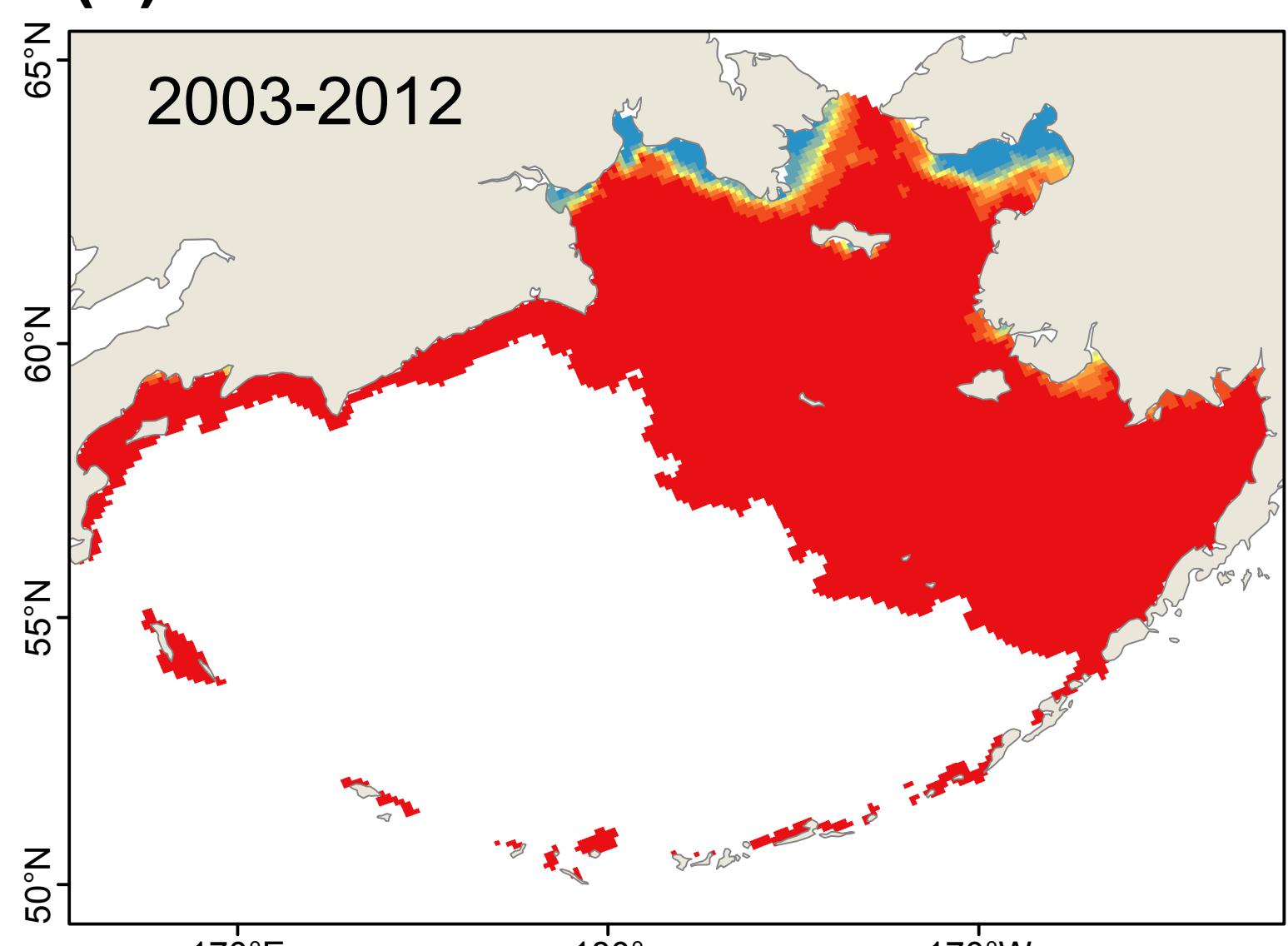
(a) Model: CGCM3-t47



(b) Model: ECHO-G

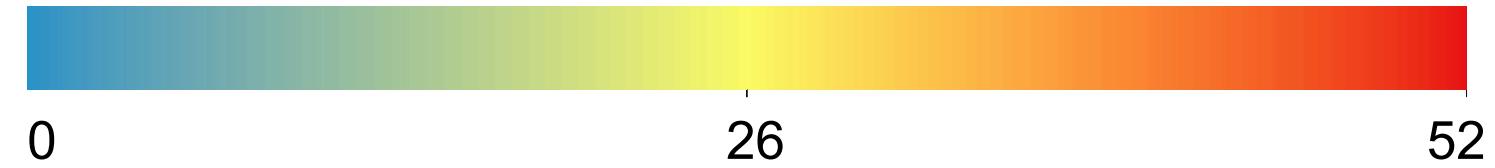


(c) Model: MIROC3.2

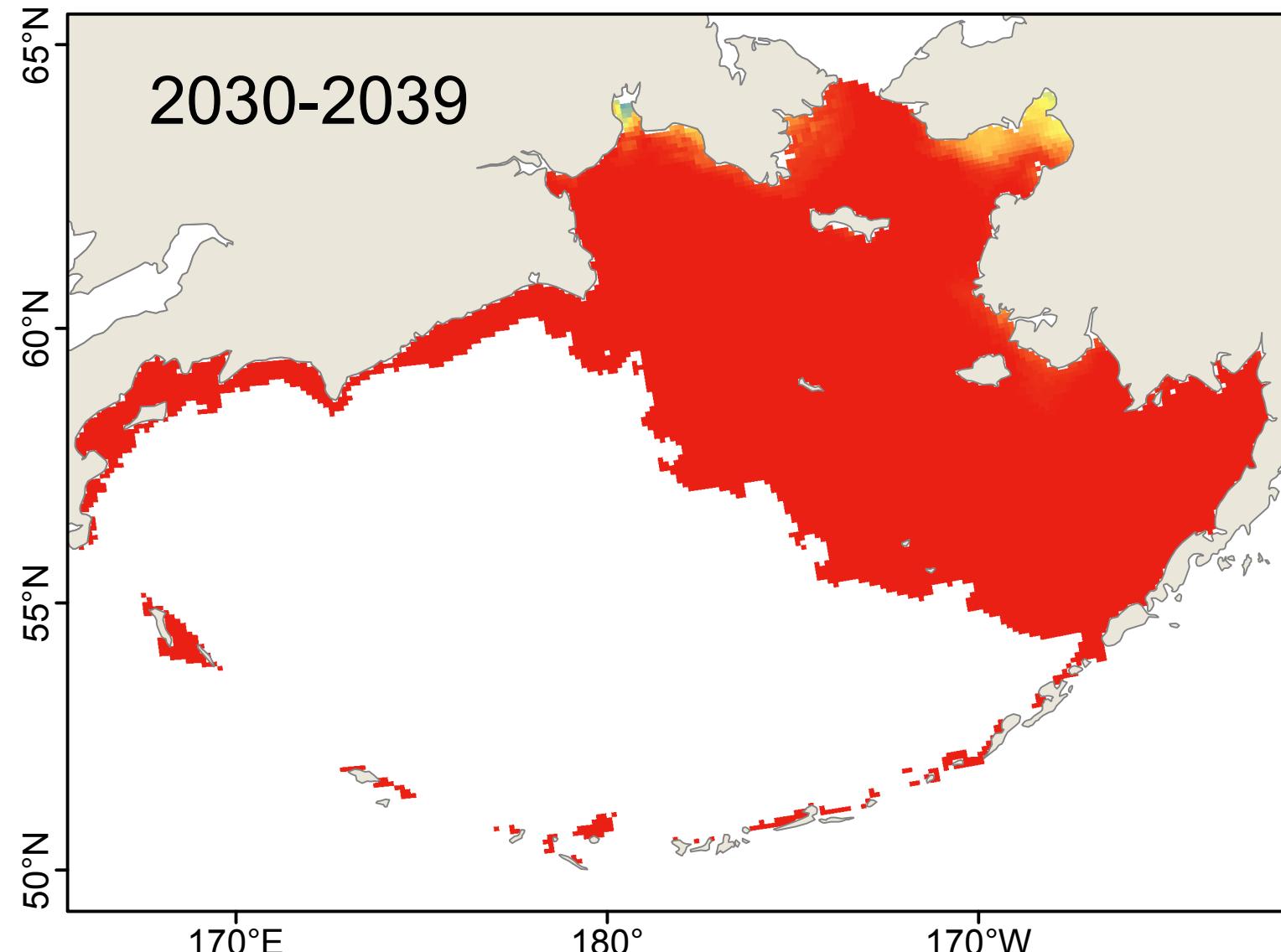
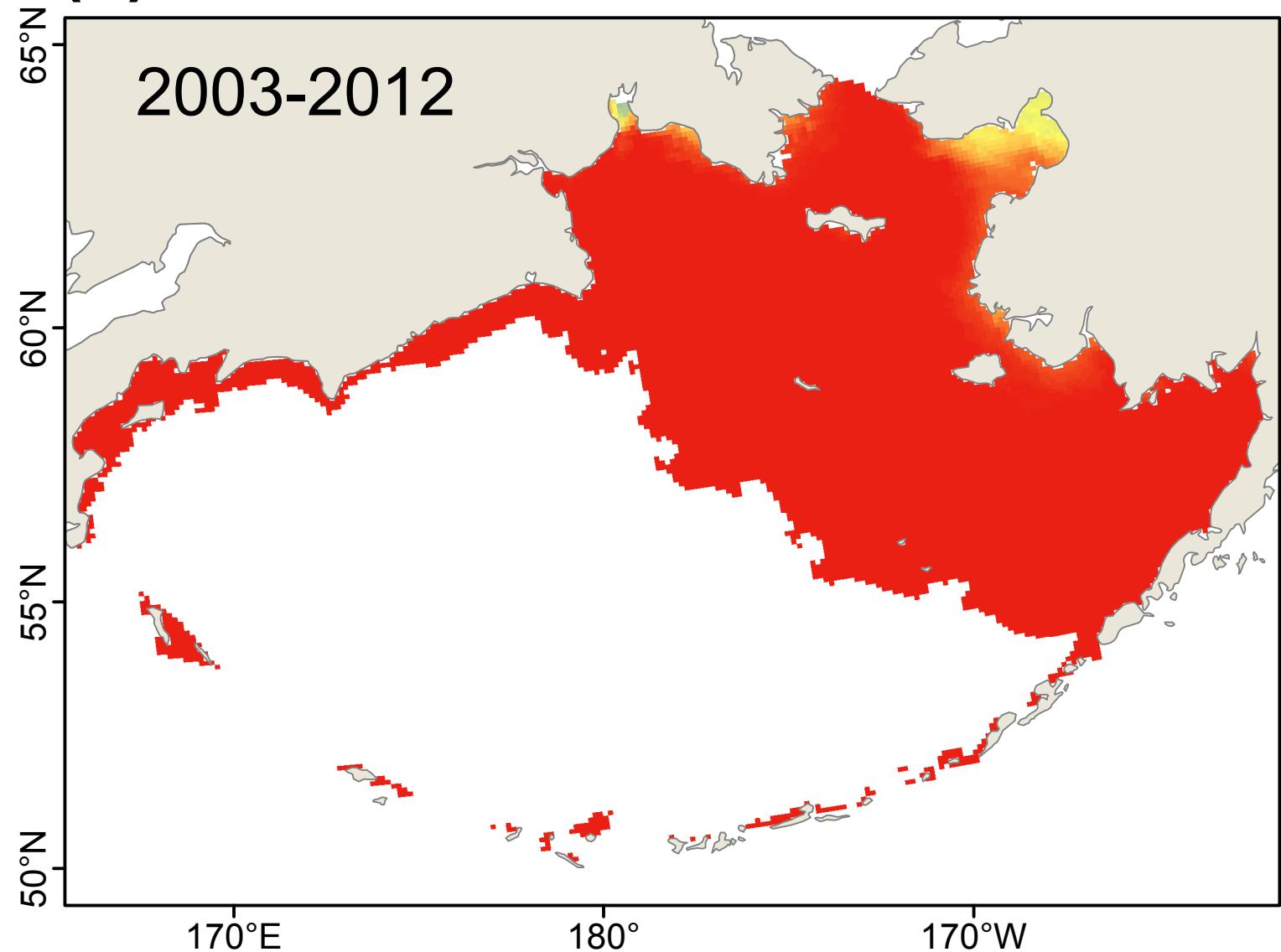


# *Jassa marmorata: Weekly Survival*

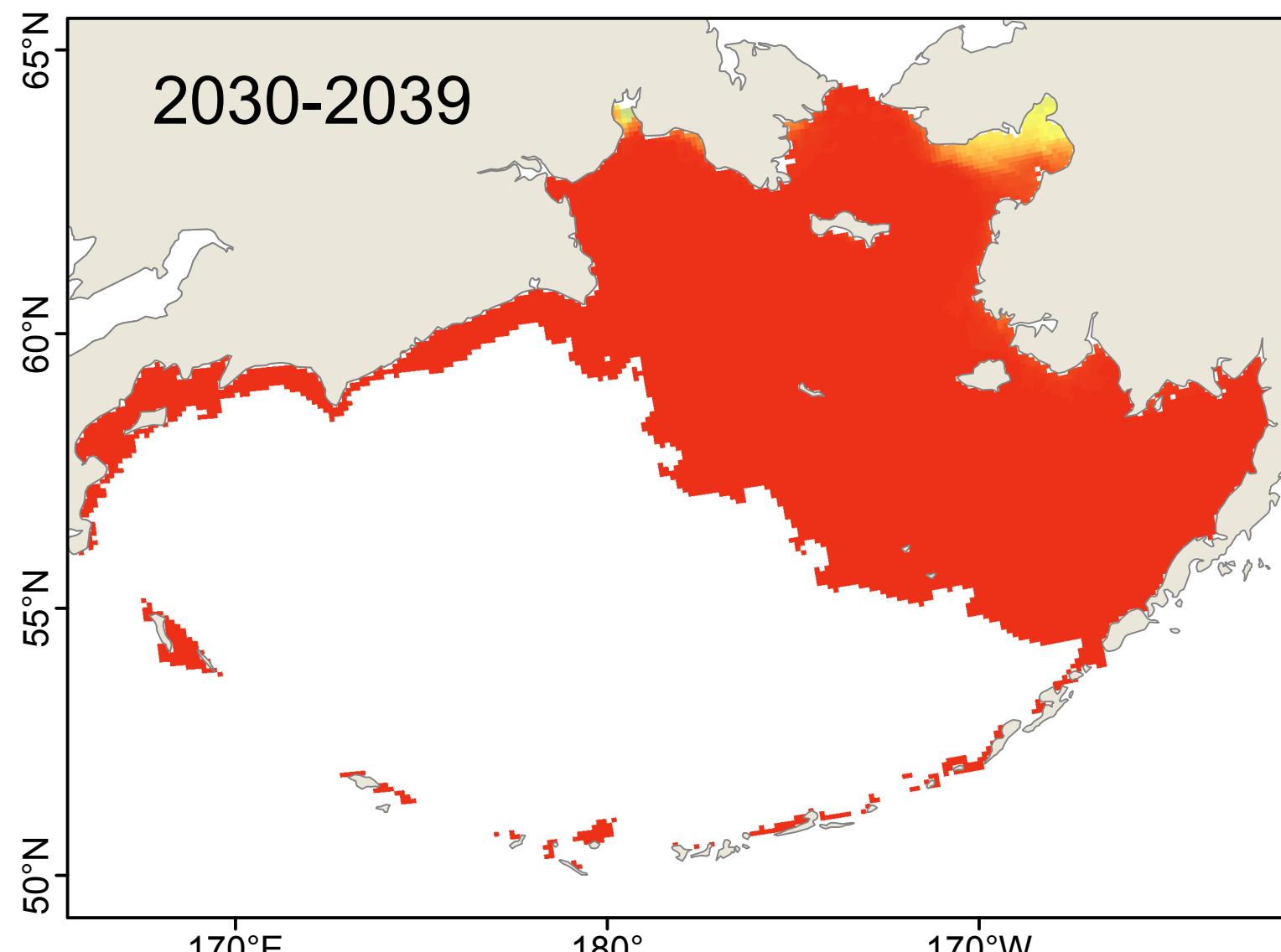
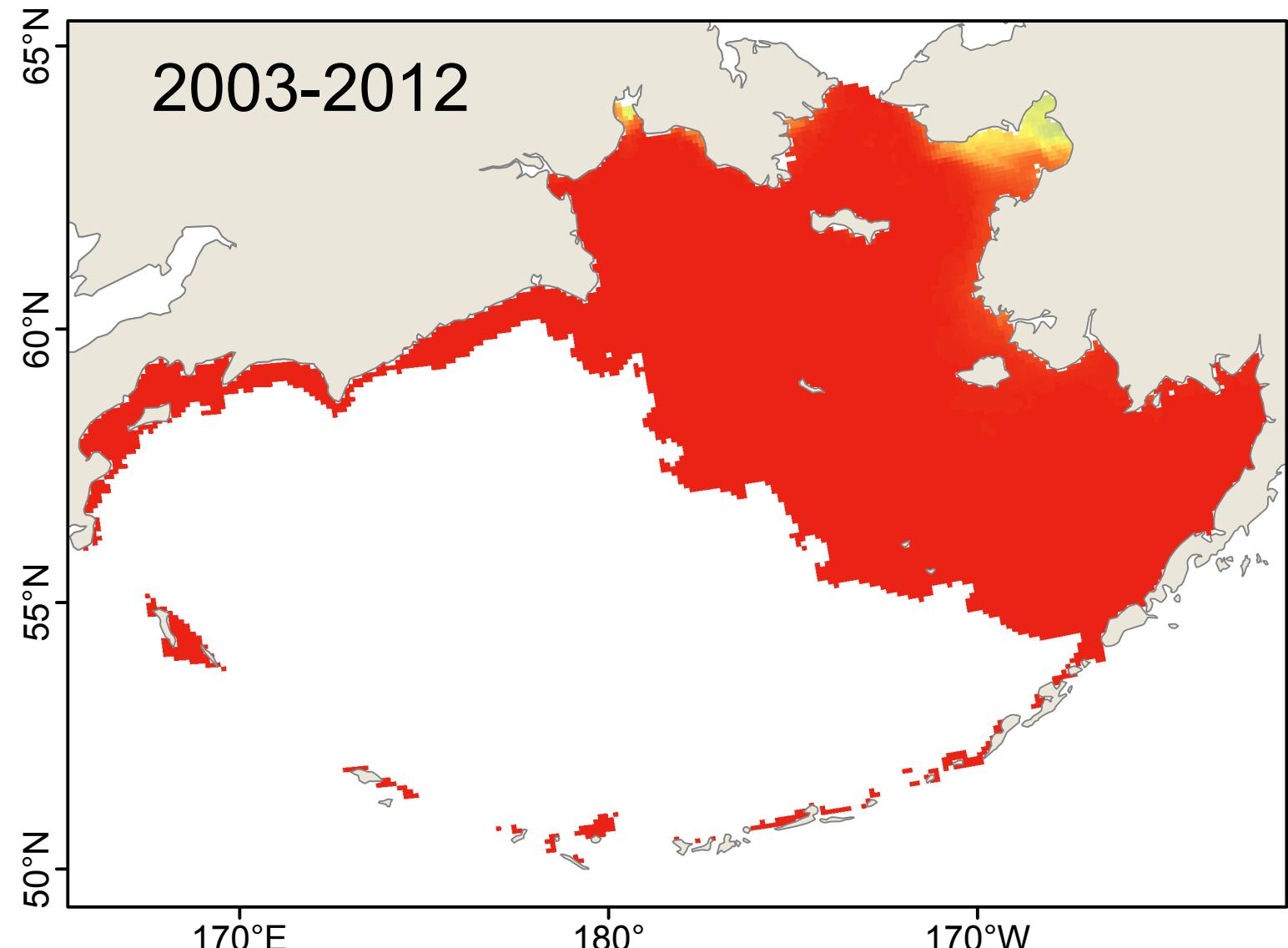
Average number of weeks of suitable habitat



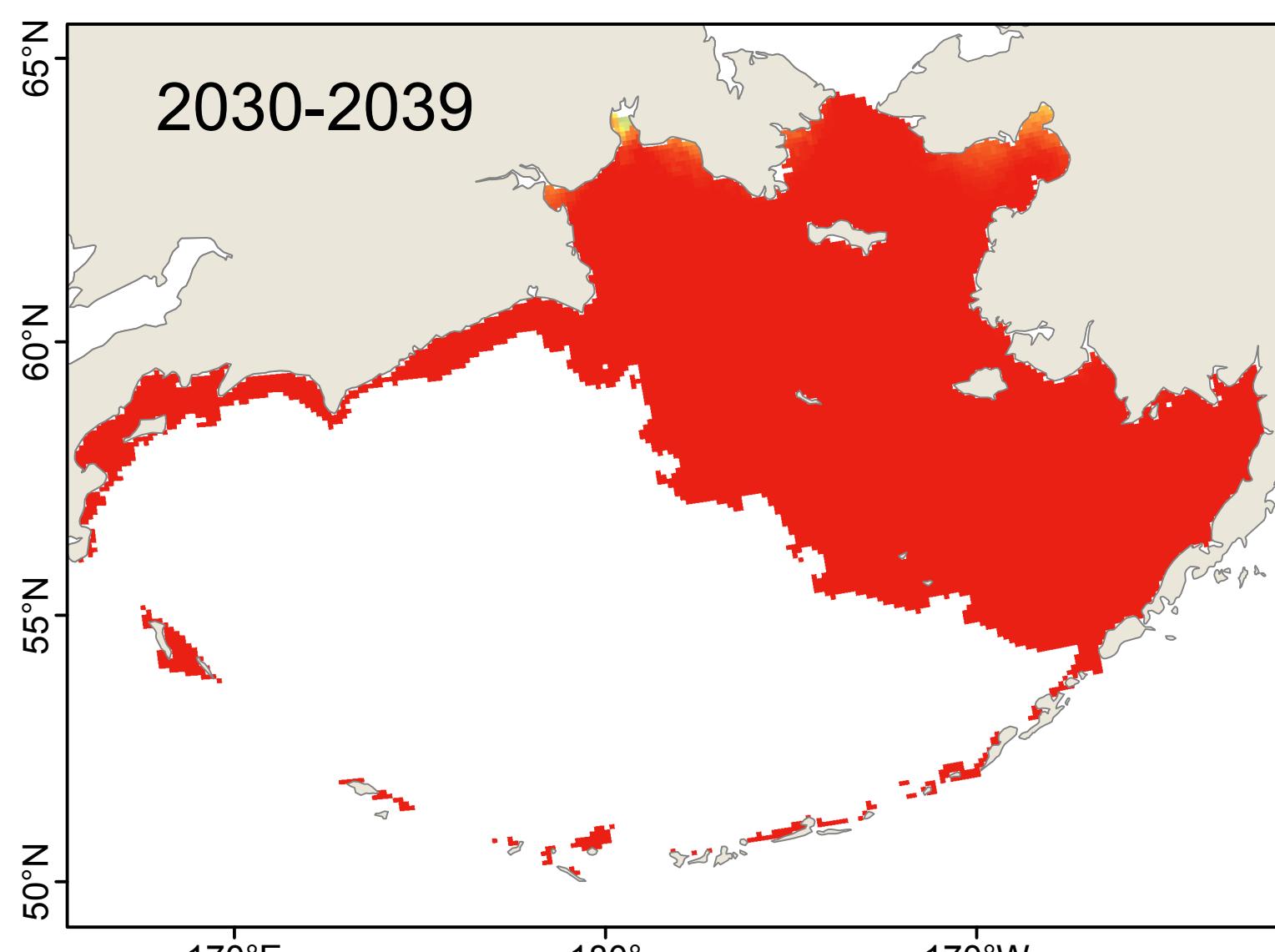
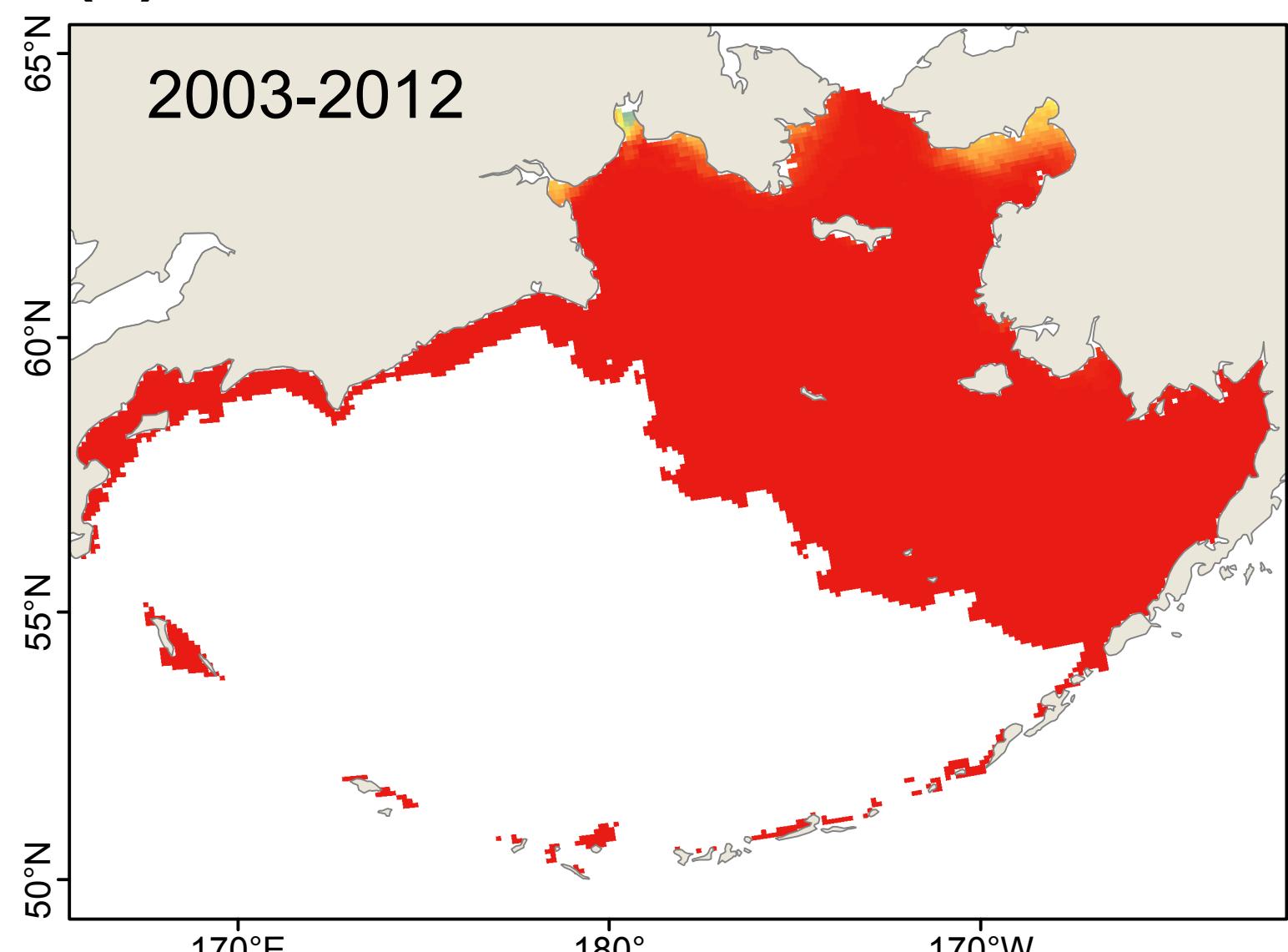
(a) Model: CGCM3-t47



(b) Model: ECHO-G

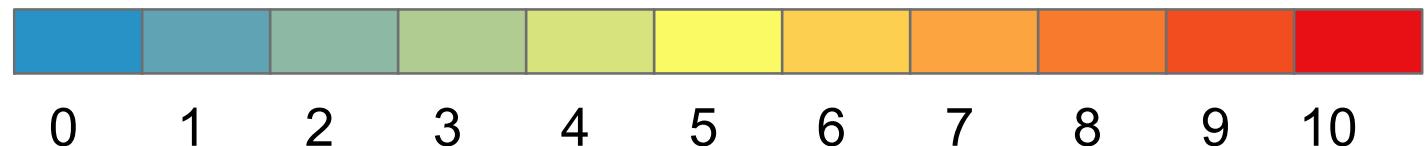


(c) Model: MIROC3.2

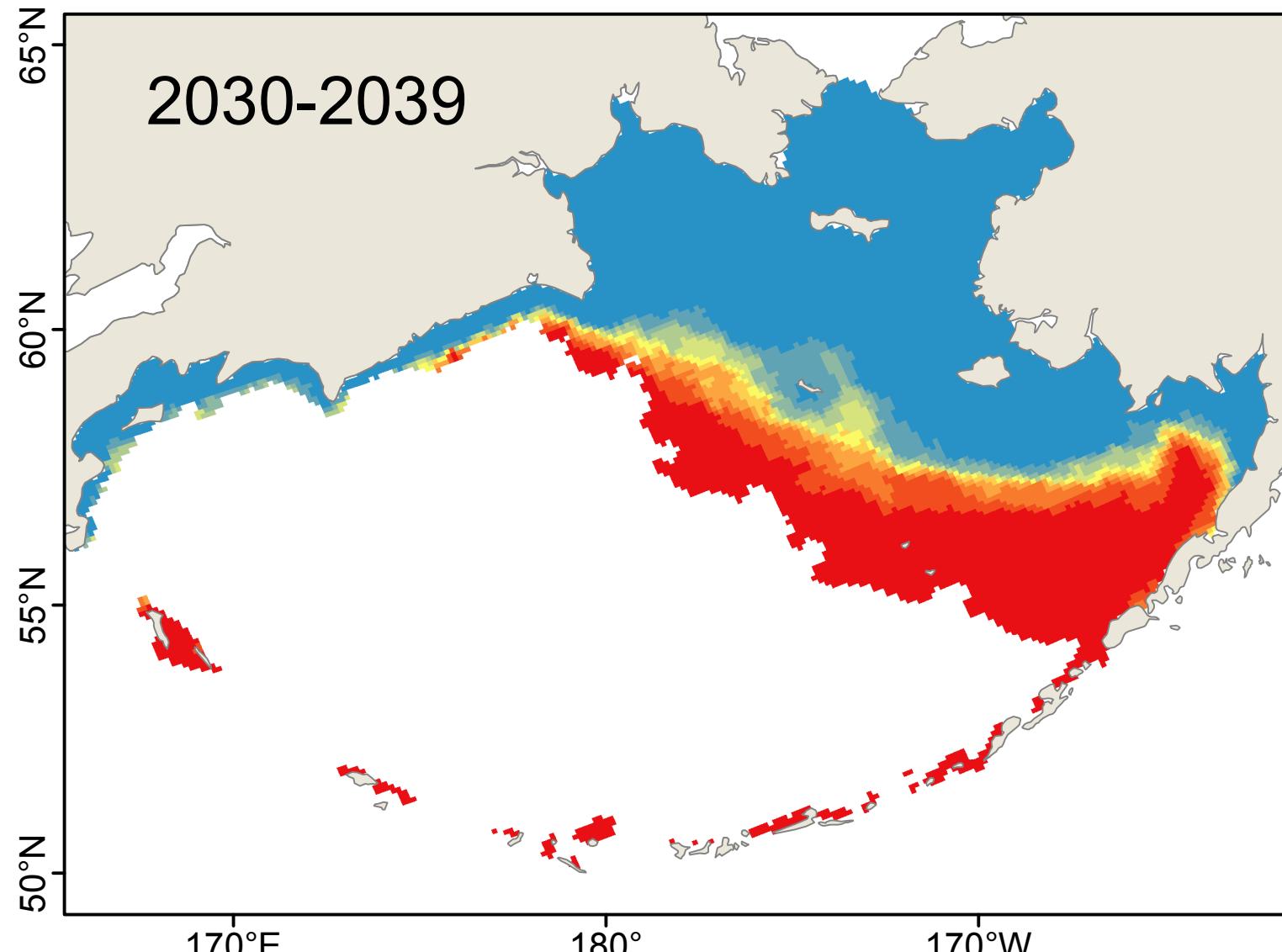
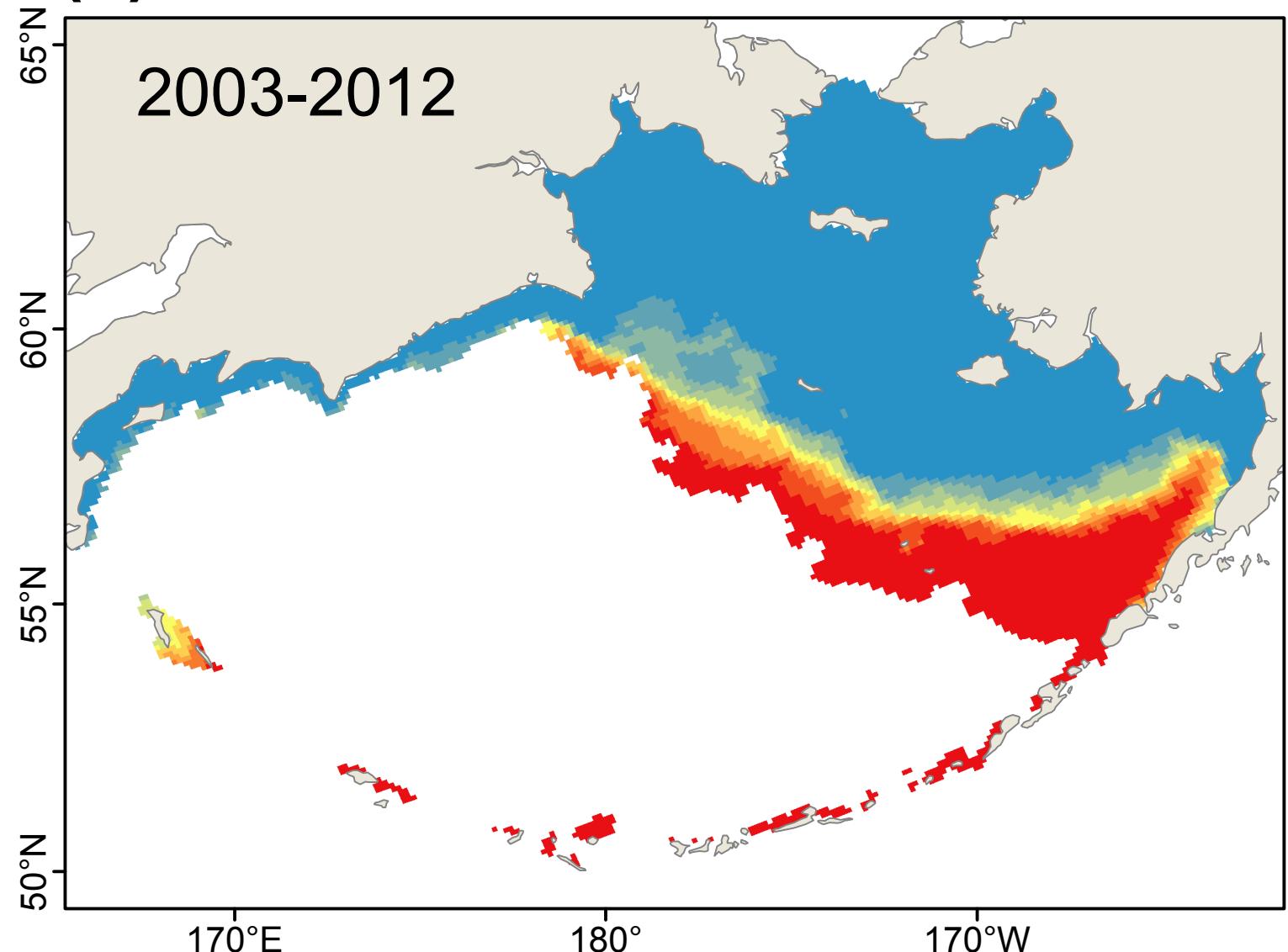


# *Melita nitida: Year-round Survival*

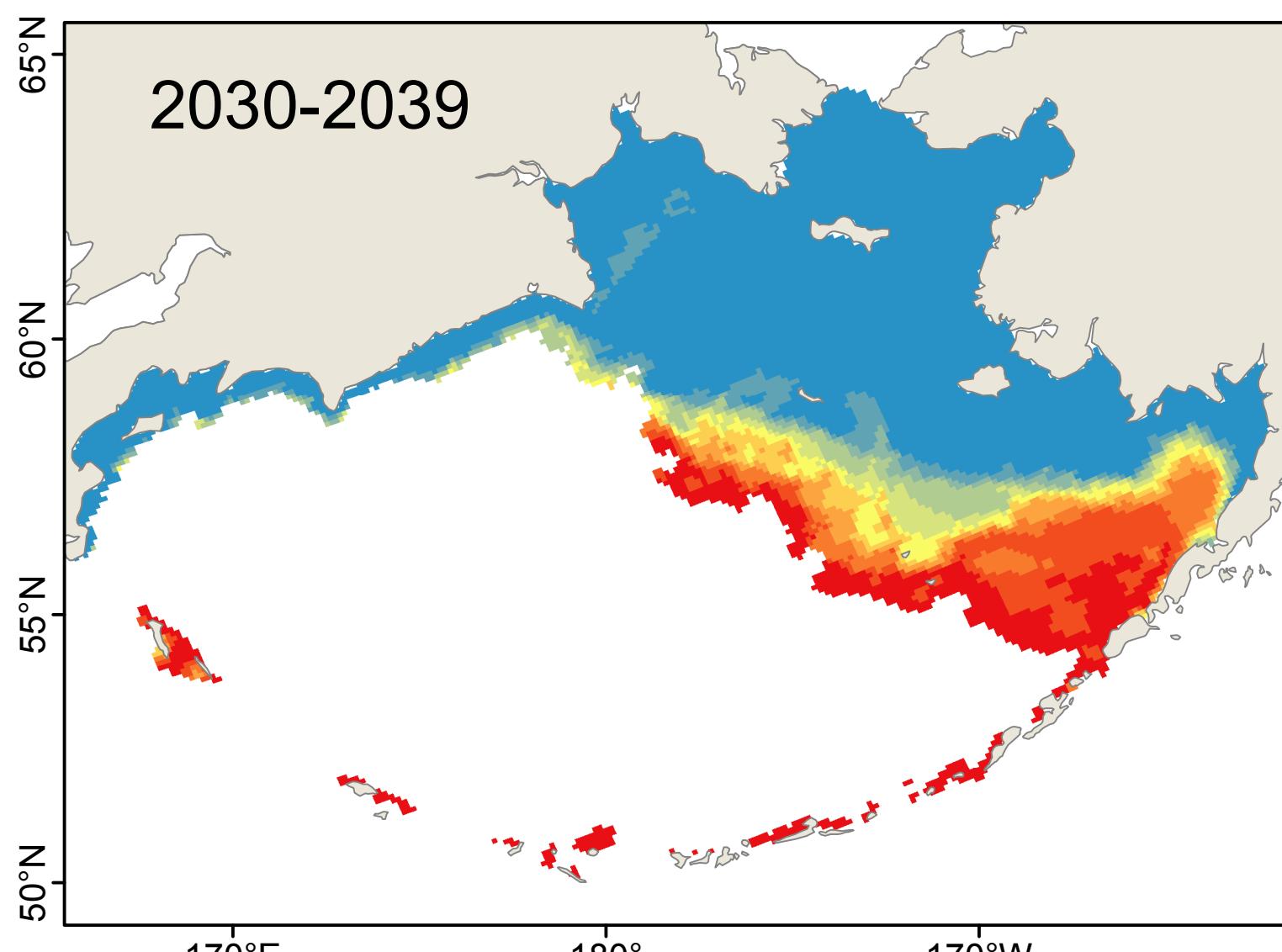
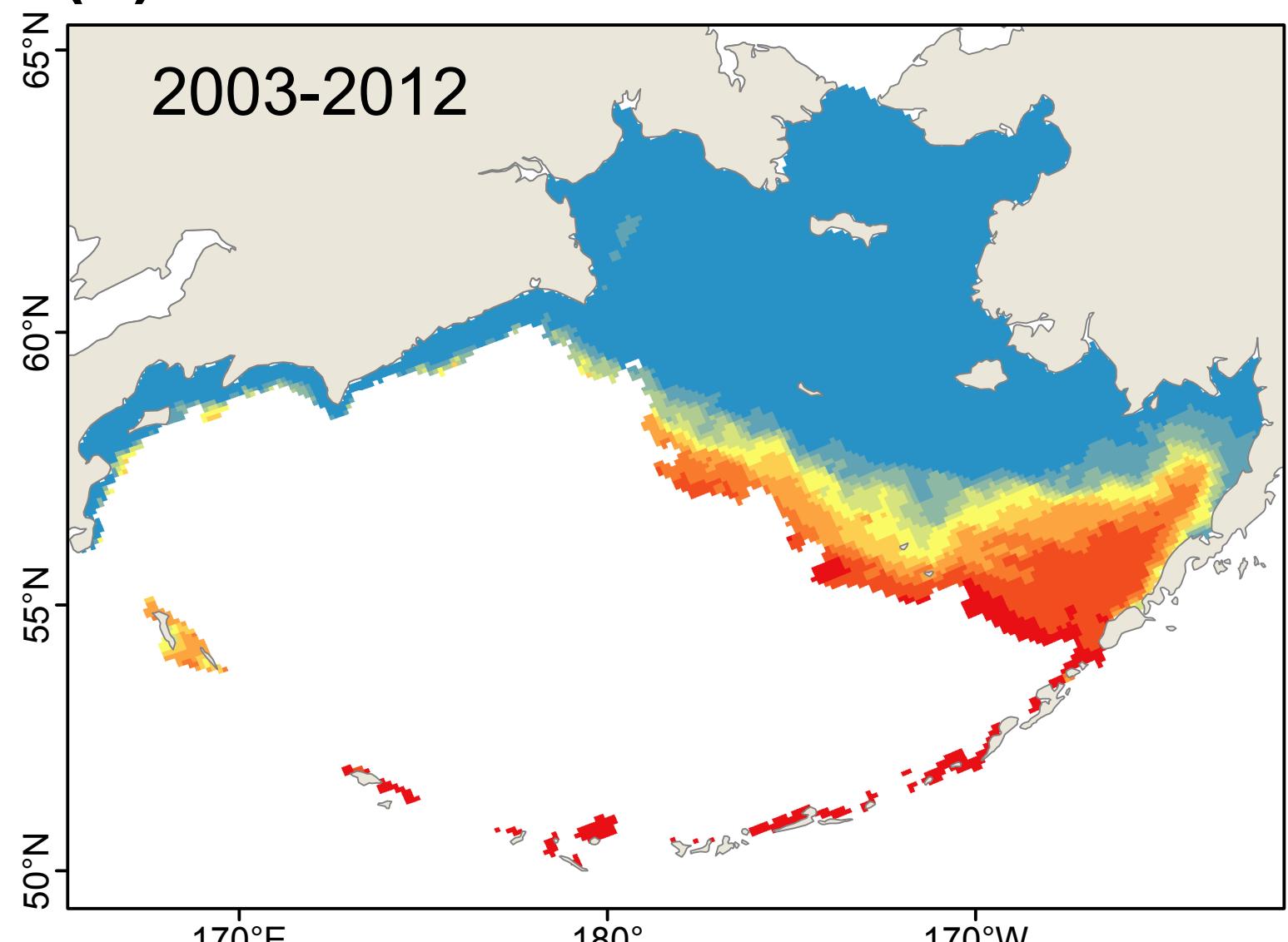
Number of years with suitable habitat



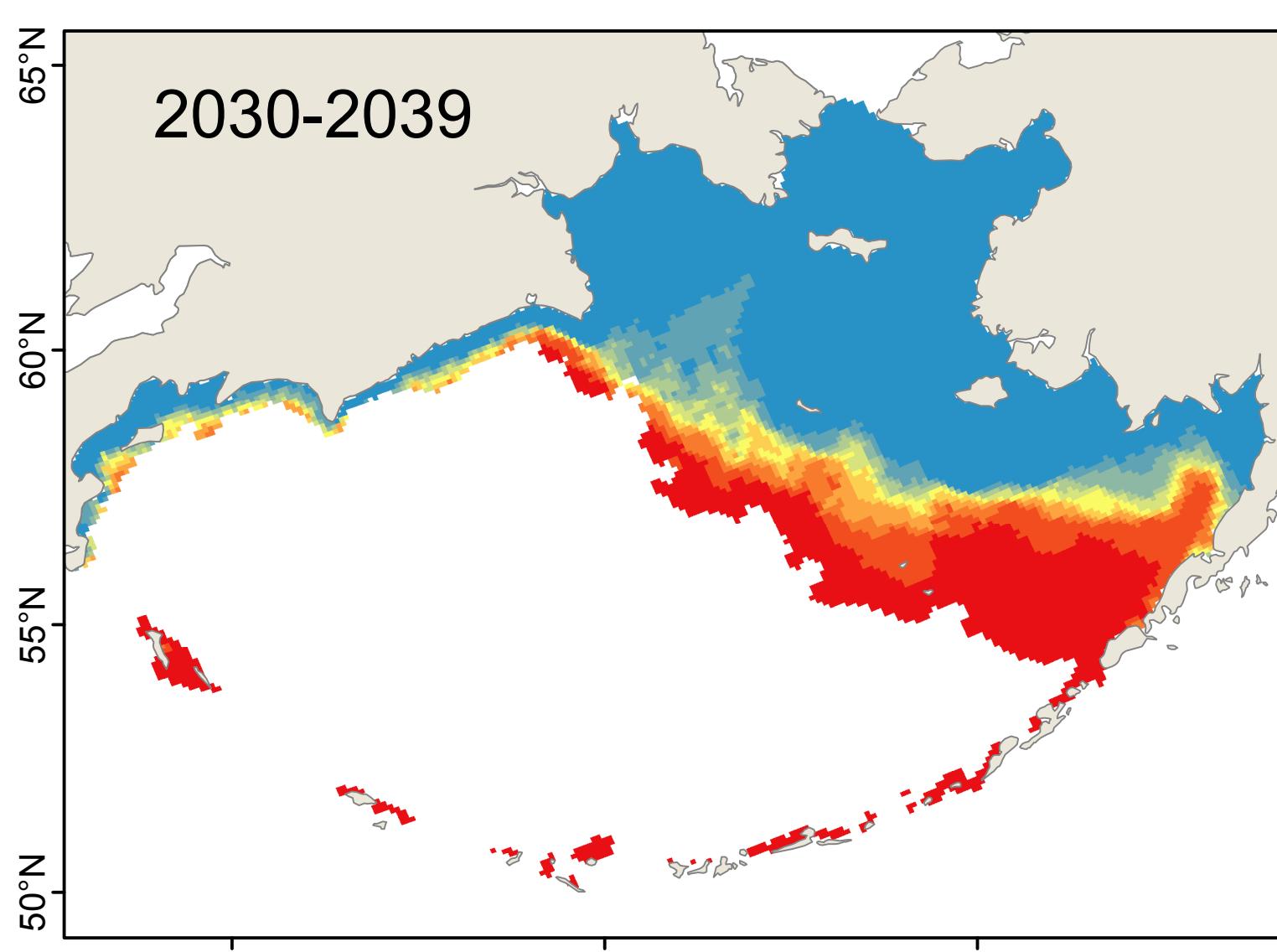
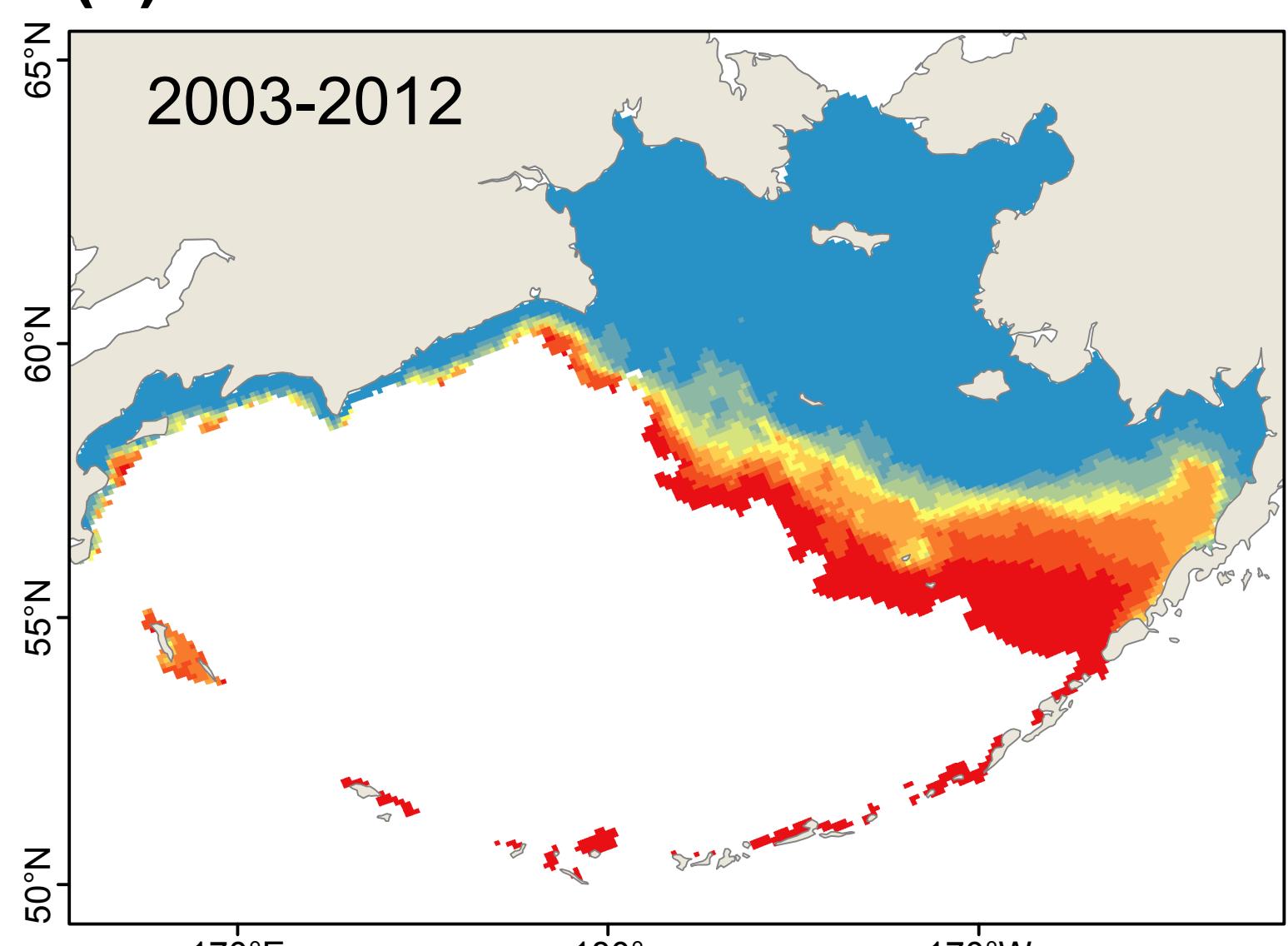
(a) Model: CGCM3-t47



(b) Model: ECHO-G

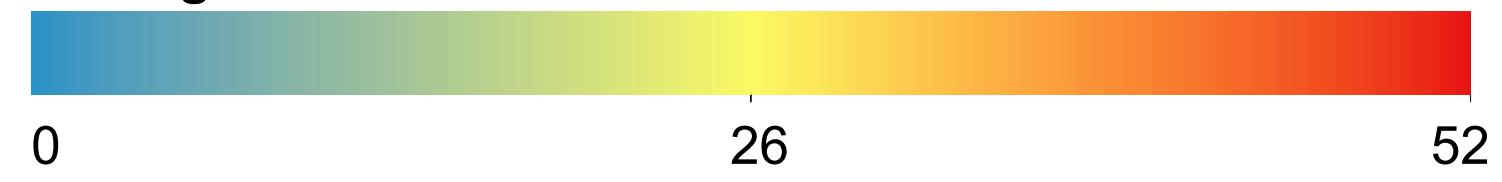


(c) Model: MIROC3.2

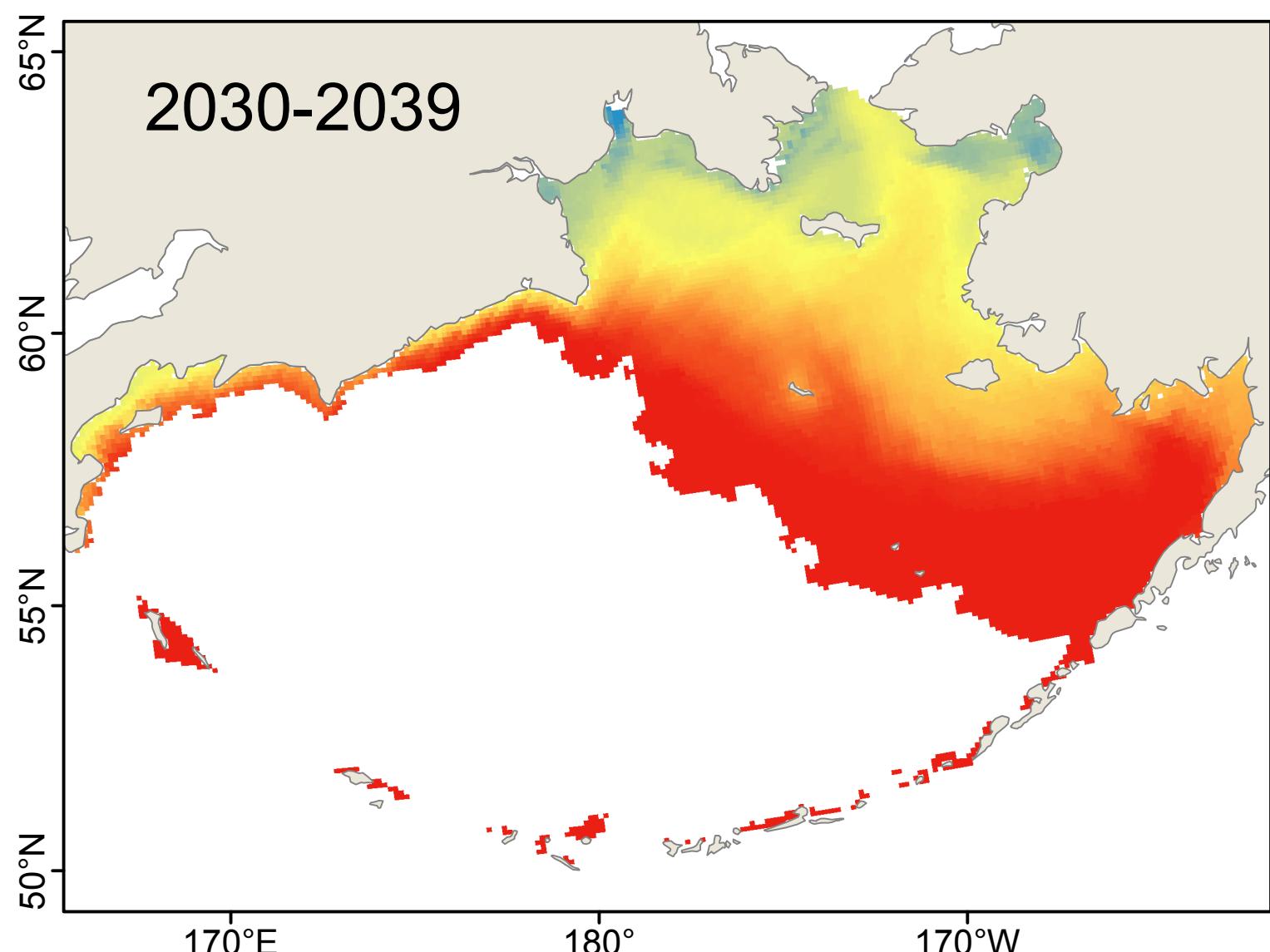
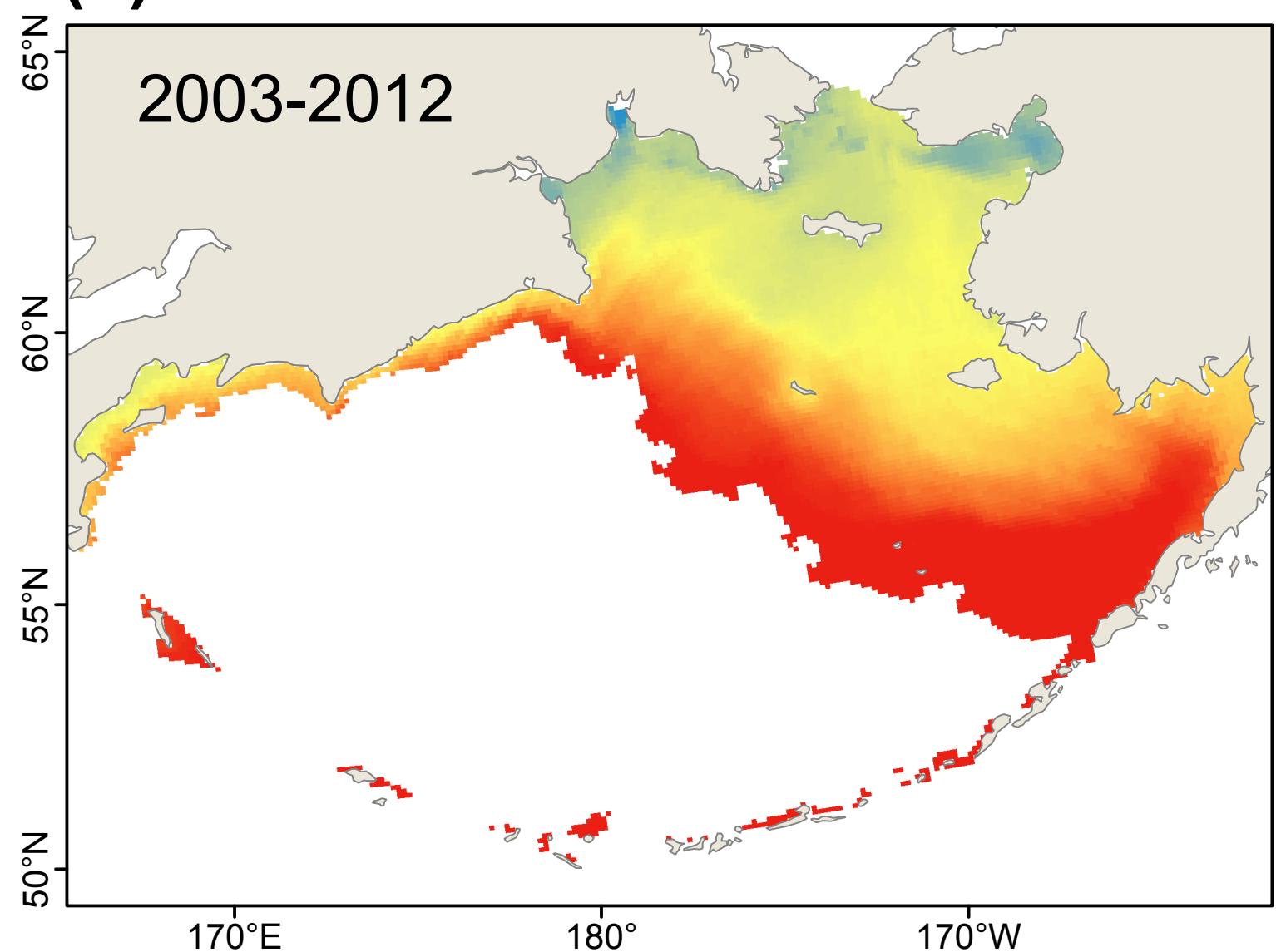


# *Melita nitida: Weekly Survival*

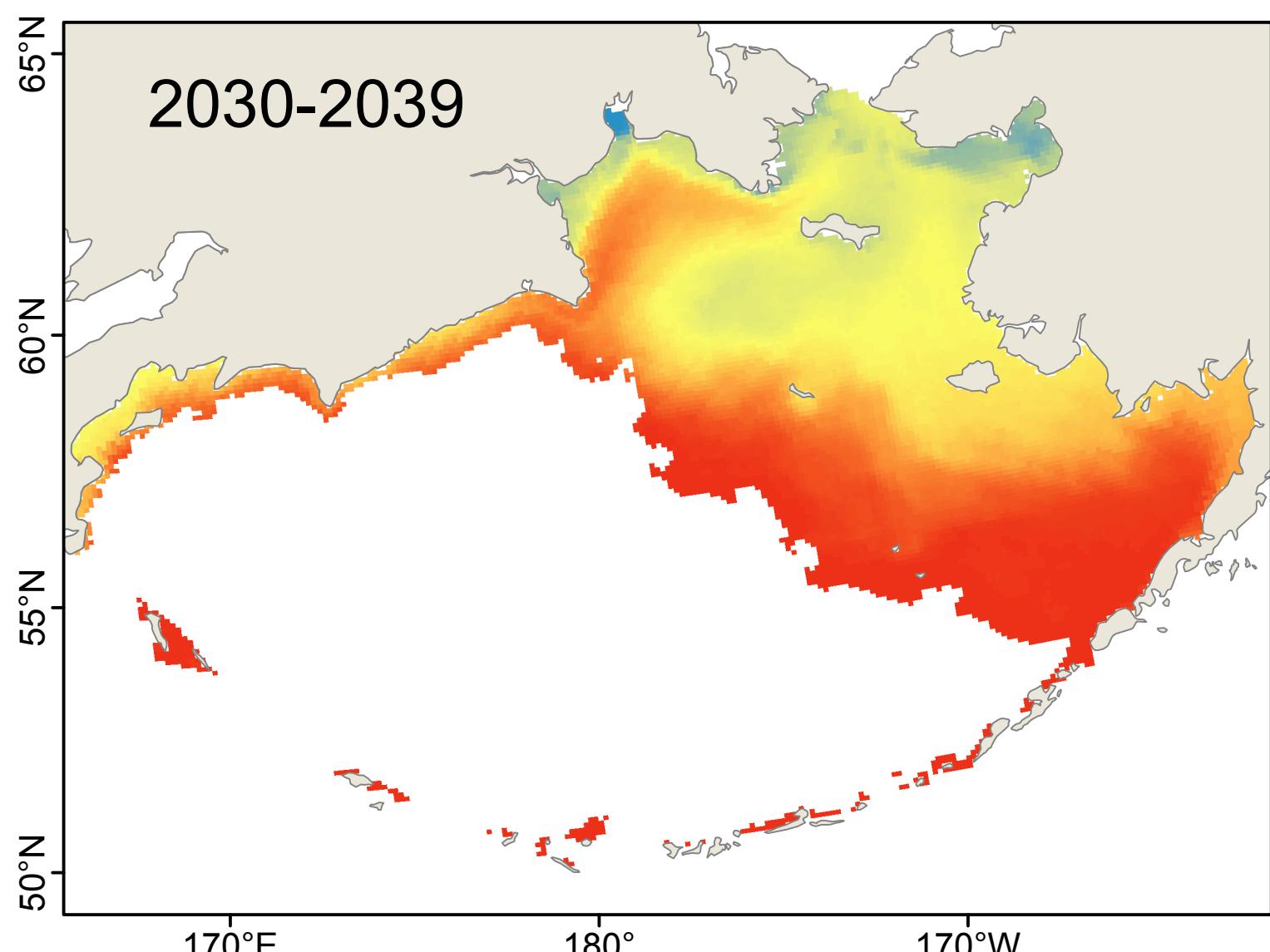
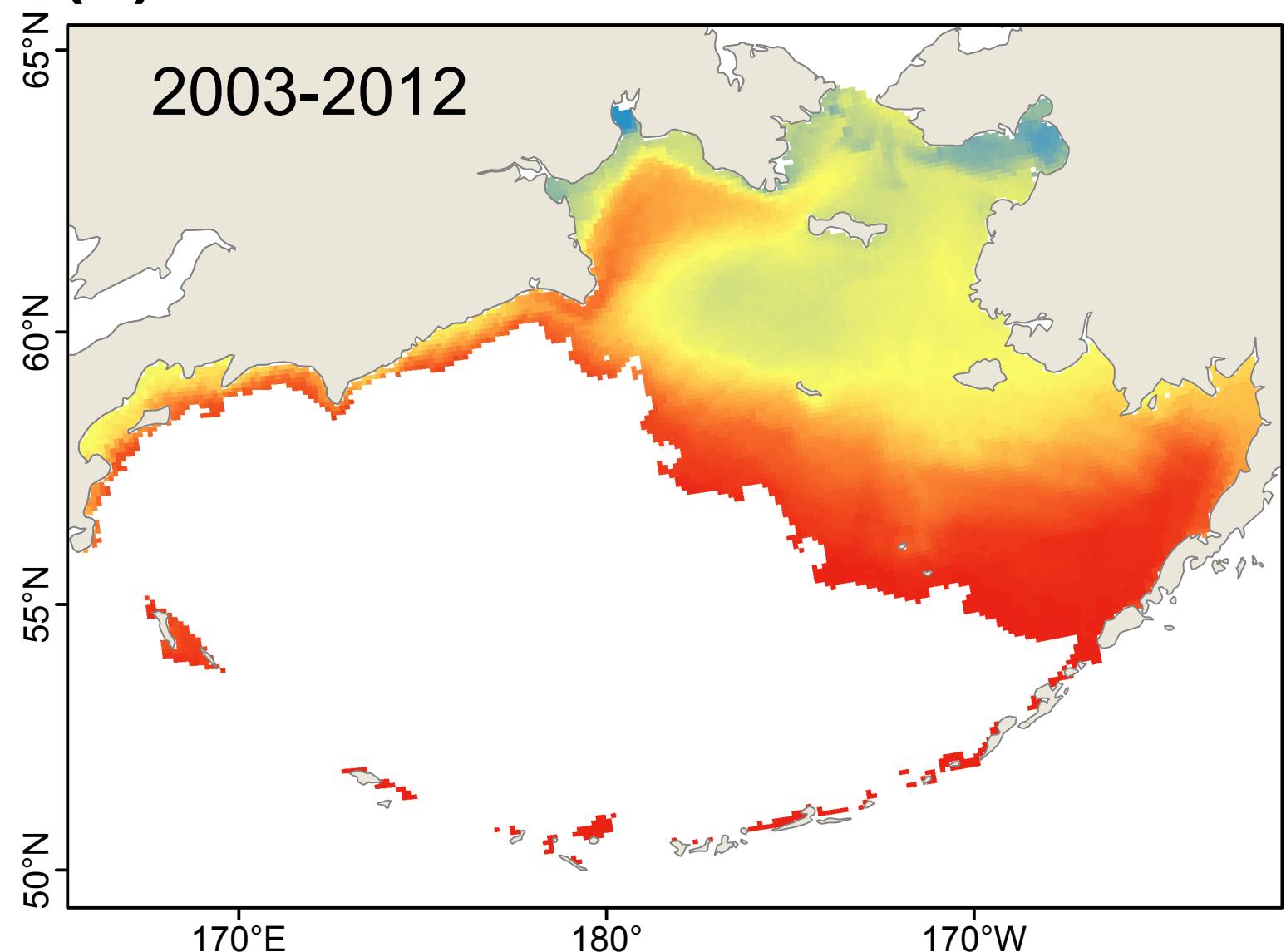
Average number of weeks of suitable habitat



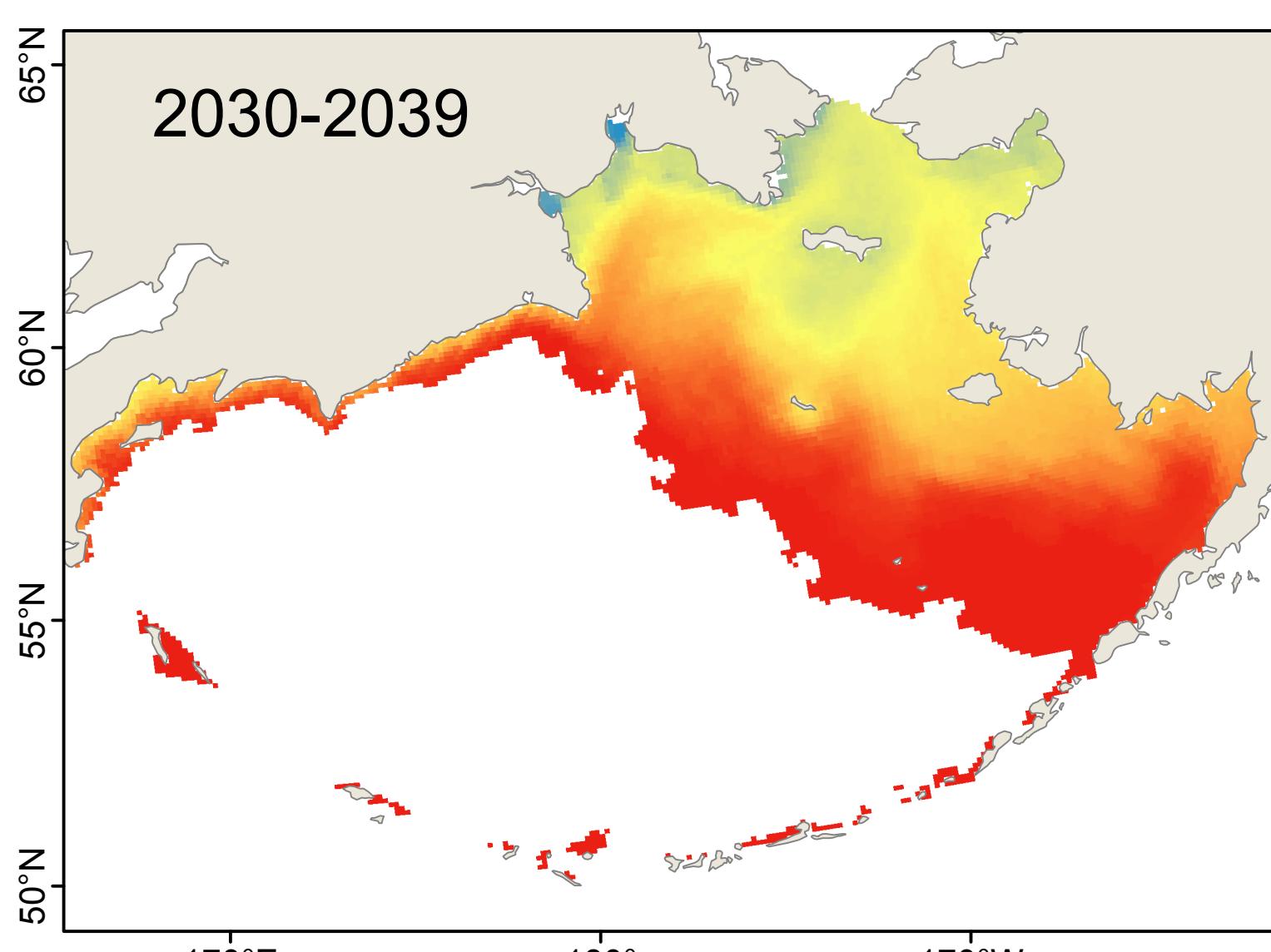
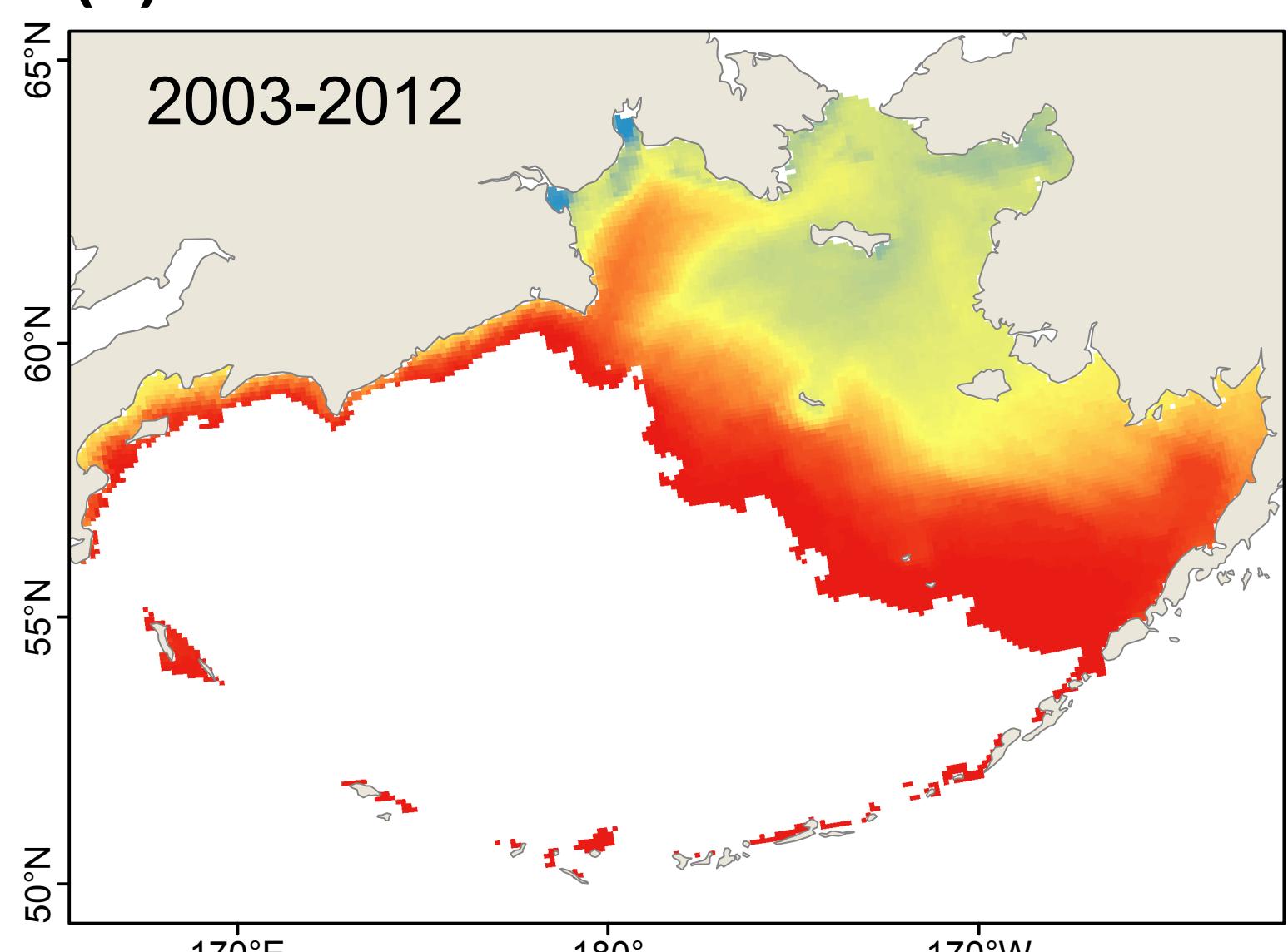
(a) Model: CGCM3-t47



(b) Model: ECHO-G



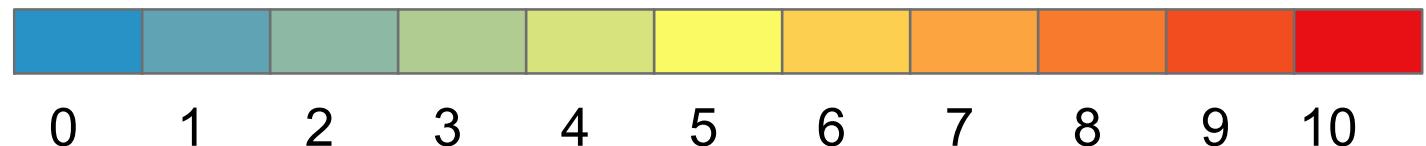
(c) Model: MIROC3.2



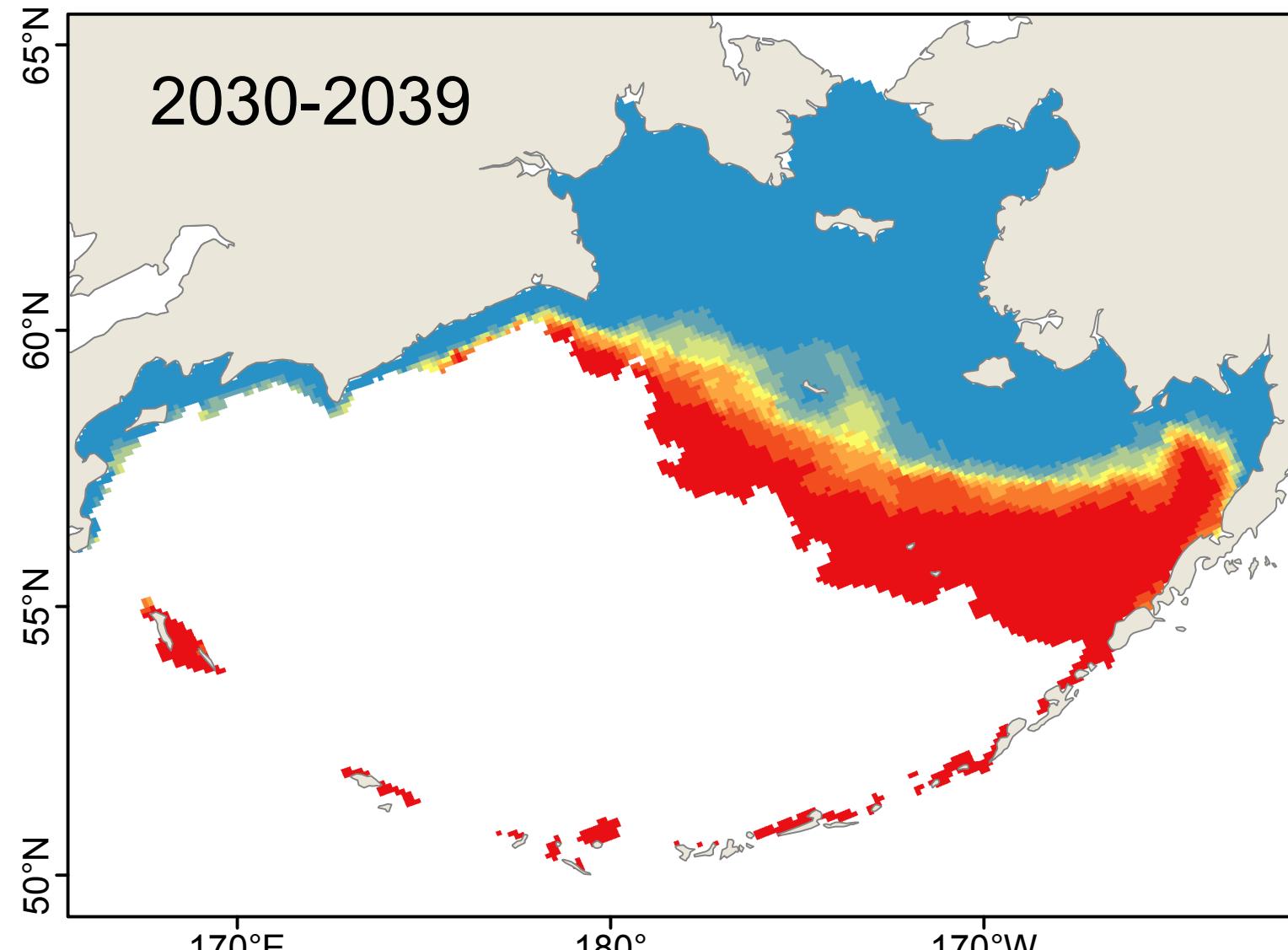
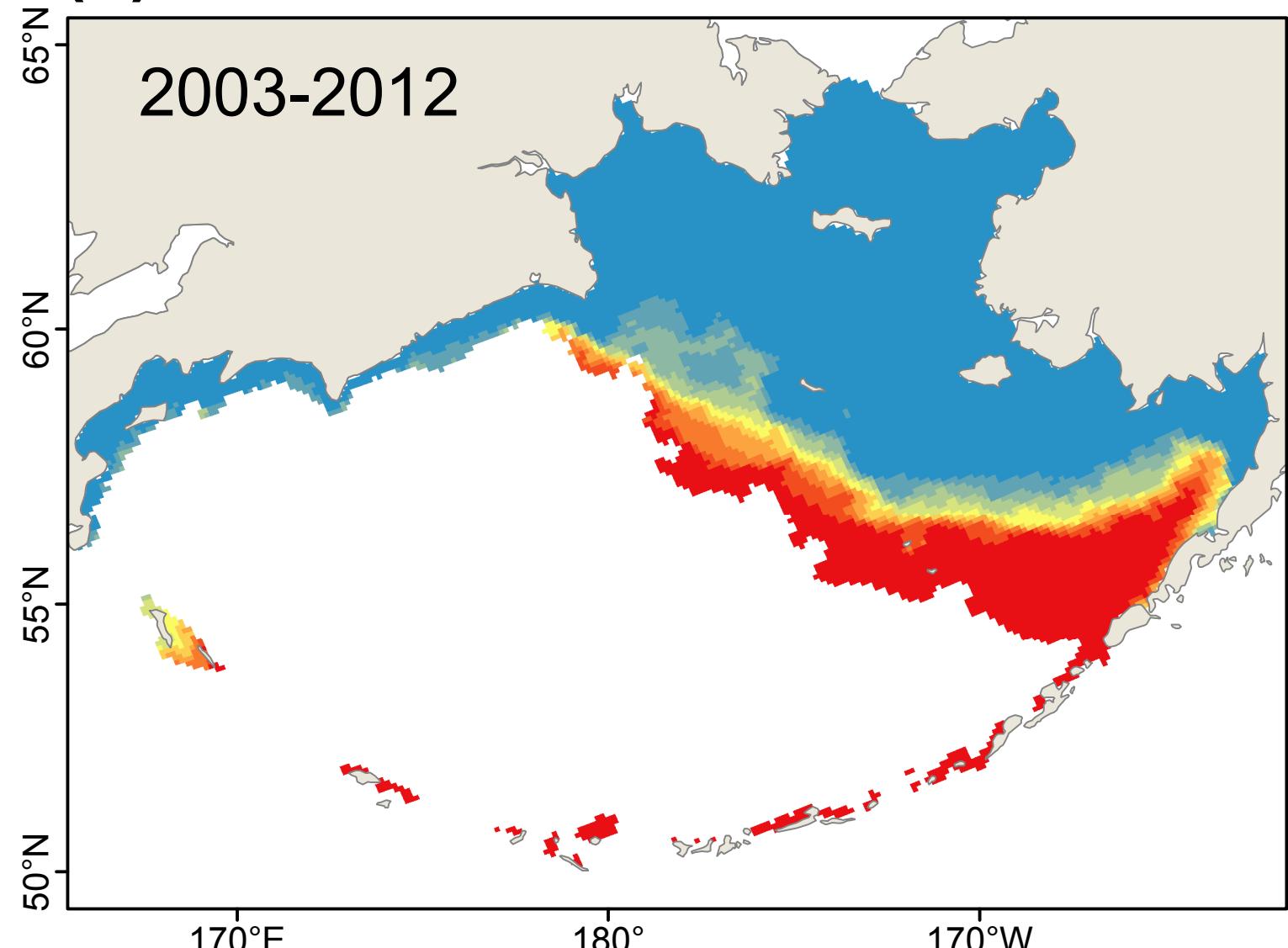
# *Amphibalanus amphitrite*: Year-round Survival

60

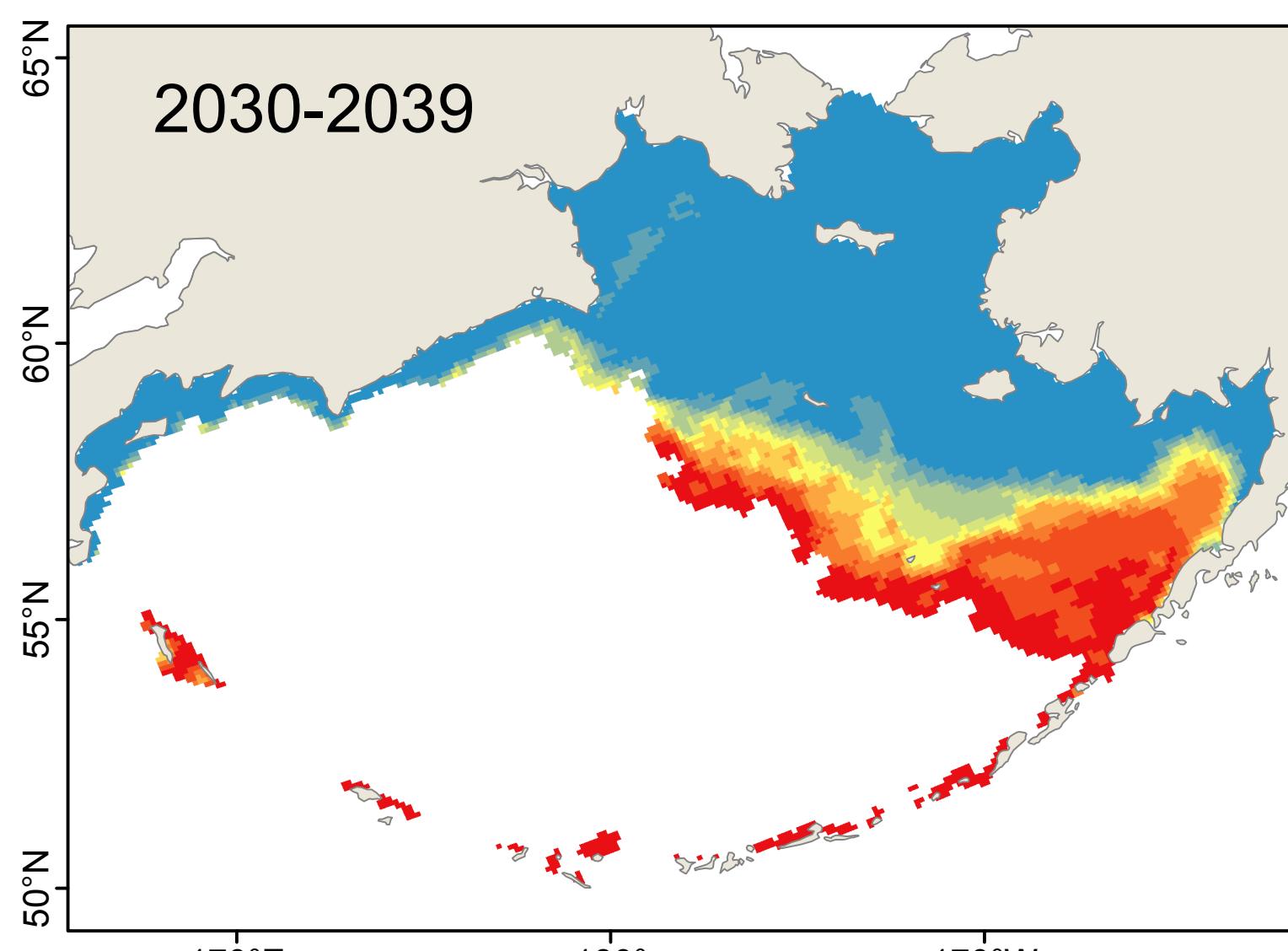
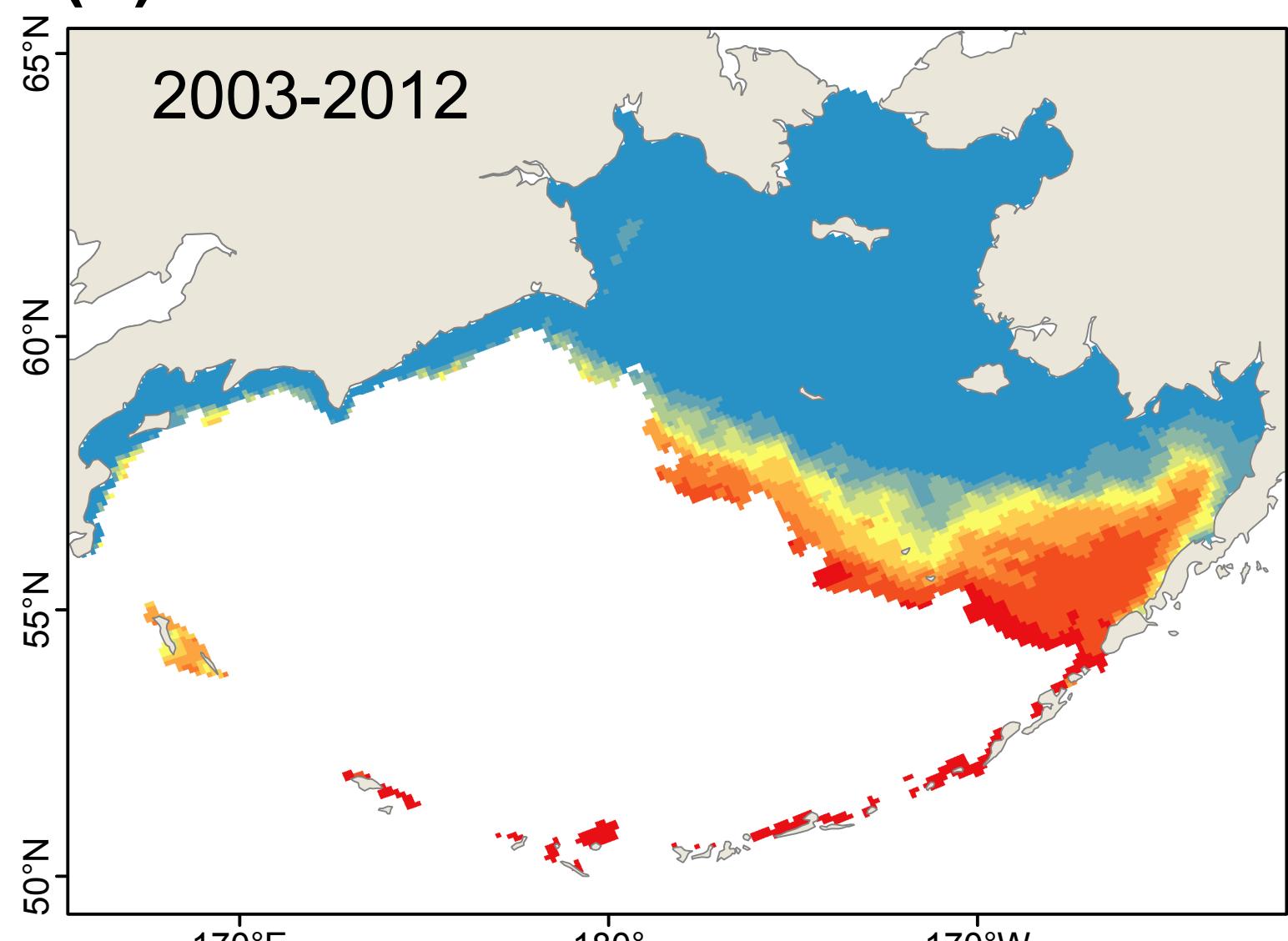
Number of years with suitable habitat



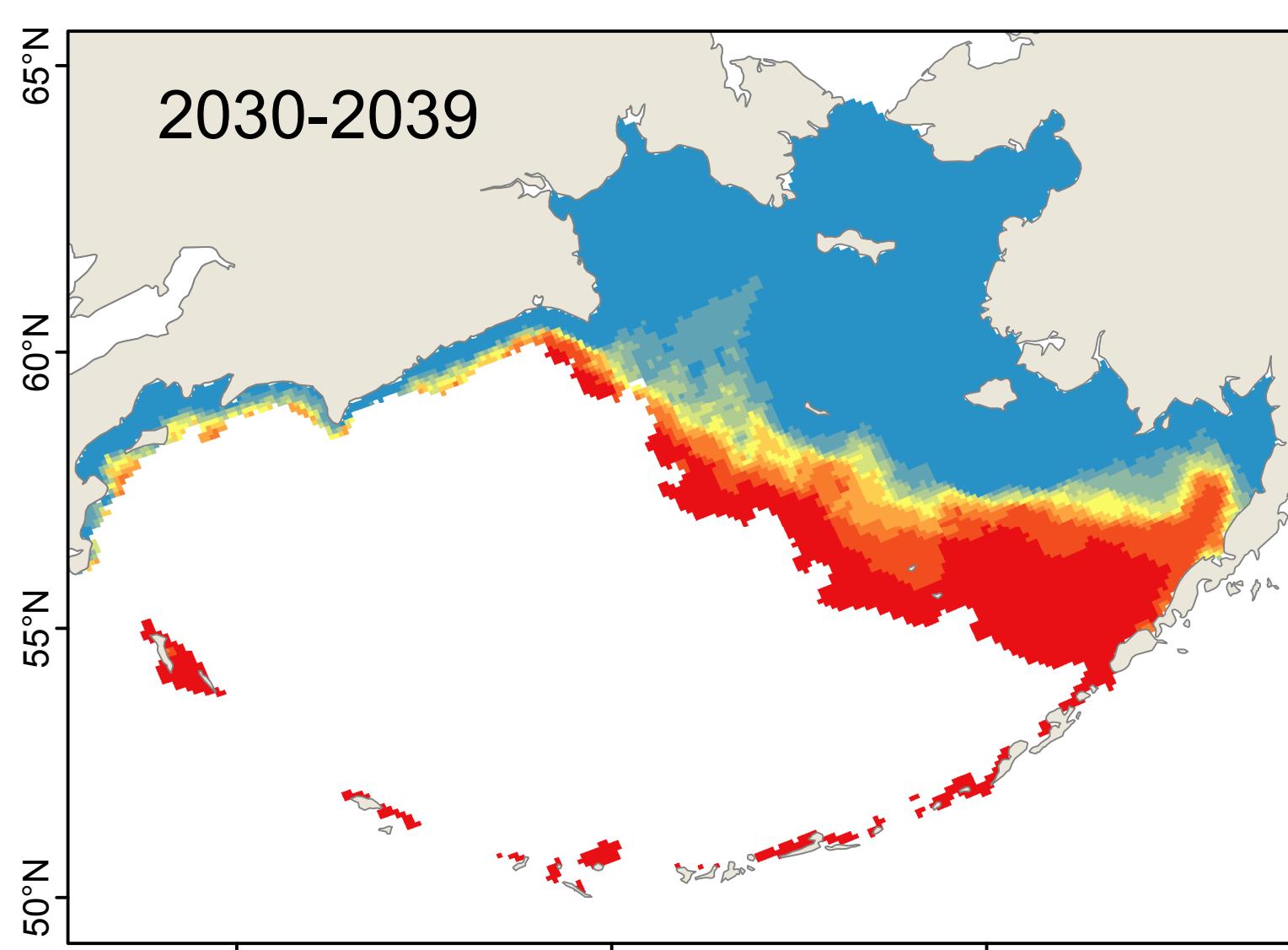
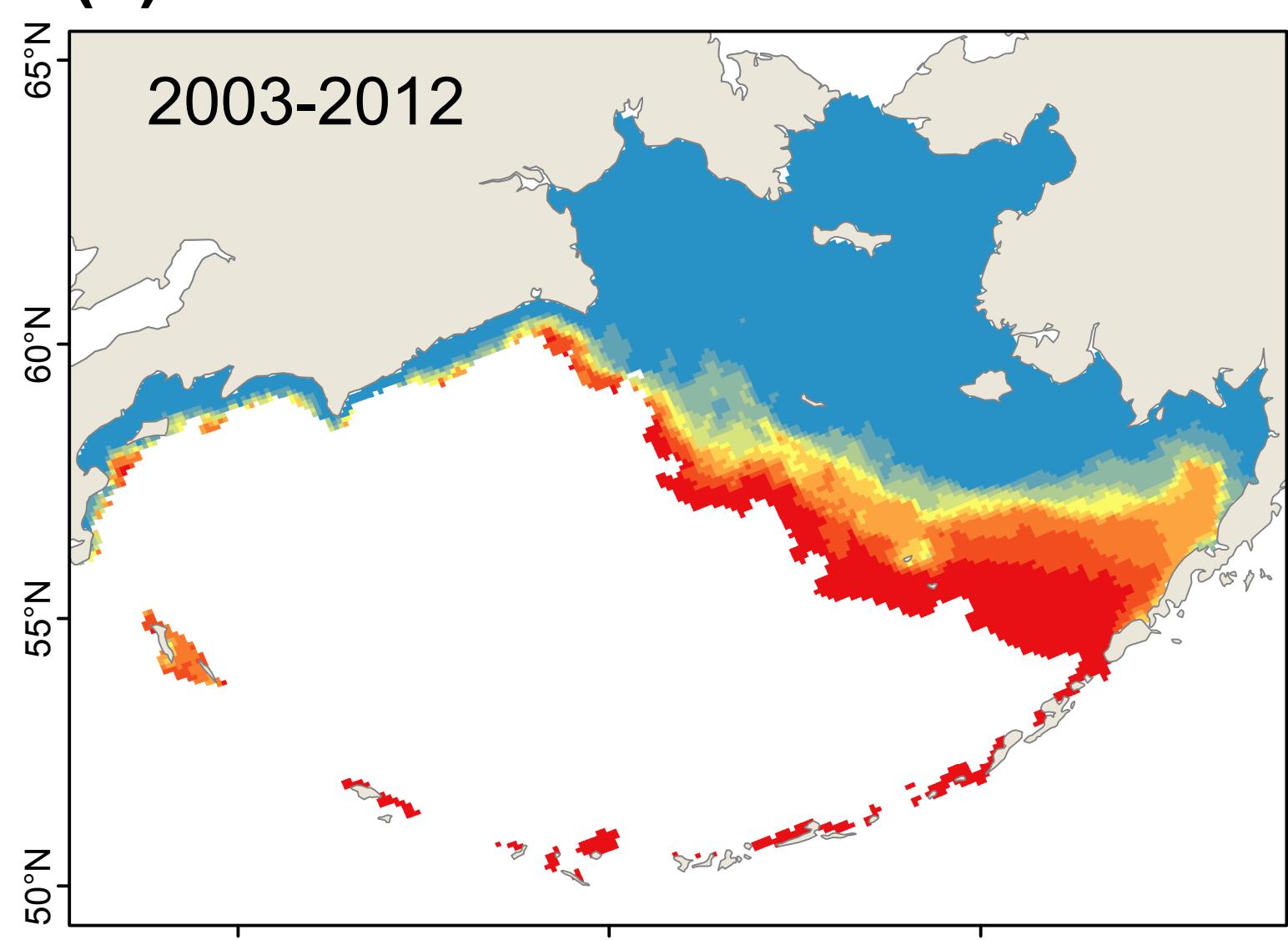
(a) Model: CGCM3-t47



(b) Model: ECHO-G

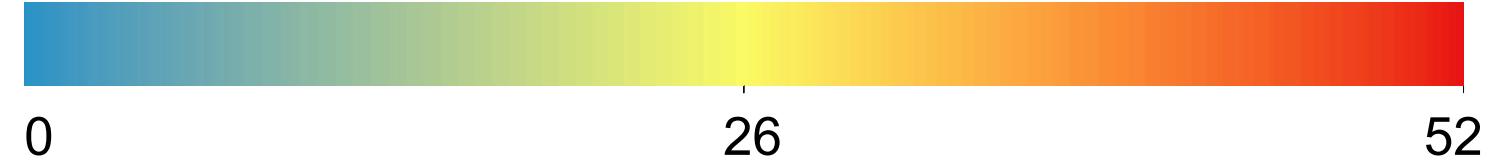


(c) Model: MIROC3.2

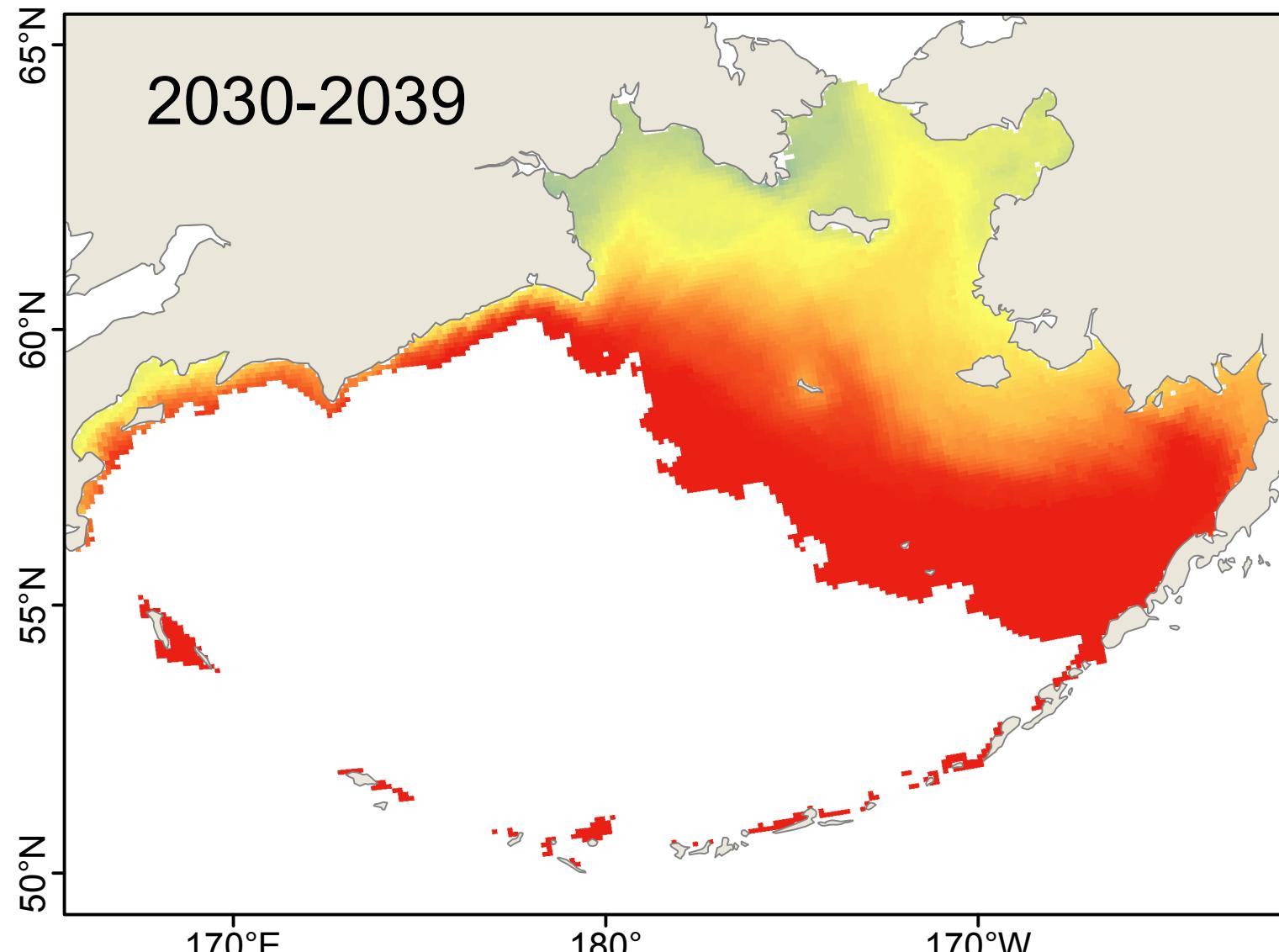
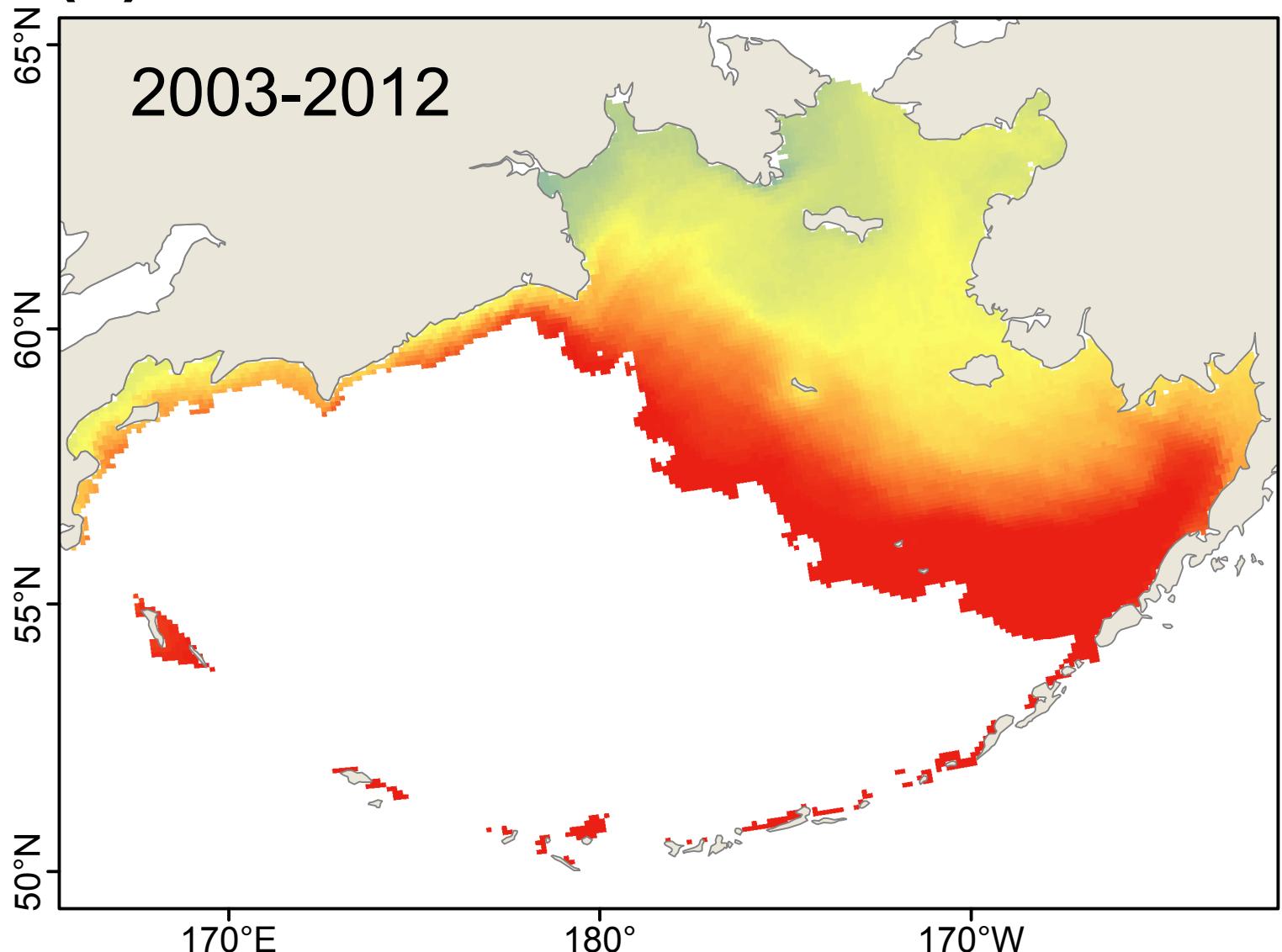


# *Amphibalanus amphitrite: Weekly Survival*

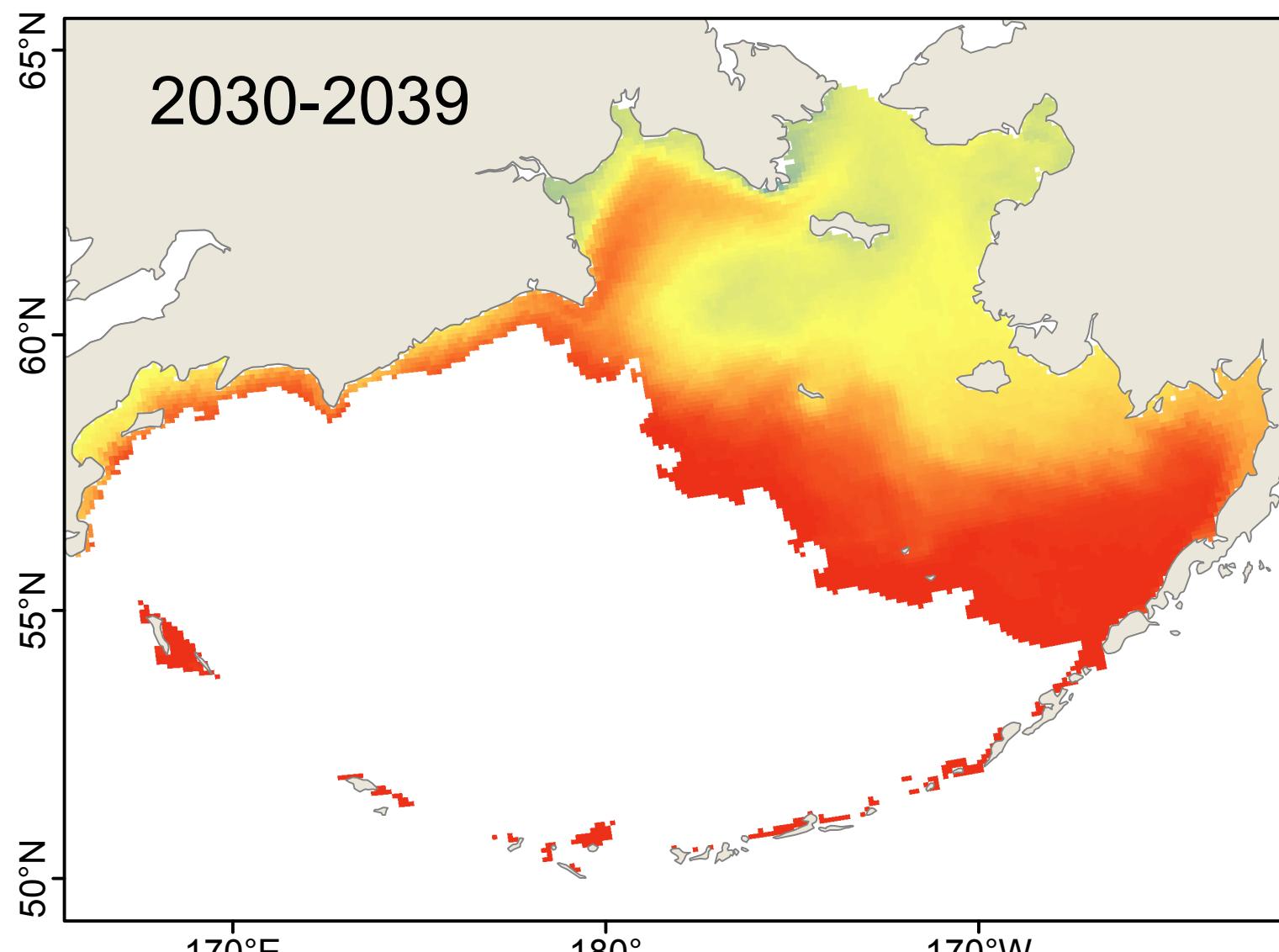
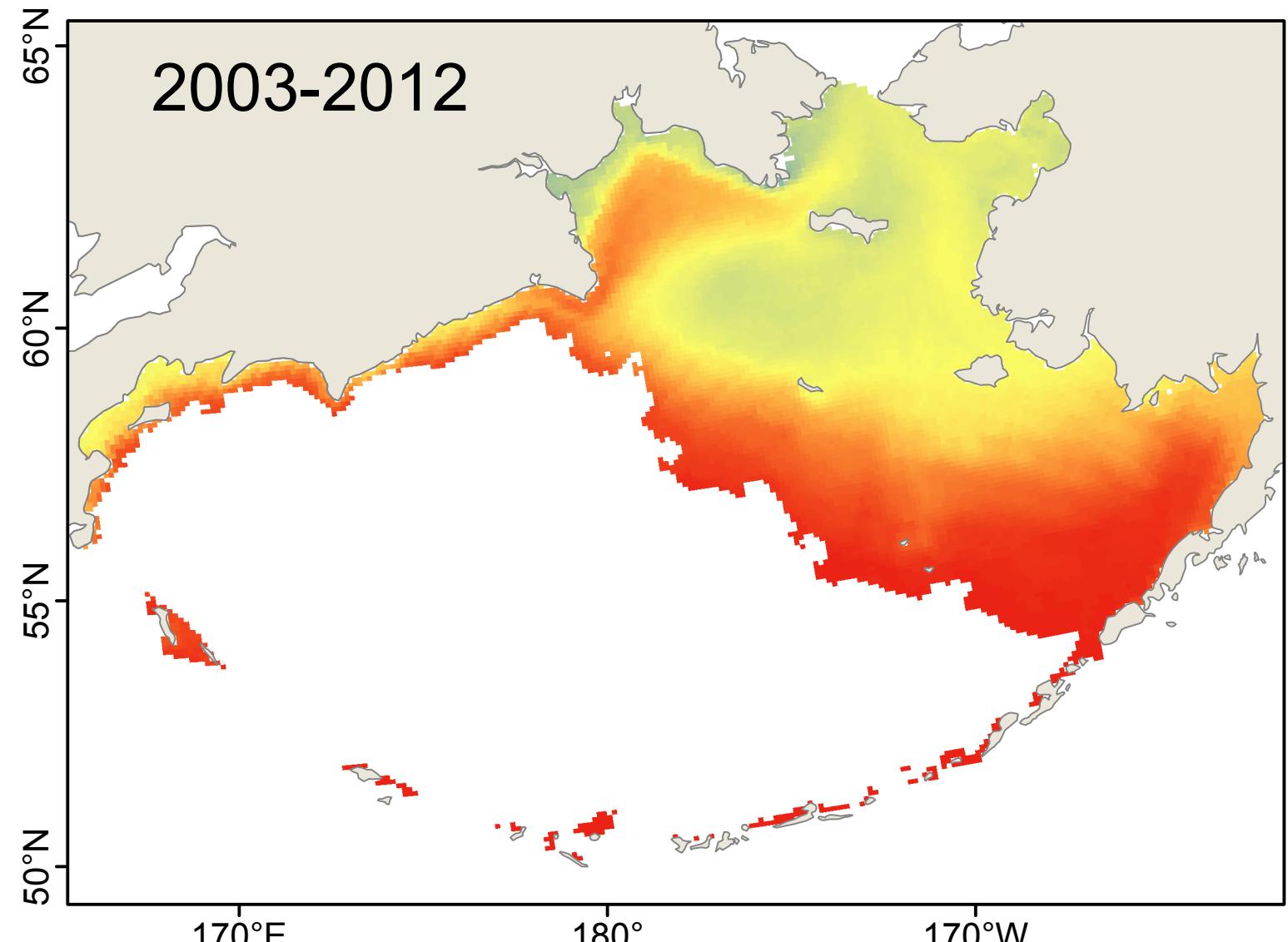
Average number of weeks of suitable habitat



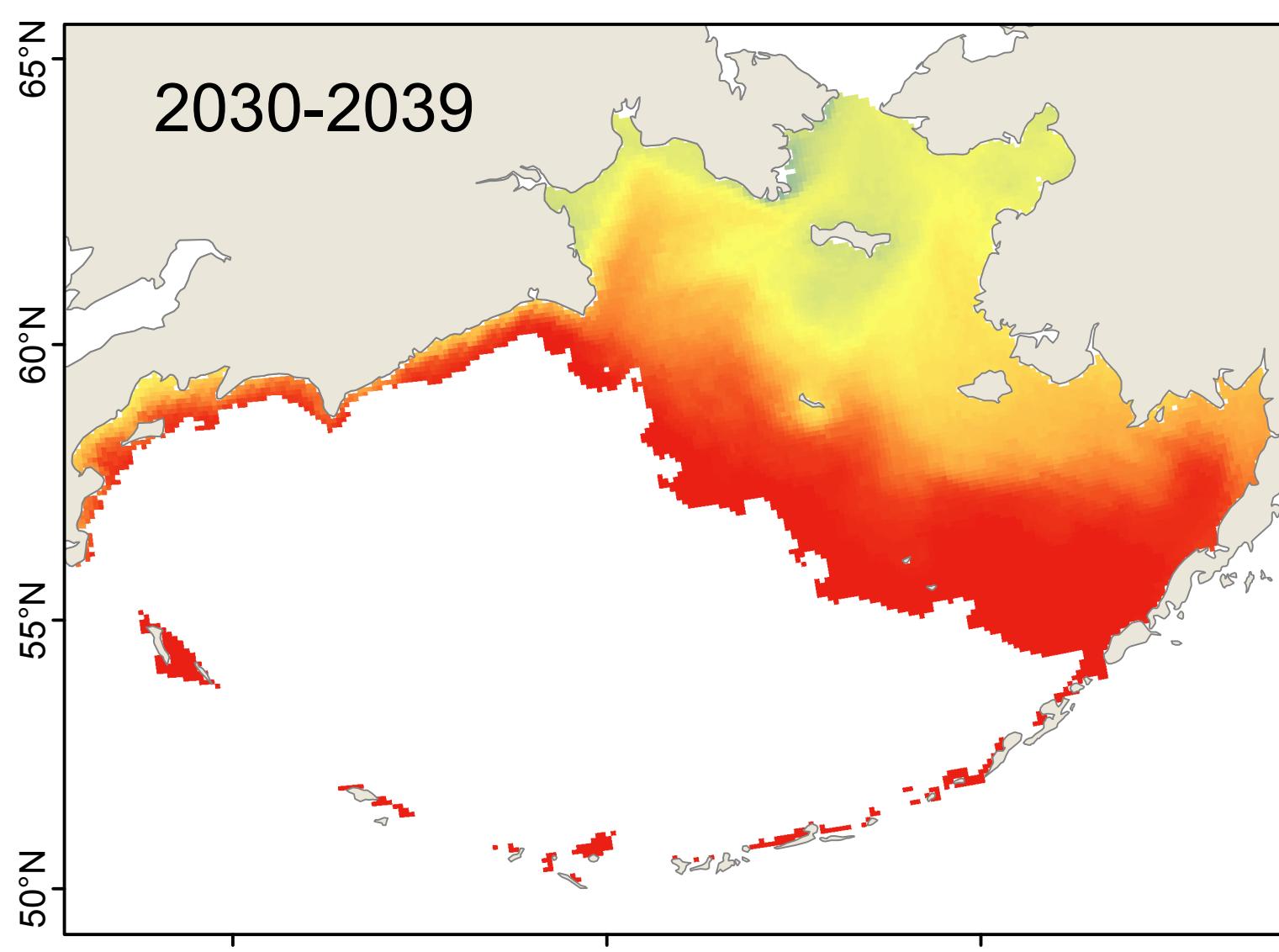
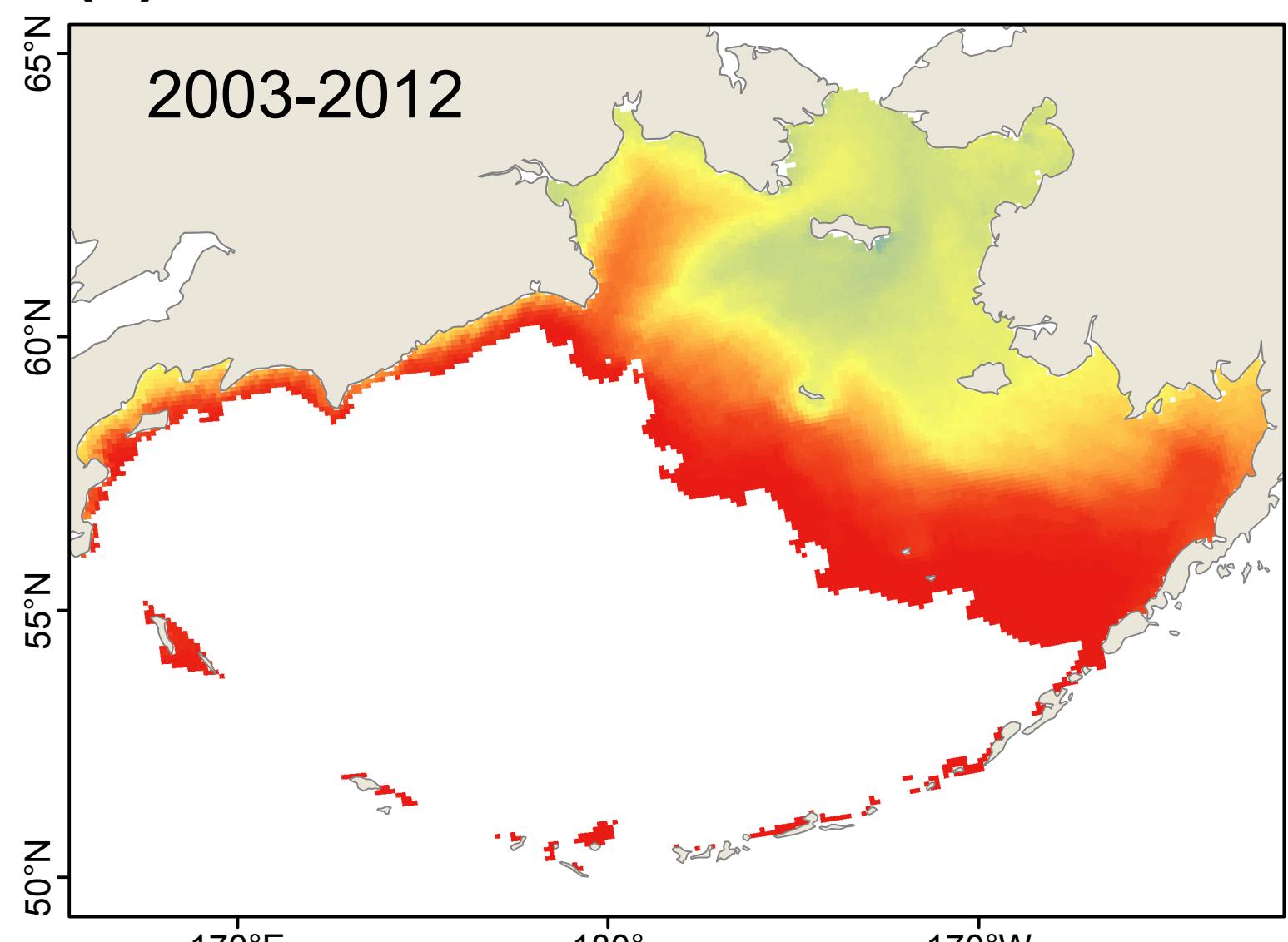
(a) Model: CGCM3-t47



(b) Model: ECHO-G

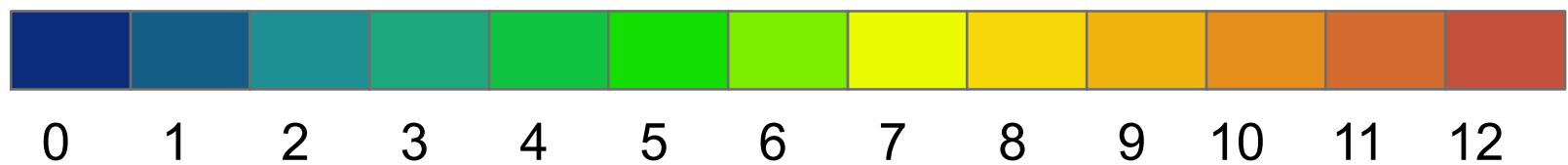


(c) Model: MIROC3.2

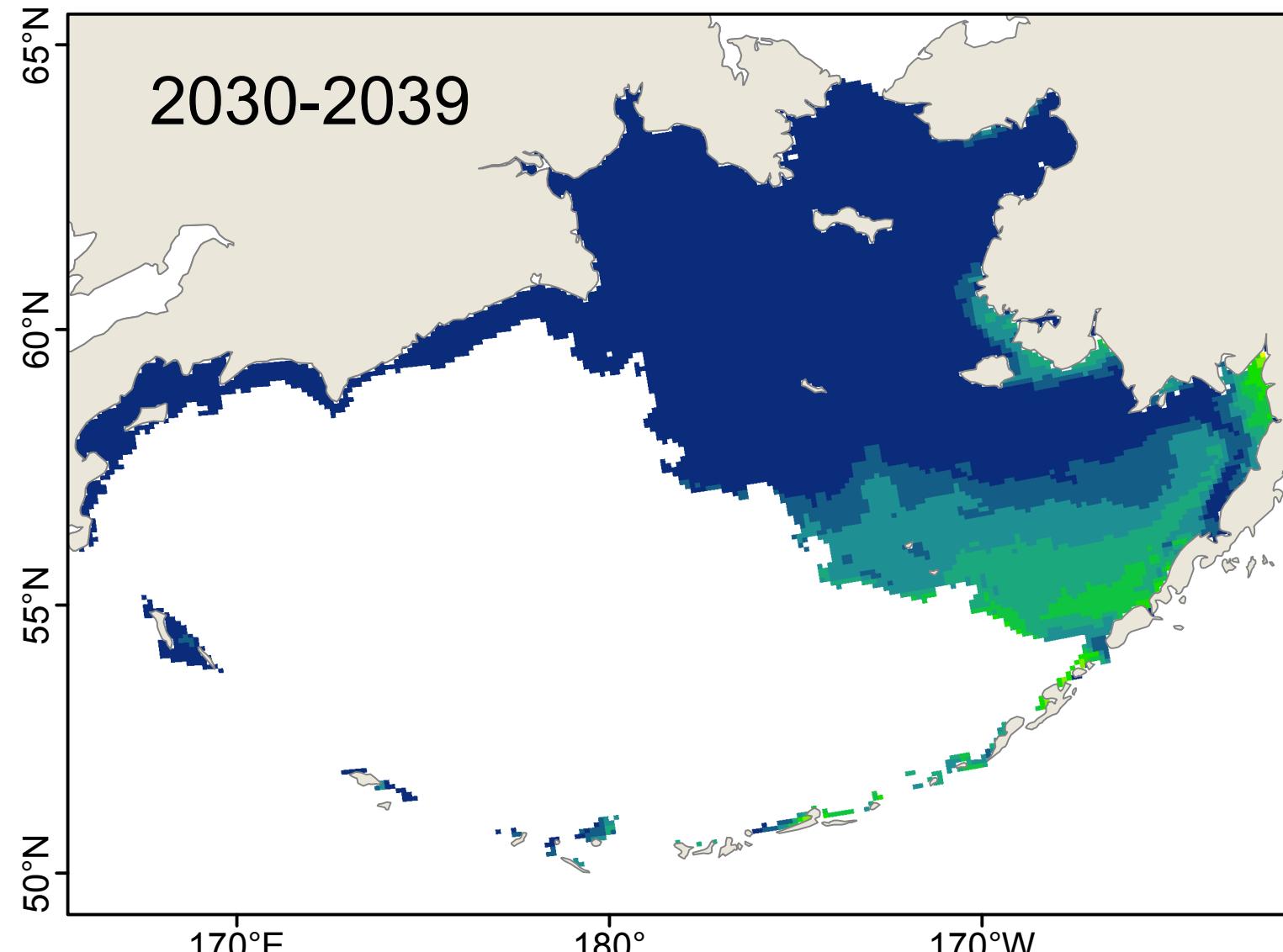
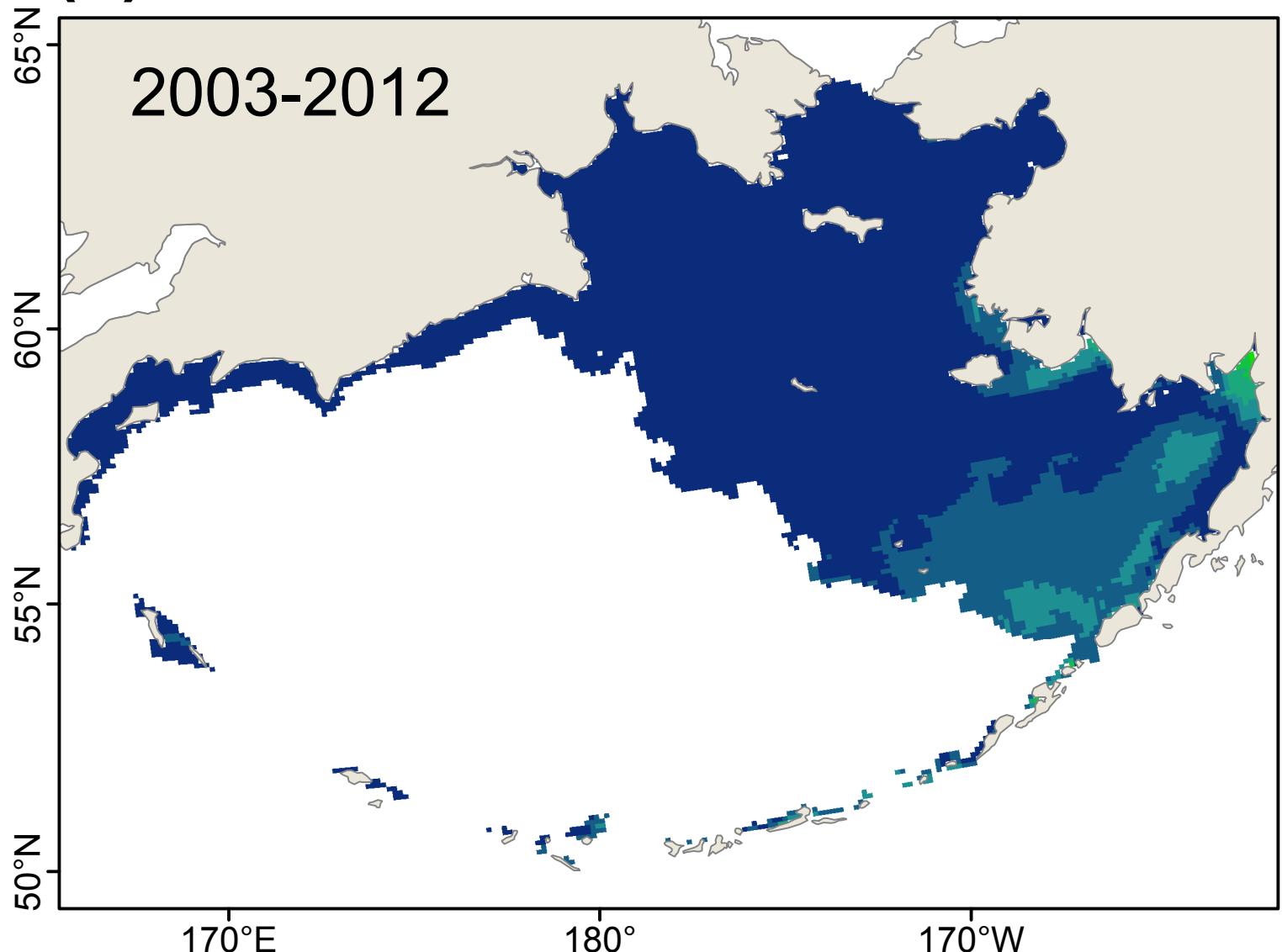


# *Amphibalanus amphitrite: Reproduction*

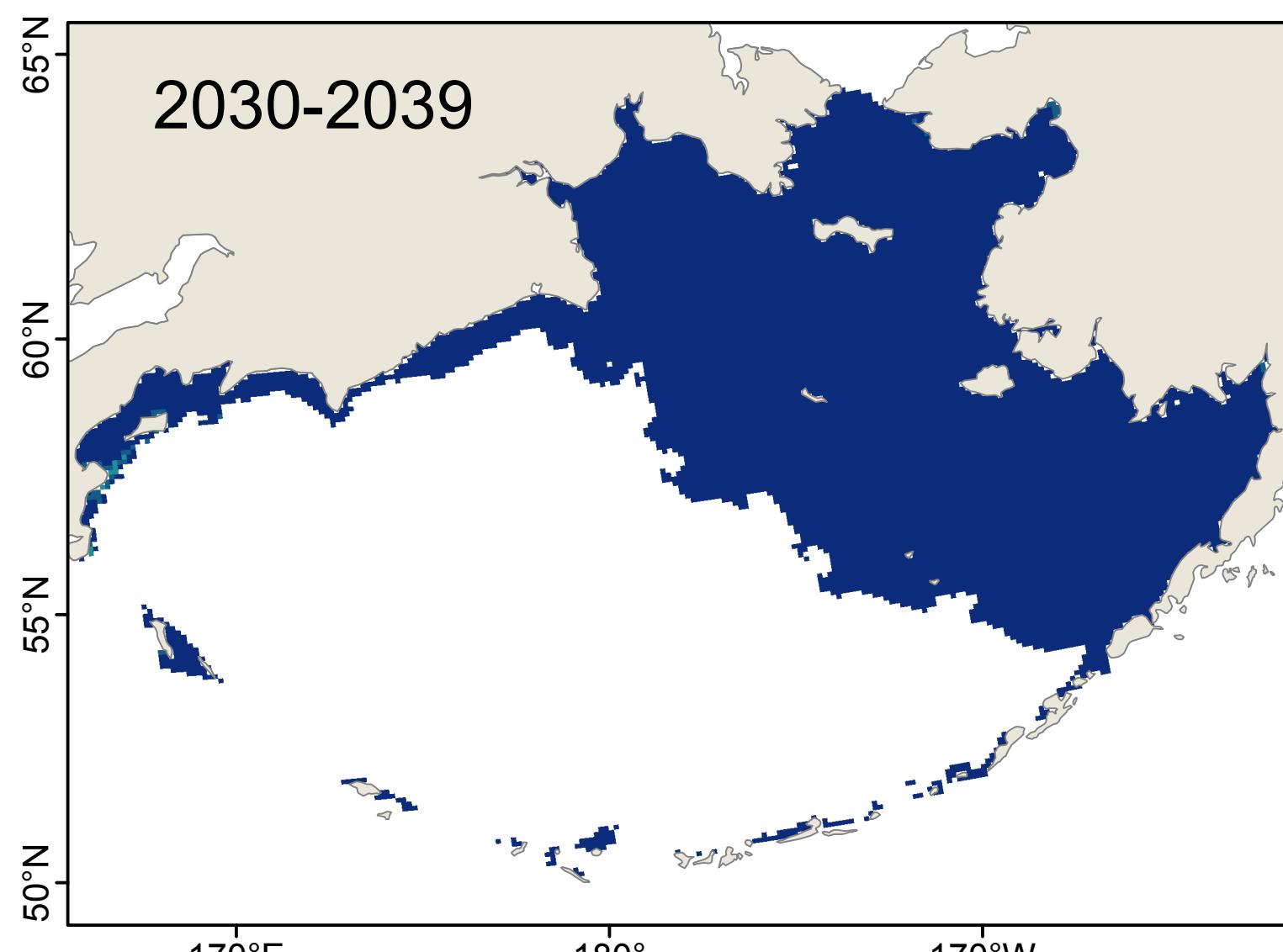
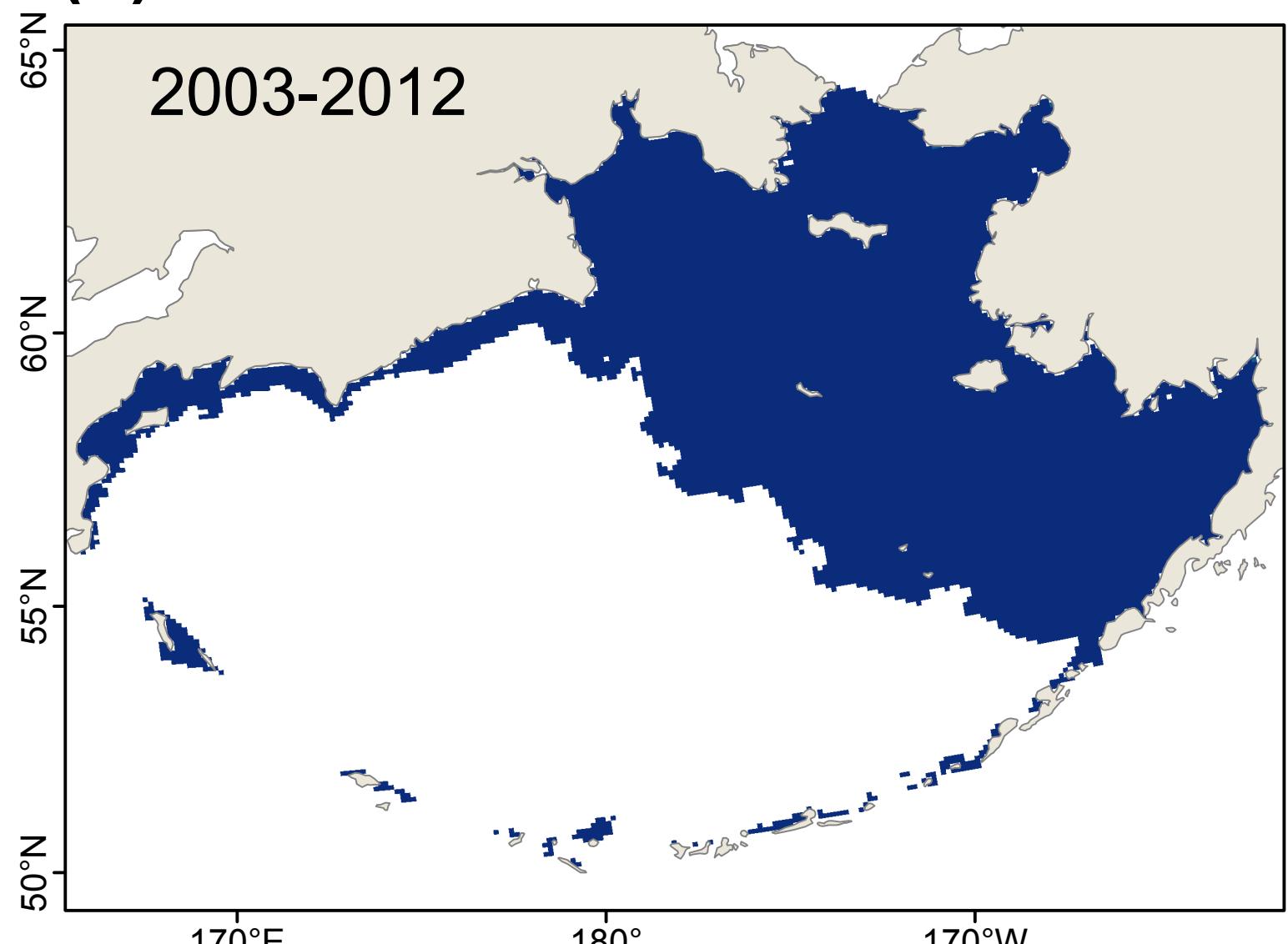
Average number of consecutive weeks of suitable habitat



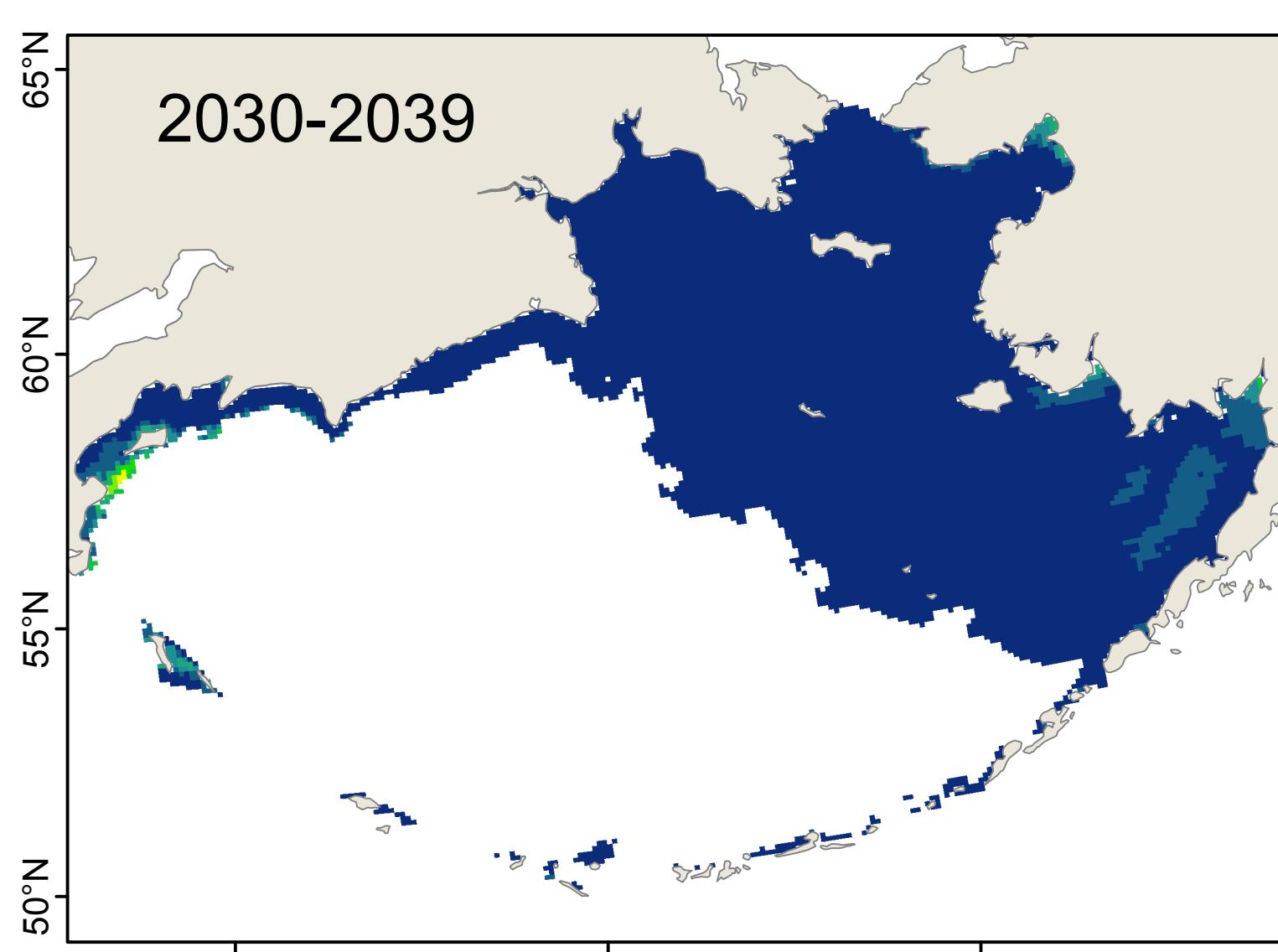
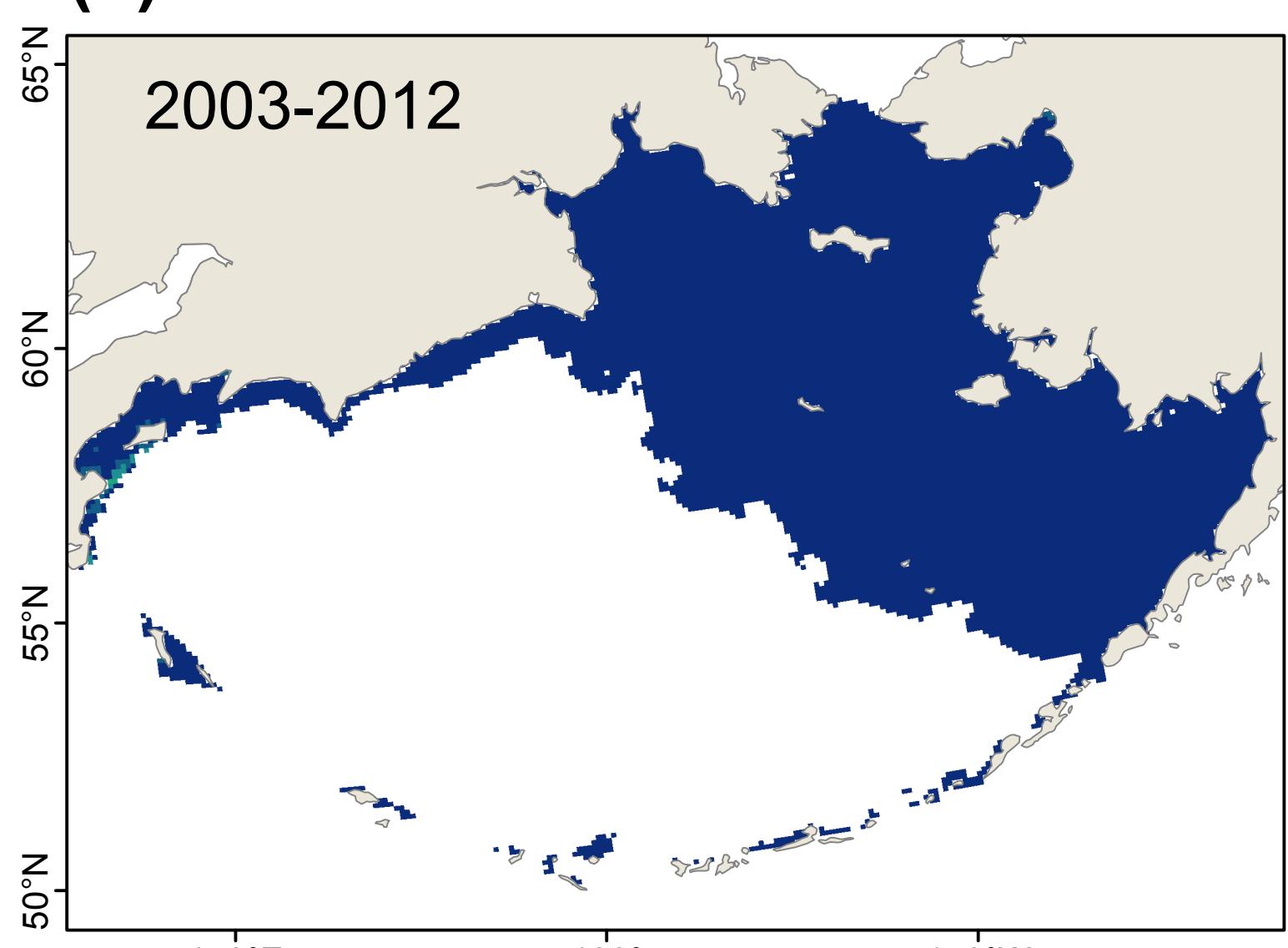
(a) Model: CGCM3-t47



(b) Model: ECHO-G

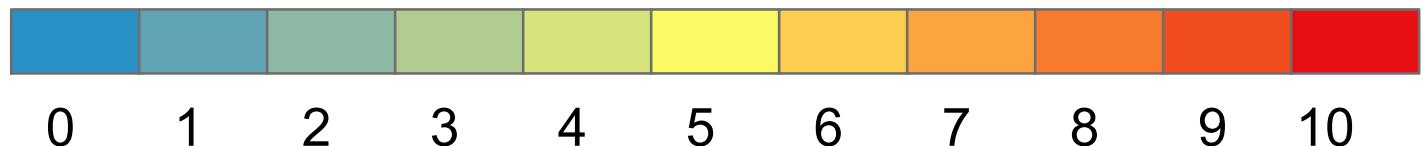


(c) Model: MIROC3.2

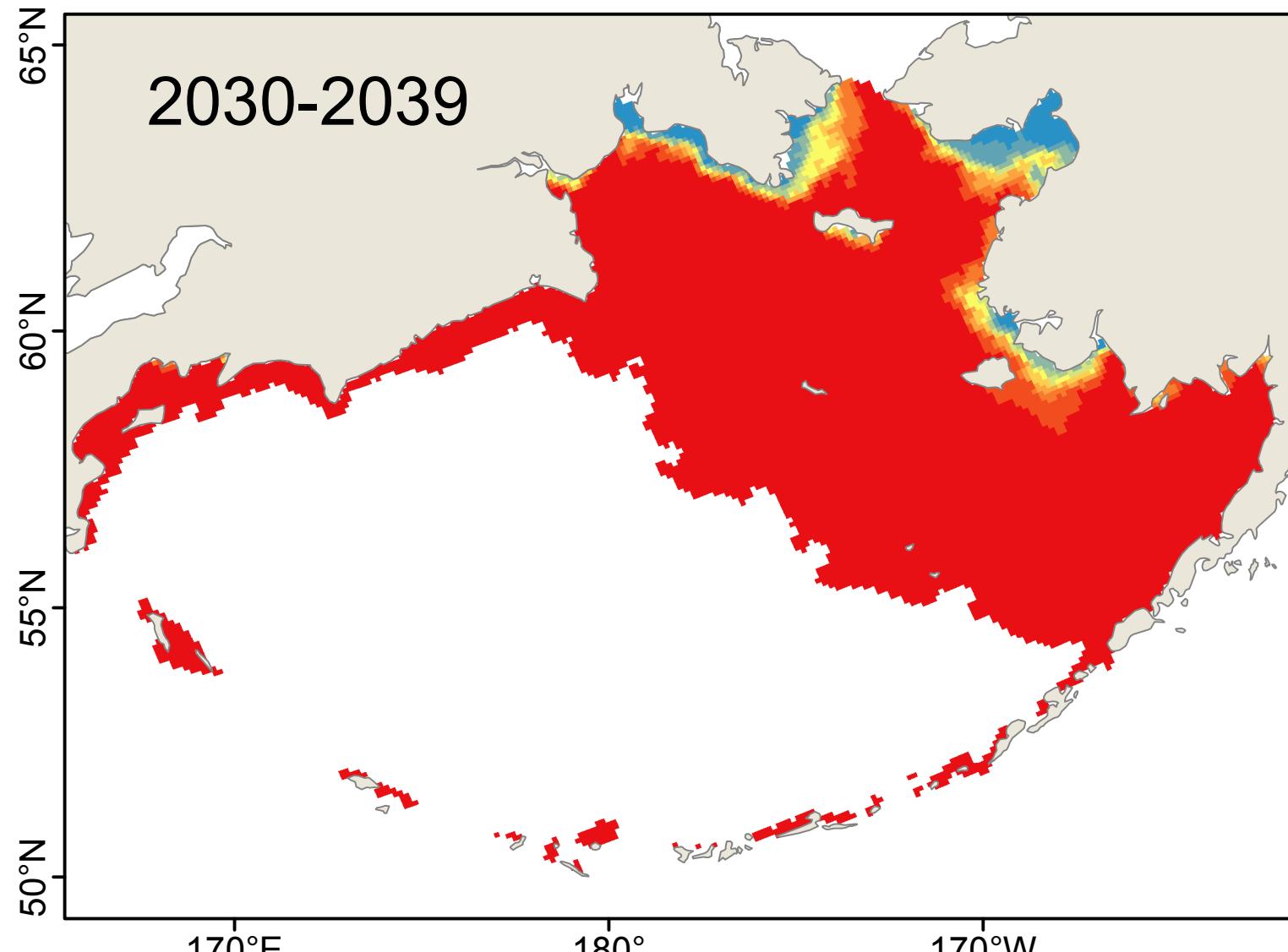
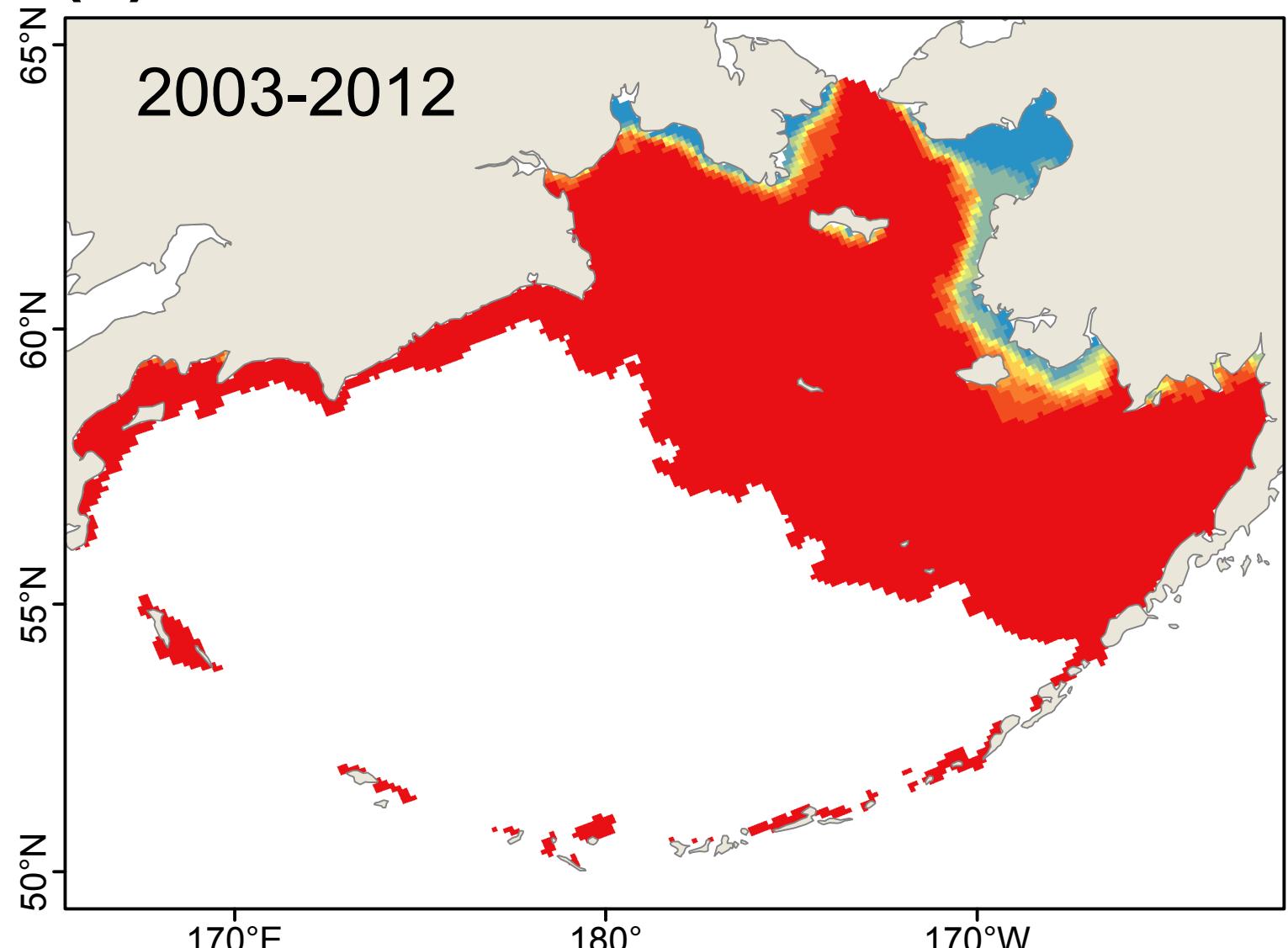


# *Amphibalanus improvisus*: Year-round Survival

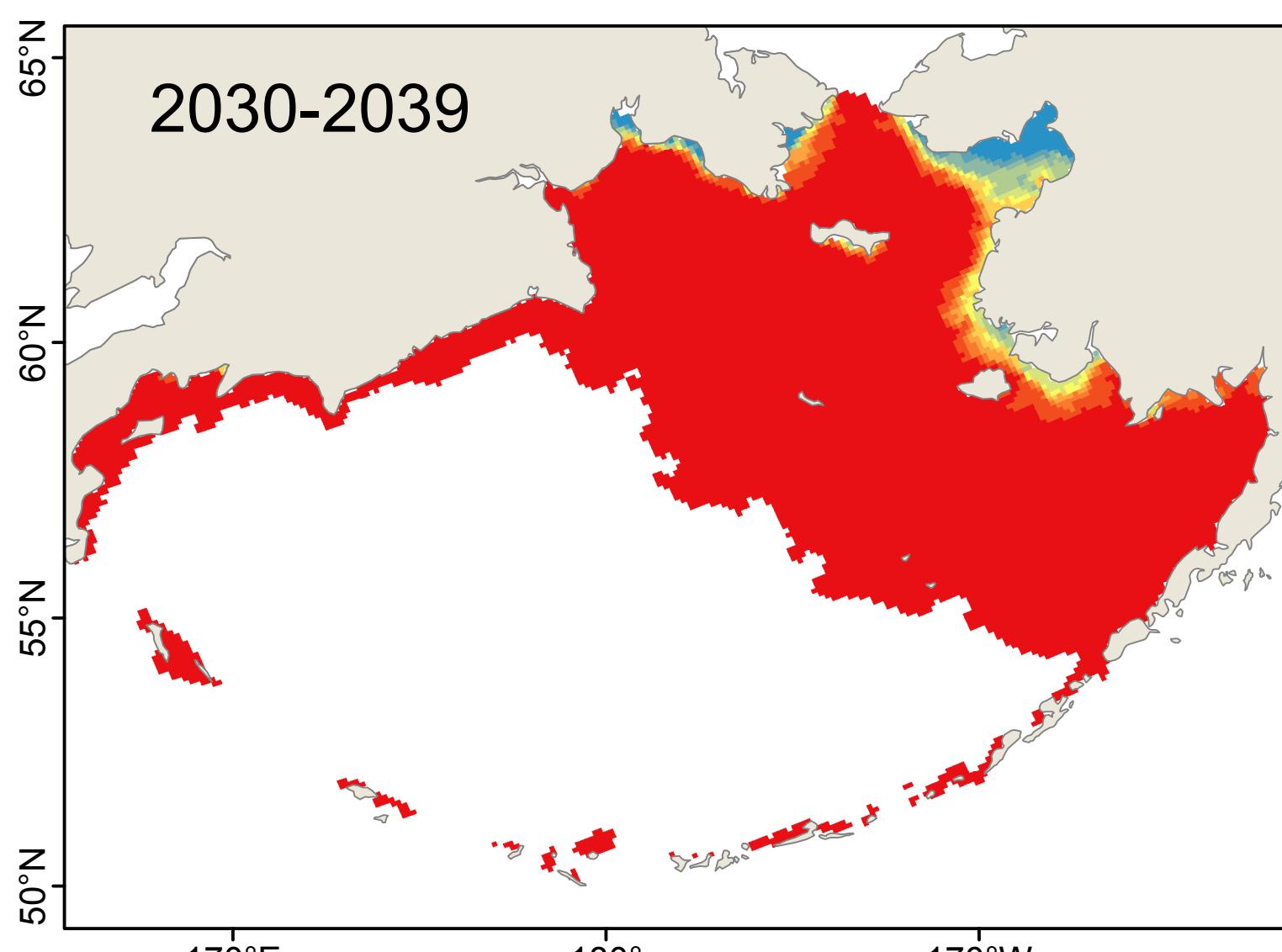
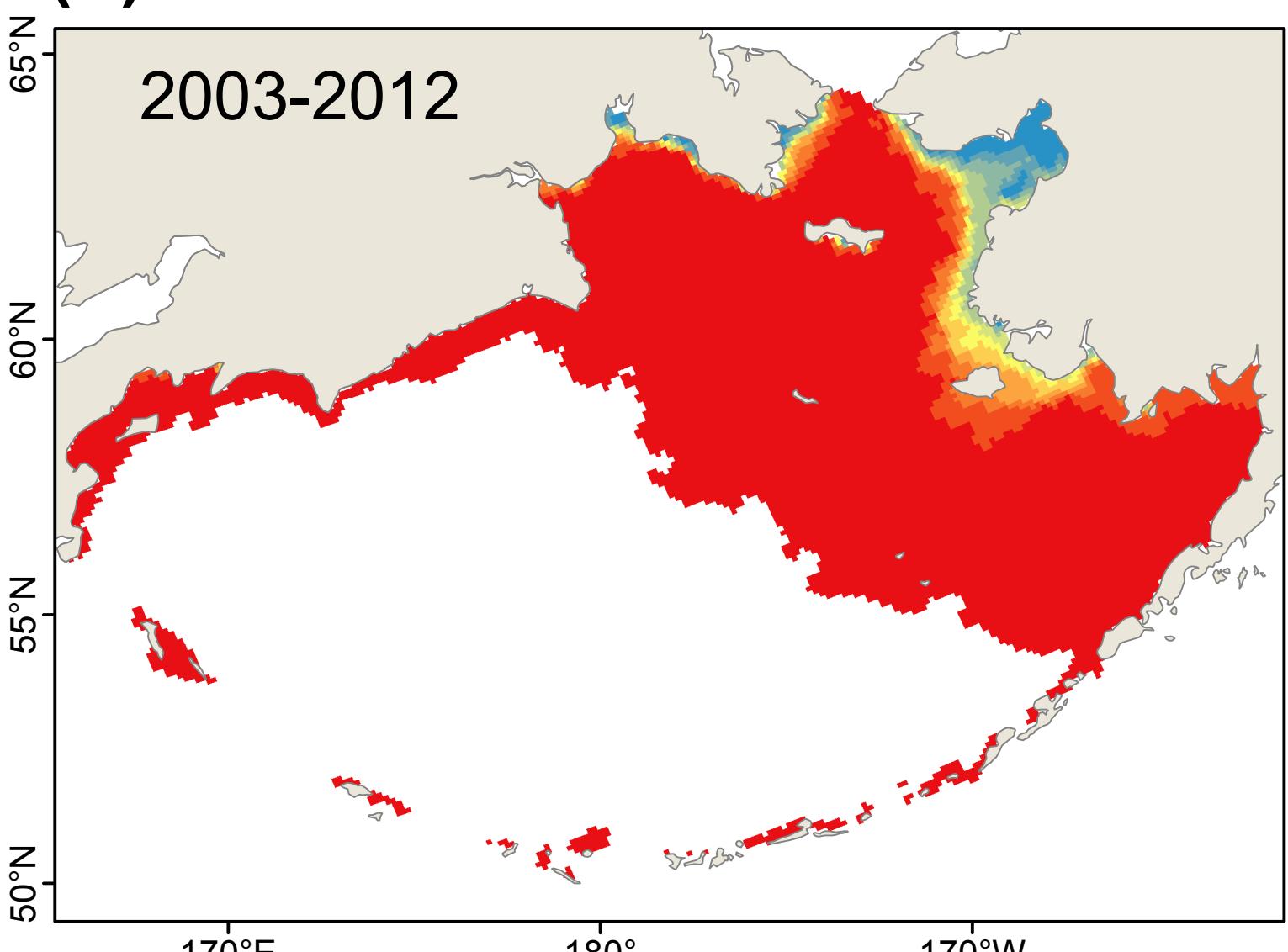
Number of years with suitable habitat



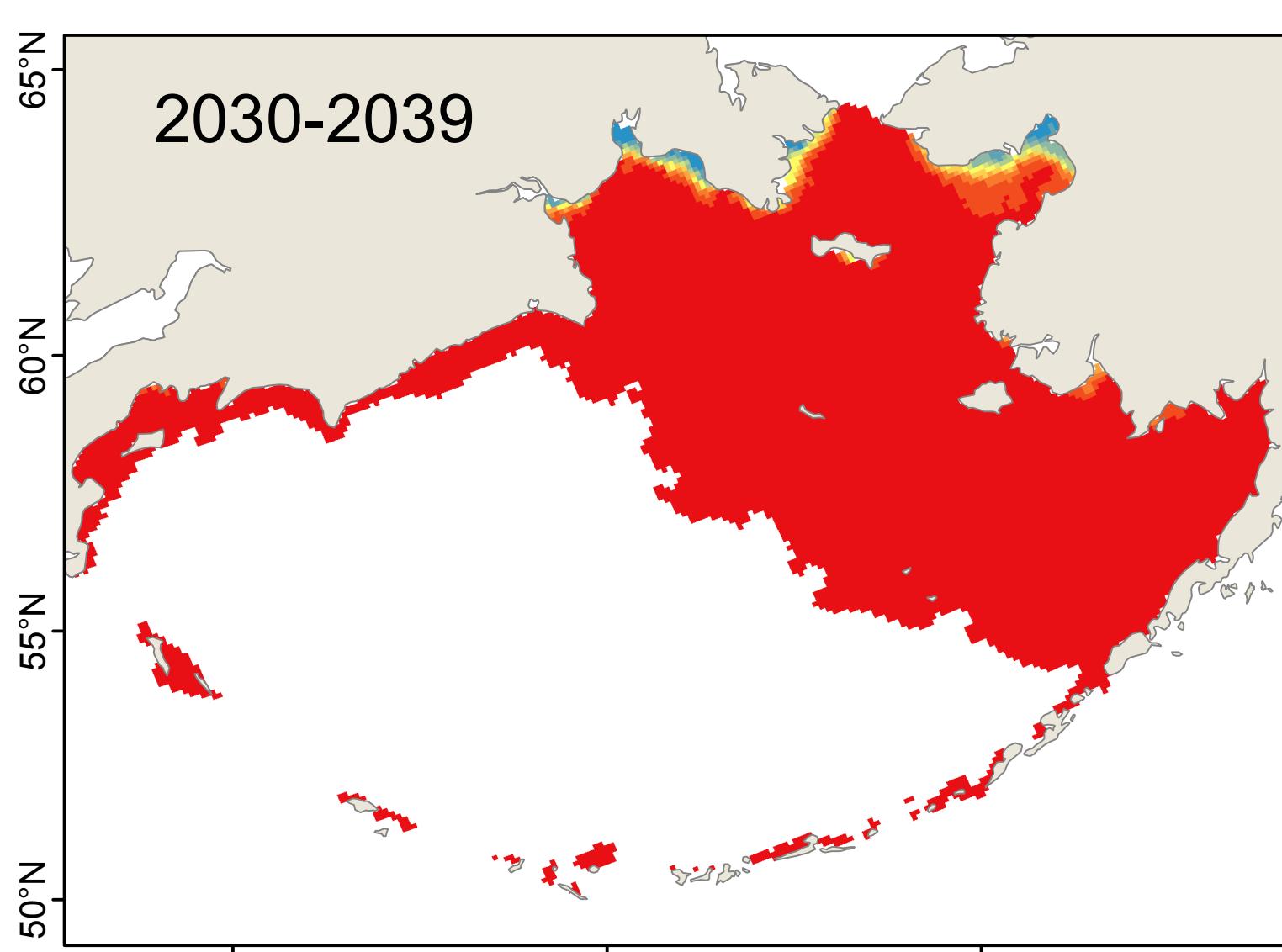
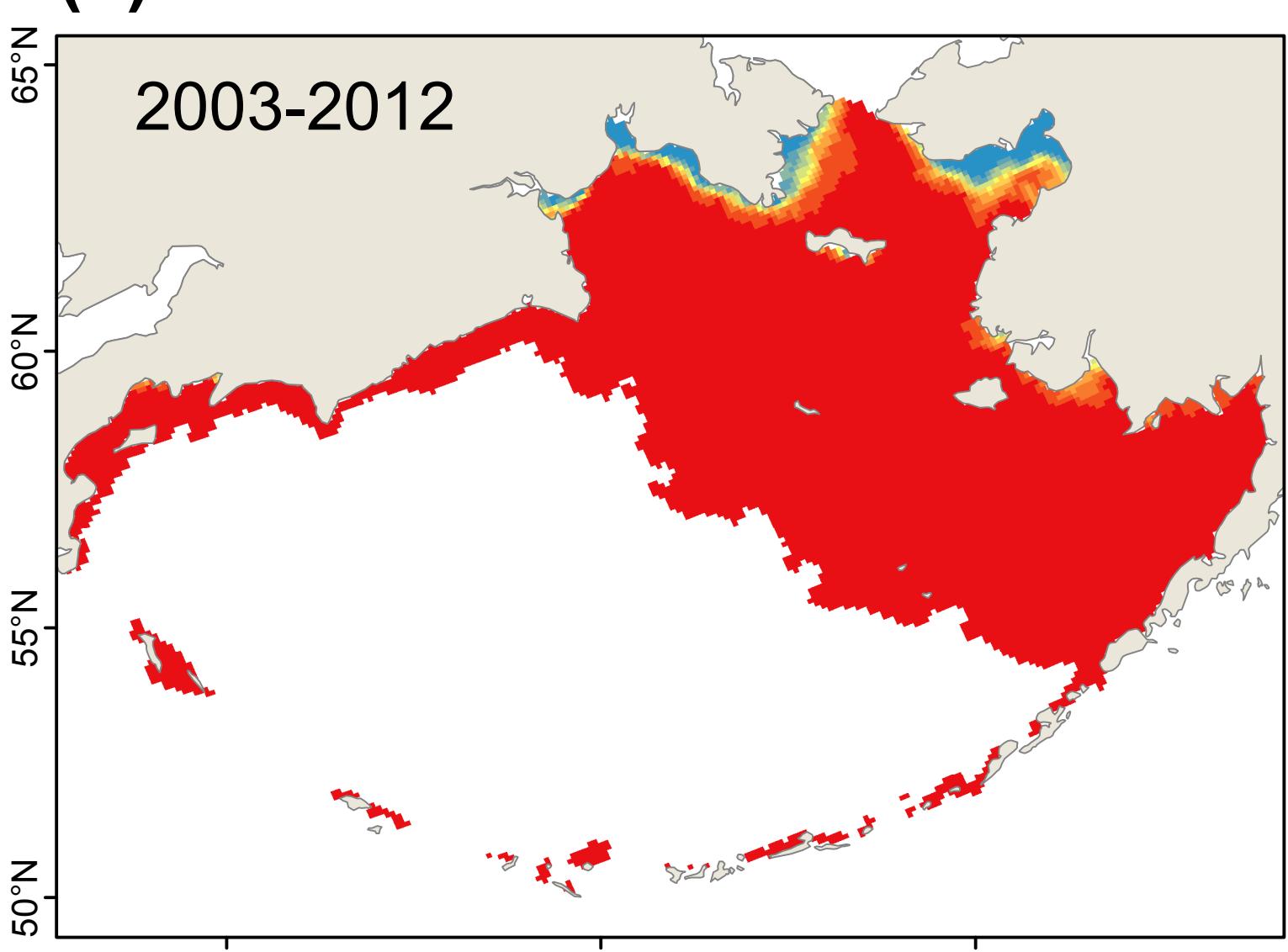
(a) Model: CGCM3-t47



(b) Model: ECHO-G

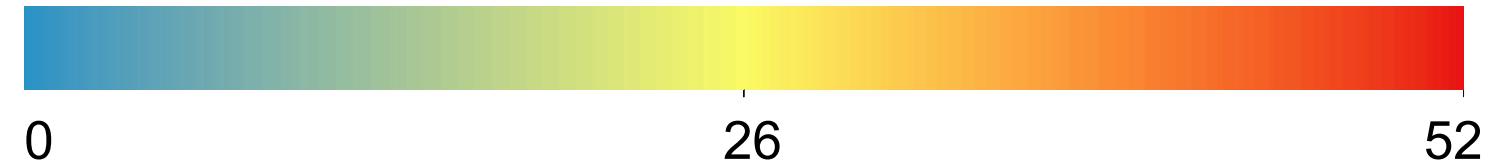


(c) Model: MIROC3.2

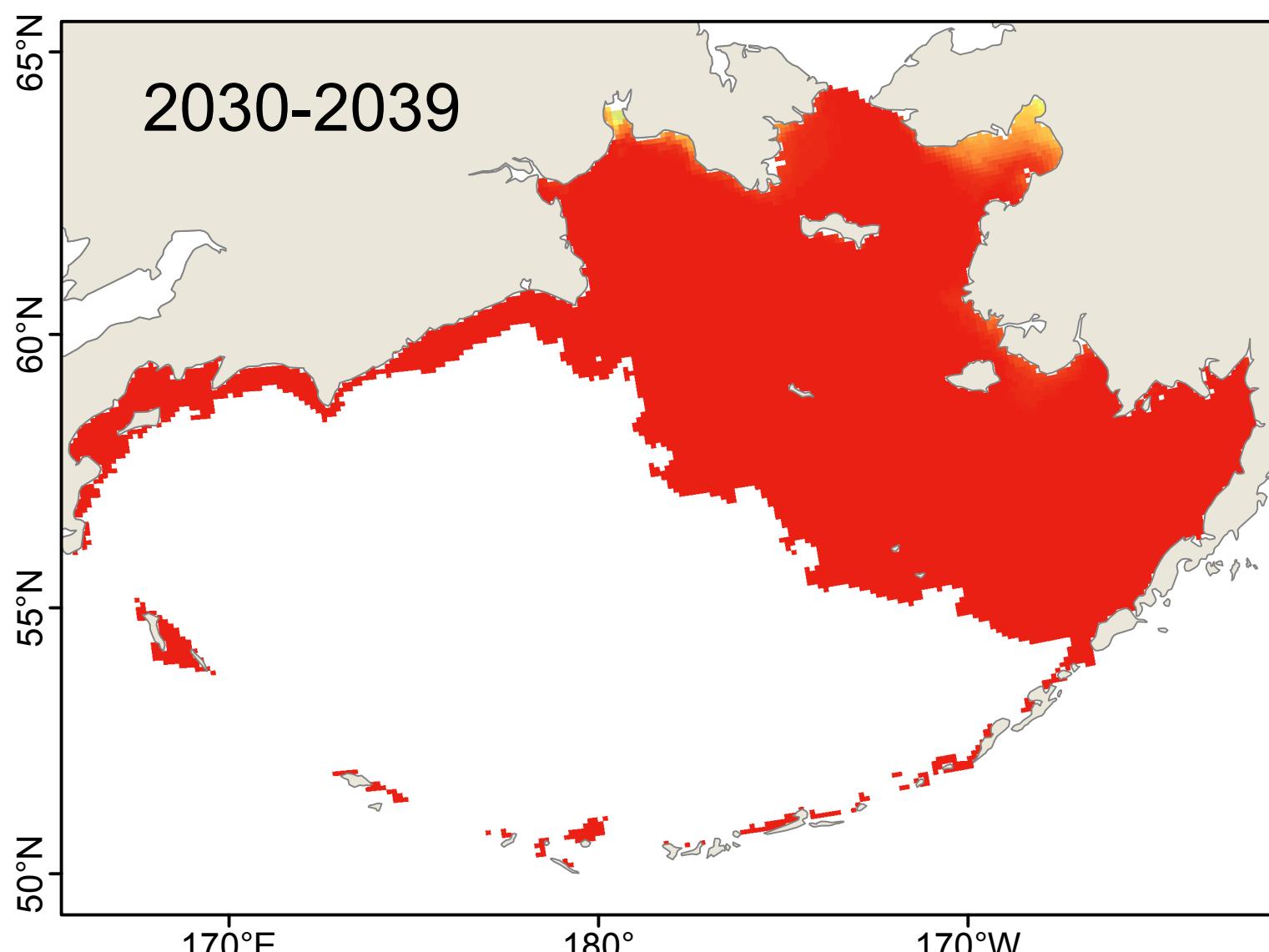
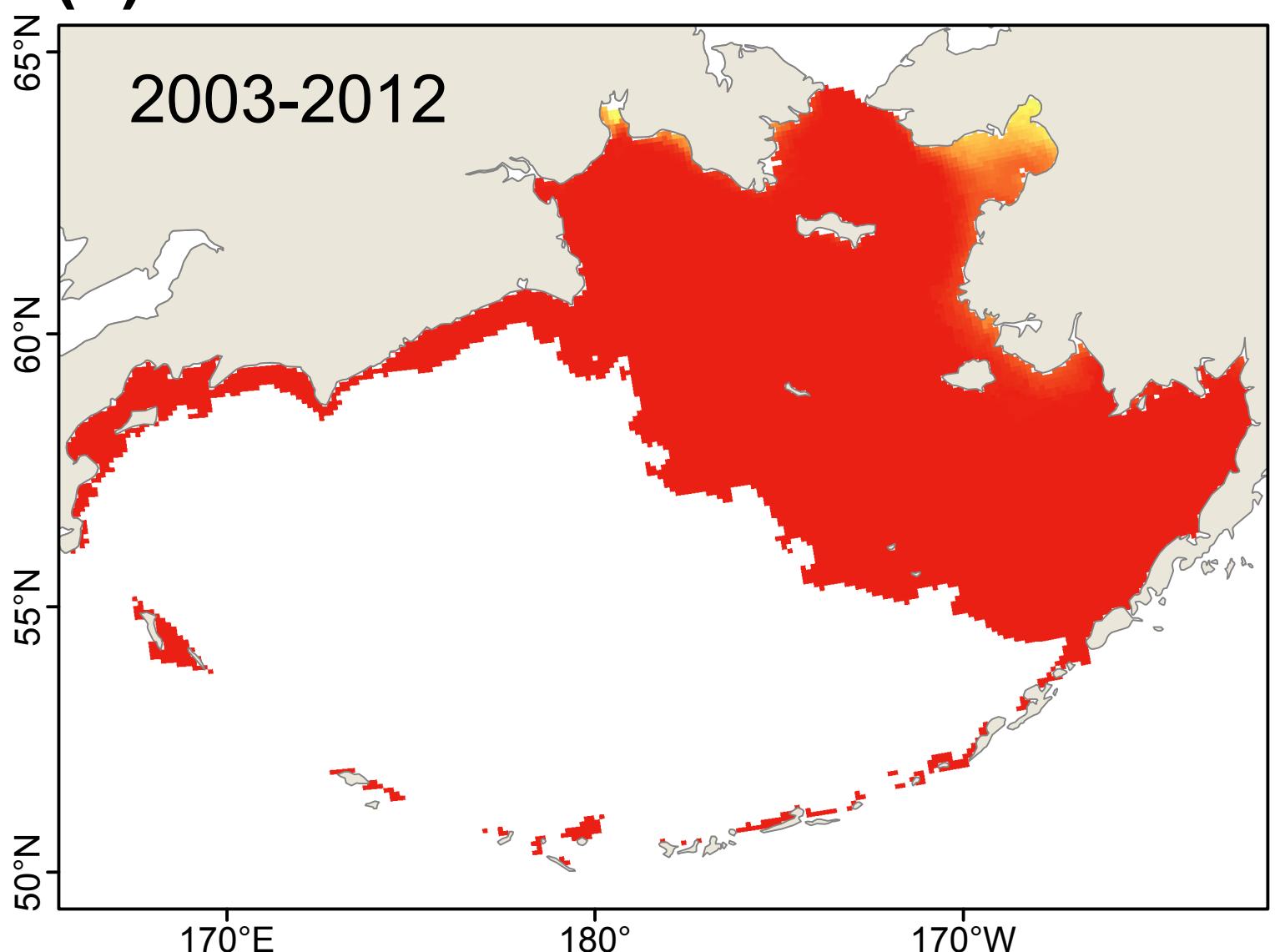


# *Amphibalanus improvisus*: Weekly Survival

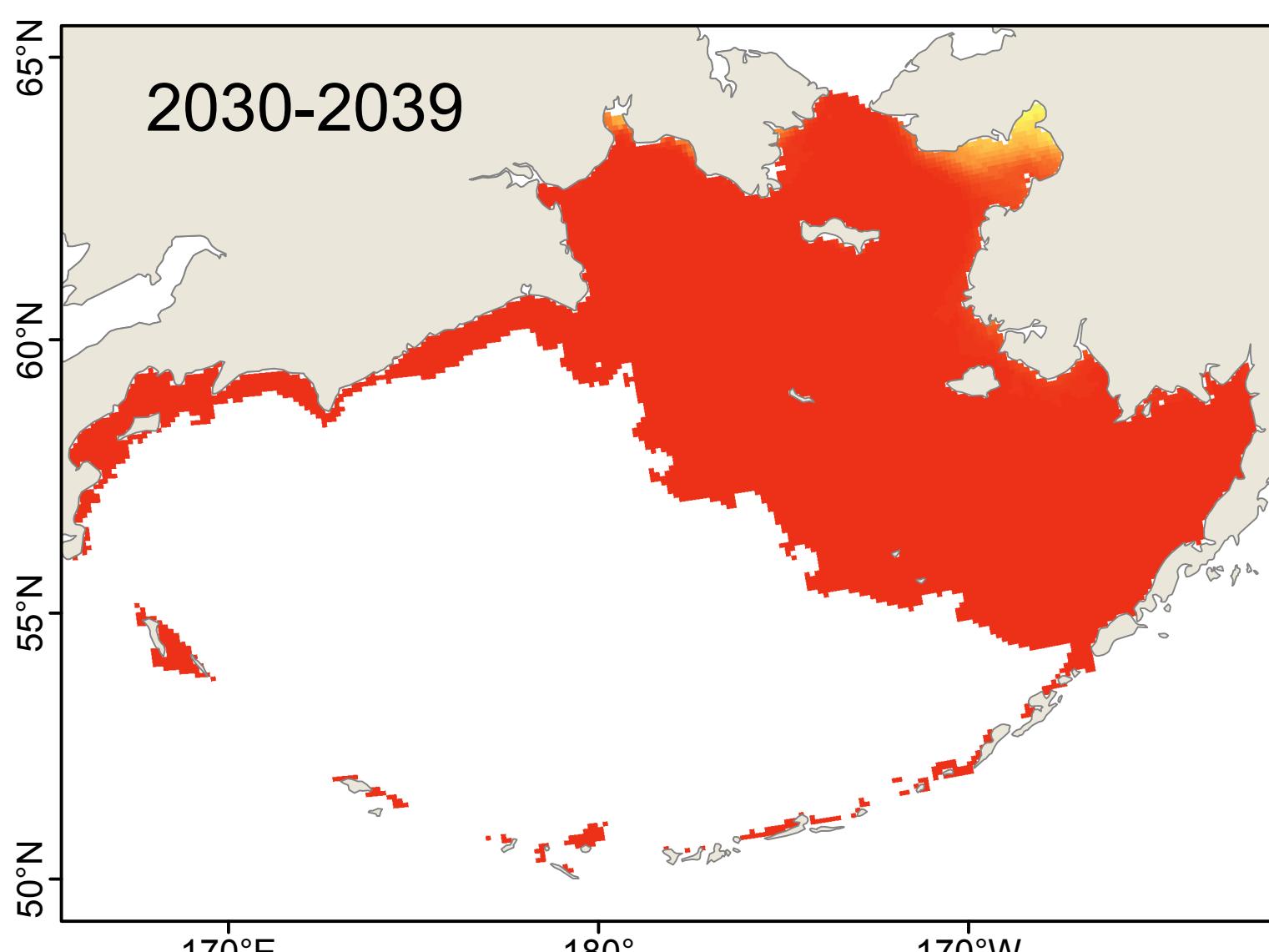
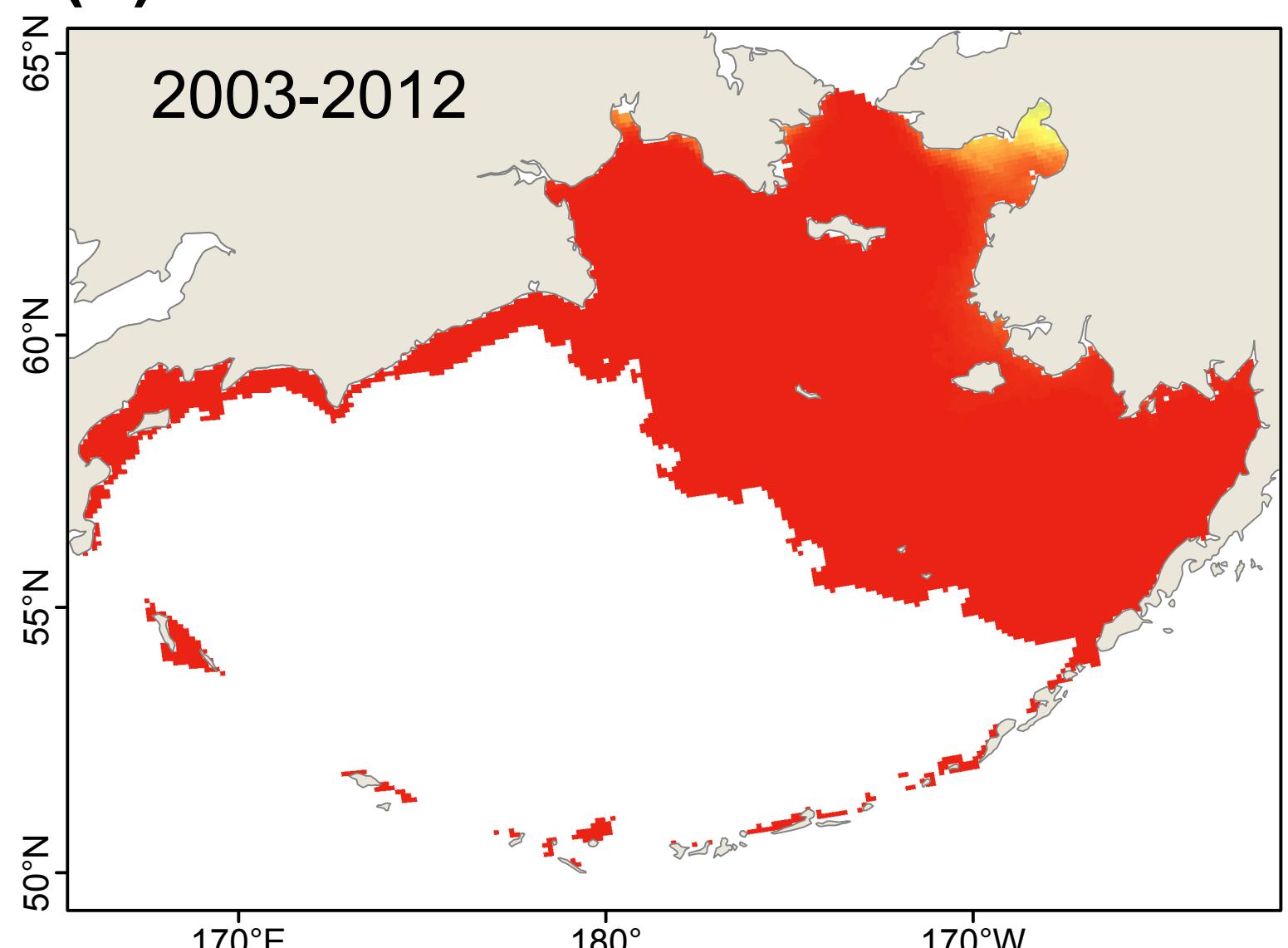
Average number of weeks of suitable habitat



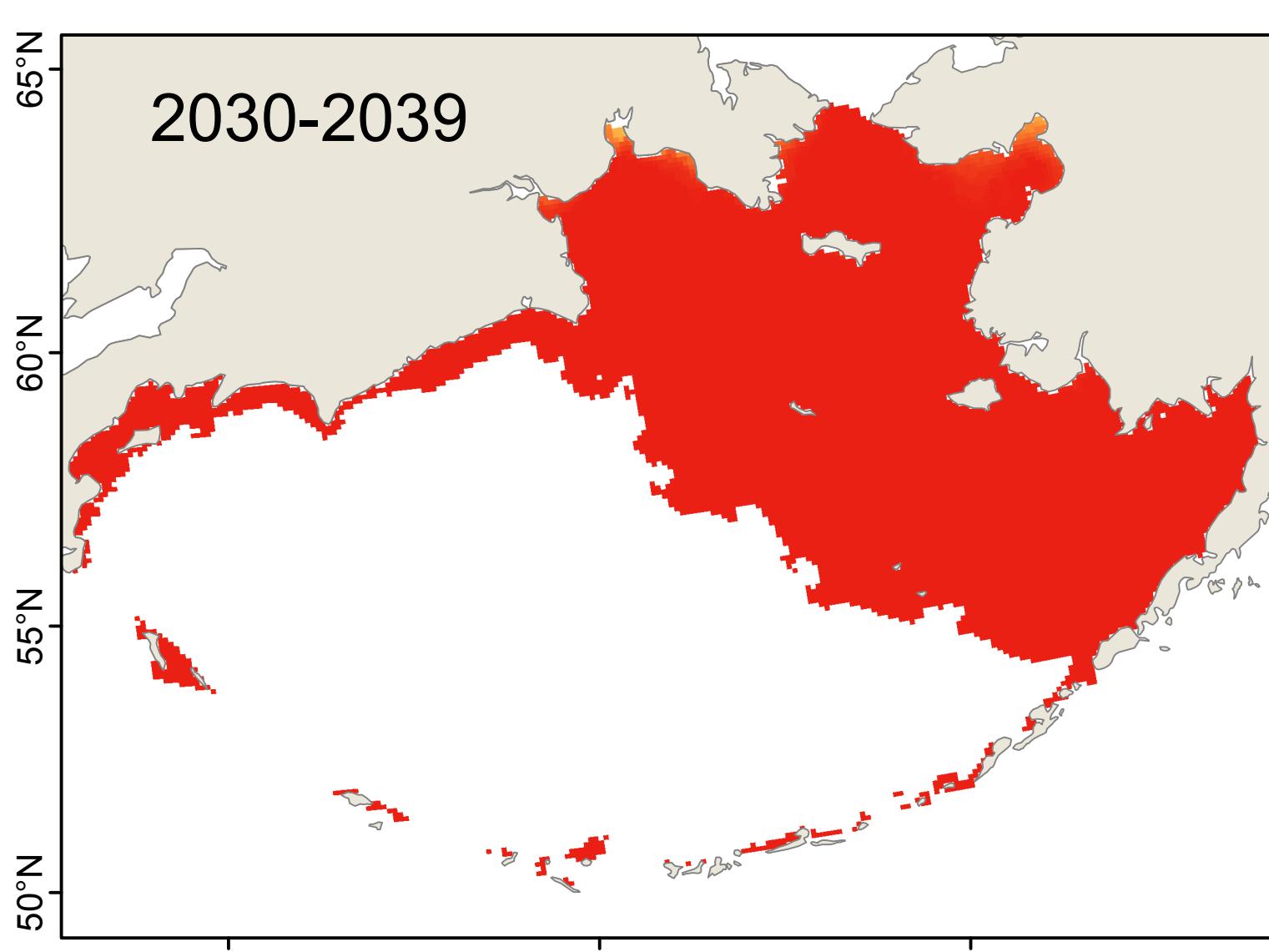
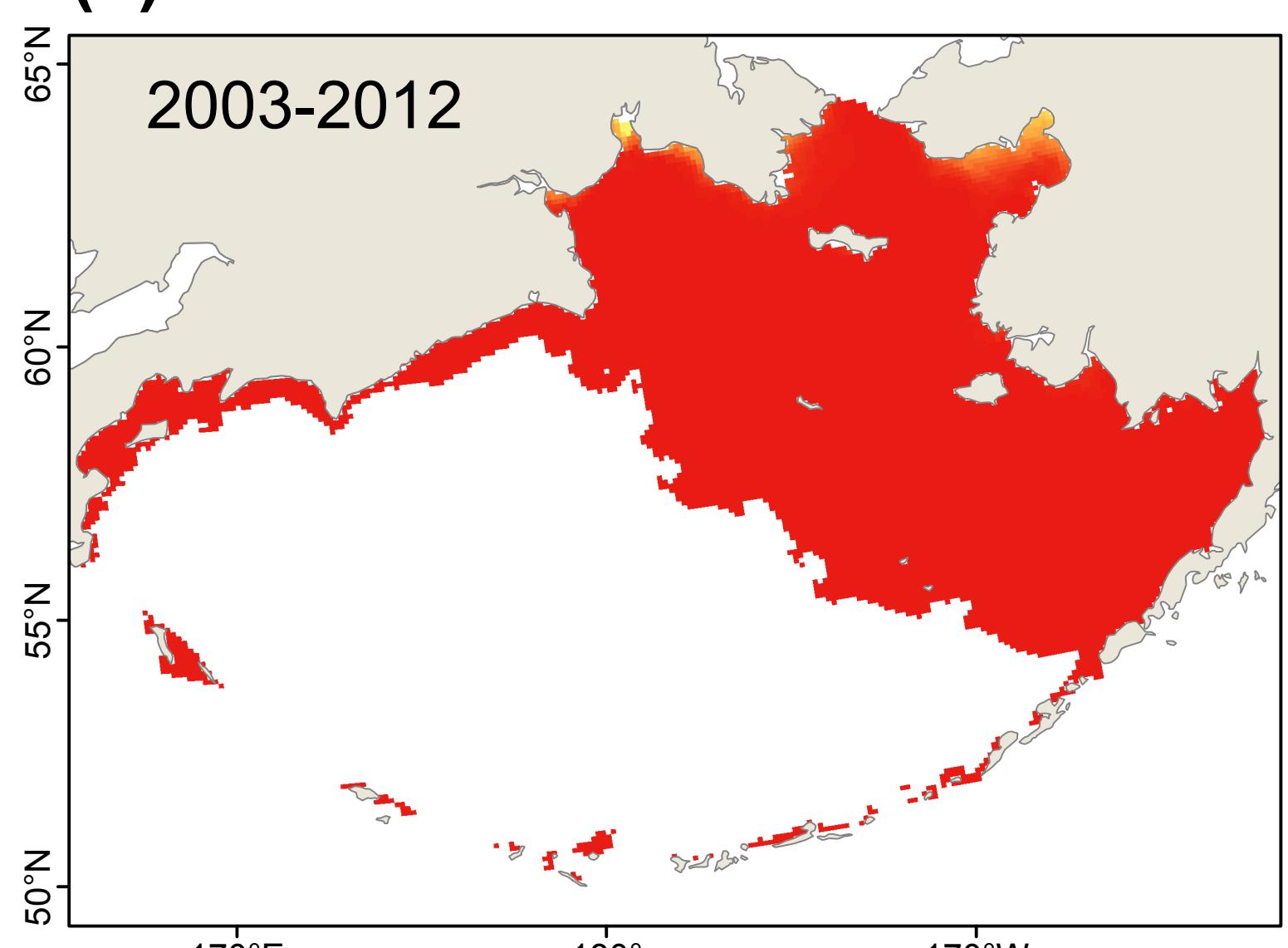
(a) Model: CGCM3-t47



(b) Model: ECHO-G

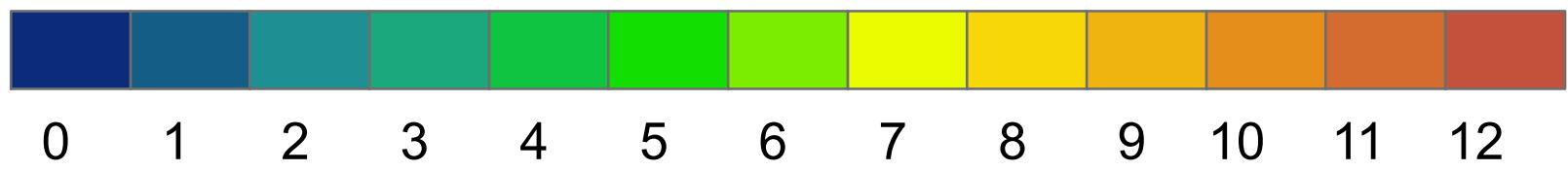


(c) Model: MIROC3.2

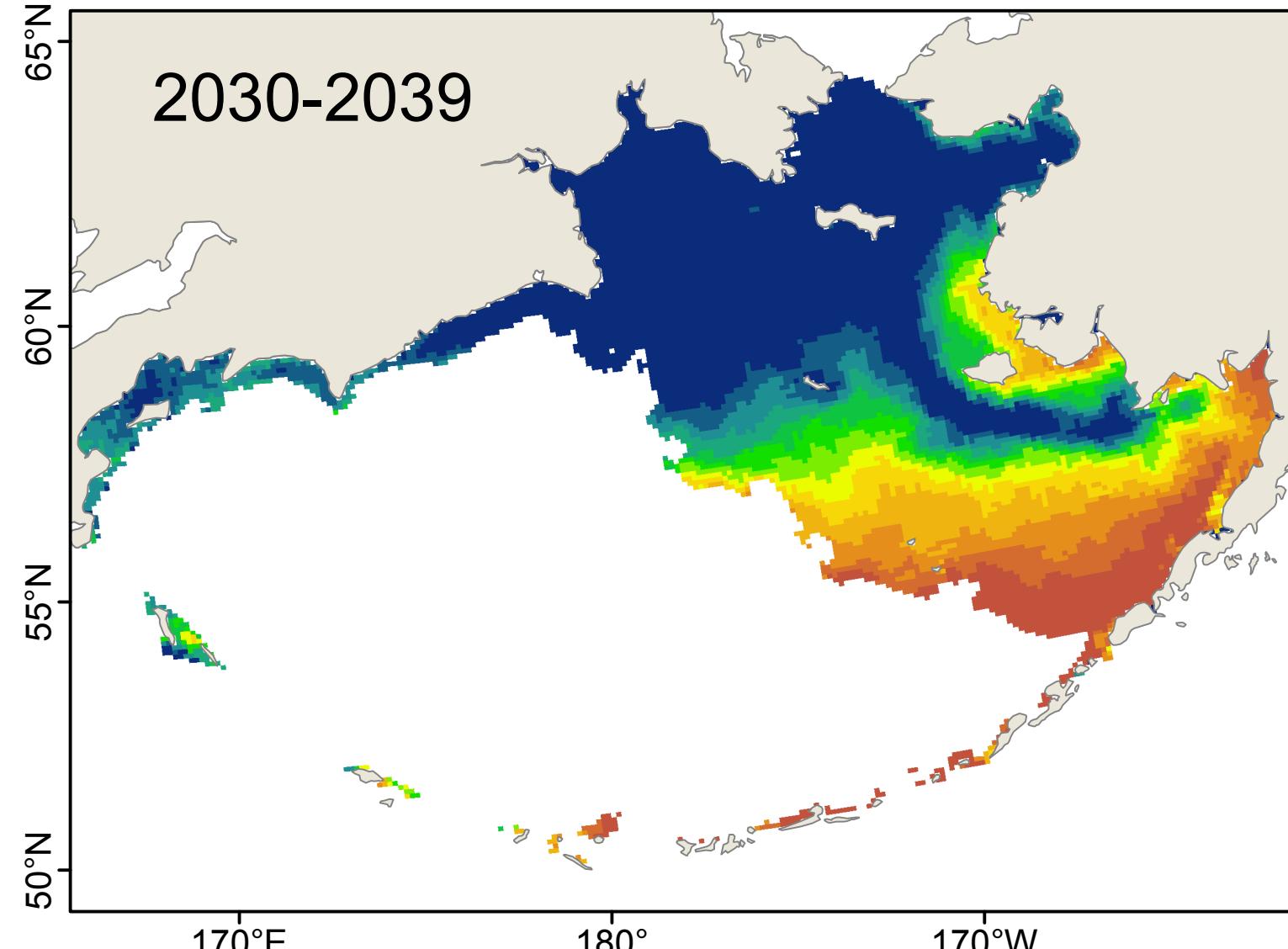
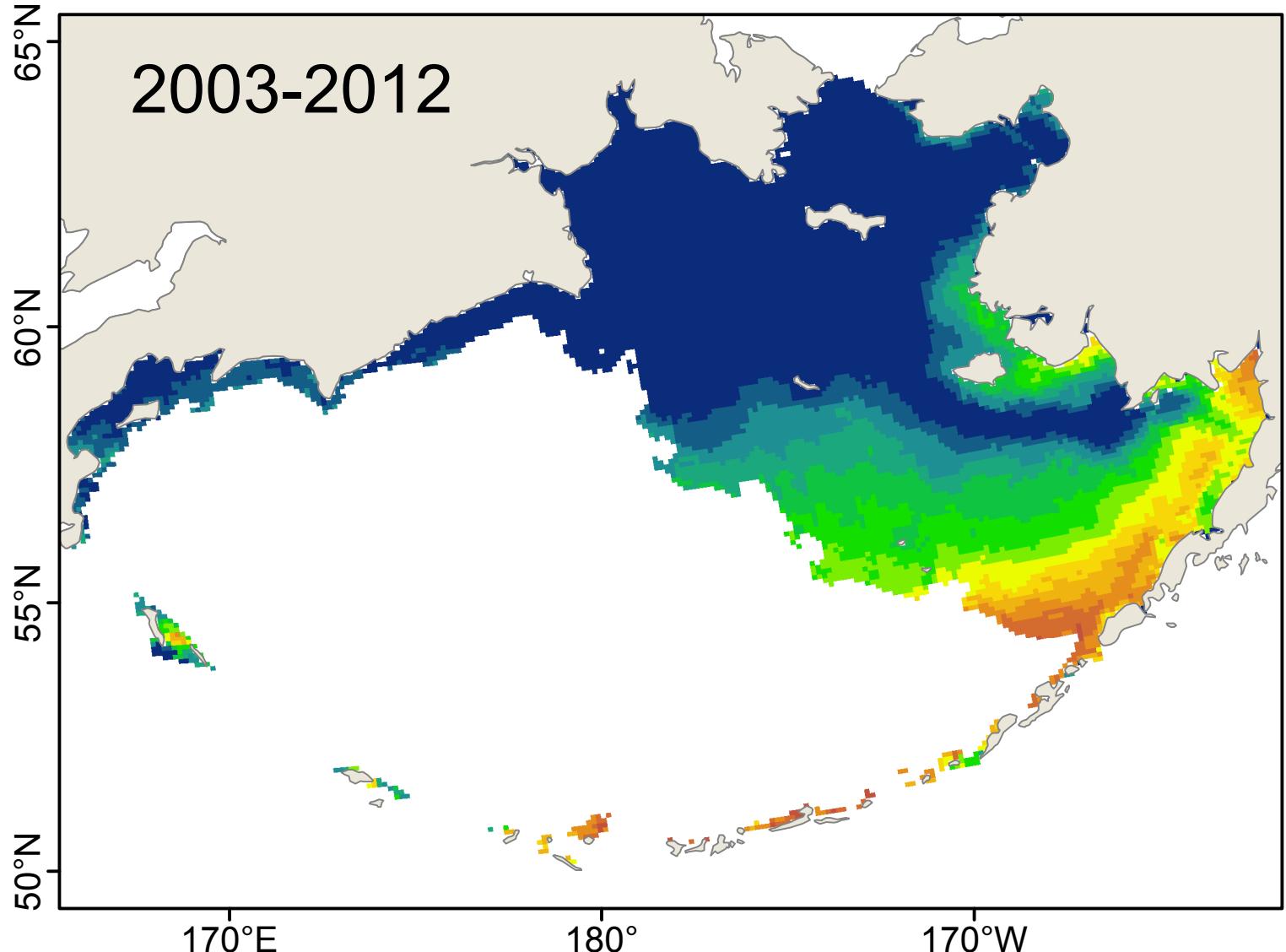


# *Amphibalanus improvisus: Reproduction*

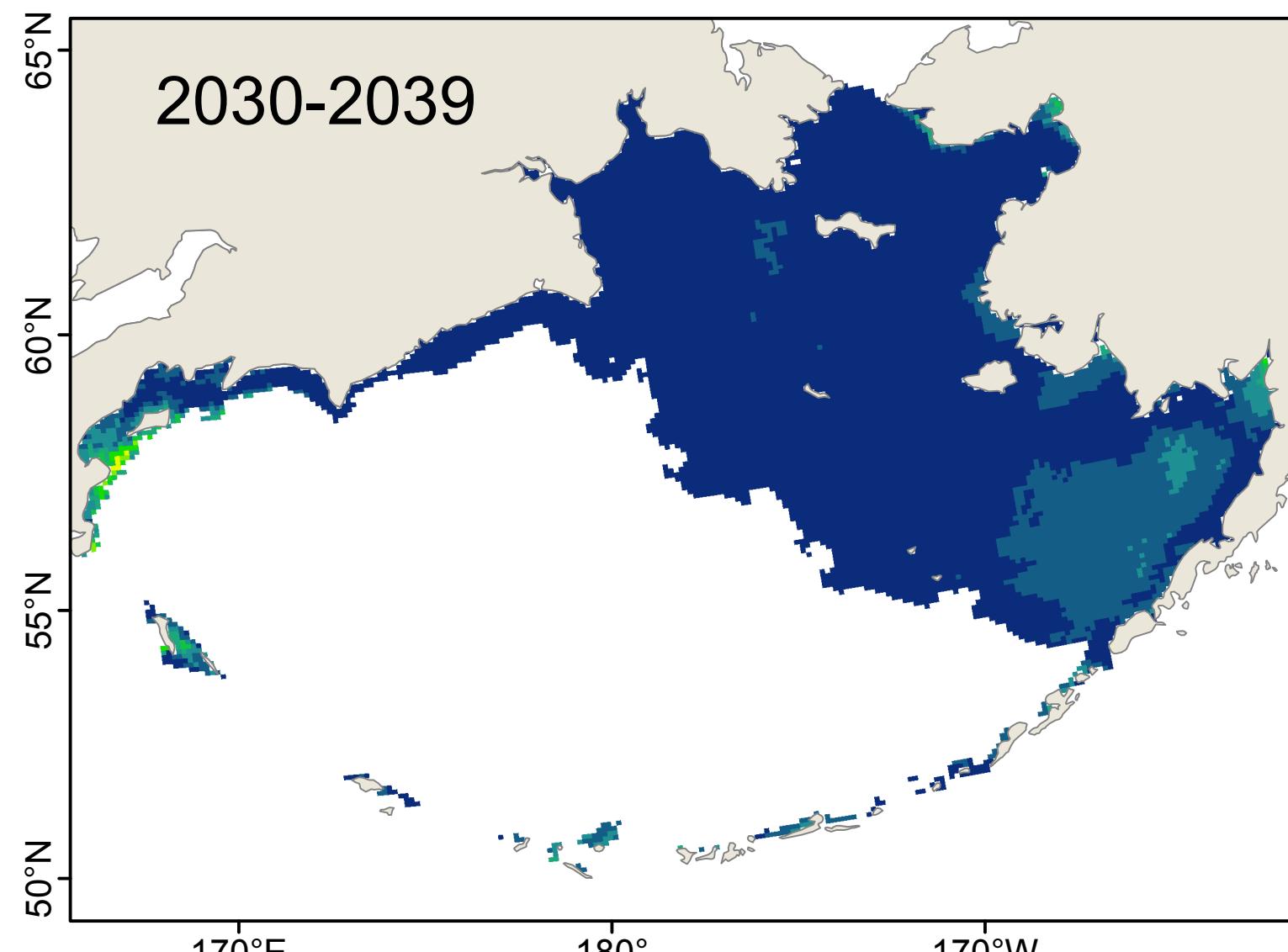
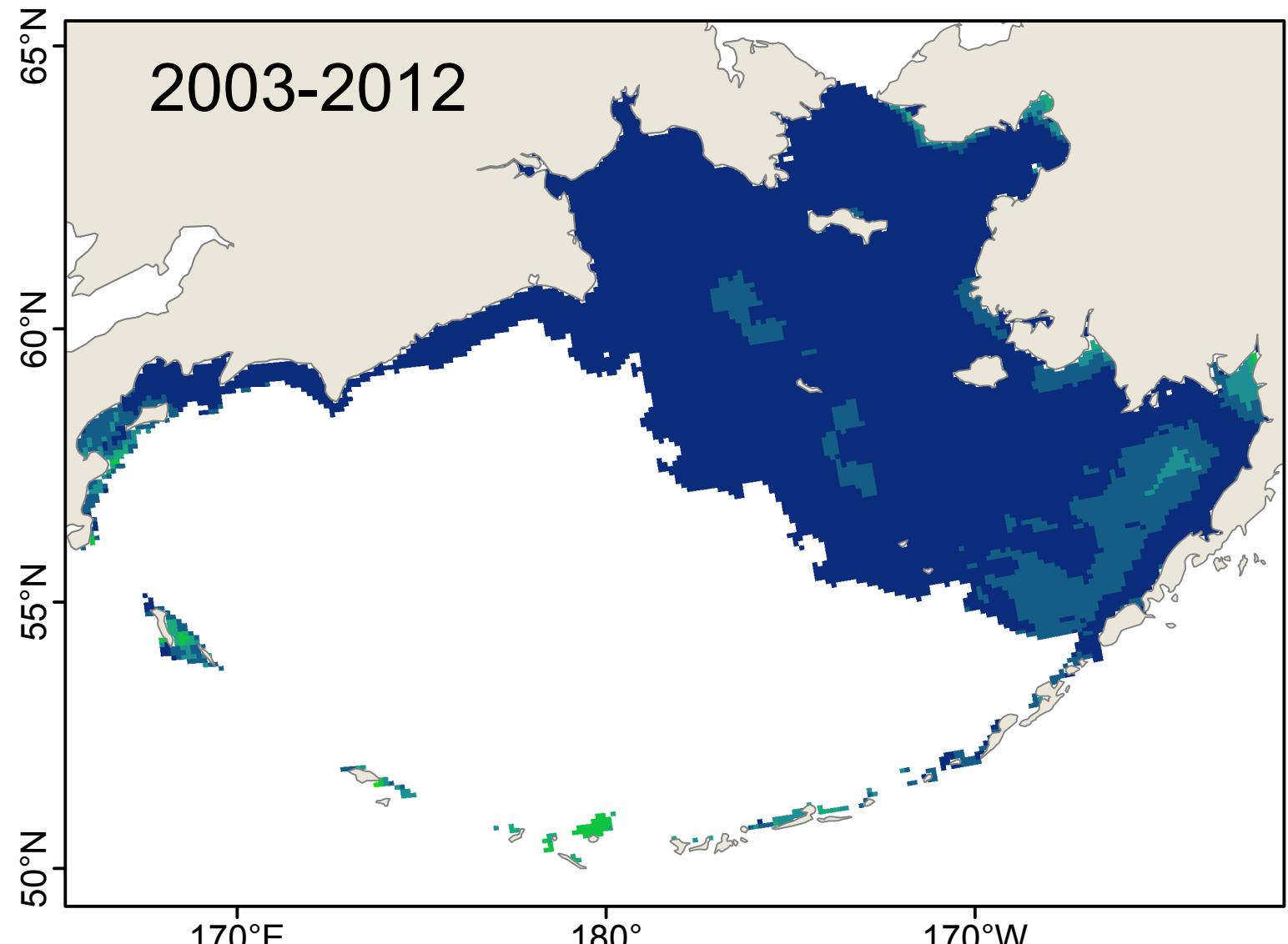
Average number of consecutive weeks of suitable habitat



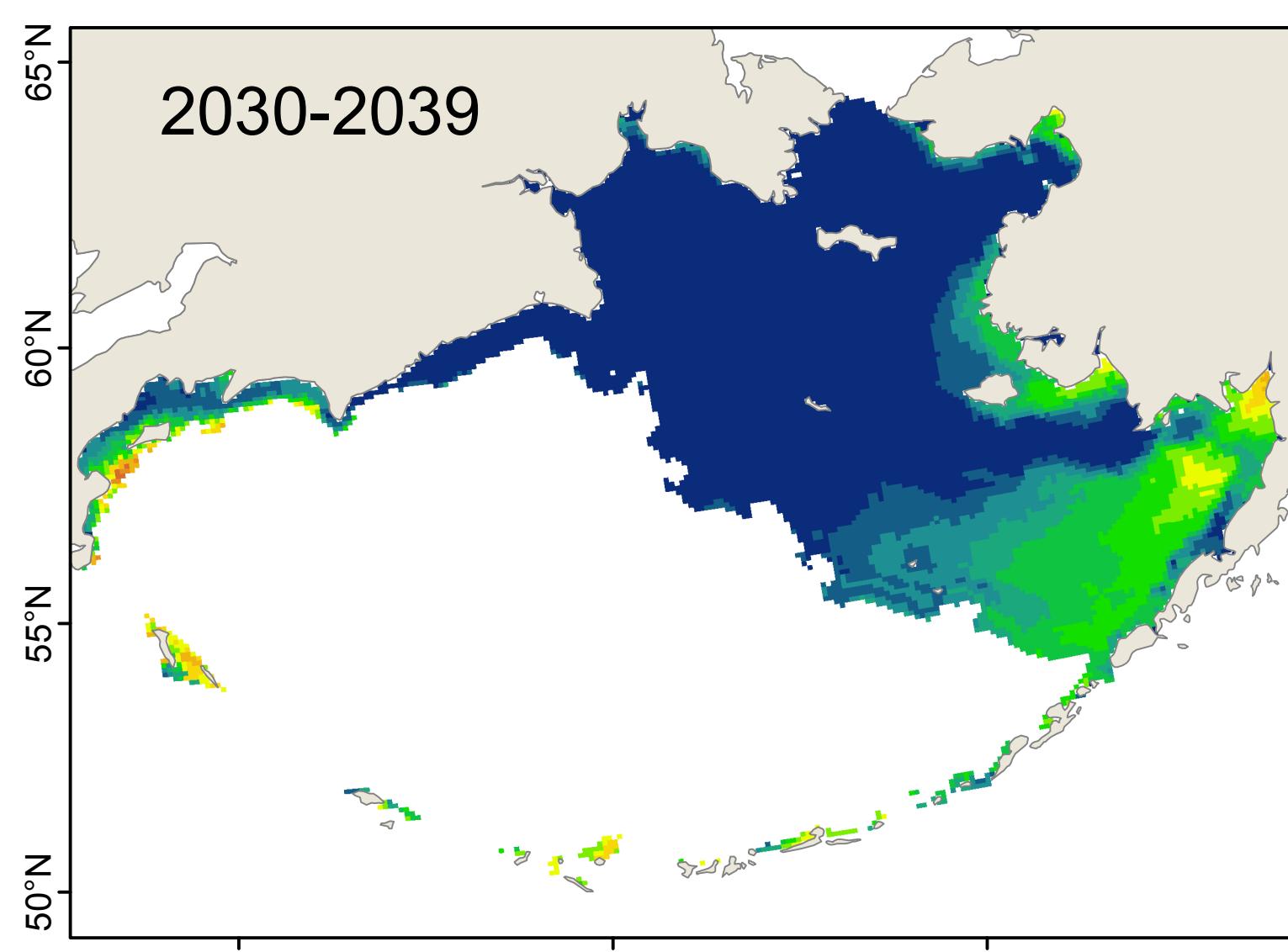
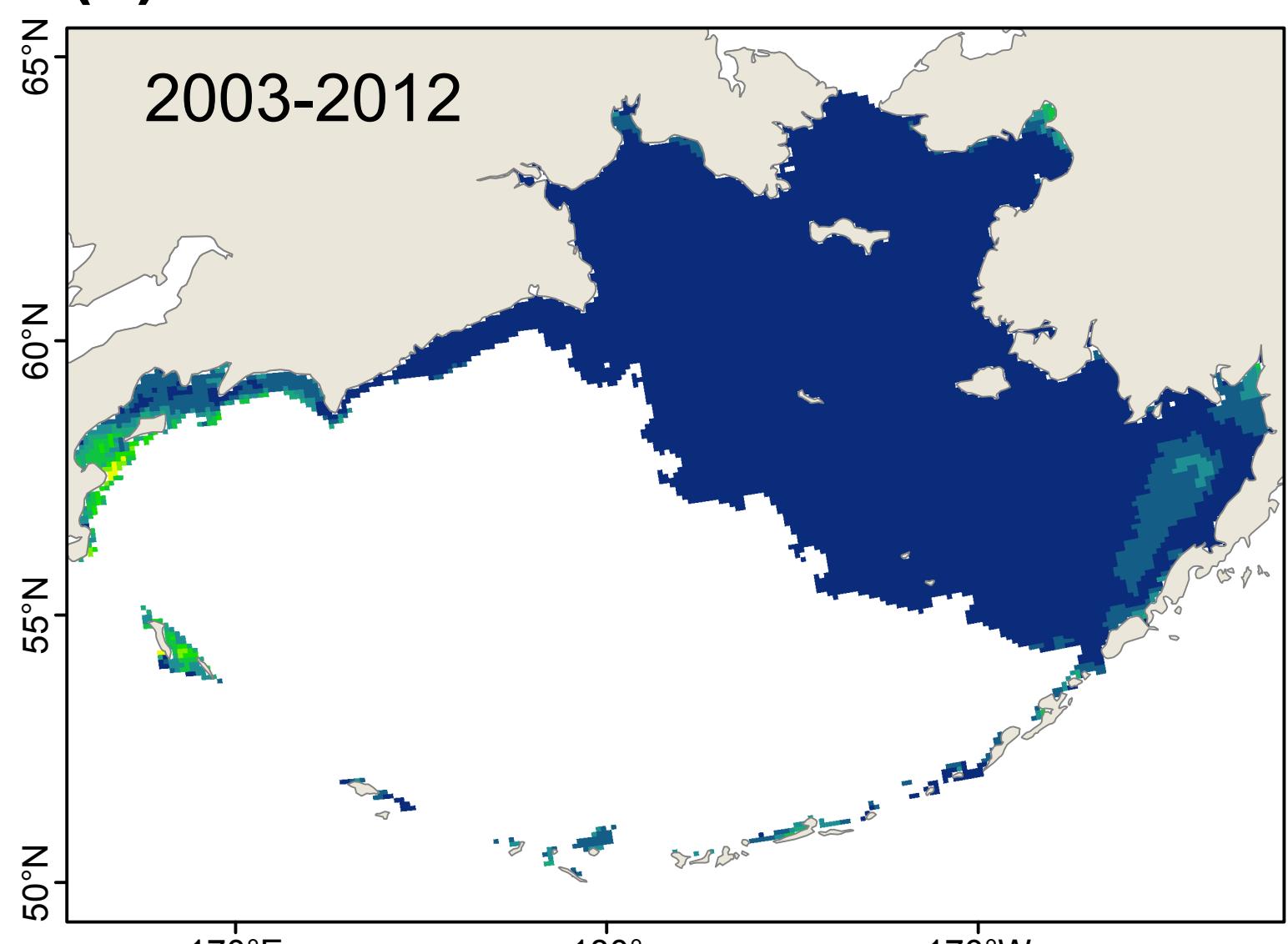
(a) Model: CGCM3-t47



(b) Model: ECHO-G

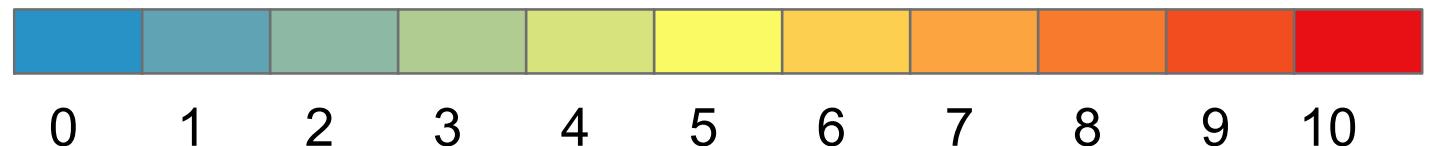


(c) Model: MIROC3.2

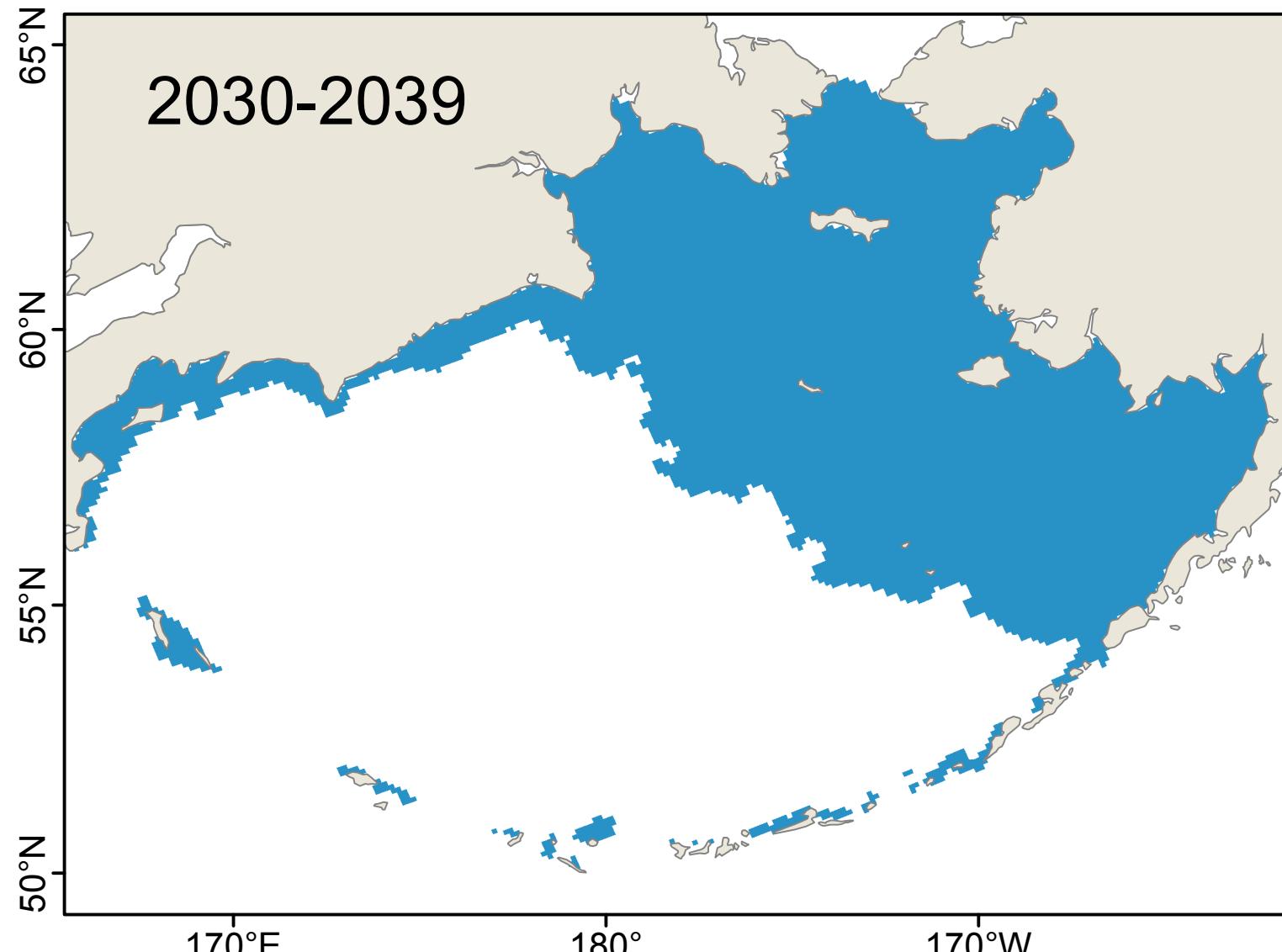
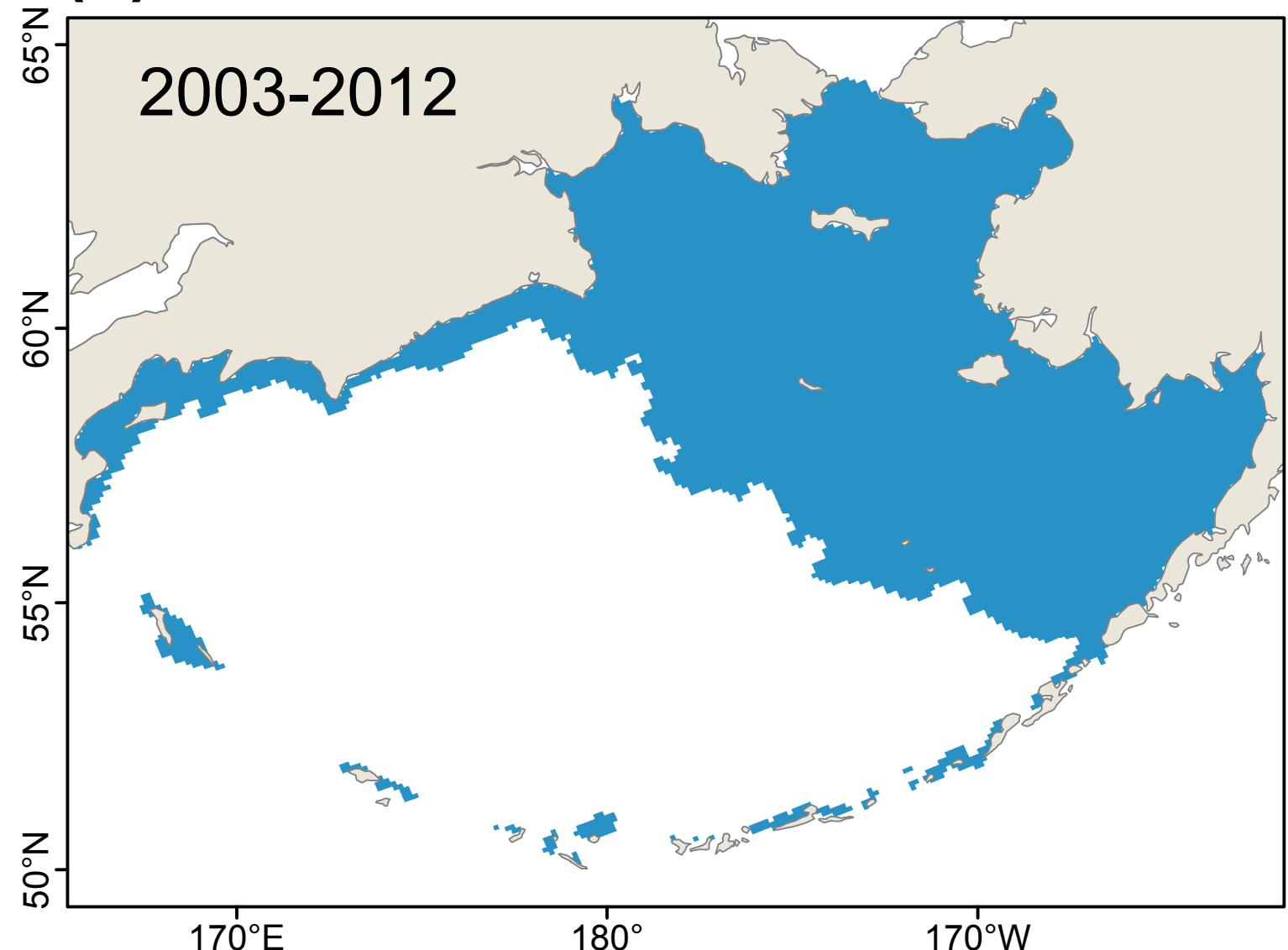


# *Limnoithona tetraspina*: Year-round Survival

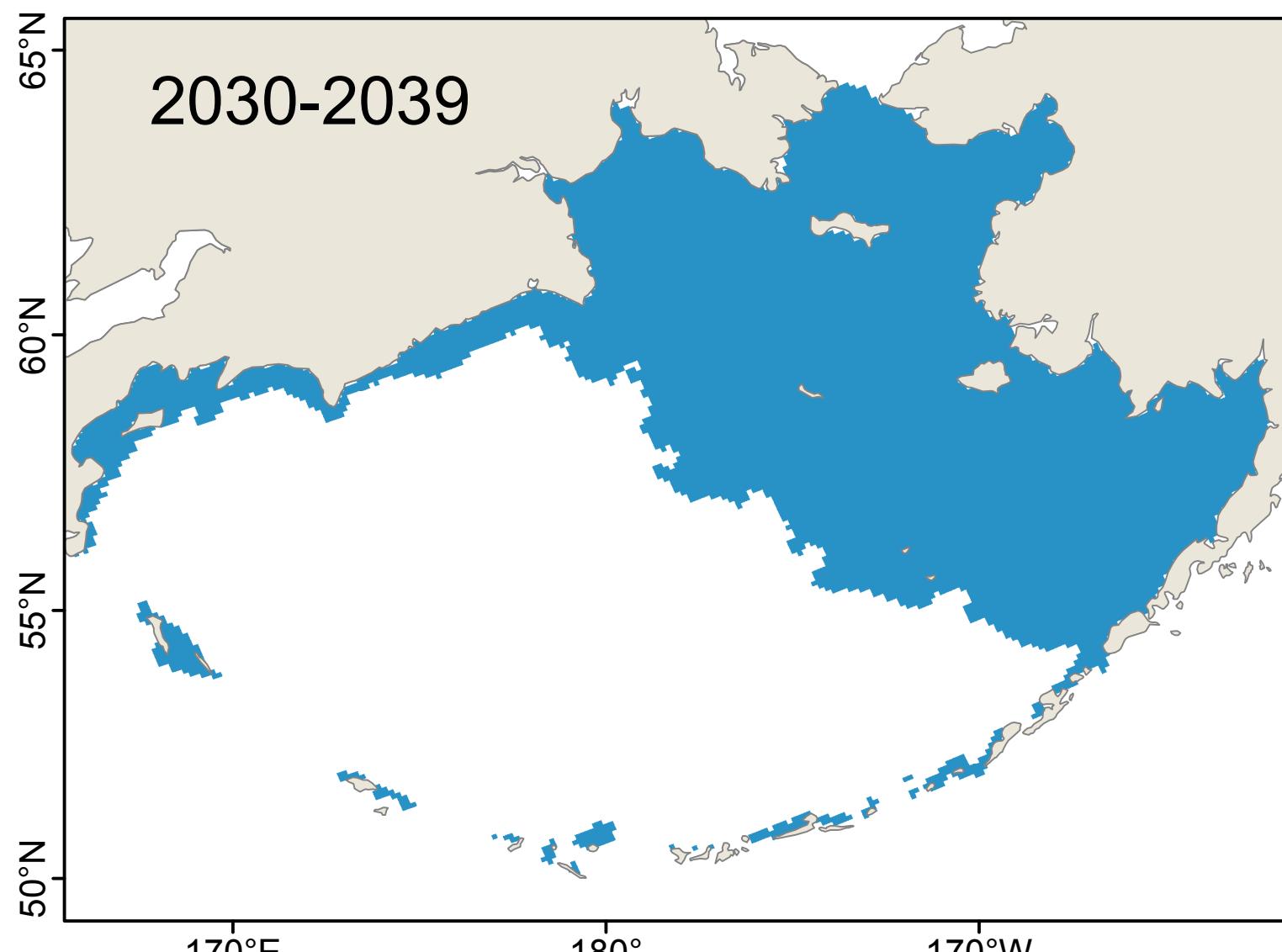
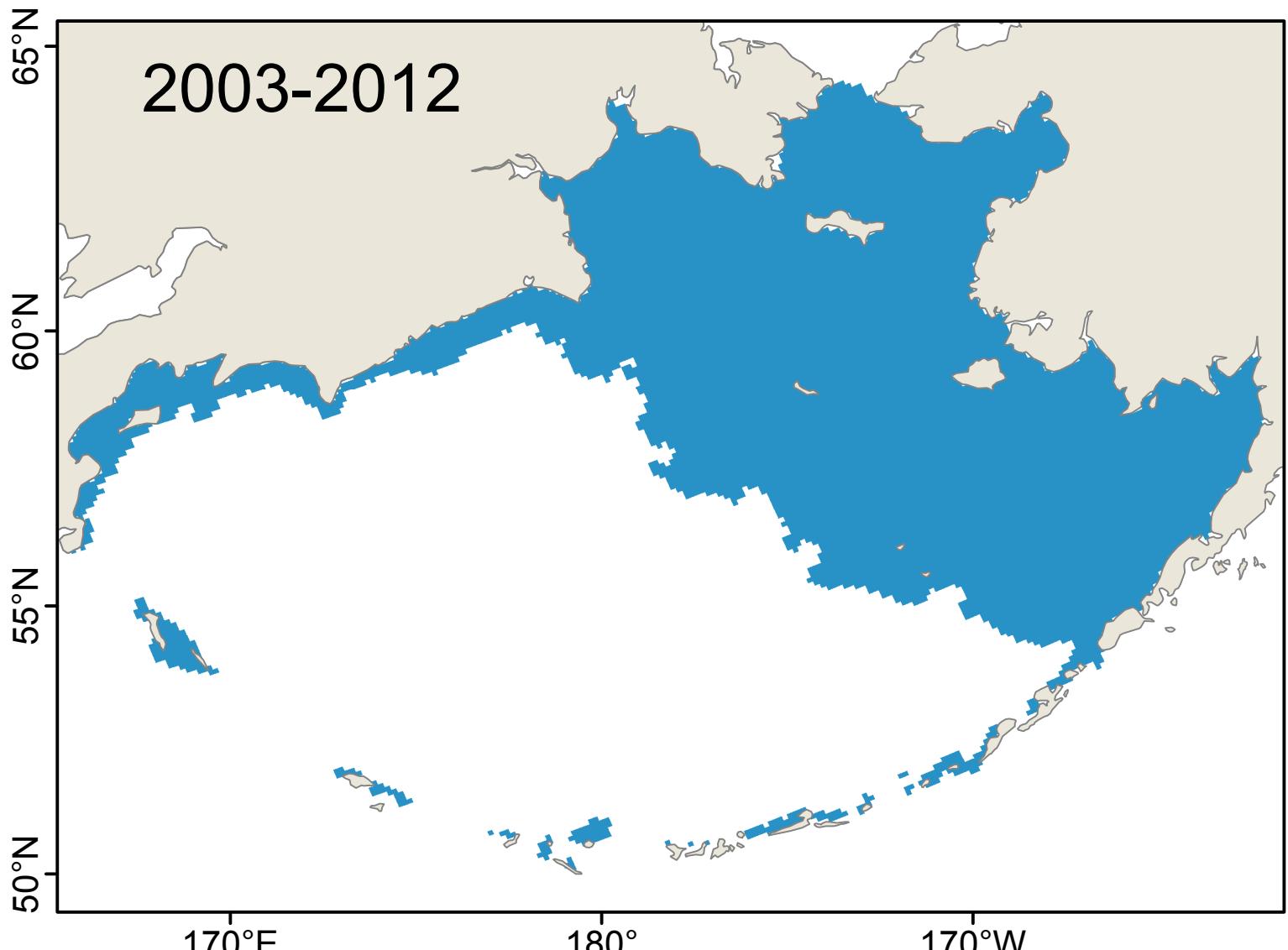
Number of years with suitable habitat



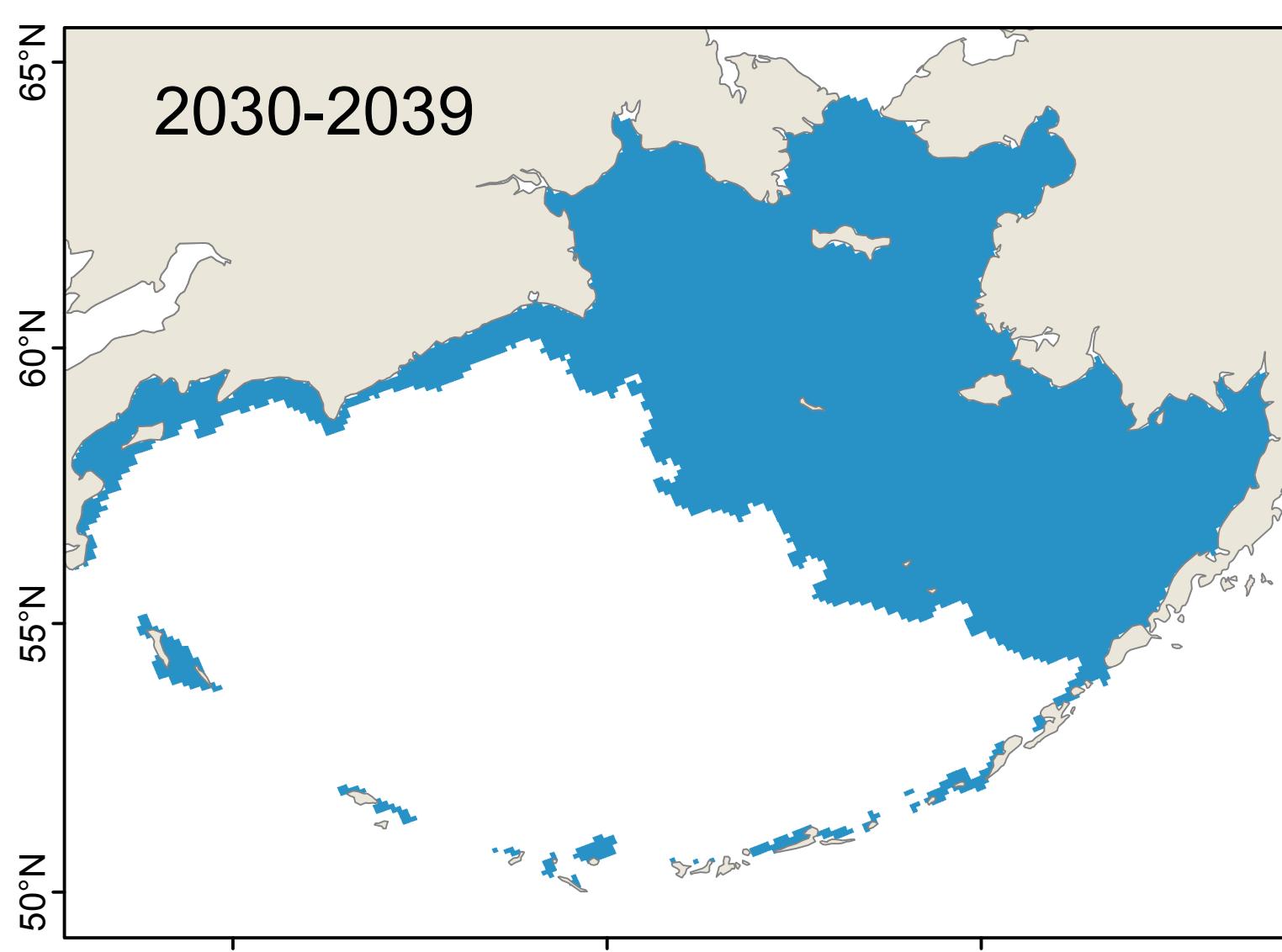
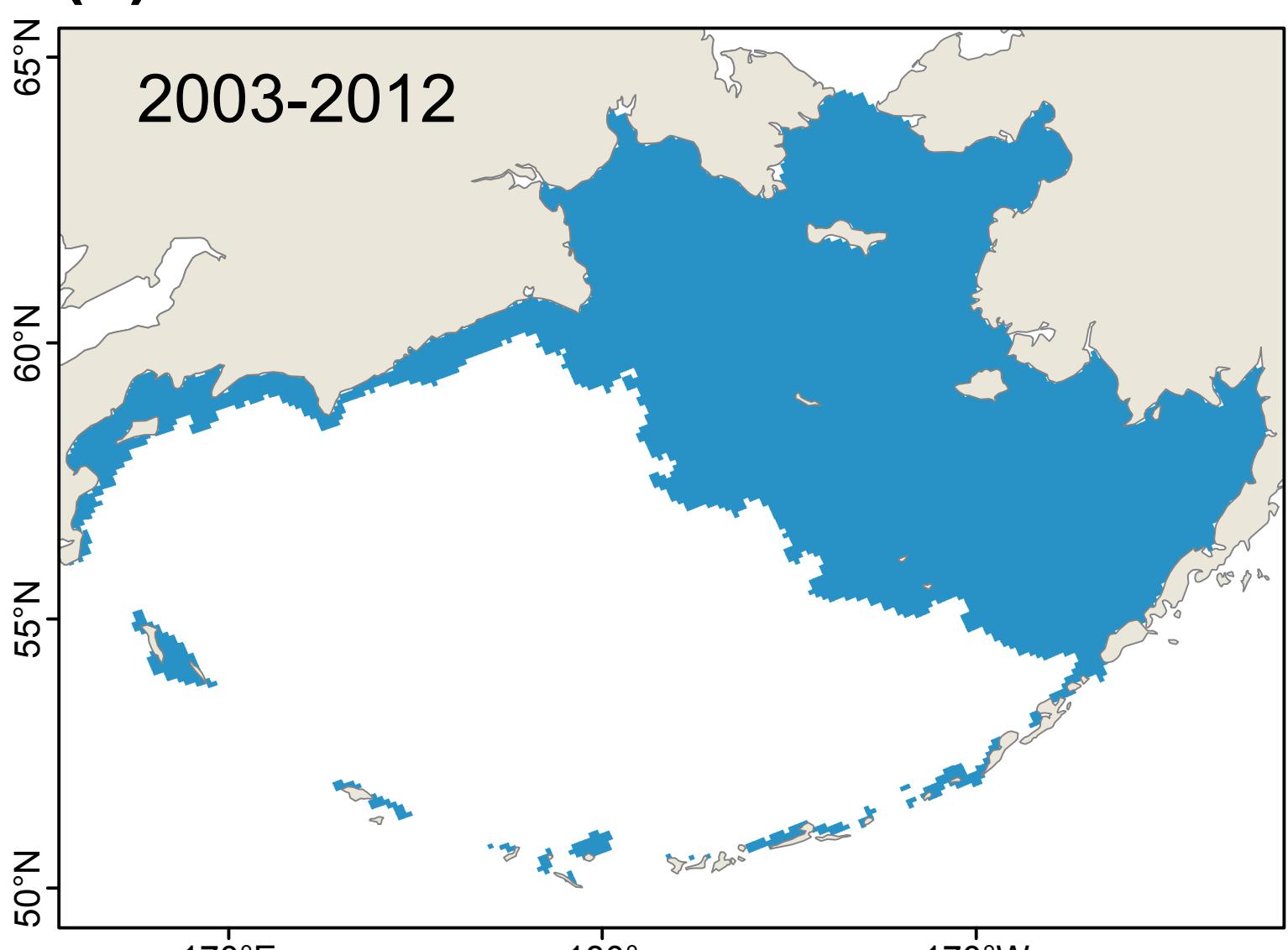
(a) Model: CGCM3-t47



(b) Model: ECHO-G

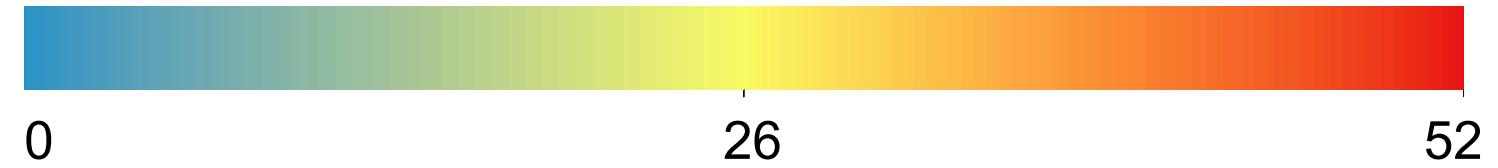


(c) Model: MIROC3.2

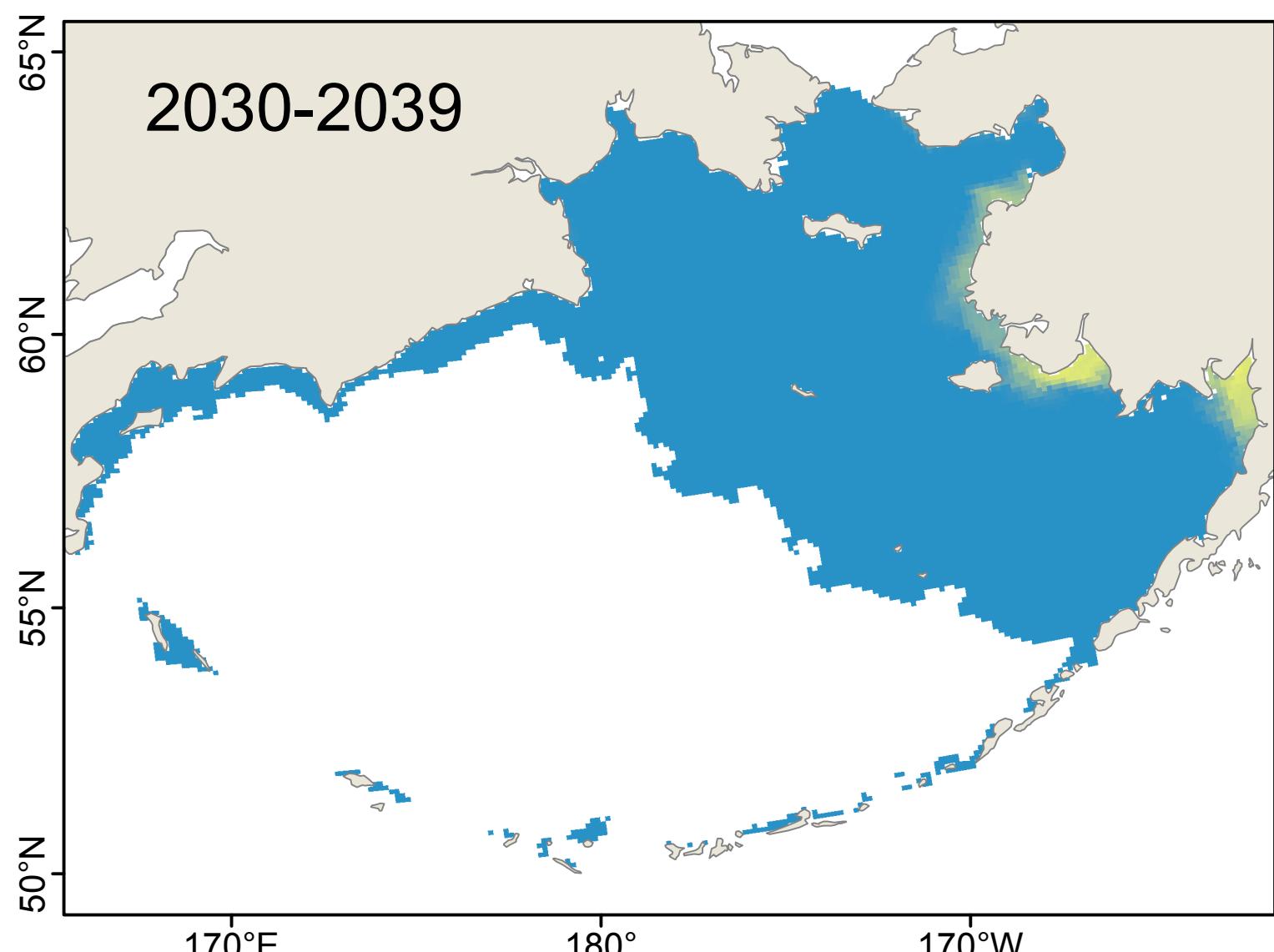
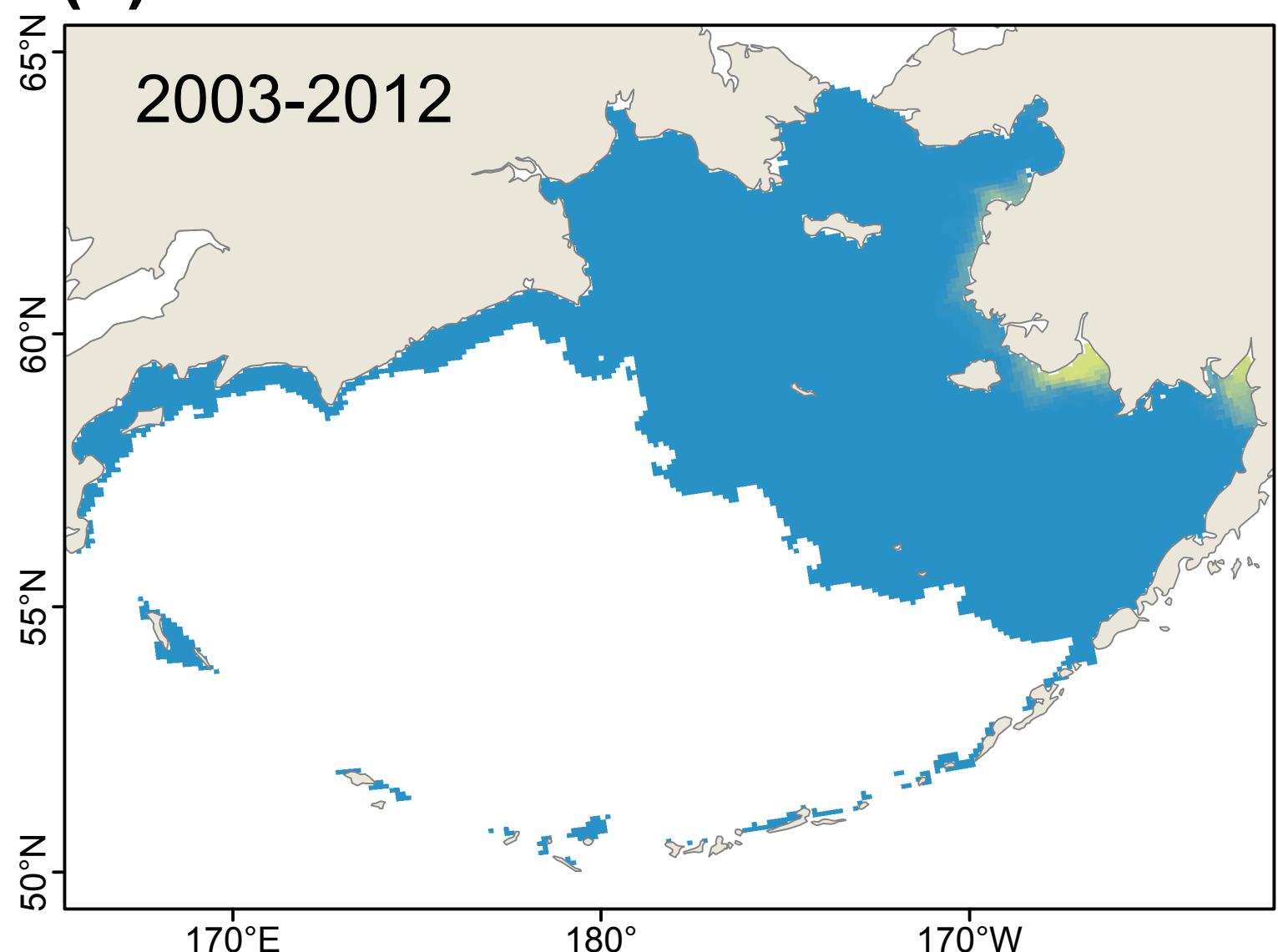


# *Limnoithona tetraspina: Weekly Survival*

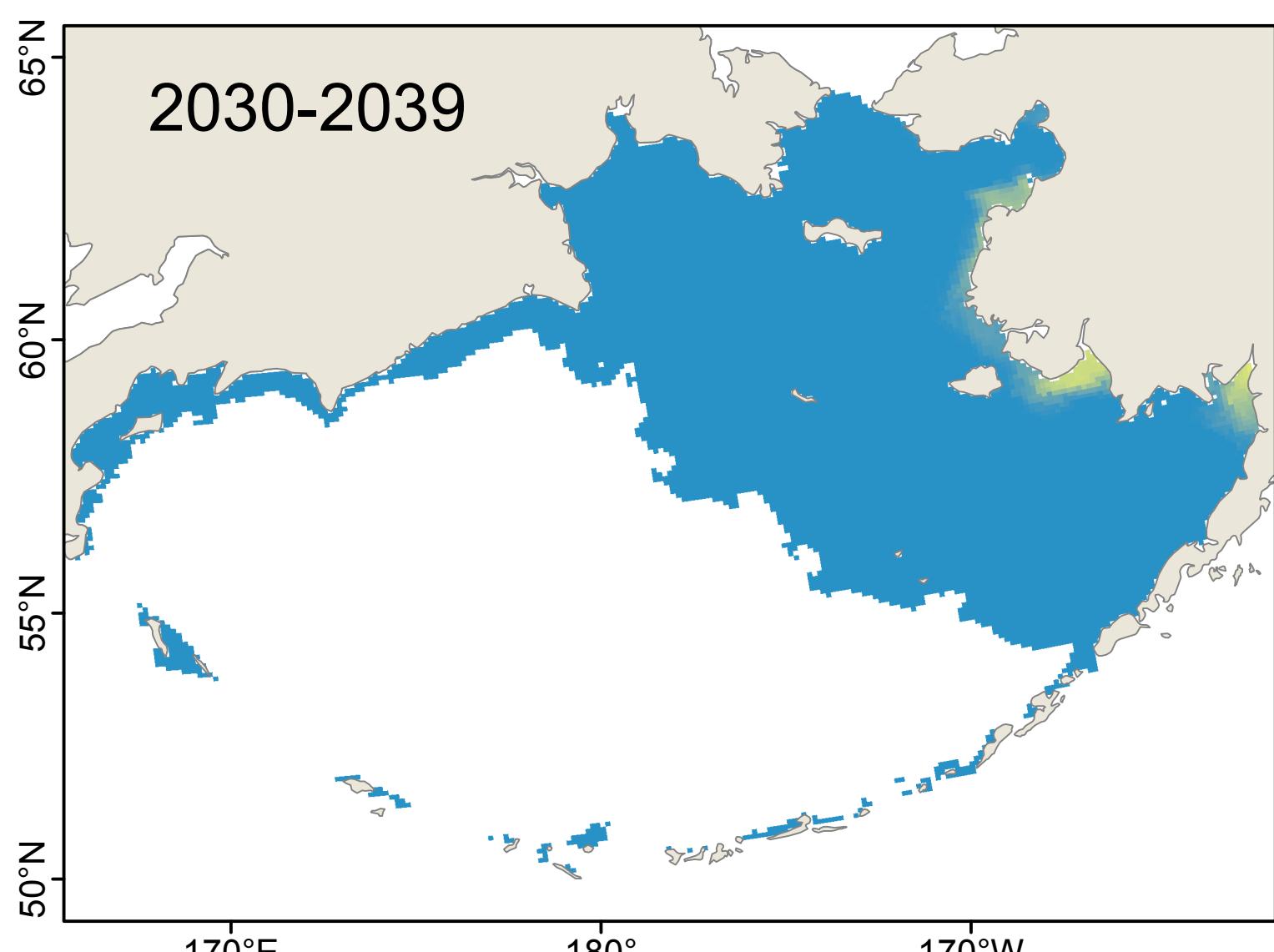
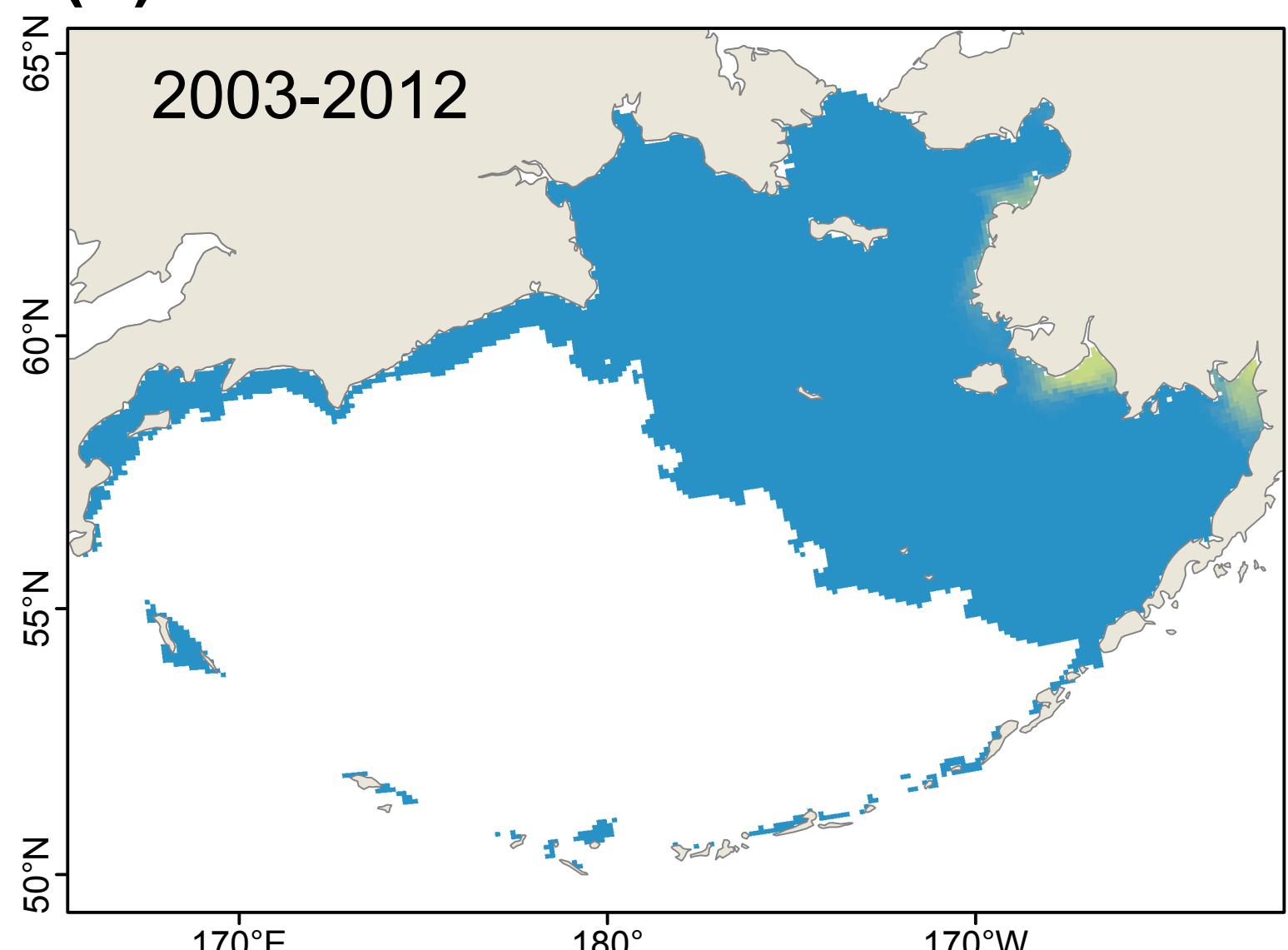
Average number of weeks of suitable habitat



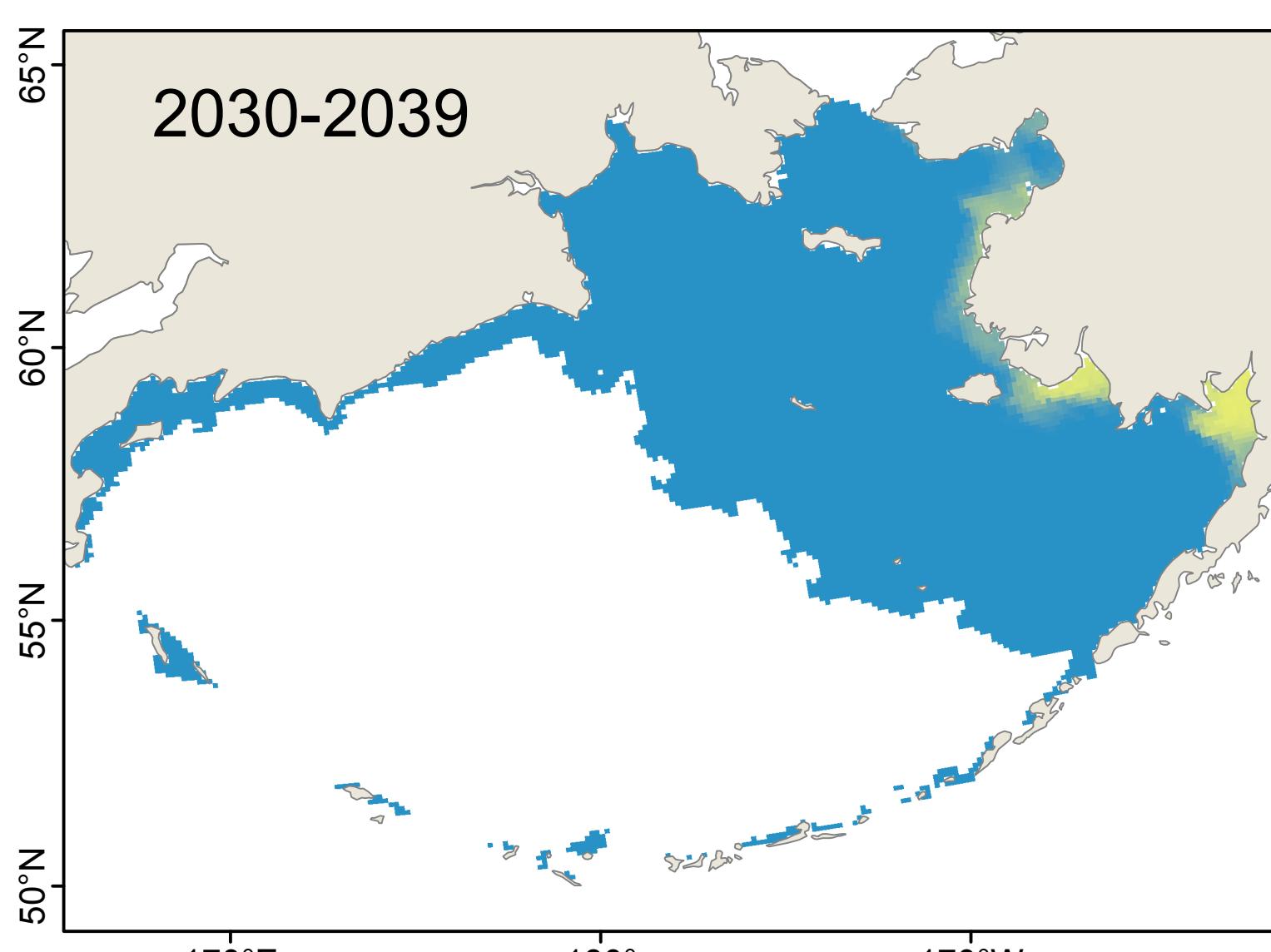
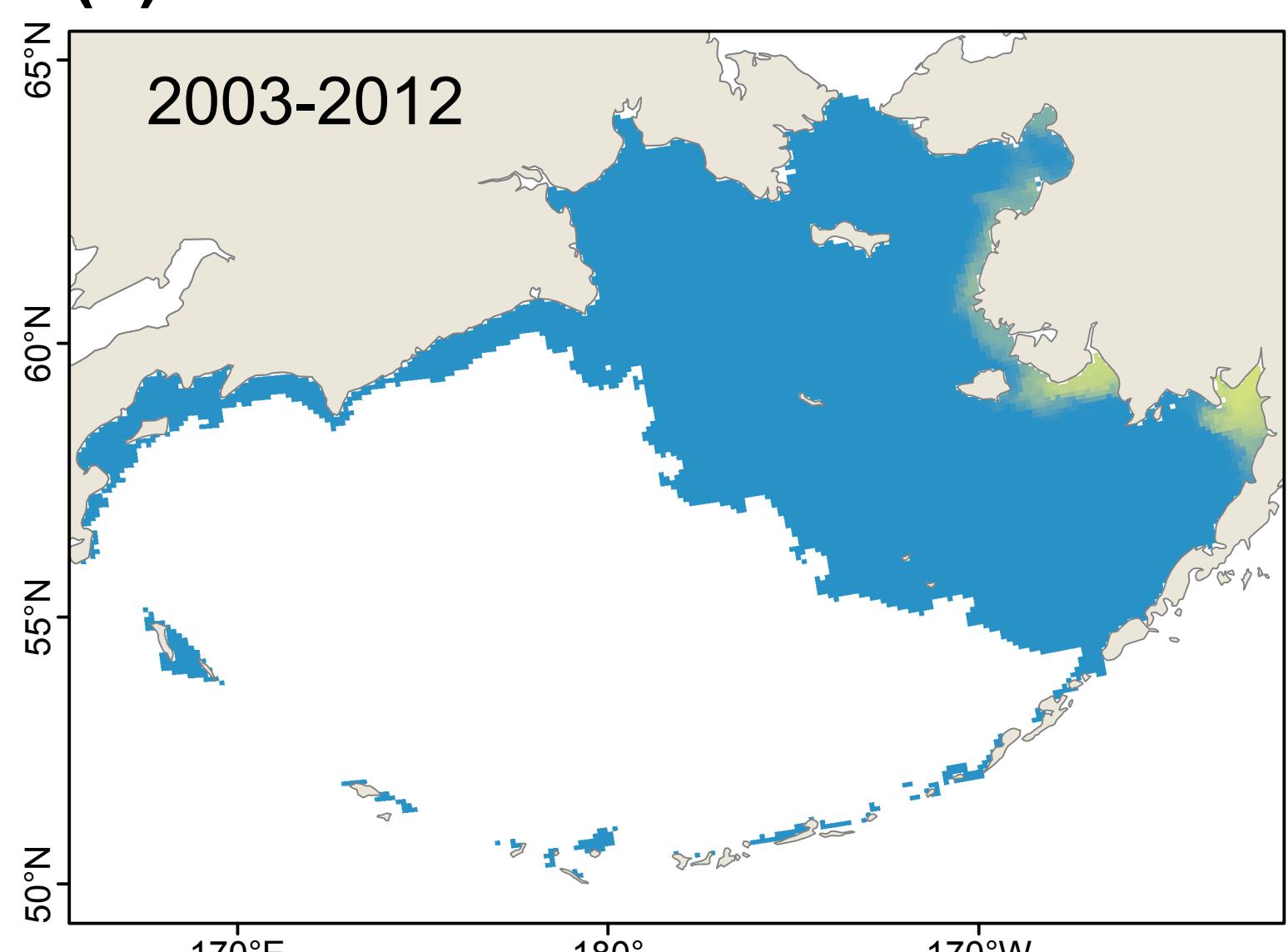
(a) Model: CGCM3-t47



(b) Model: ECHO-G

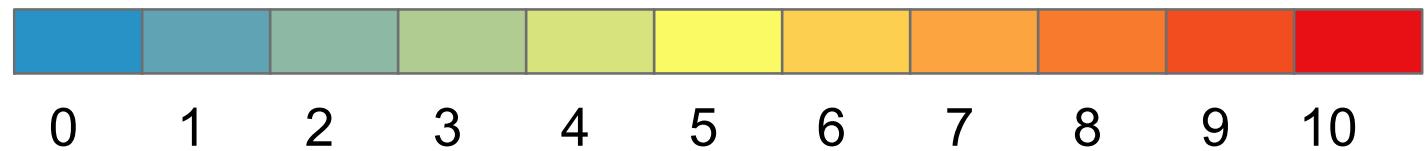


(c) Model: MIROC3.2

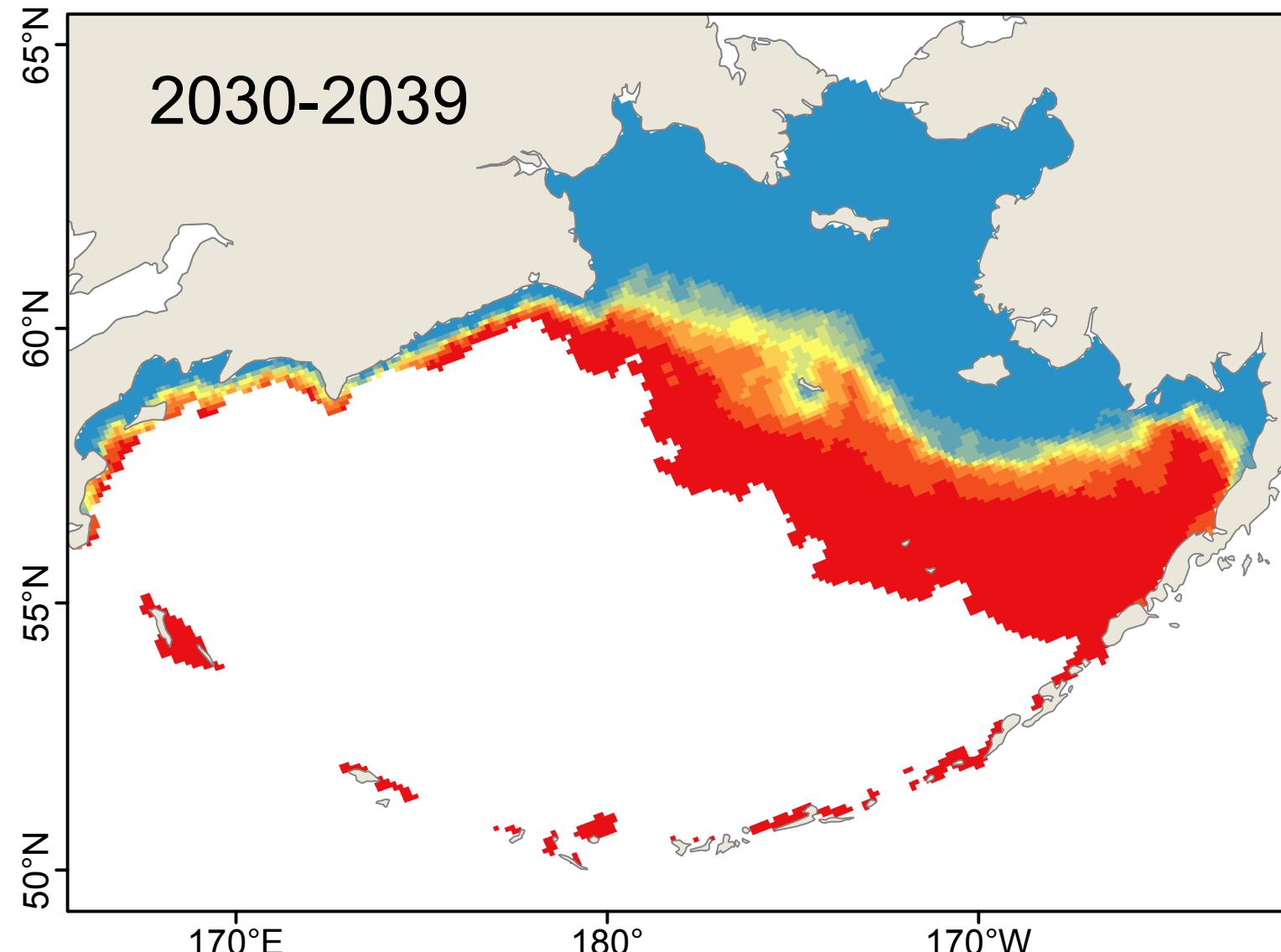
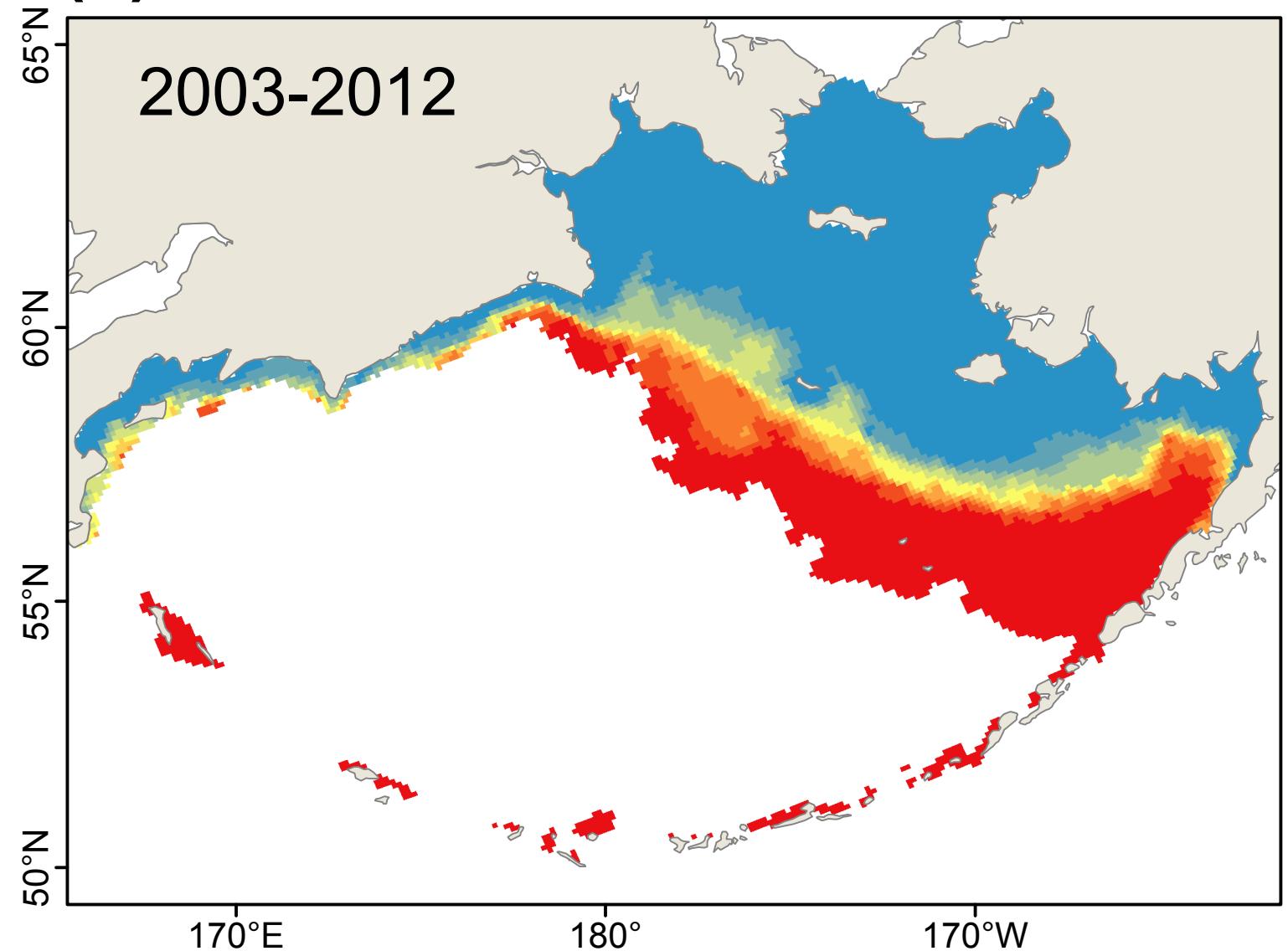


# *Carcinus maenas*: Year-round Survival

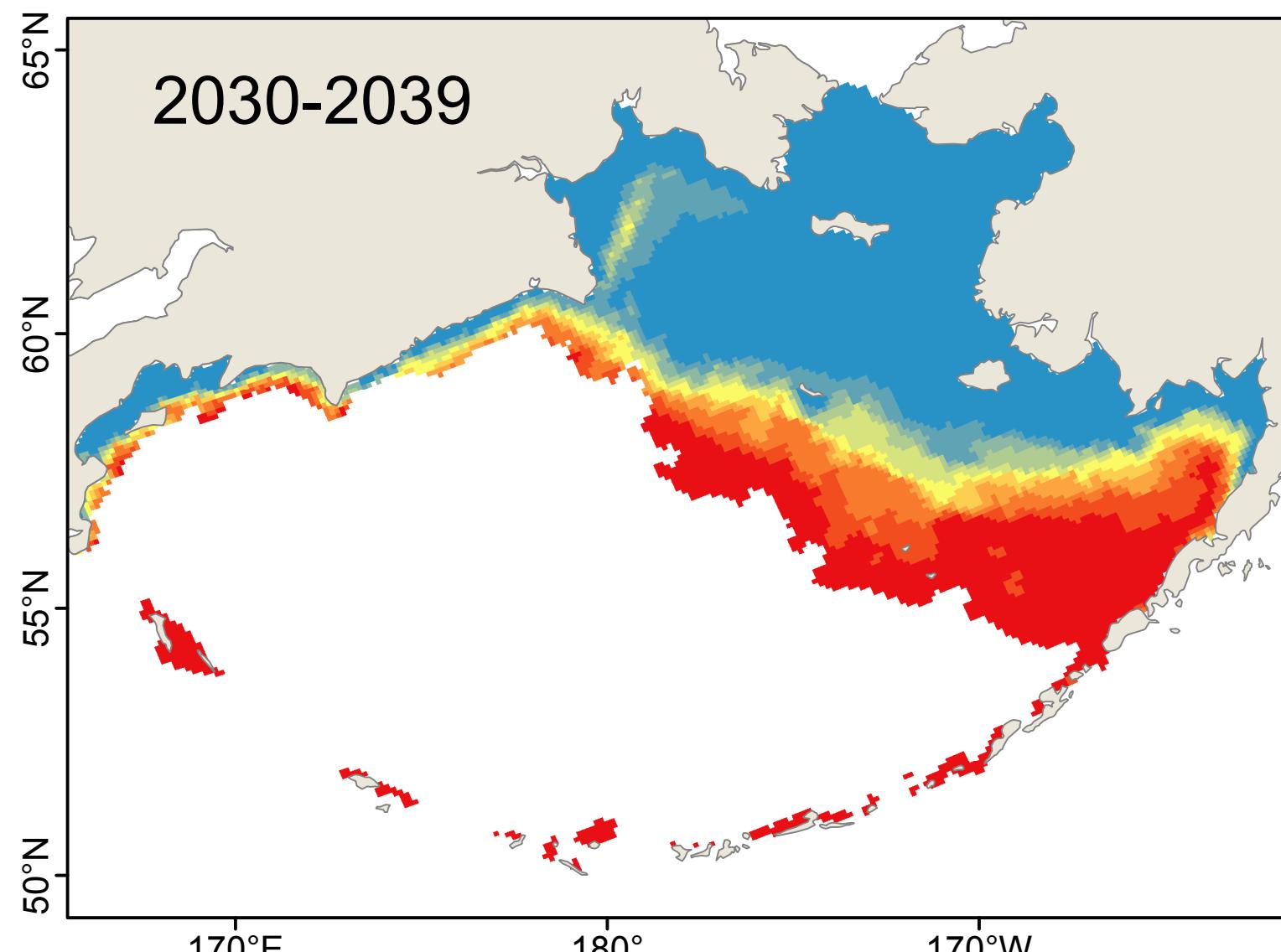
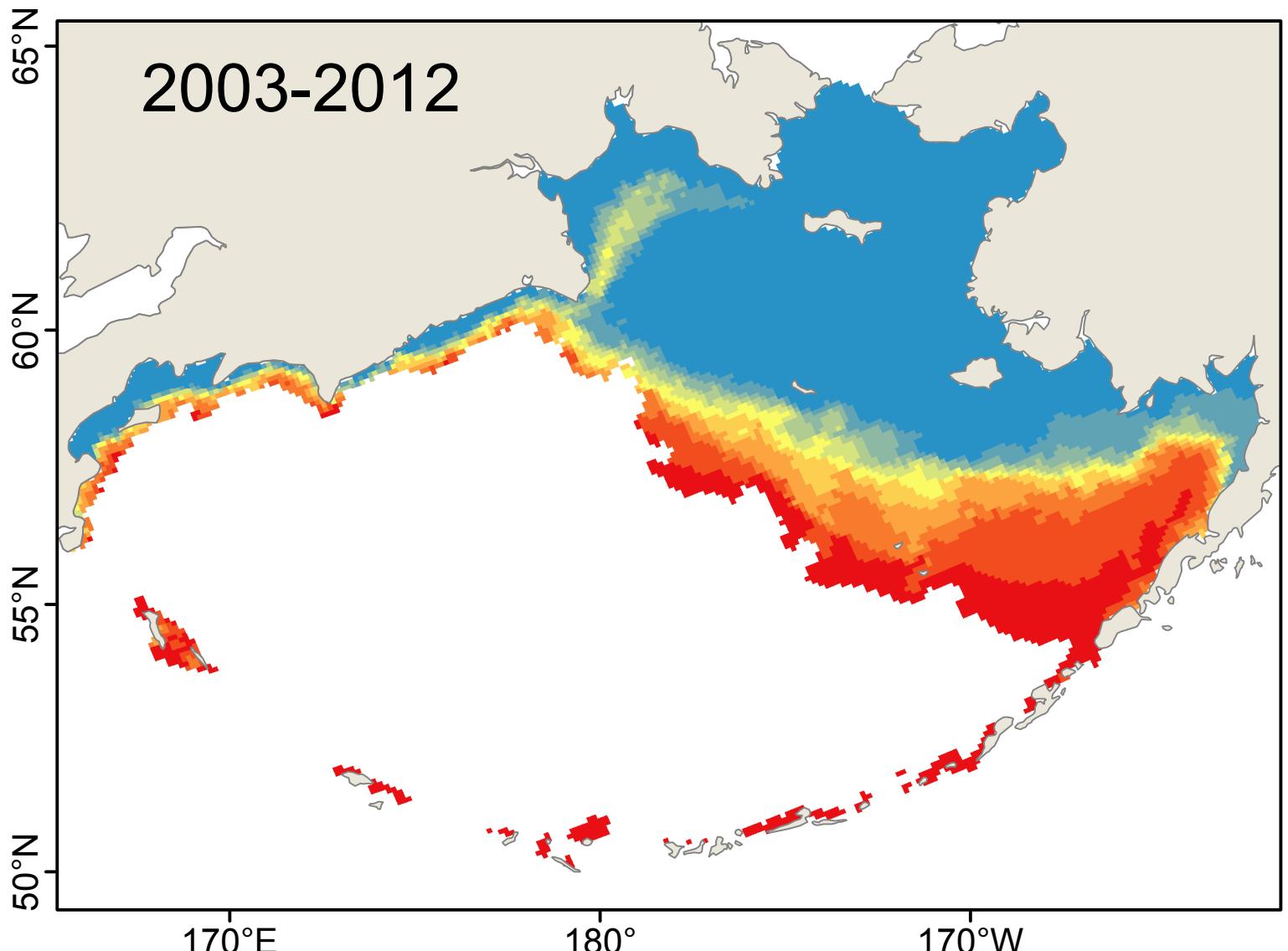
Number of years with suitable habitat



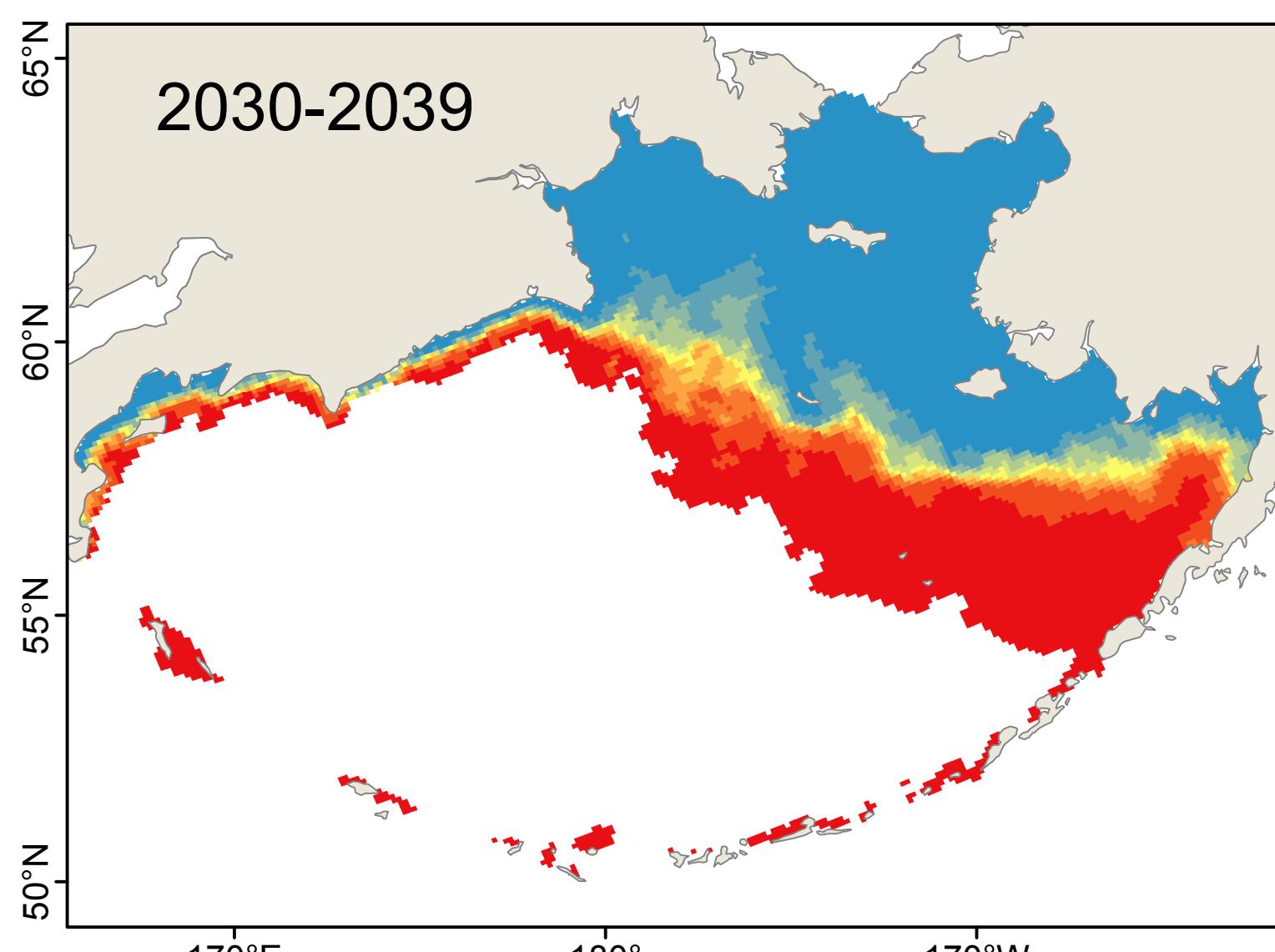
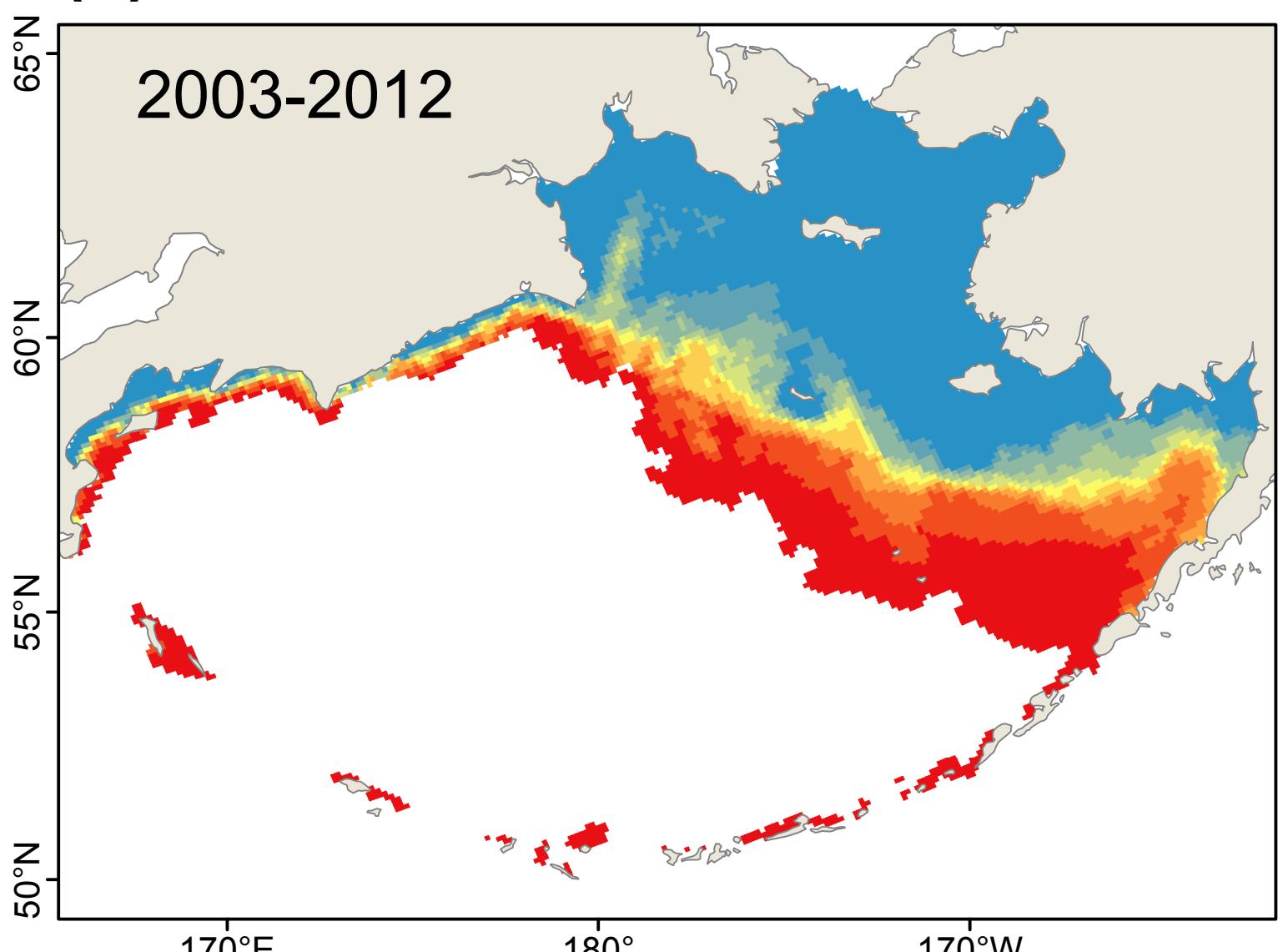
(a) Model: CGCM3-t47



(b) Model: ECHO-G

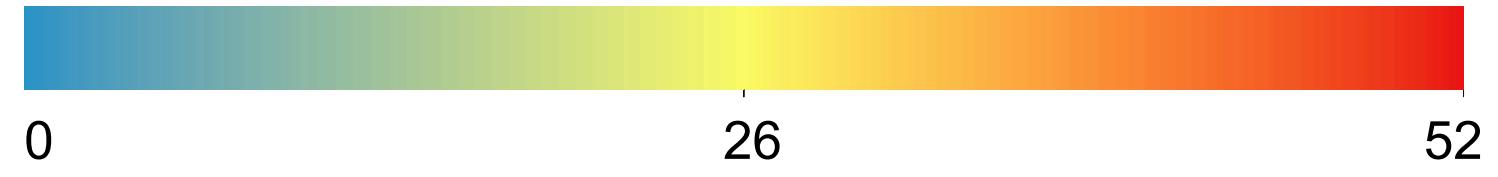


(c) Model: MIROC3.2

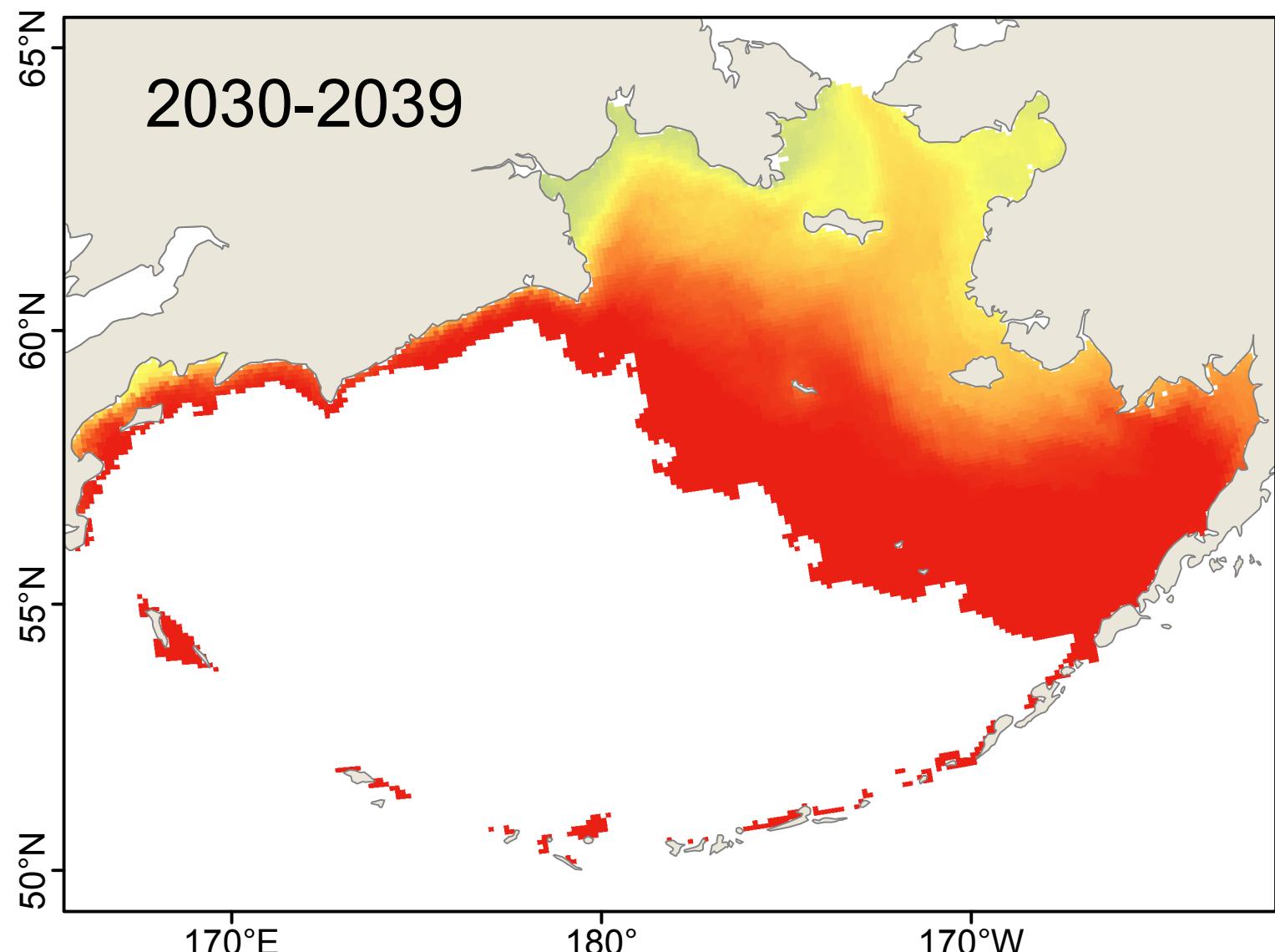
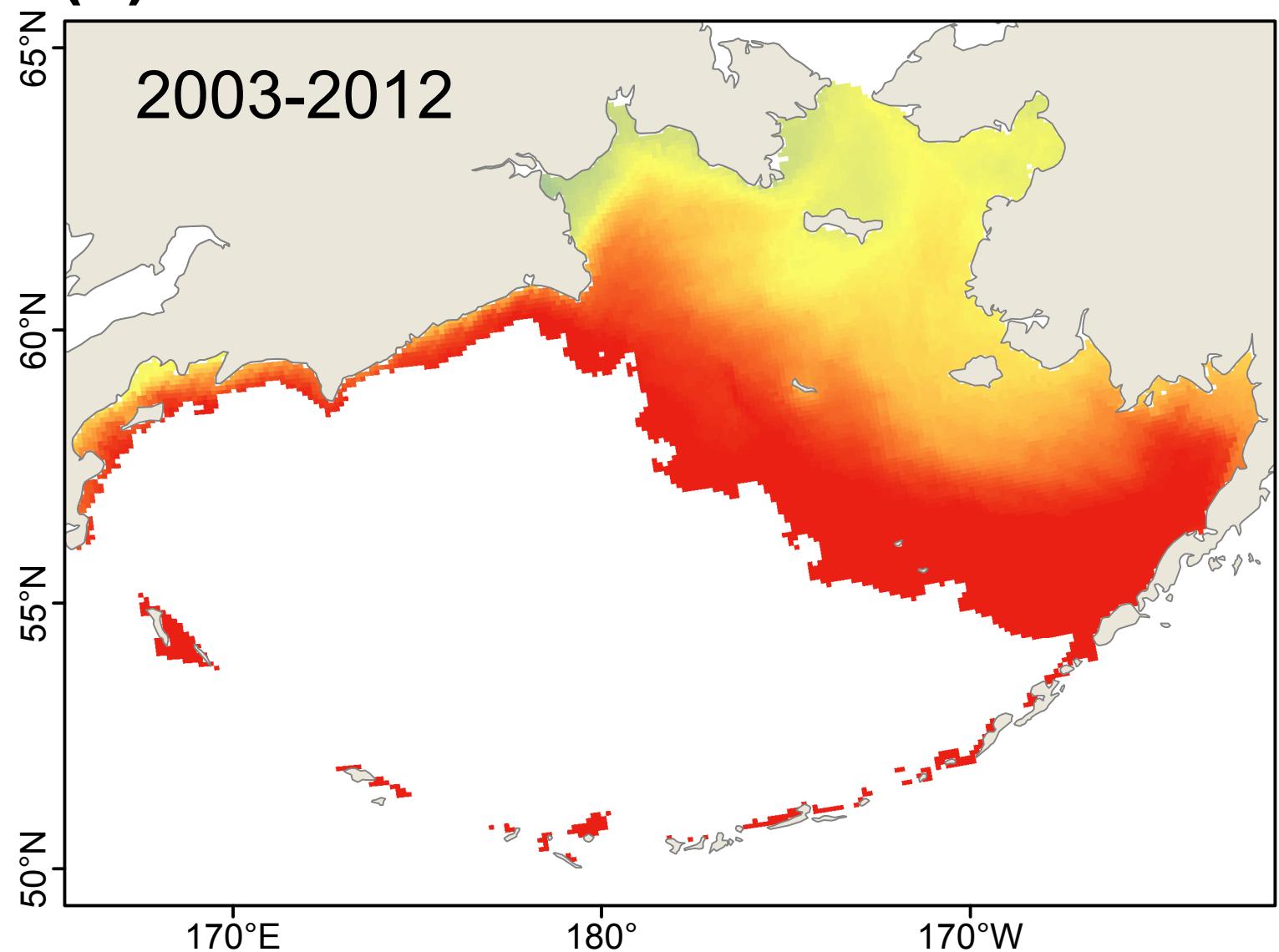


# Carcinus maenas: Weekly Survival

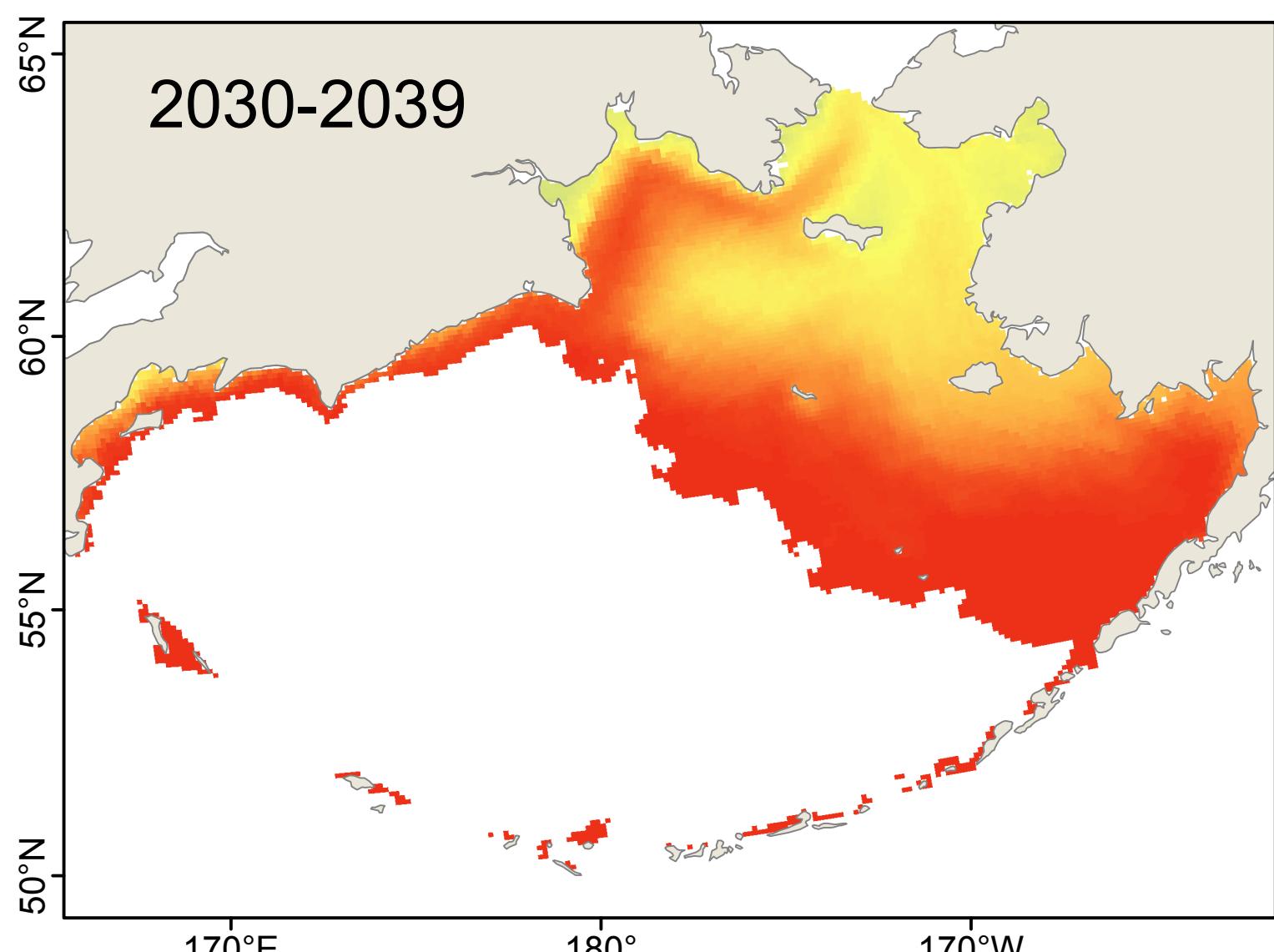
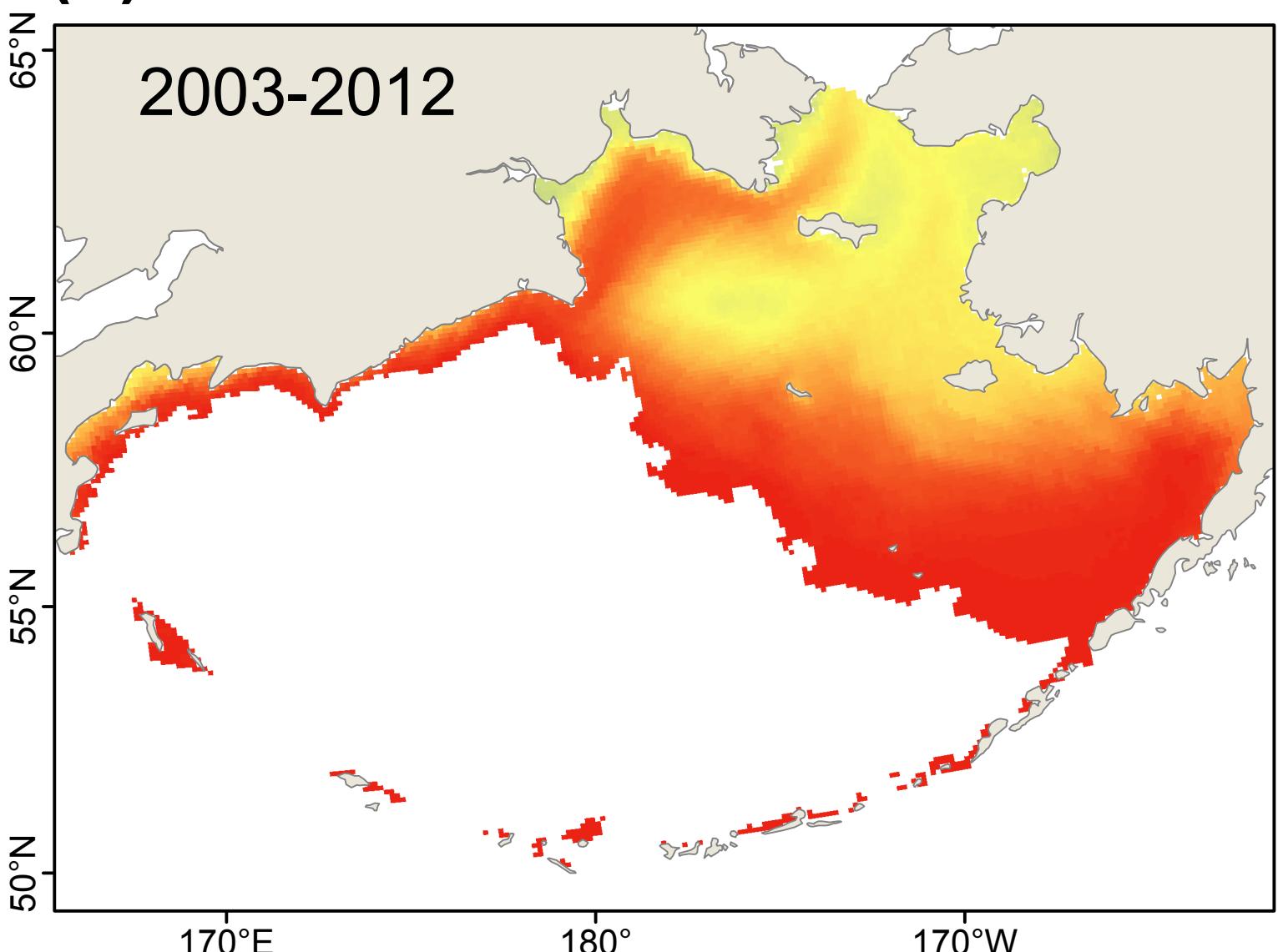
Average number of weeks of suitable habitat



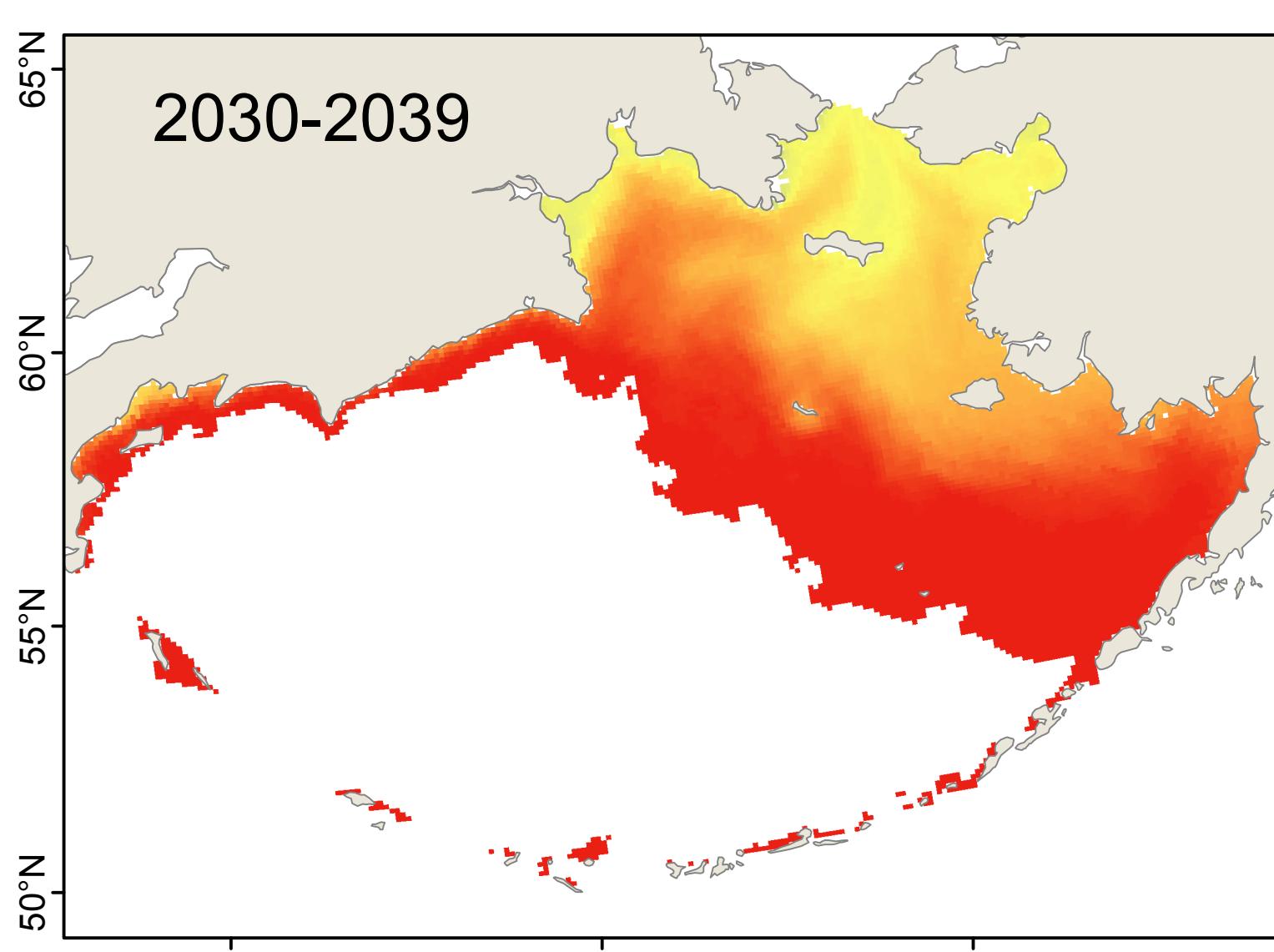
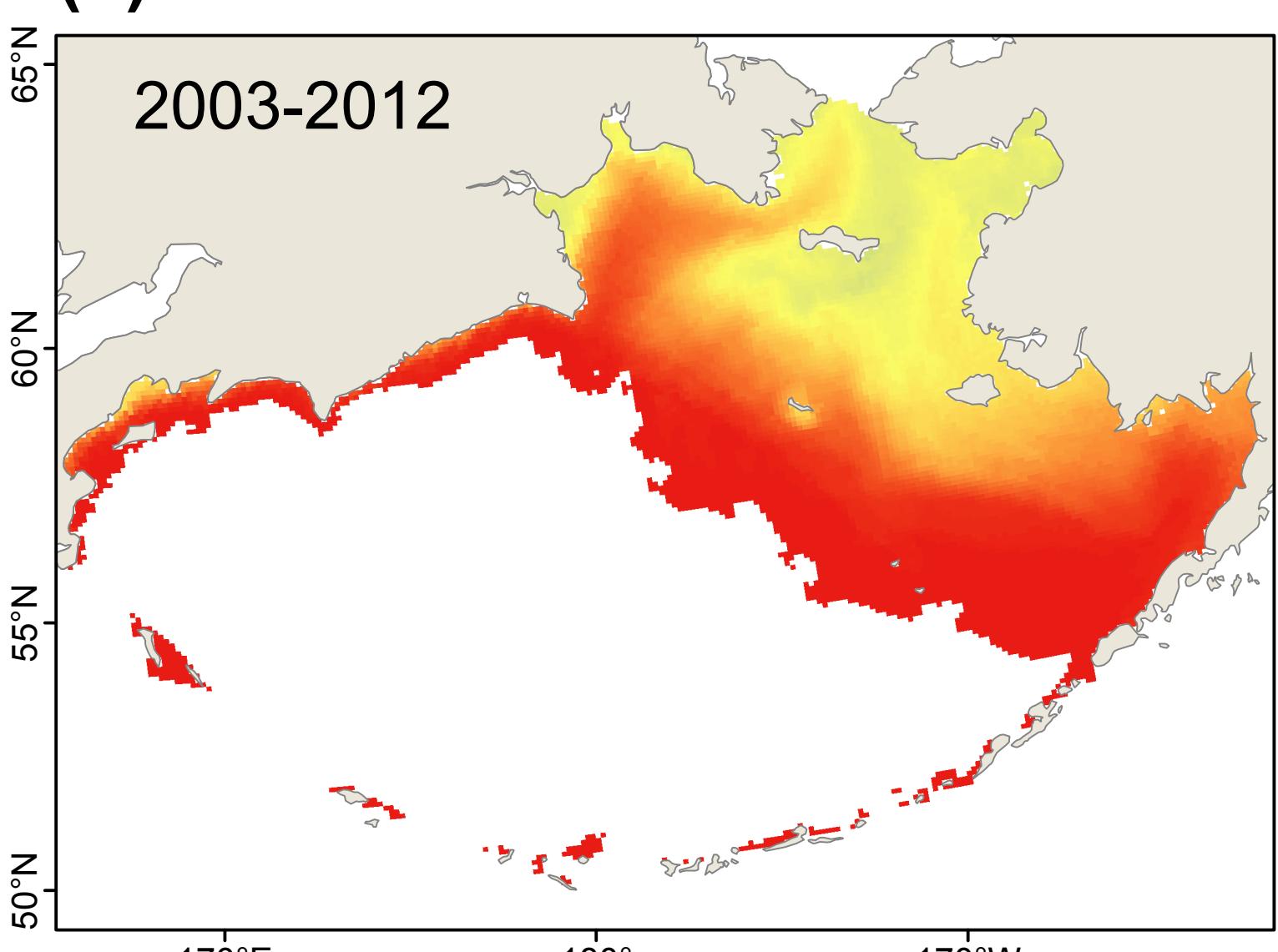
(a) Model: CGCM3-t47



(b) Model: ECHO-G

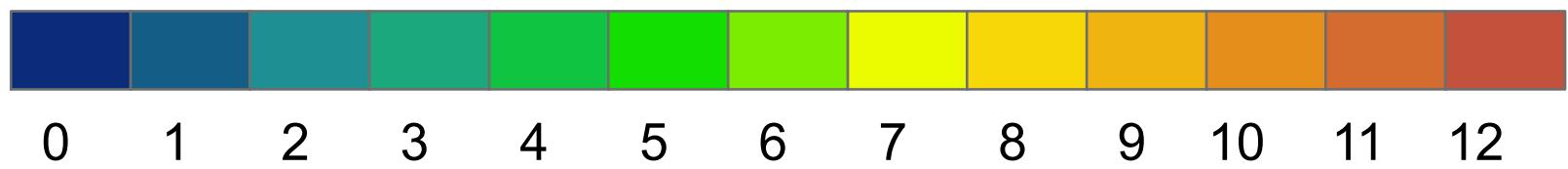


(c) Model: MIROC3.2

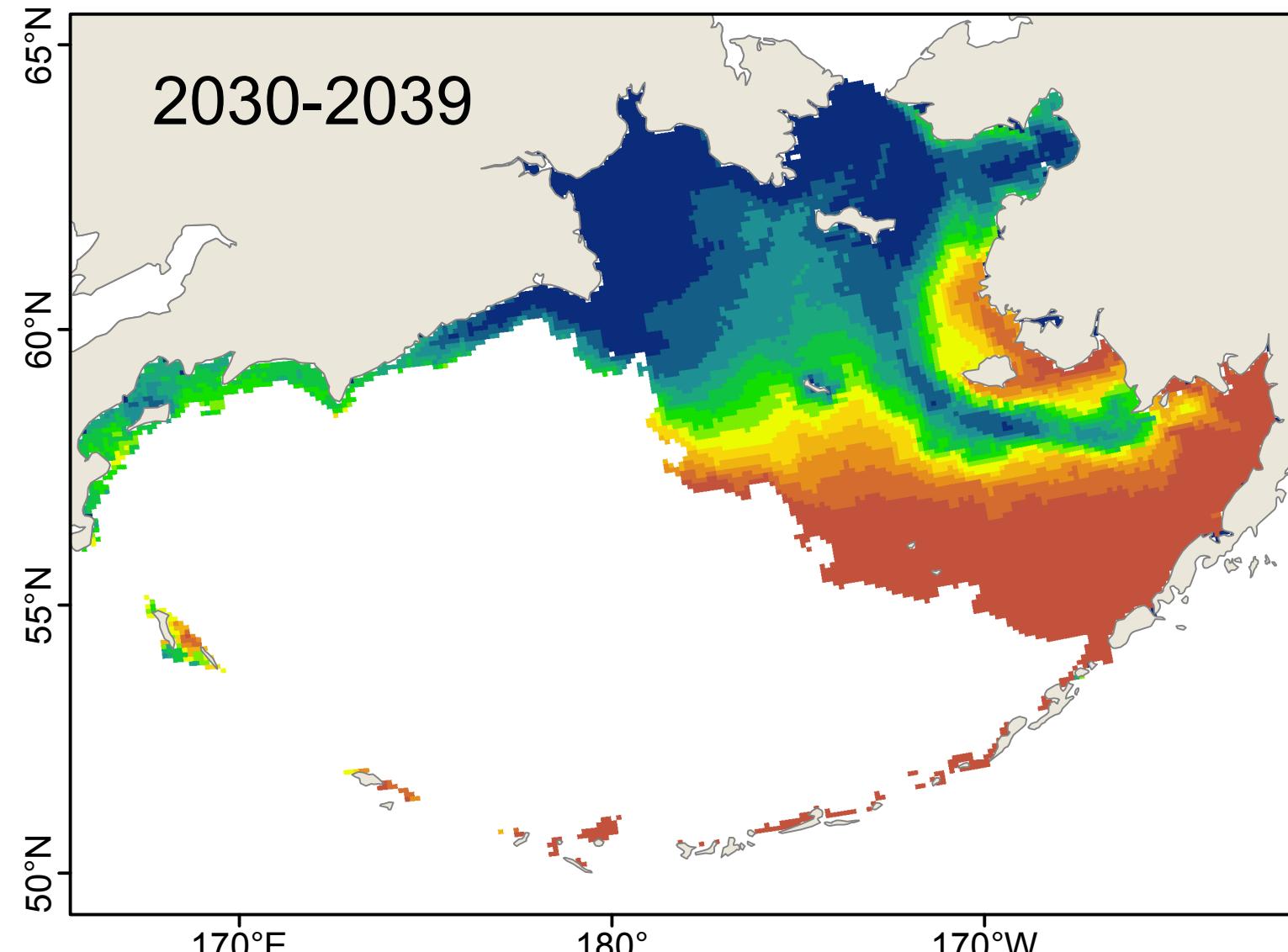
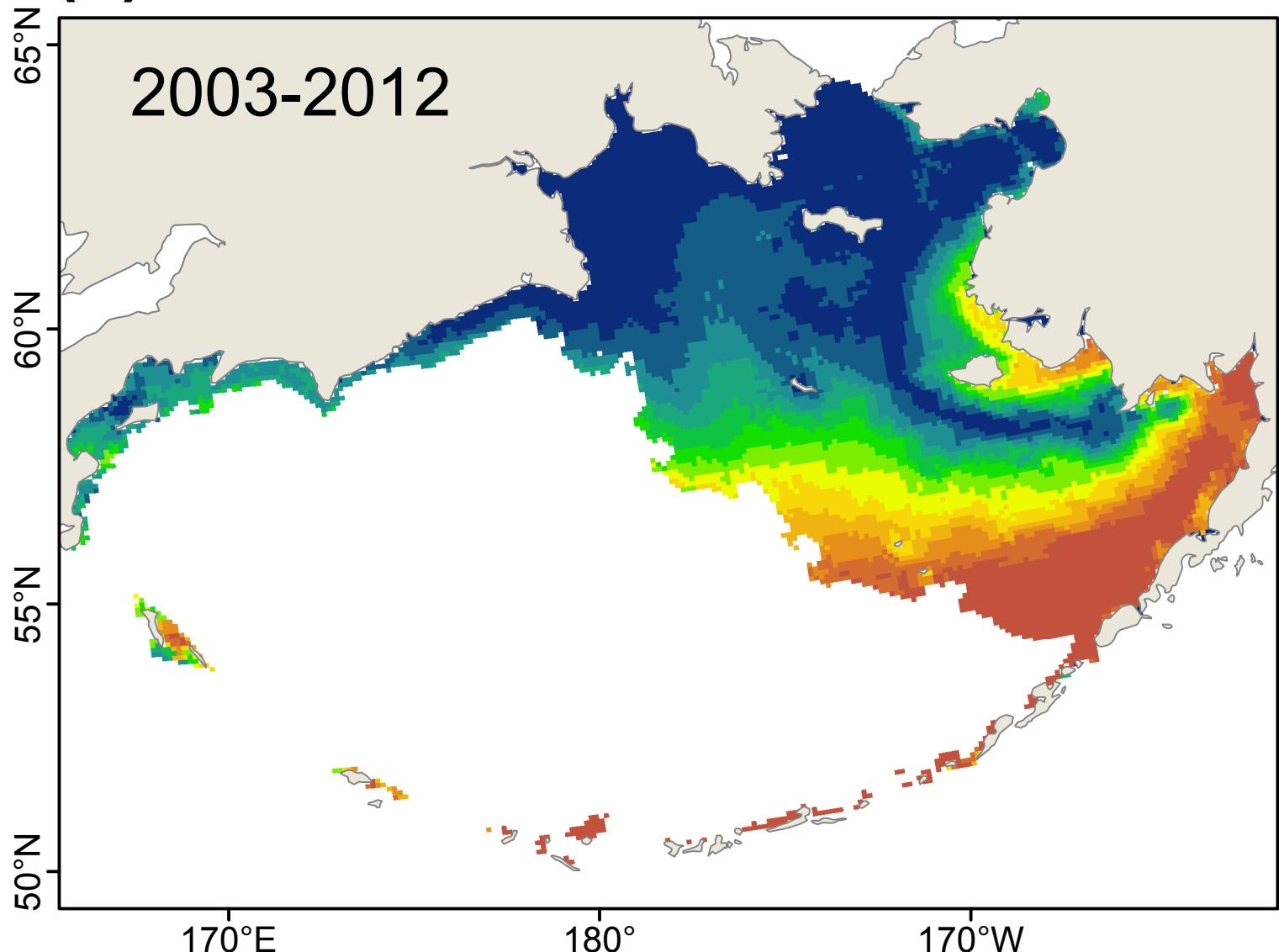


# *Carcinus maenas: Reproduction*

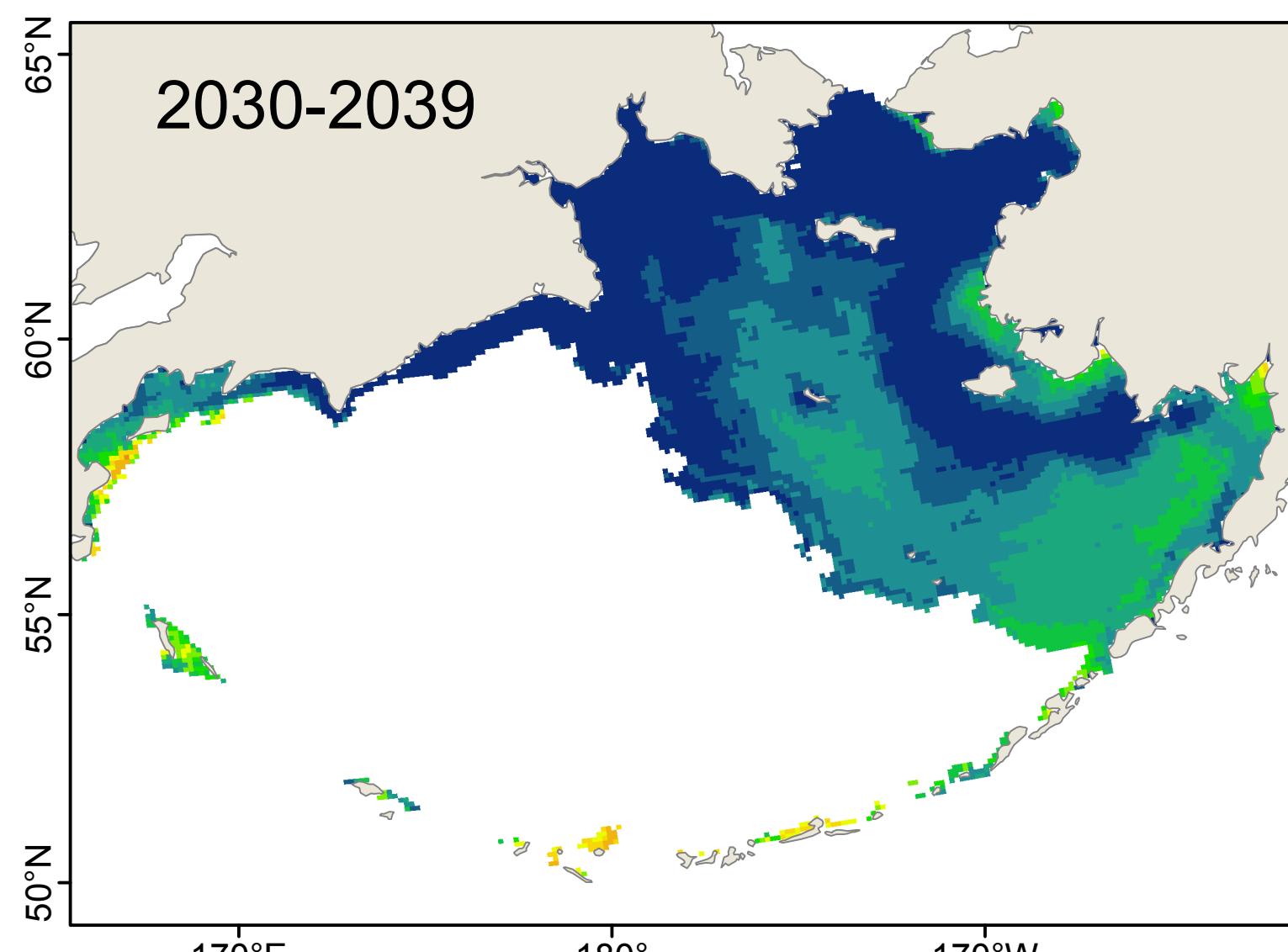
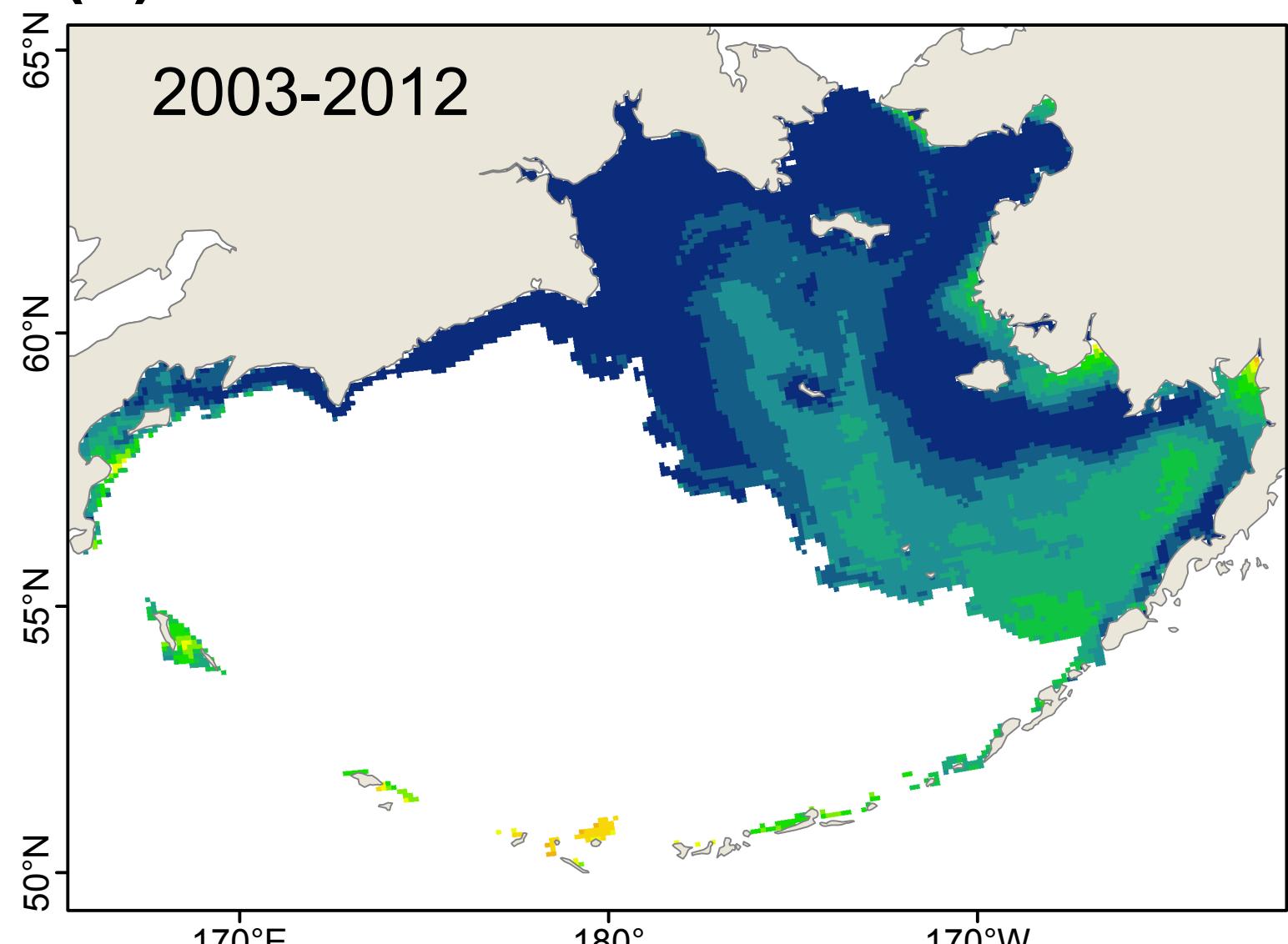
Average number of consecutive weeks of suitable habitat



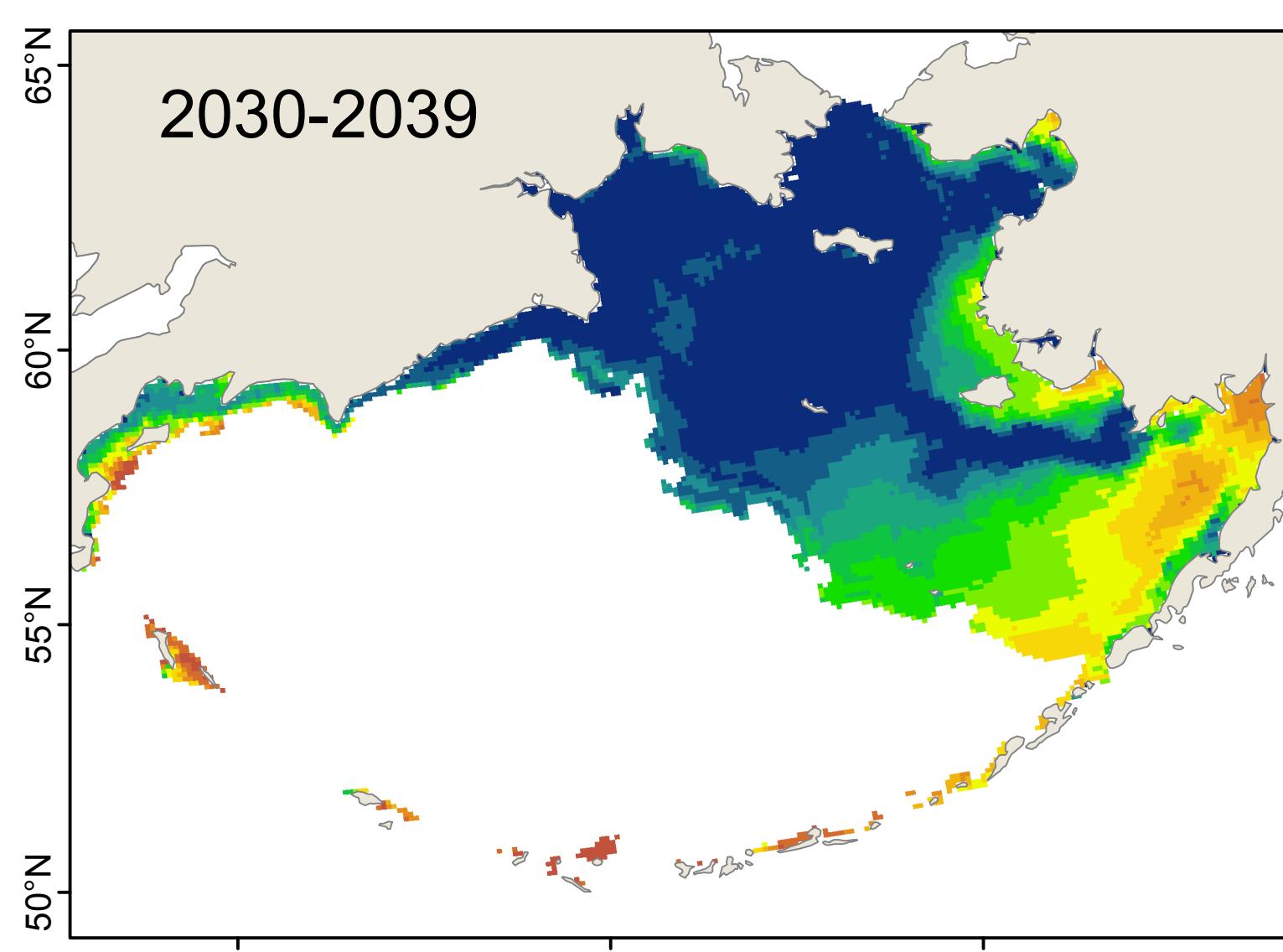
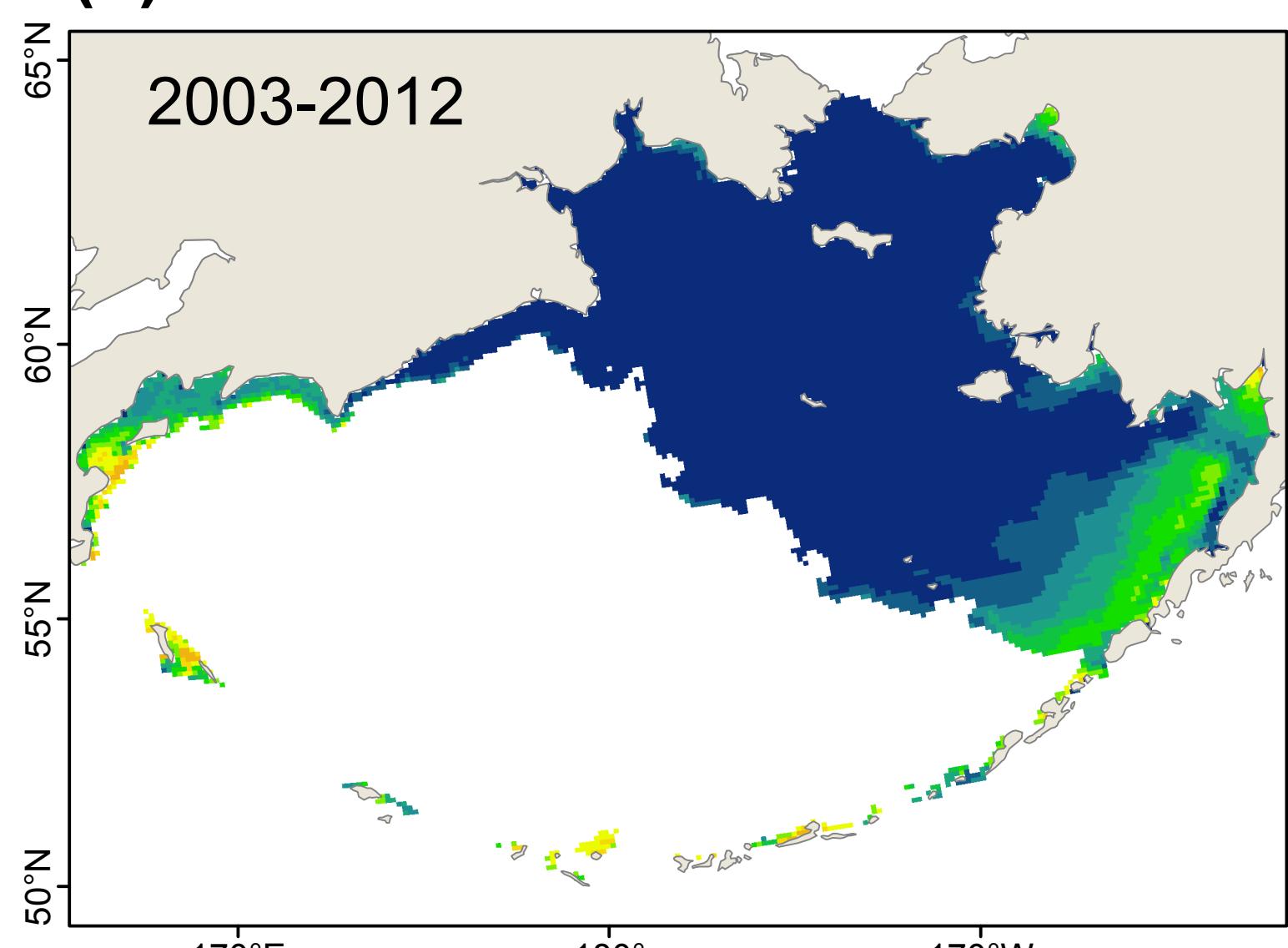
(a) Model: CGCM3-t47



(b) Model: ECHO-G

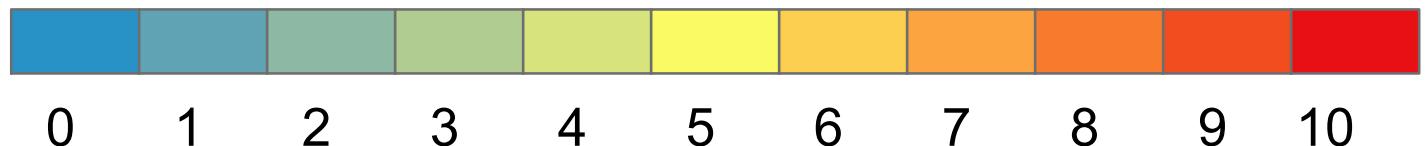


(c) Model: MIROC3.2

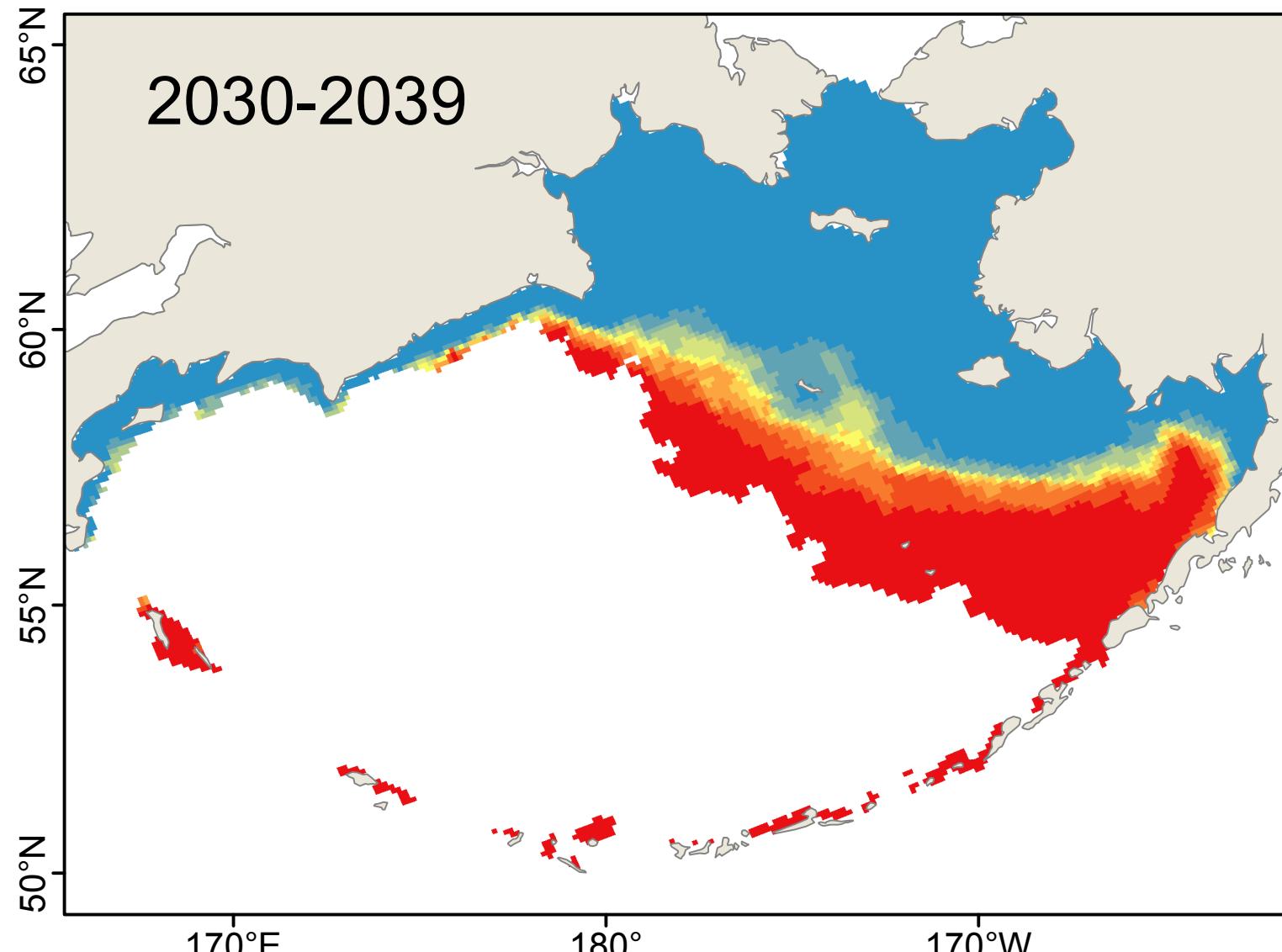
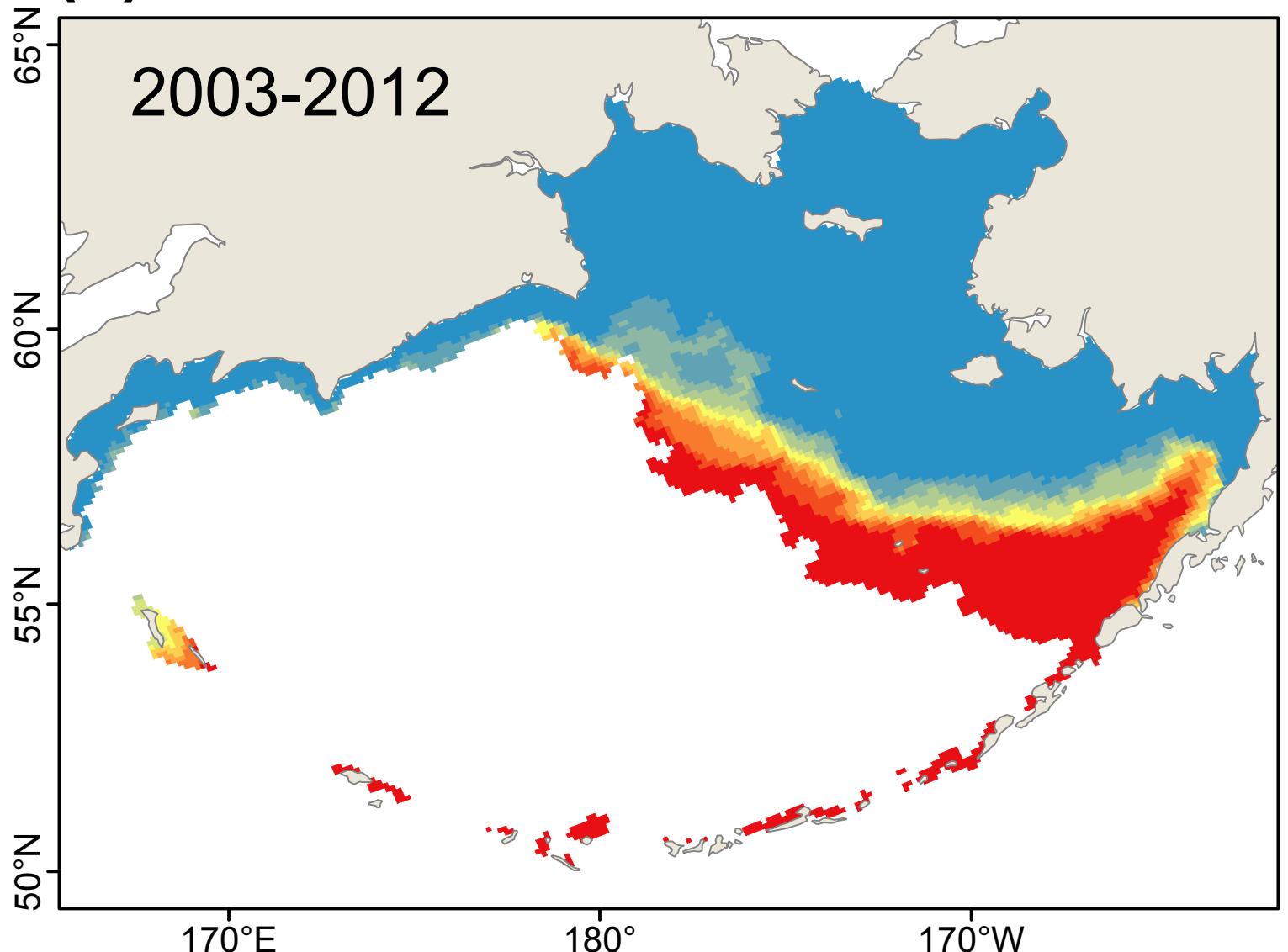


# *Eriocheir sinensis*: Year-round Survival

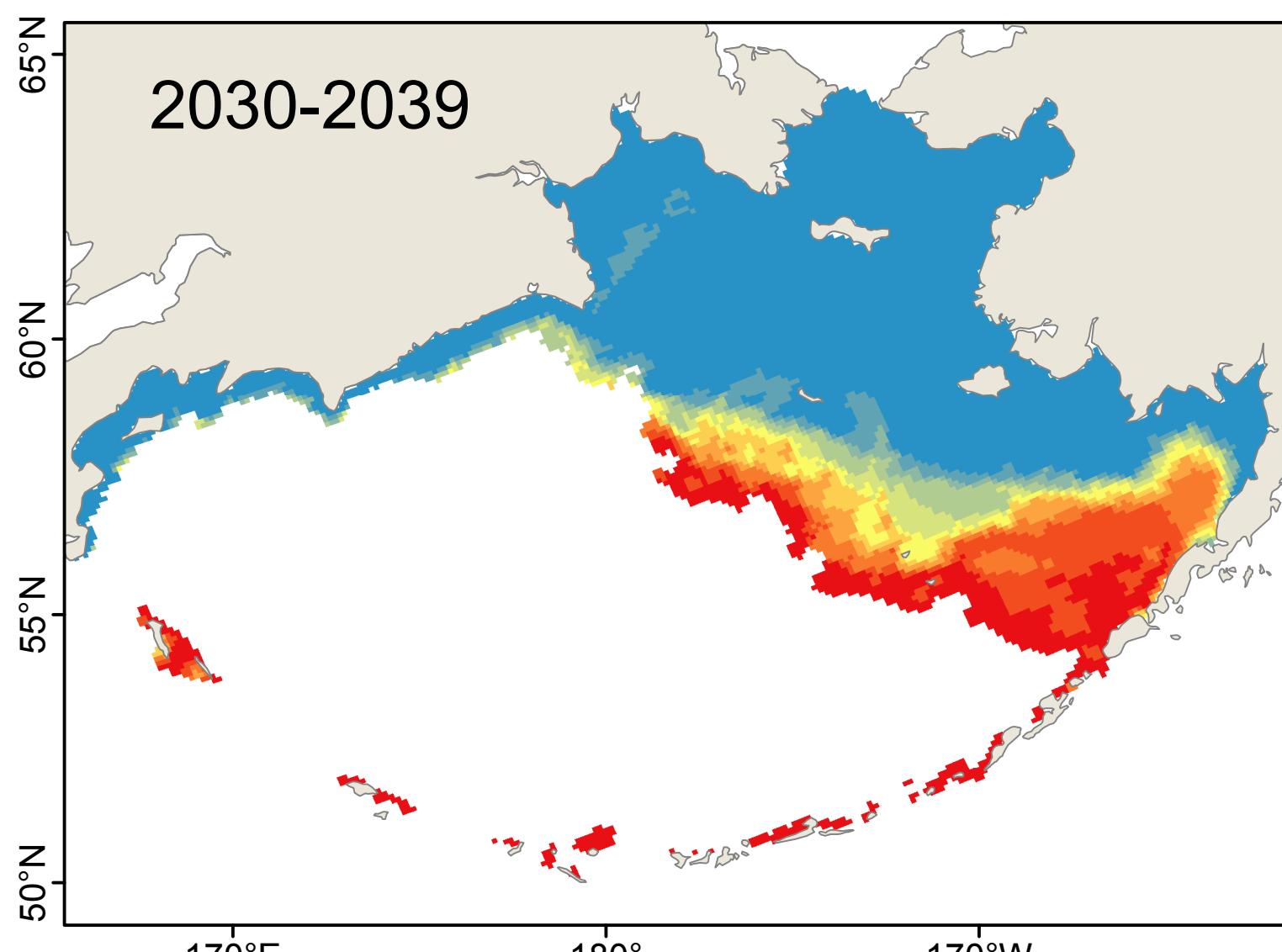
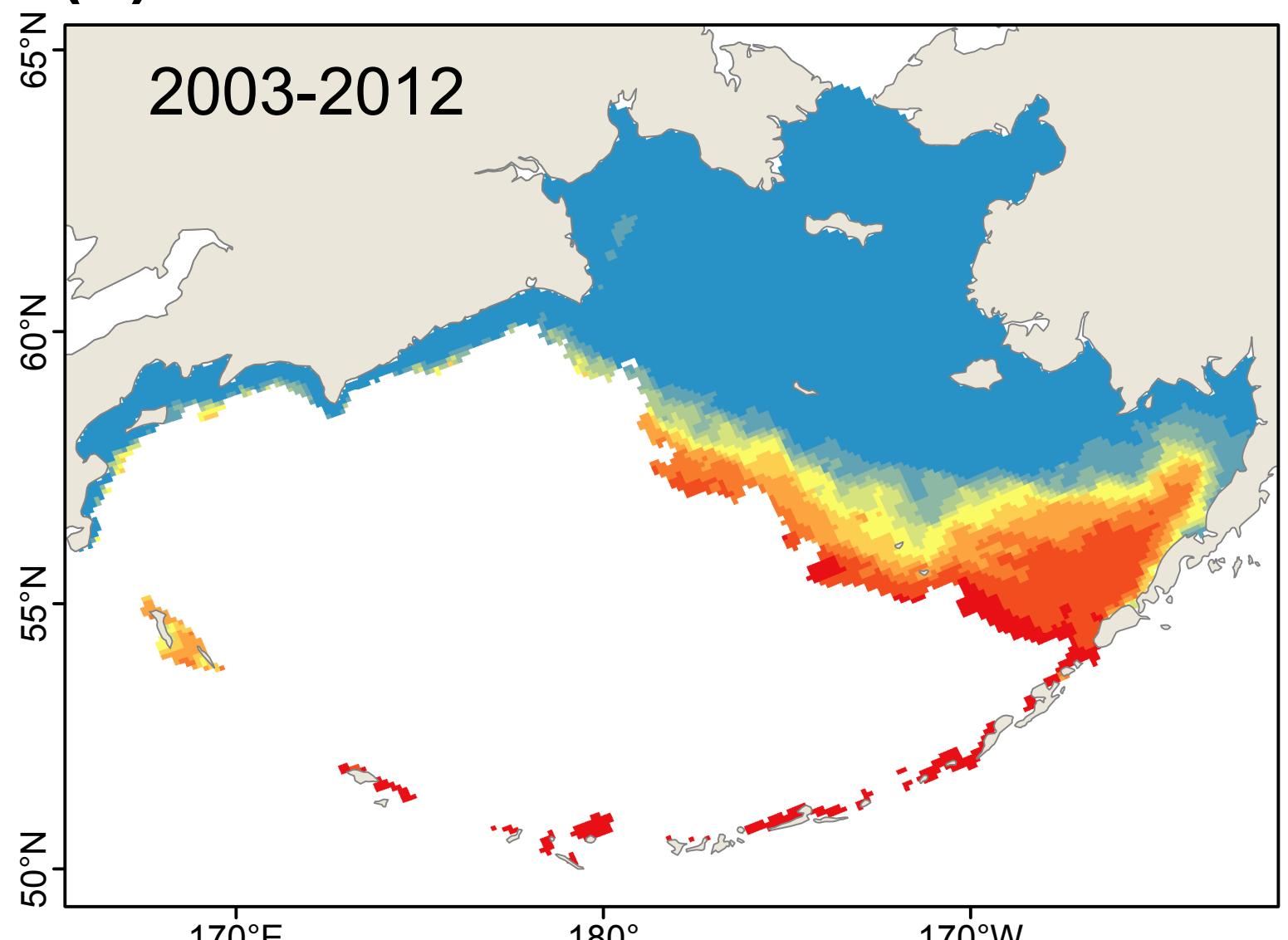
Number of years with suitable habitat



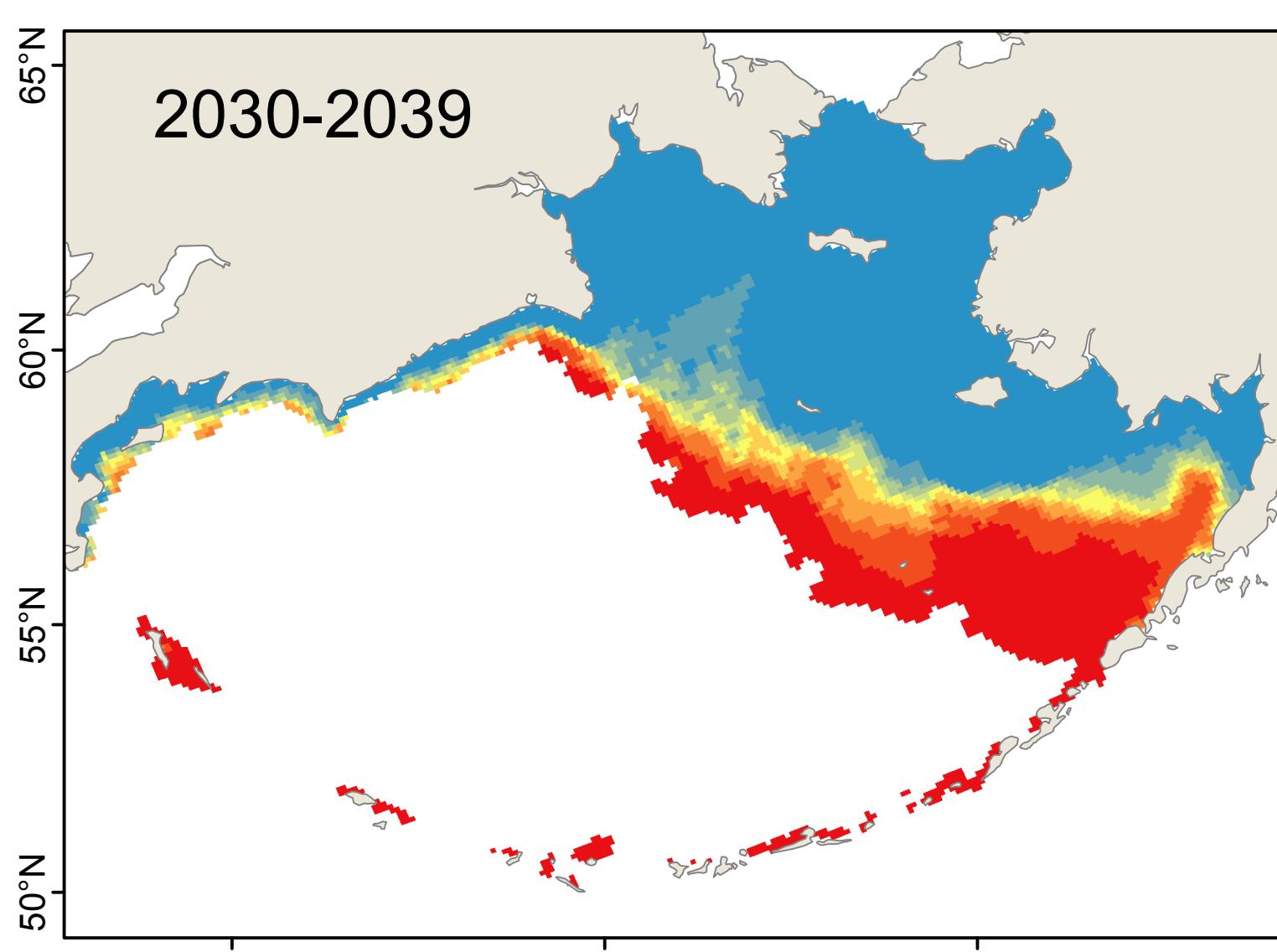
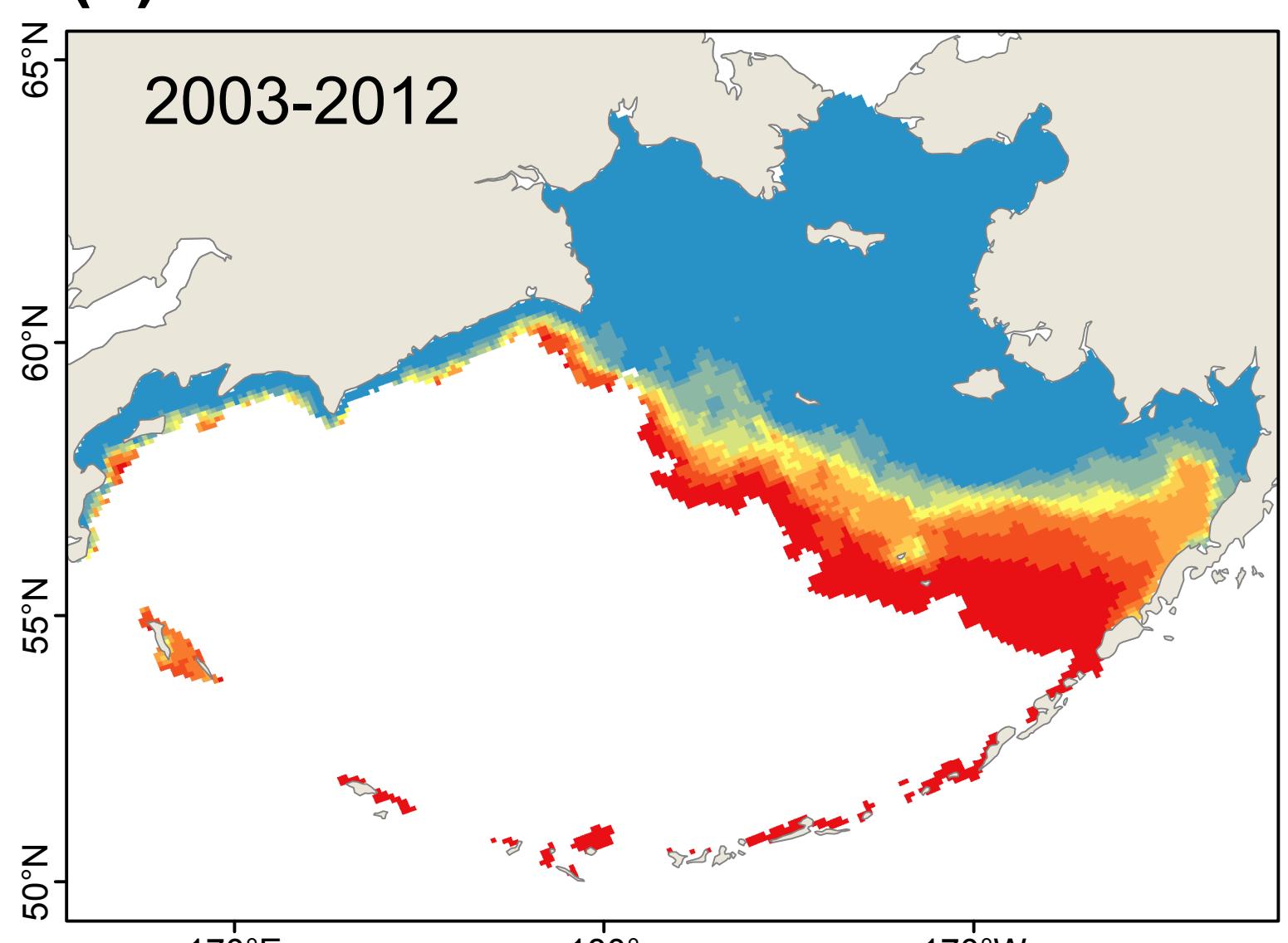
(a) Model: CGCM3-t47



(b) Model: ECHO-G

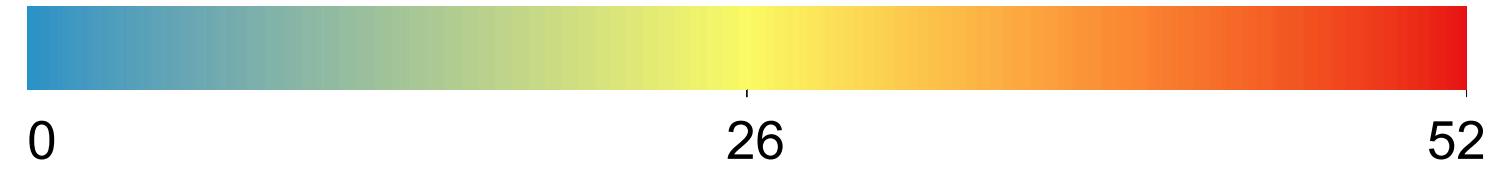


(c) Model: MIROC3.2

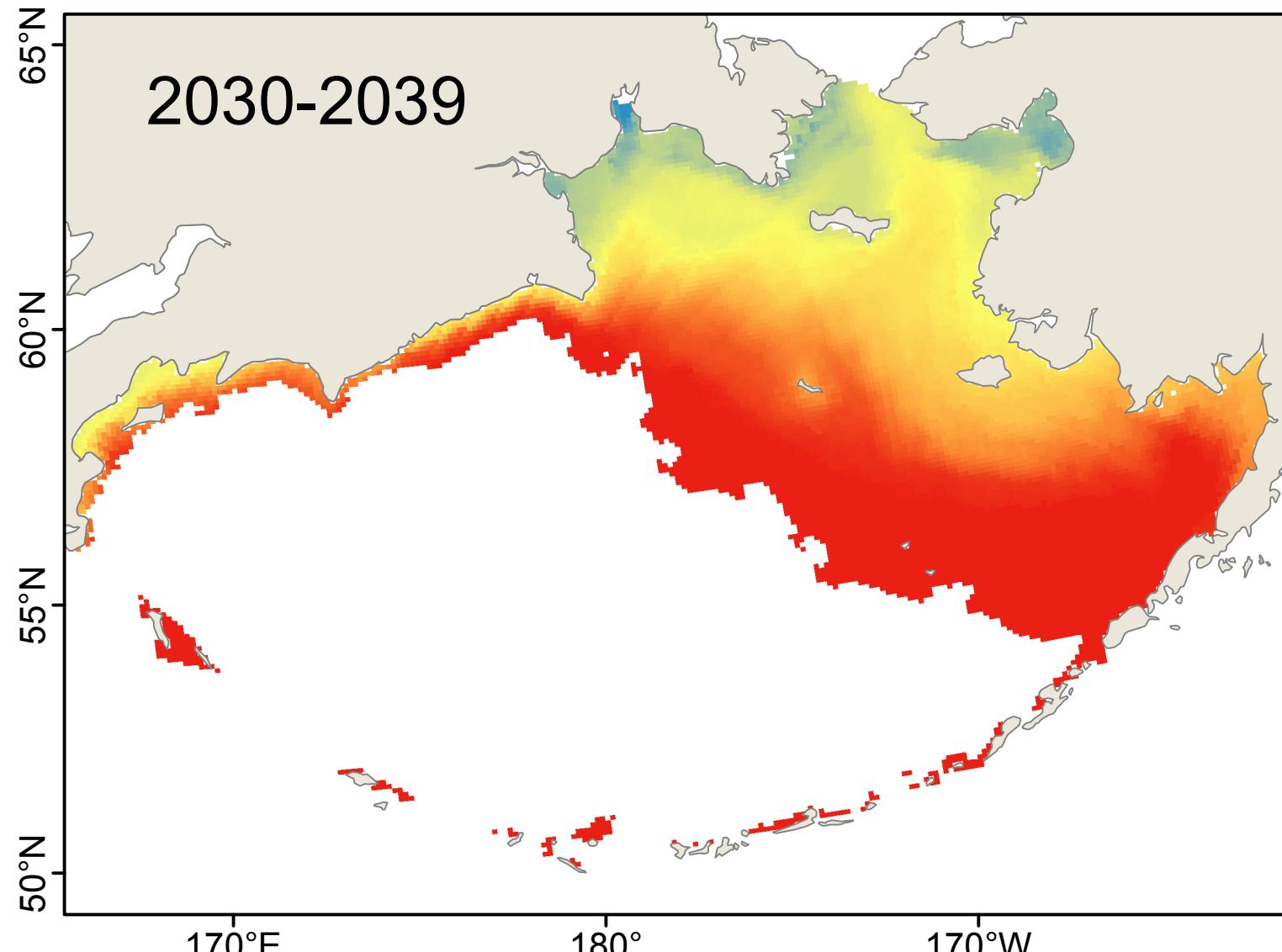
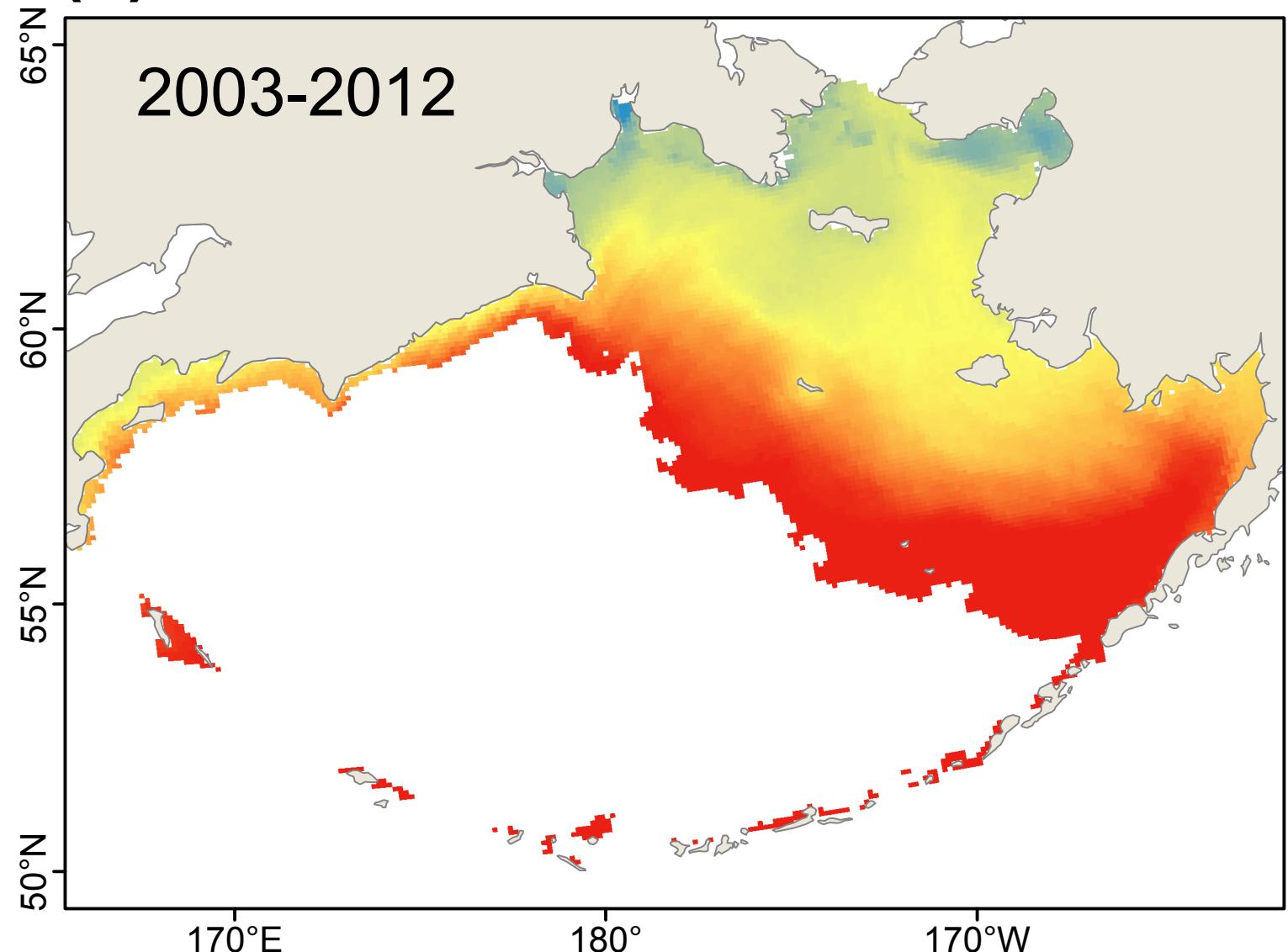


# *Eriocheir sinensis: Weekly Survival*

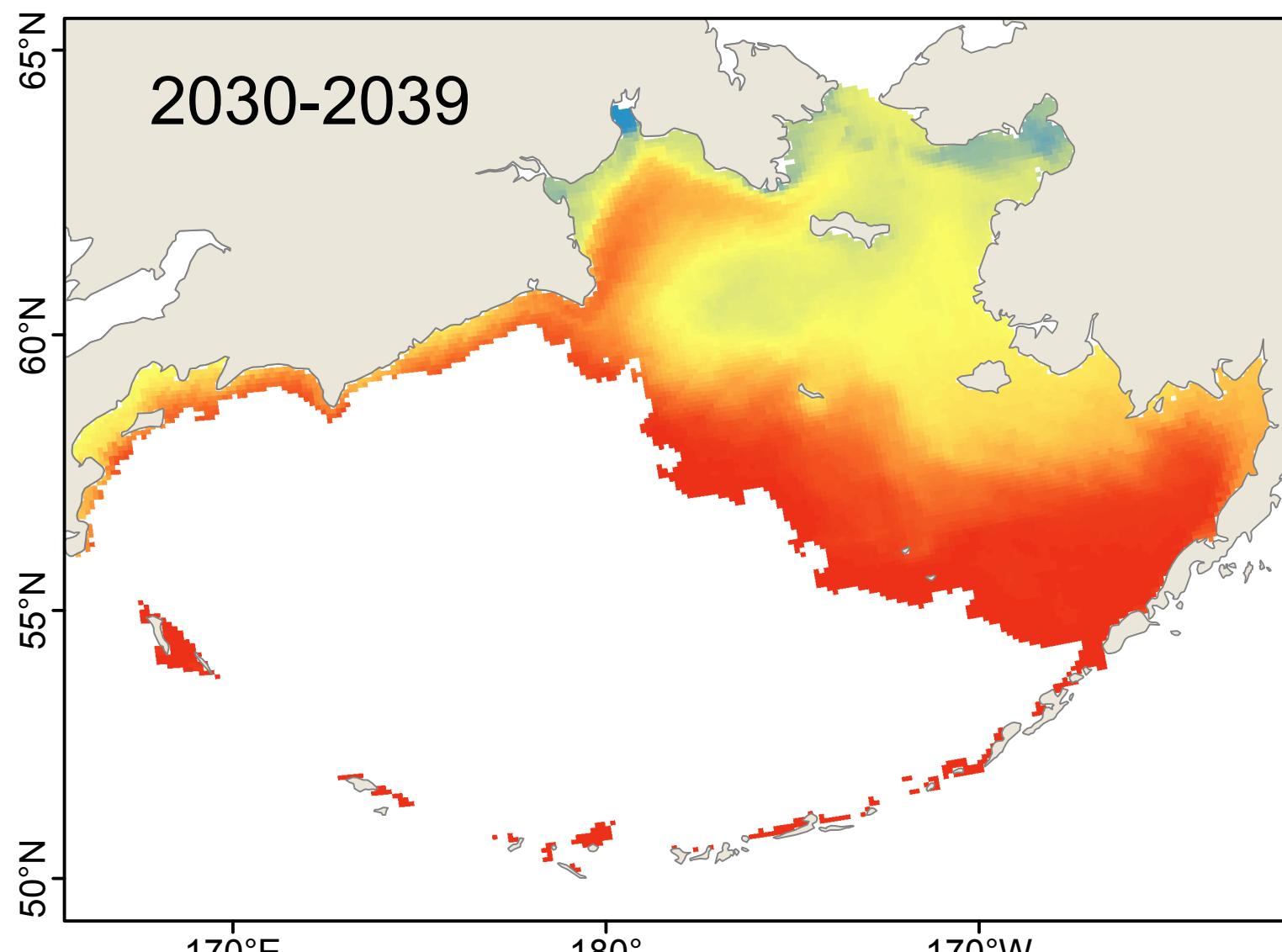
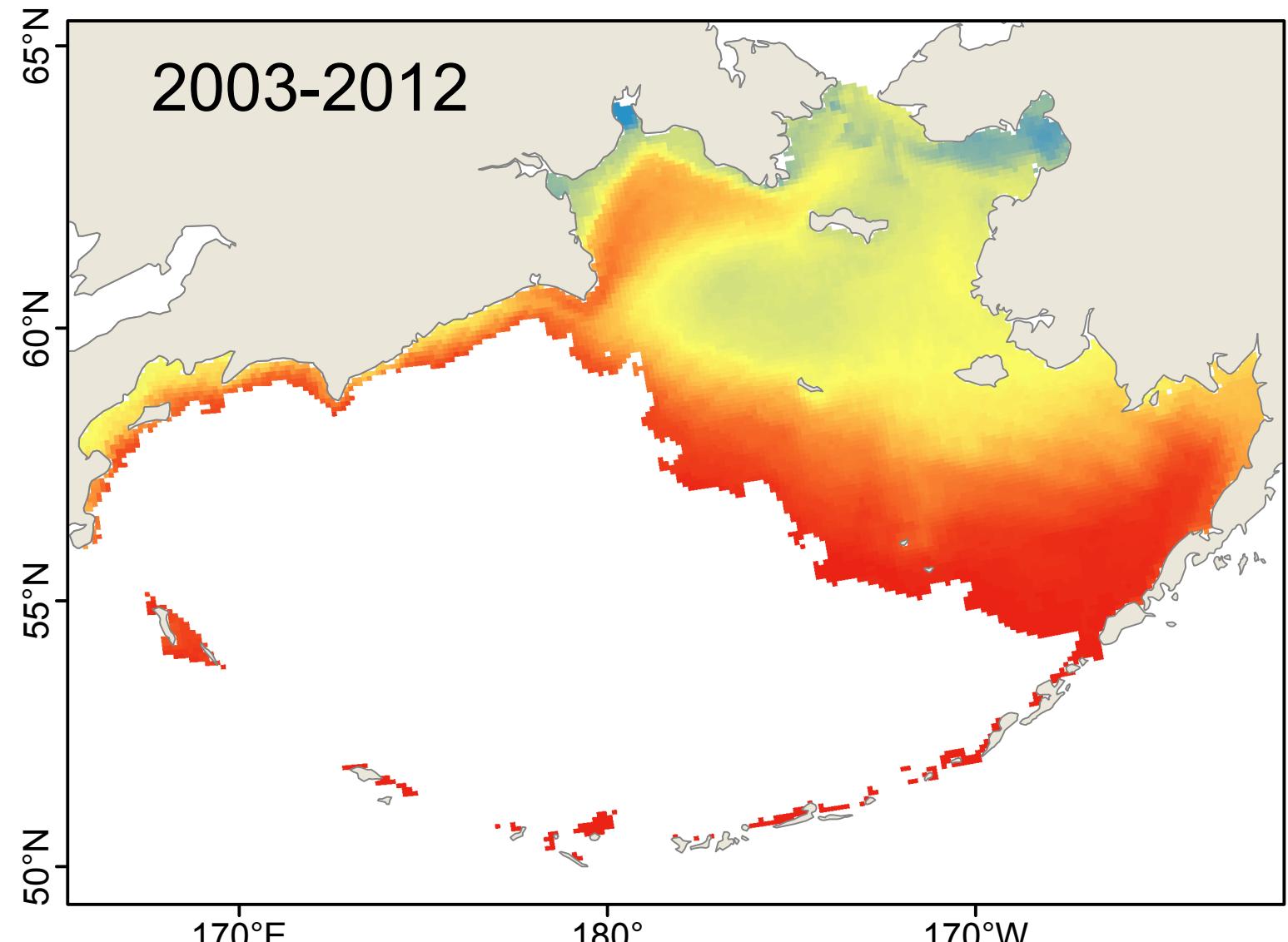
Average number of weeks of suitable habitat



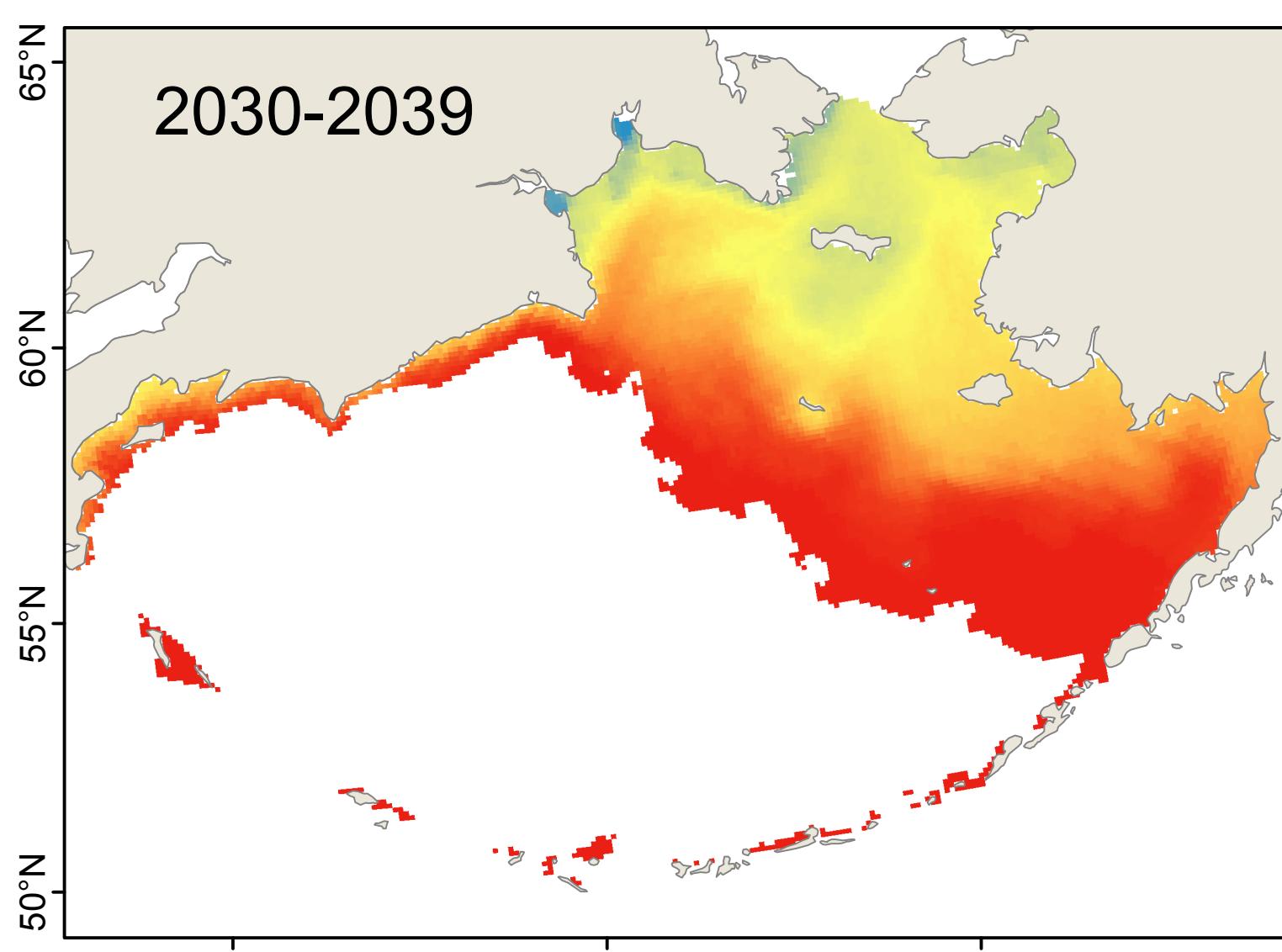
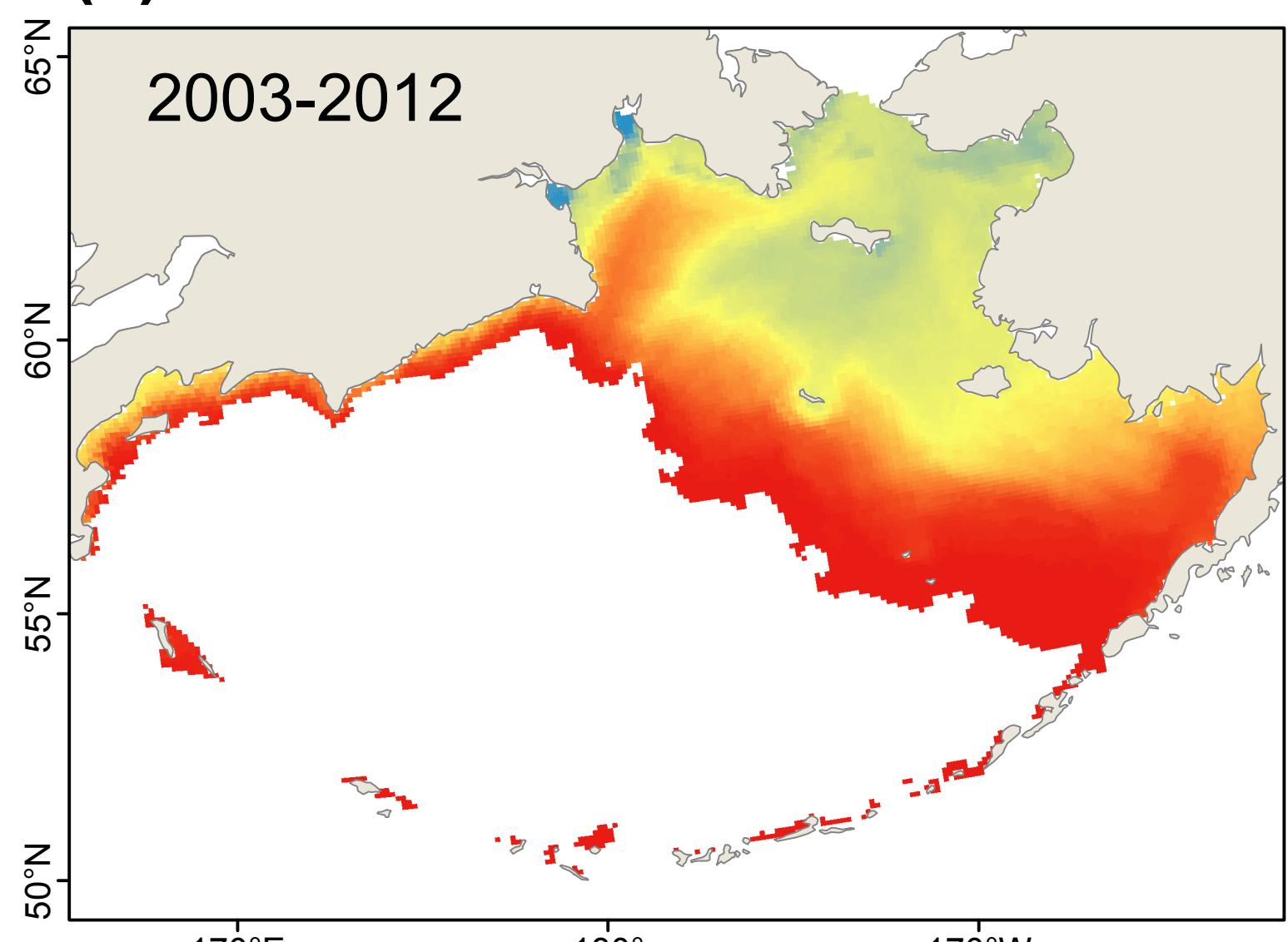
(a) Model: CGCM3-t47



(b) Model: ECHO-G

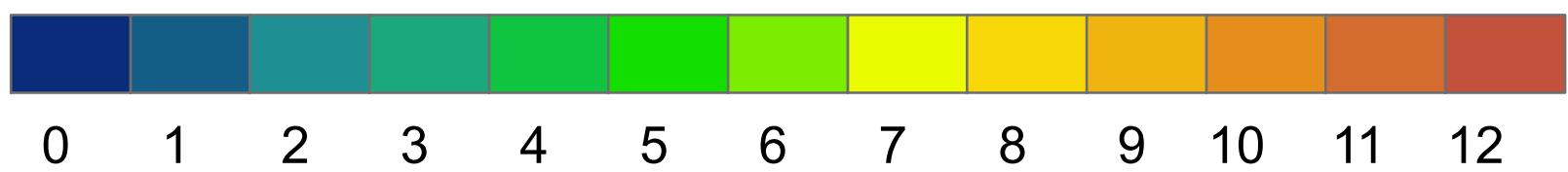


(c) Model: MIROC3.2

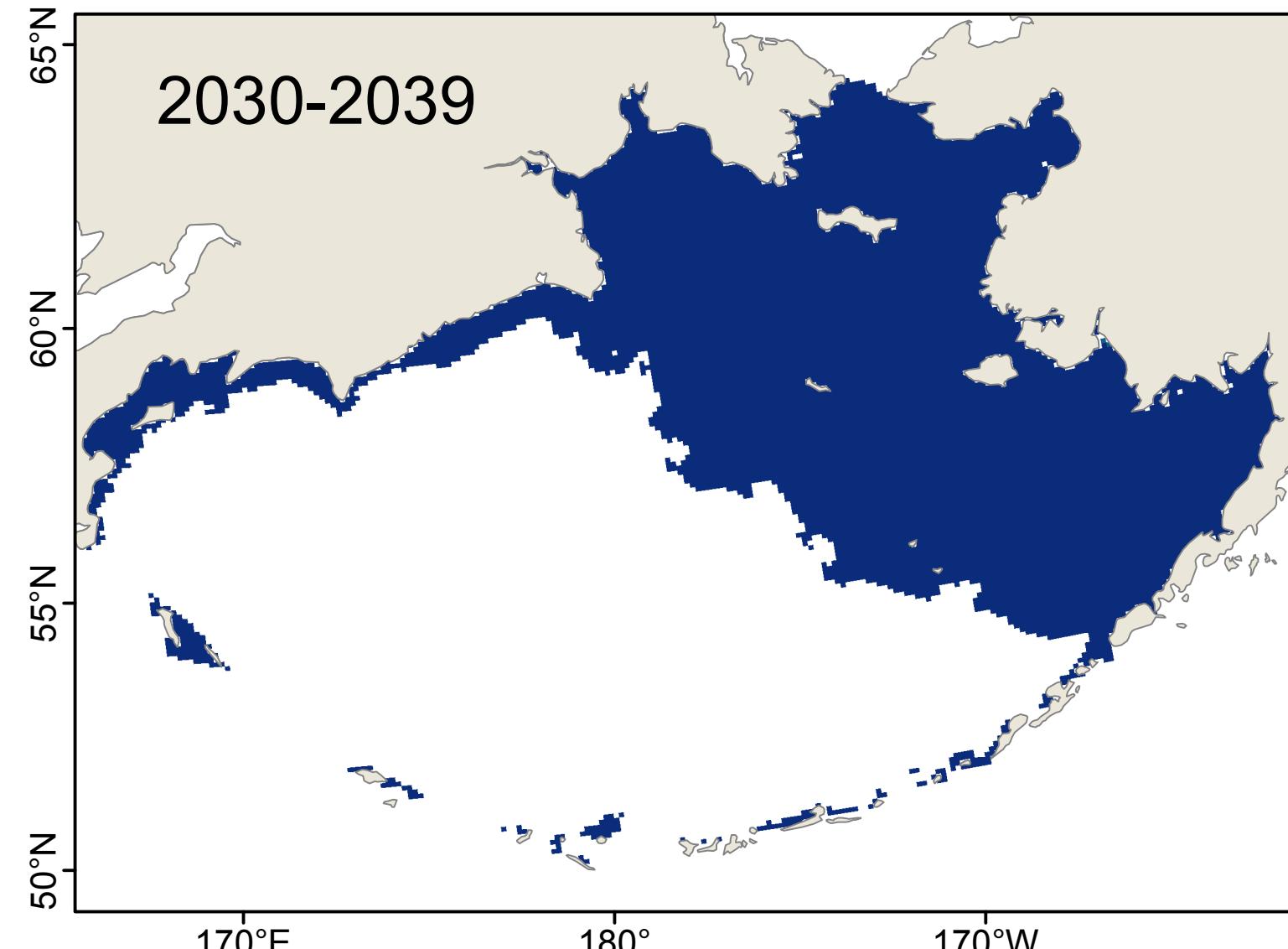
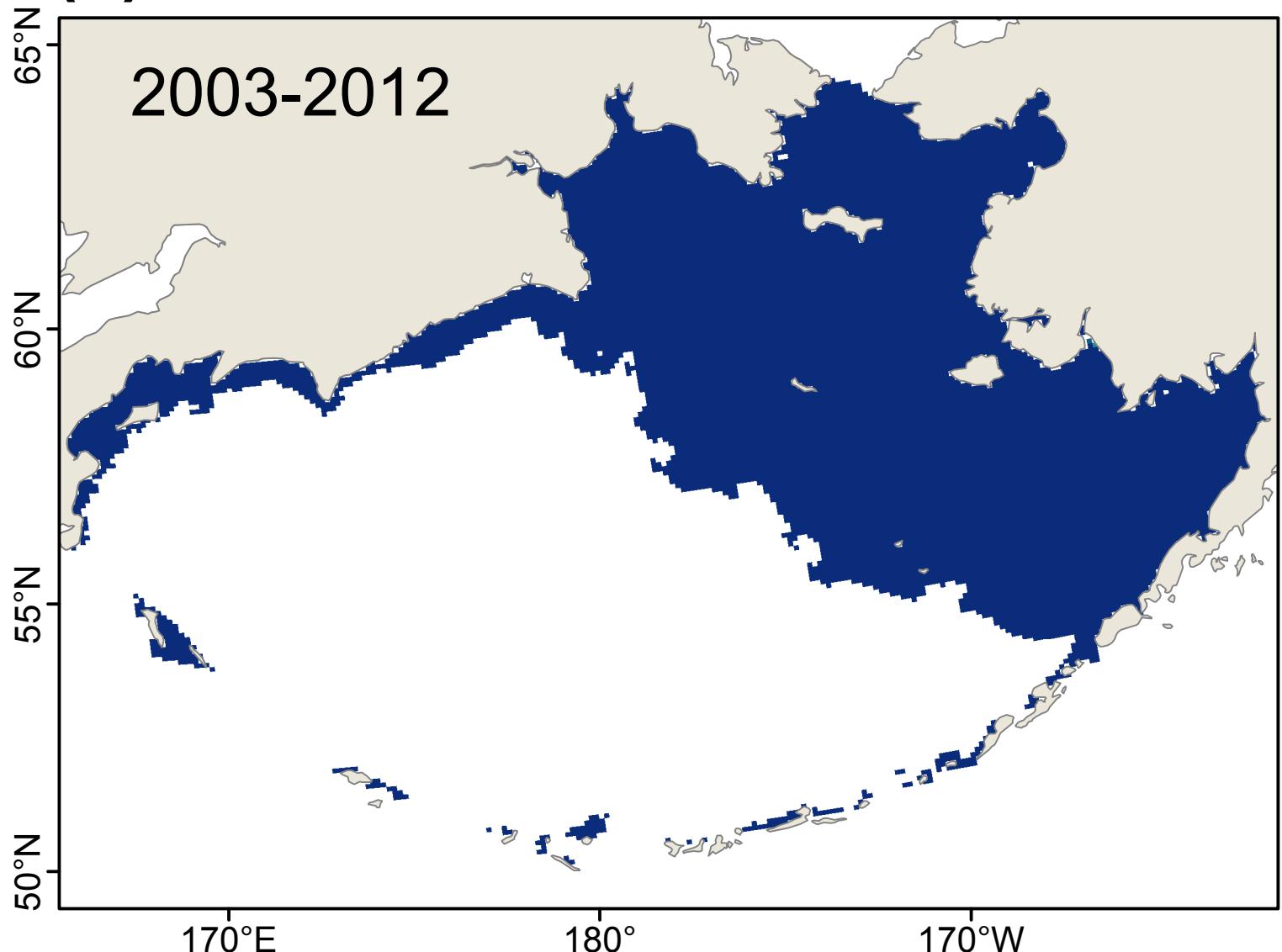


# *Eriocheir sinensis: Reproduction*

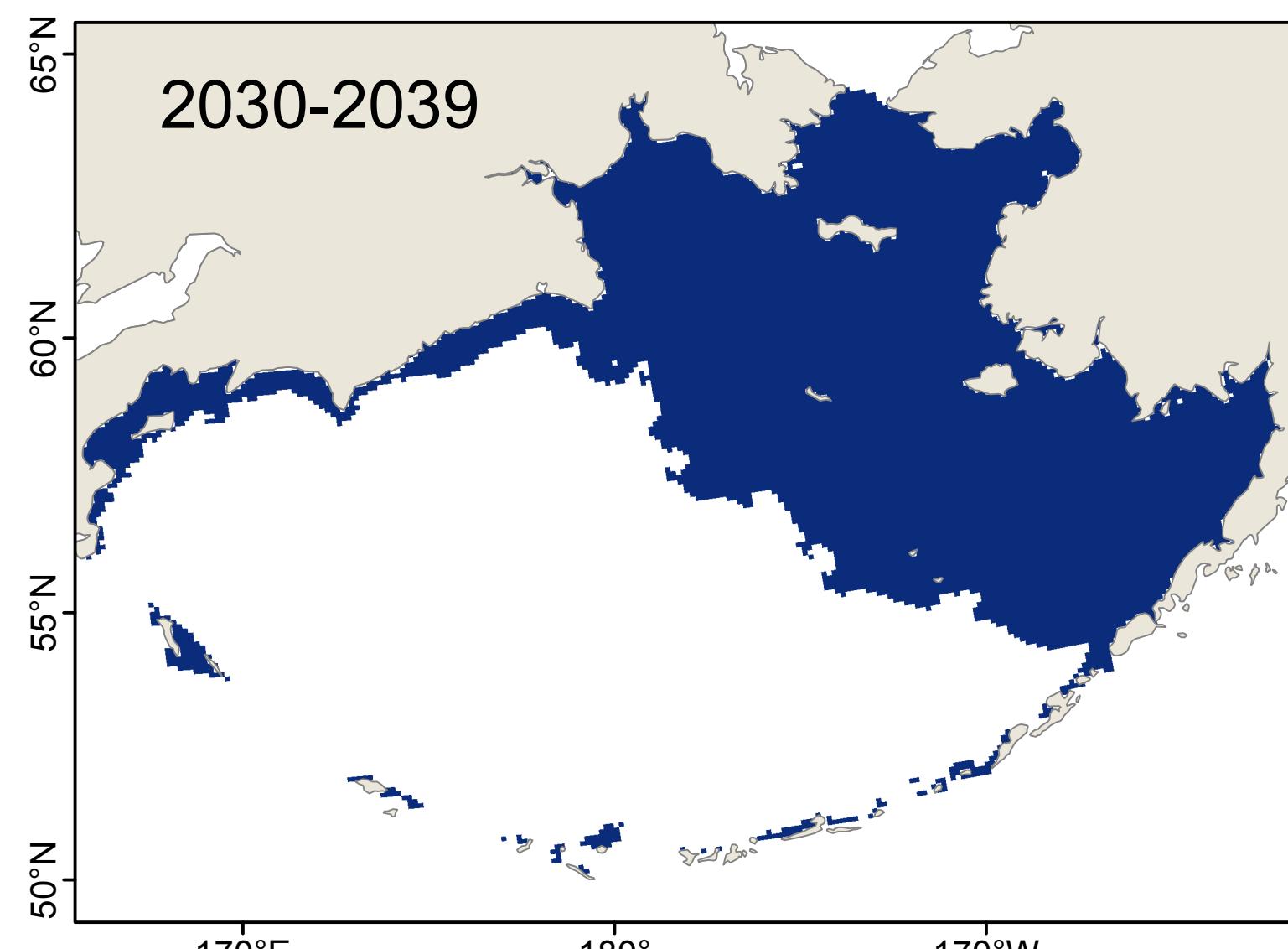
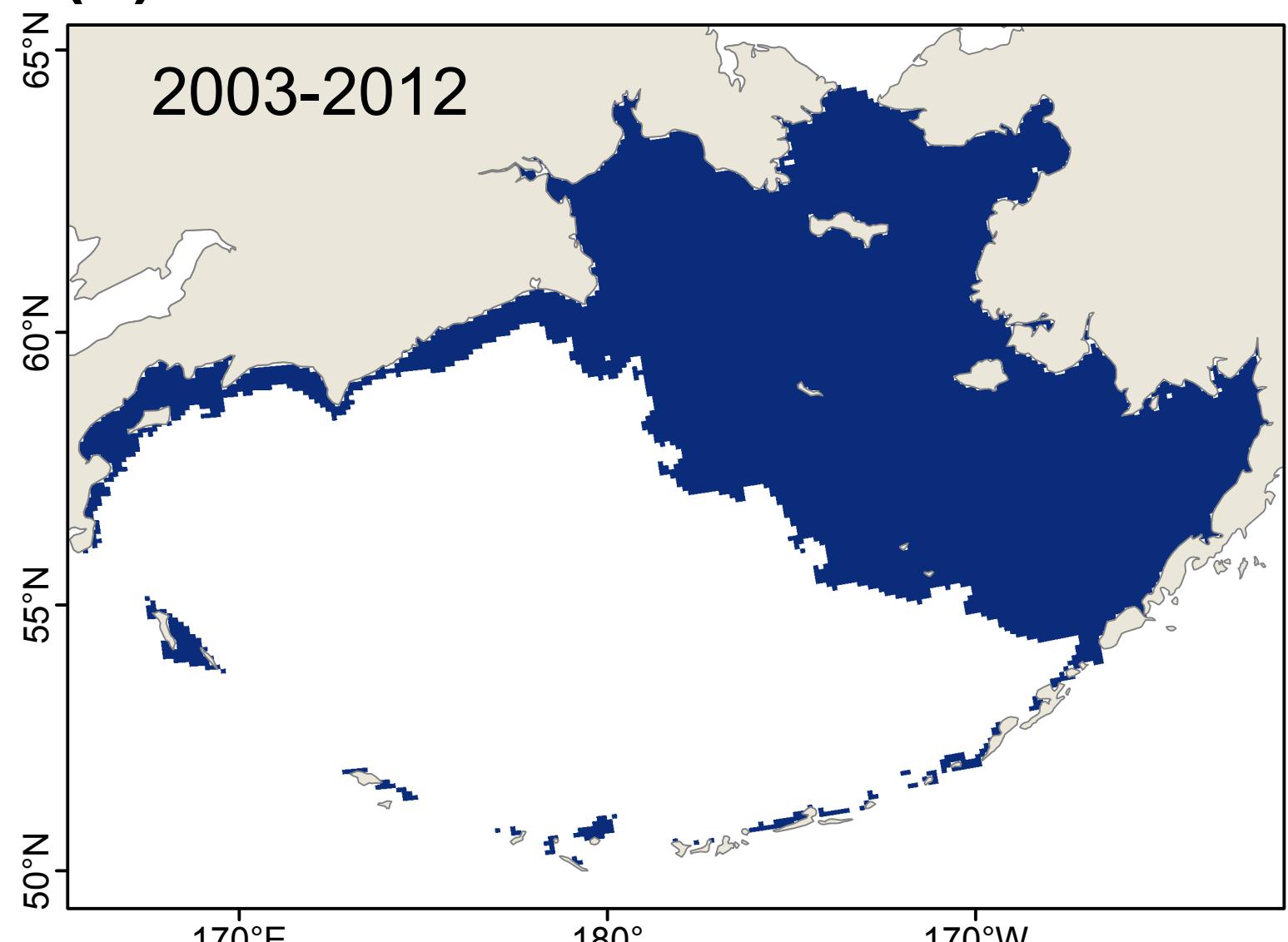
Average number of consecutive weeks of suitable habitat



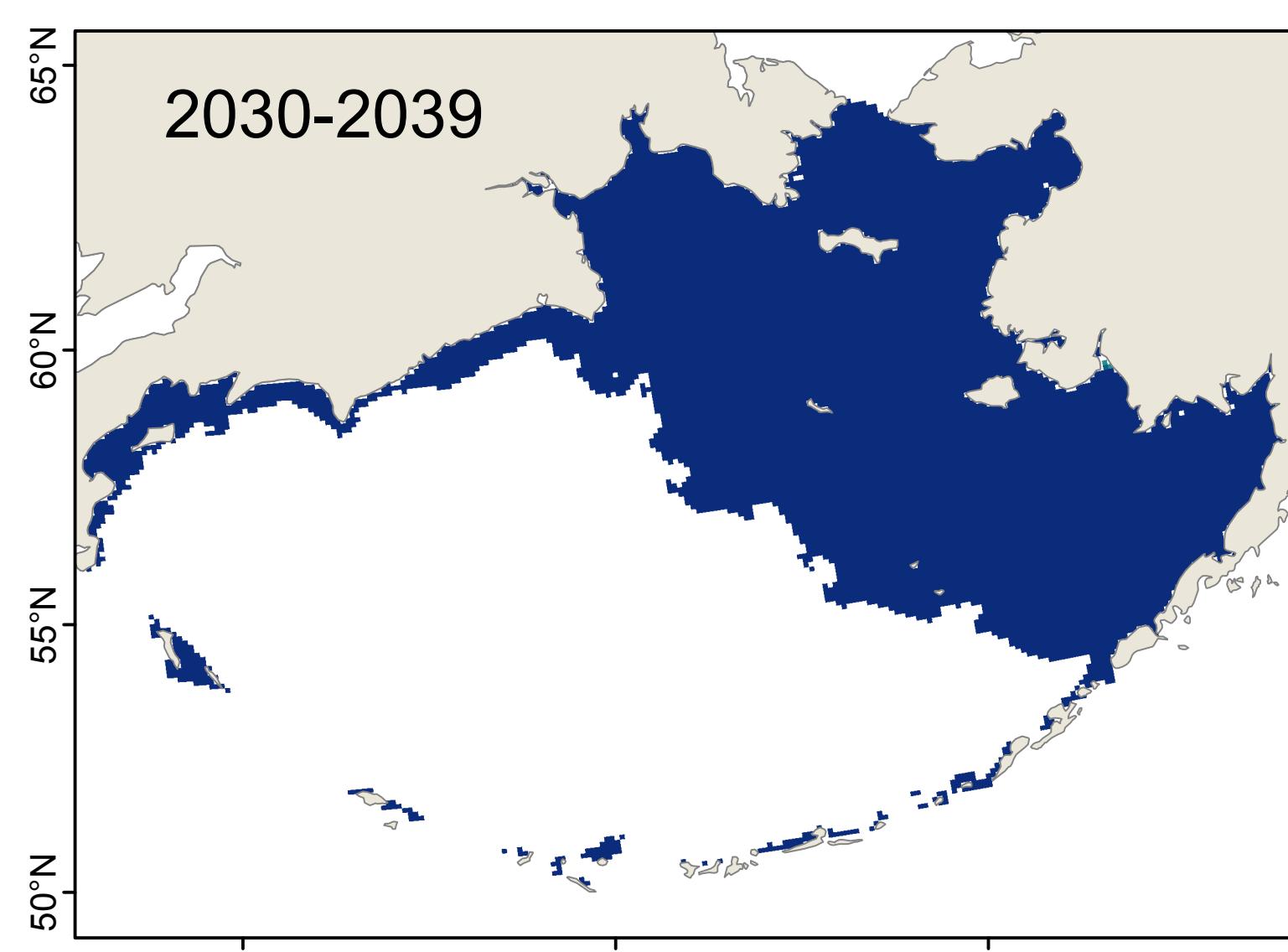
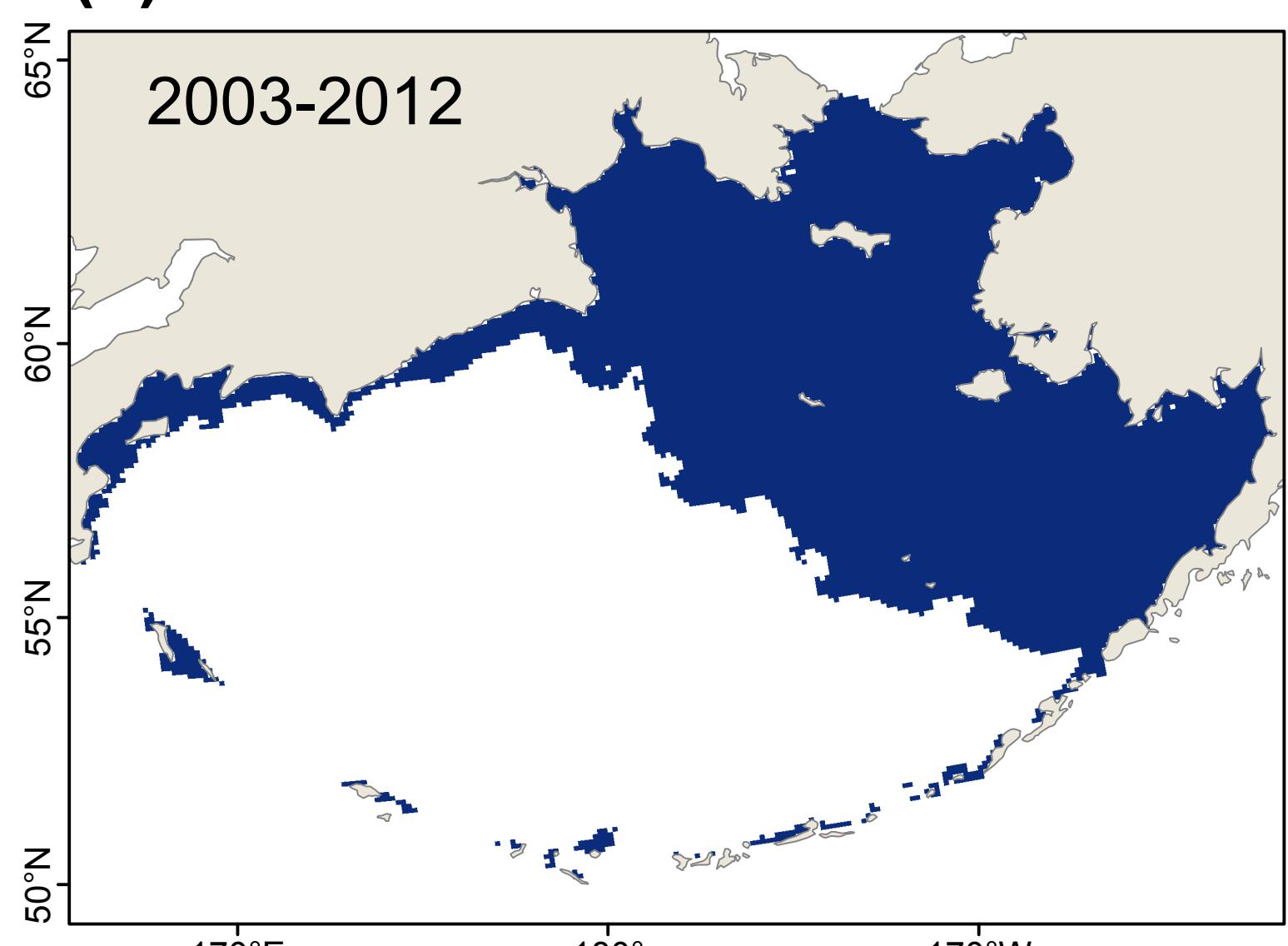
(a) Model: CGCM3-t47



(b) Model: ECHO-G

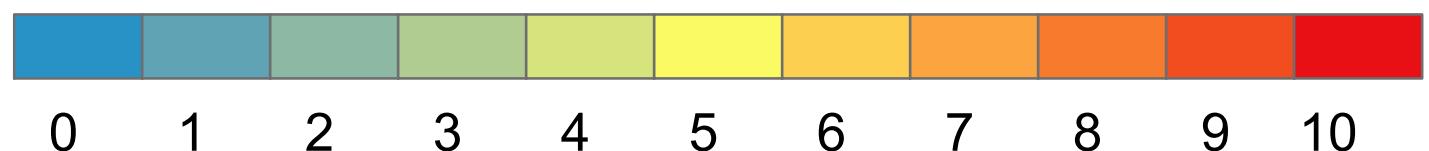


(c) Model: MIROC3.2

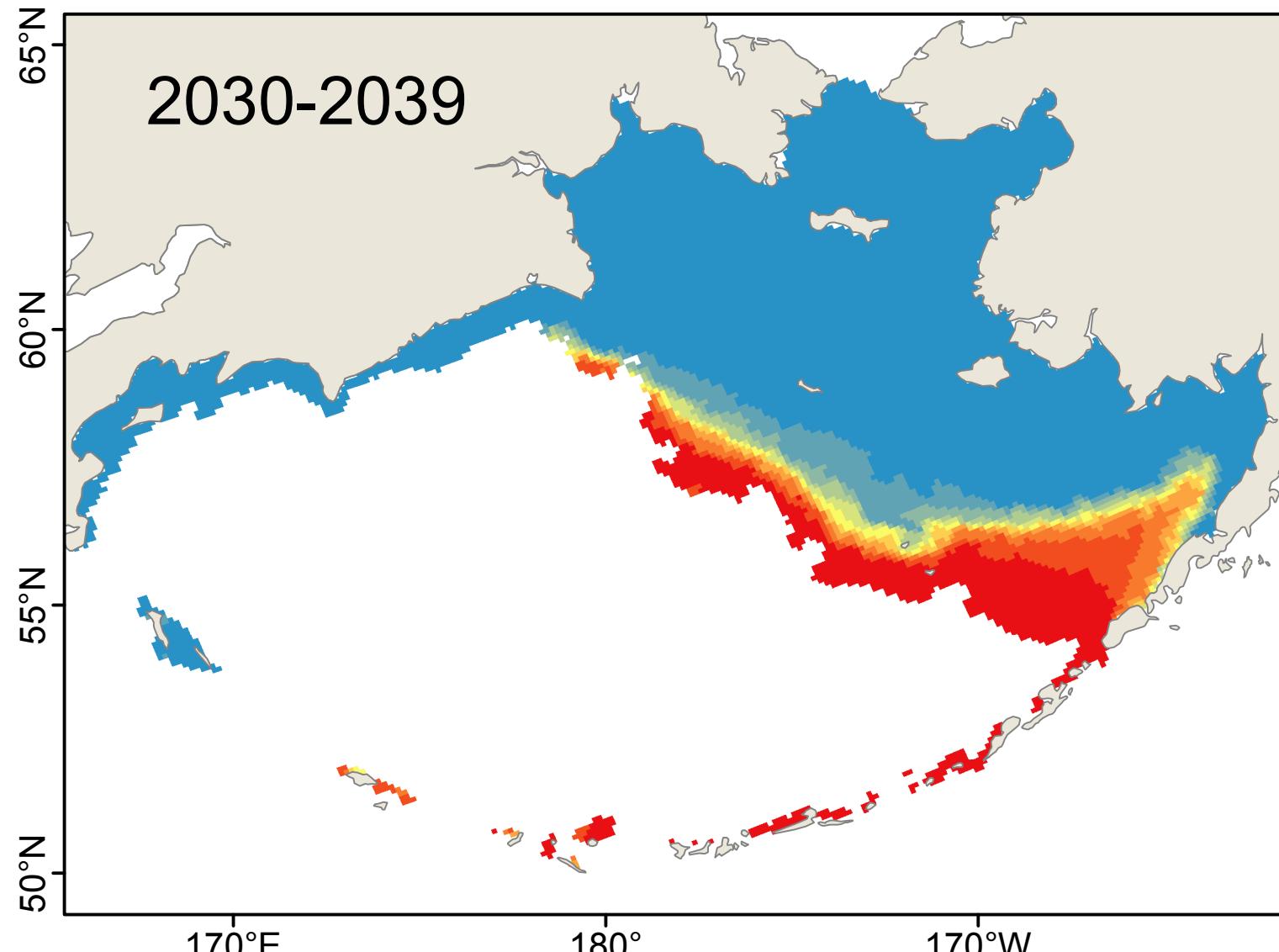
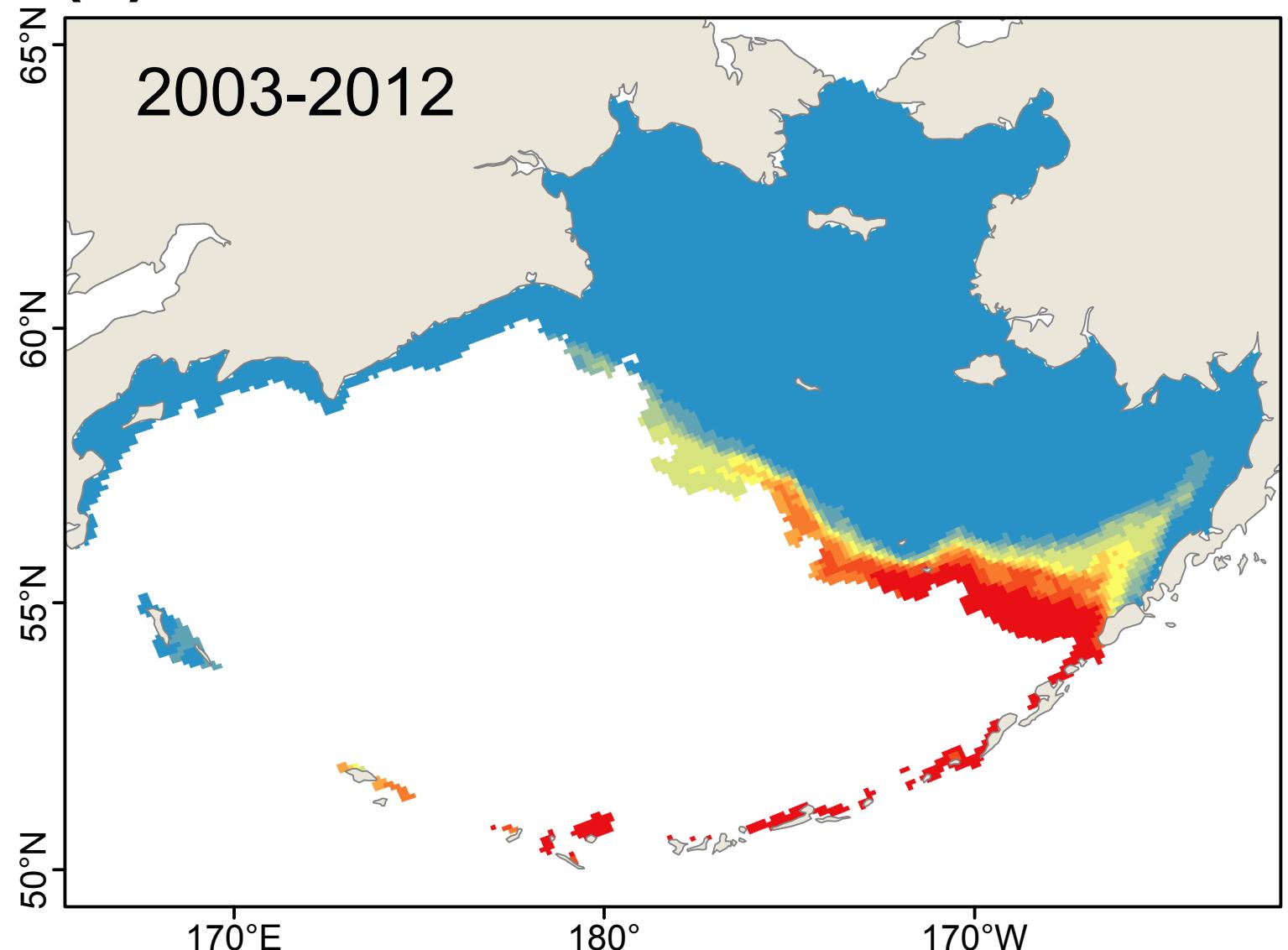


# *Limnoria tripunctata*: Year-round Survival

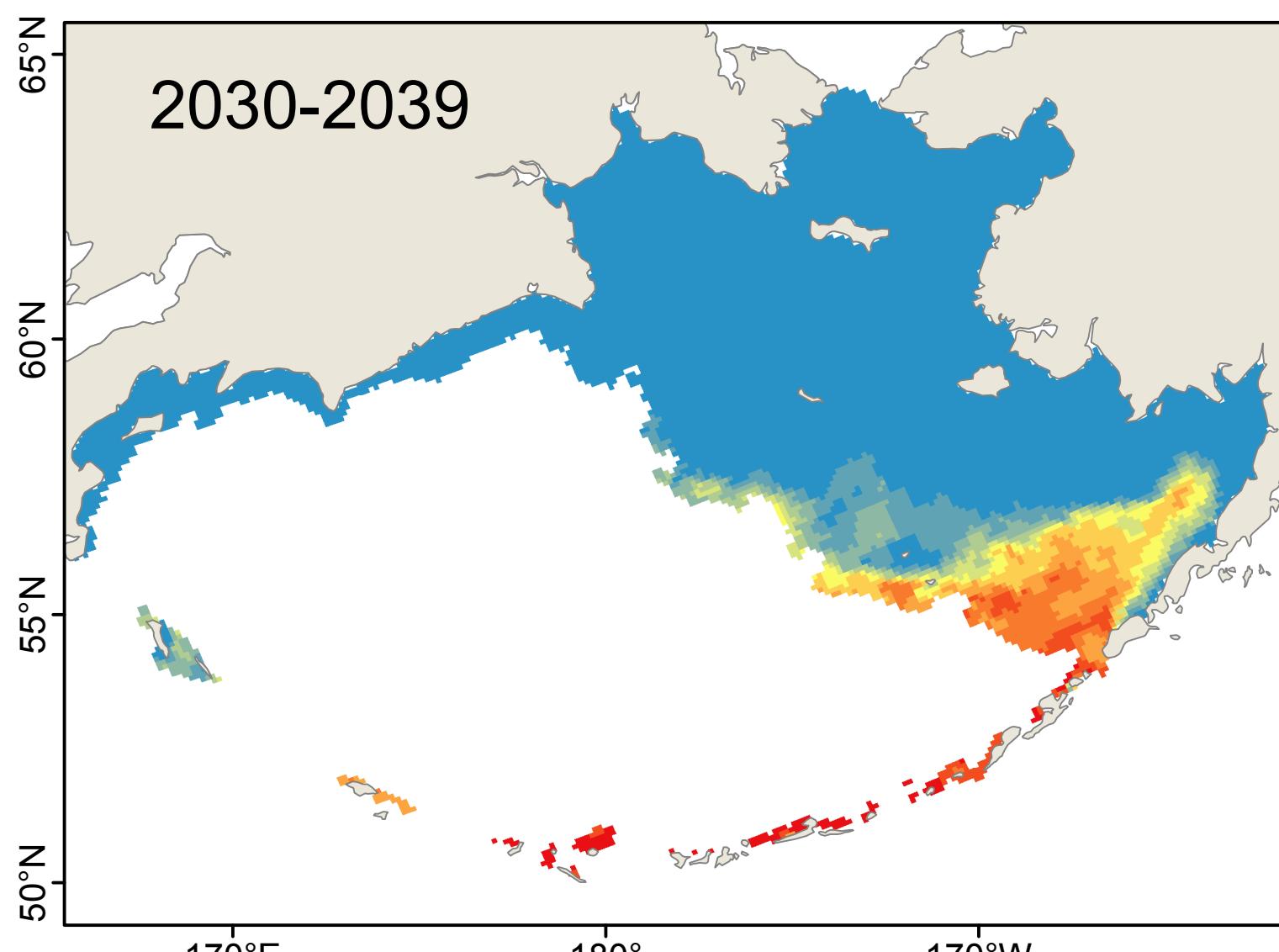
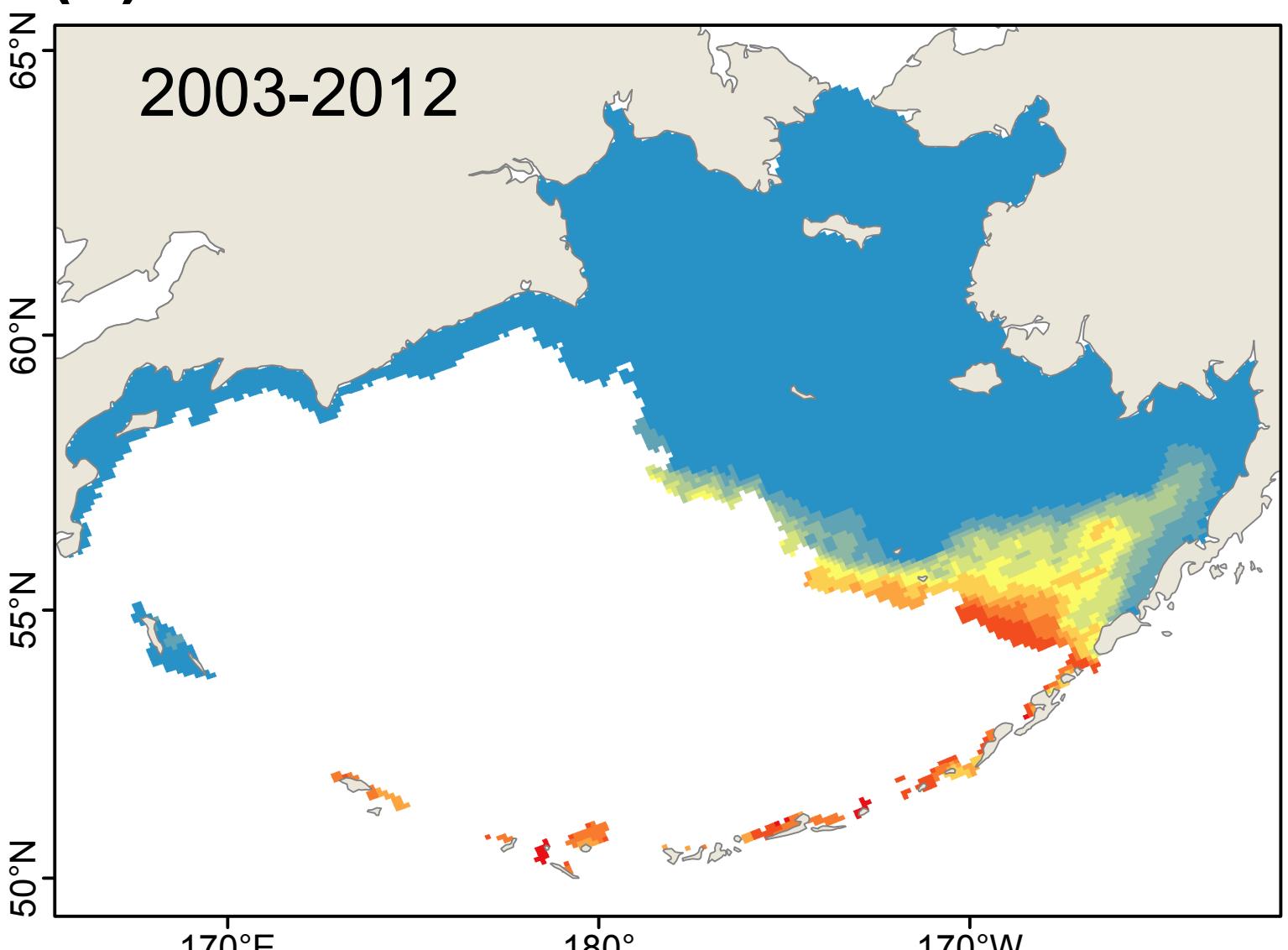
Number of years with suitable habitat



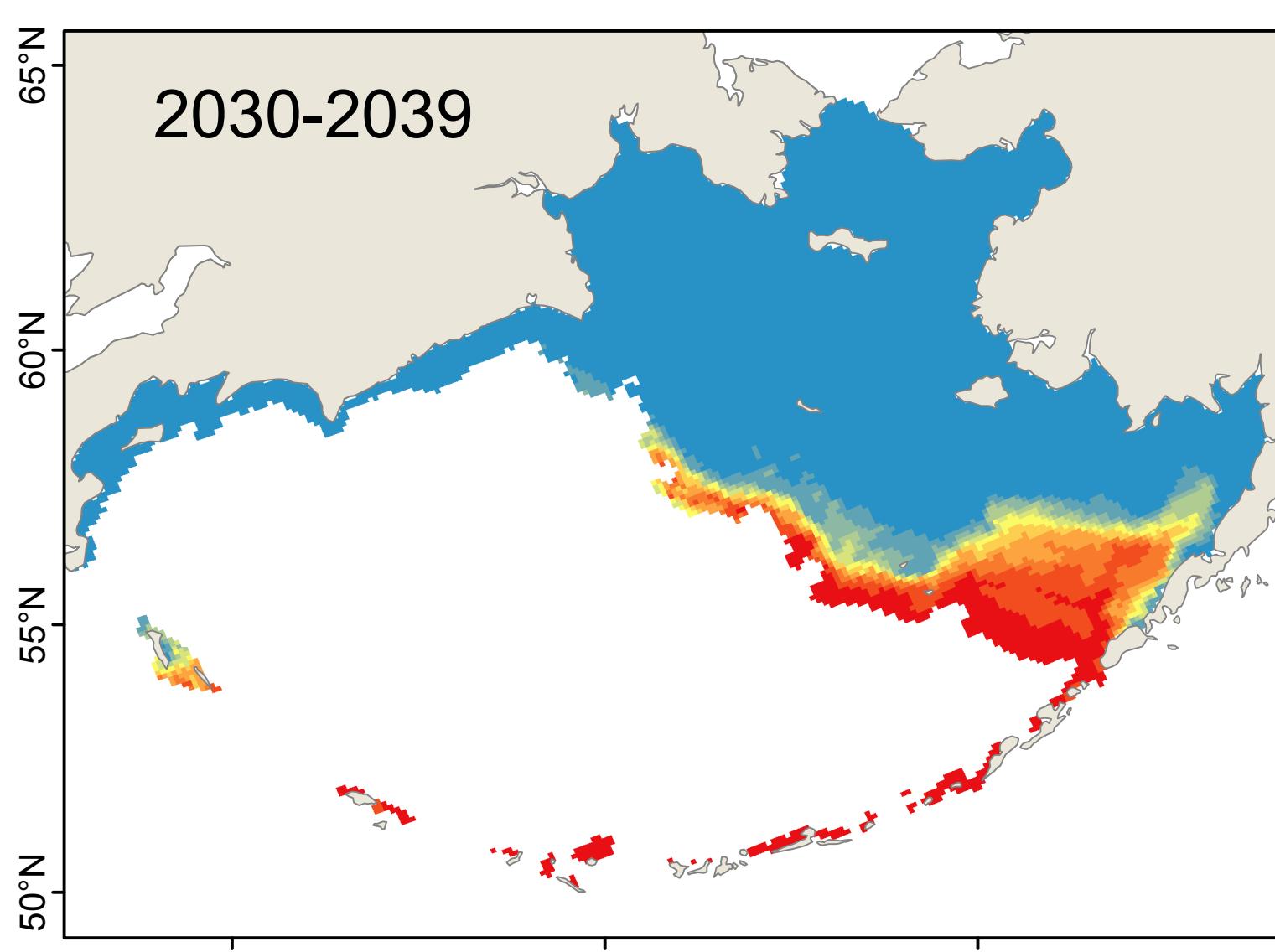
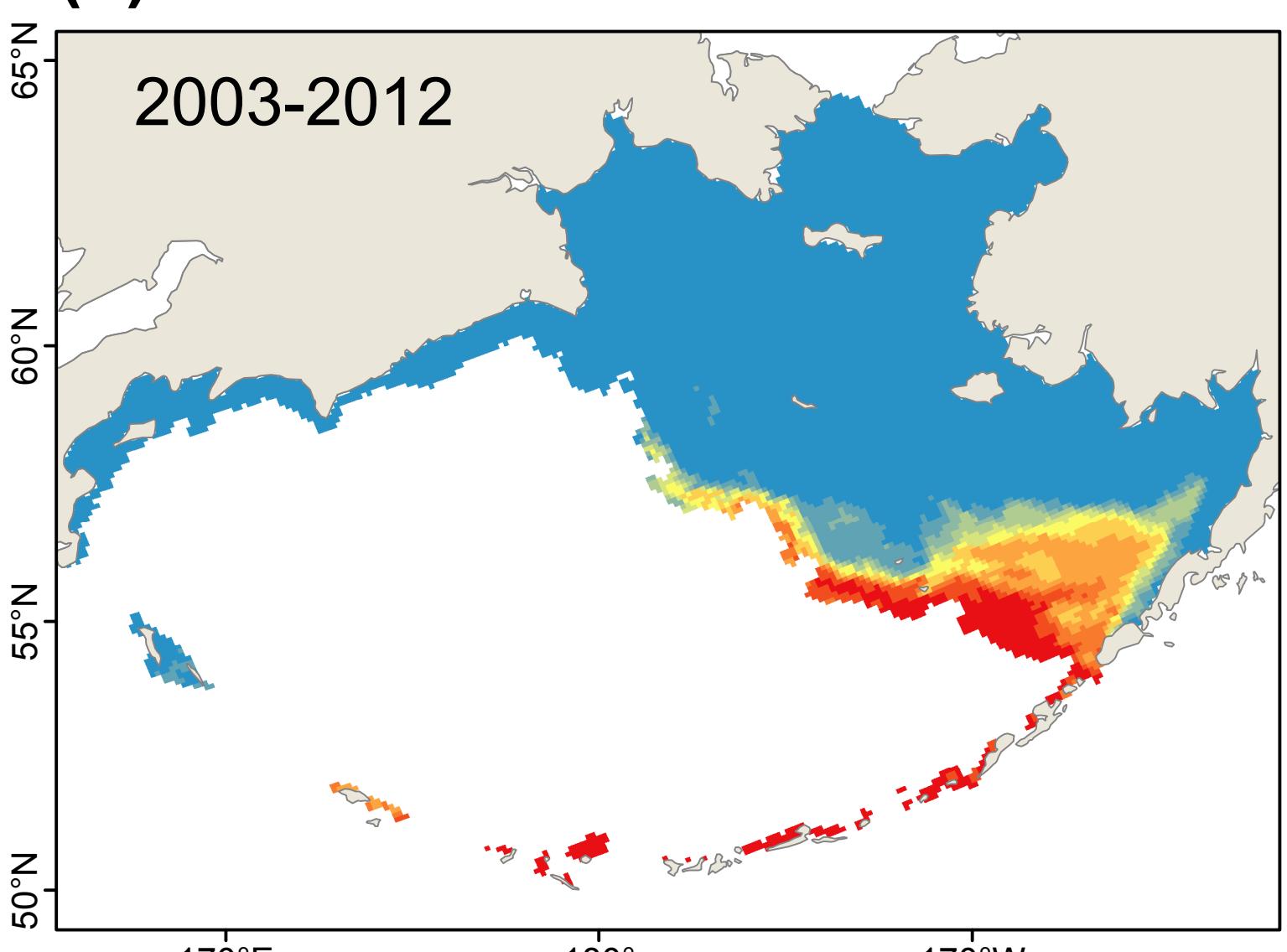
(a) Model: CGCM3-t47



(b) Model: ECHO-G

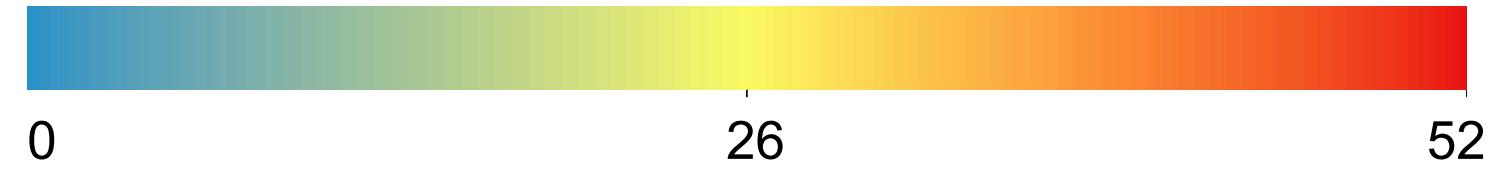


(c) Model: MIROC3.2

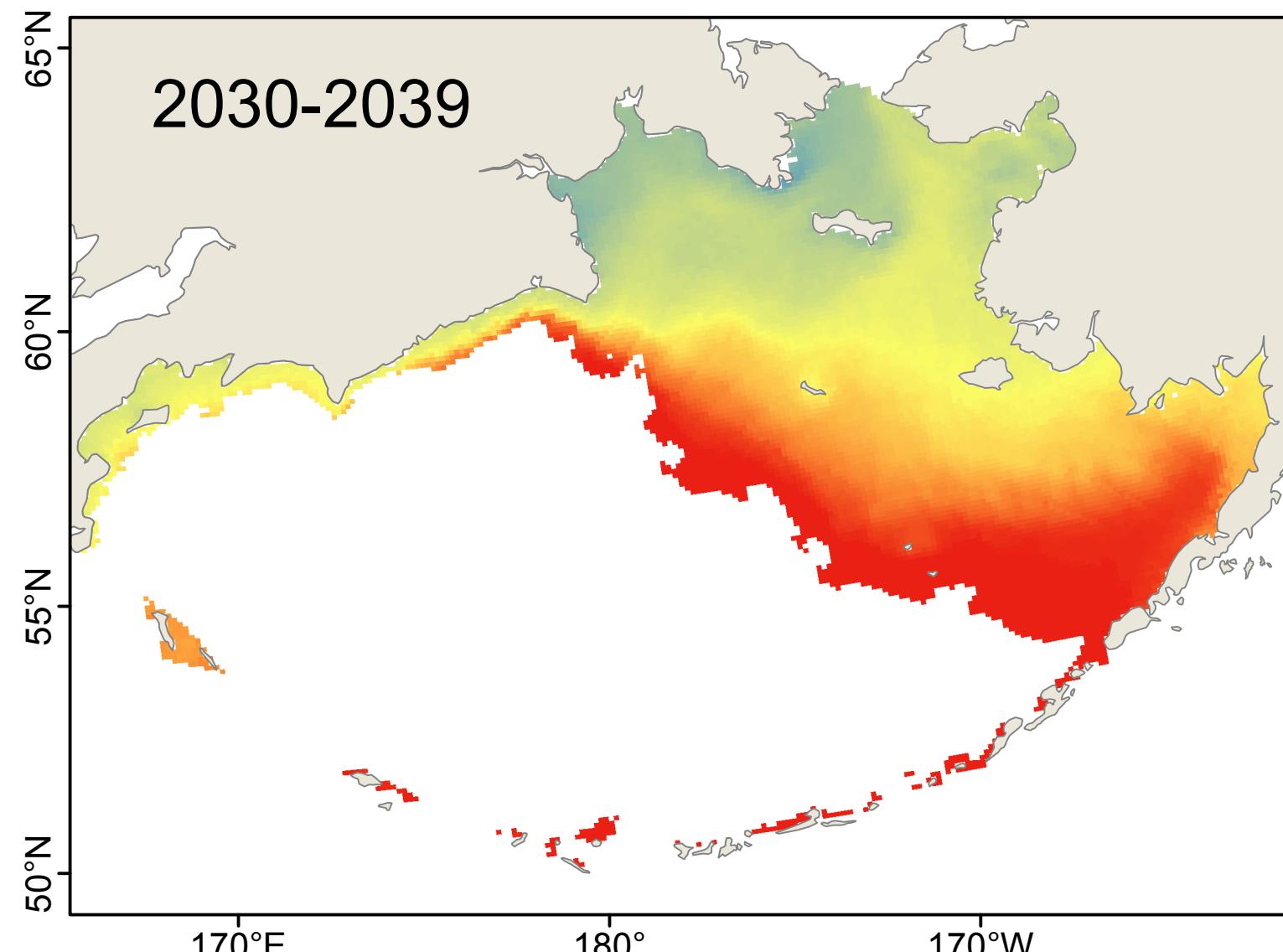
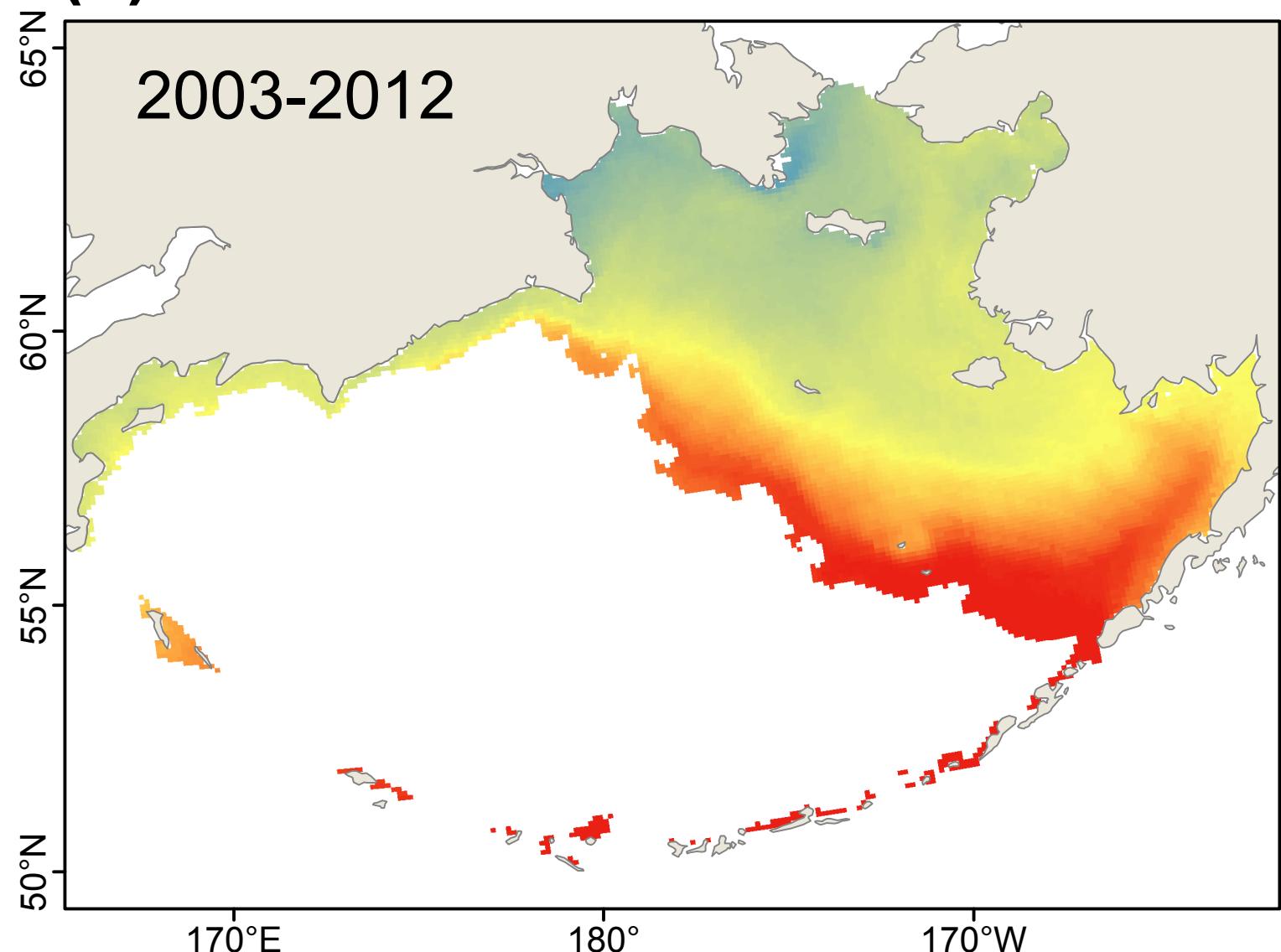


# *Limnoria tripunctata*: Weekly Survival

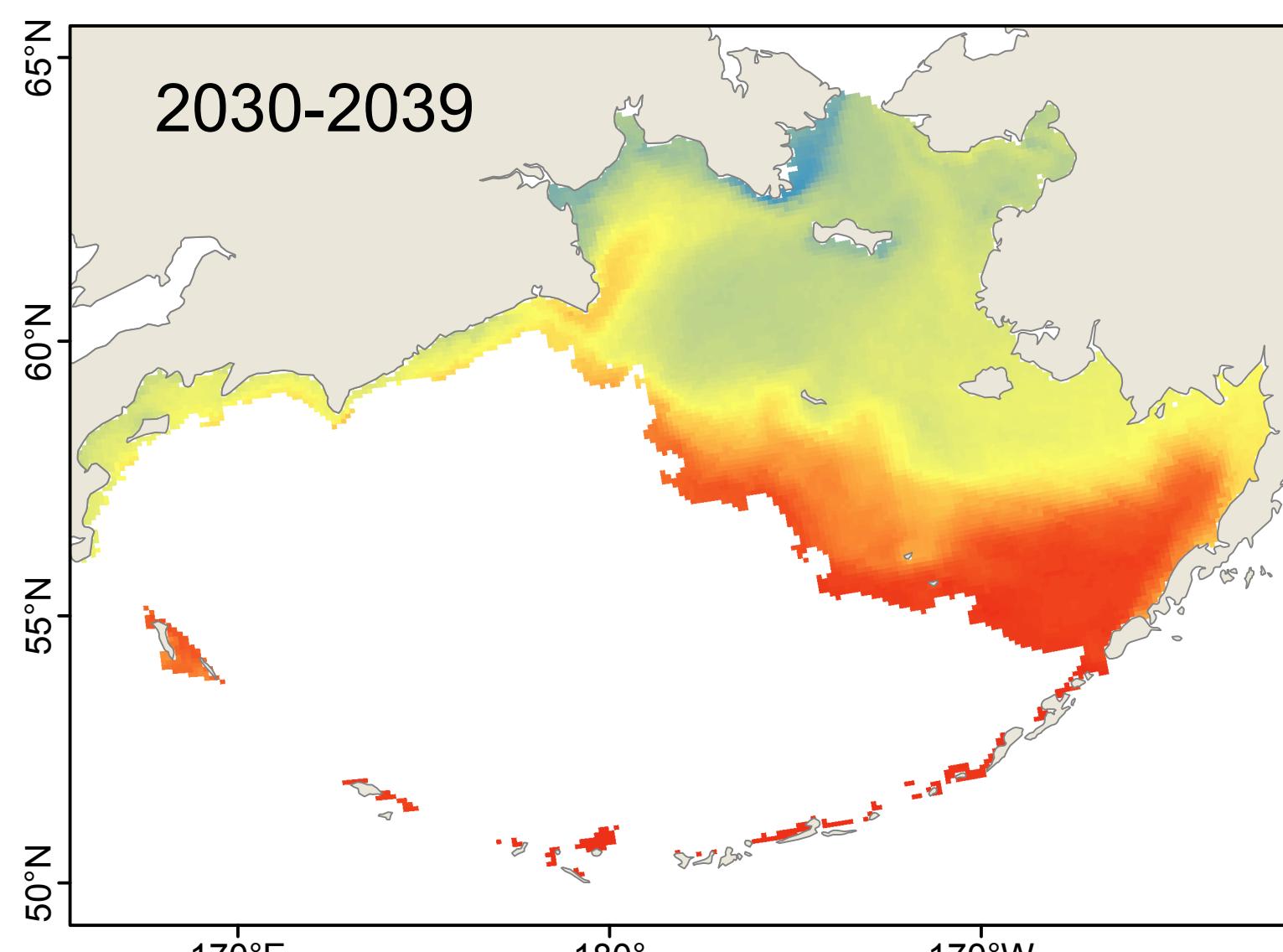
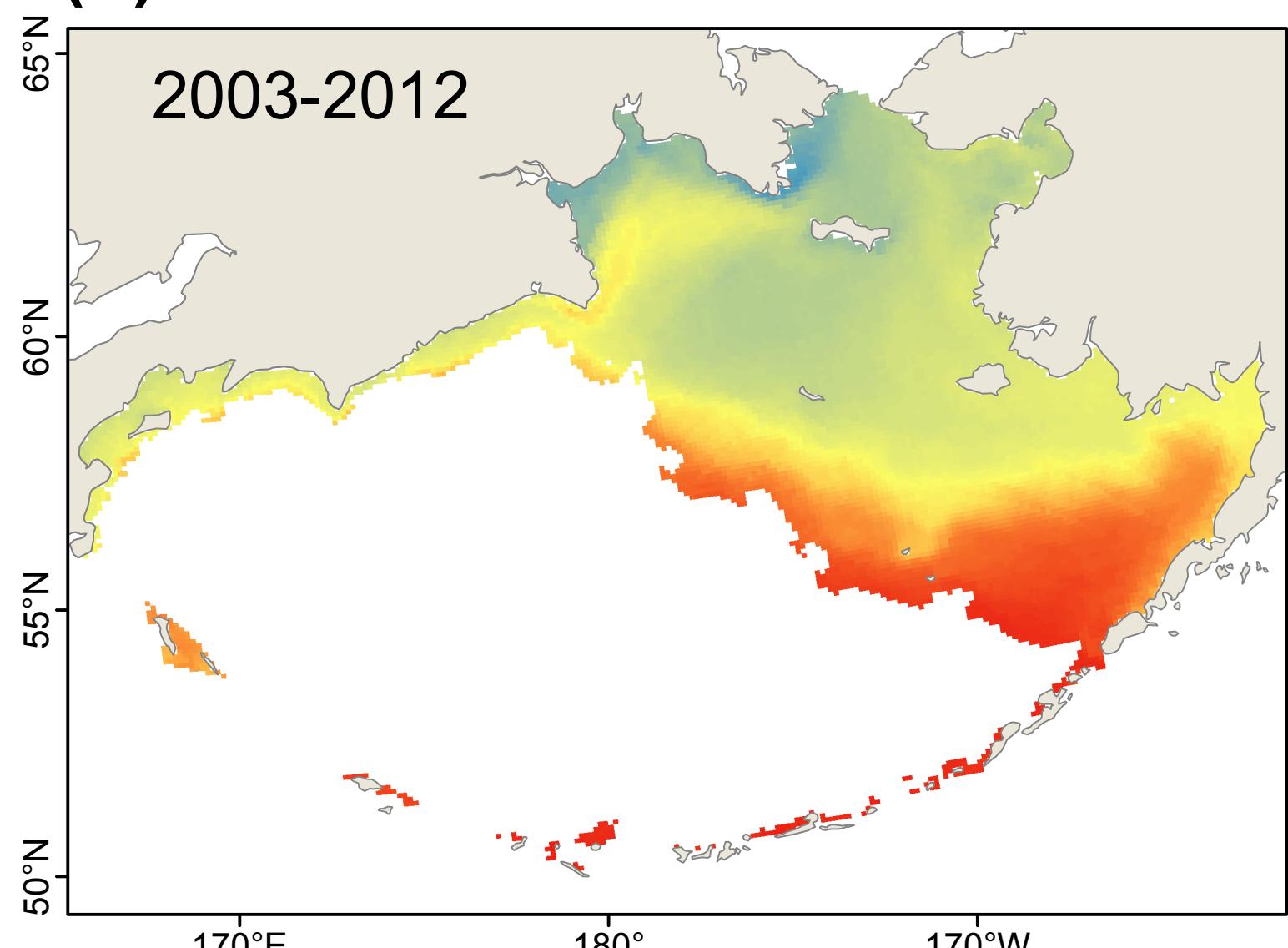
Average number of weeks of suitable habitat



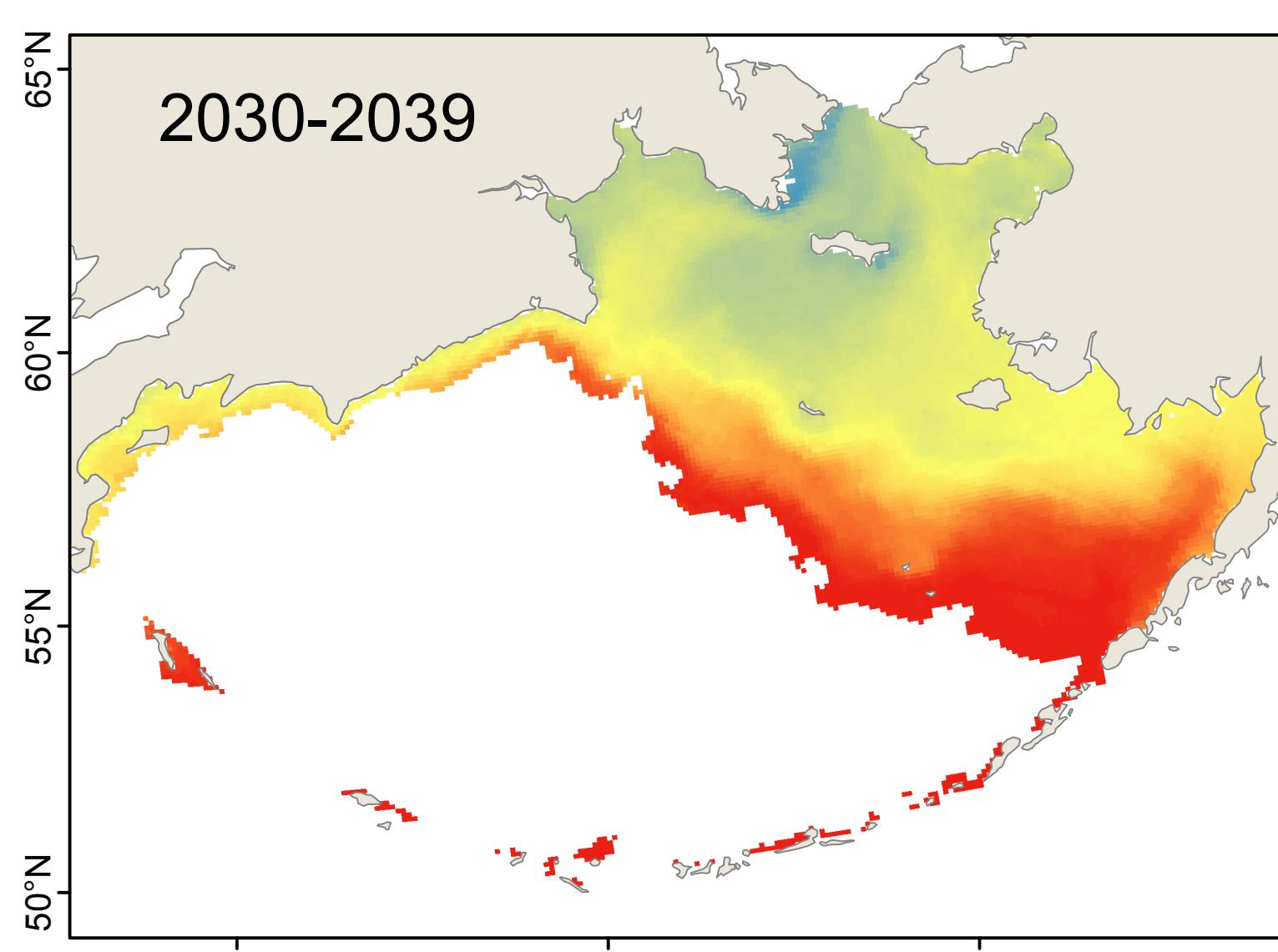
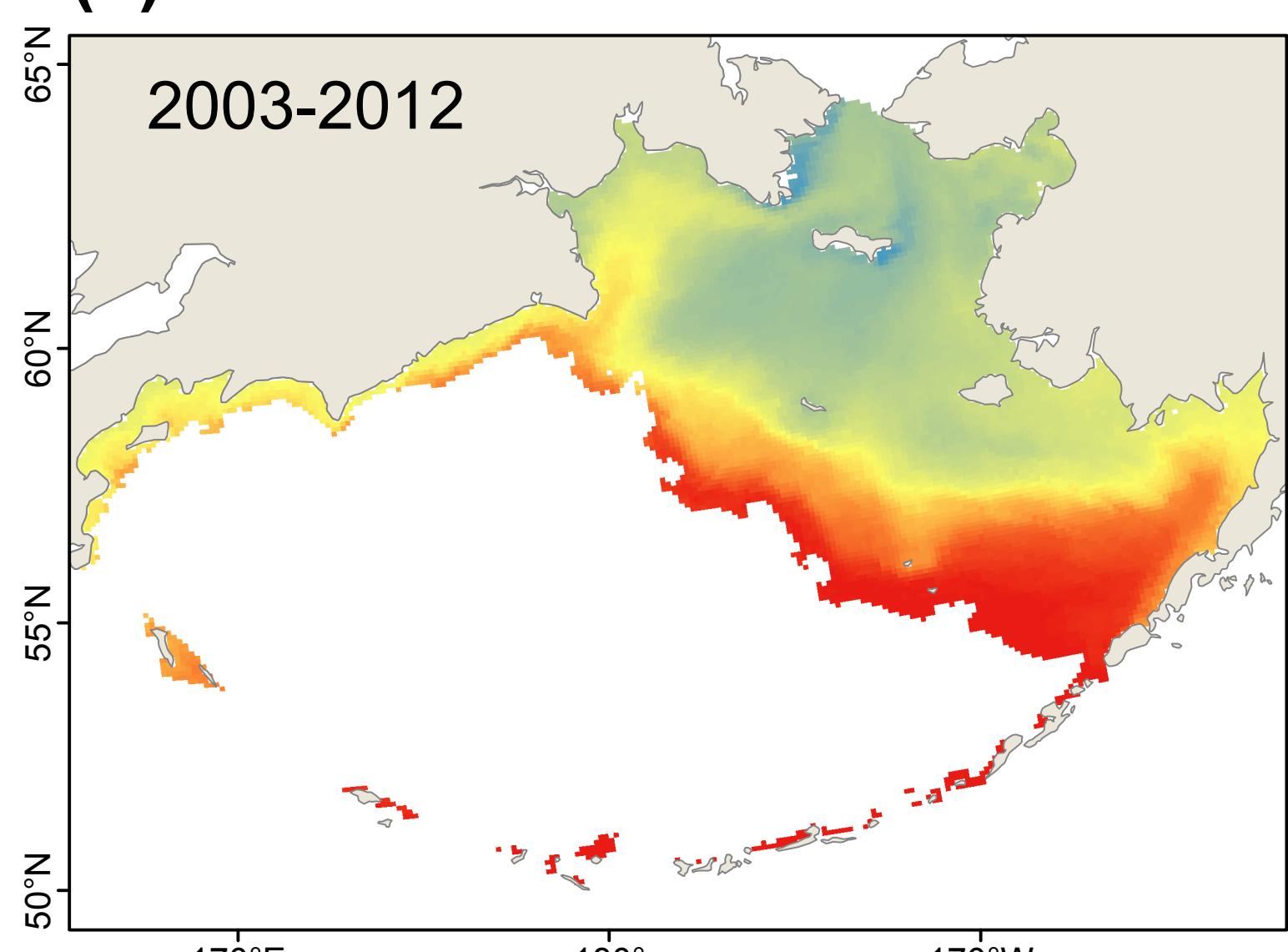
(a) Model: CGCM3-t47



(b) Model: ECHO-G

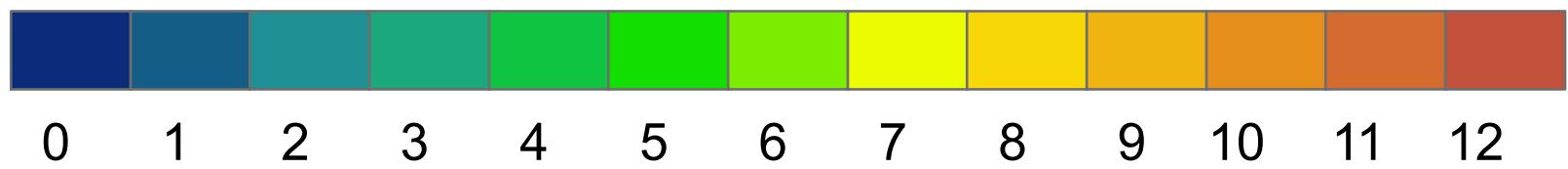


(c) Model: MIROC3.2

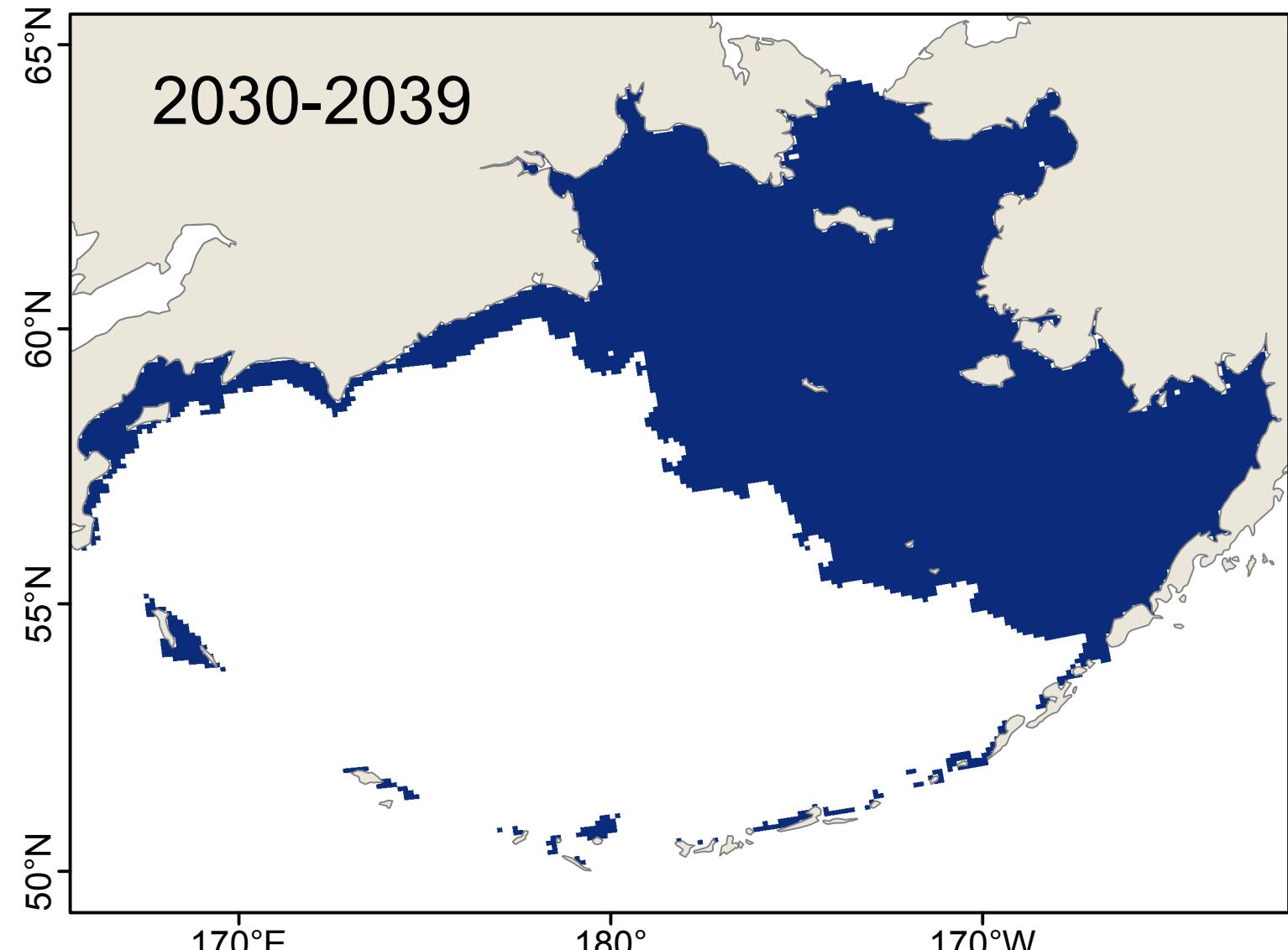
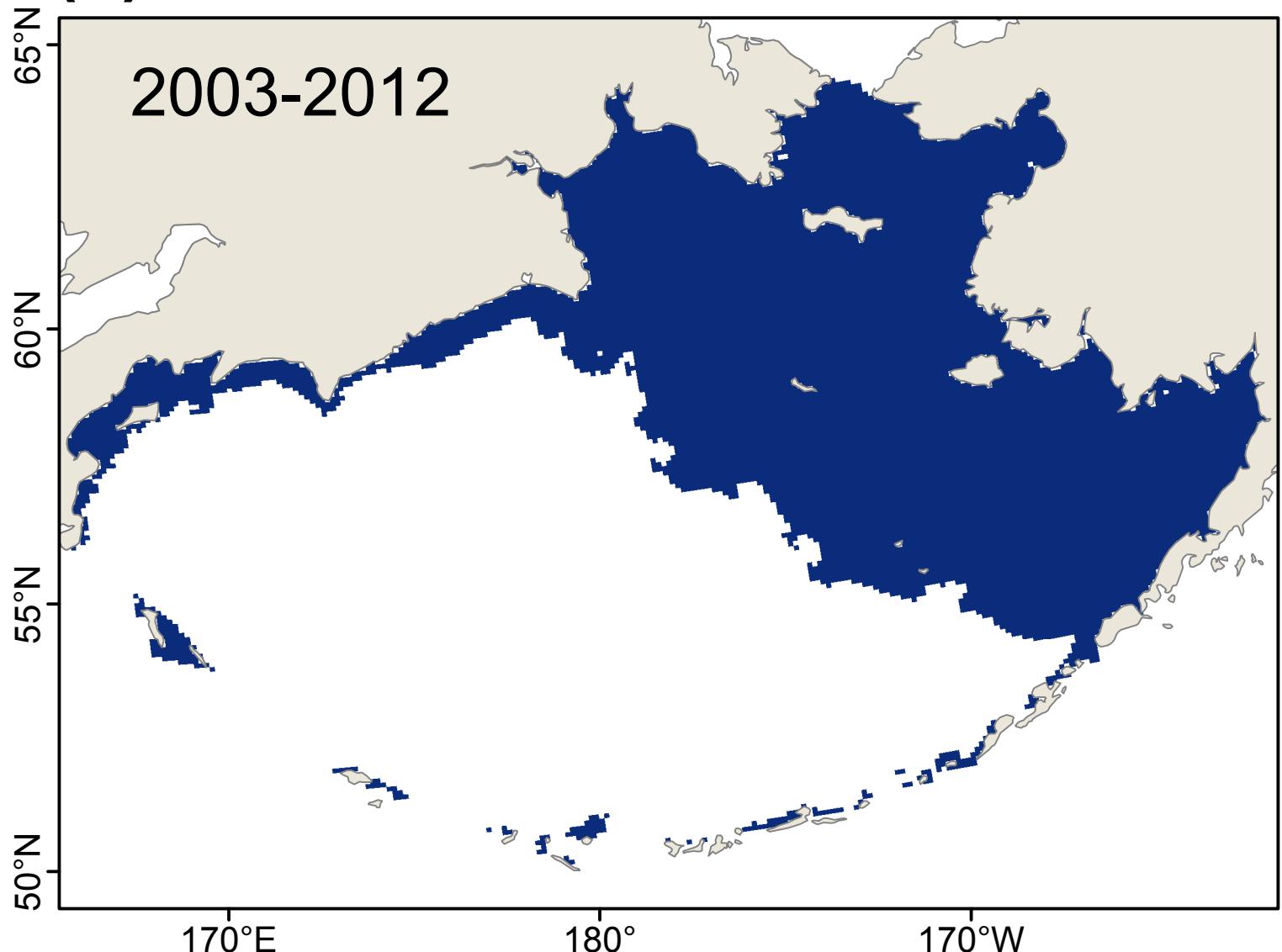


# *Limnoria tripunctata: Reproduction*

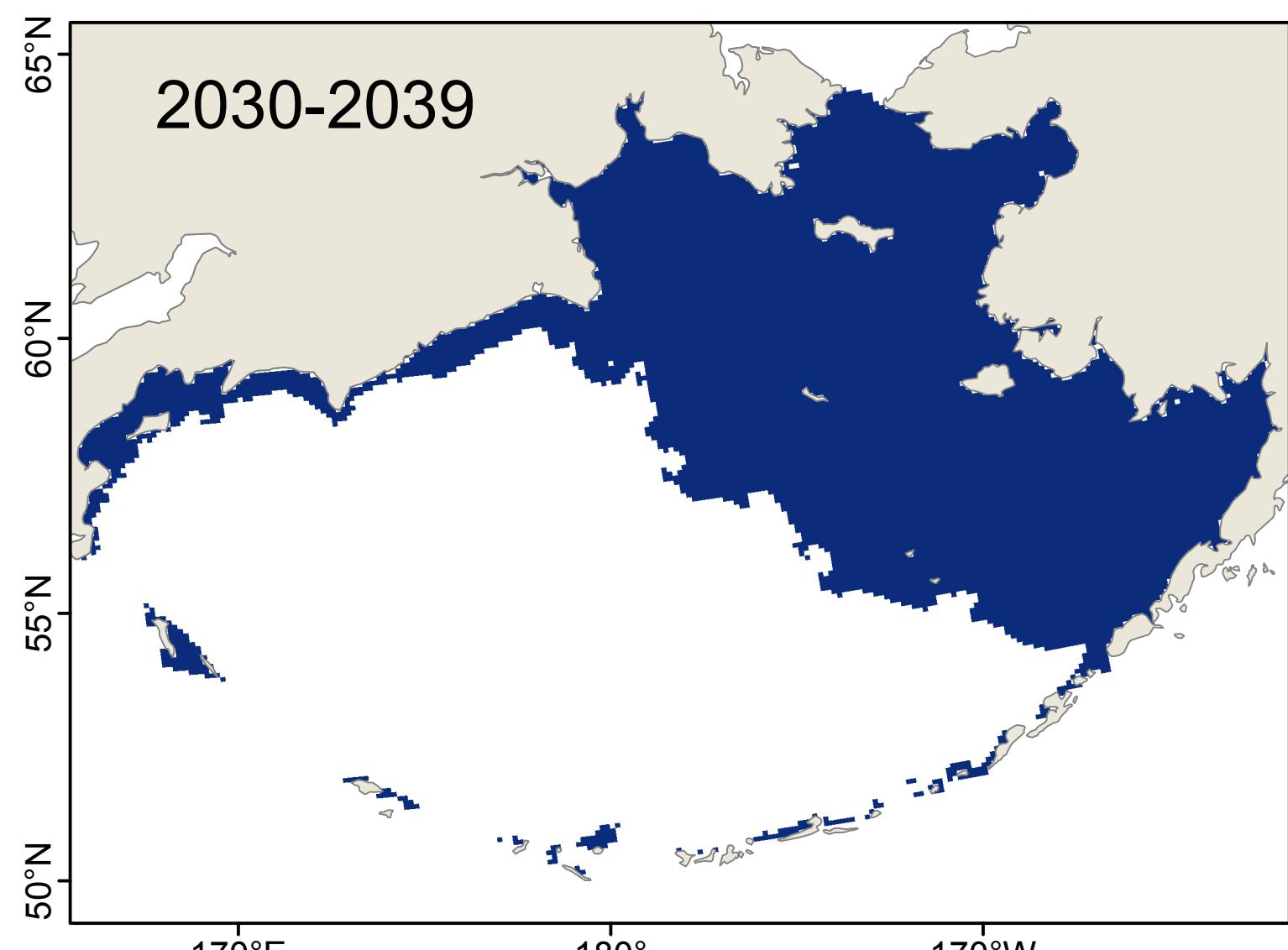
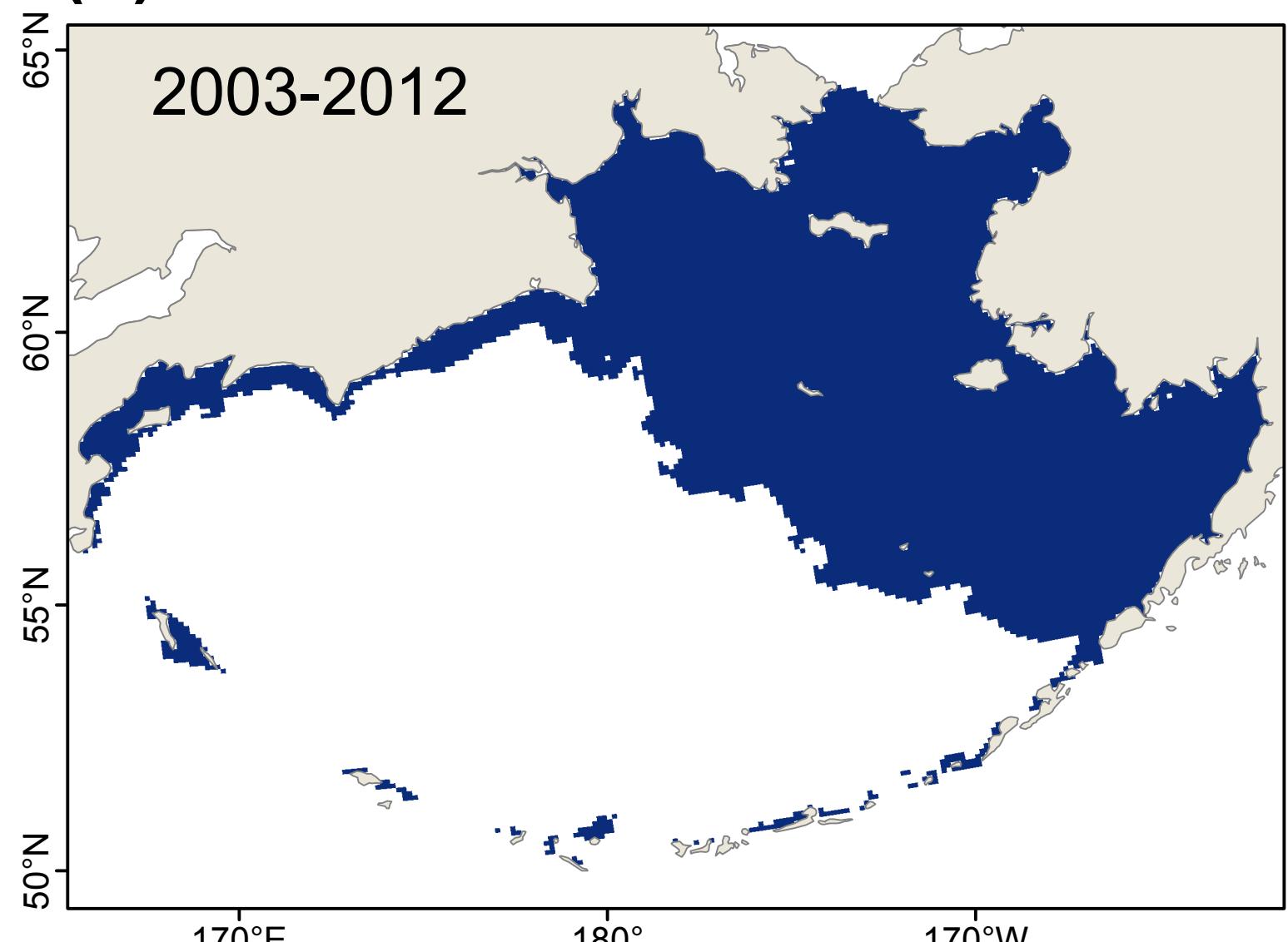
Average number of consecutive weeks of suitable habitat



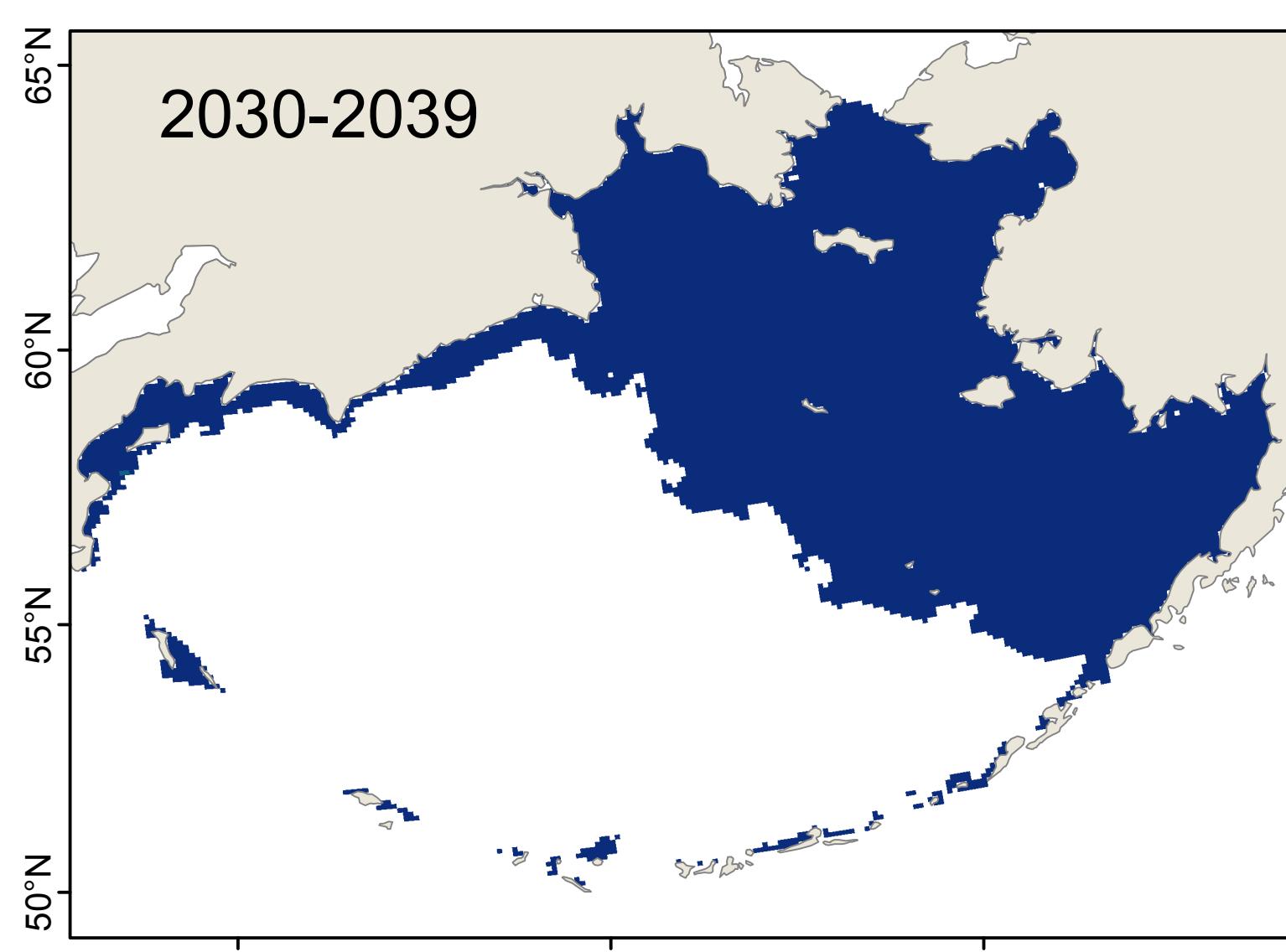
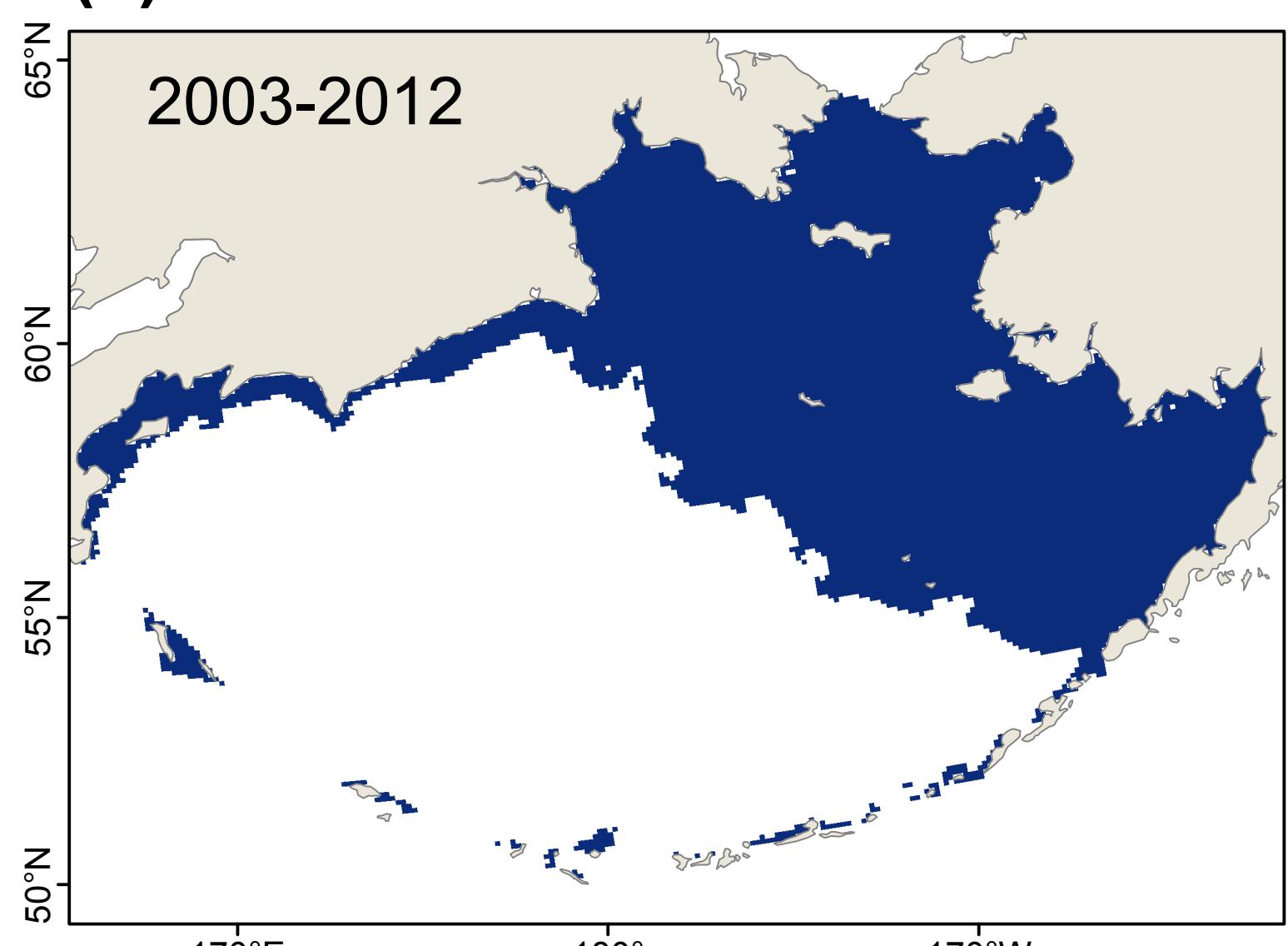
(a) Model: CGCM3-t47



(b) Model: ECHO-G

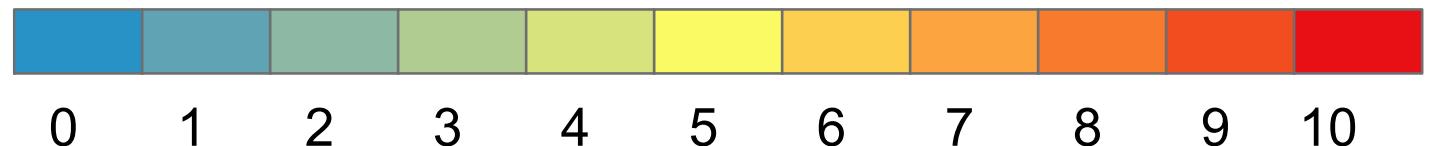


(c) Model: MIROC3.2

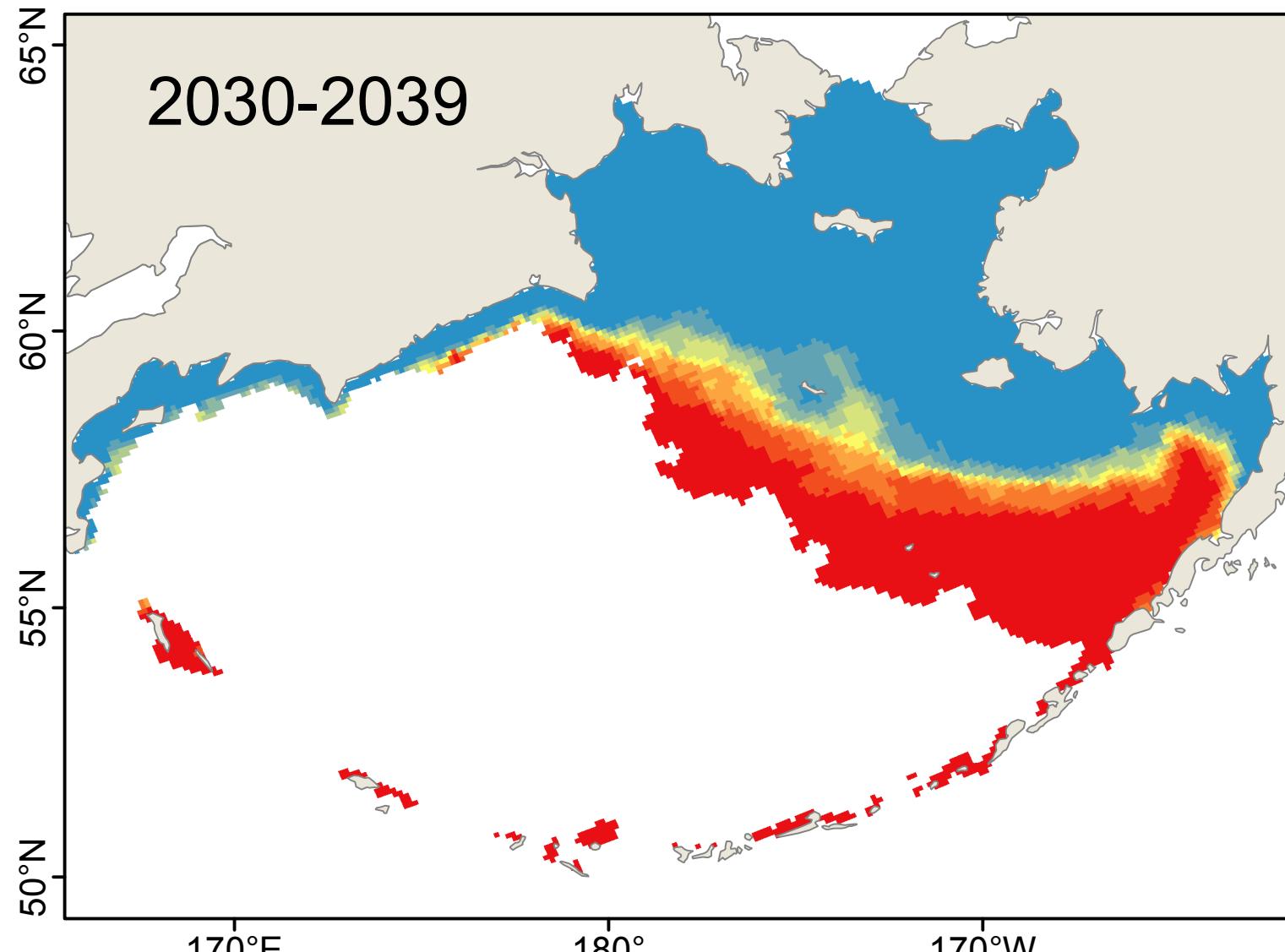
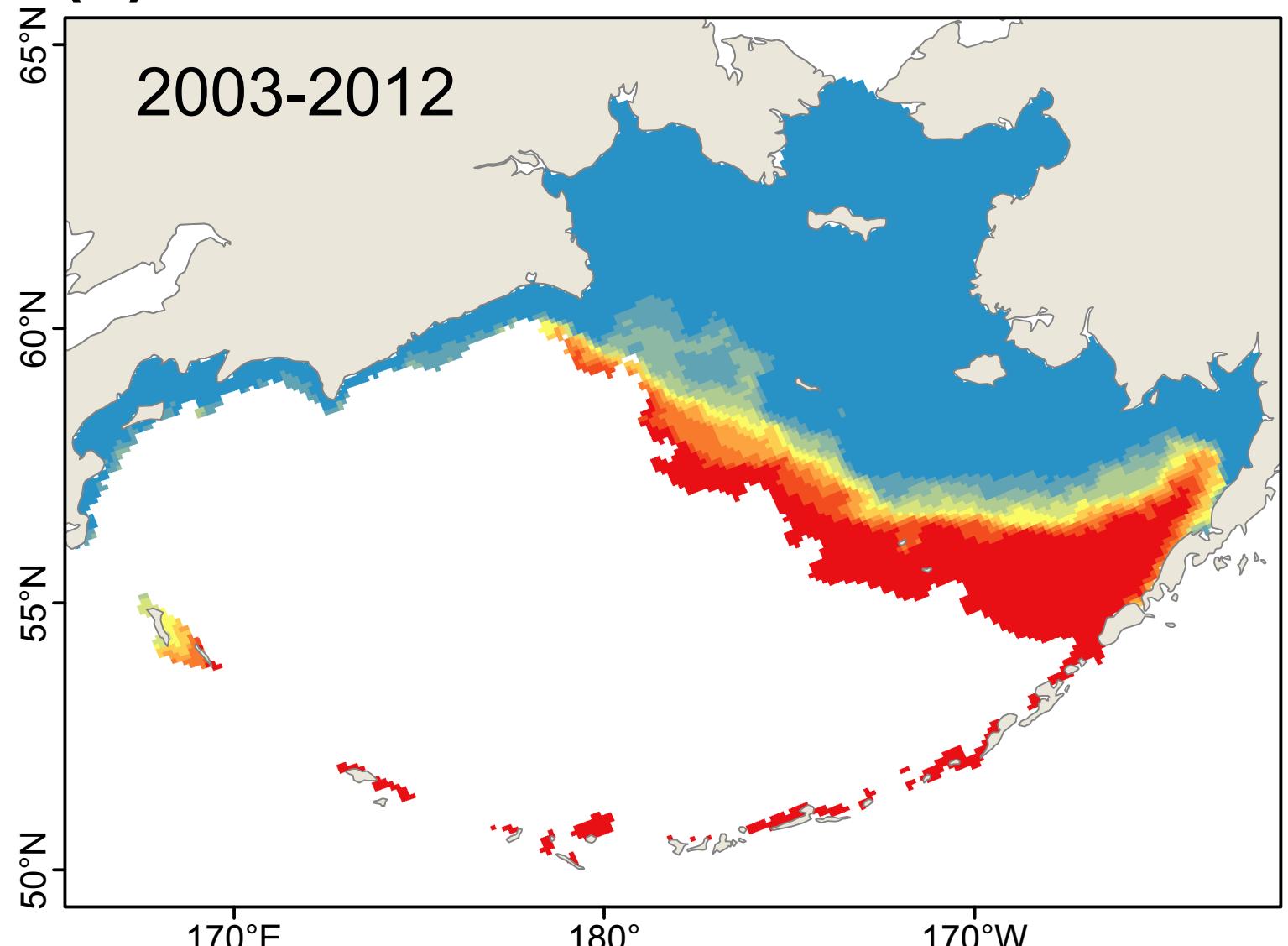


# *Synidotea laticauda: Year-round Survival*

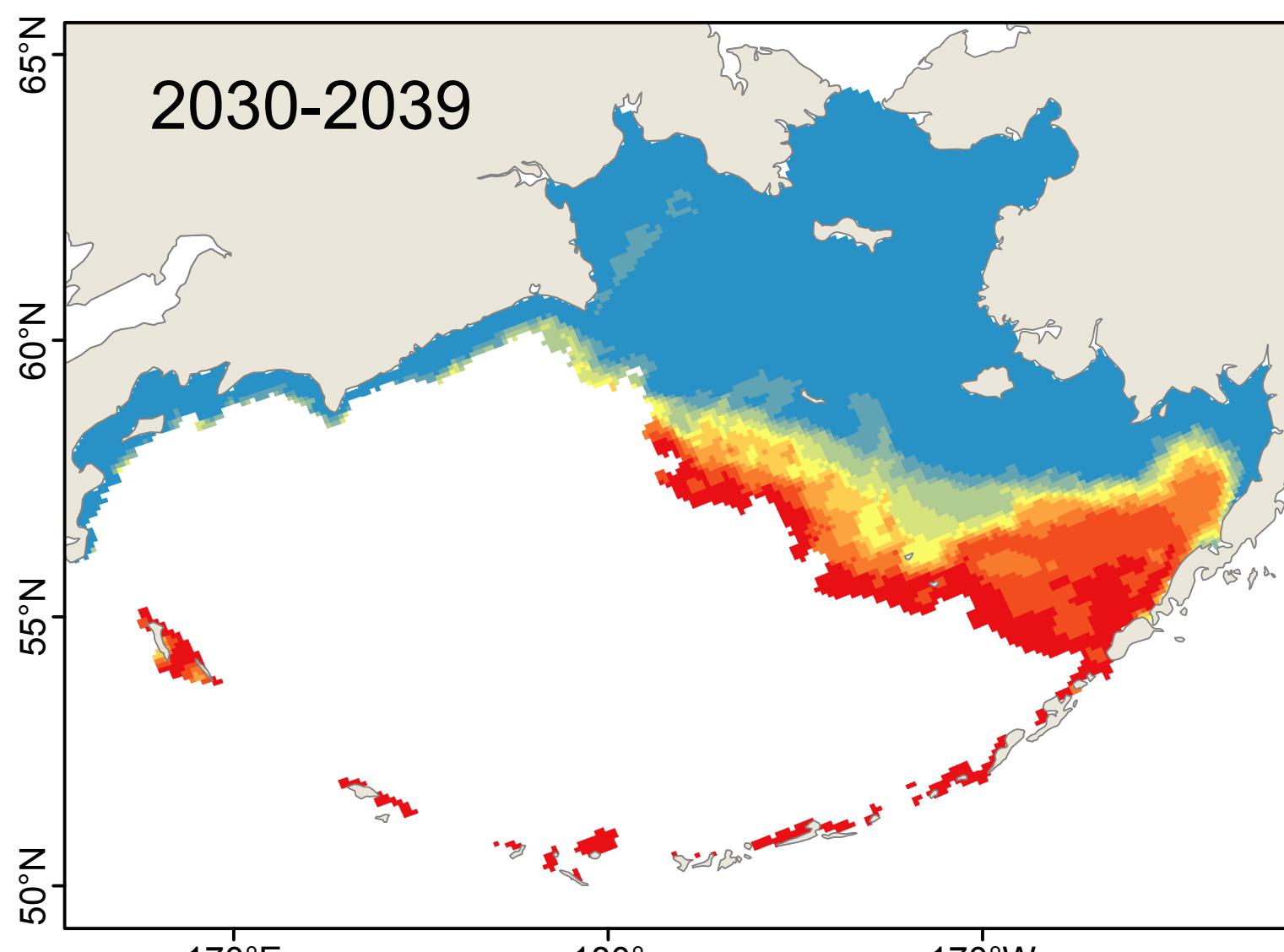
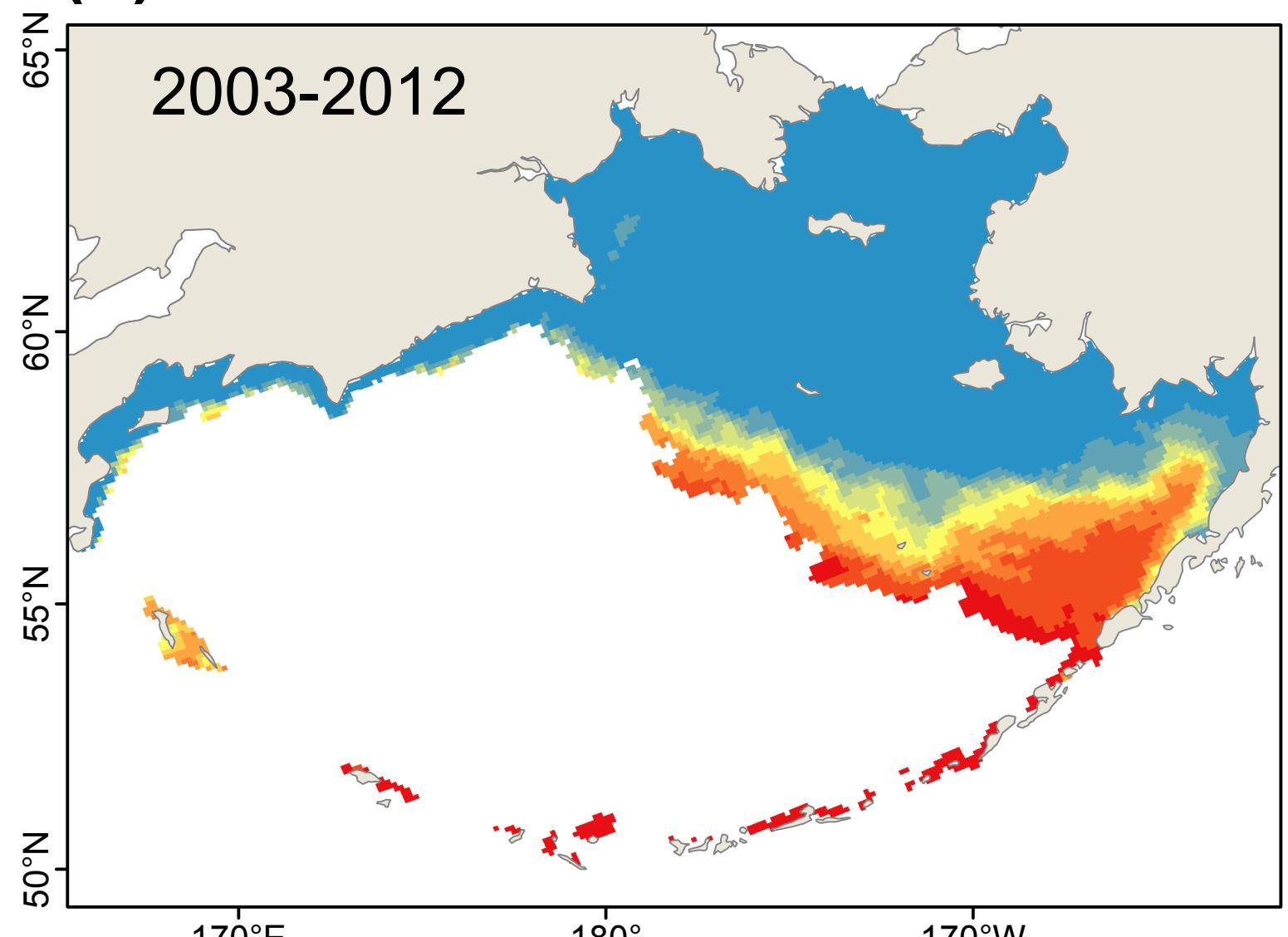
Number of years with suitable habitat



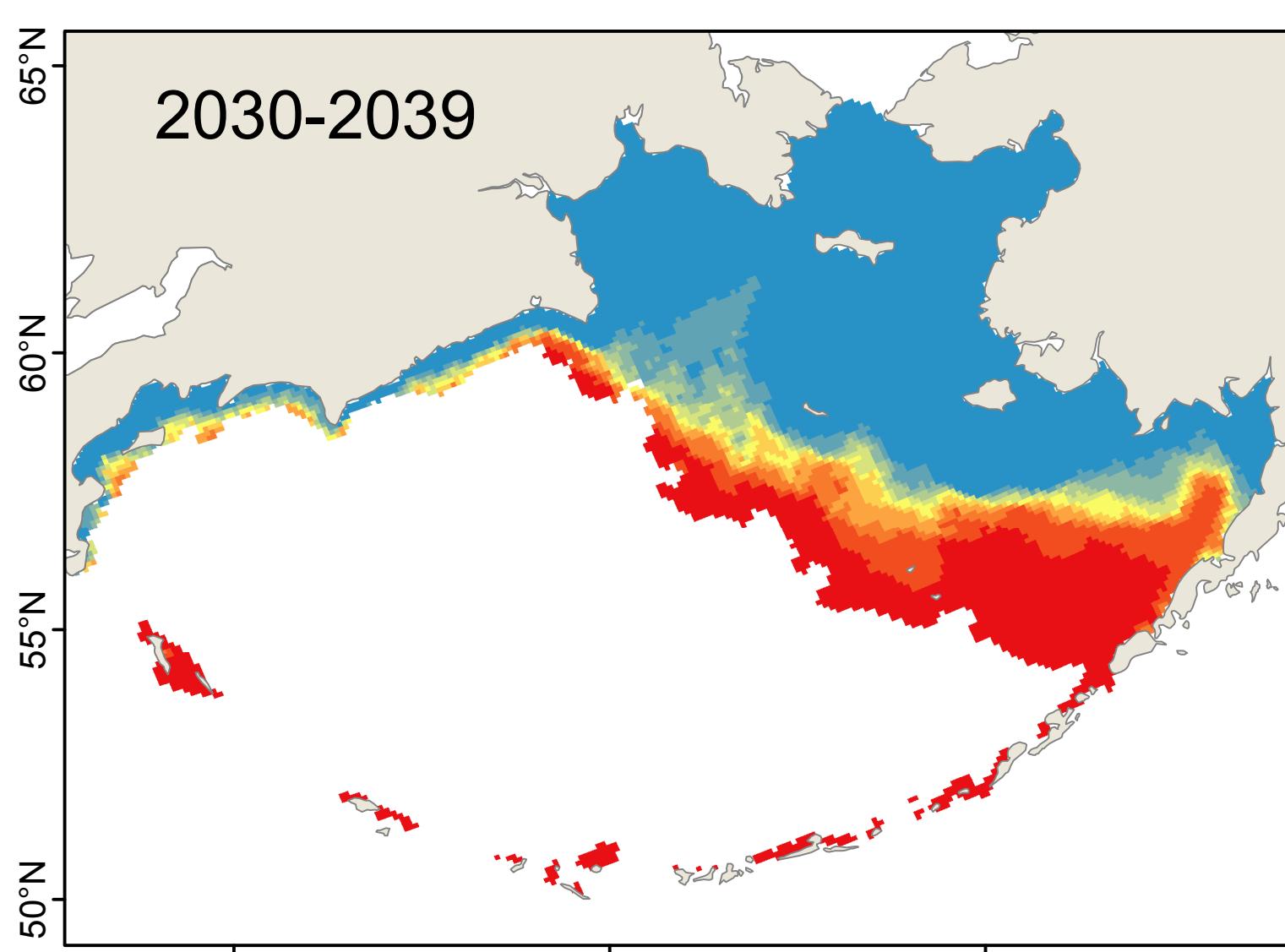
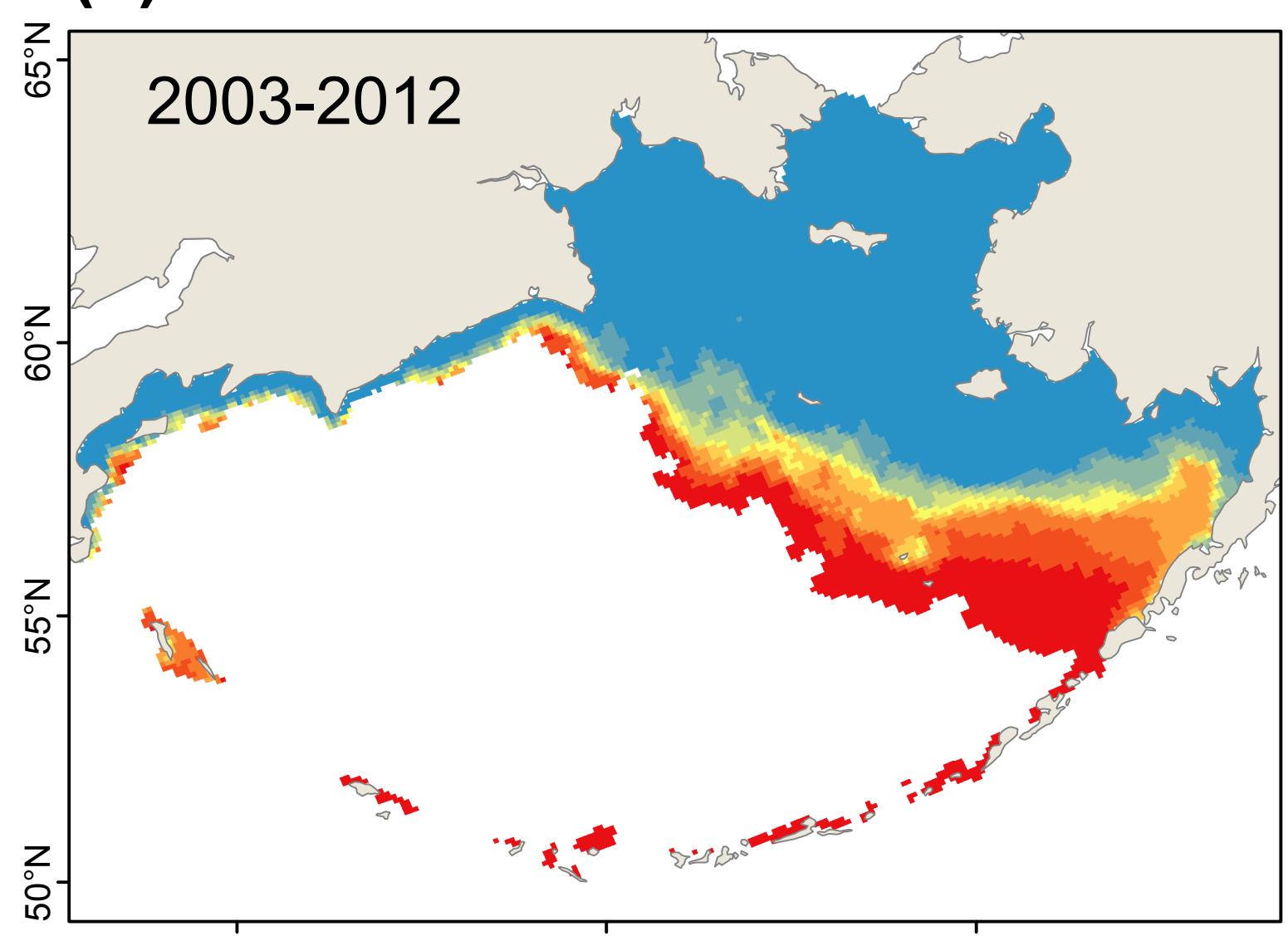
(a) Model: CGCM3-t47



(b) Model: ECHO-G

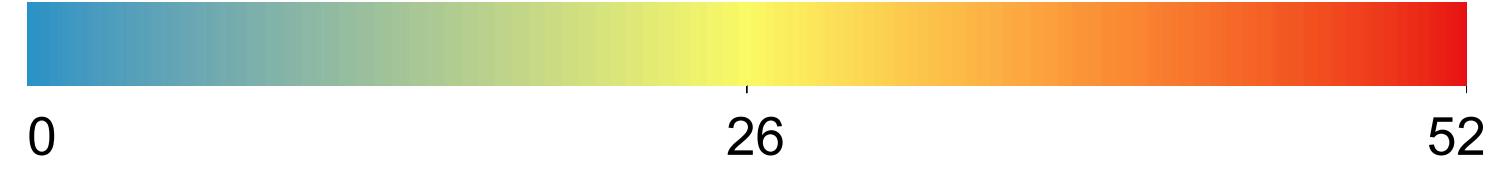


(c) Model: MIROC3.2

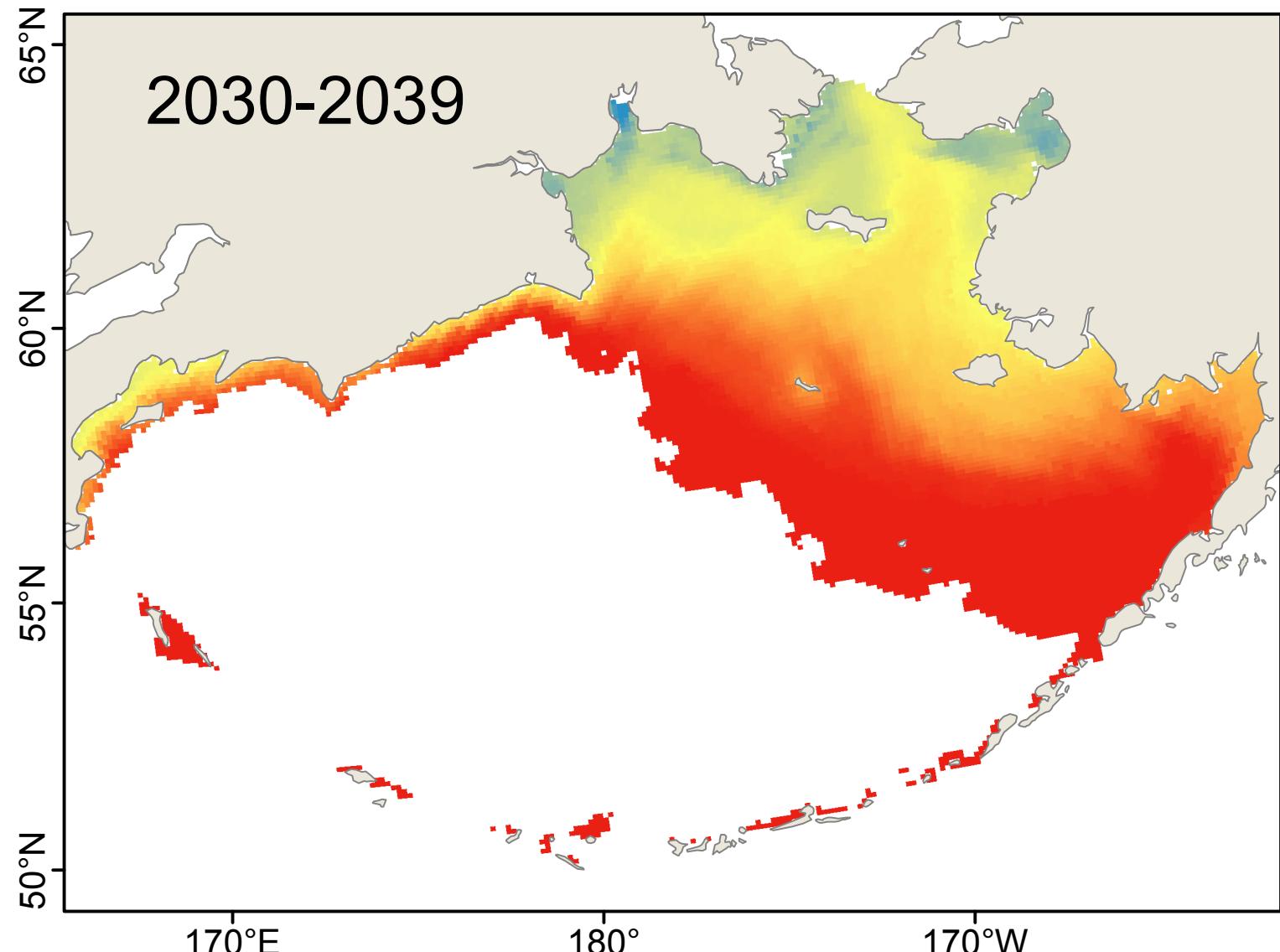
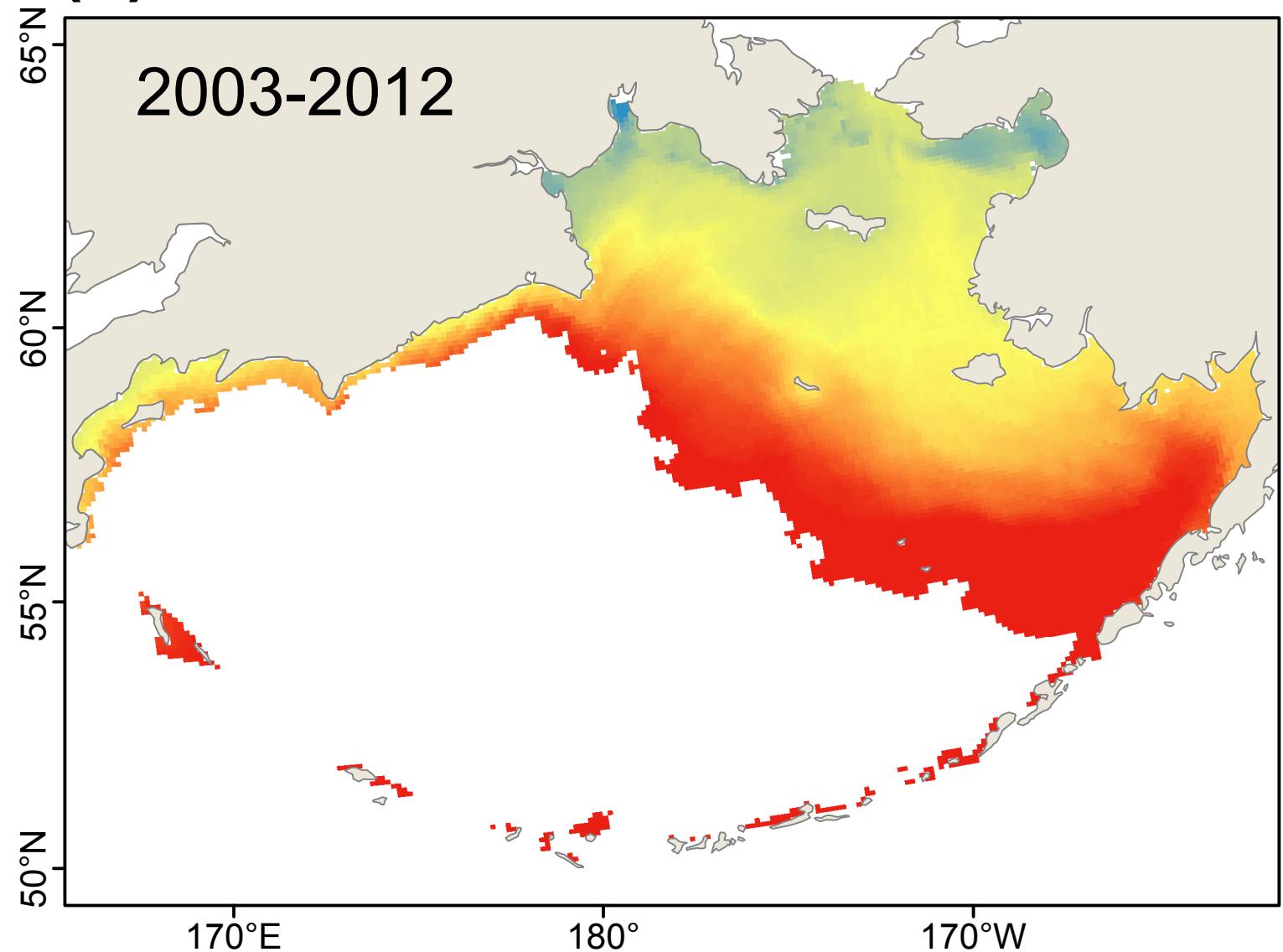


# *Synidotea laticauda: Weekly Survival*

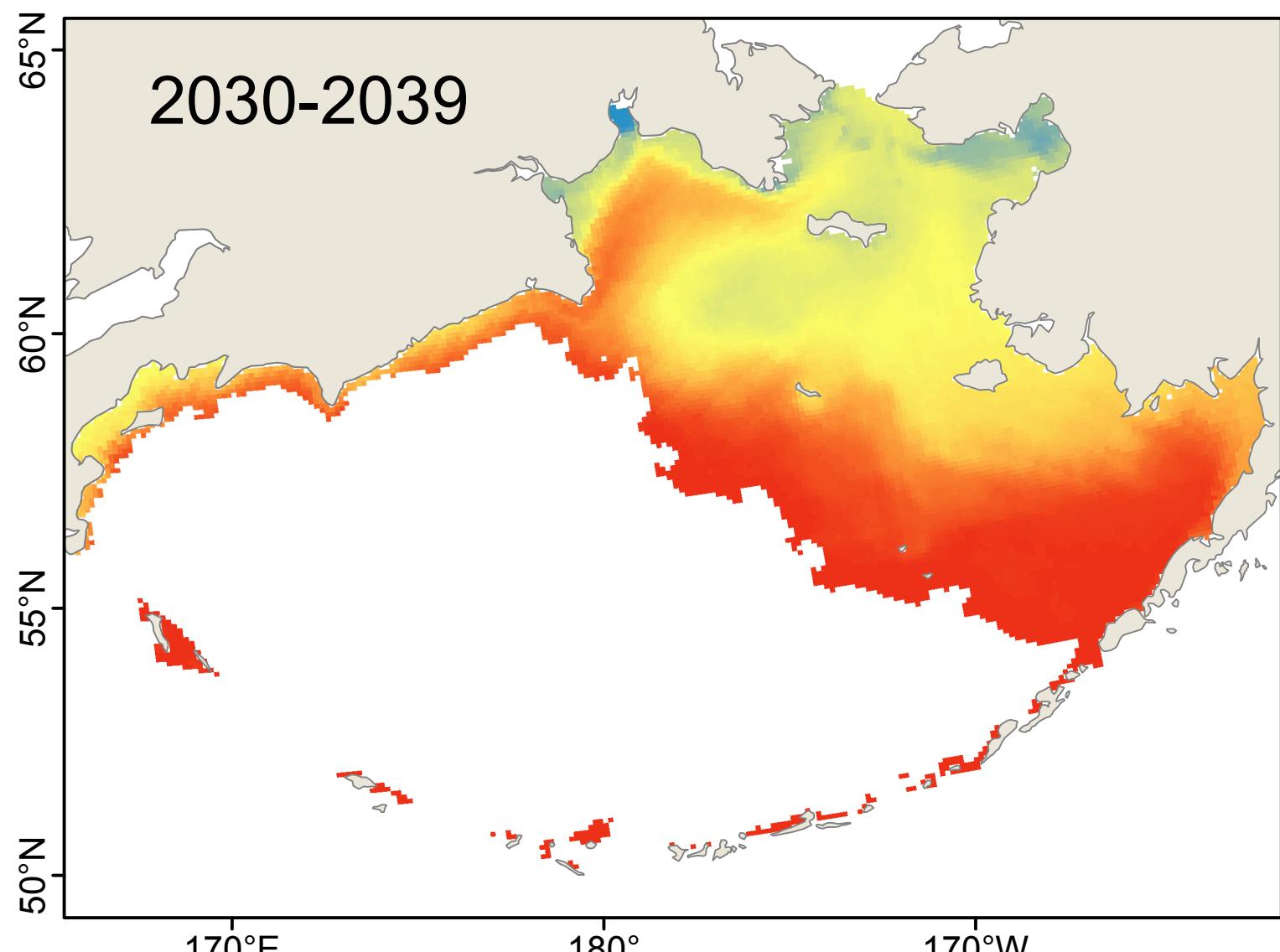
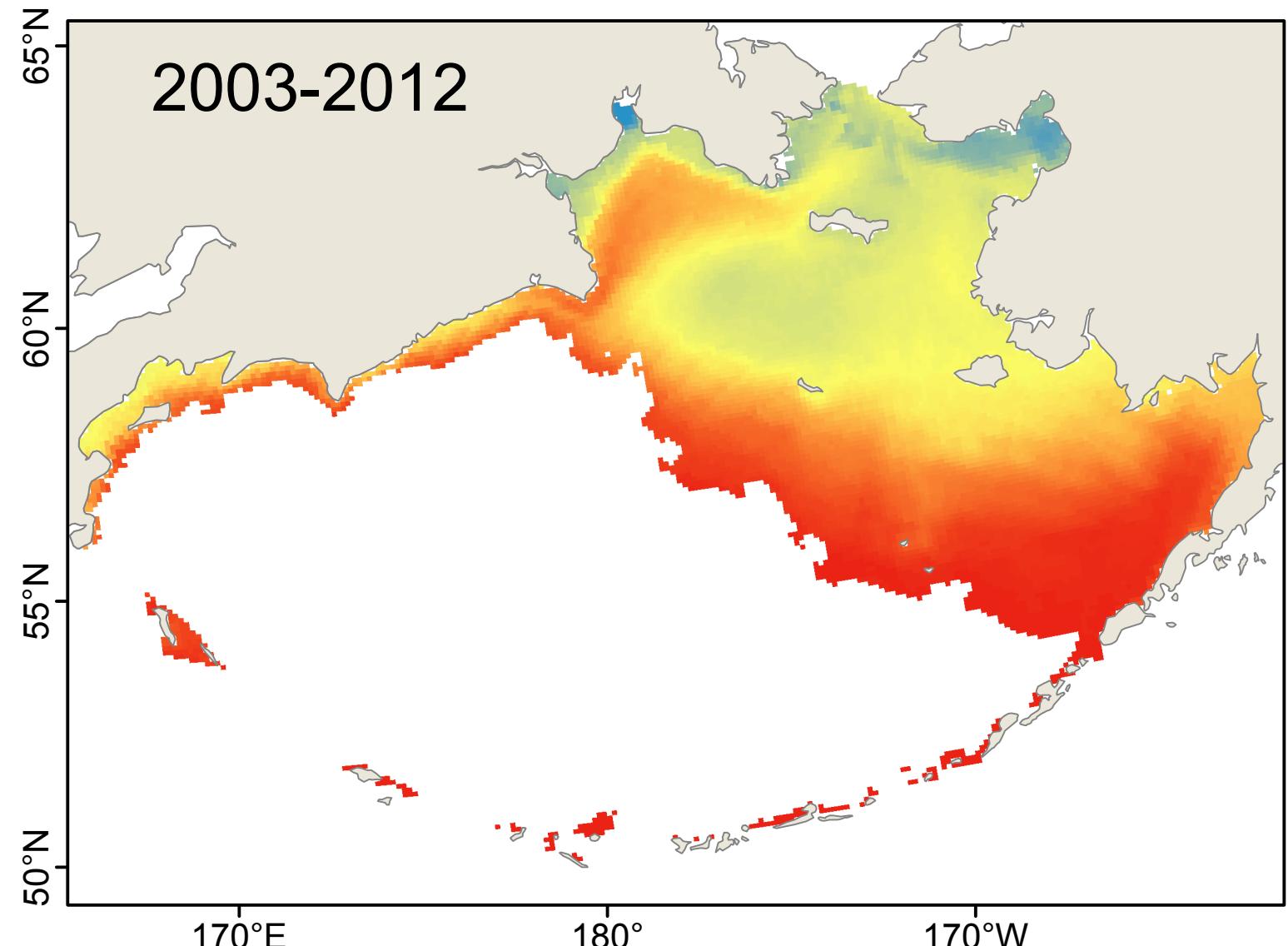
Average number of weeks of suitable habitat



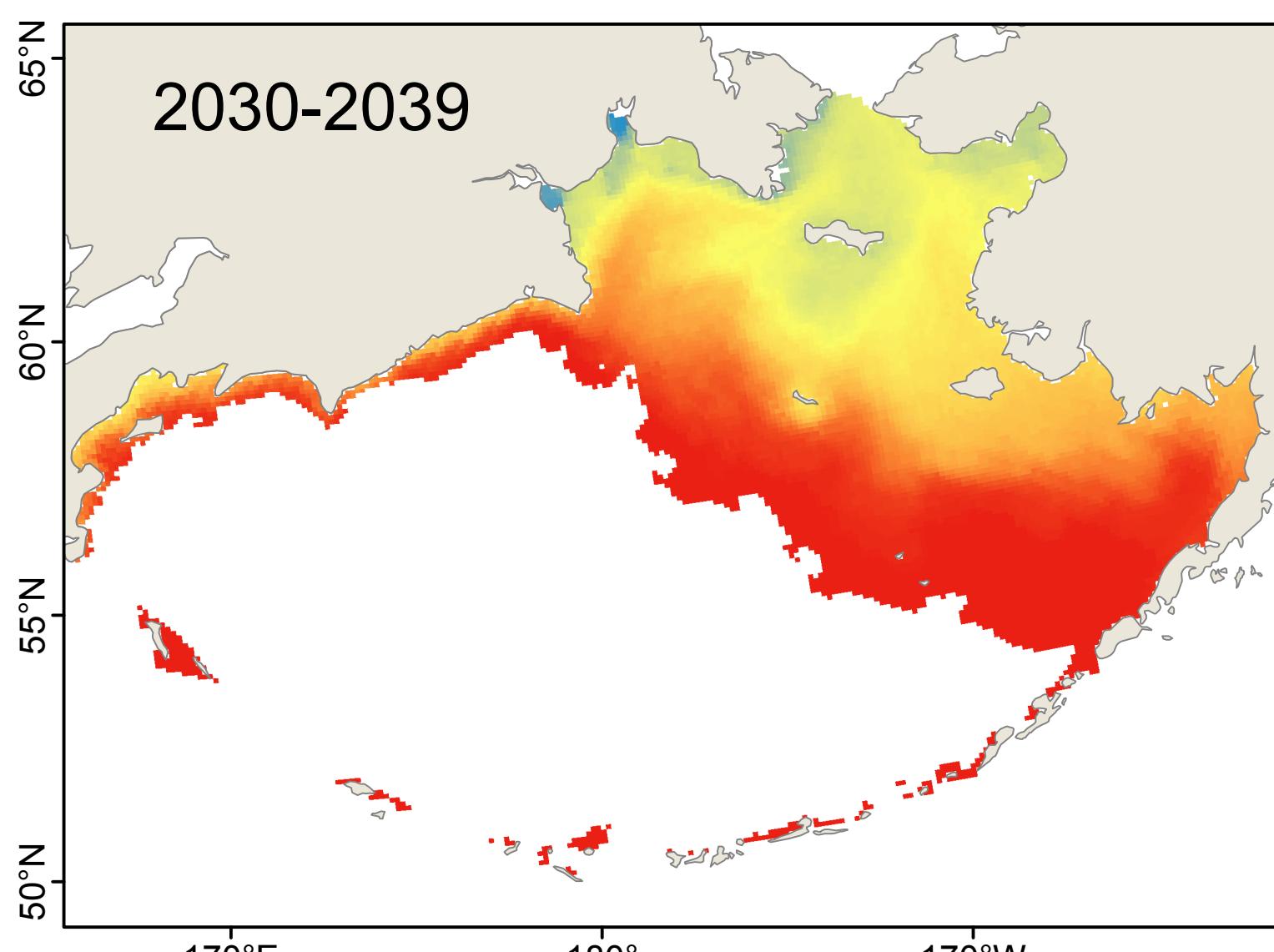
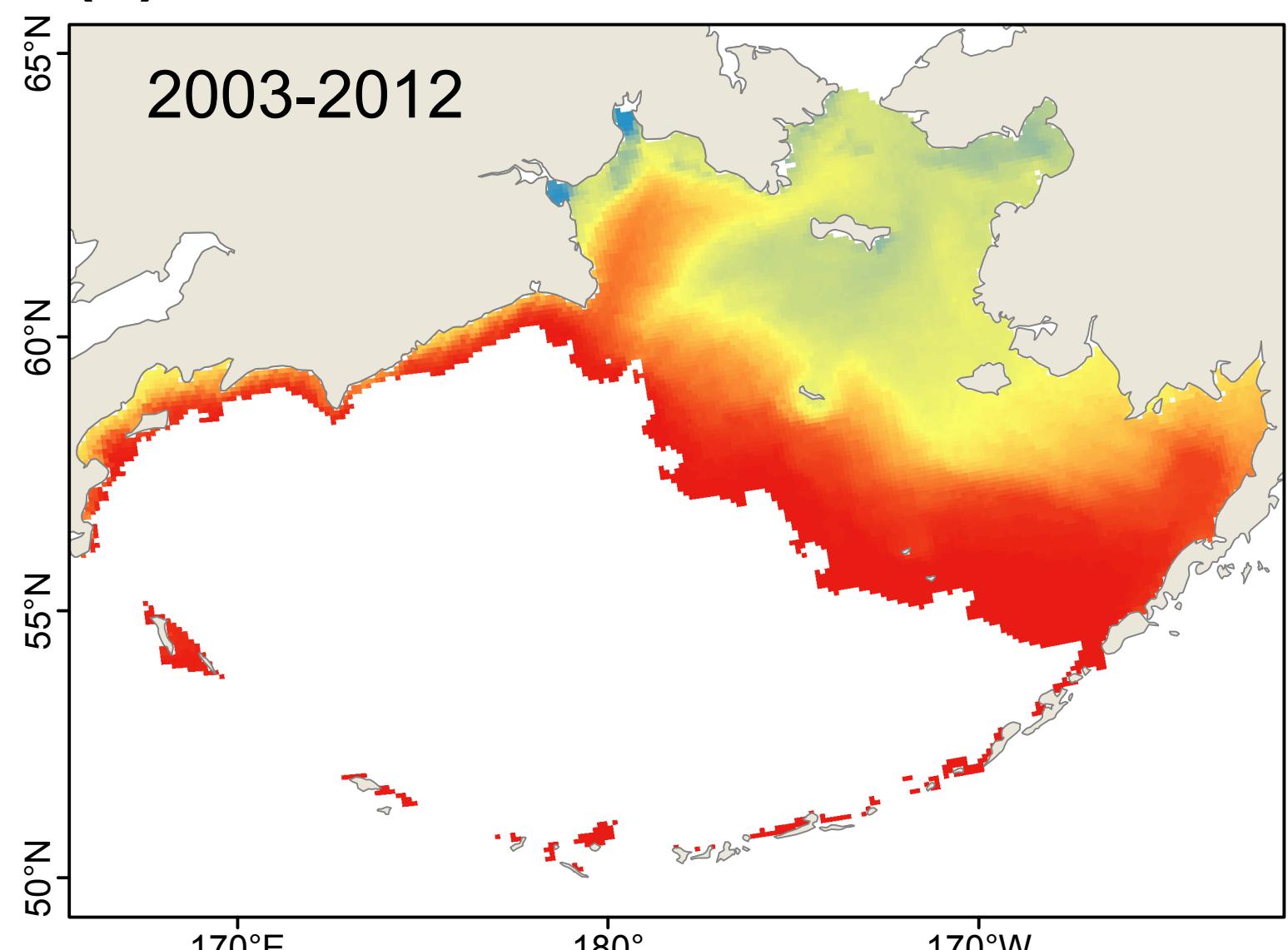
(a) Model: CGCM3-t47



(b) Model: ECHO-G

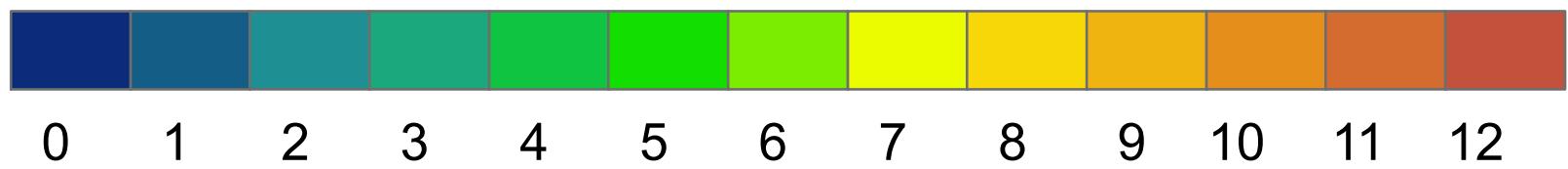


(c) Model: MIROC3.2

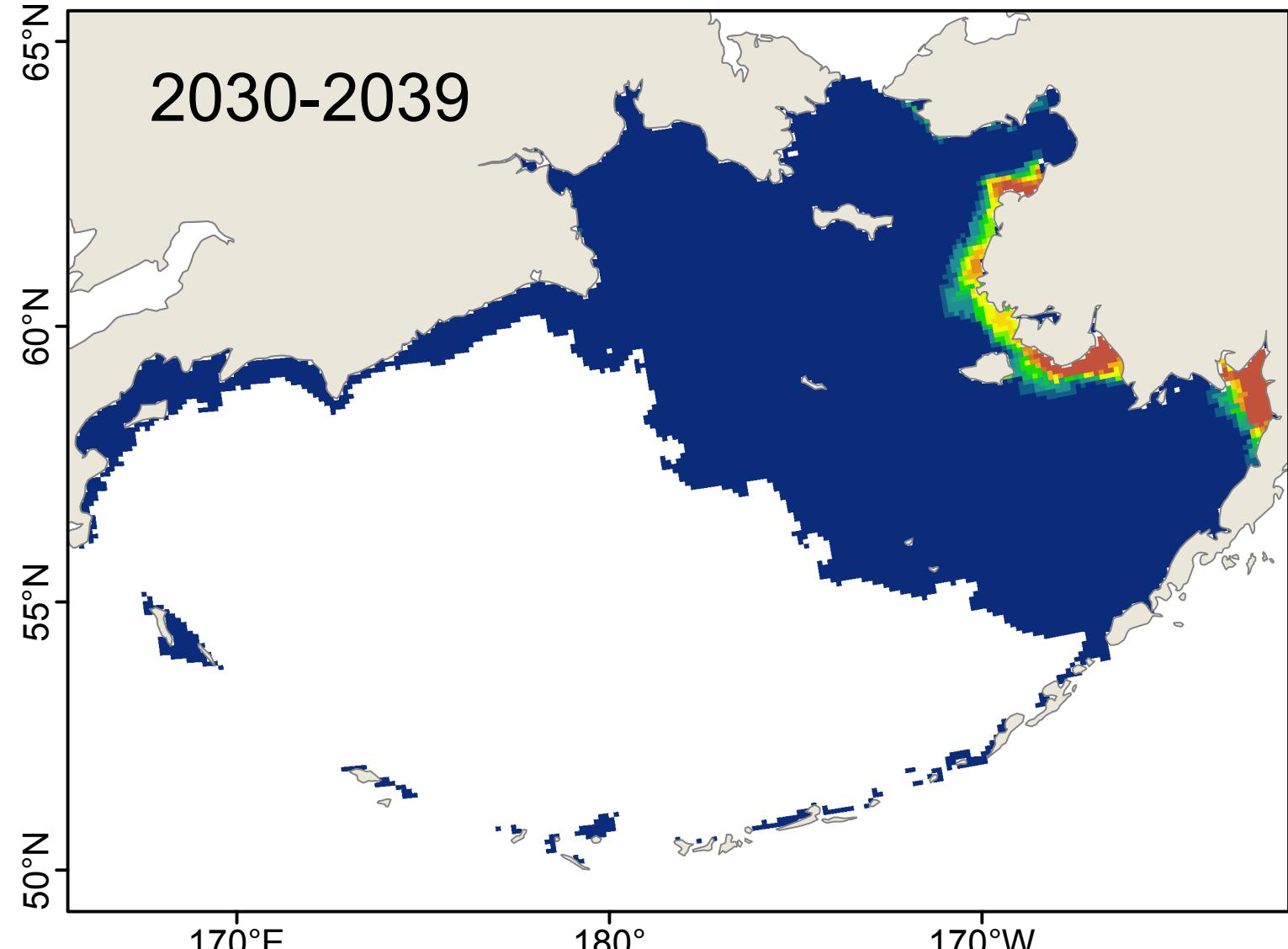
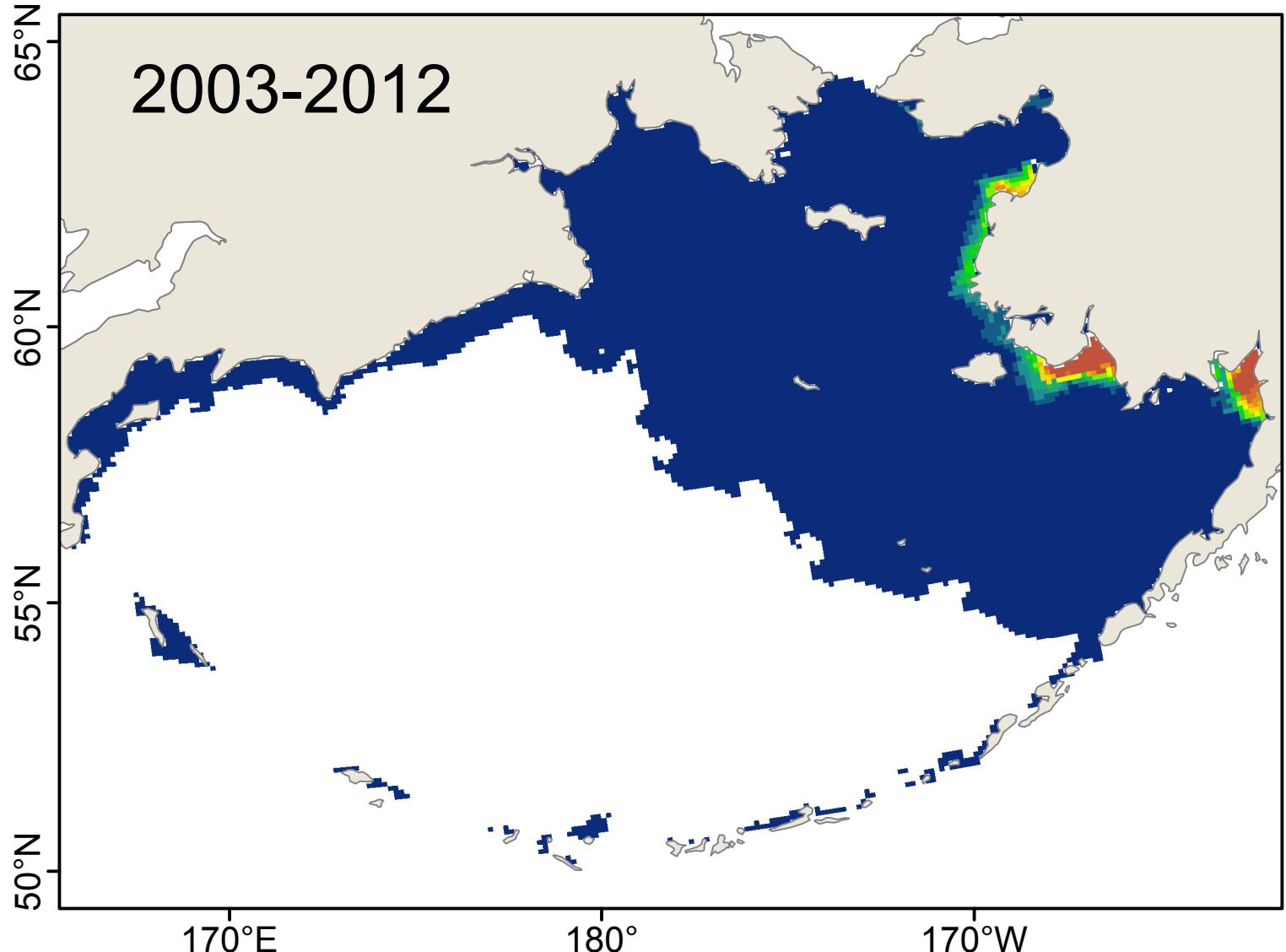


# *Synidotea laticauda: Reproduction*

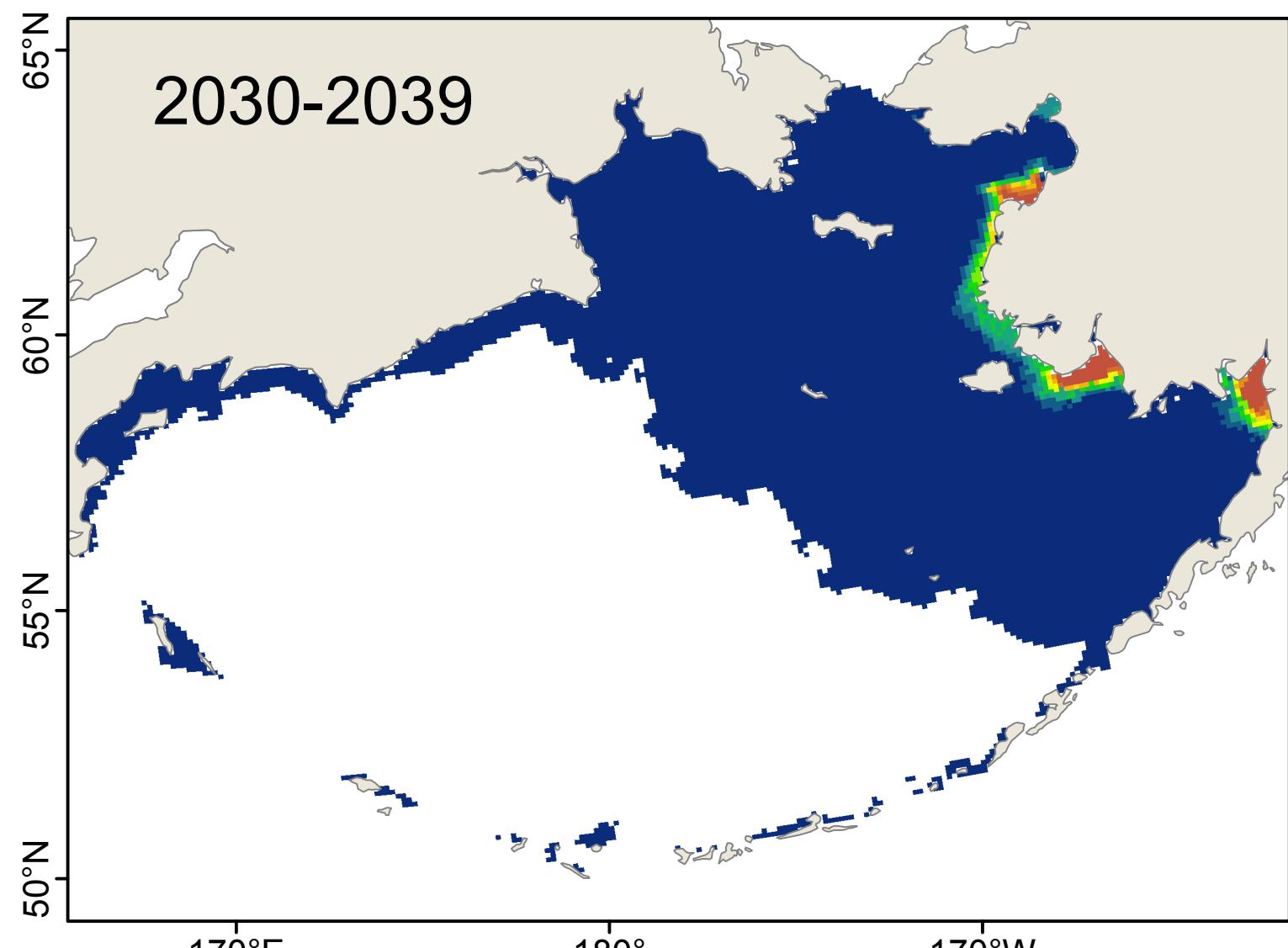
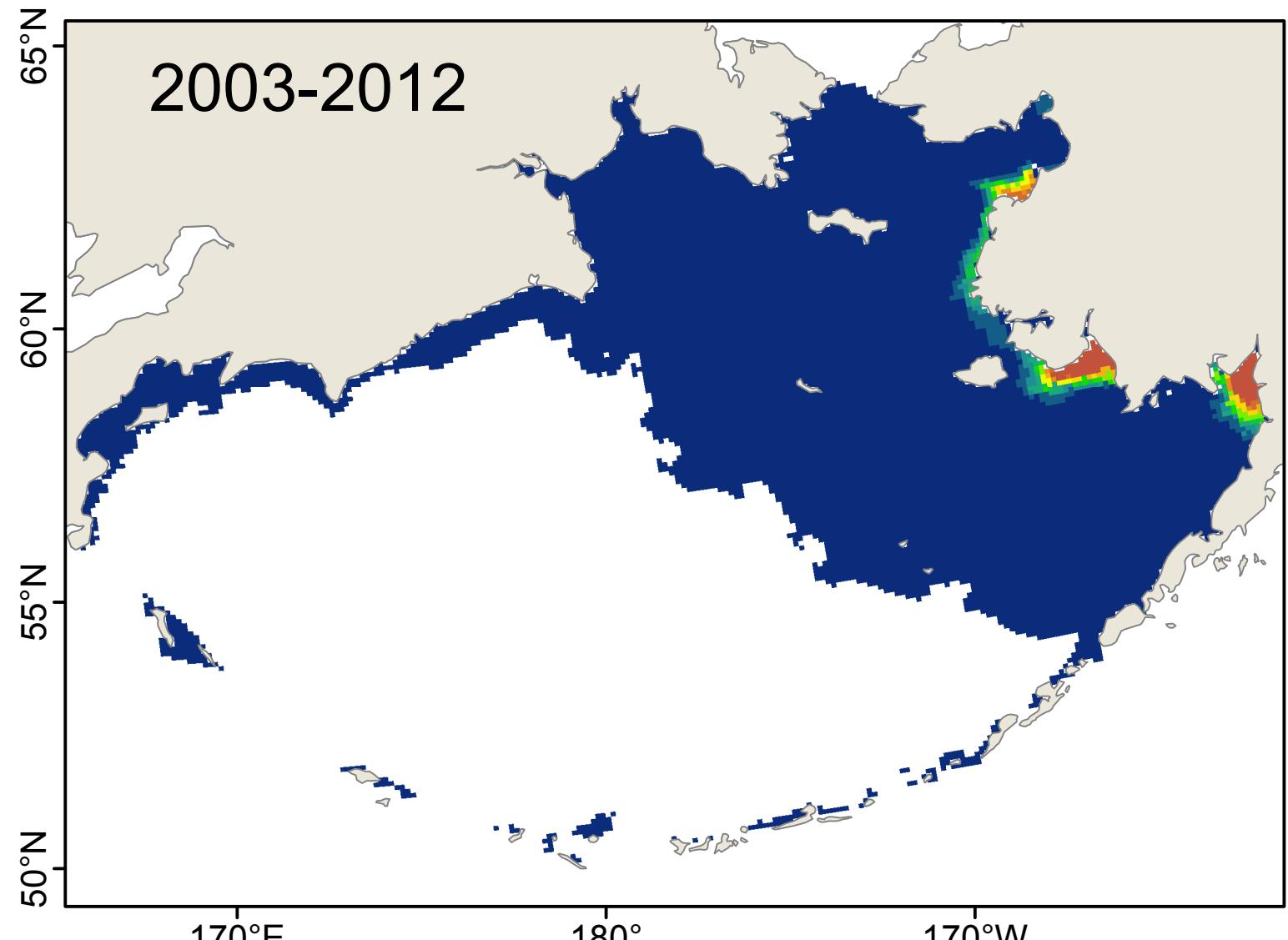
Average number of consecutive weeks of suitable habitat



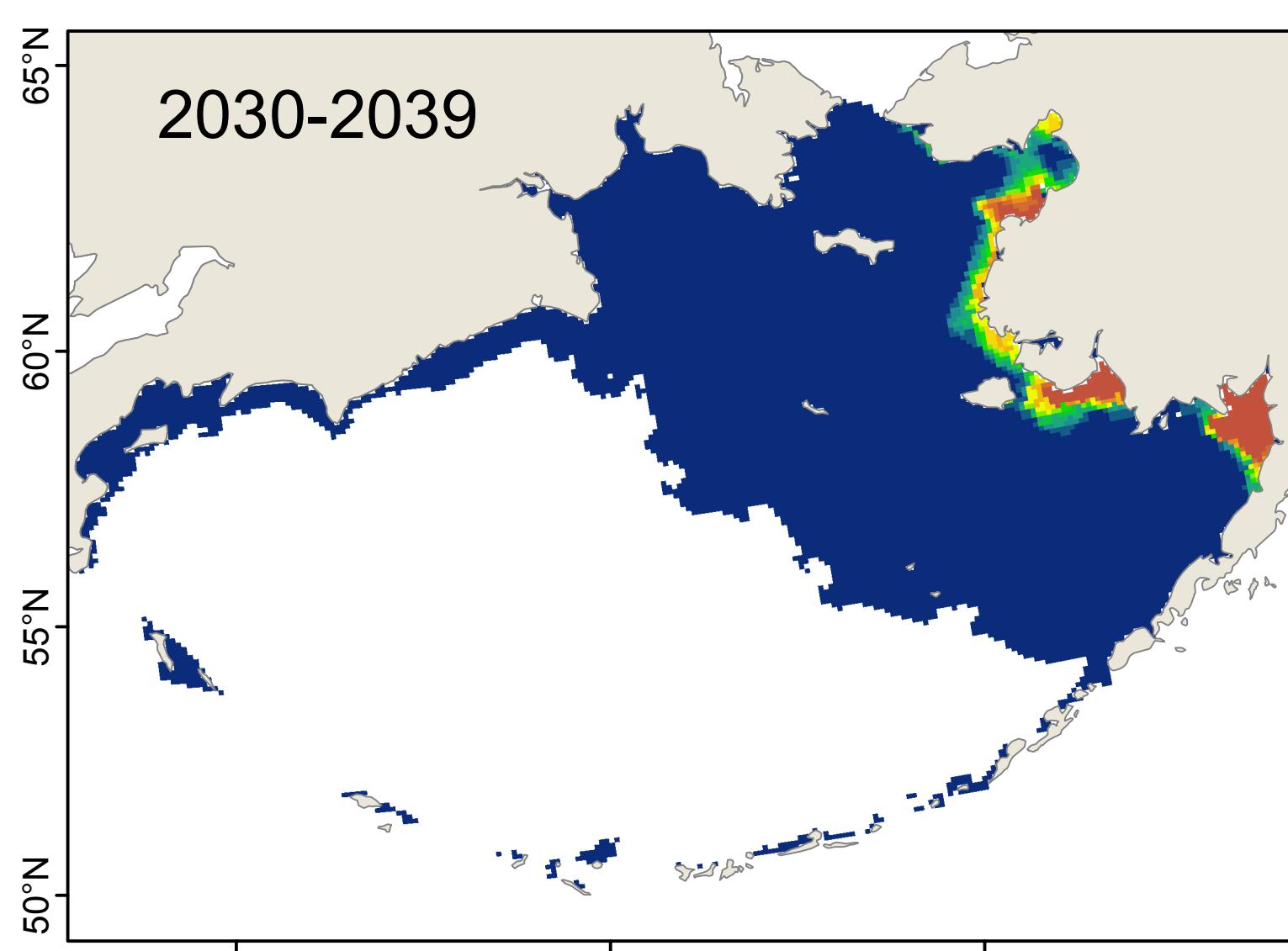
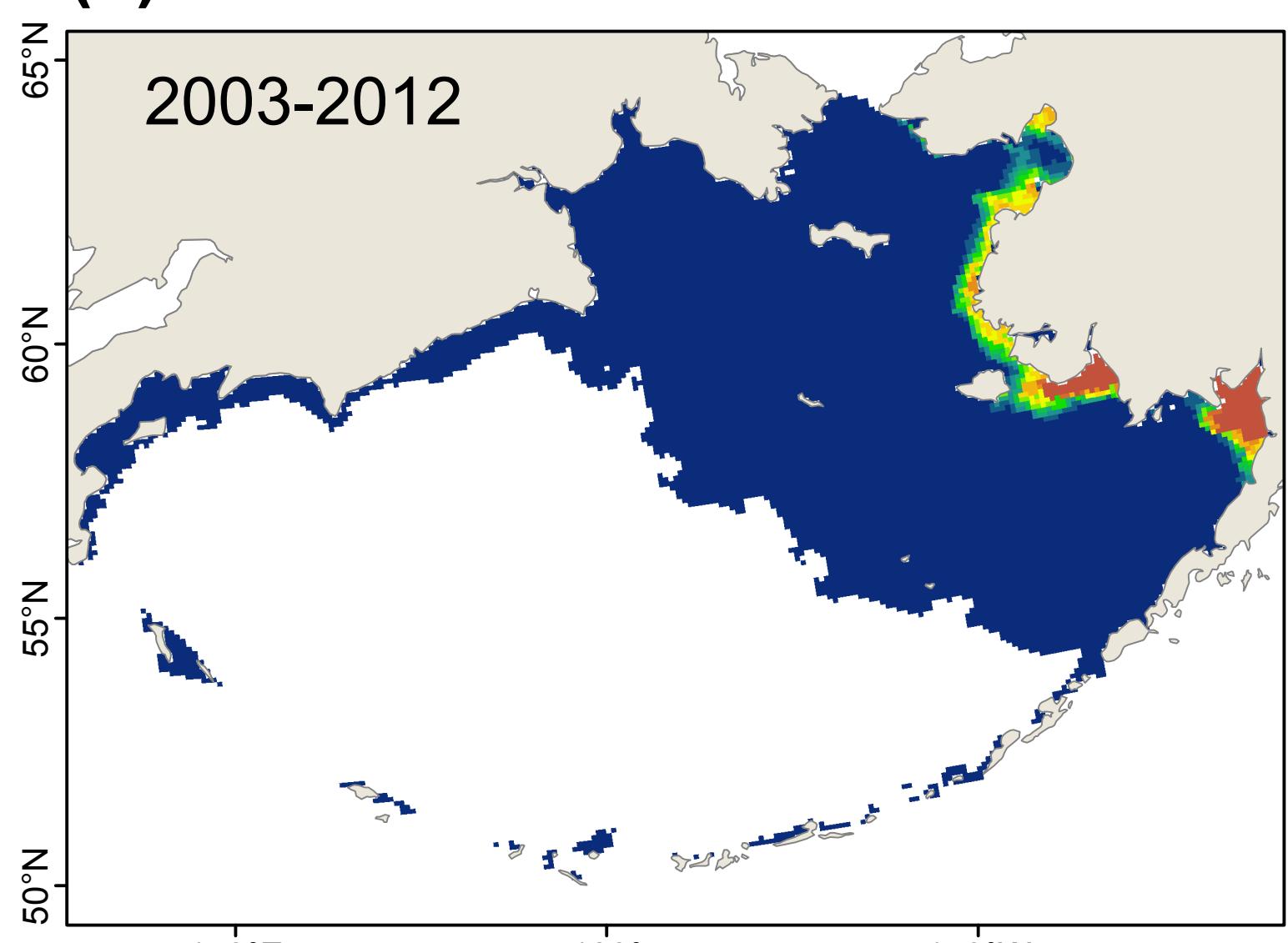
(a) Model: CGCM3-t47



(b) Model: ECHO-G

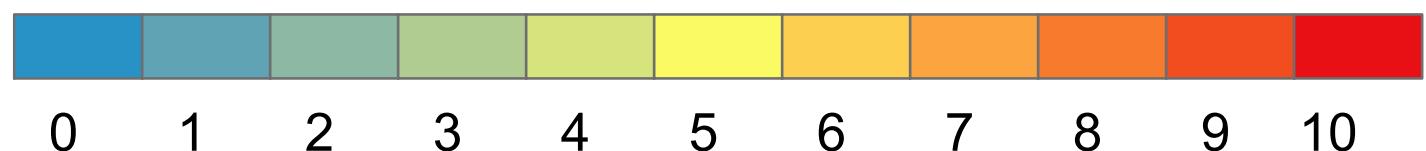


(c) Model: MIROC3.2

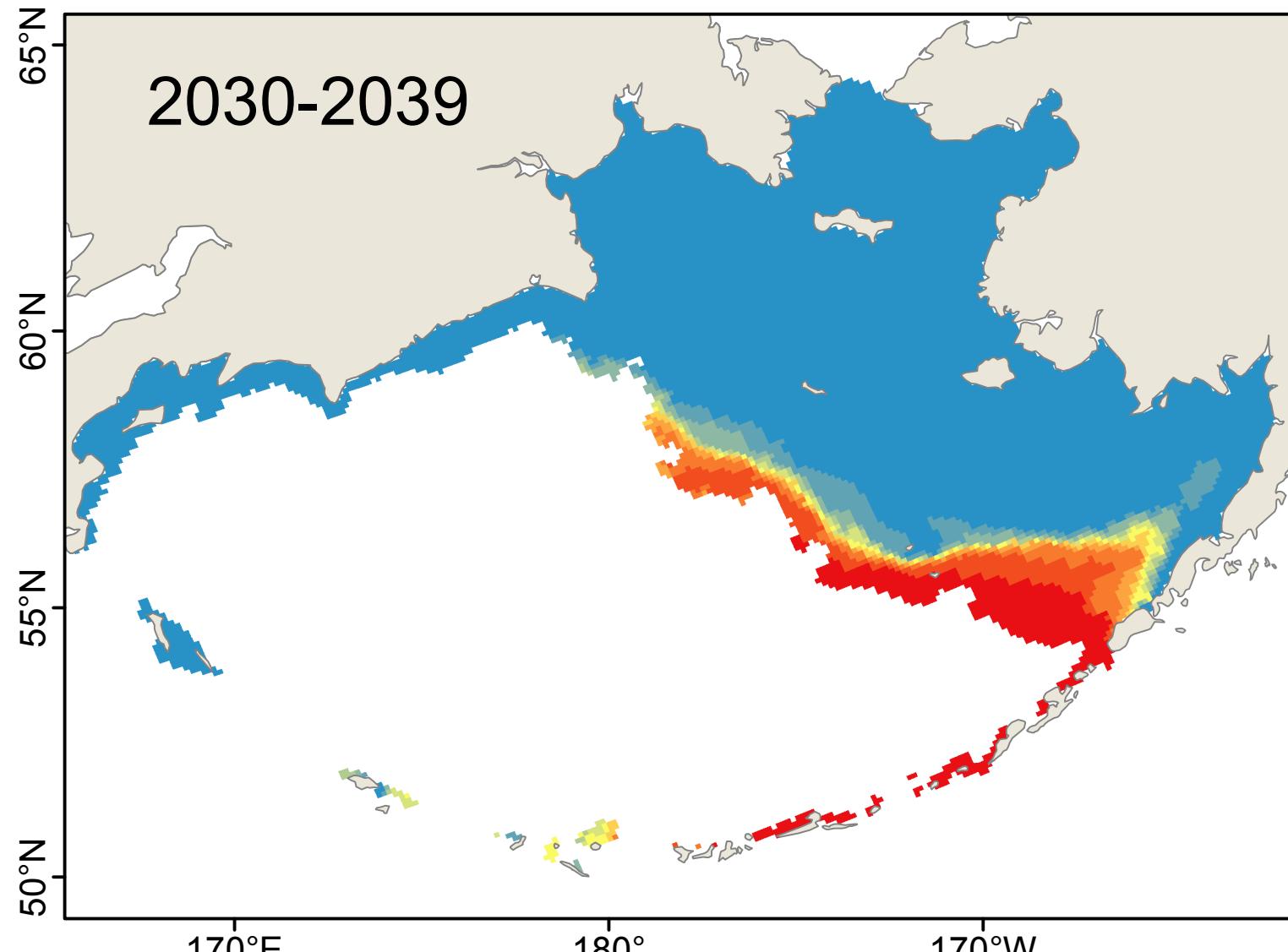
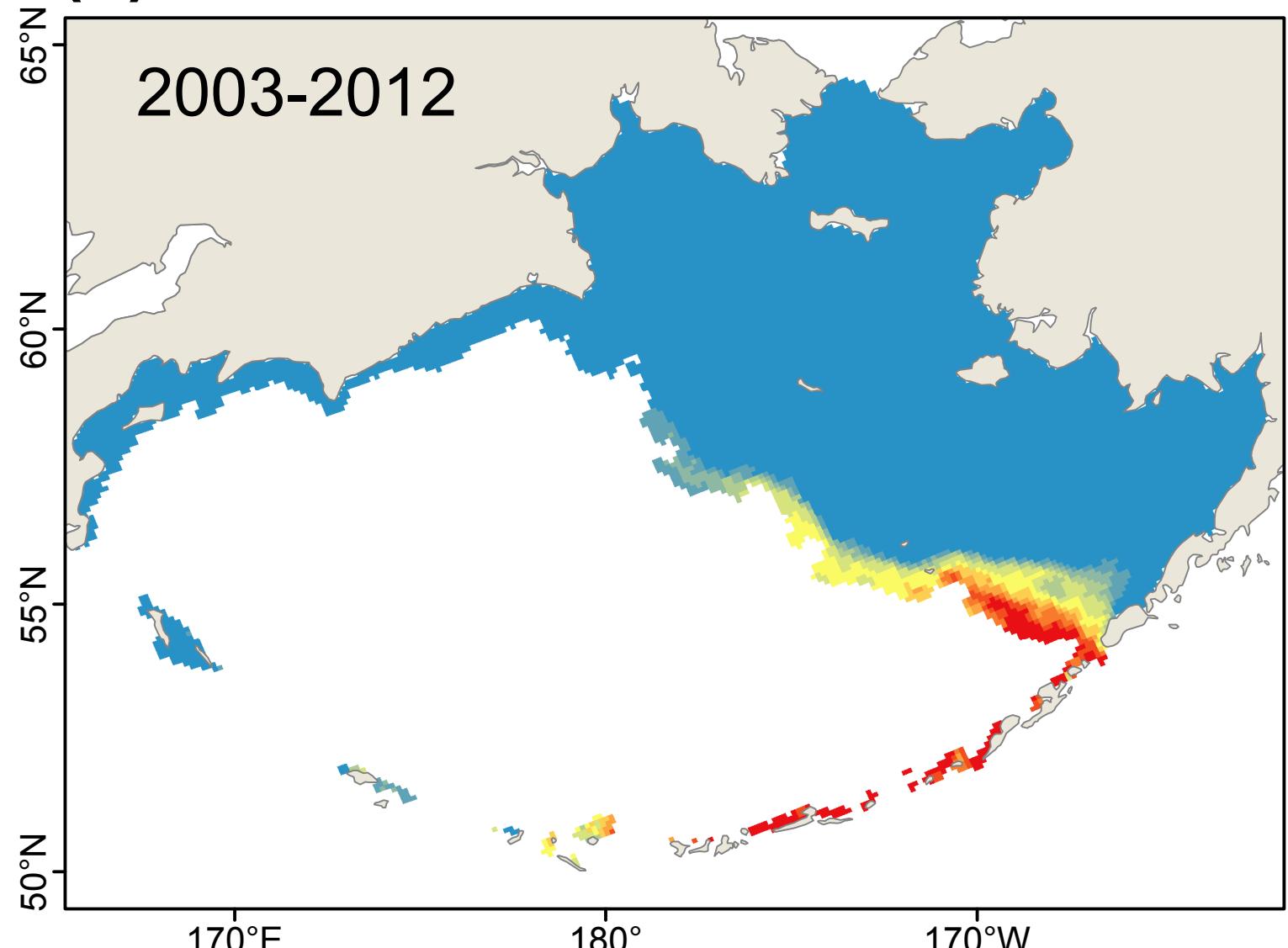


# *Eusarsiella zostericola*: Year-round Survival

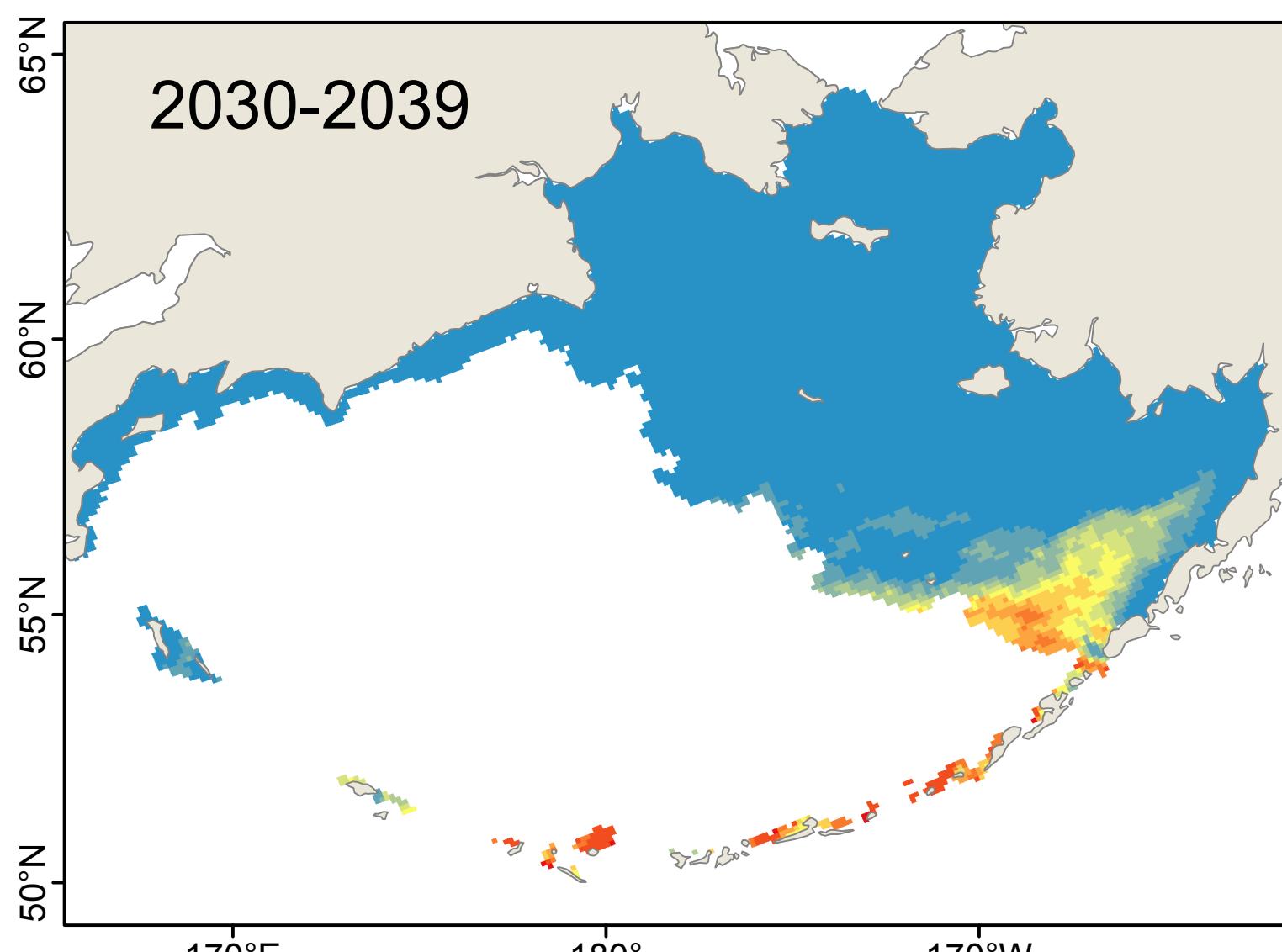
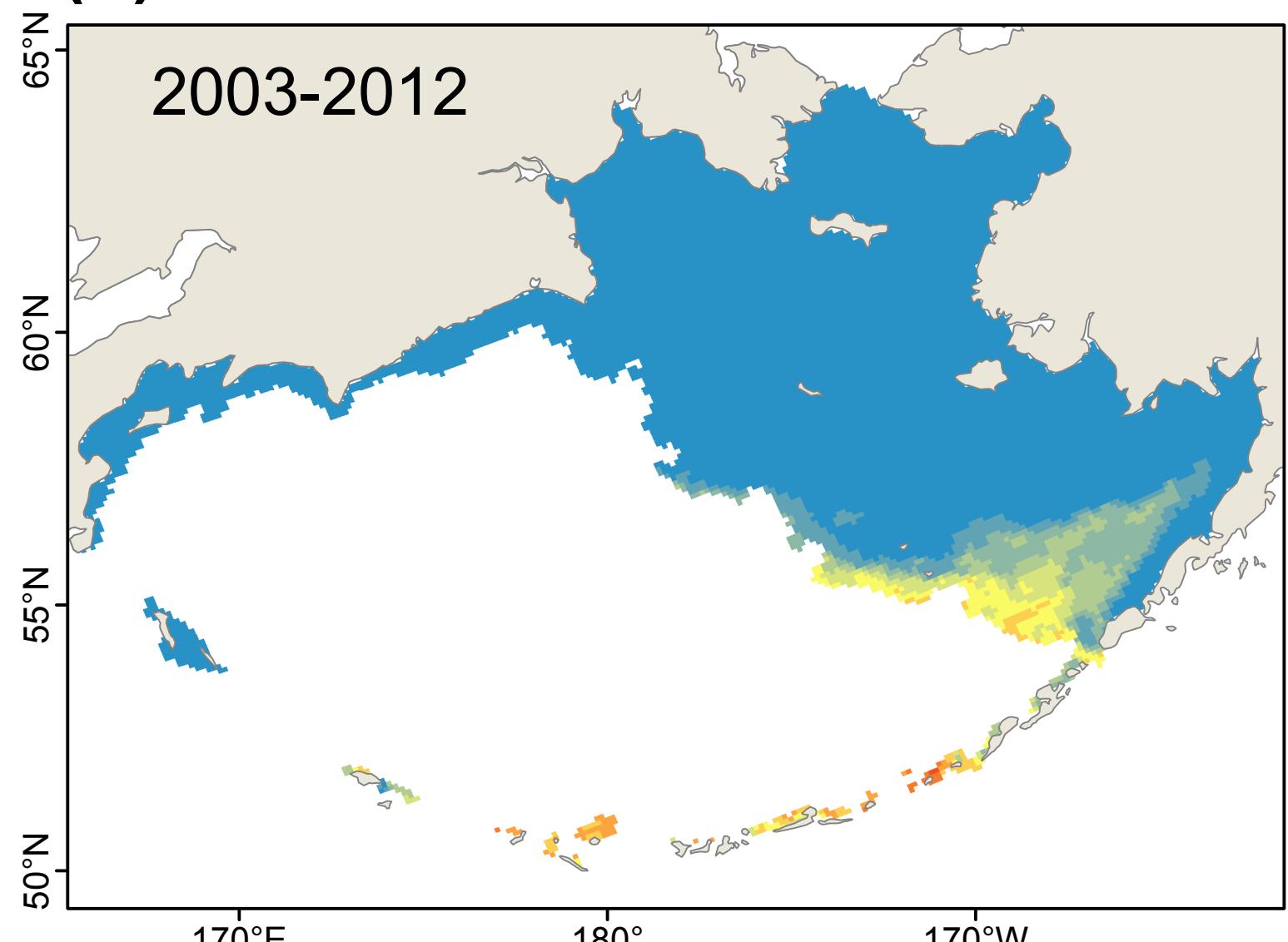
Number of years with suitable habitat



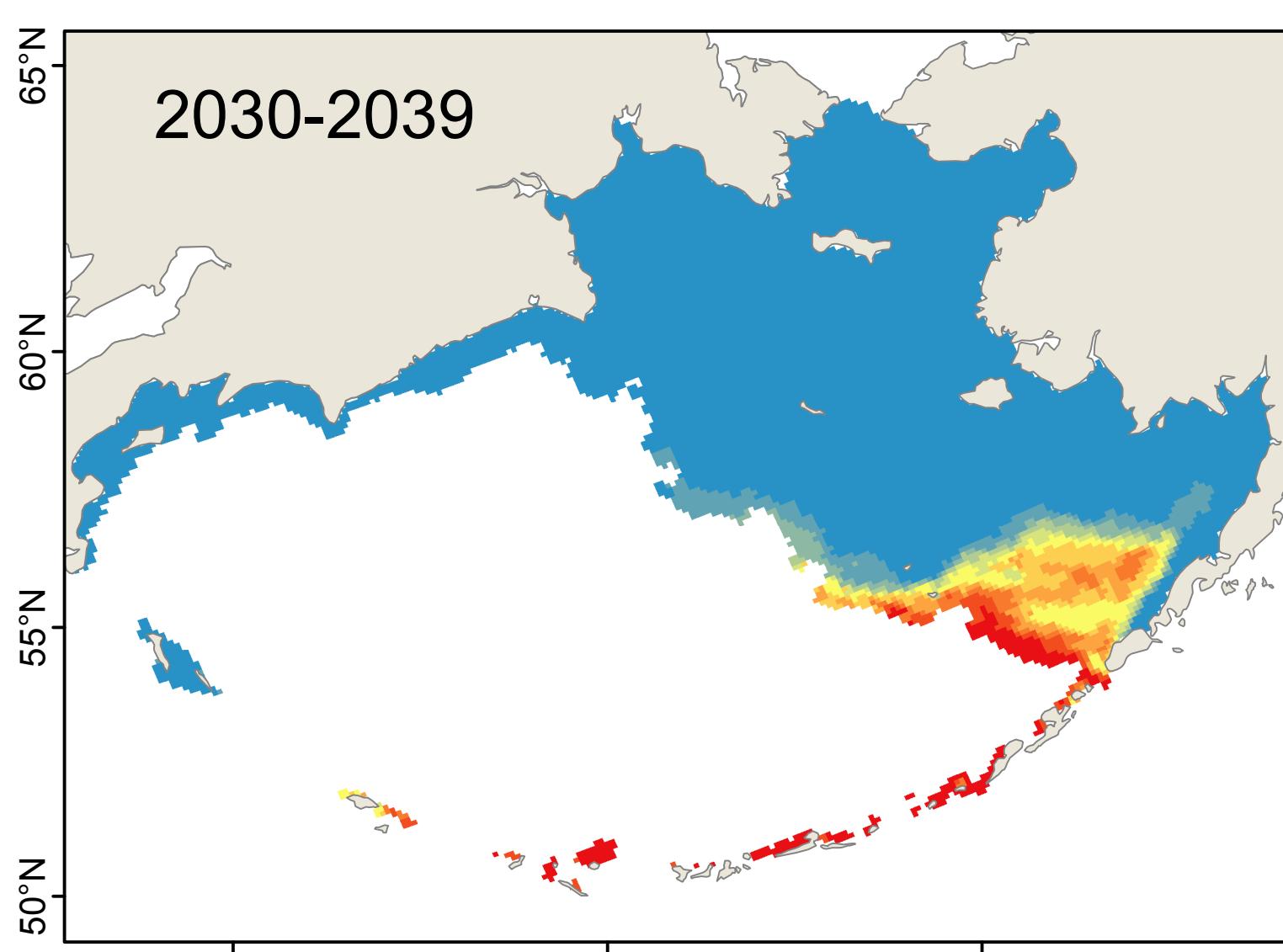
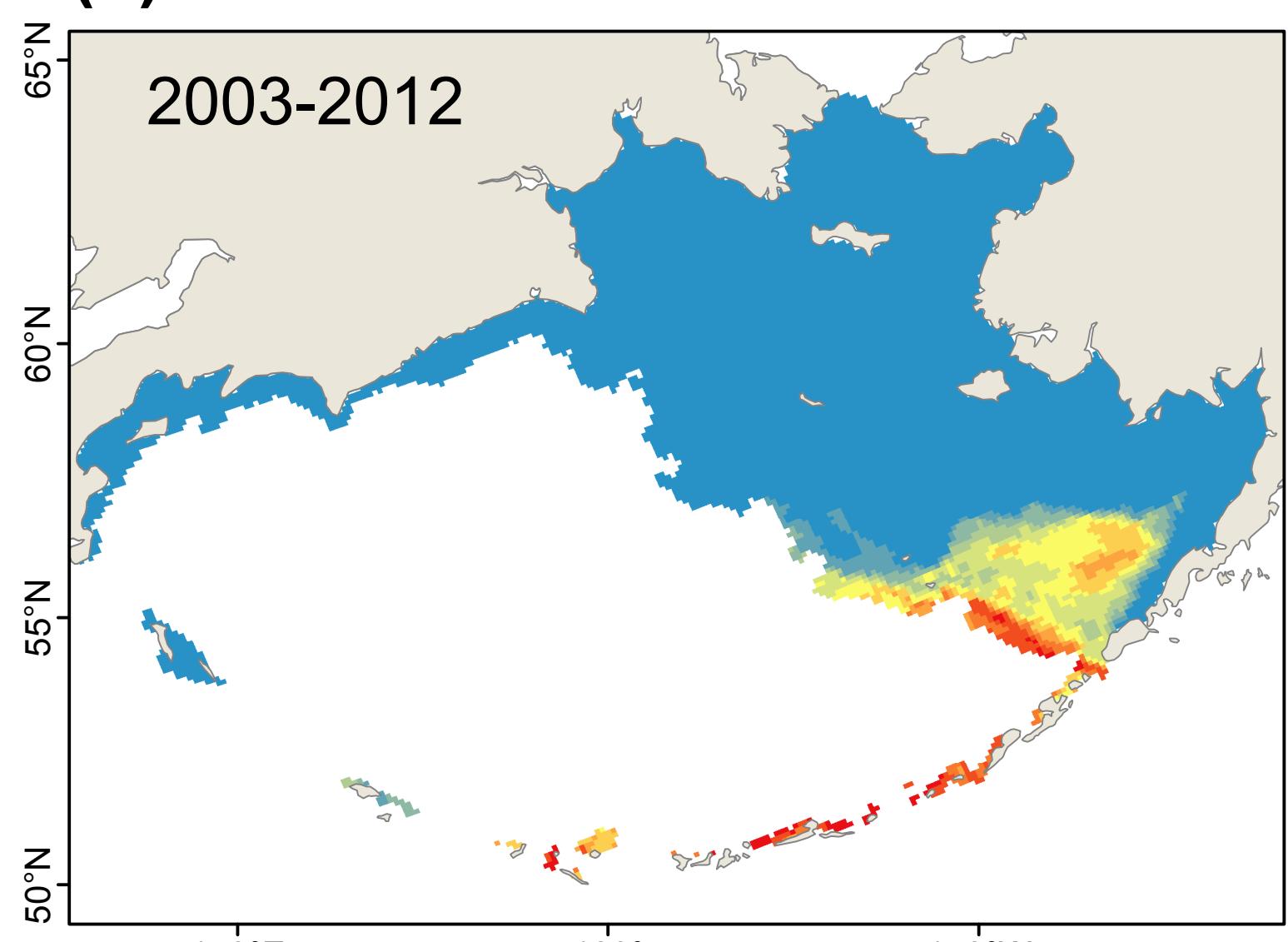
(a) Model: CGCM3-t47



(b) Model: ECHO-G

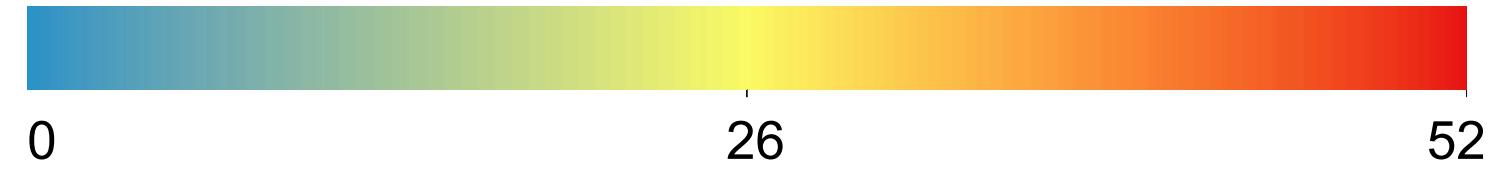


(c) Model: MIROC3.2

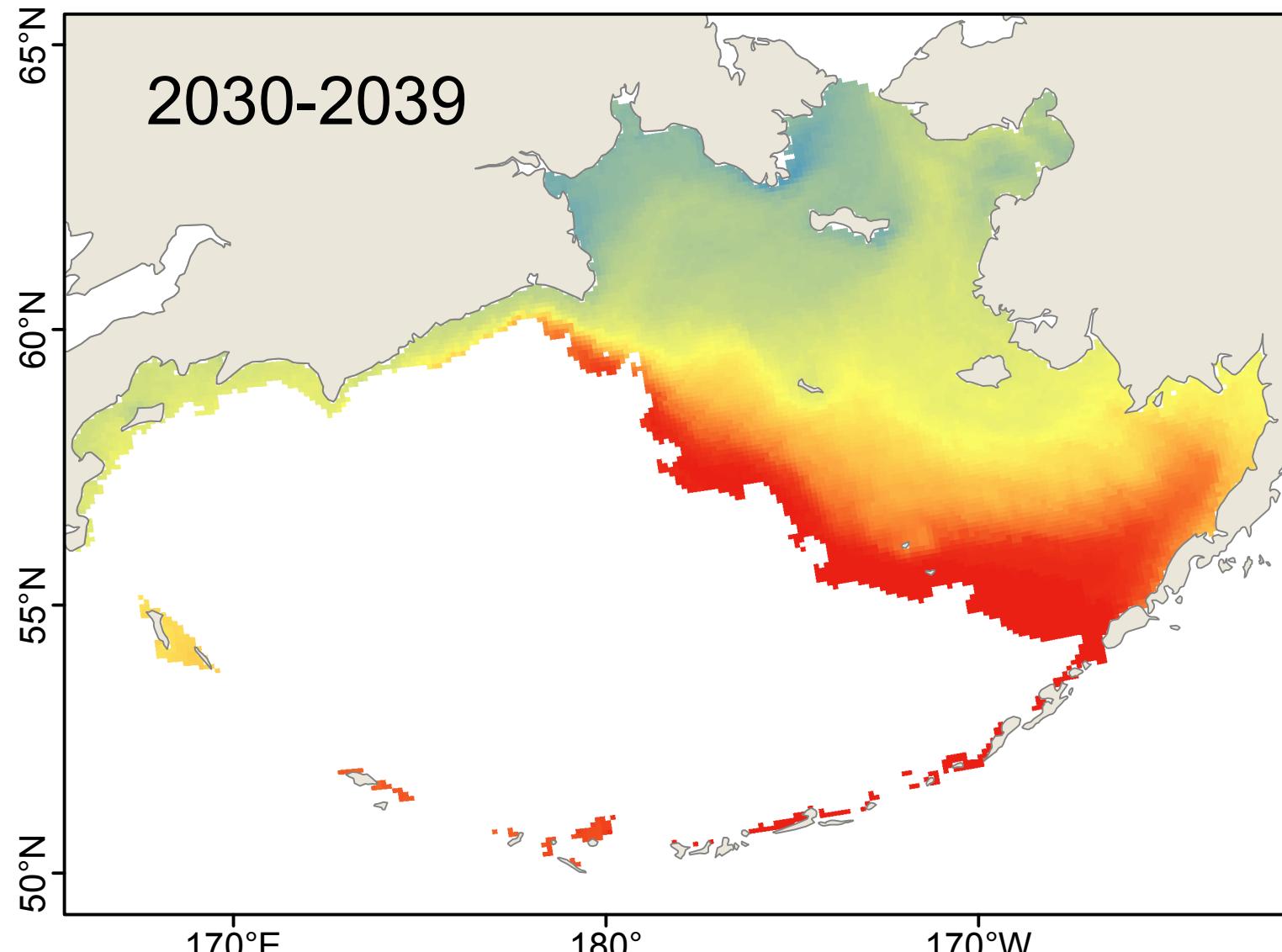
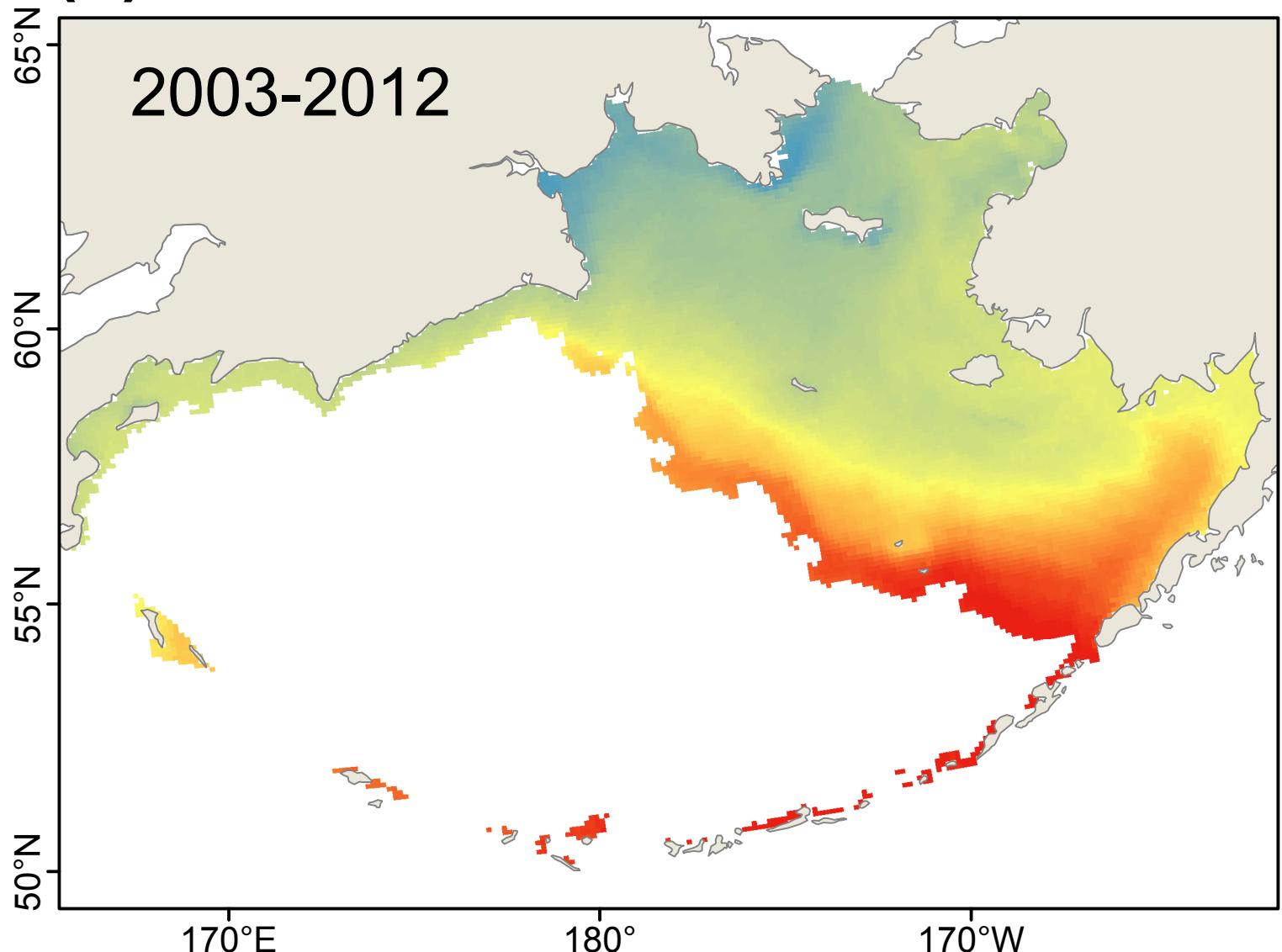


# *Eusarsiella zostericola: Weekly Survival*

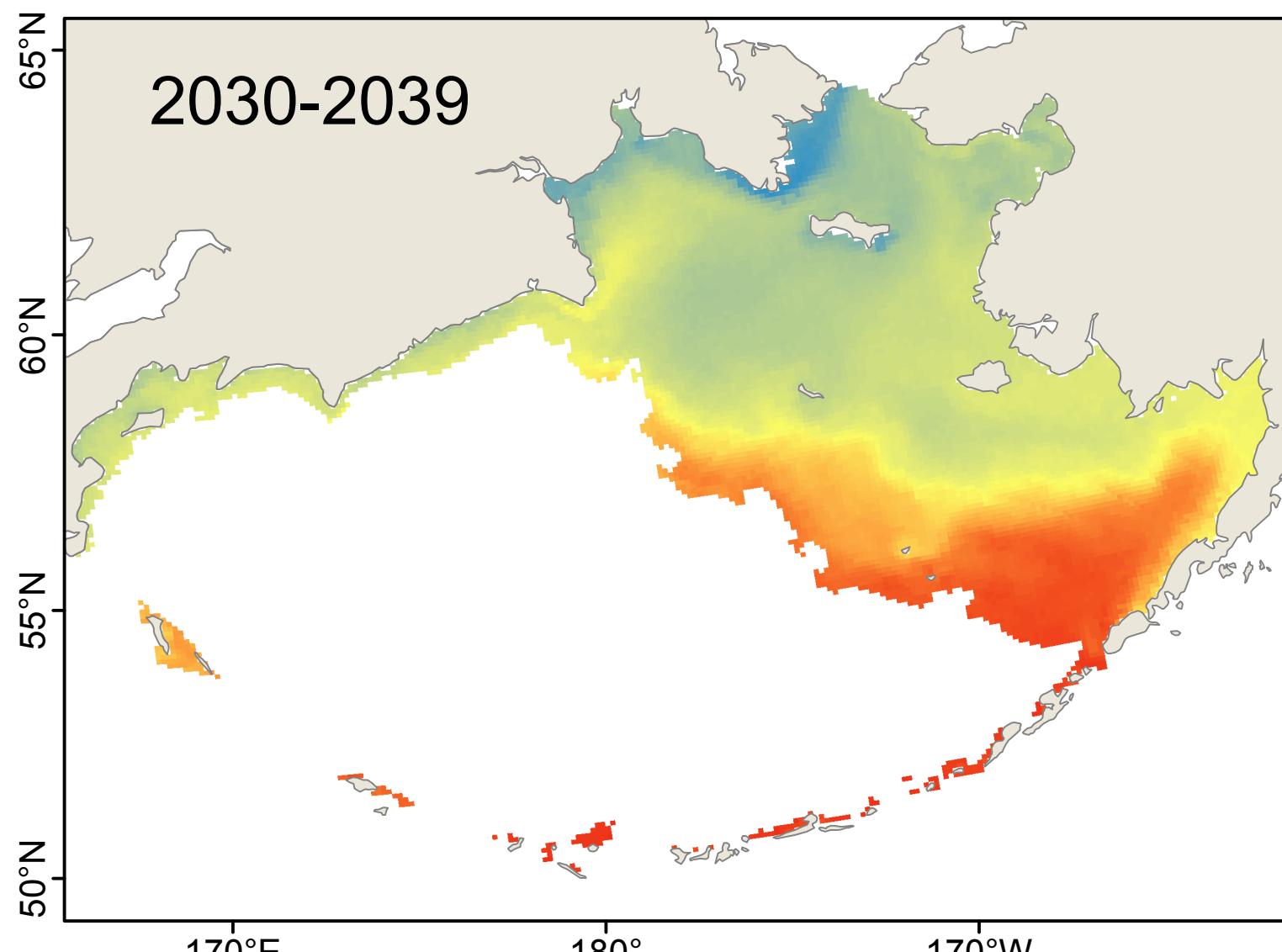
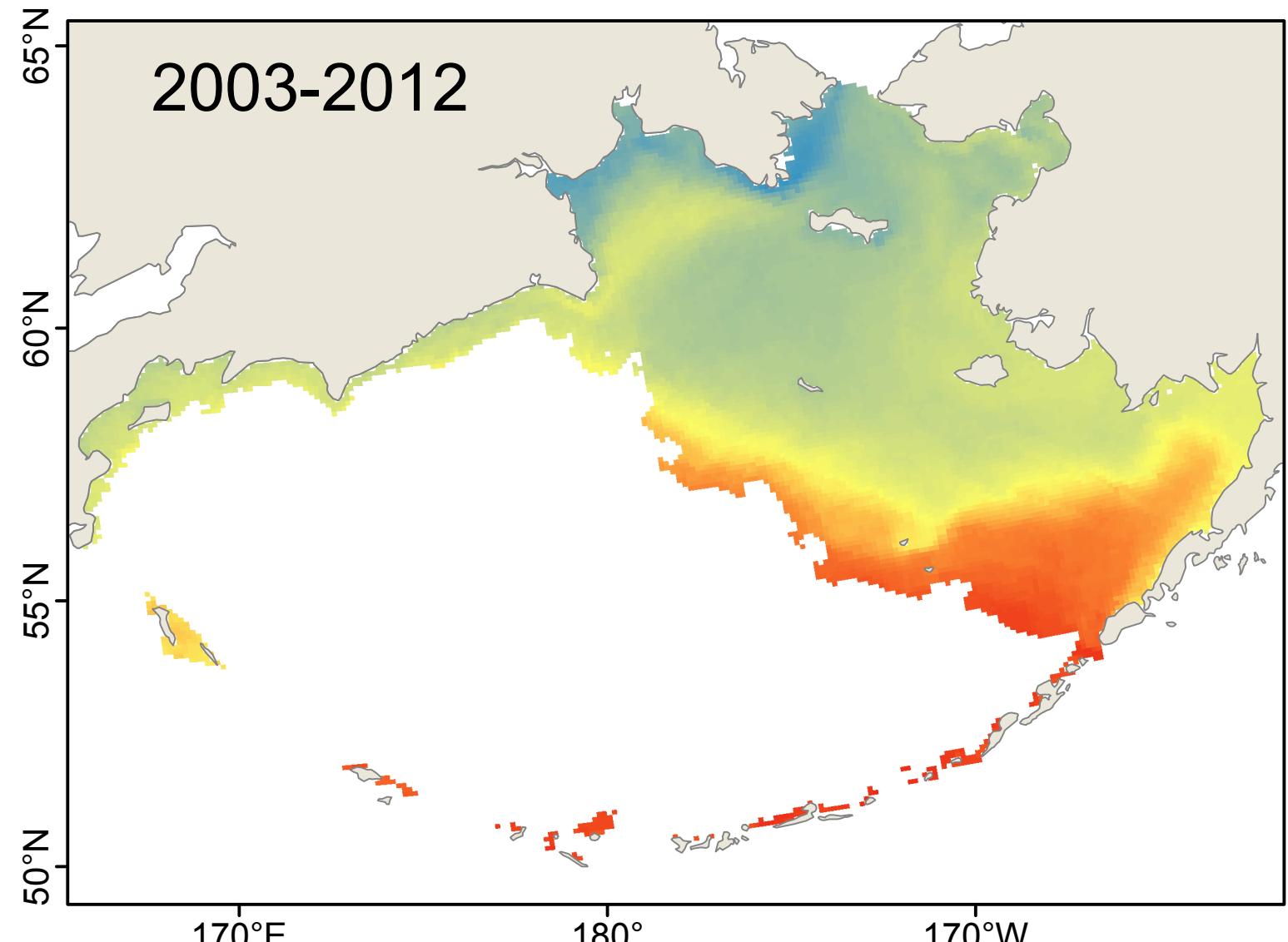
Average number of weeks of suitable habitat



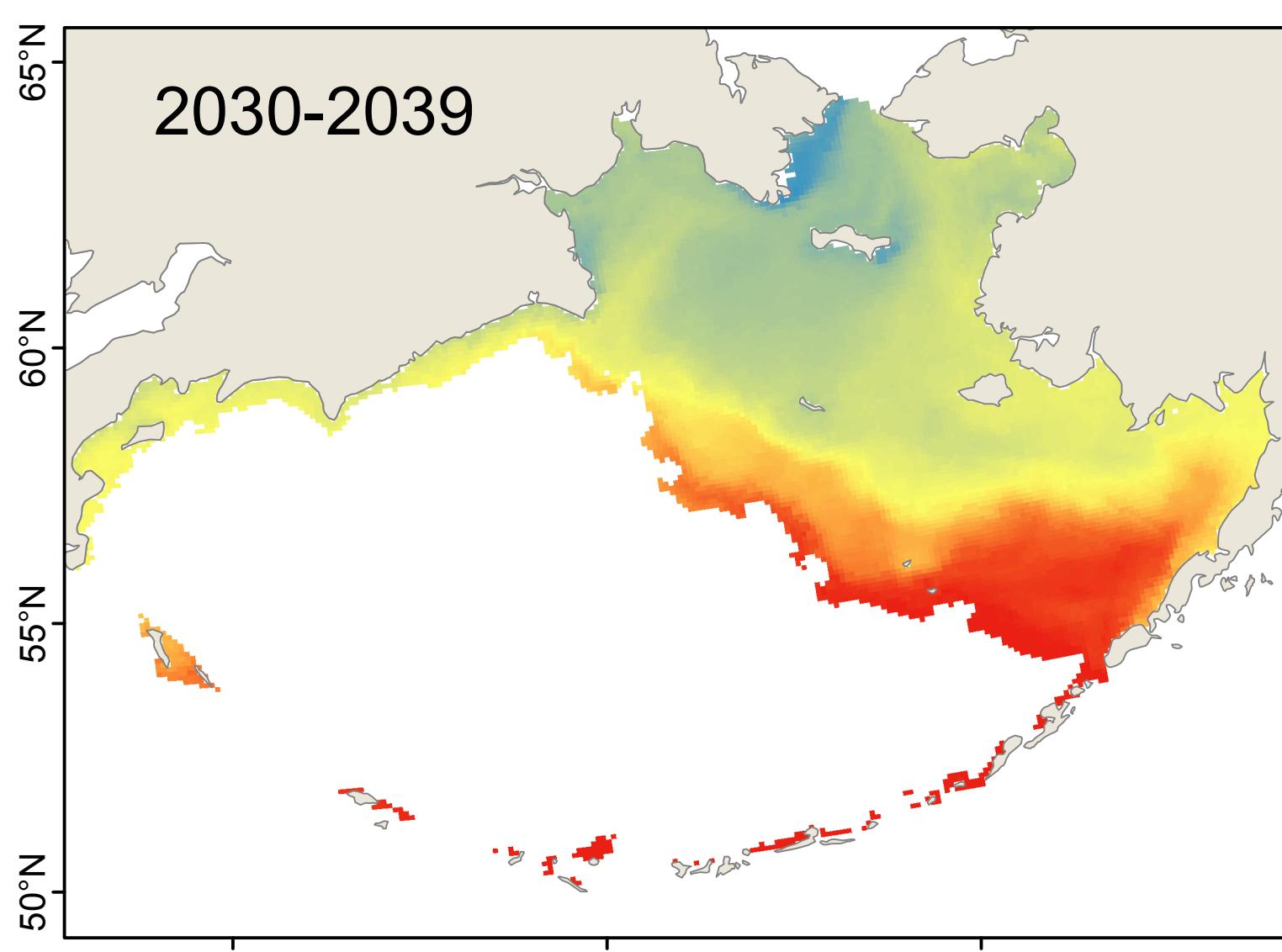
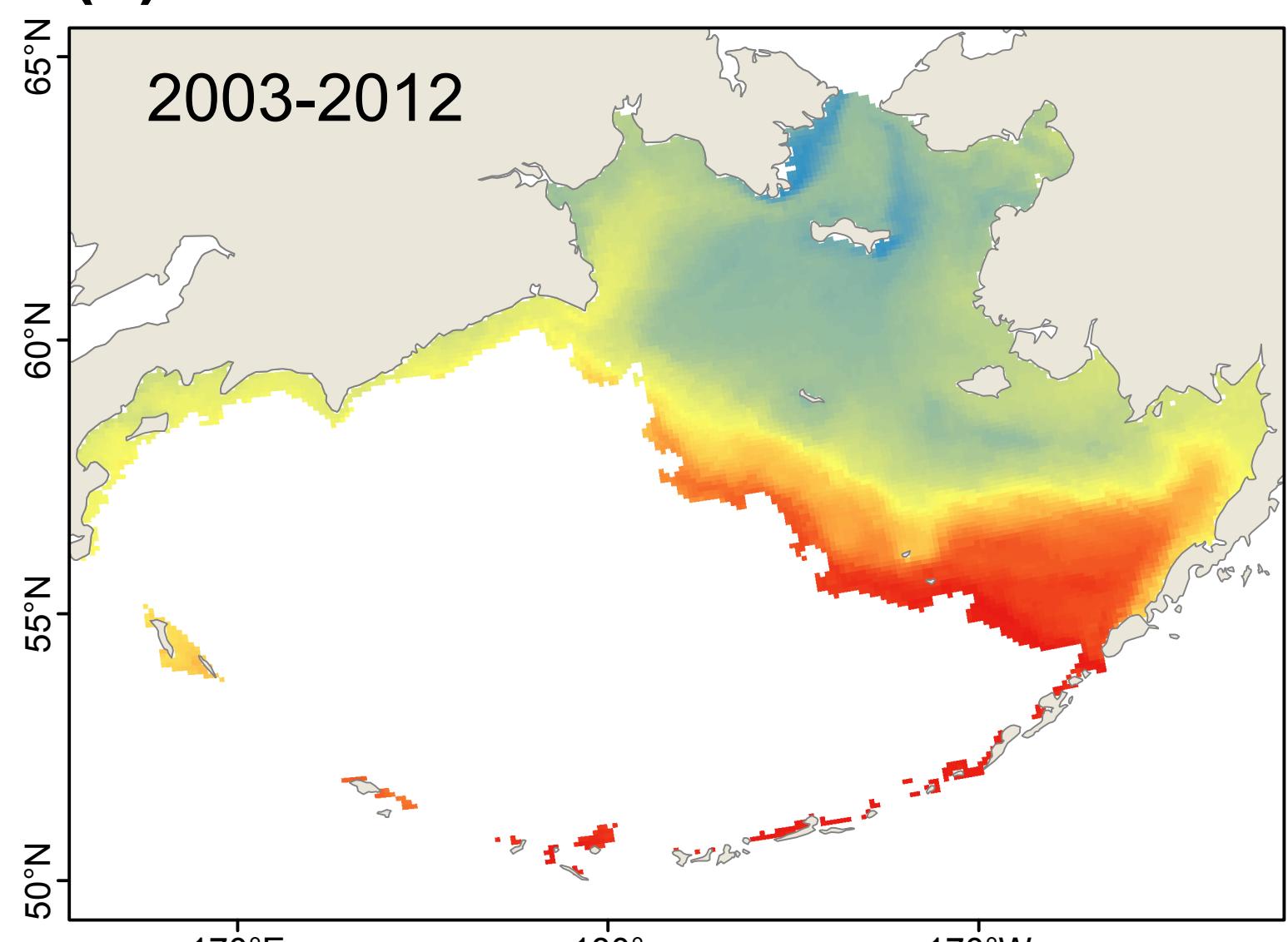
(a) Model: CGCM3-t47



(b) Model: ECHO-G

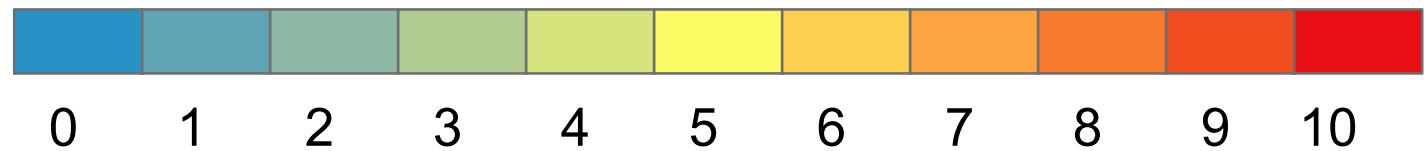


(c) Model: MIROC3.2

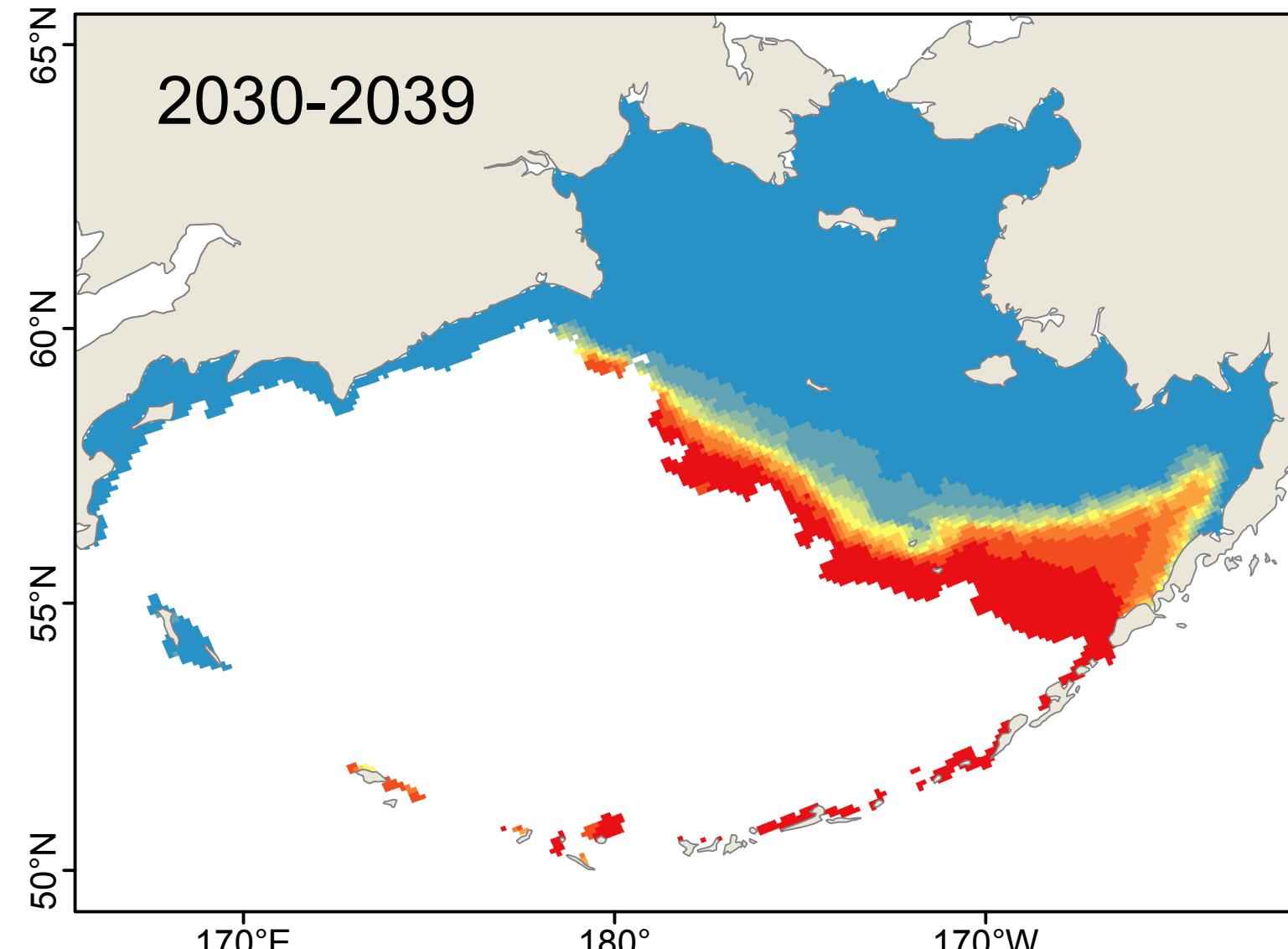
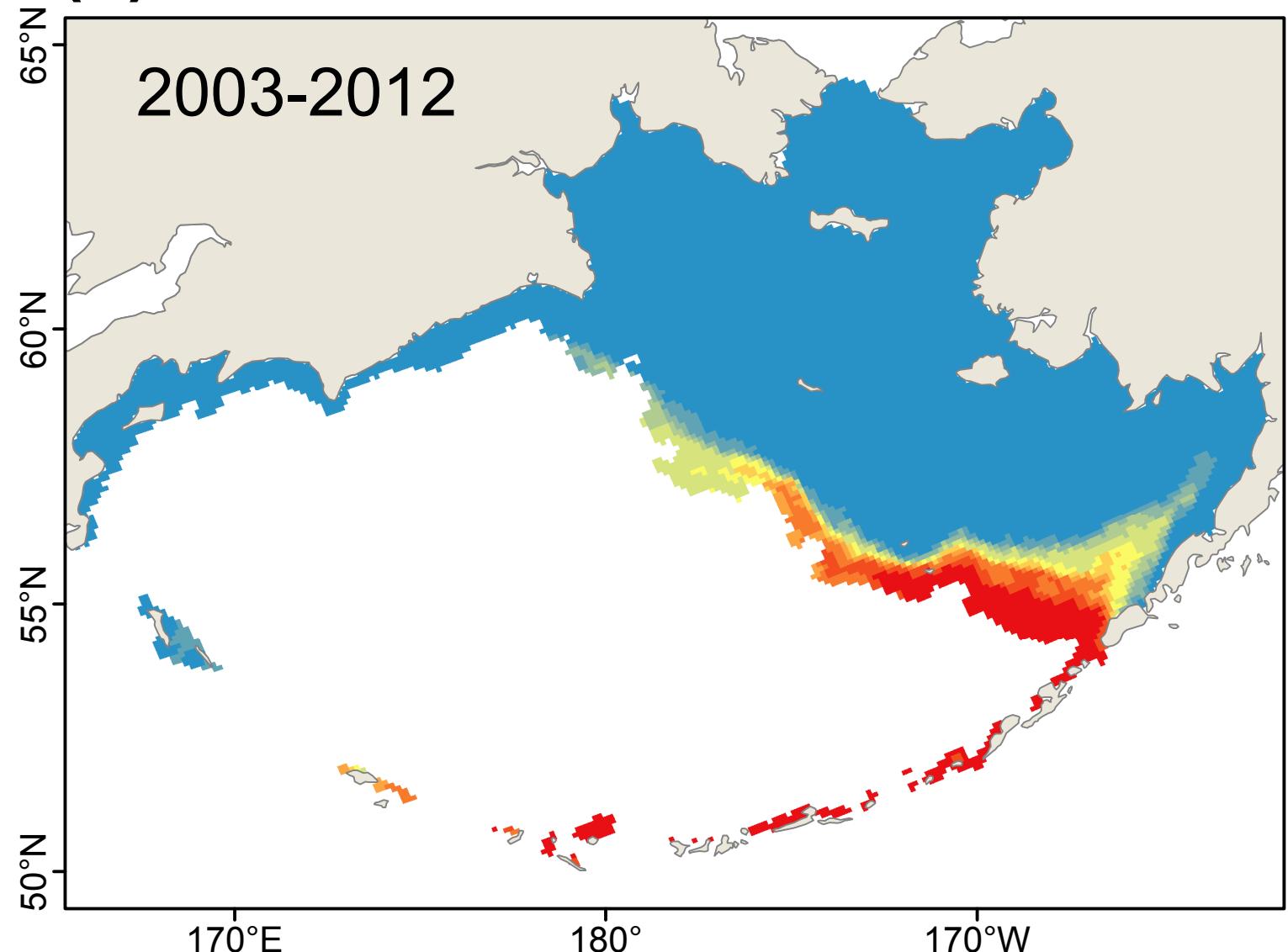


# *Palaemon macrodactylus*: Year-round Survival<sup>82</sup>

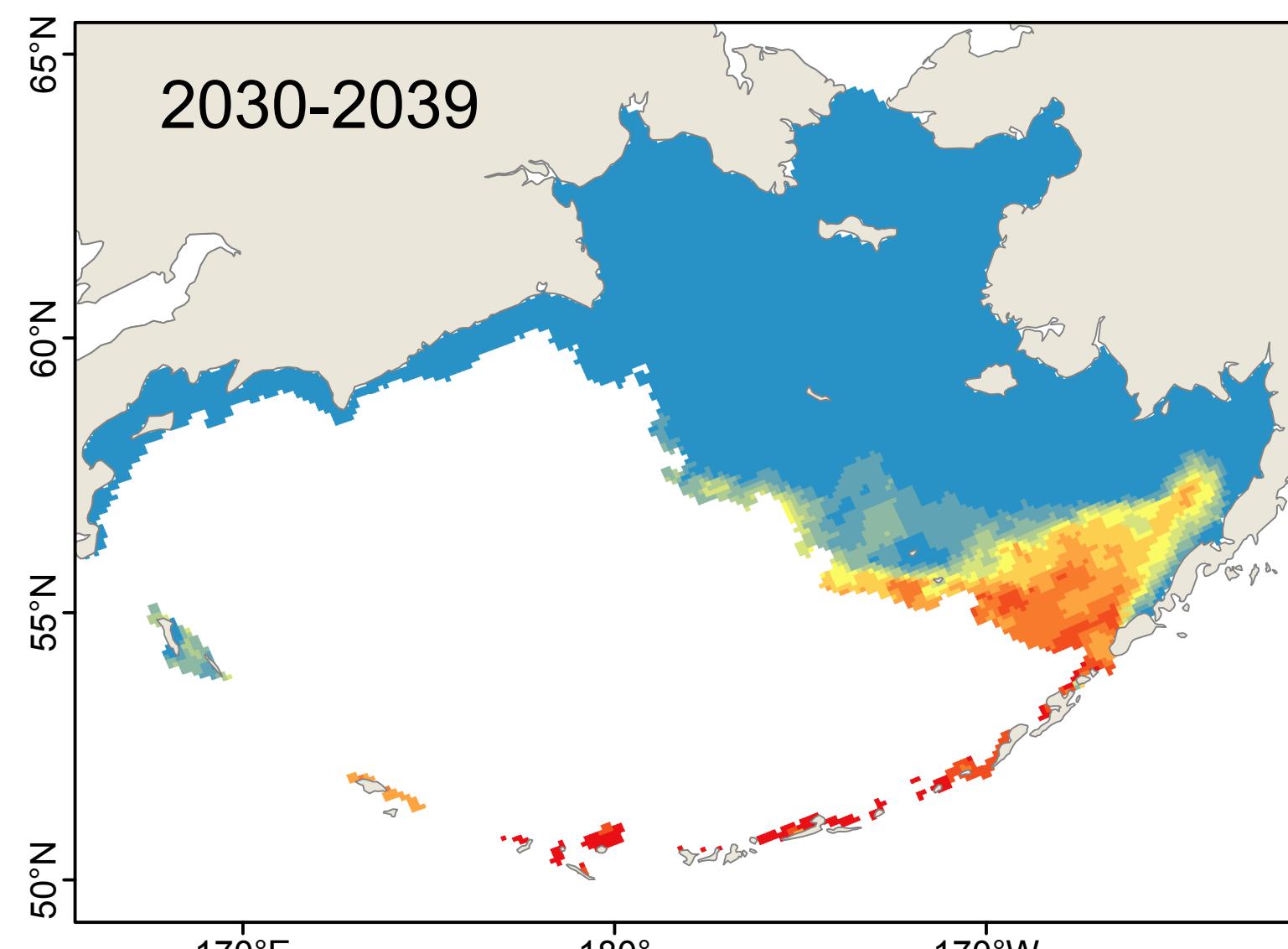
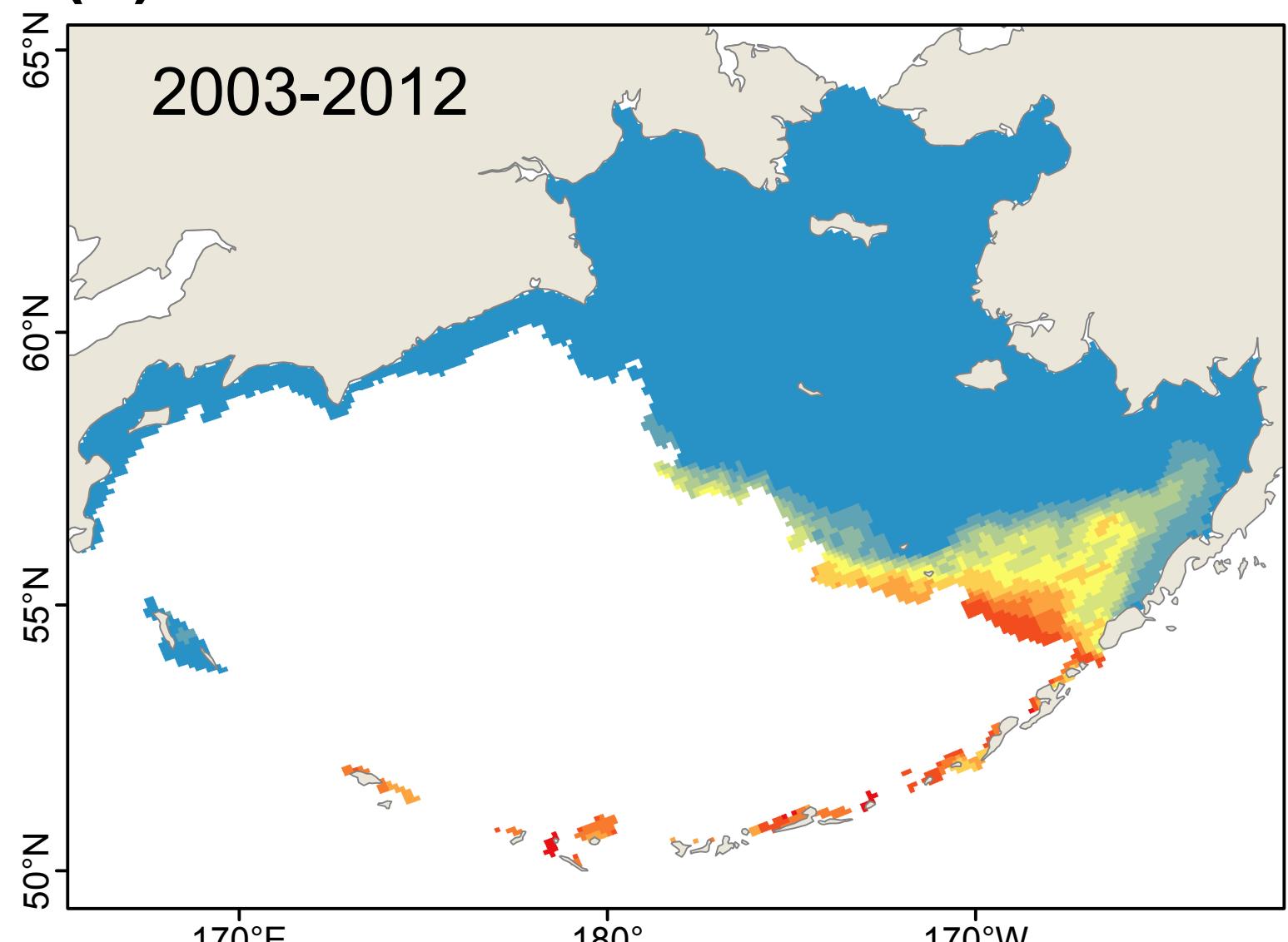
Number of years with suitable habitat



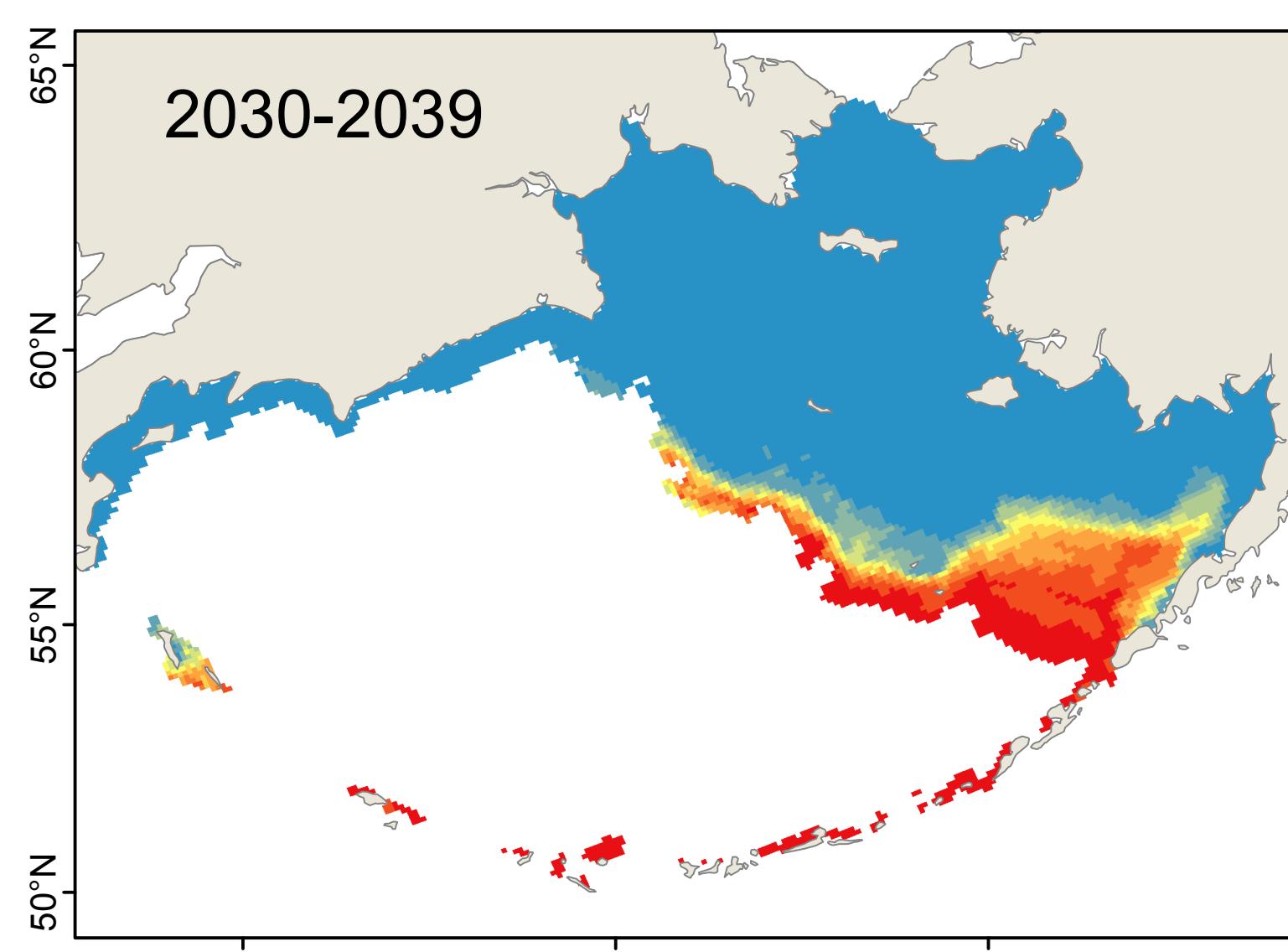
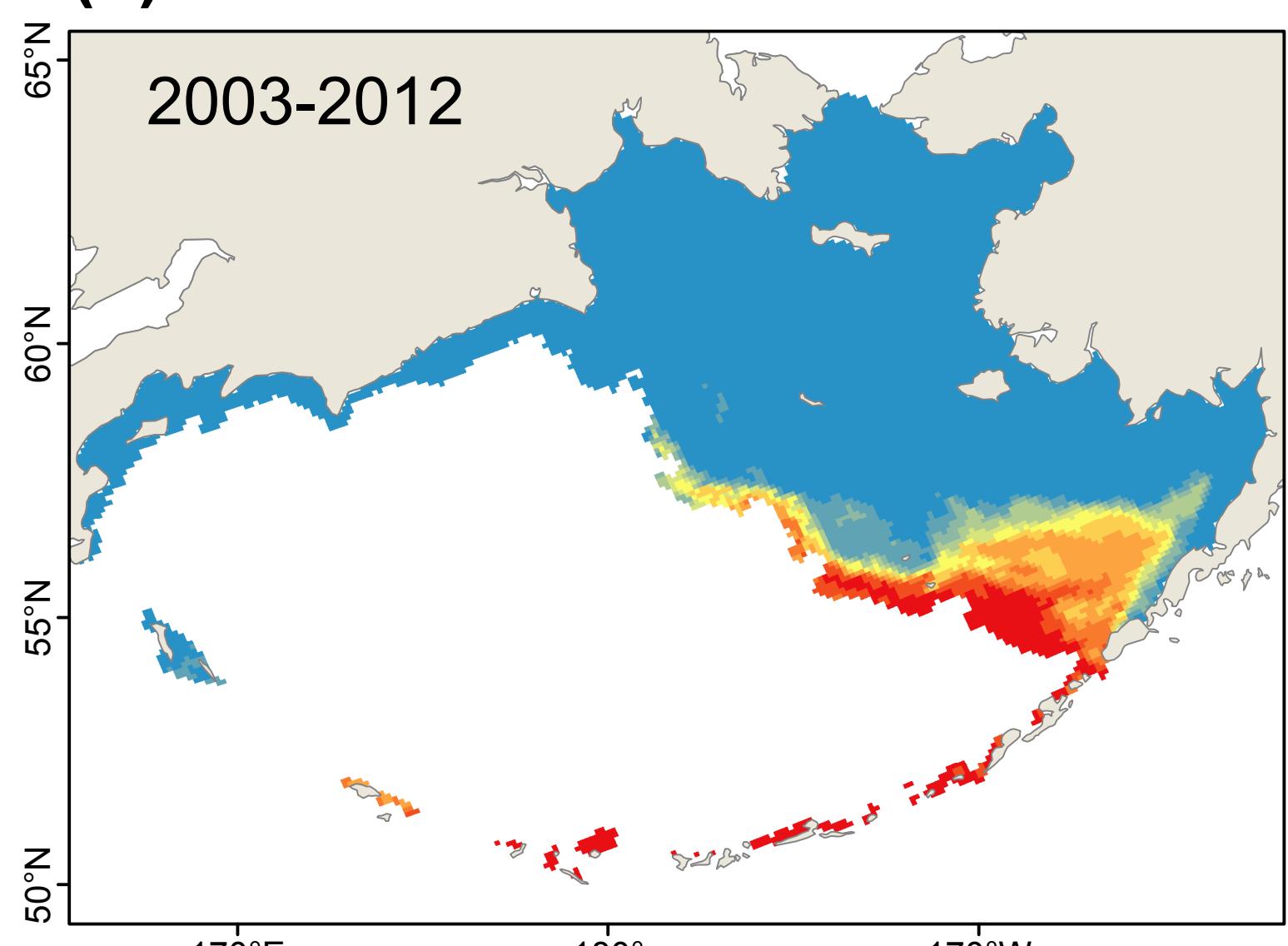
(a) Model: CGCM3-t47



(b) Model: ECHO-G

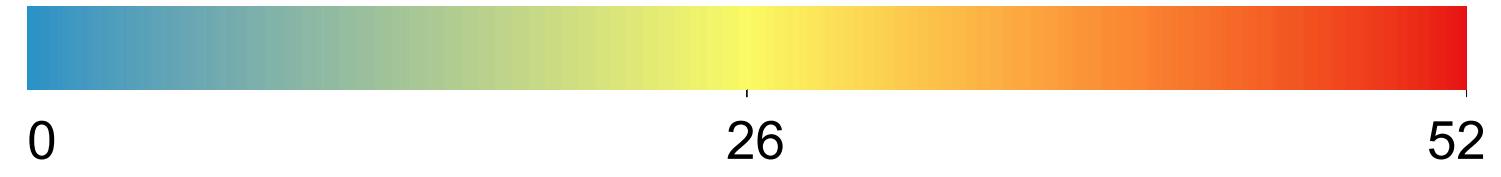


(c) Model: MIROC3.2

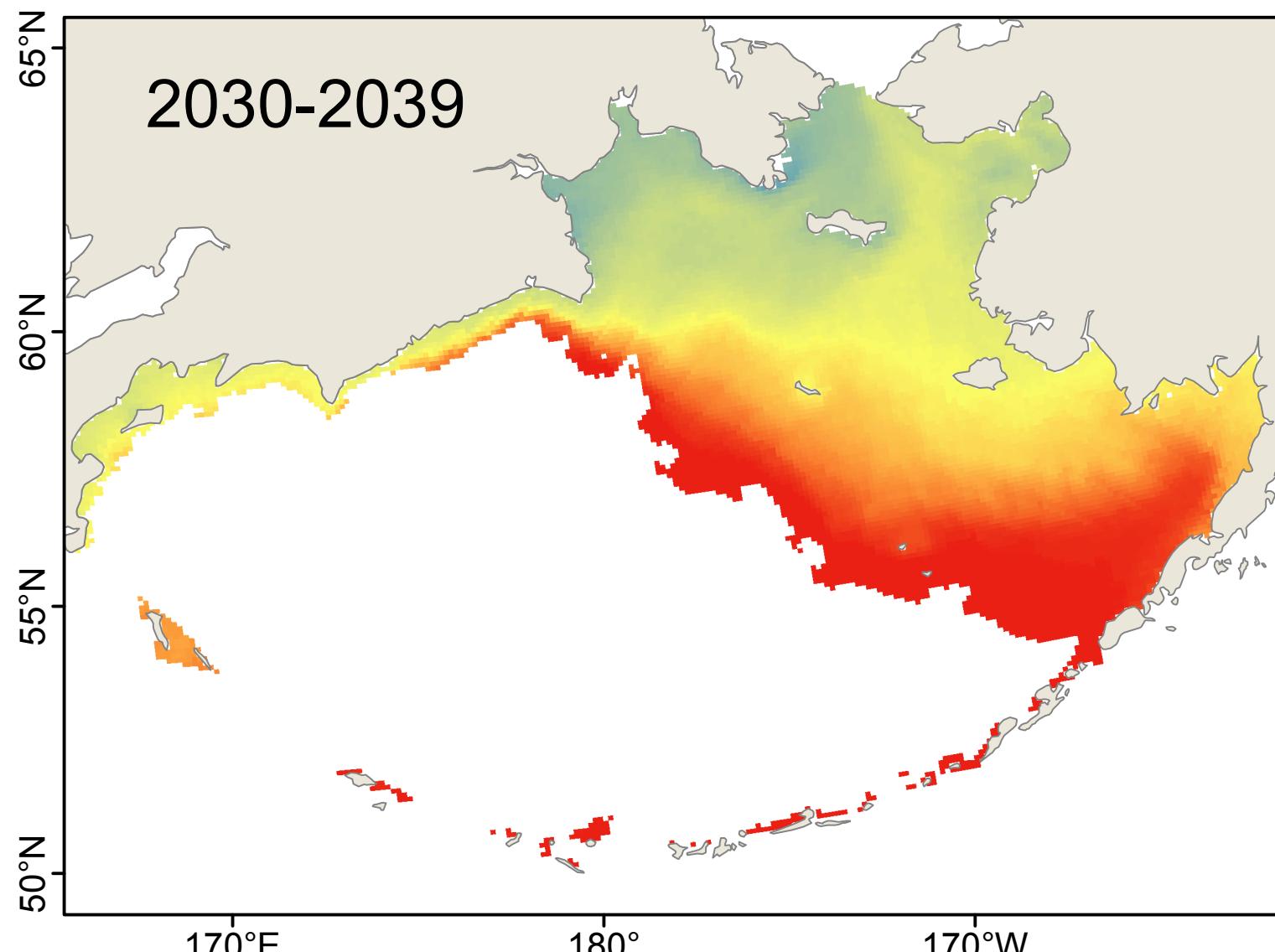
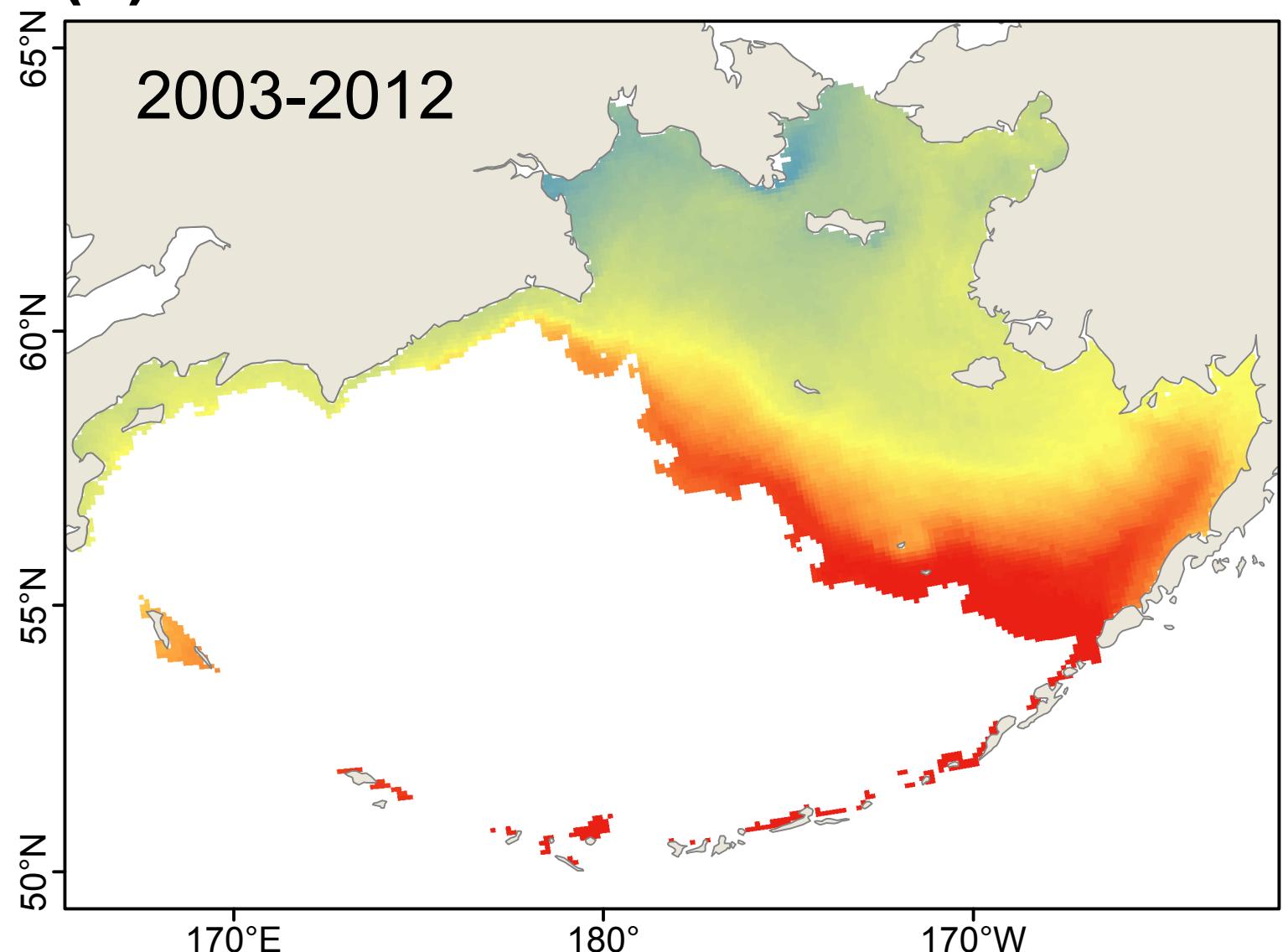


# *Palaemon macrodactylus*: Weekly Survival

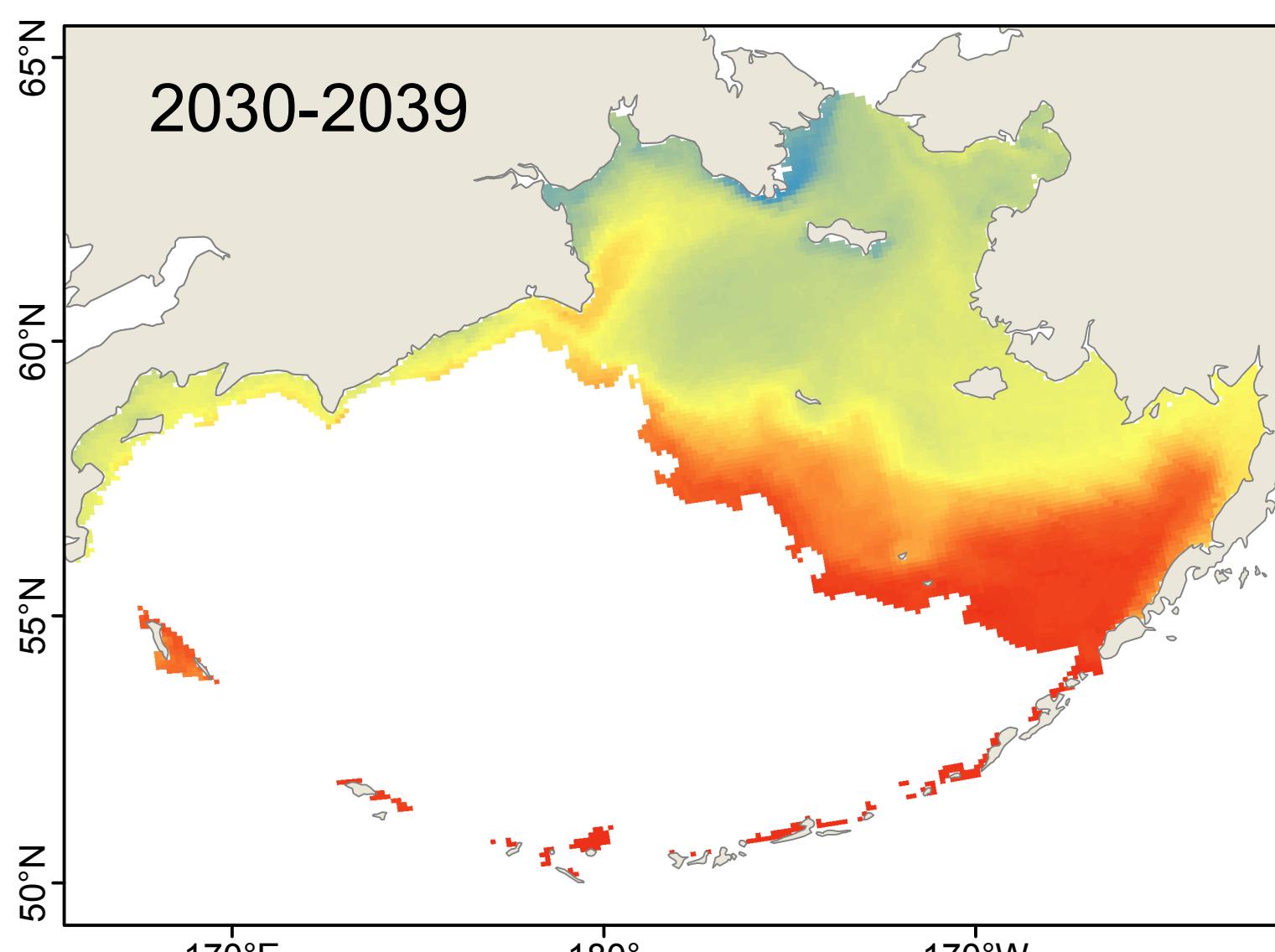
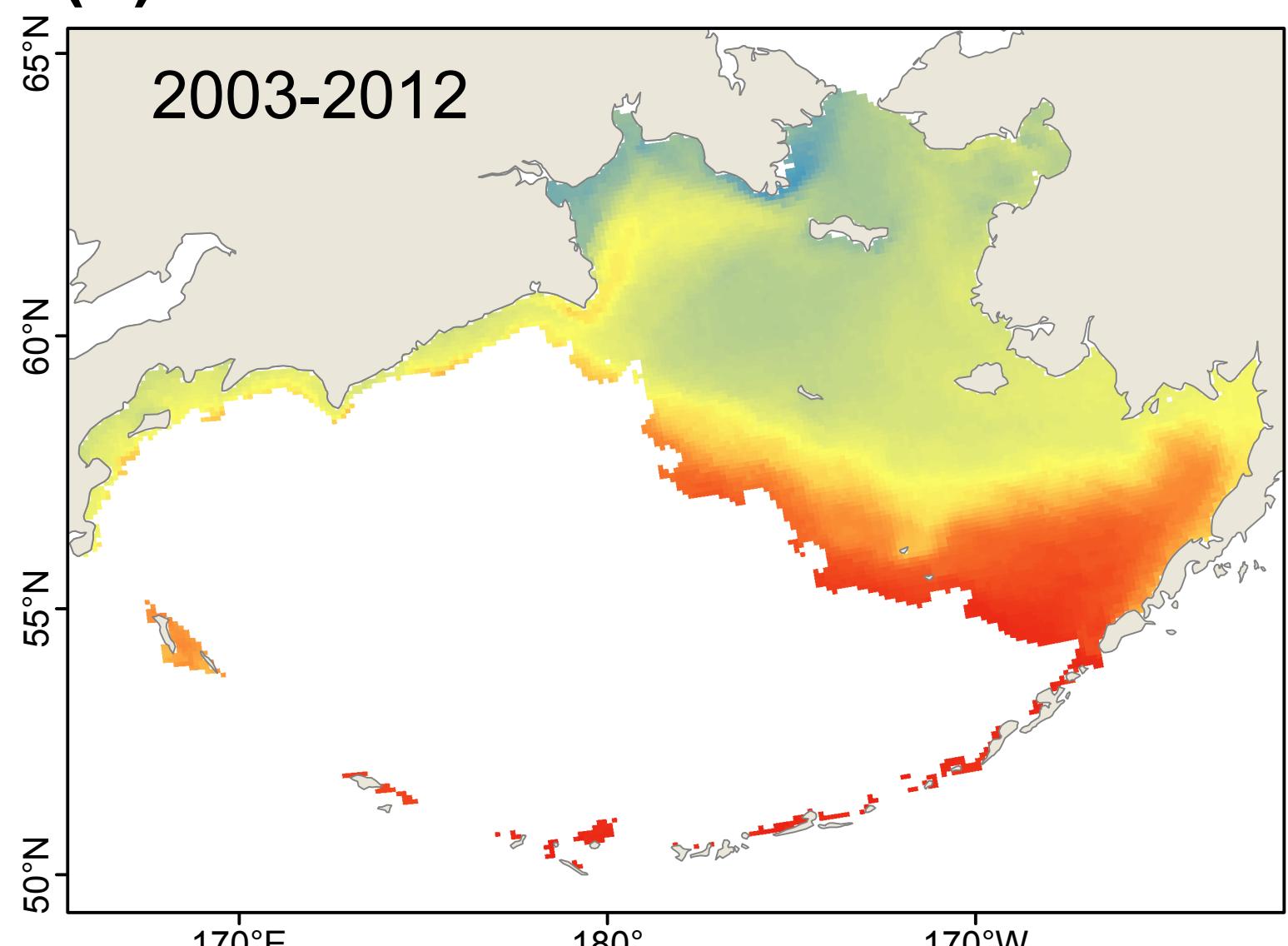
Average number of weeks of suitable habitat



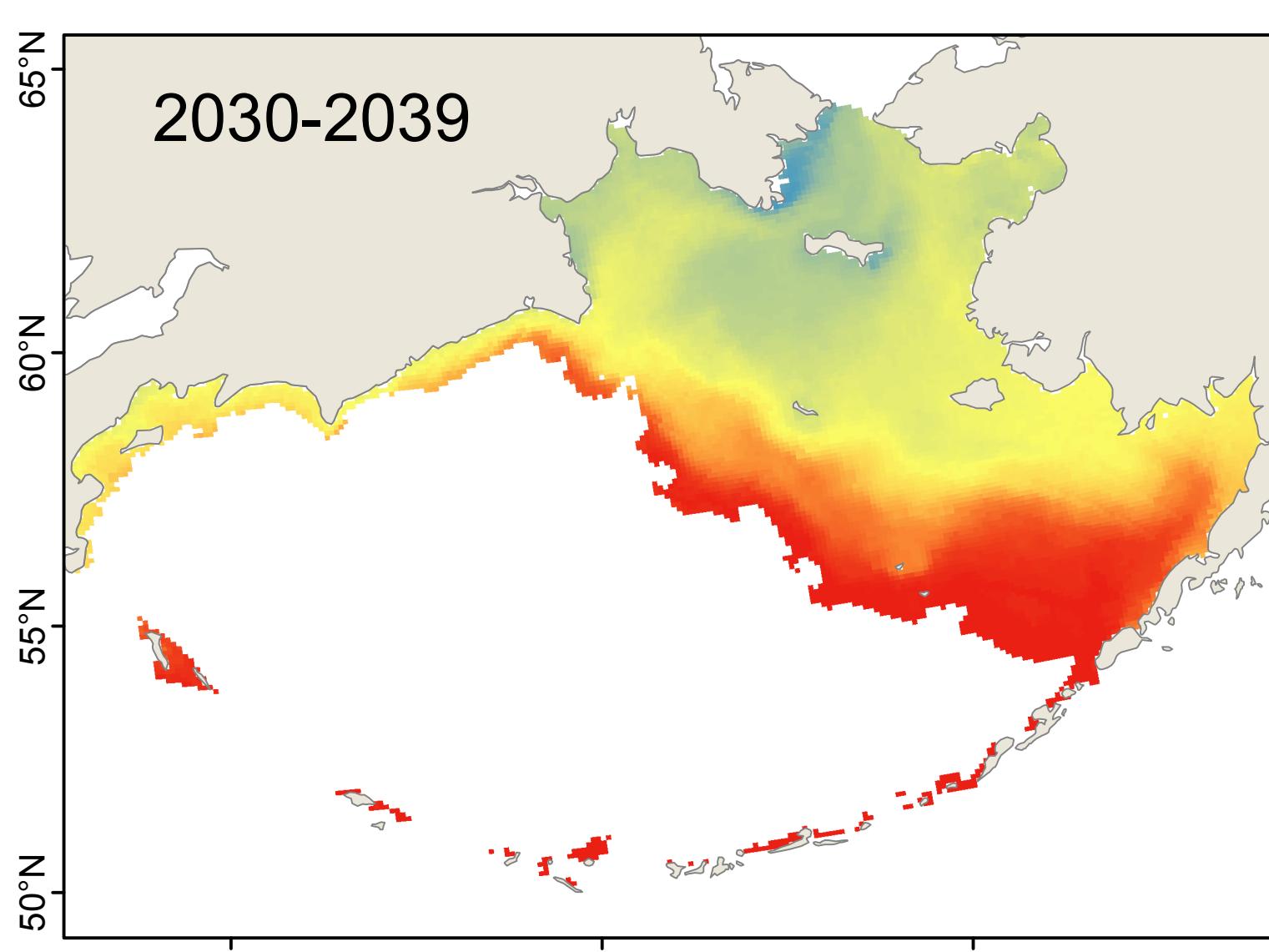
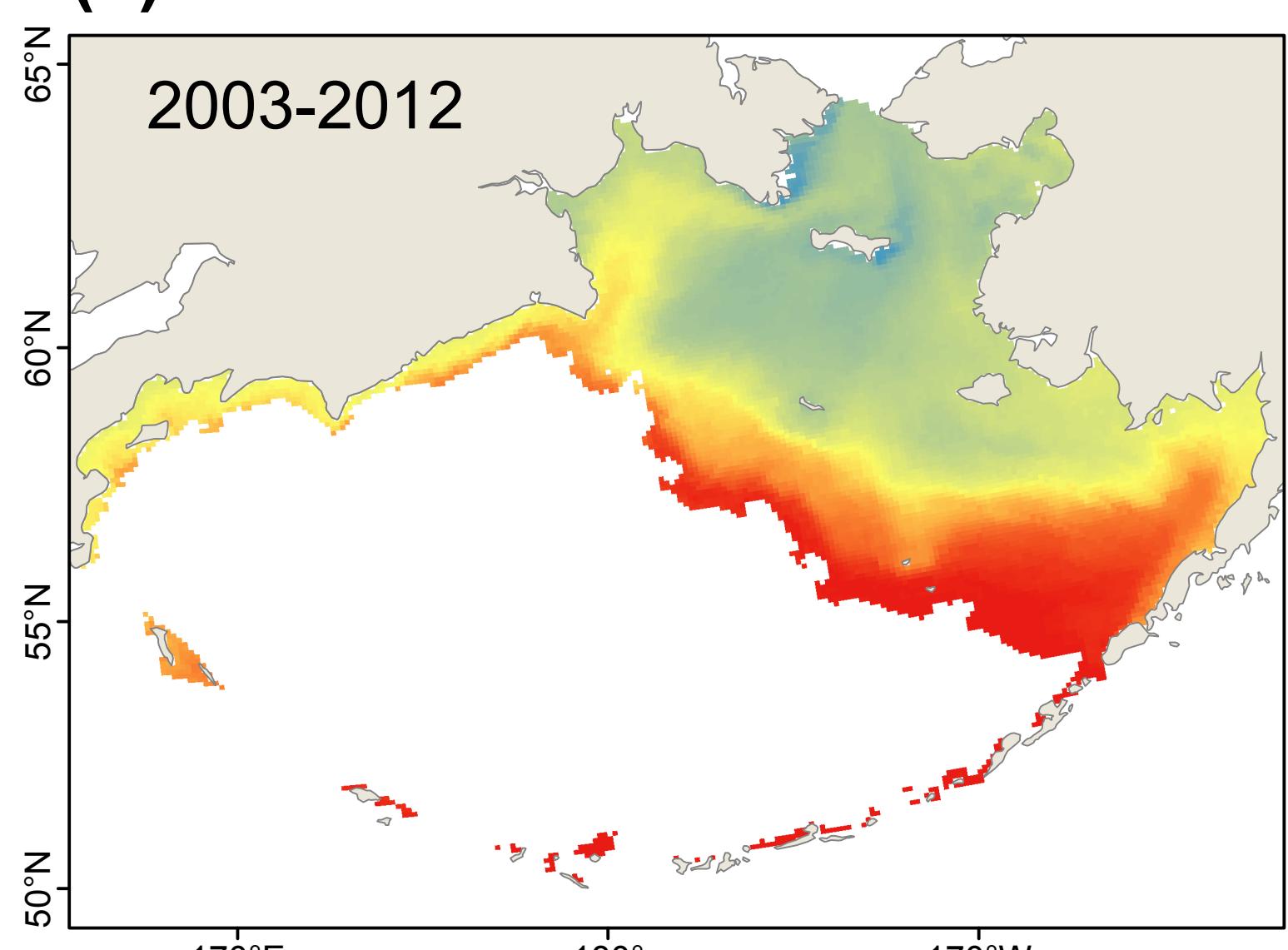
(a) Model: CGCM3-t47



(b) Model: ECHO-G

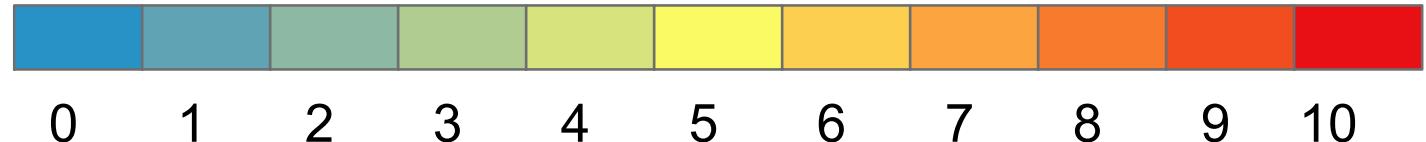


(c) Model: MIROC3.2

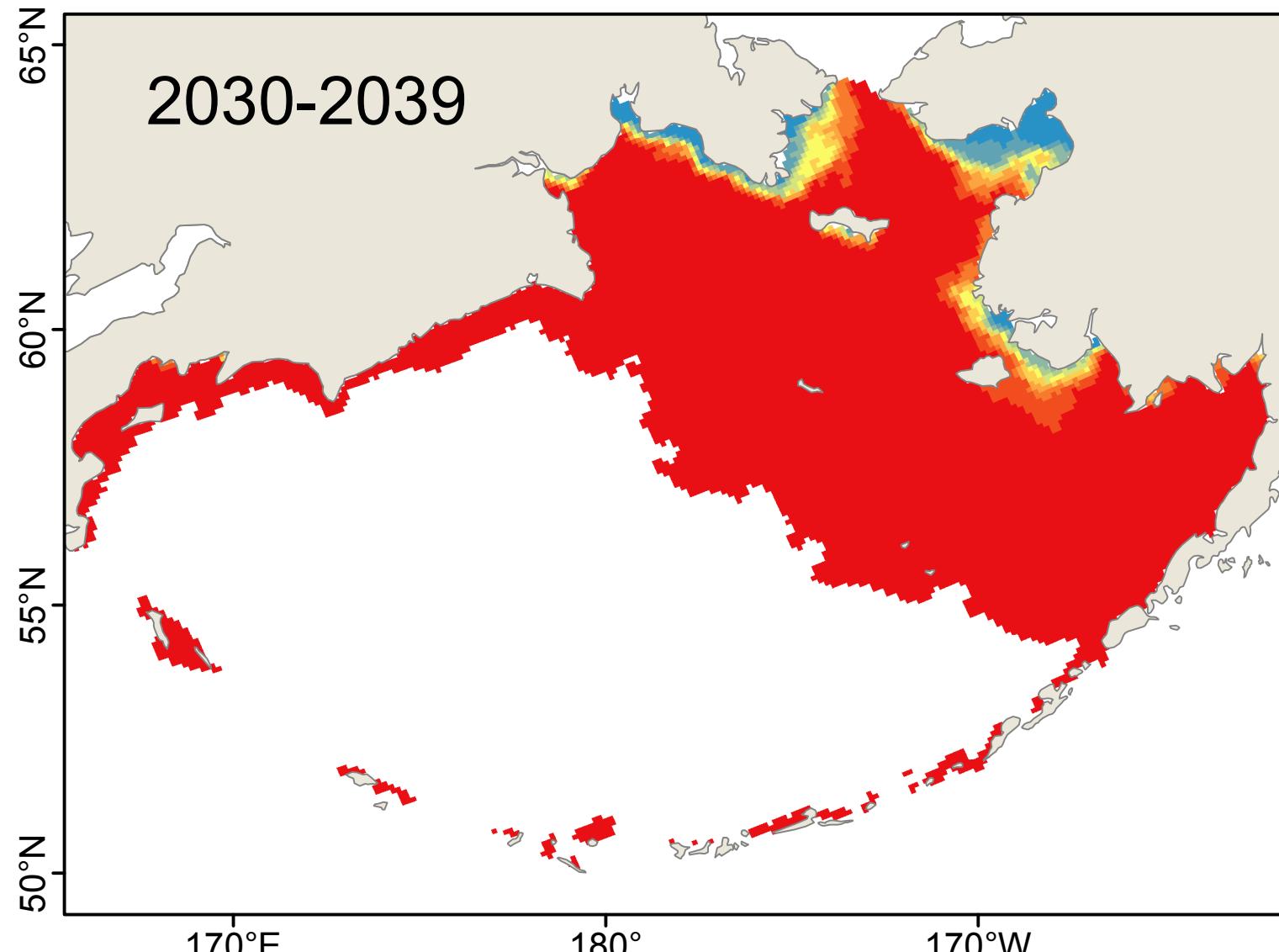
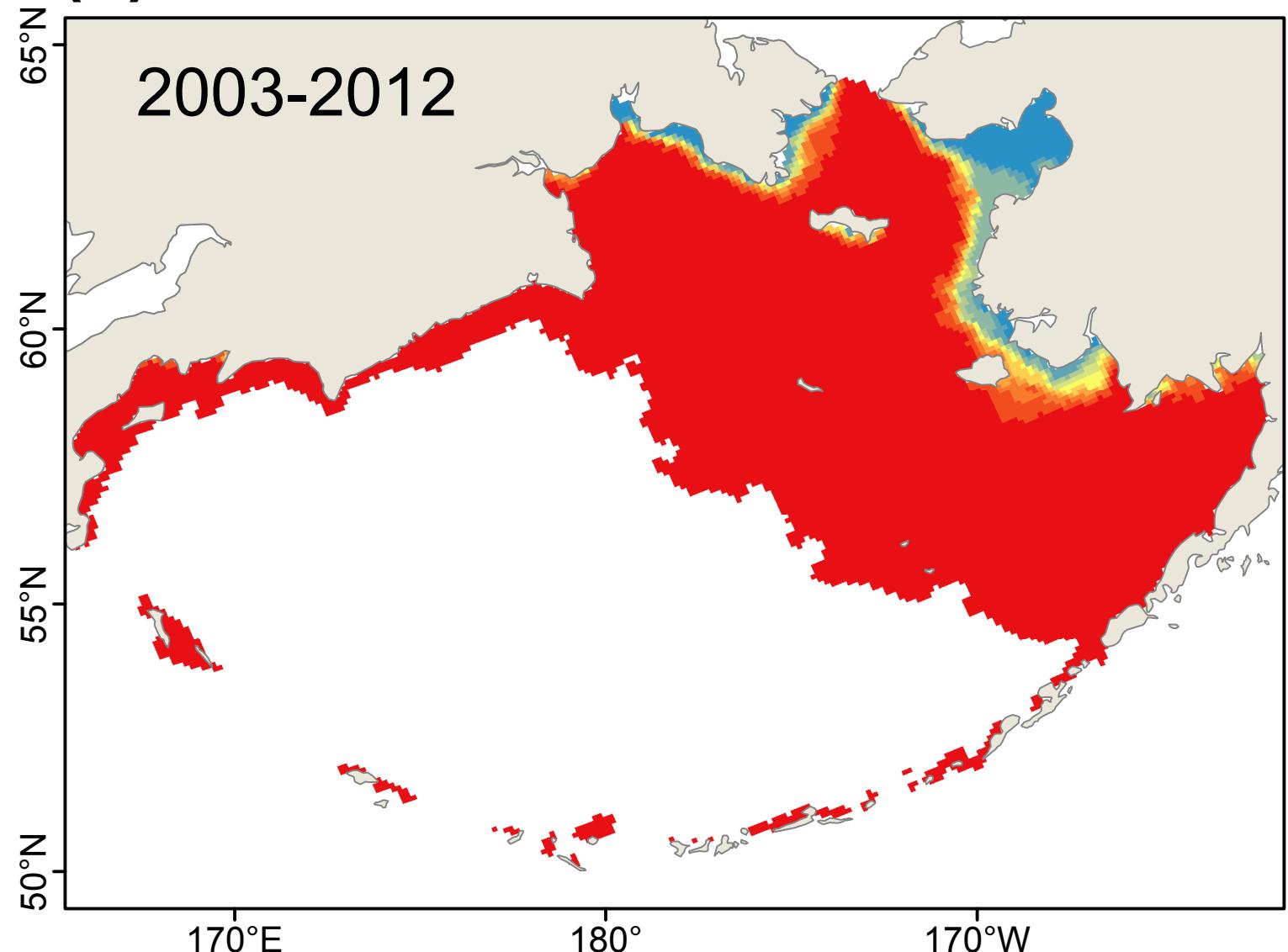


# *Sinelobus cf. stanfordi*: Year-round Survival

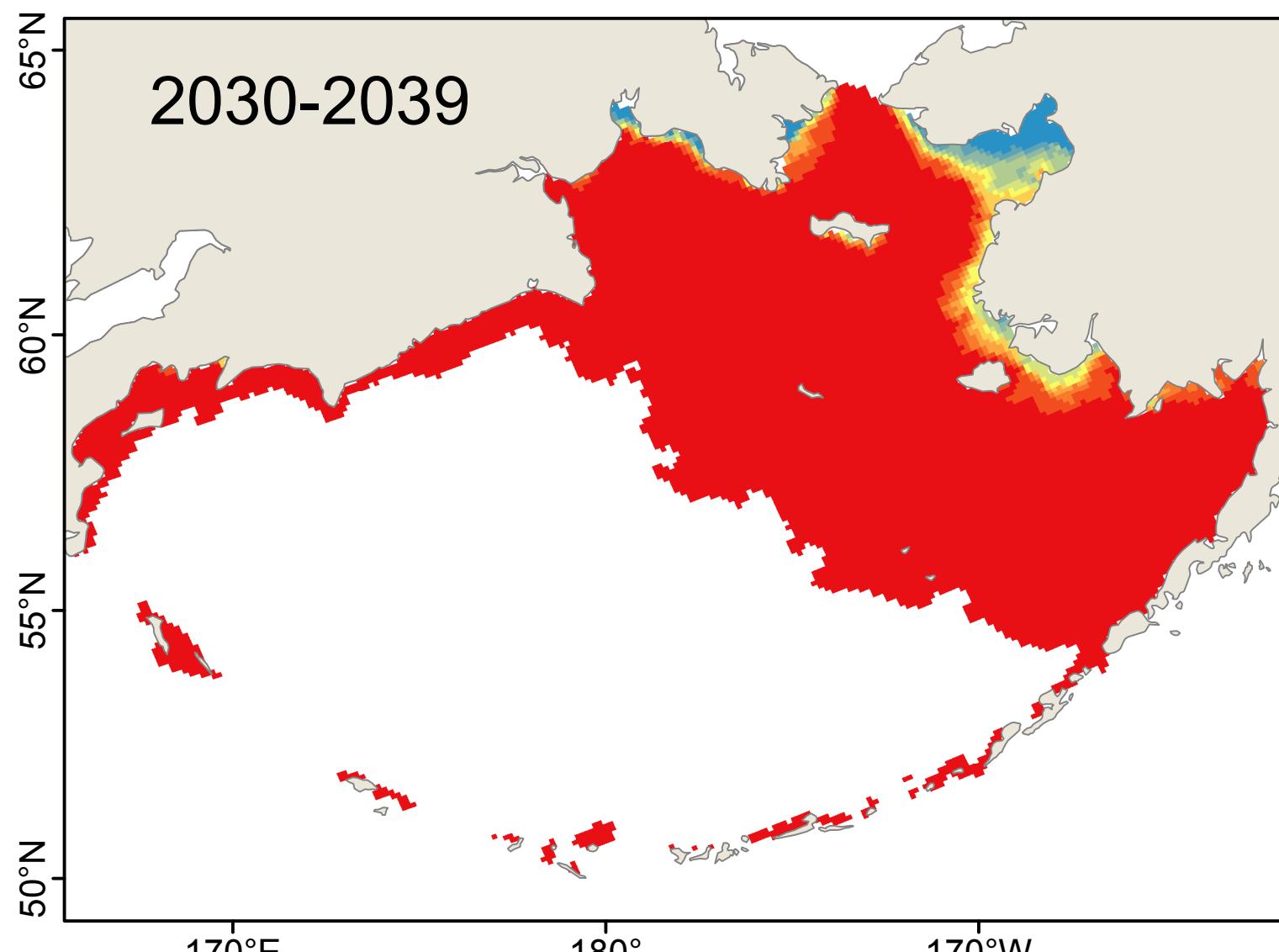
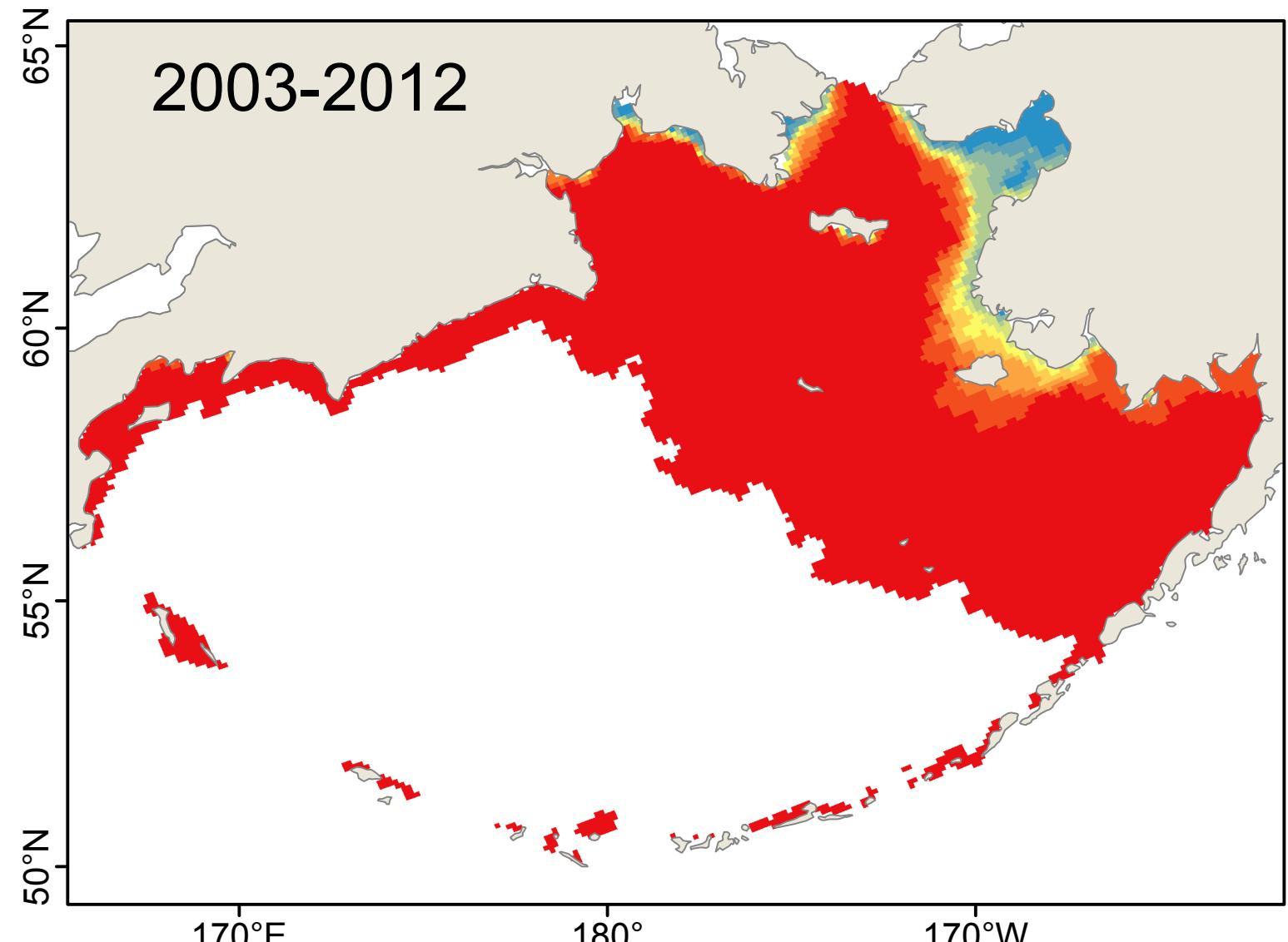
Number of years with suitable habitat



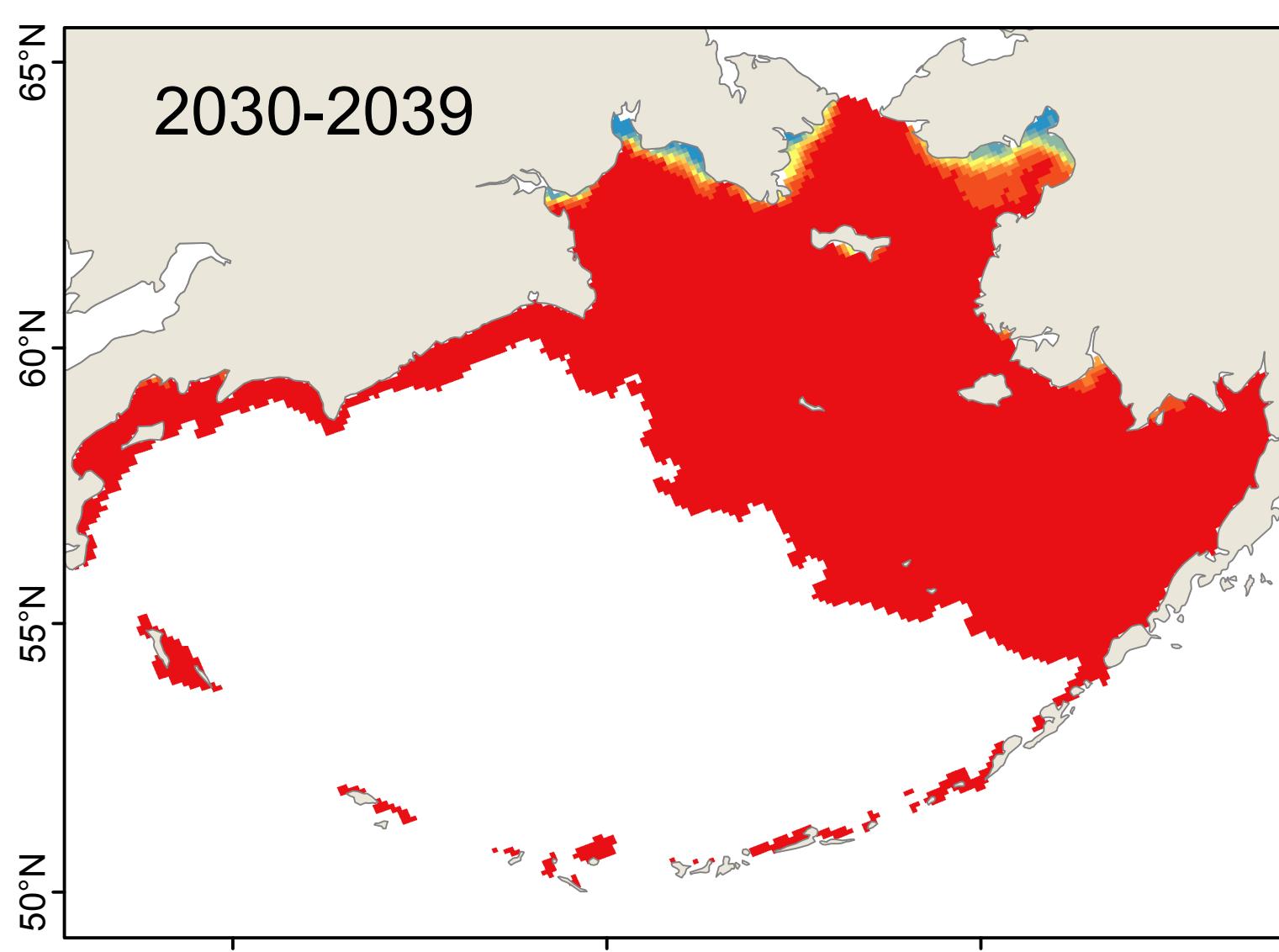
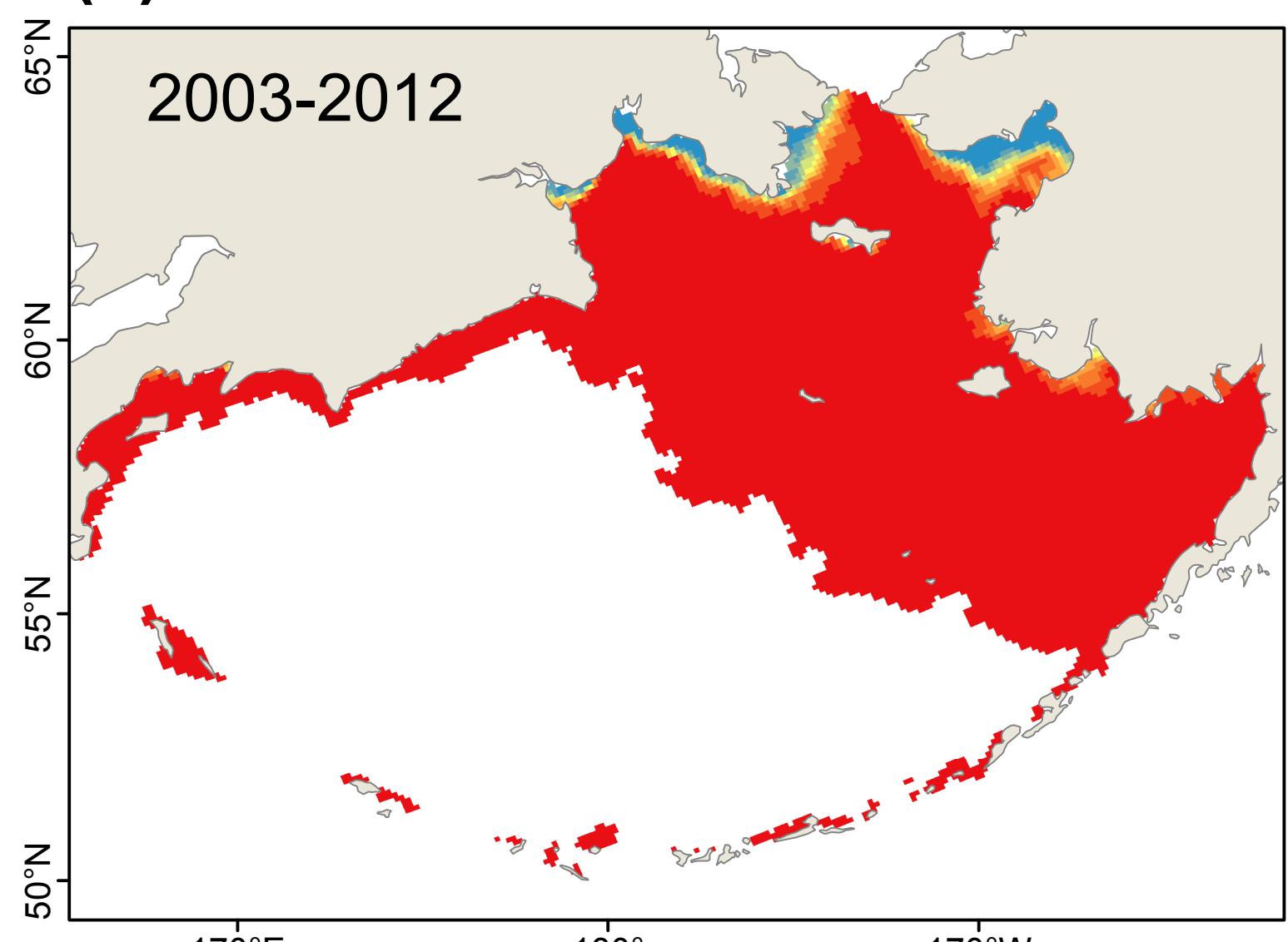
(a) Model: CGCM3-t47



(b) Model: ECHO-G

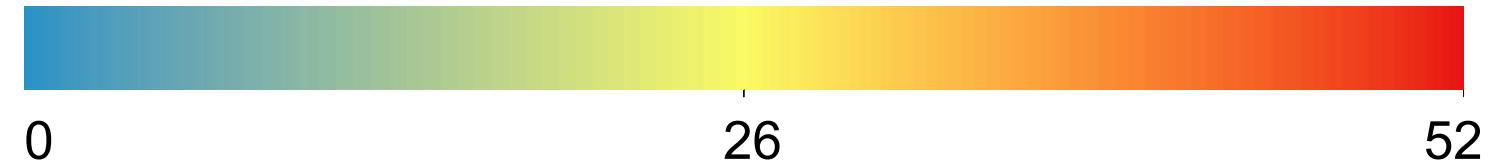


(c) Model: MIROC3.2

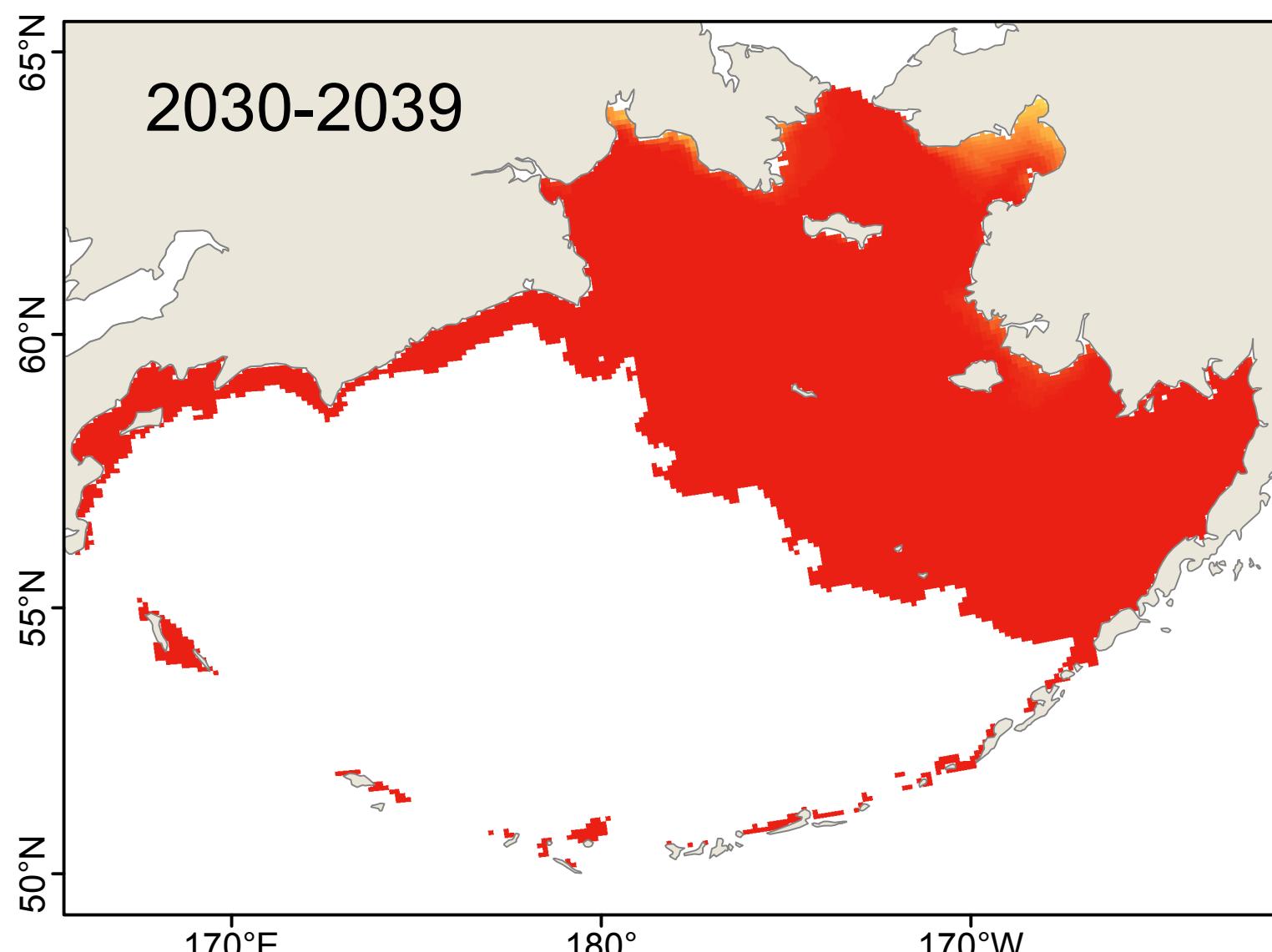
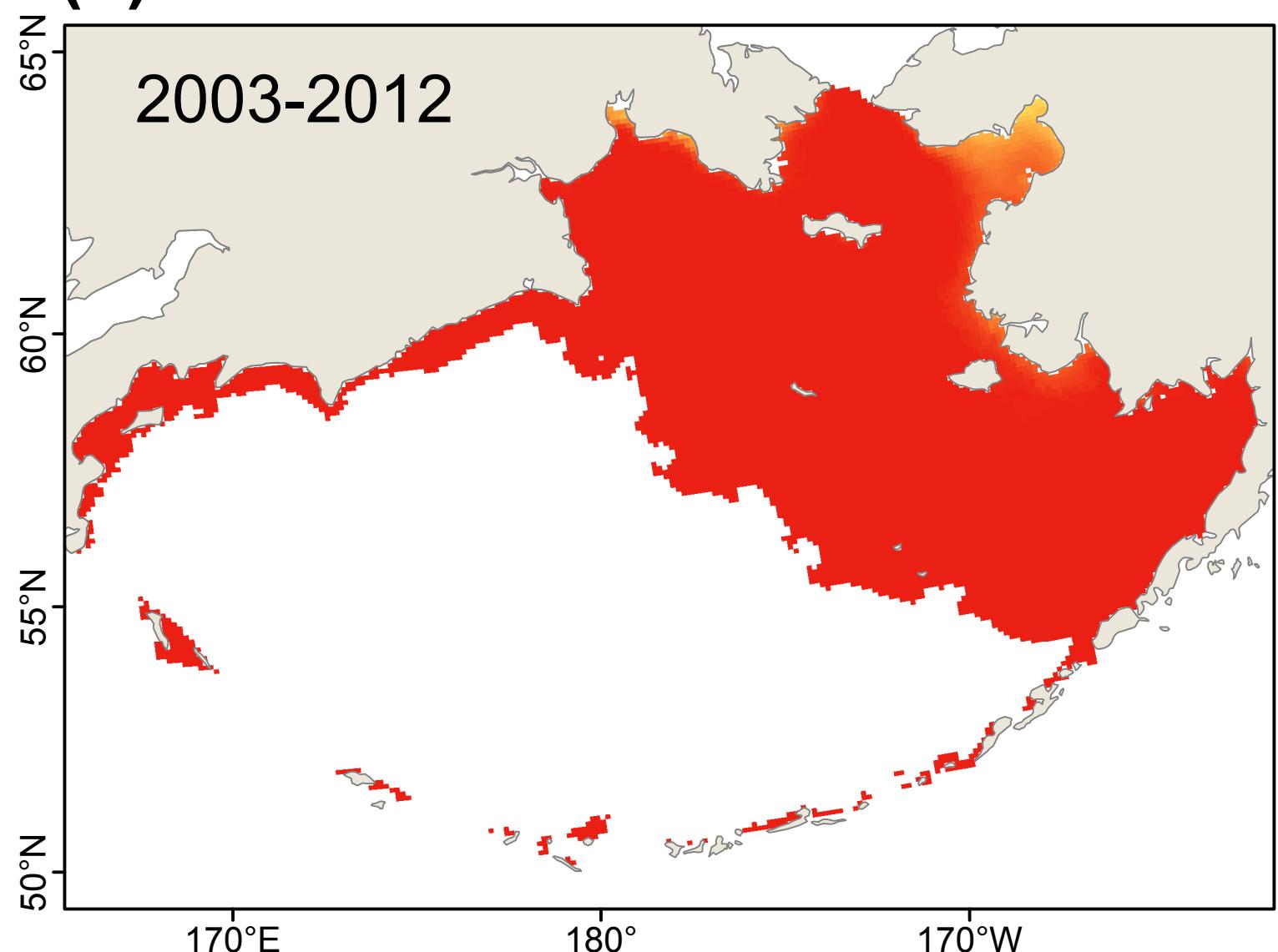


# *Sinelobus cf. stanfordi: Weekly Survival*

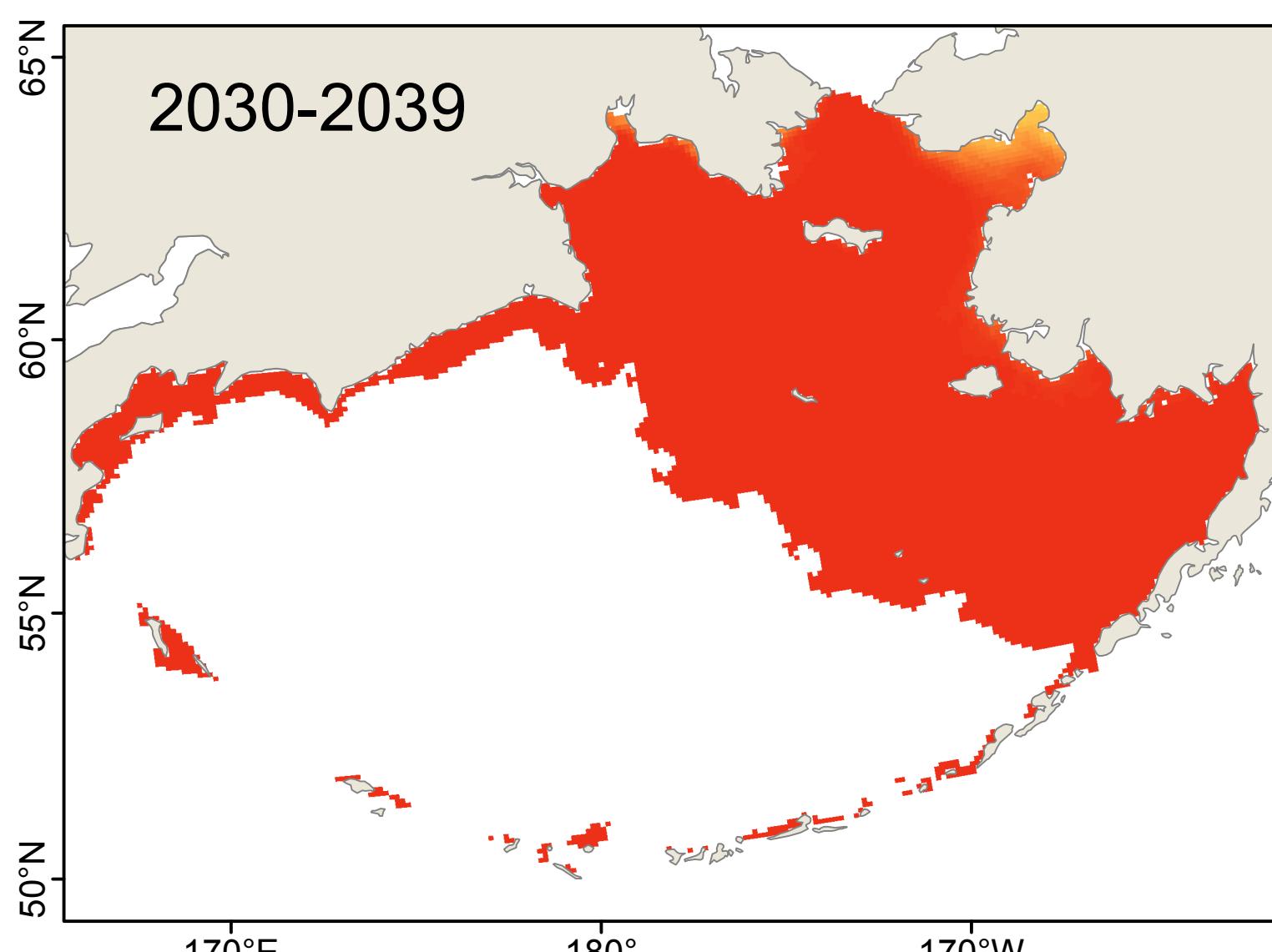
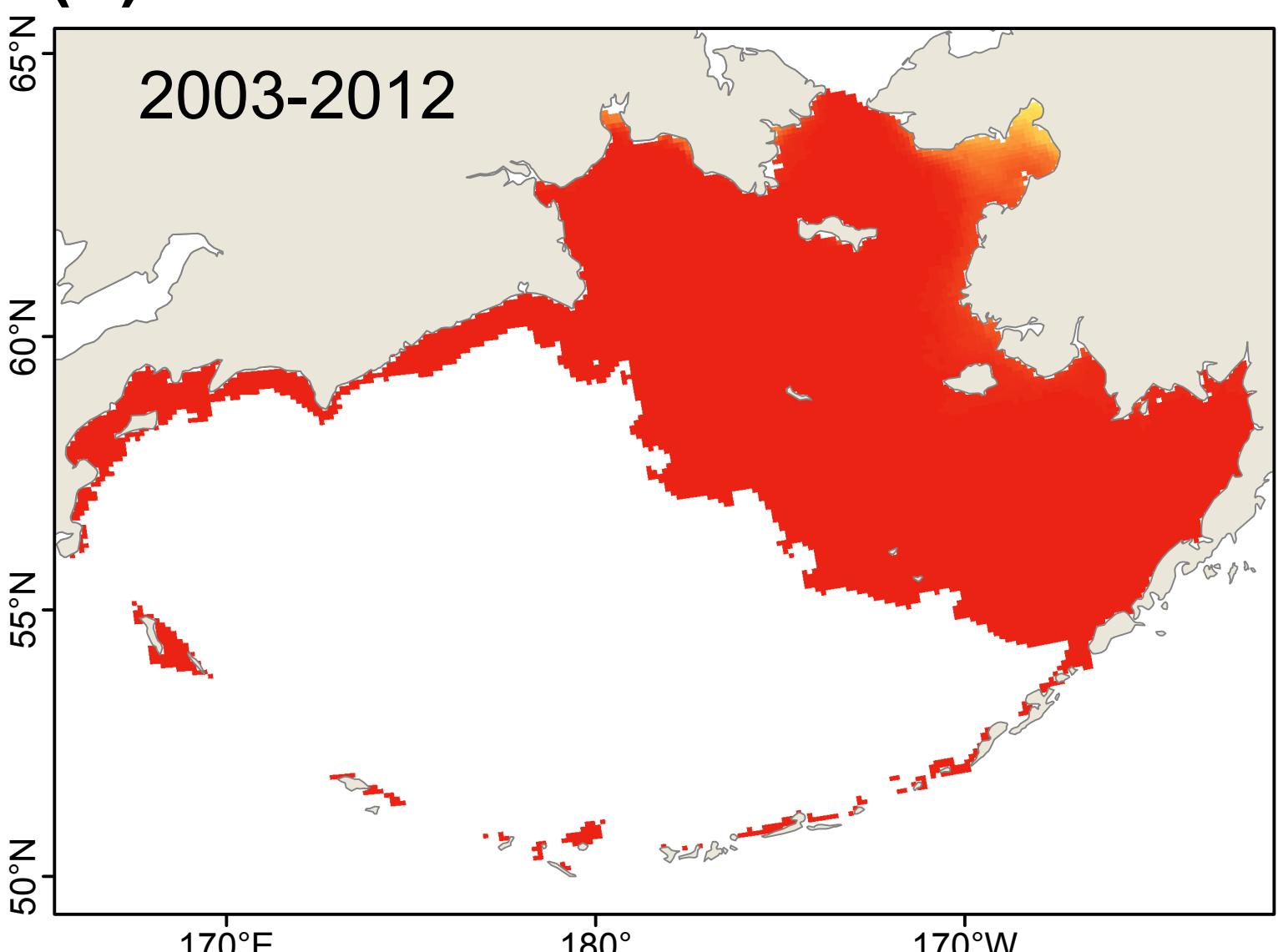
Average number of weeks of suitable habitat



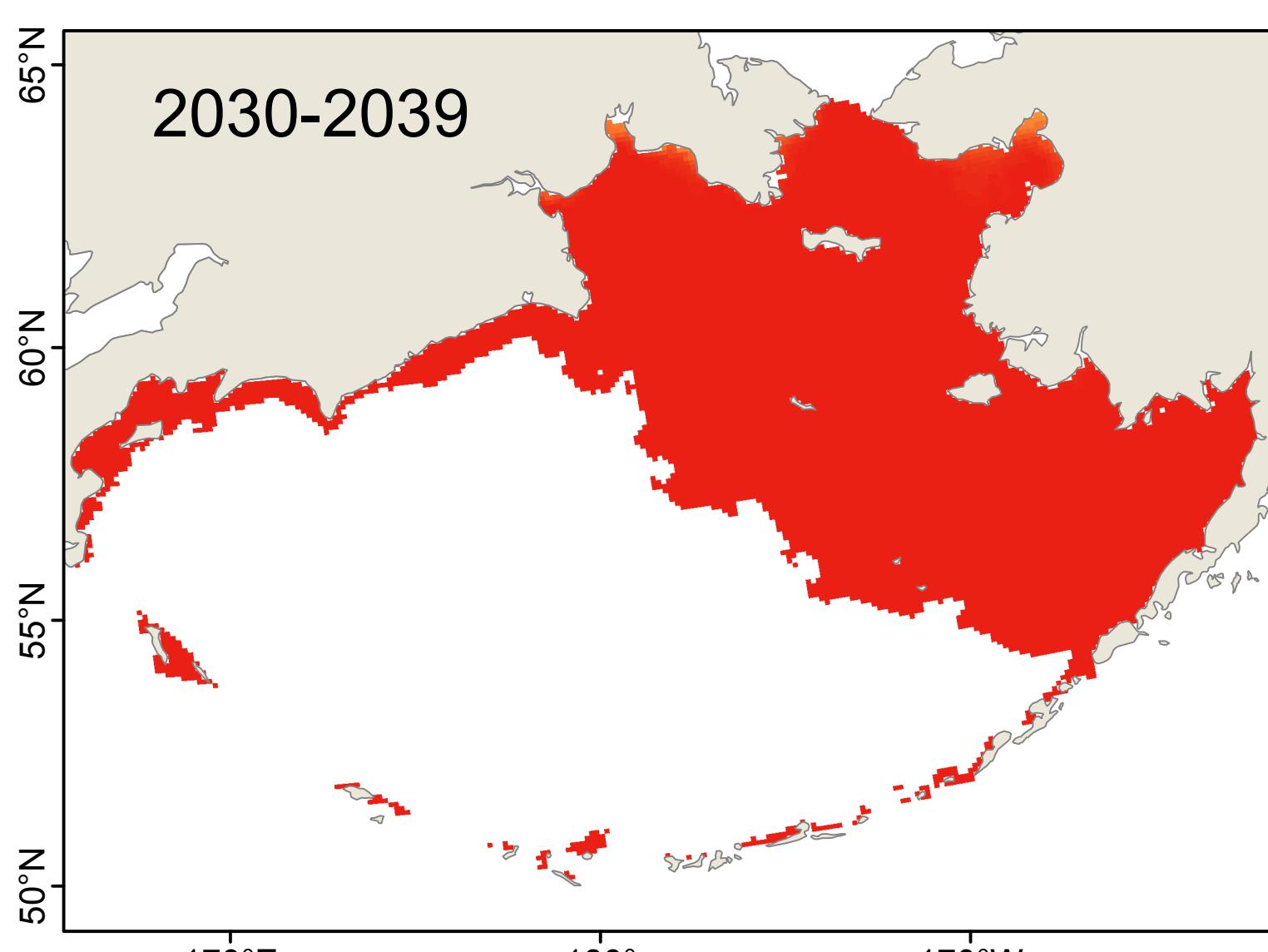
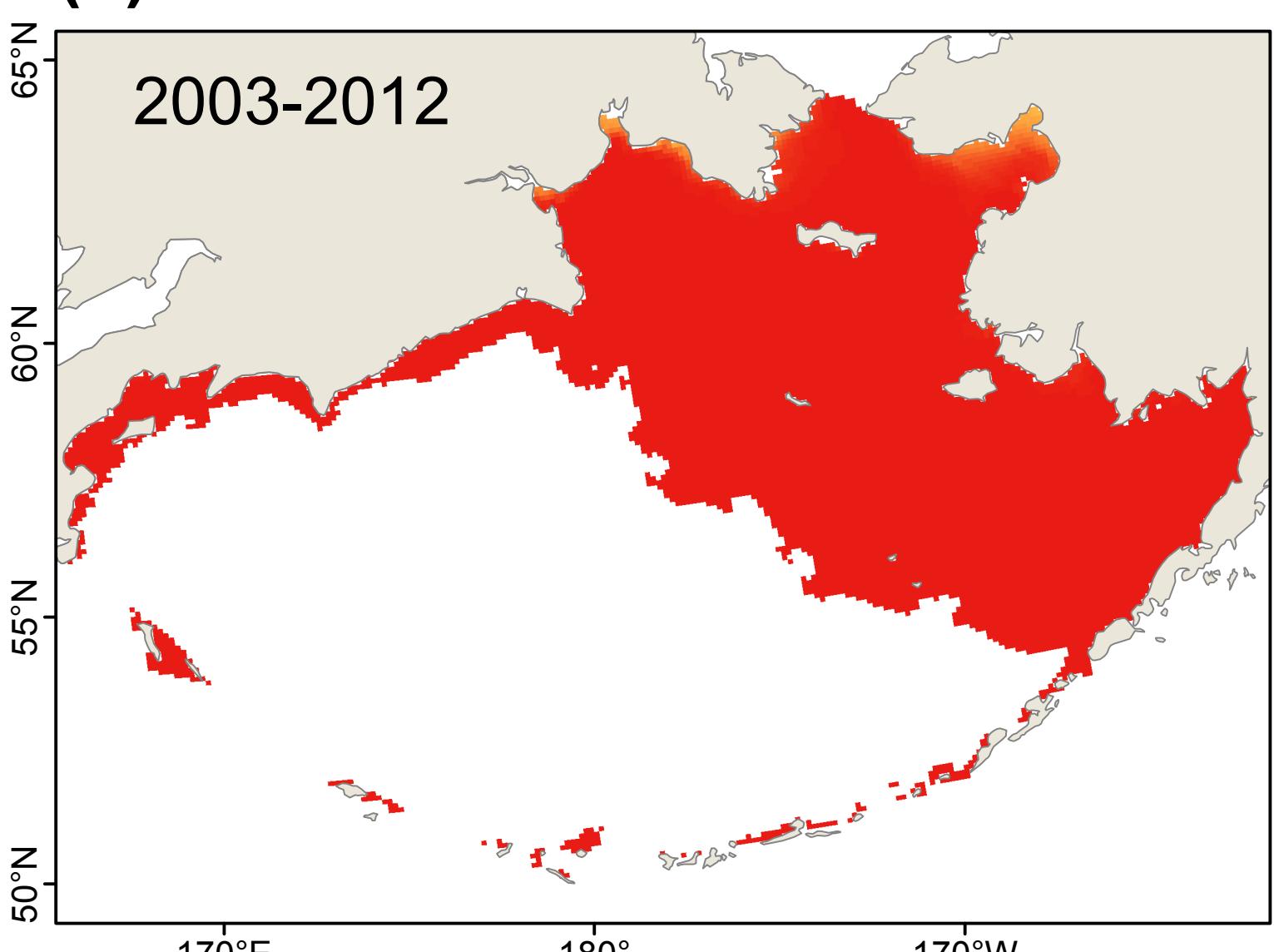
(a) Model: CGCM3-t47



(b) Model: ECHO-G

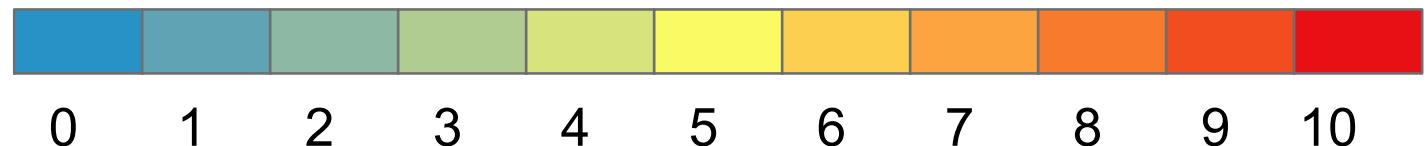


(c) Model: MIROC3.2

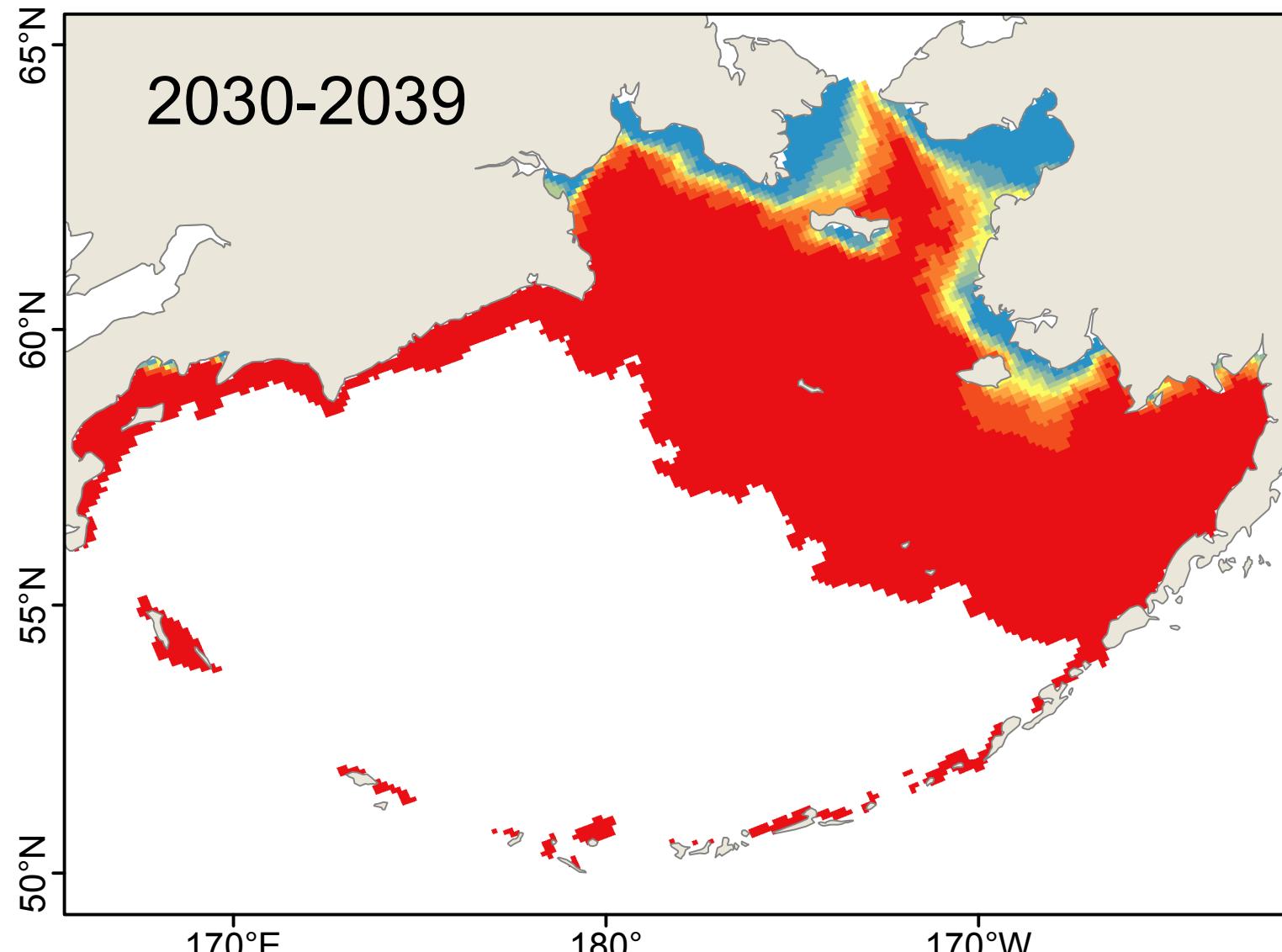
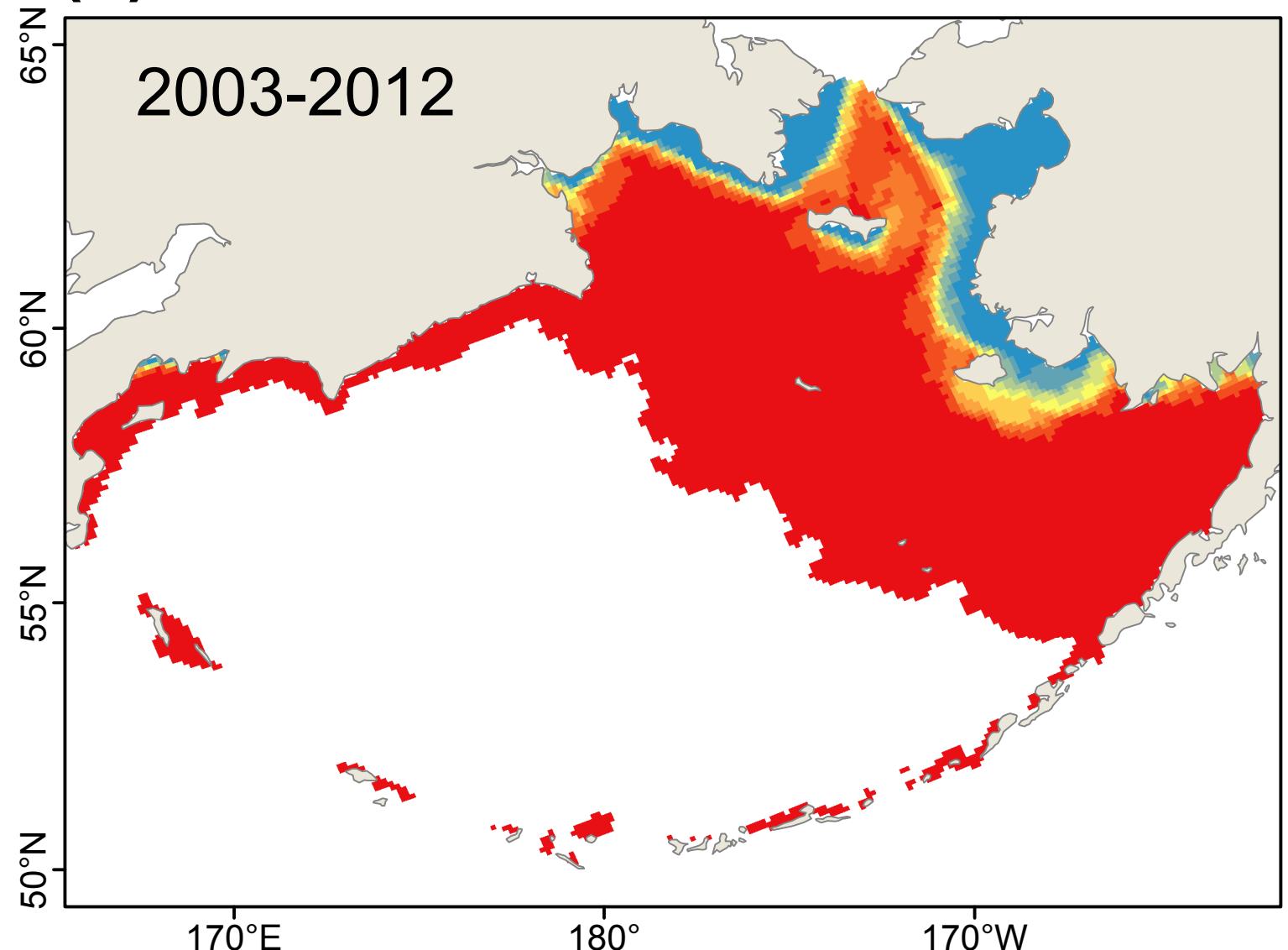


# *Crassostrea gigas*: Year-round Survival

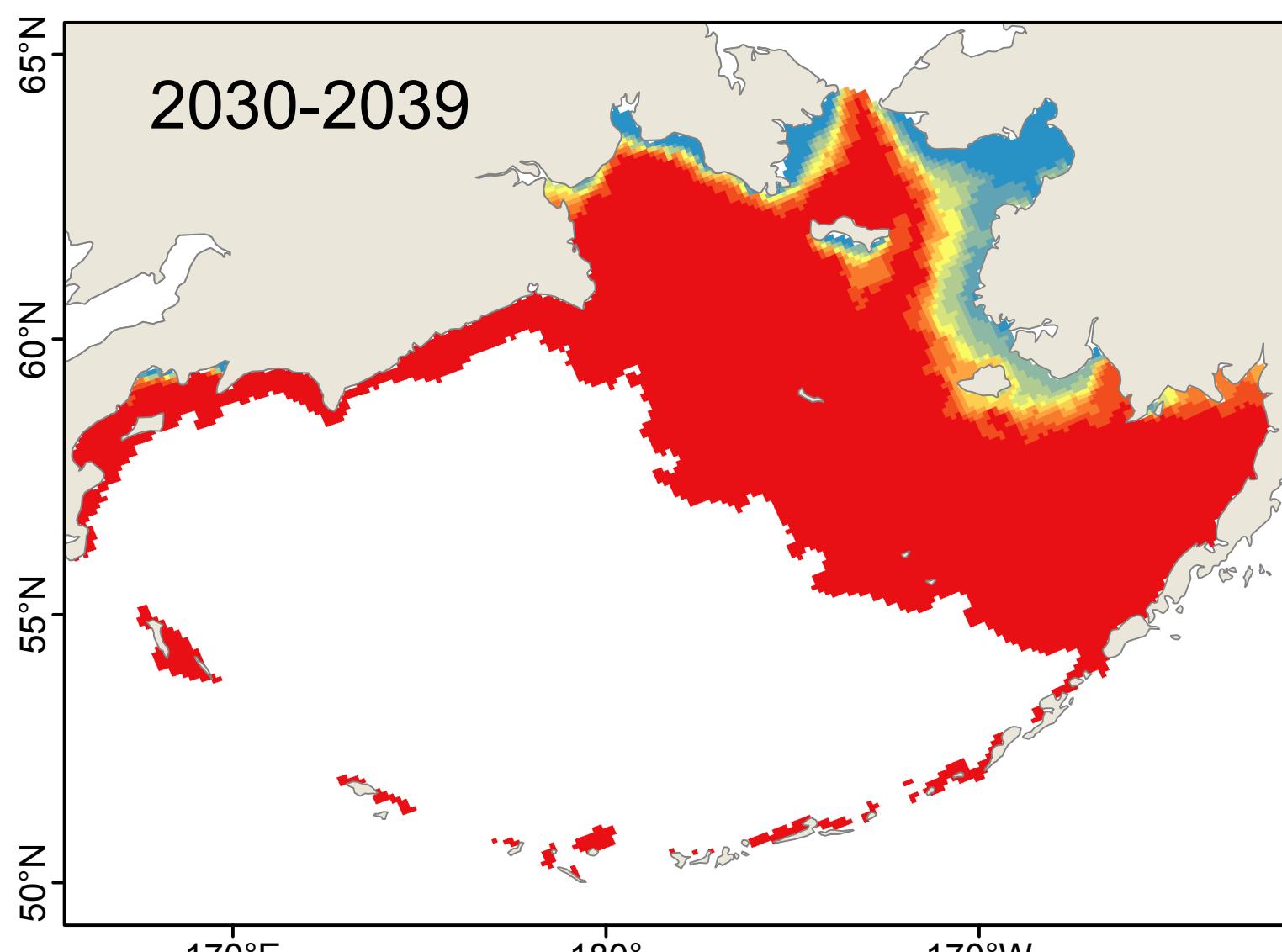
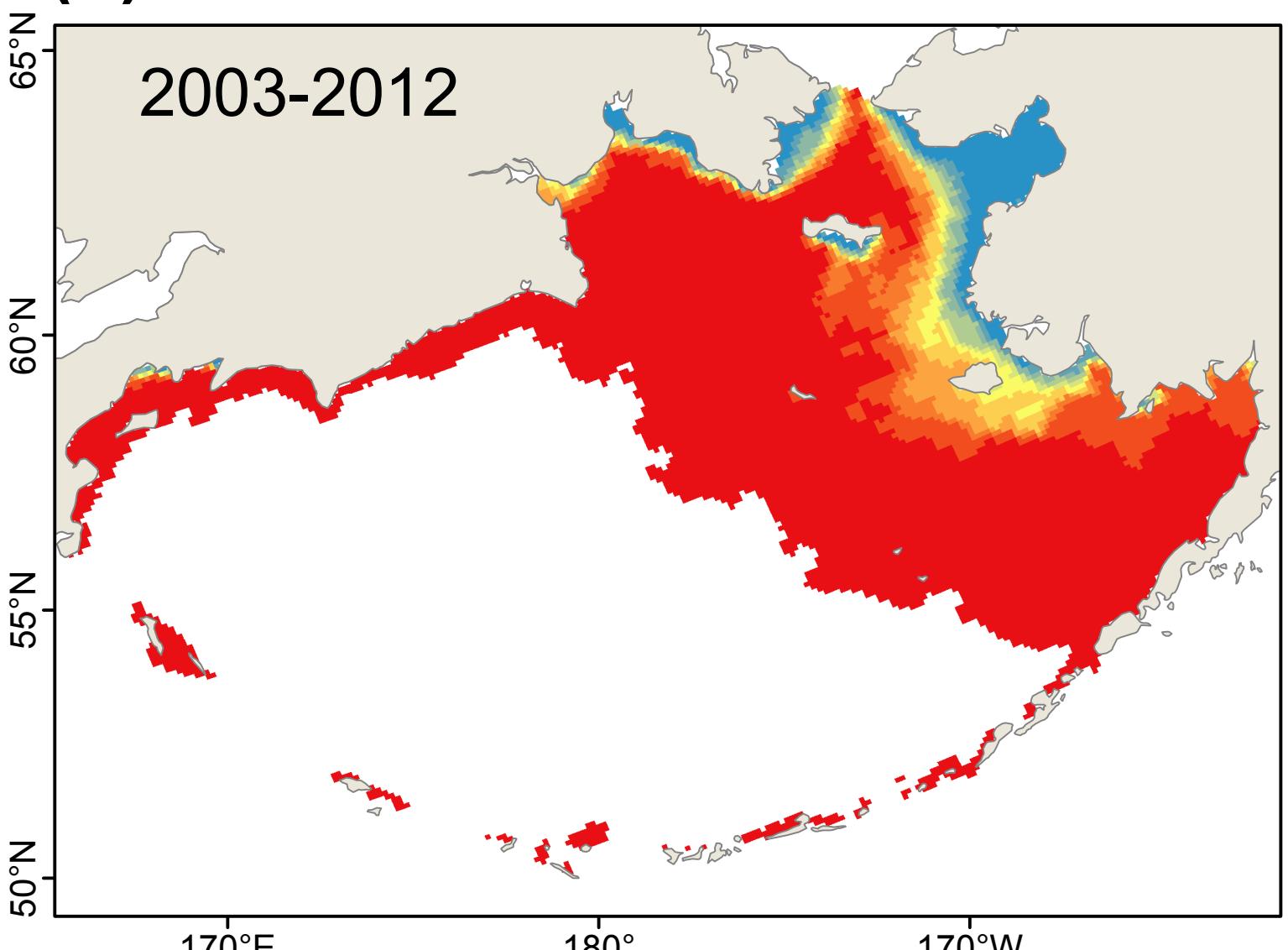
Number of years with suitable habitat



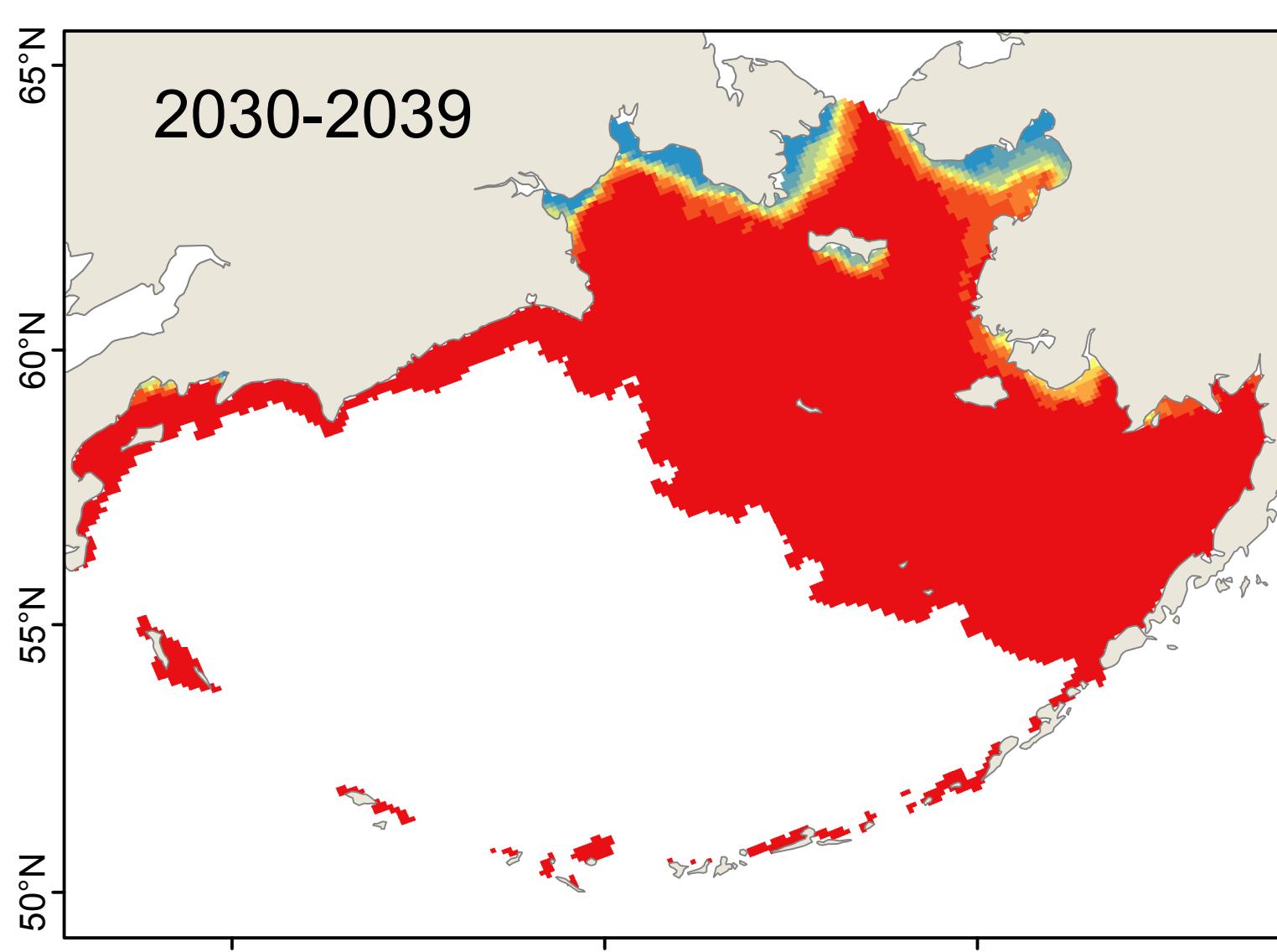
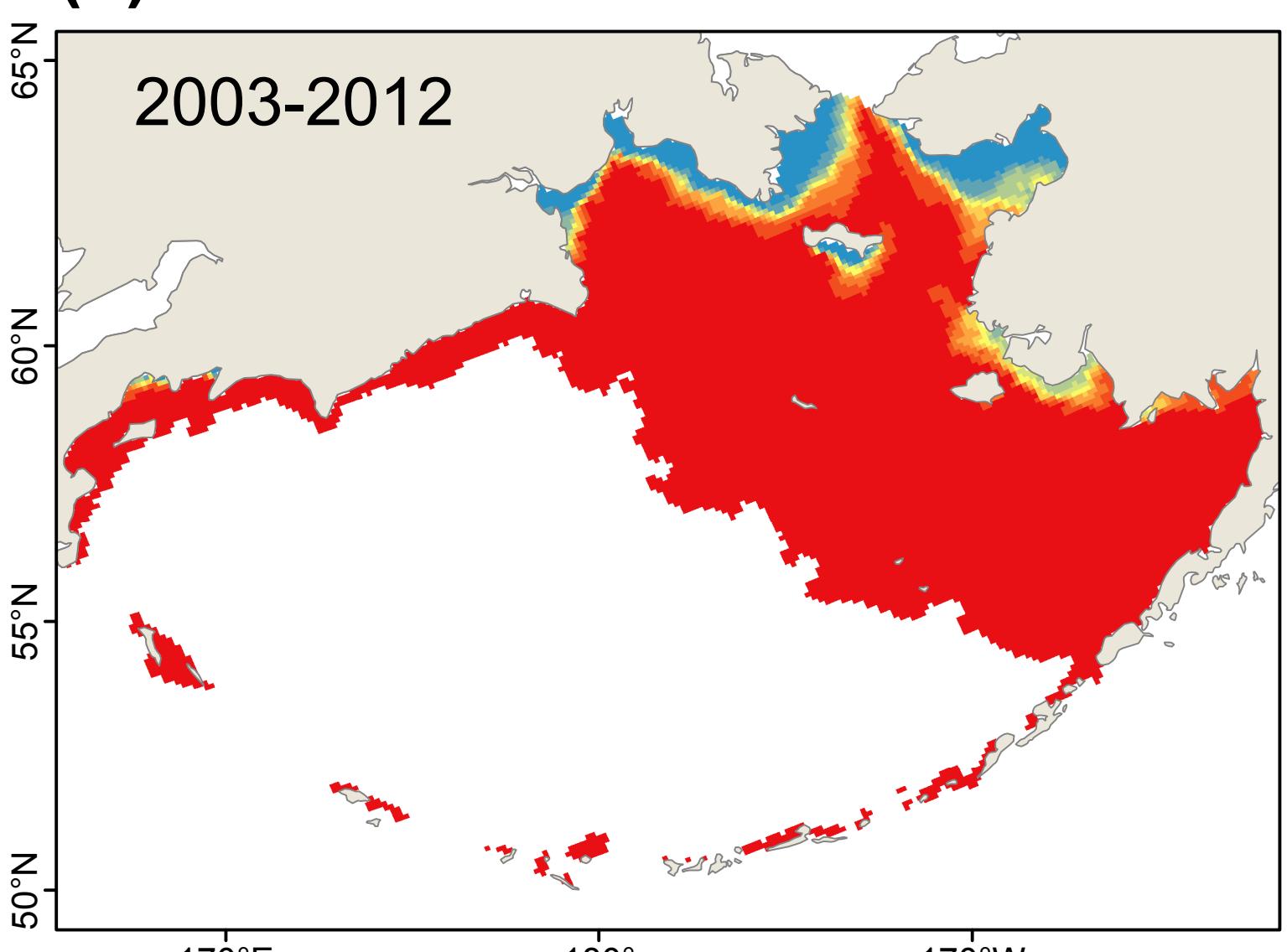
(a) Model: CGCM3-t47



(b) Model: ECHO-G

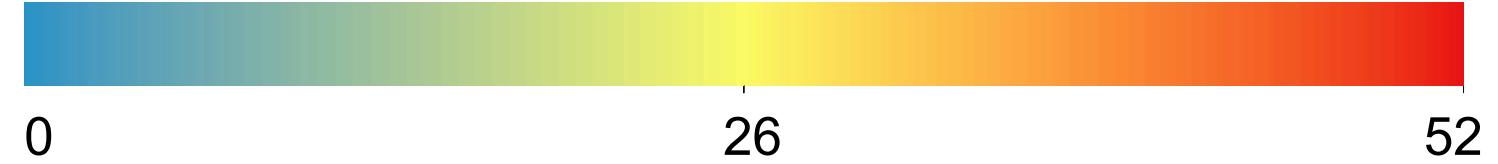


(c) Model: MIROC3.2

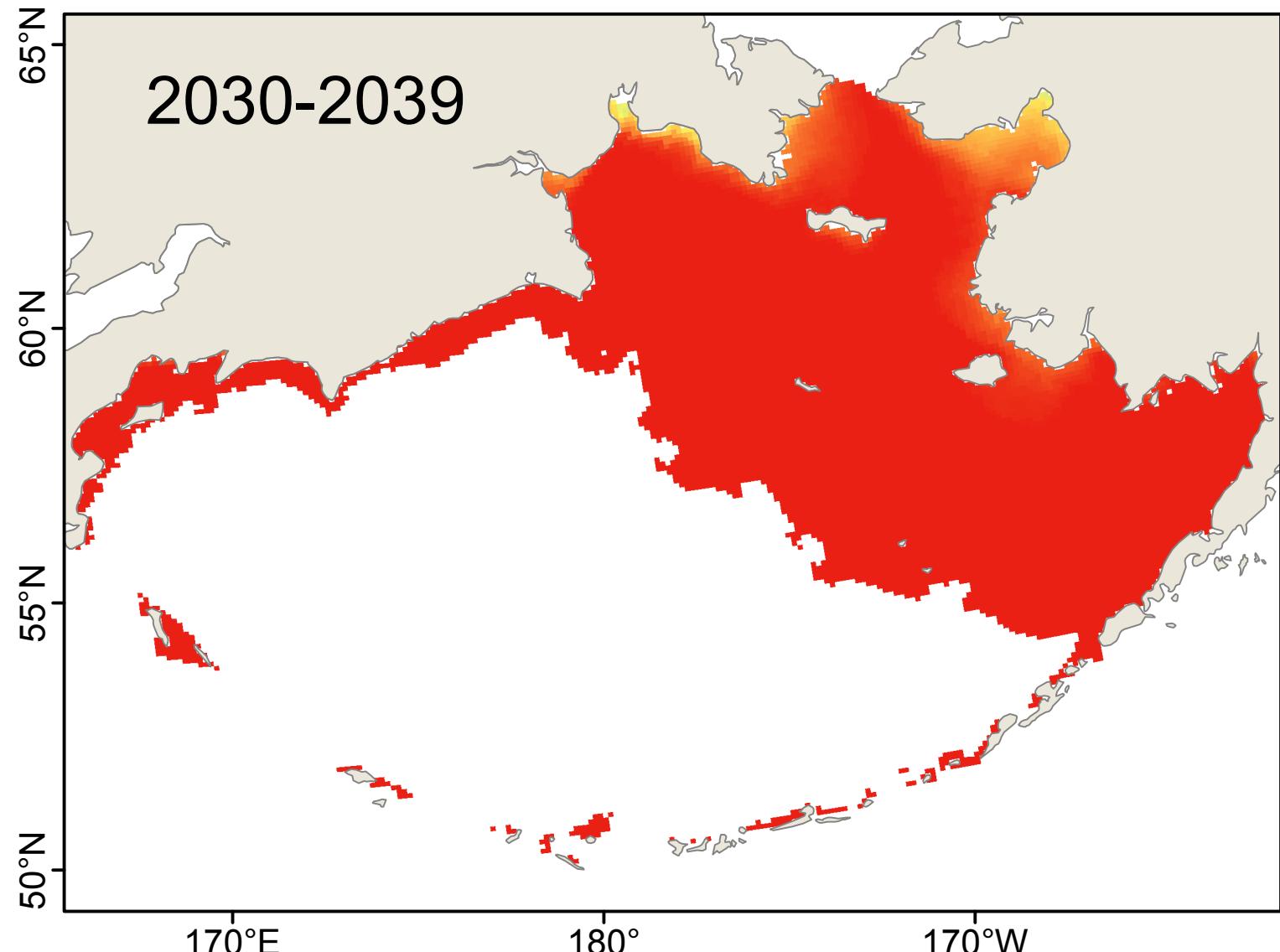
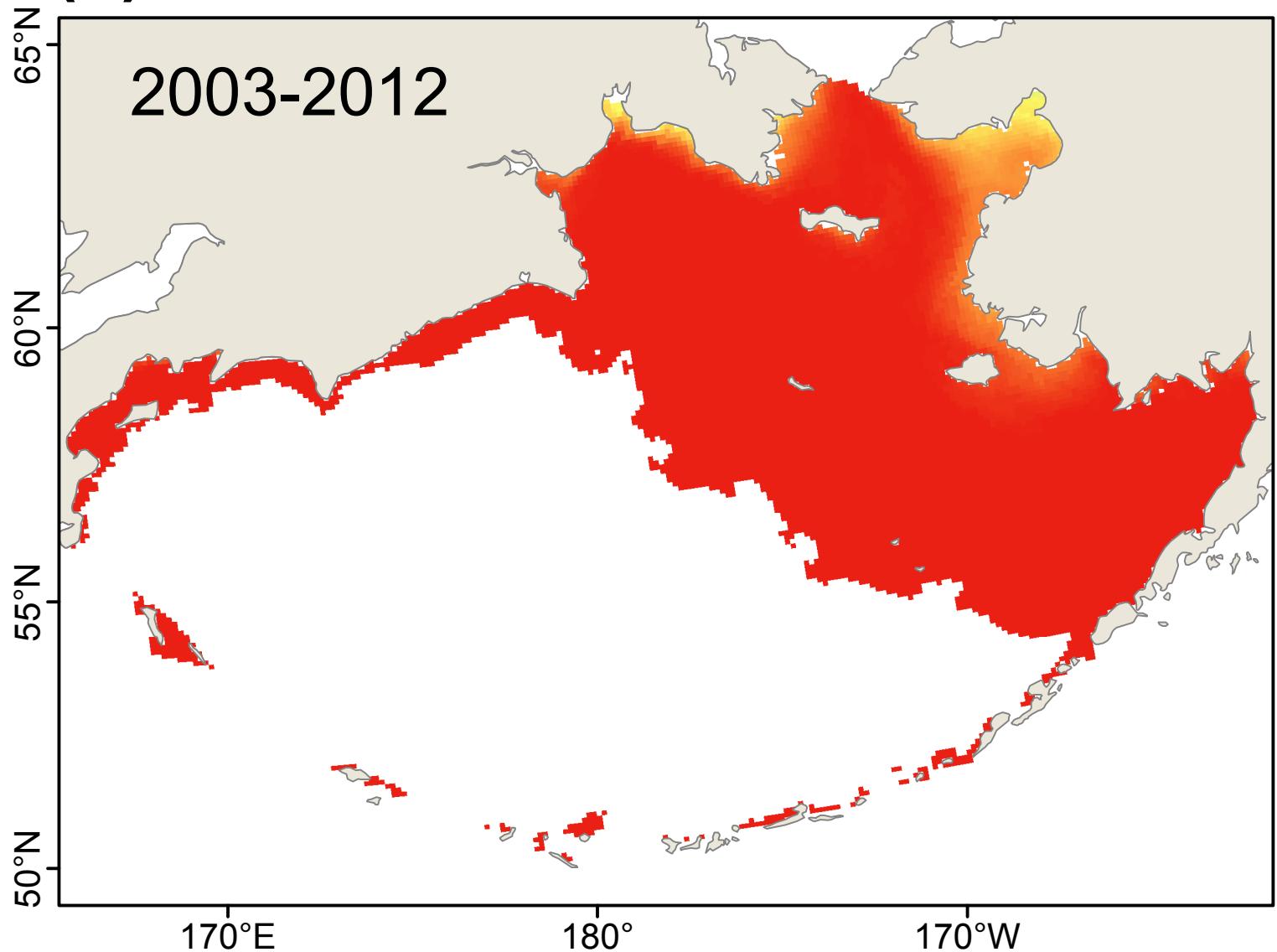


# *Crassostrea gigas: Weekly Survival*

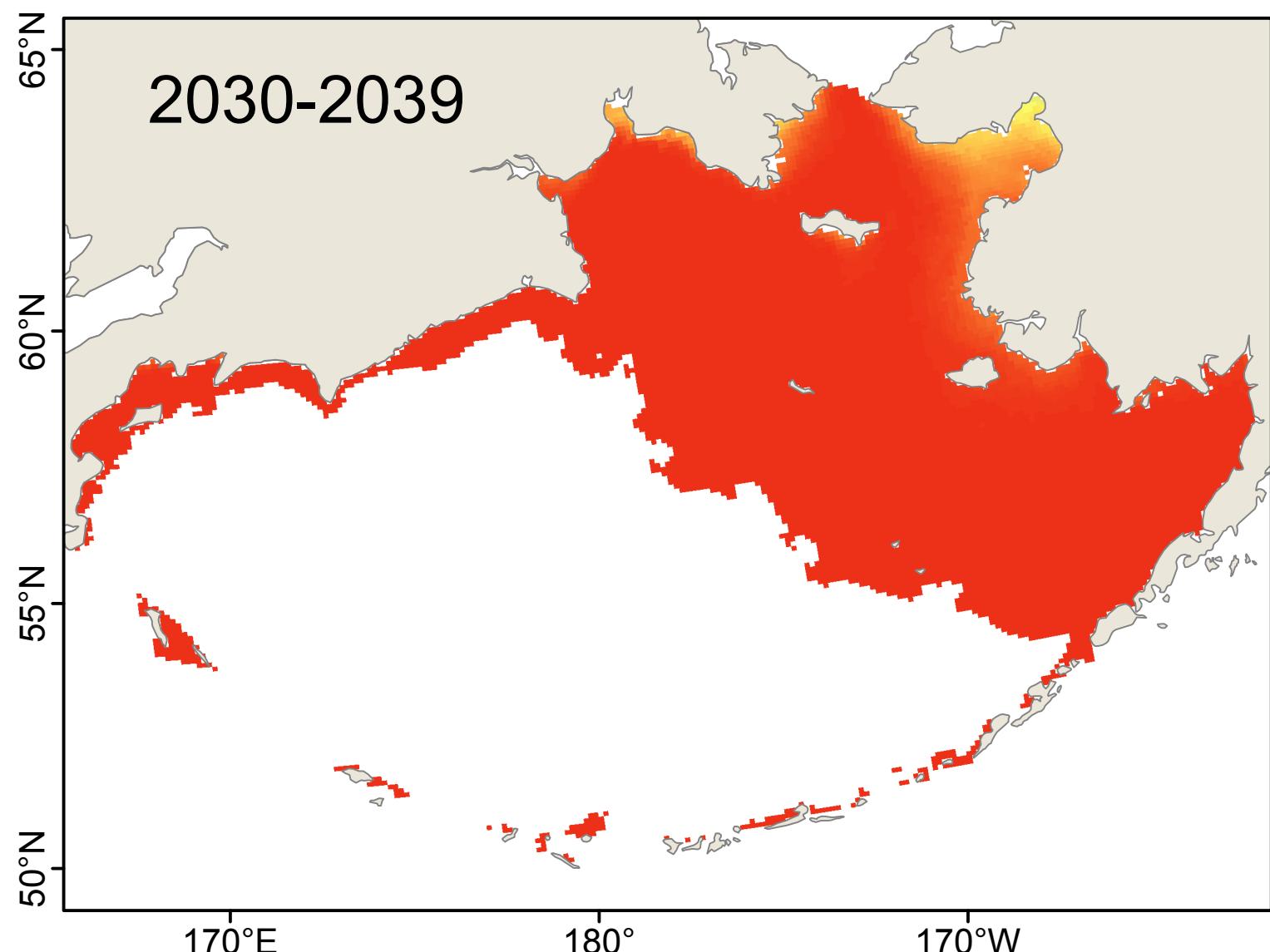
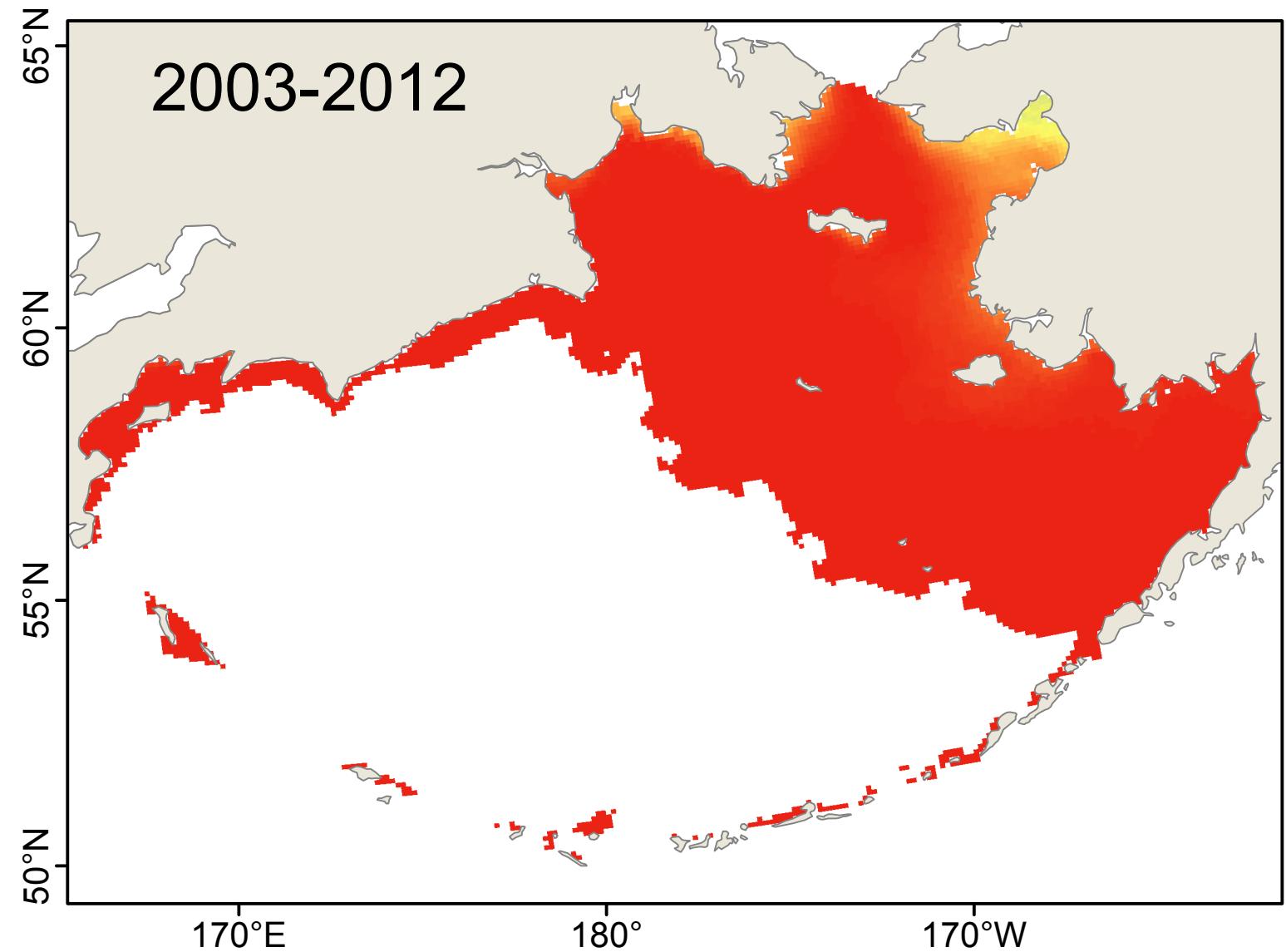
Average number of weeks of suitable habitat



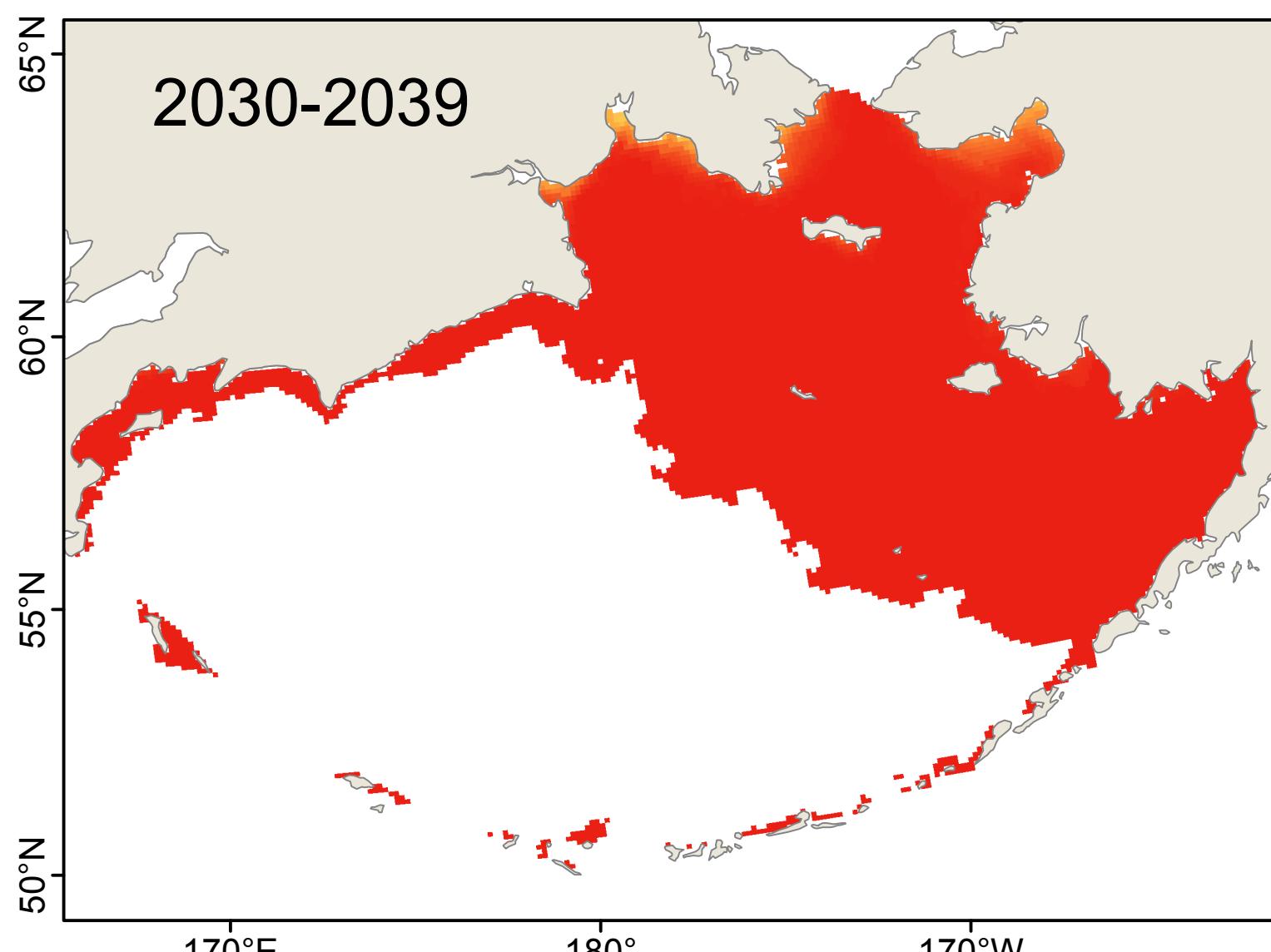
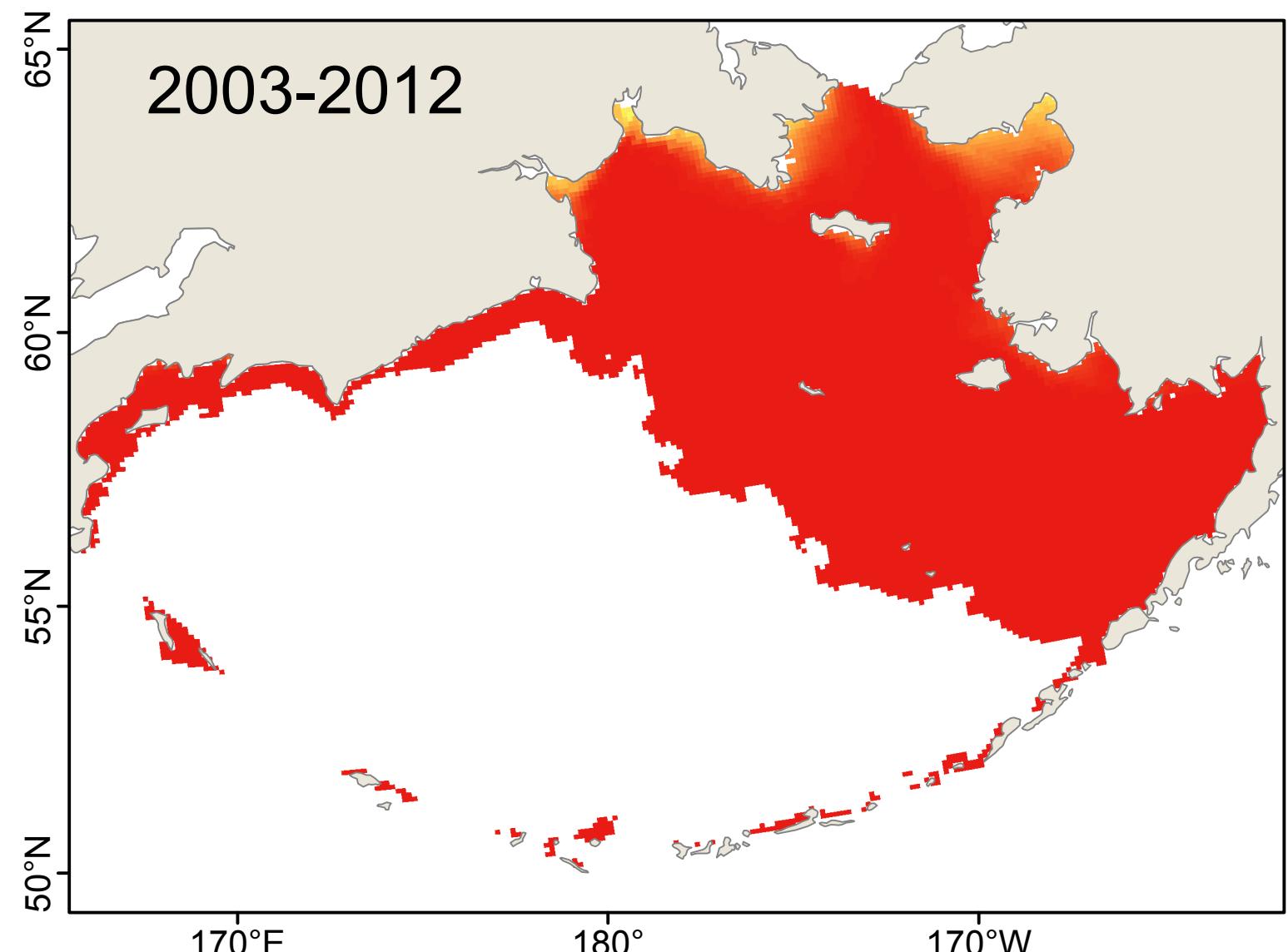
(a) Model: CGCM3-t47



(b) Model: ECHO-G

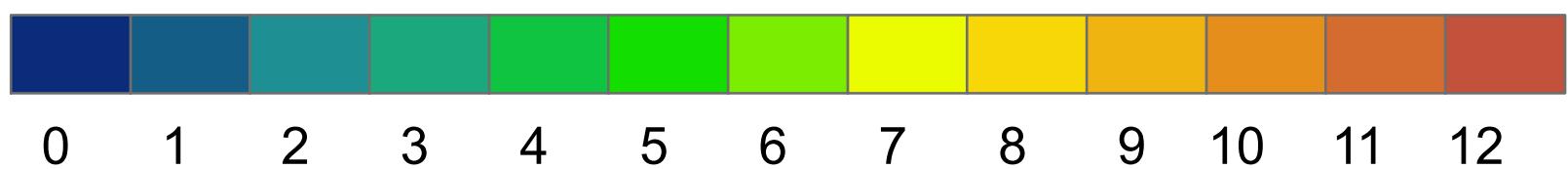


(c) Model: MIROC3.2

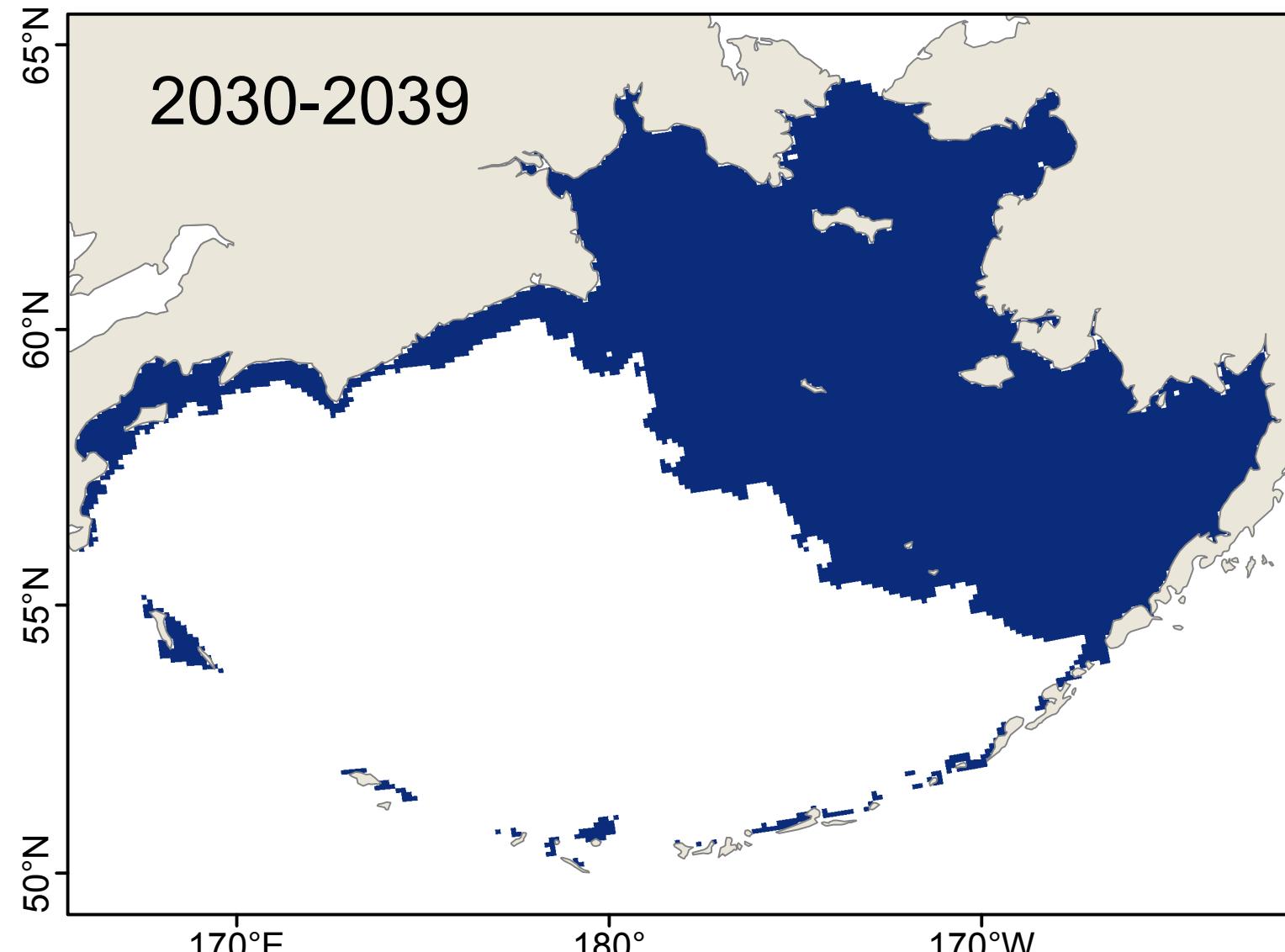
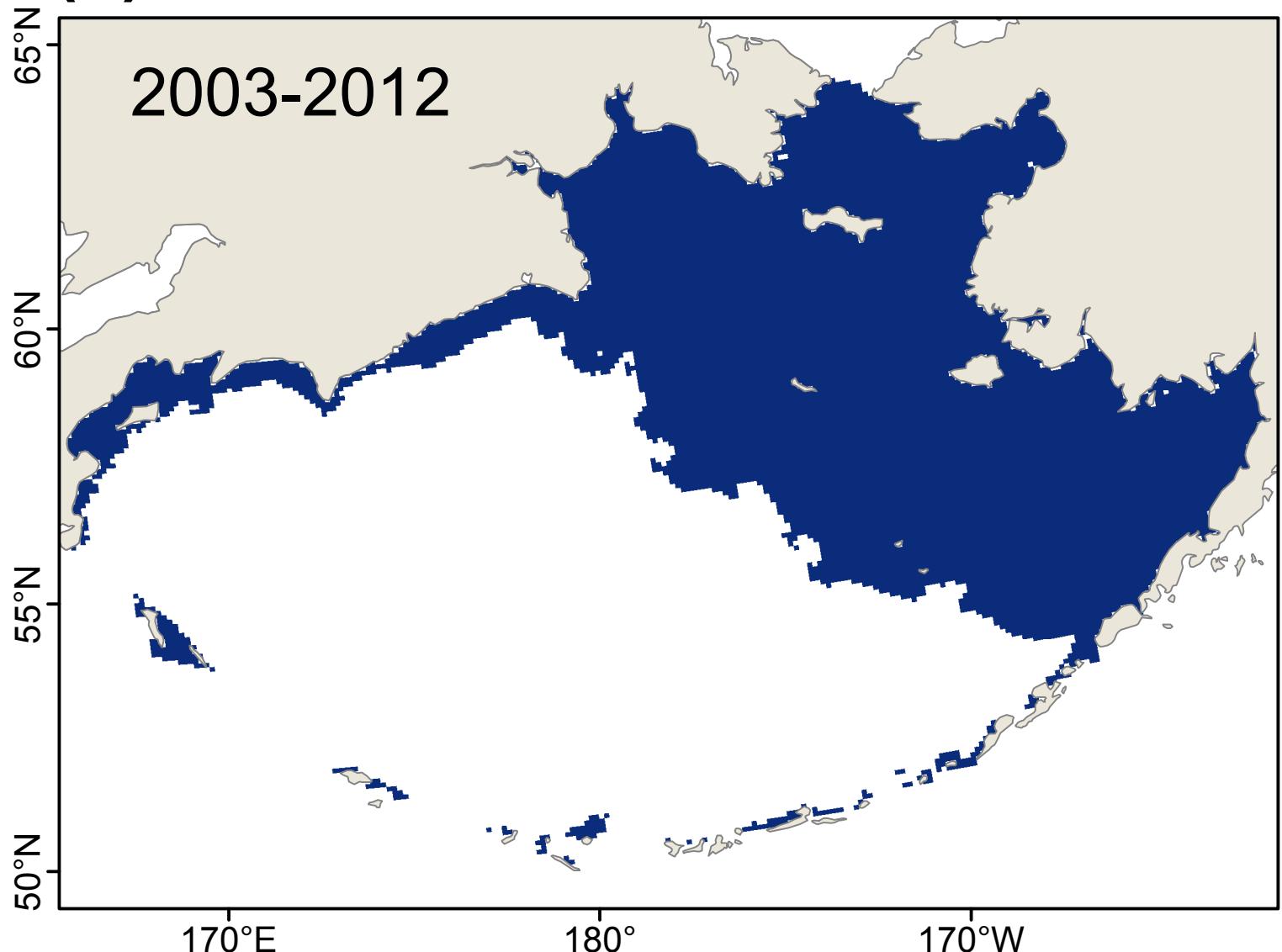


# *Crassostrea gigas: Reproduction*

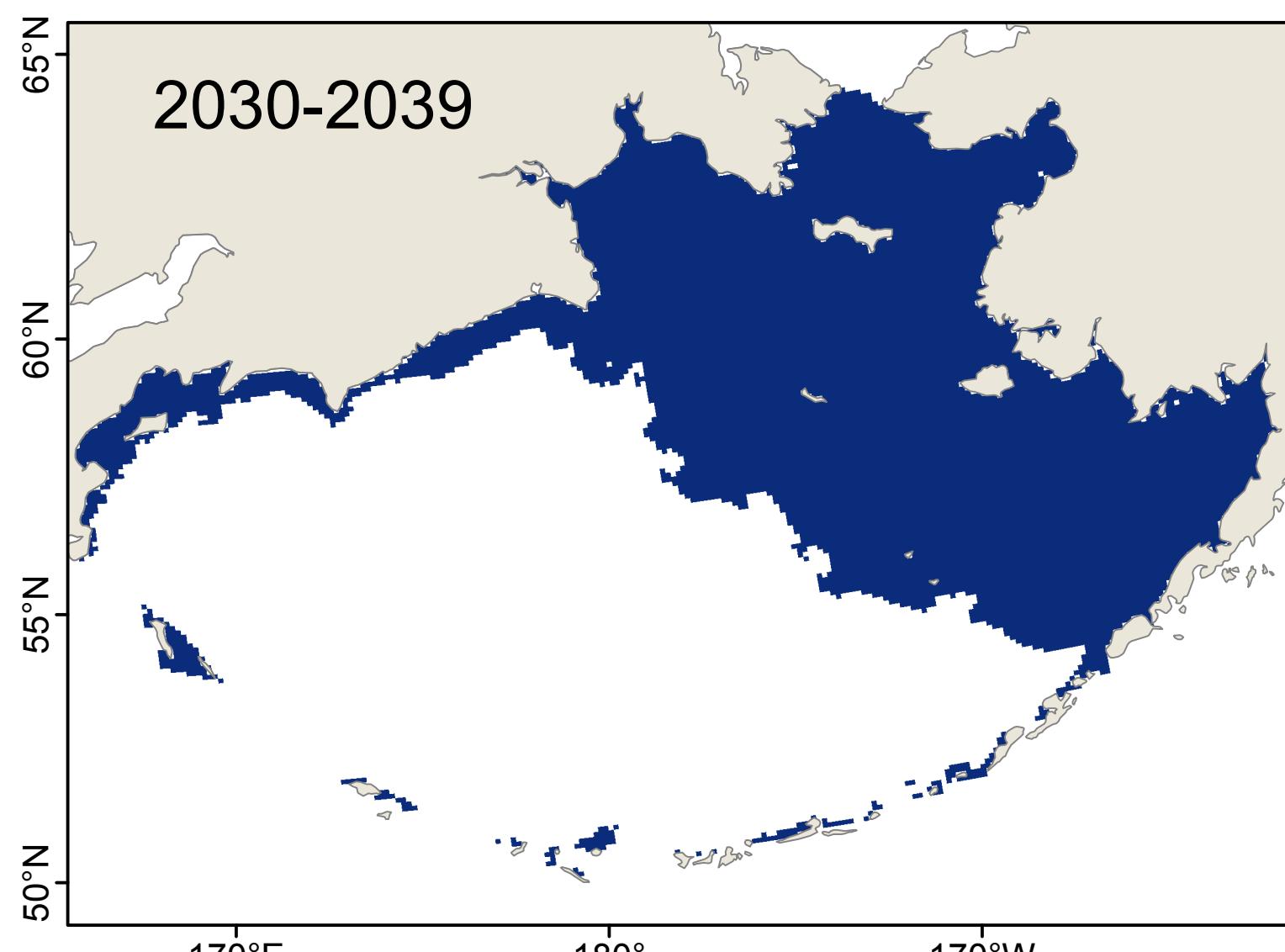
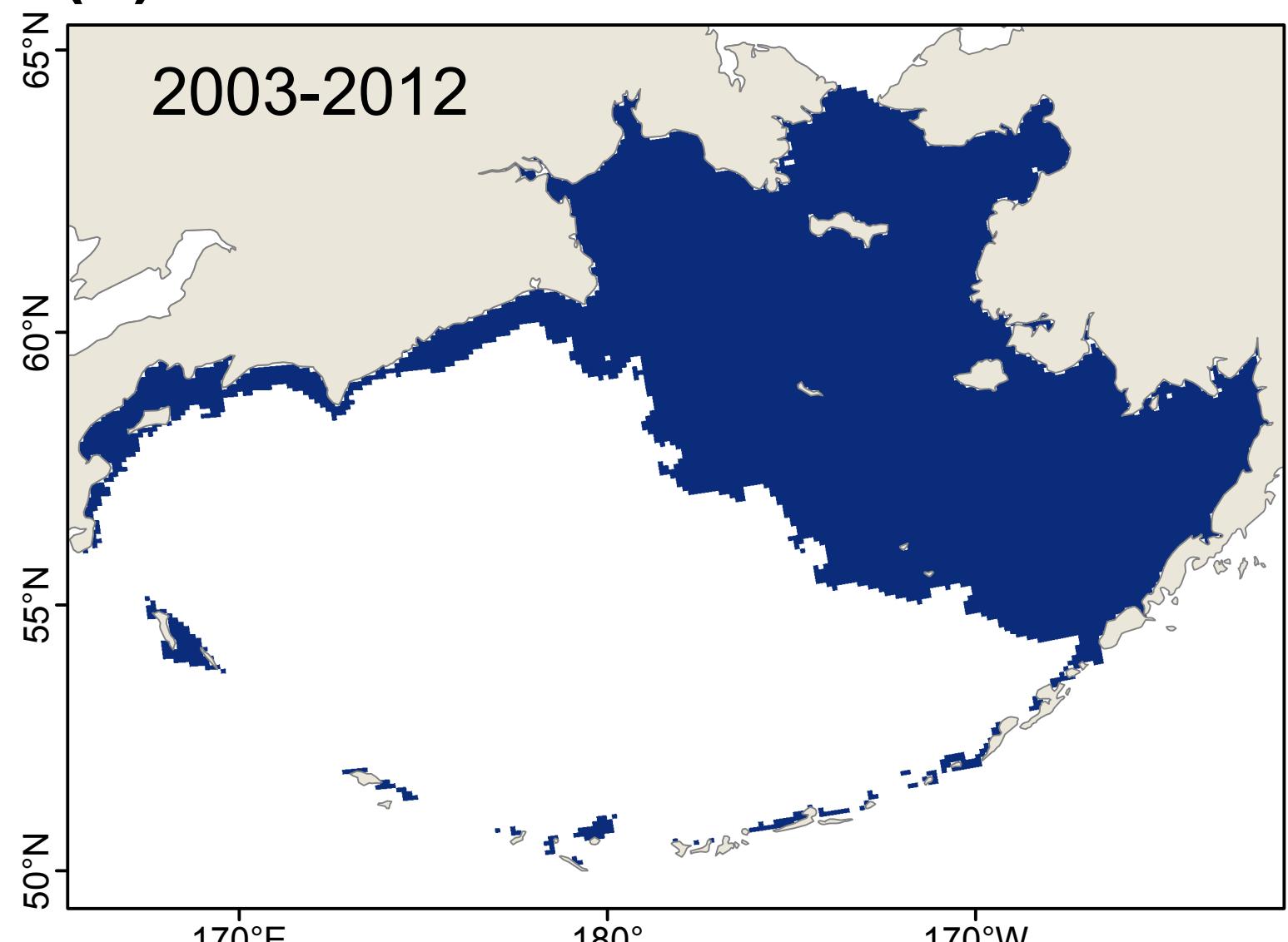
Average number of consecutive weeks of suitable habitat



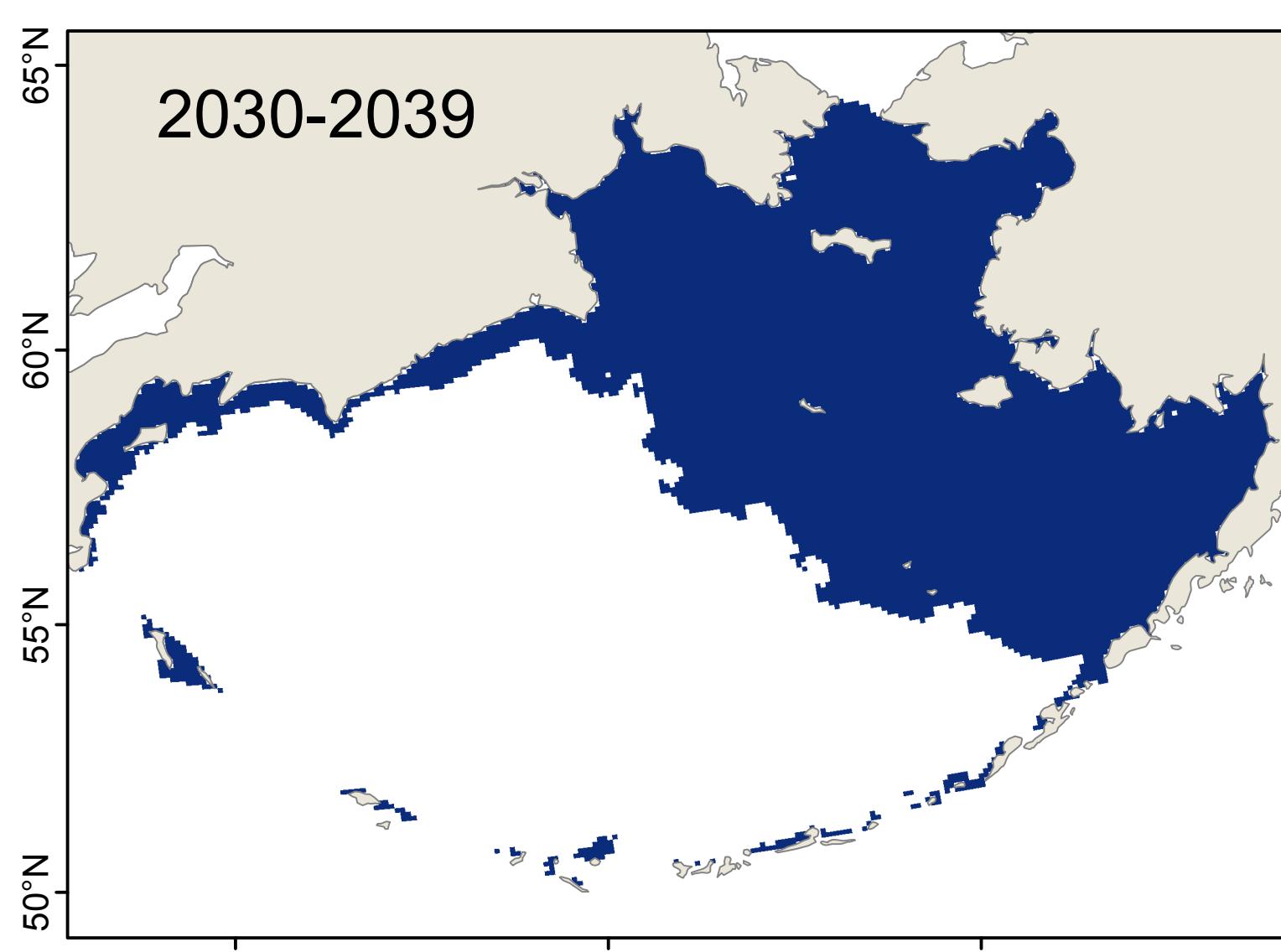
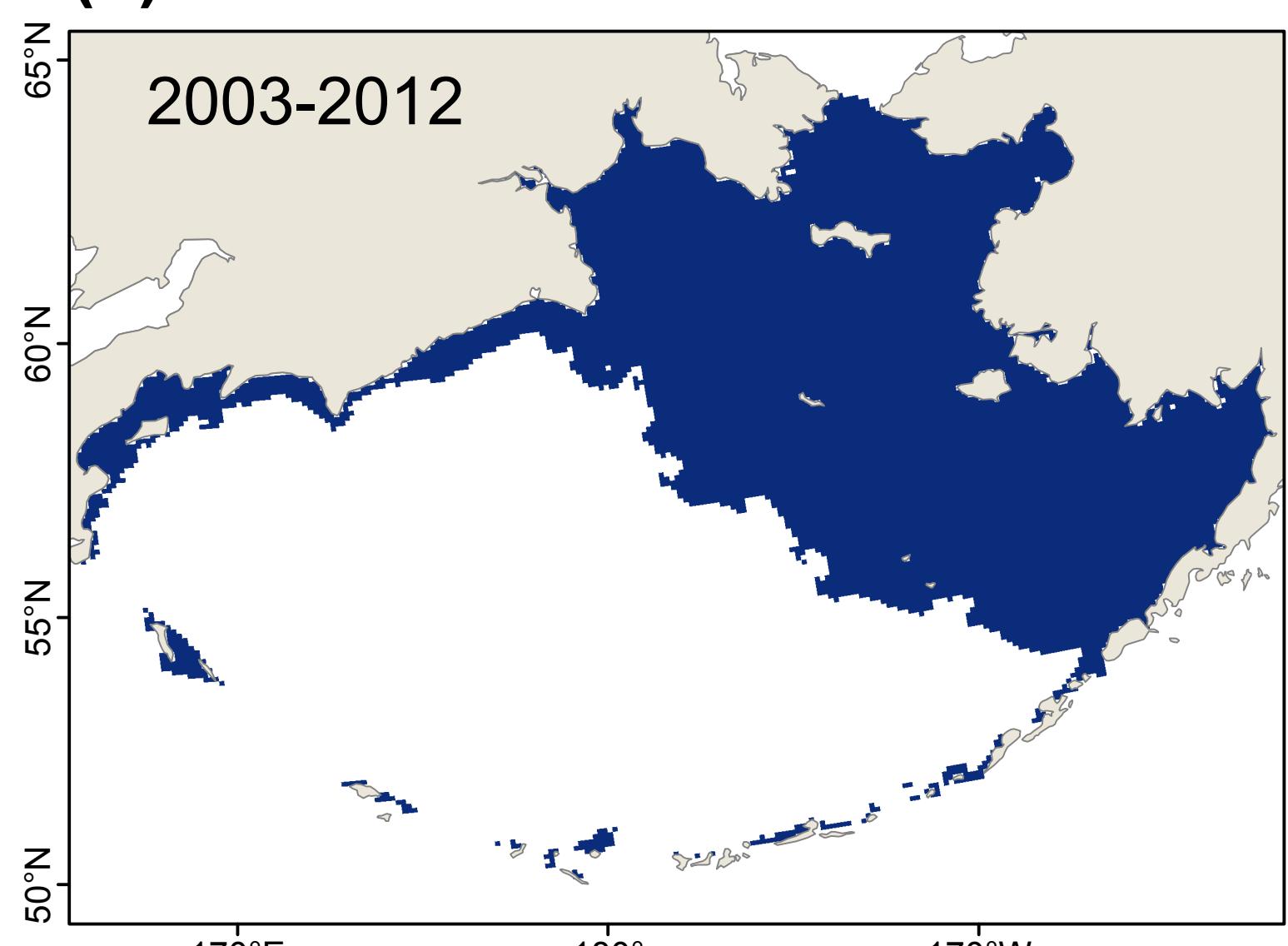
(a) Model: CGCM3-t47



(b) Model: ECHO-G

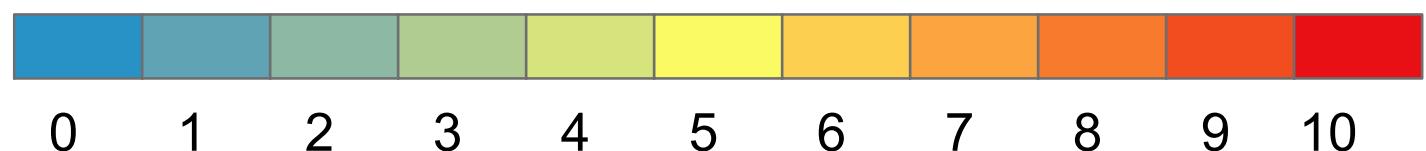


(c) Model: MIROC3.2

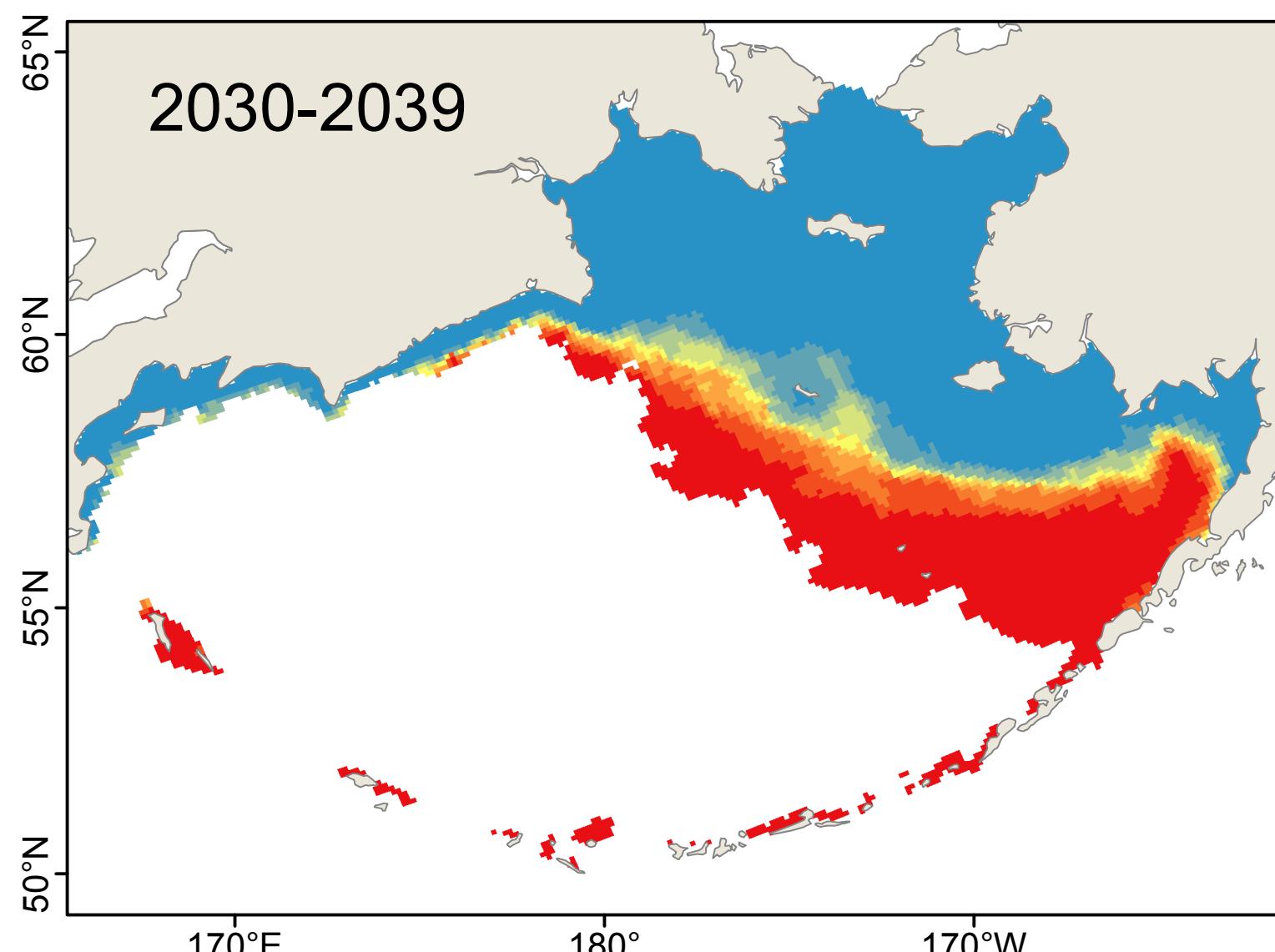
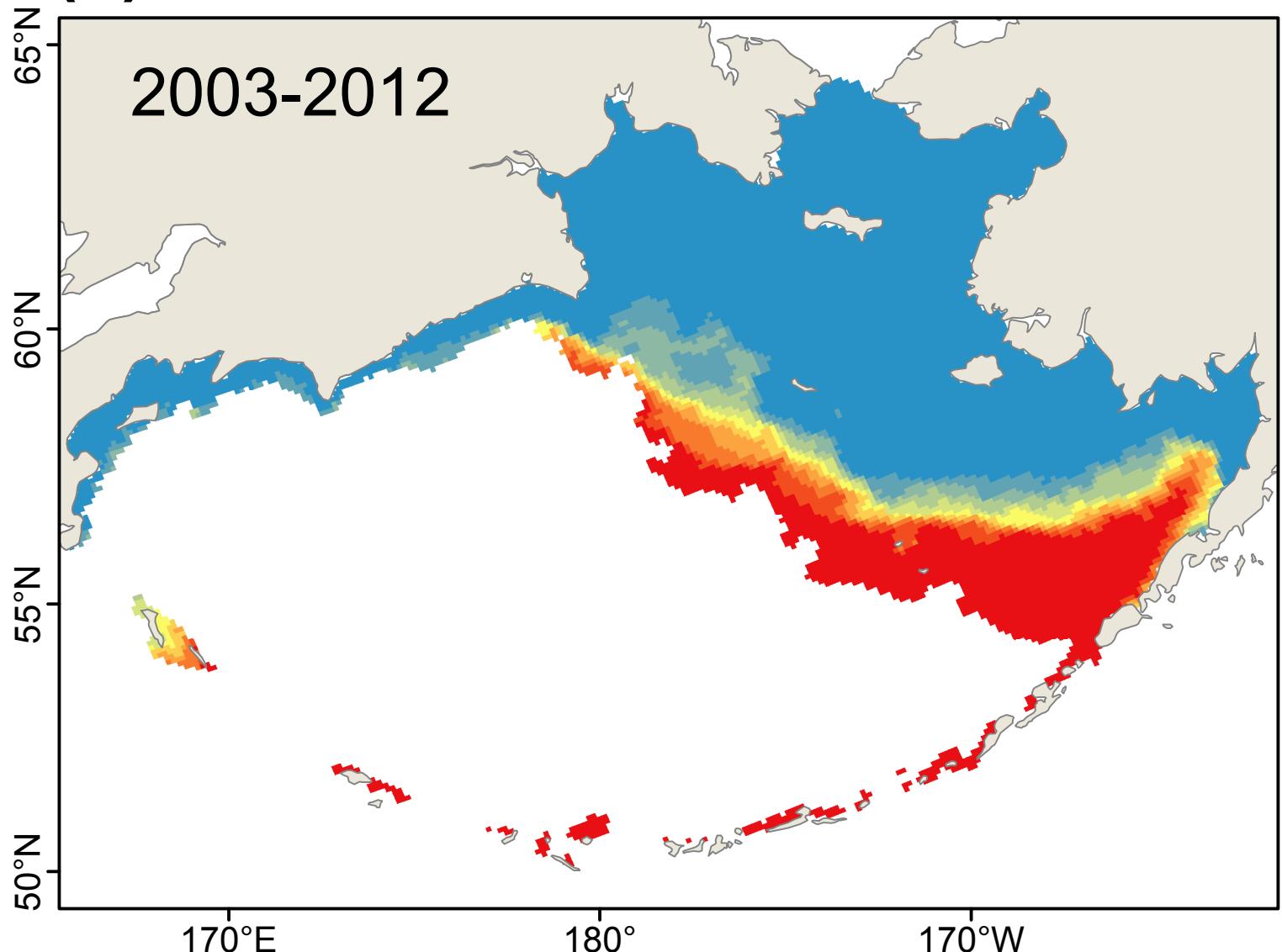


# *Macoma petalum*: Year-round Survival

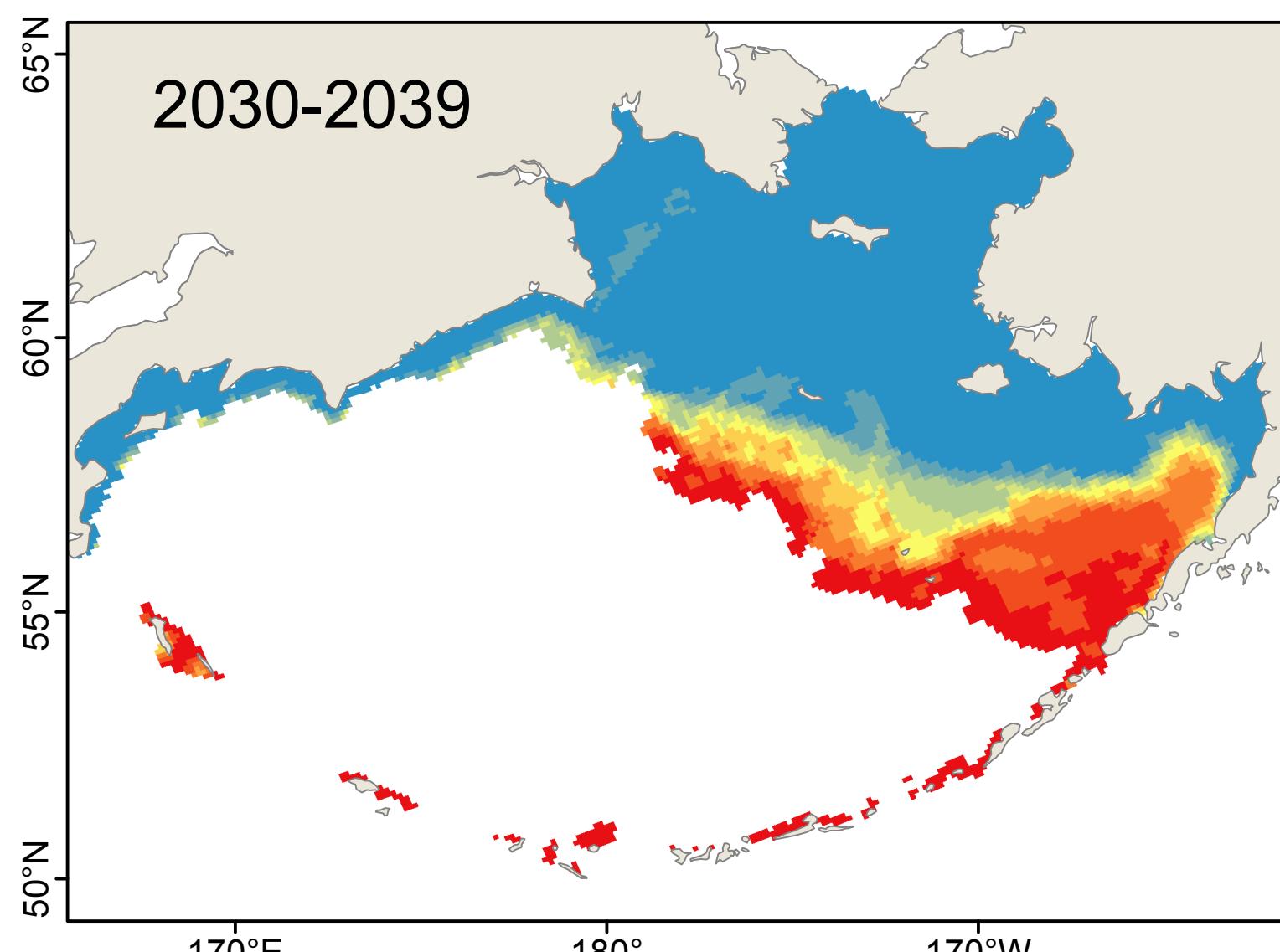
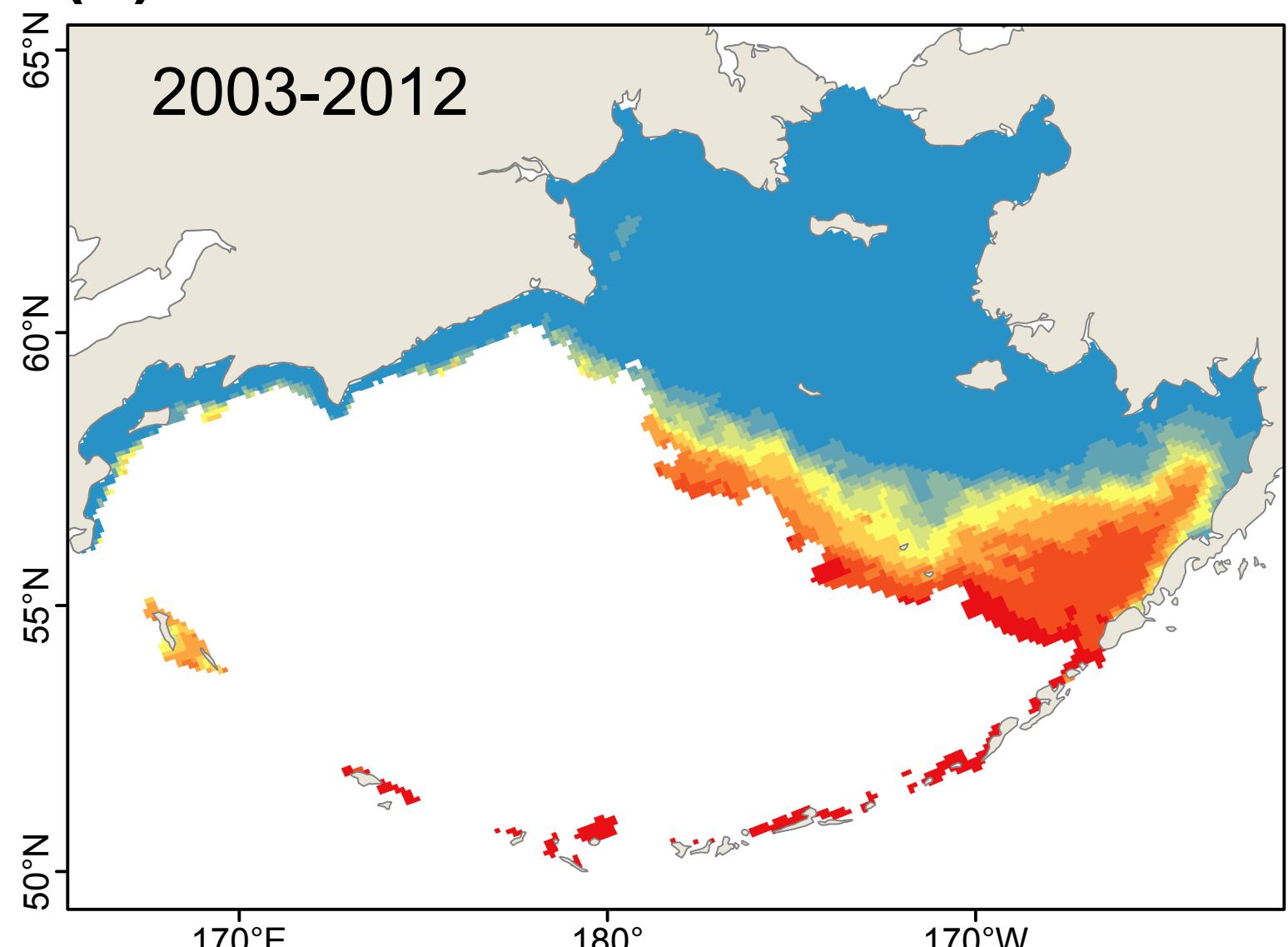
Number of years with suitable habitat



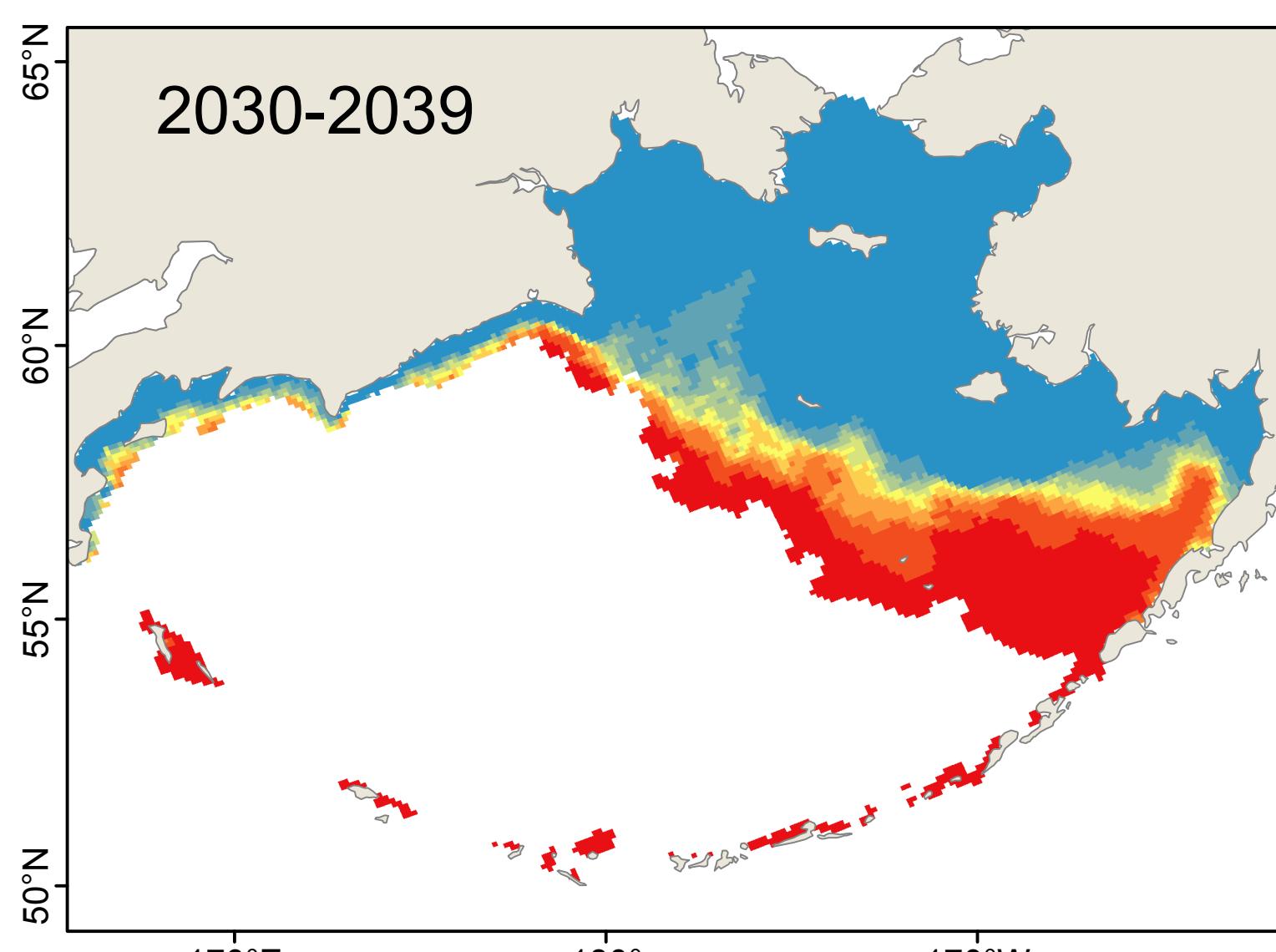
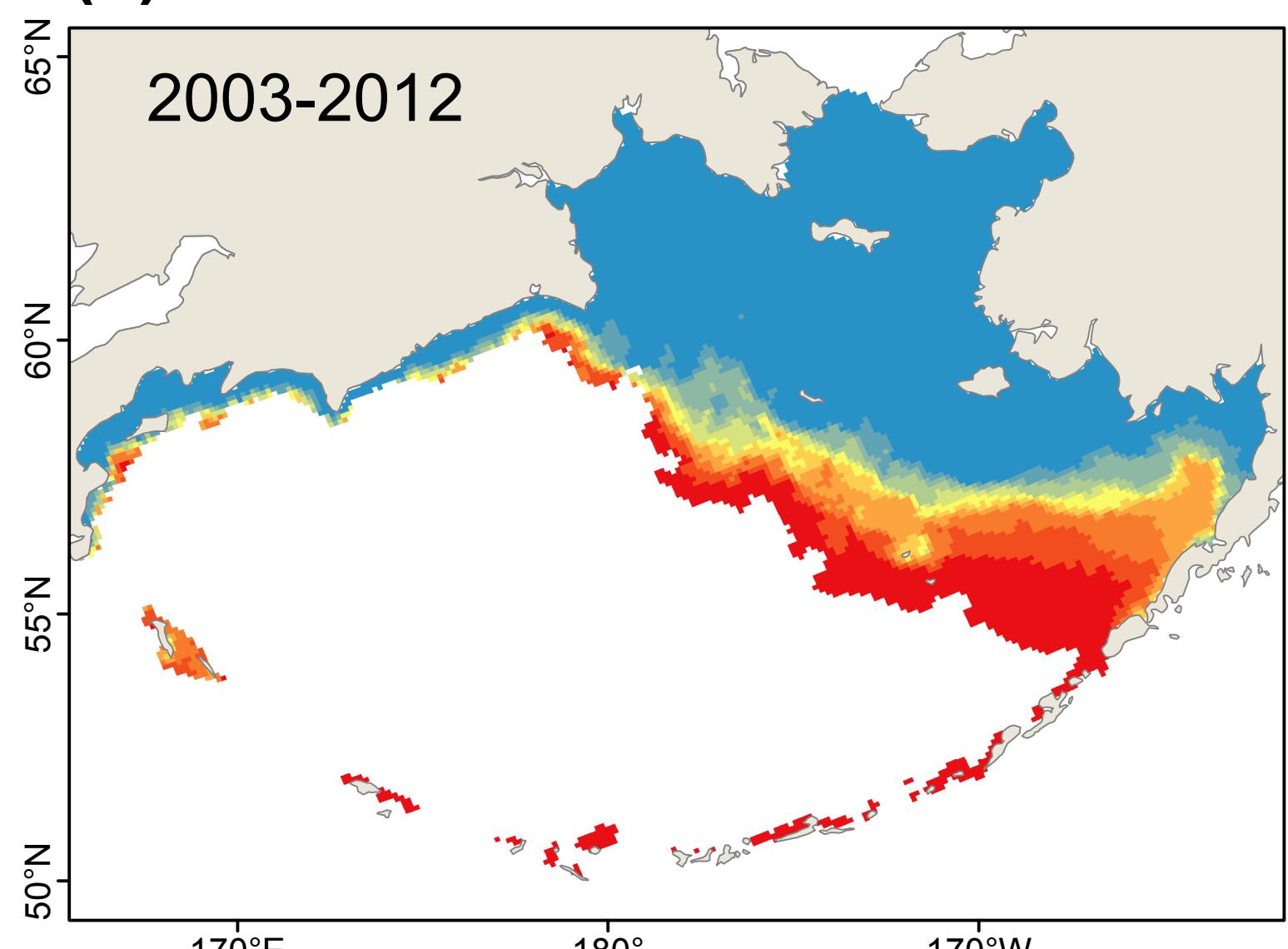
(a) Model: CGCM3-t47



(b) Model: ECHO-G

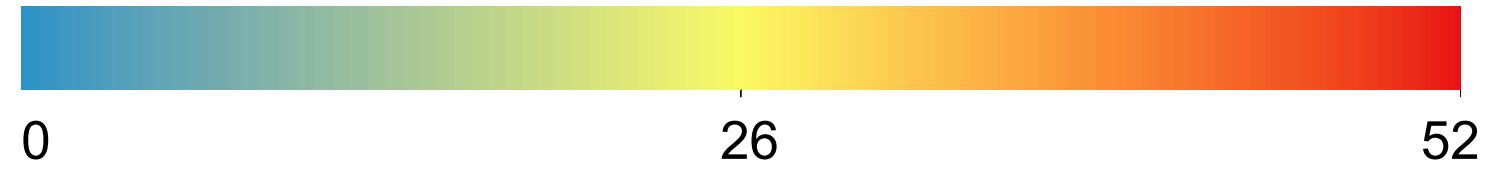


(c) Model: MIROC3.2

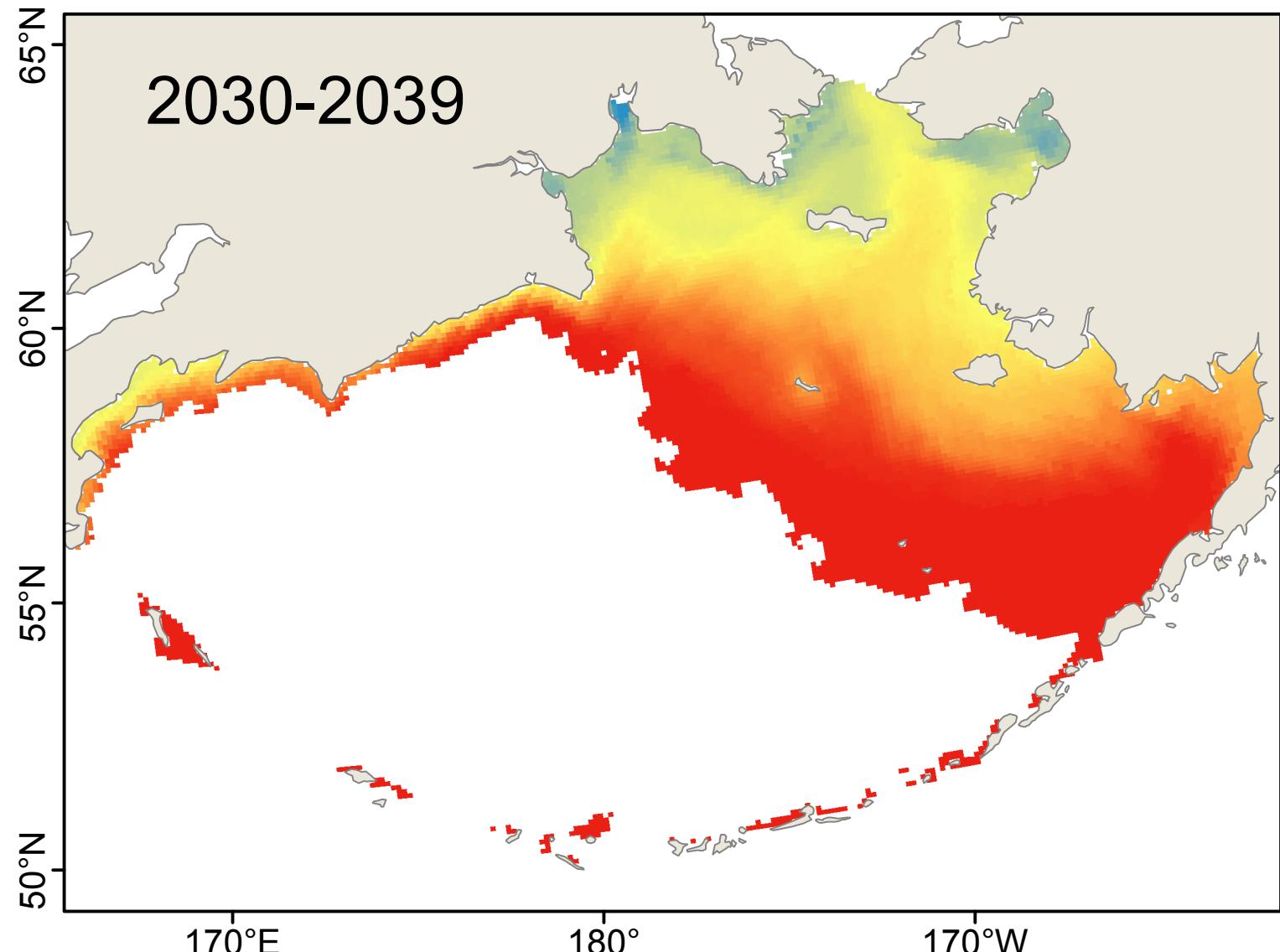
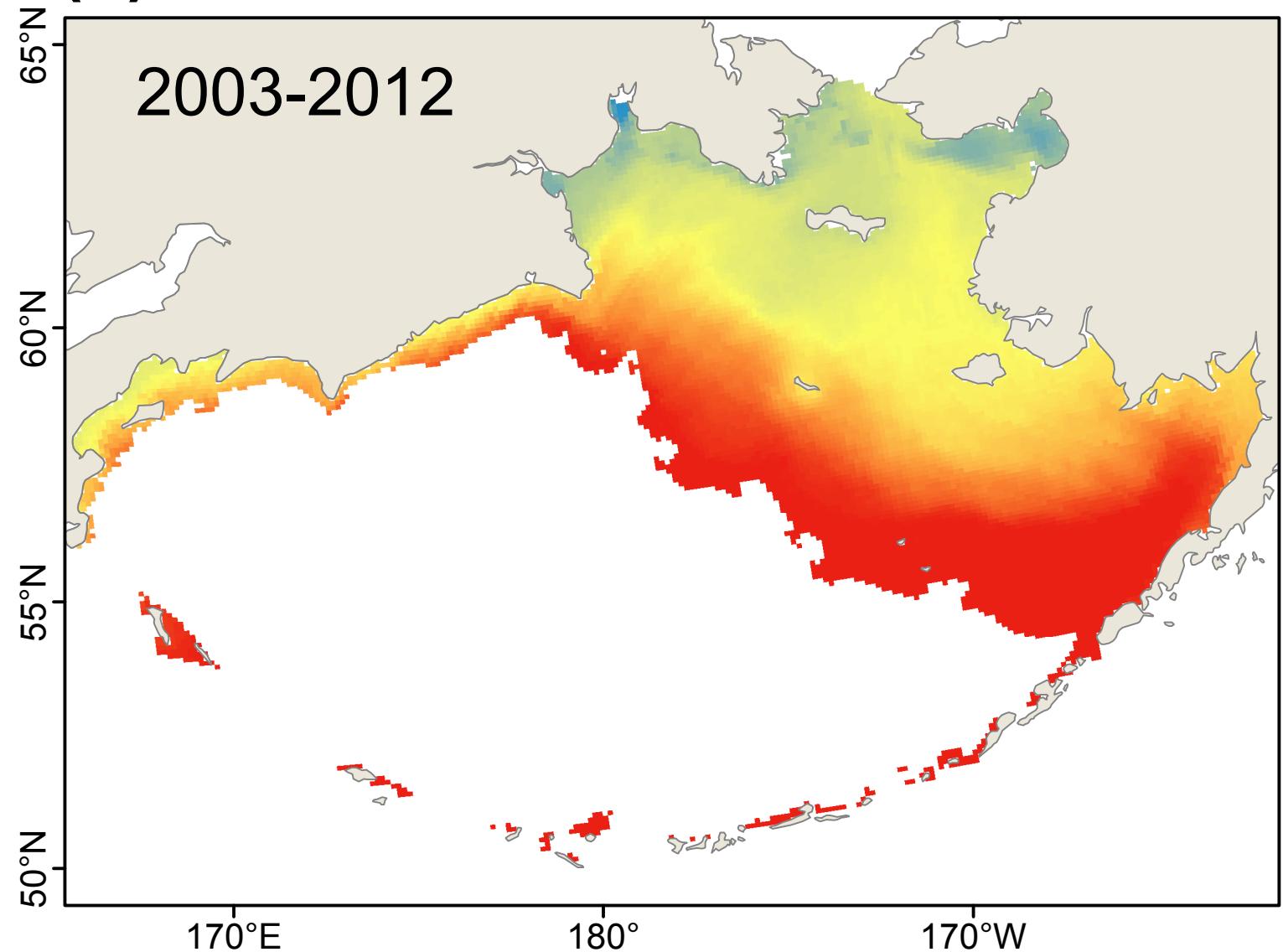


# *Macoma petalum: Weekly Survival*

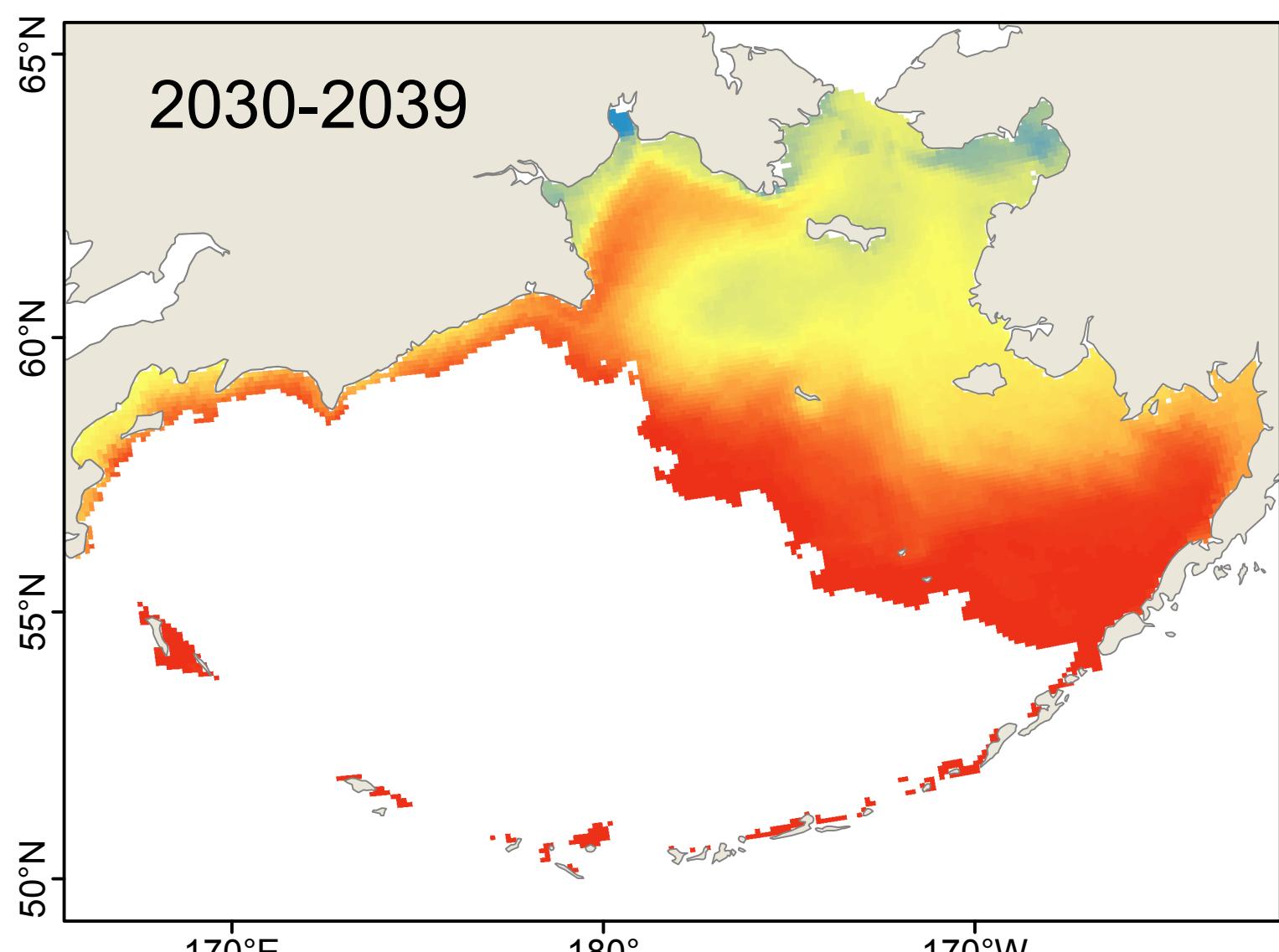
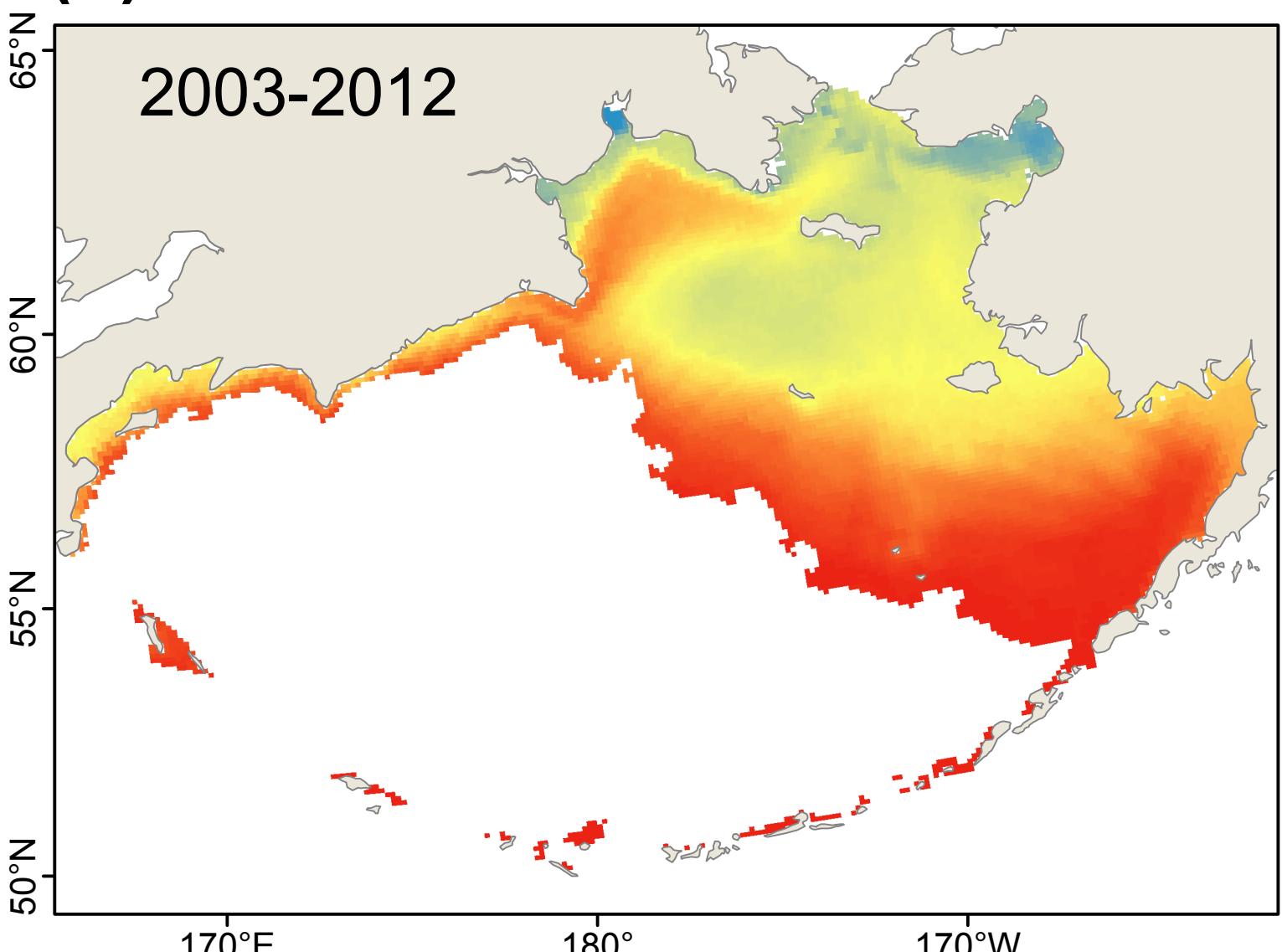
Average number of weeks of suitable habitat



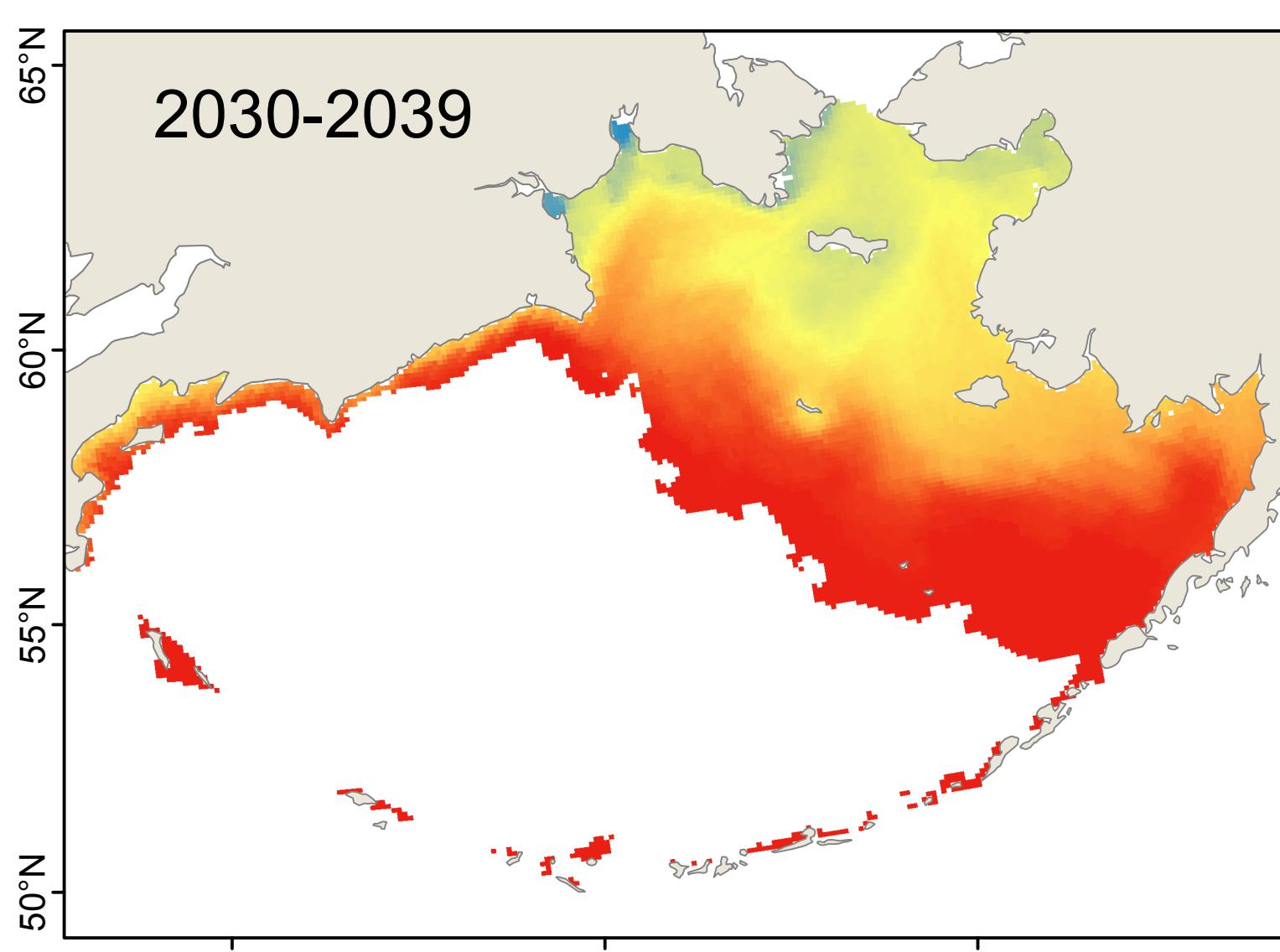
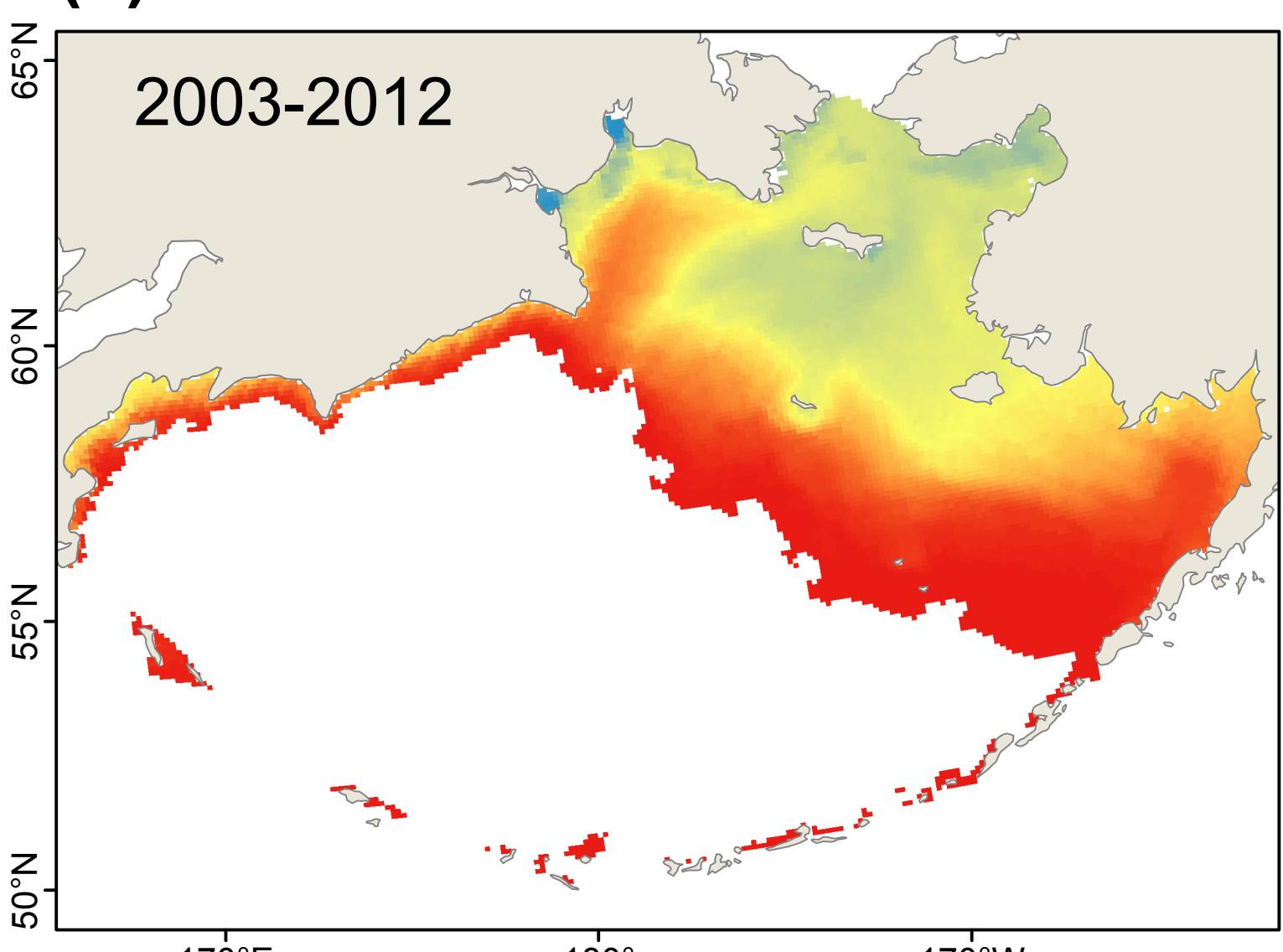
(a) Model: CGCM3-t47



(b) Model: ECHO-G

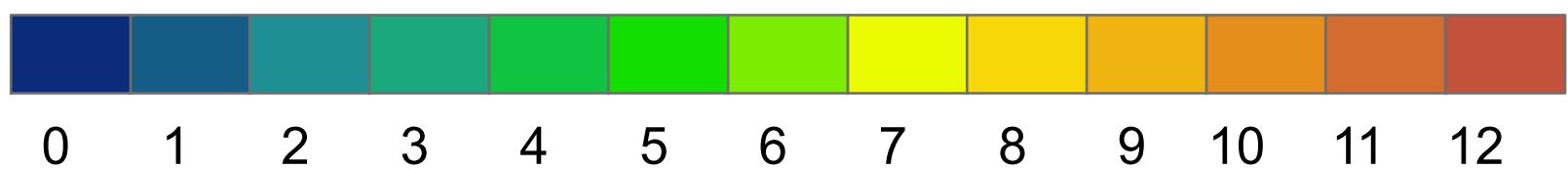


(c) Model: MIROC3.2

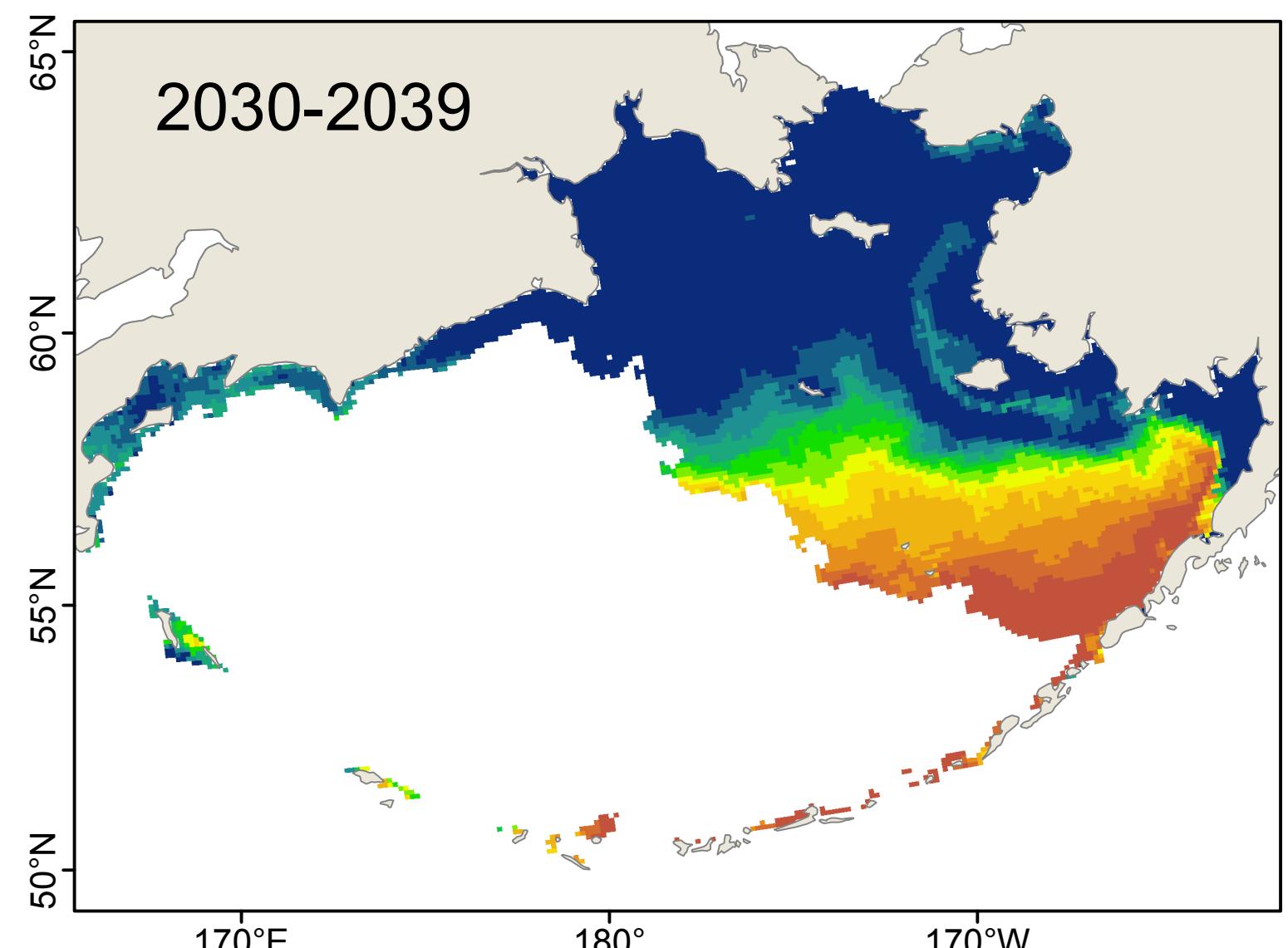
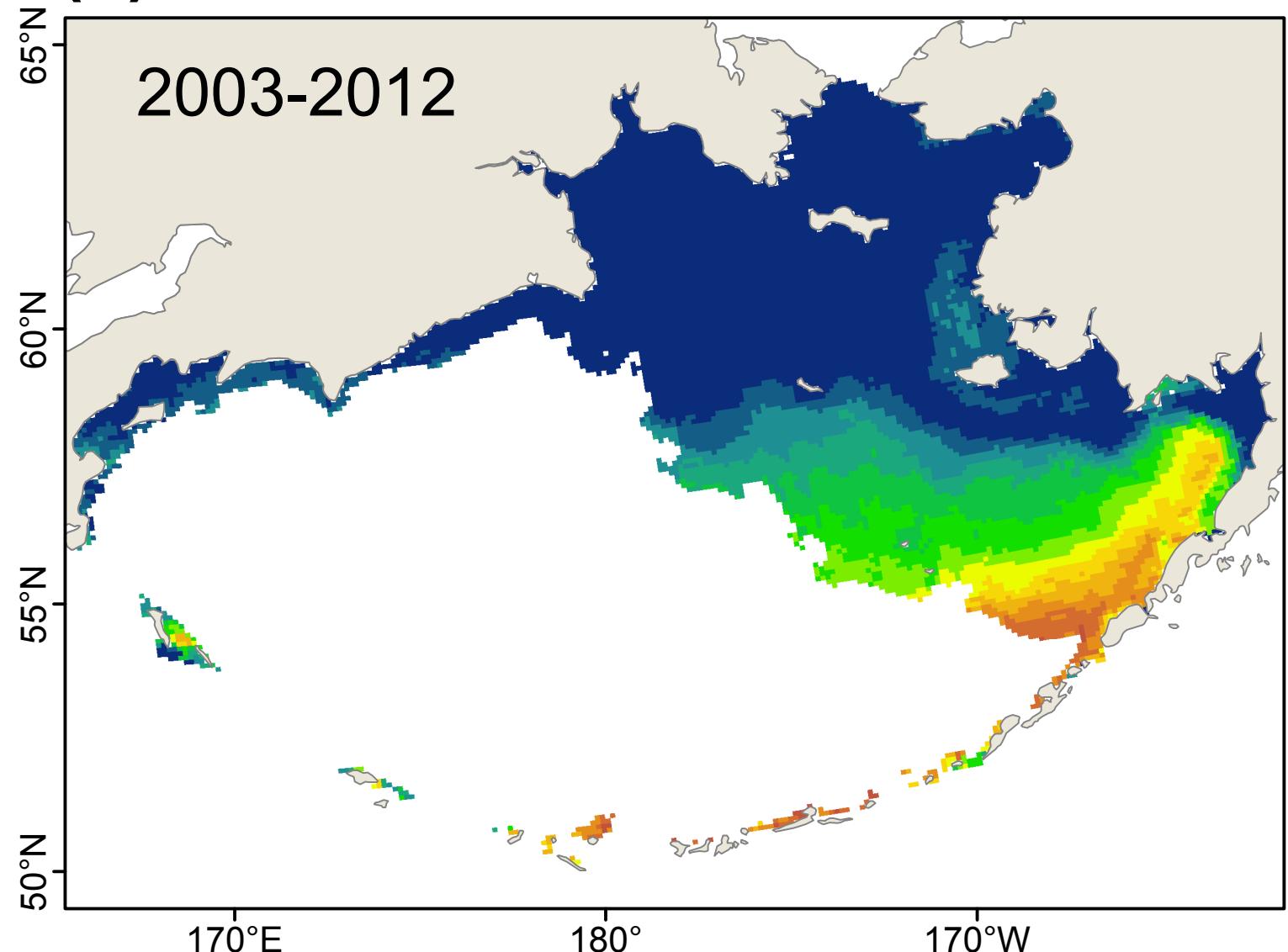


# *Macoma petalum: Reproduction*

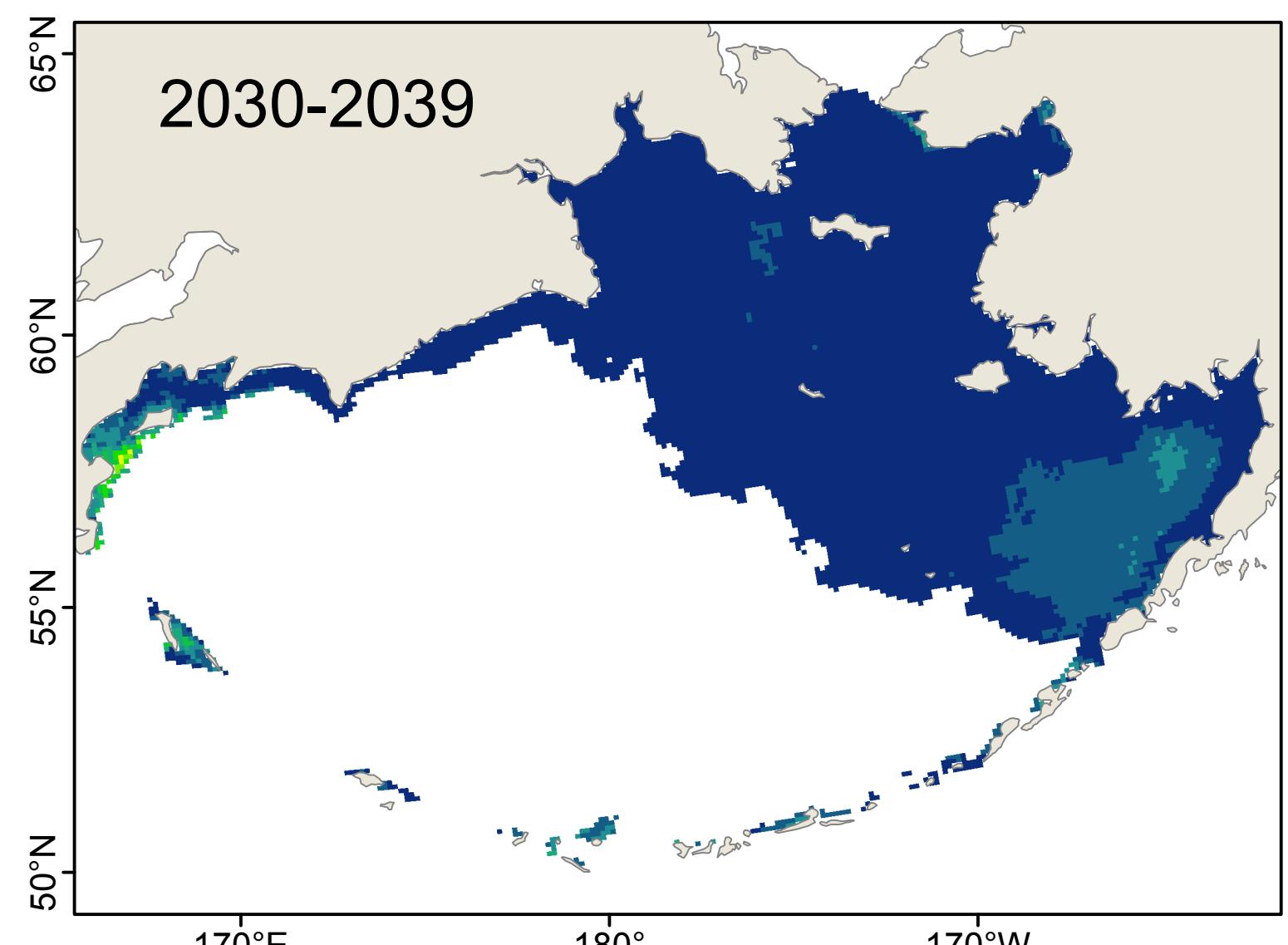
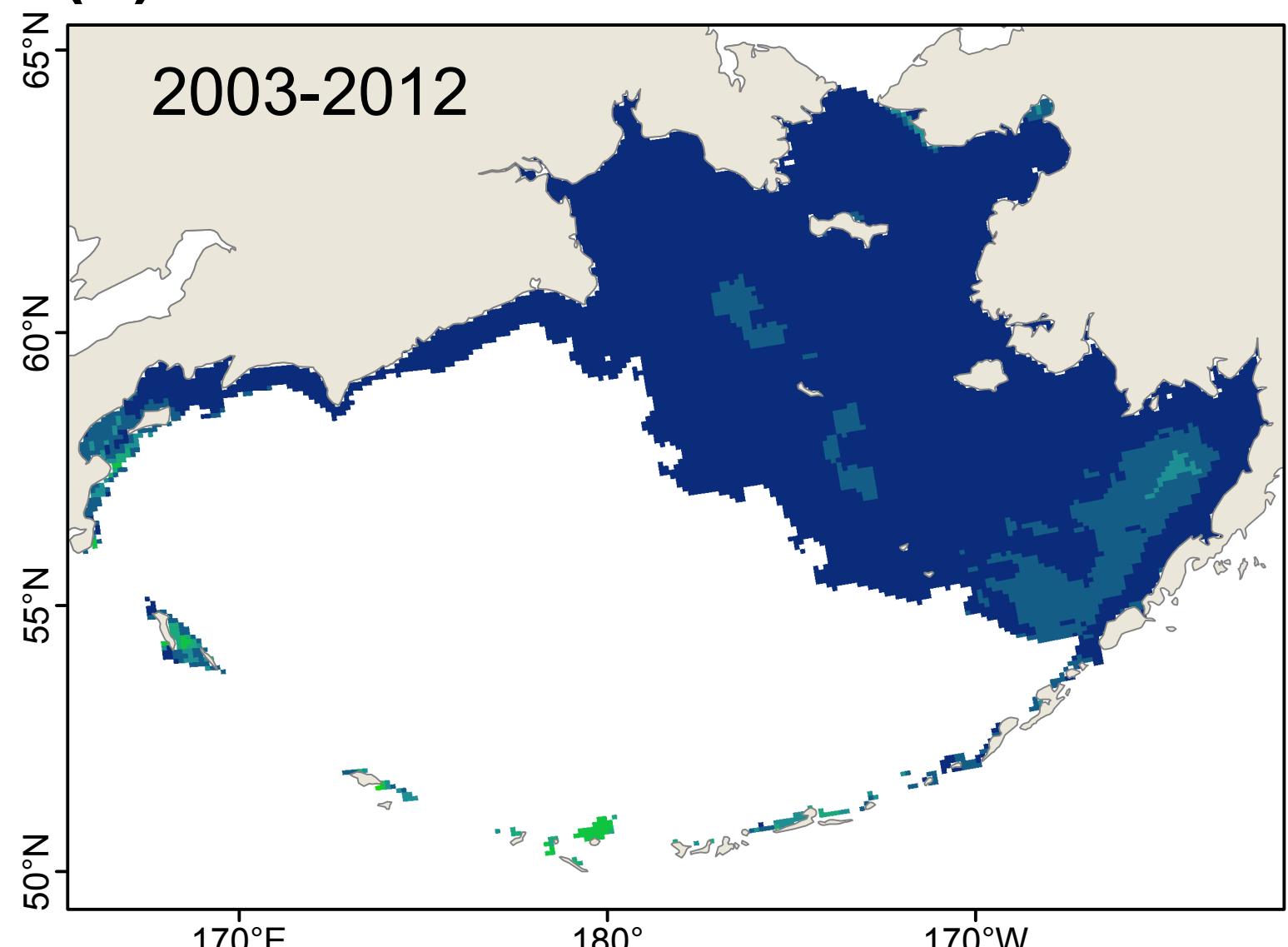
Average number of consecutive weeks of suitable habitat



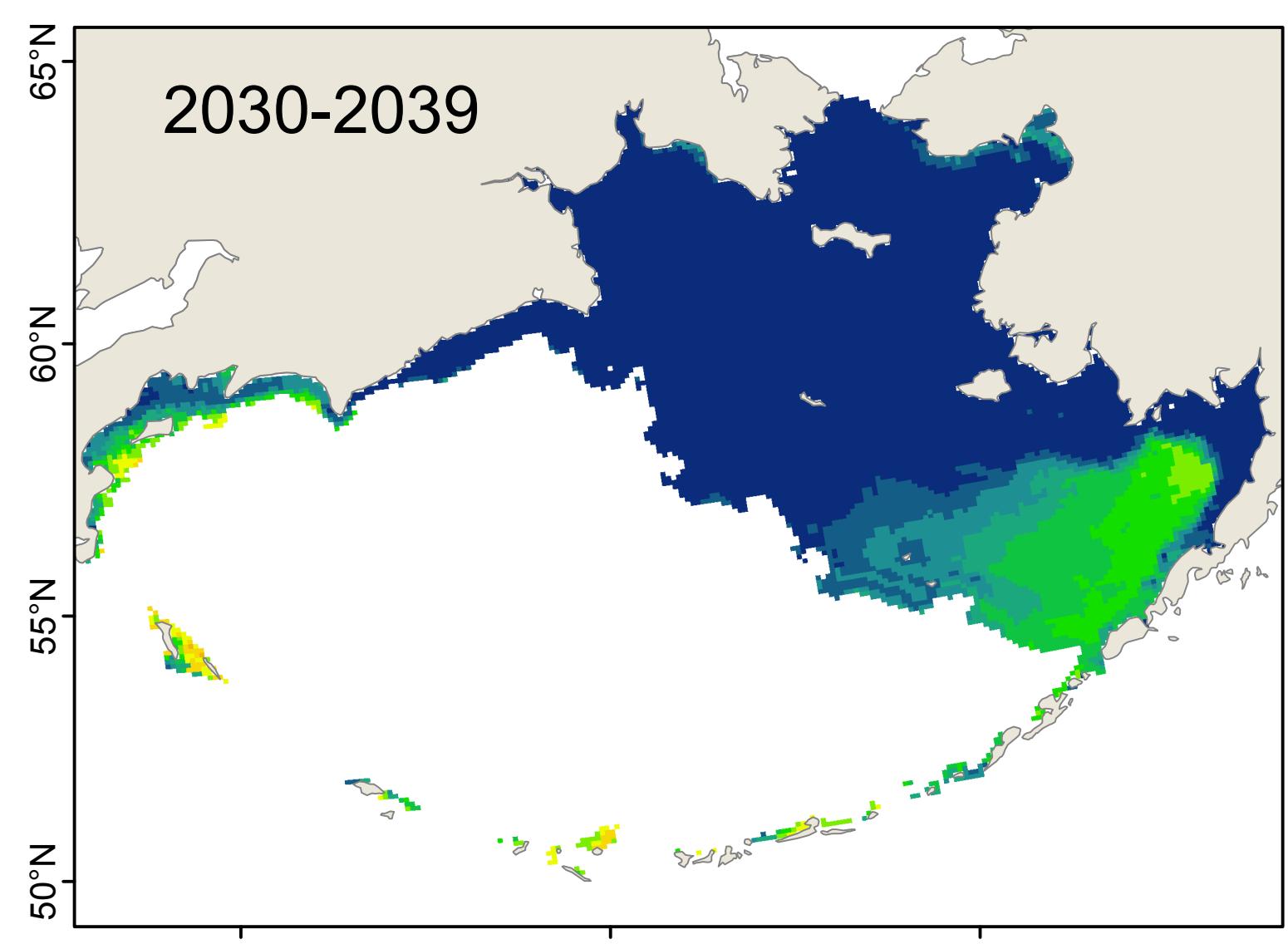
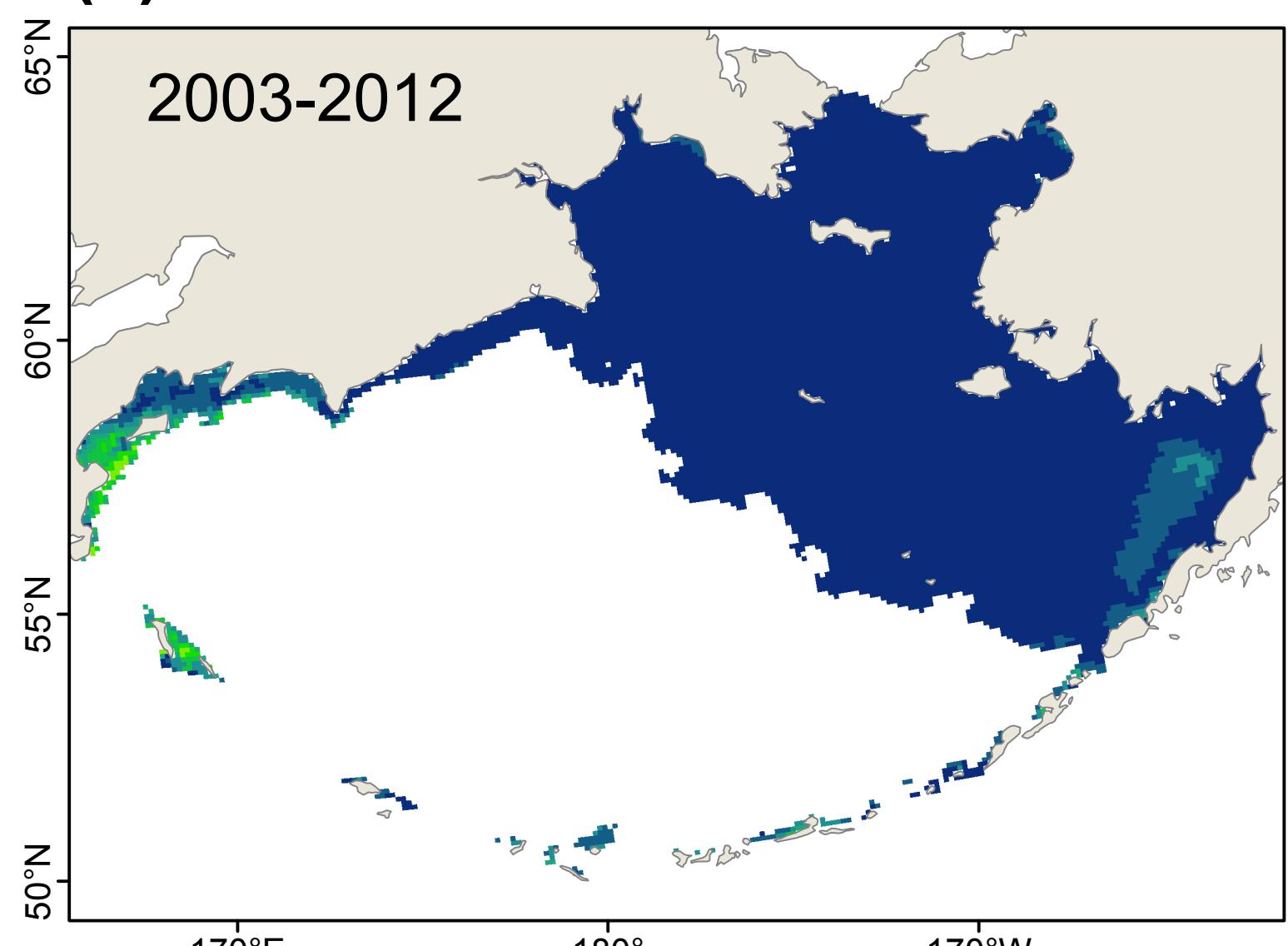
(a) Model: CGCM3-t47



(b) Model: ECHO-G

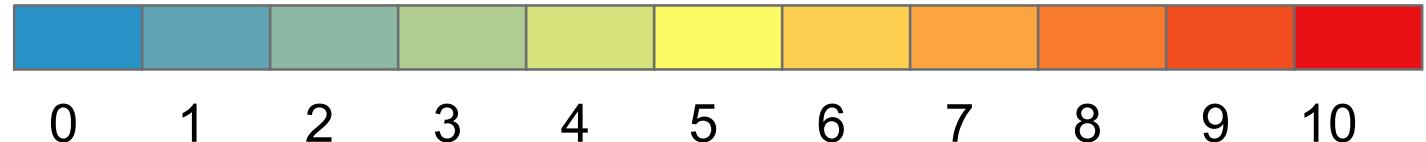


(c) Model: MIROC3.2

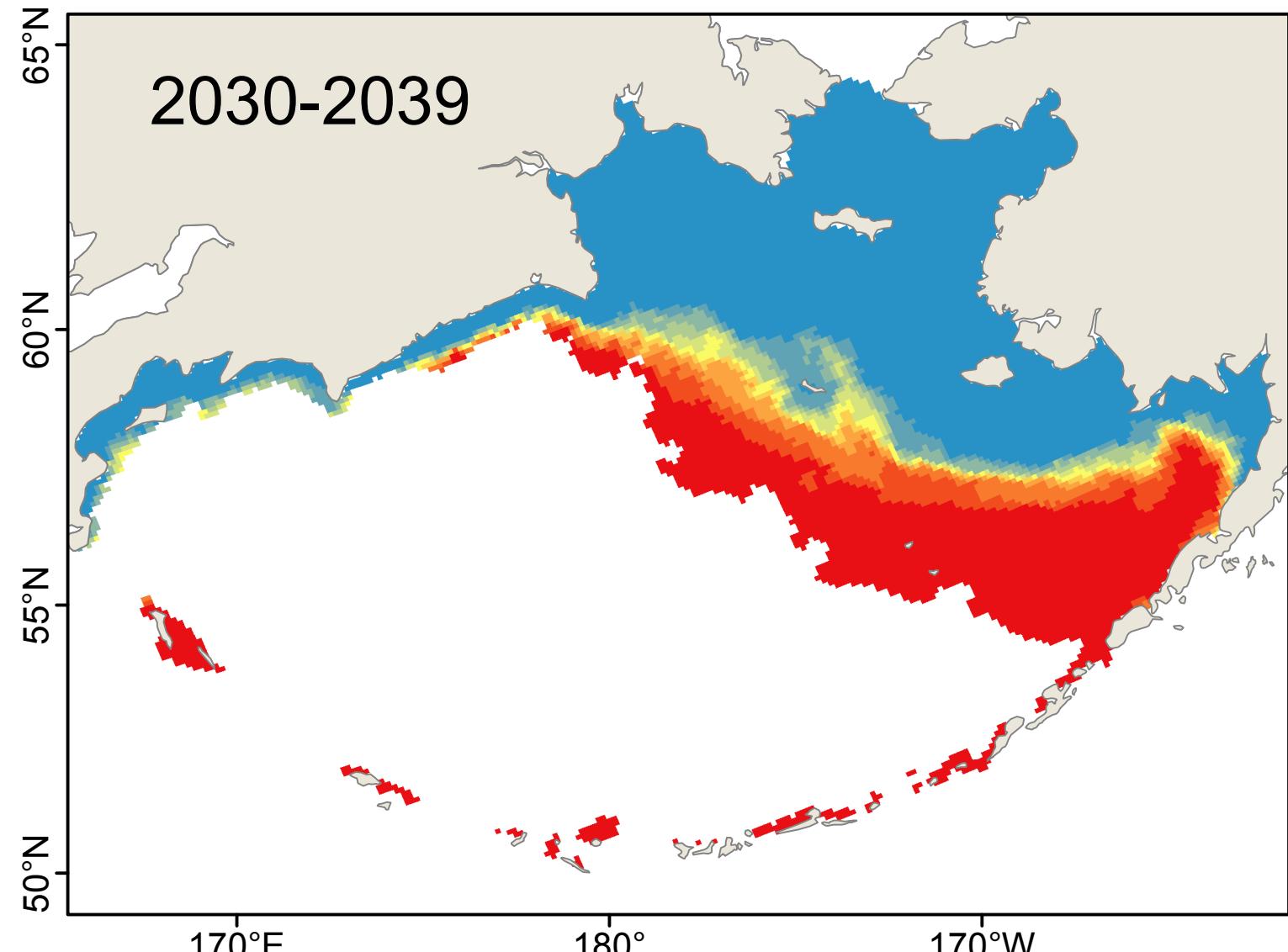
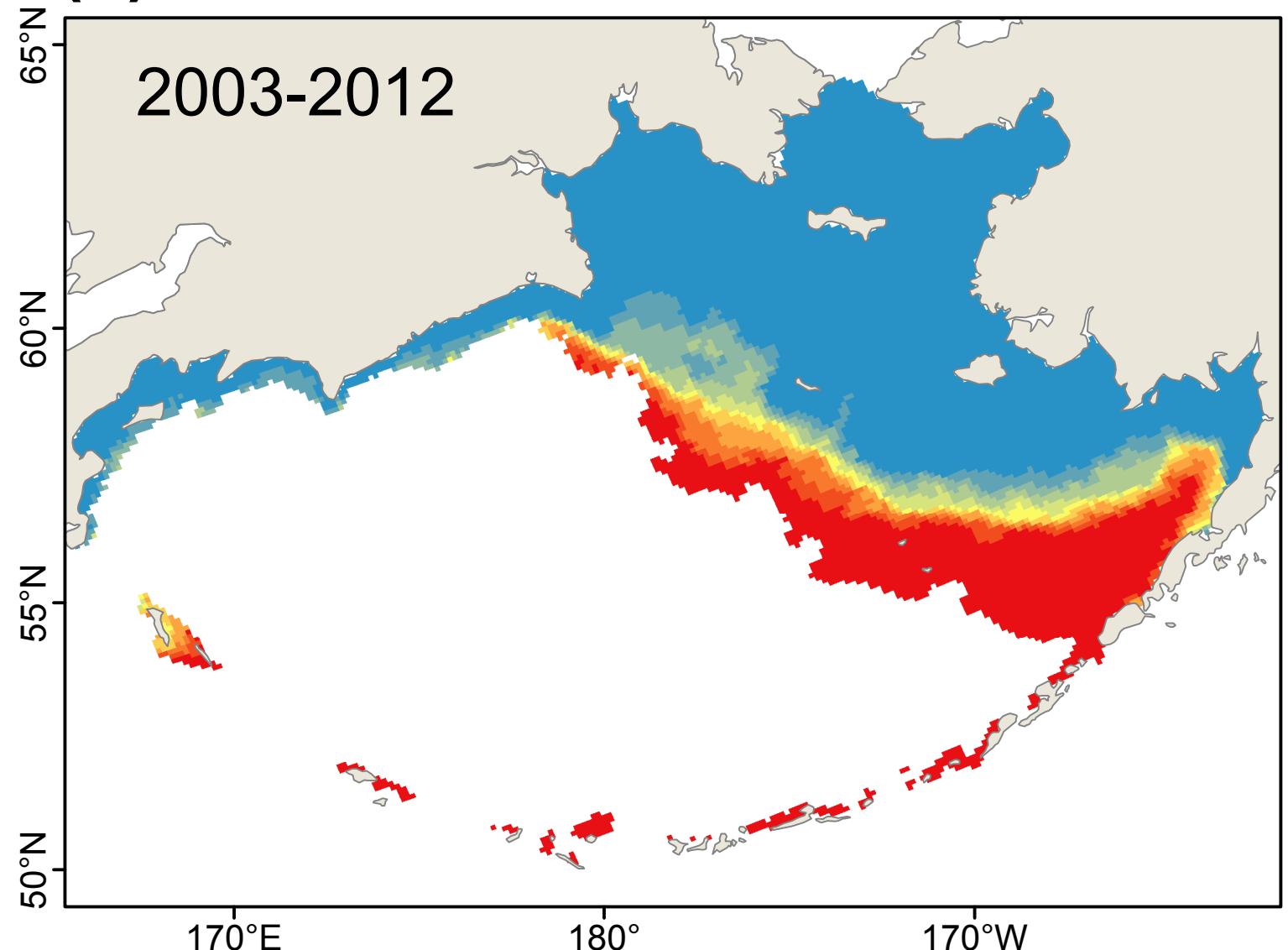


# *Mya arenaria: Year-round Survival*

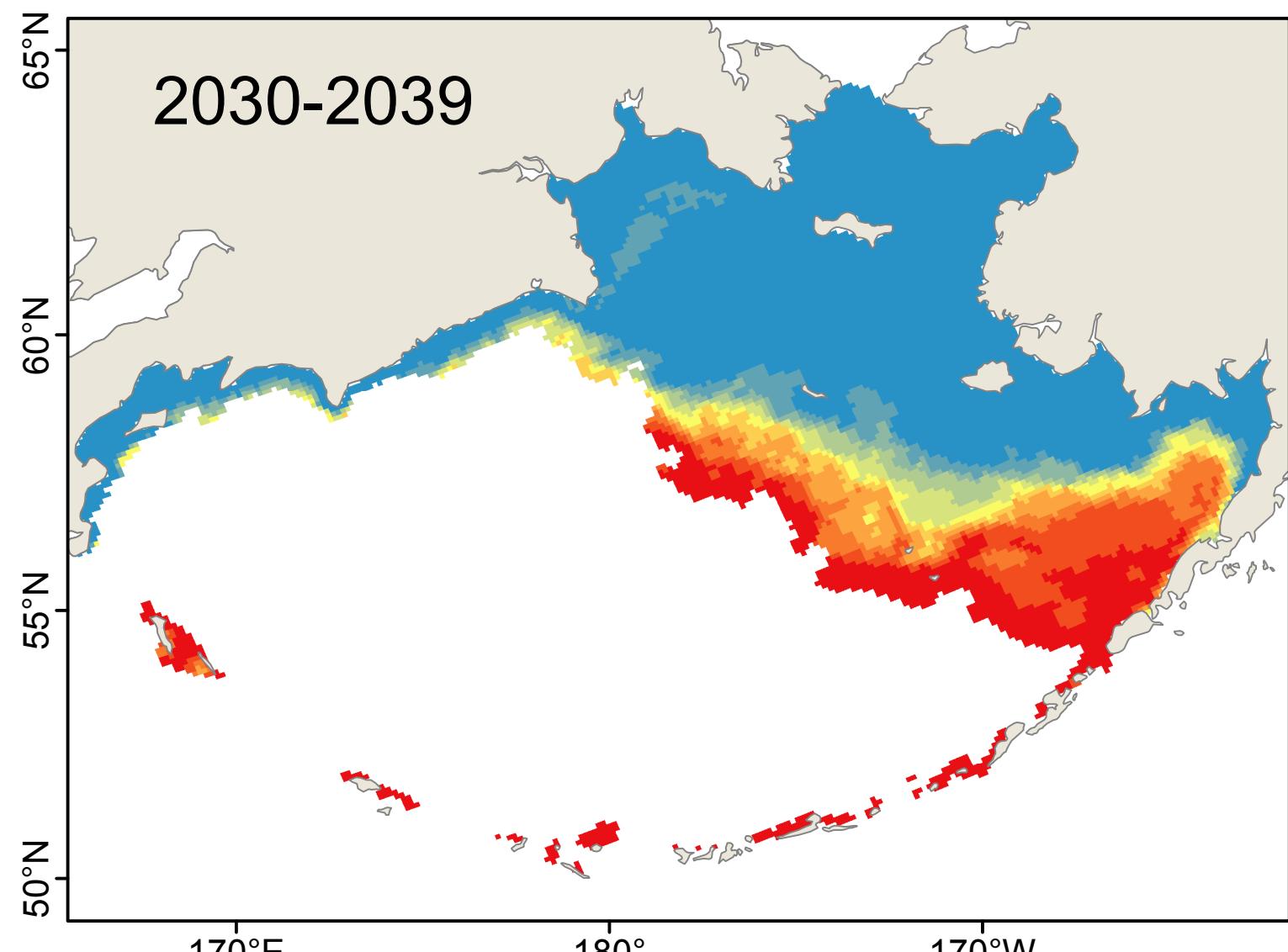
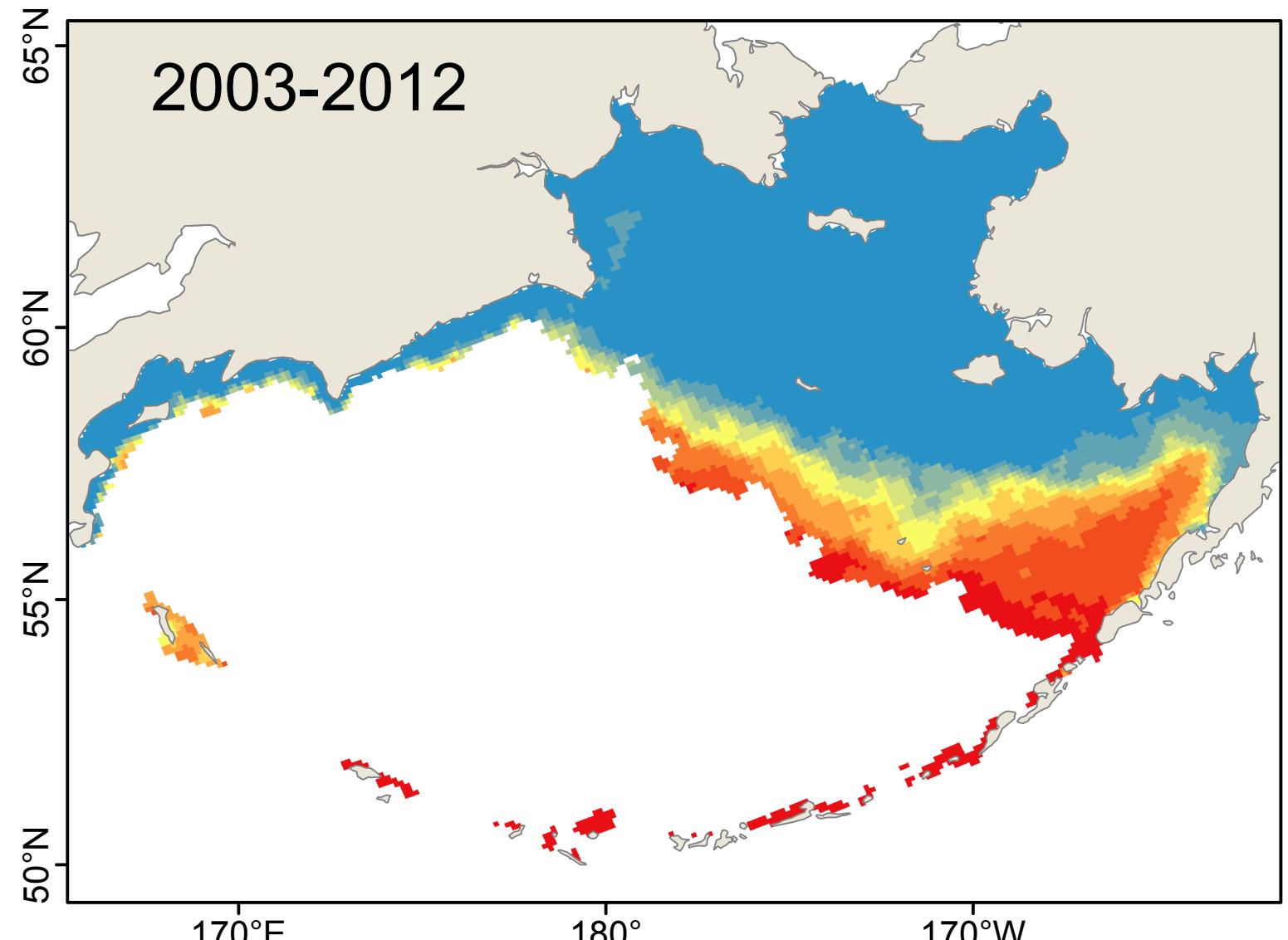
Number of years with suitable habitat



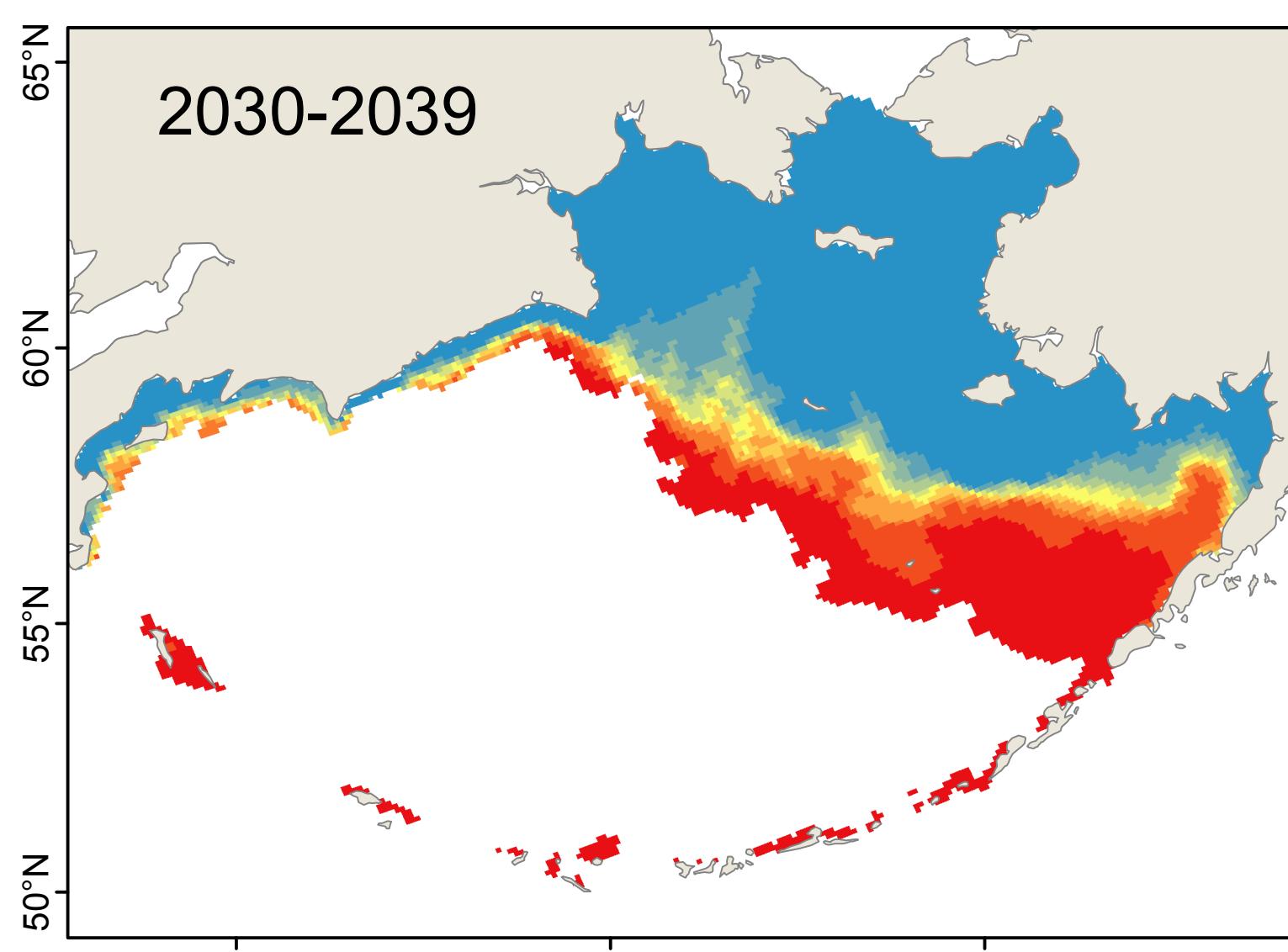
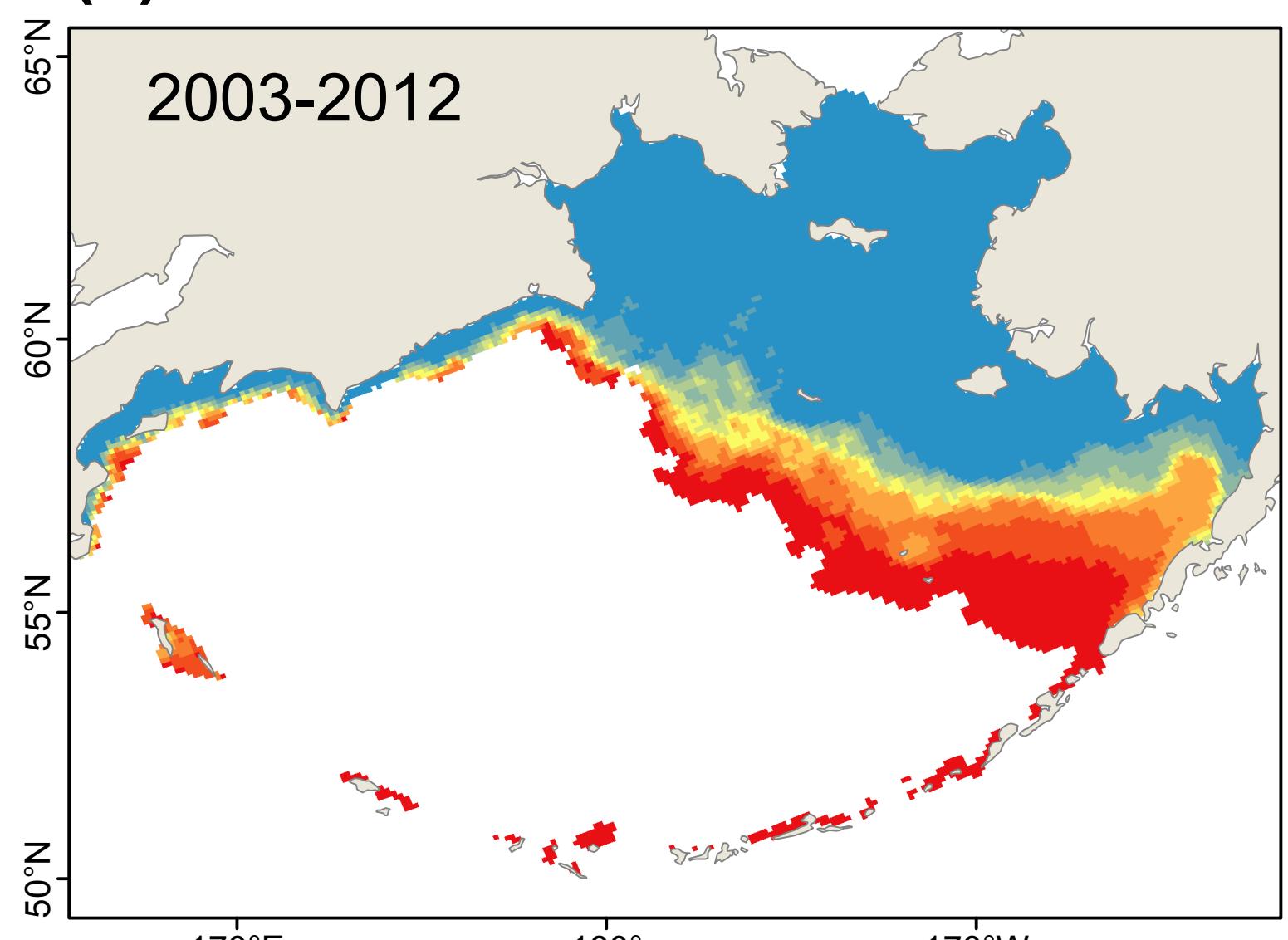
(a) Model: CGCM3-t47



(b) Model: ECHO-G

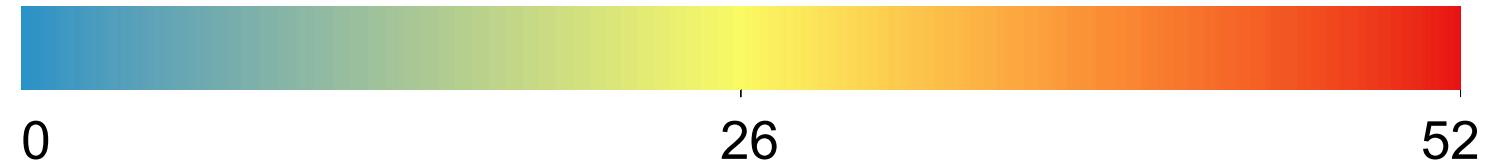


(c) Model: MIROC3.2

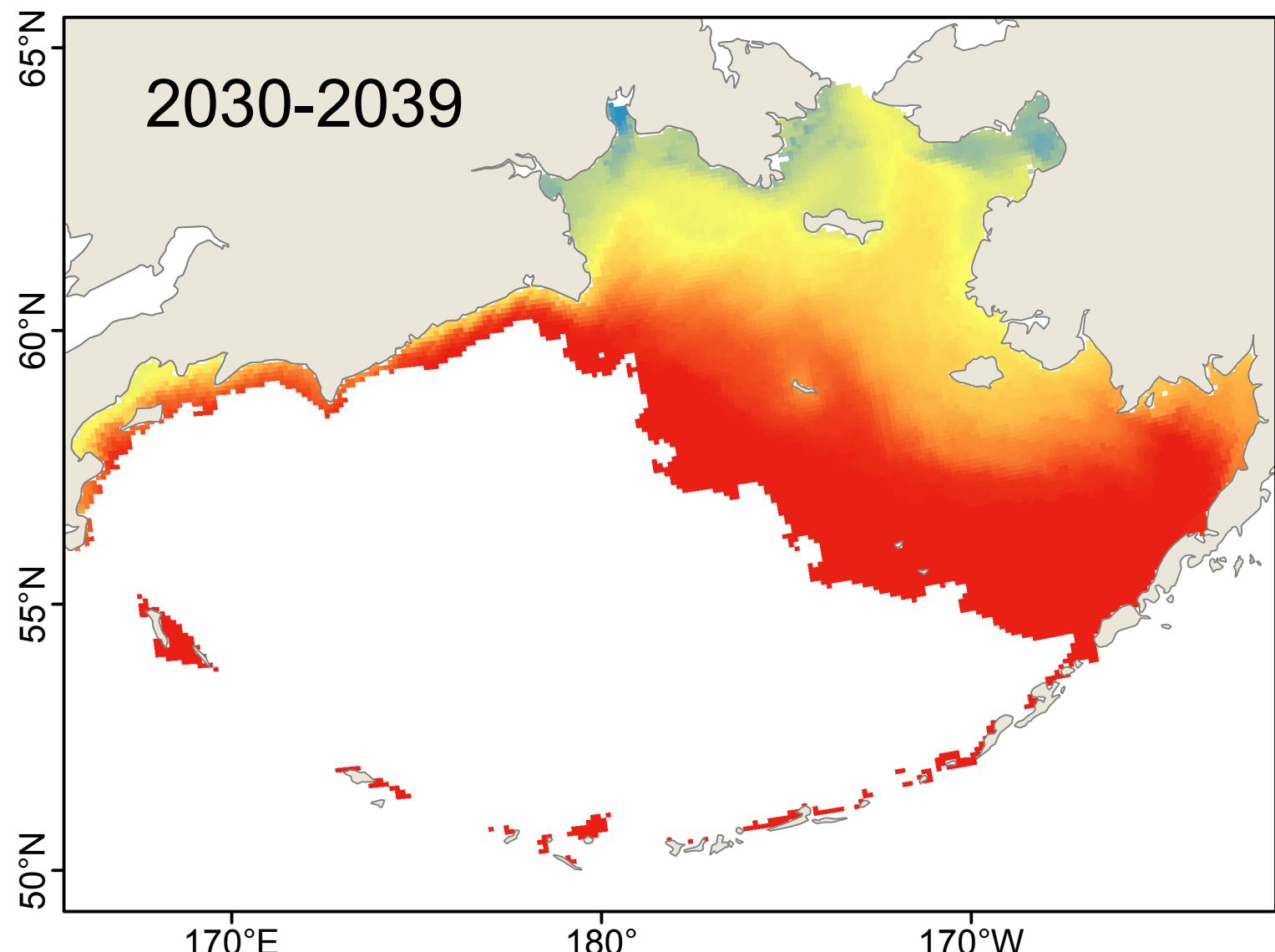
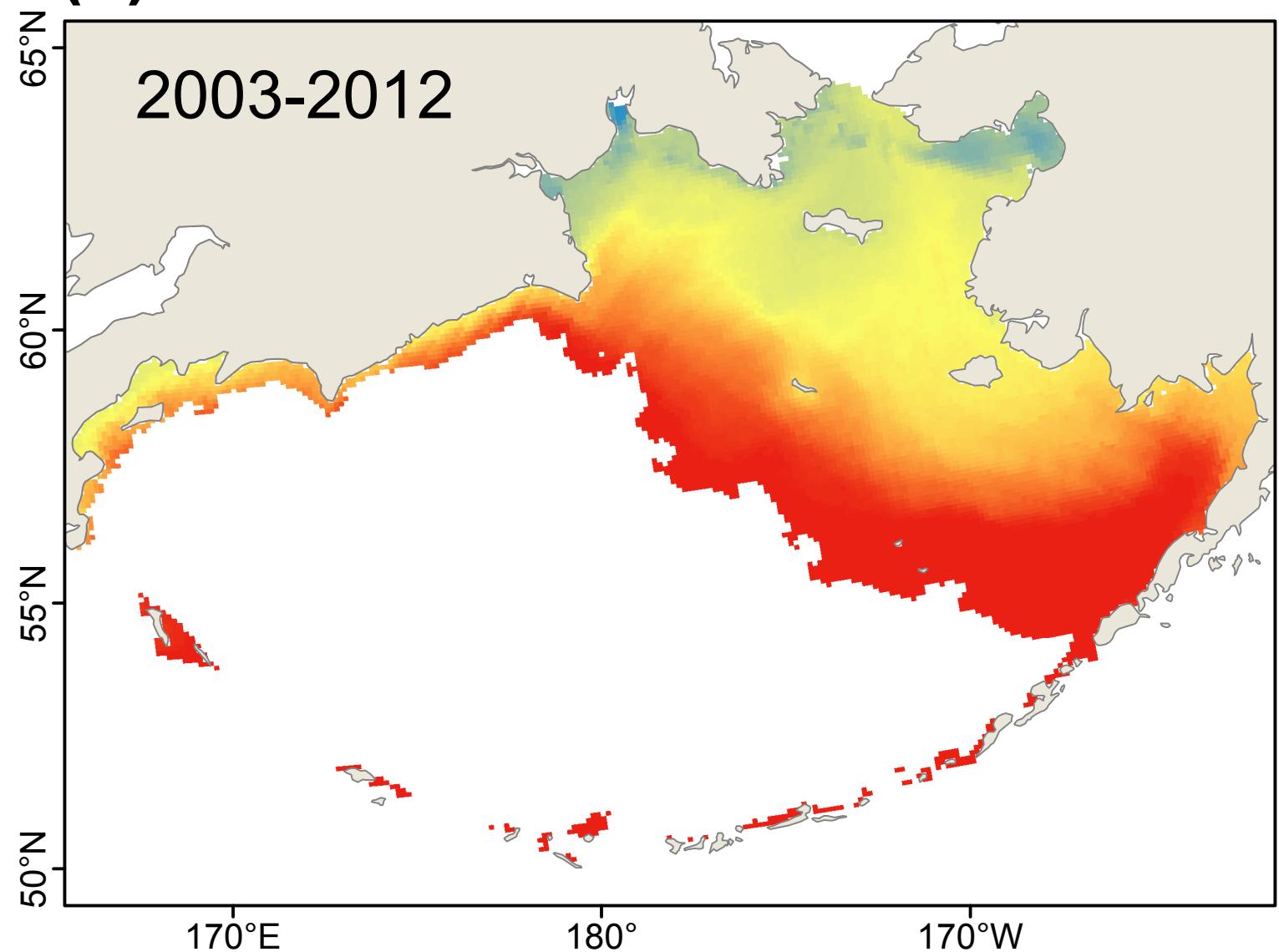


# *Mya arenaria: Weekly Survival*

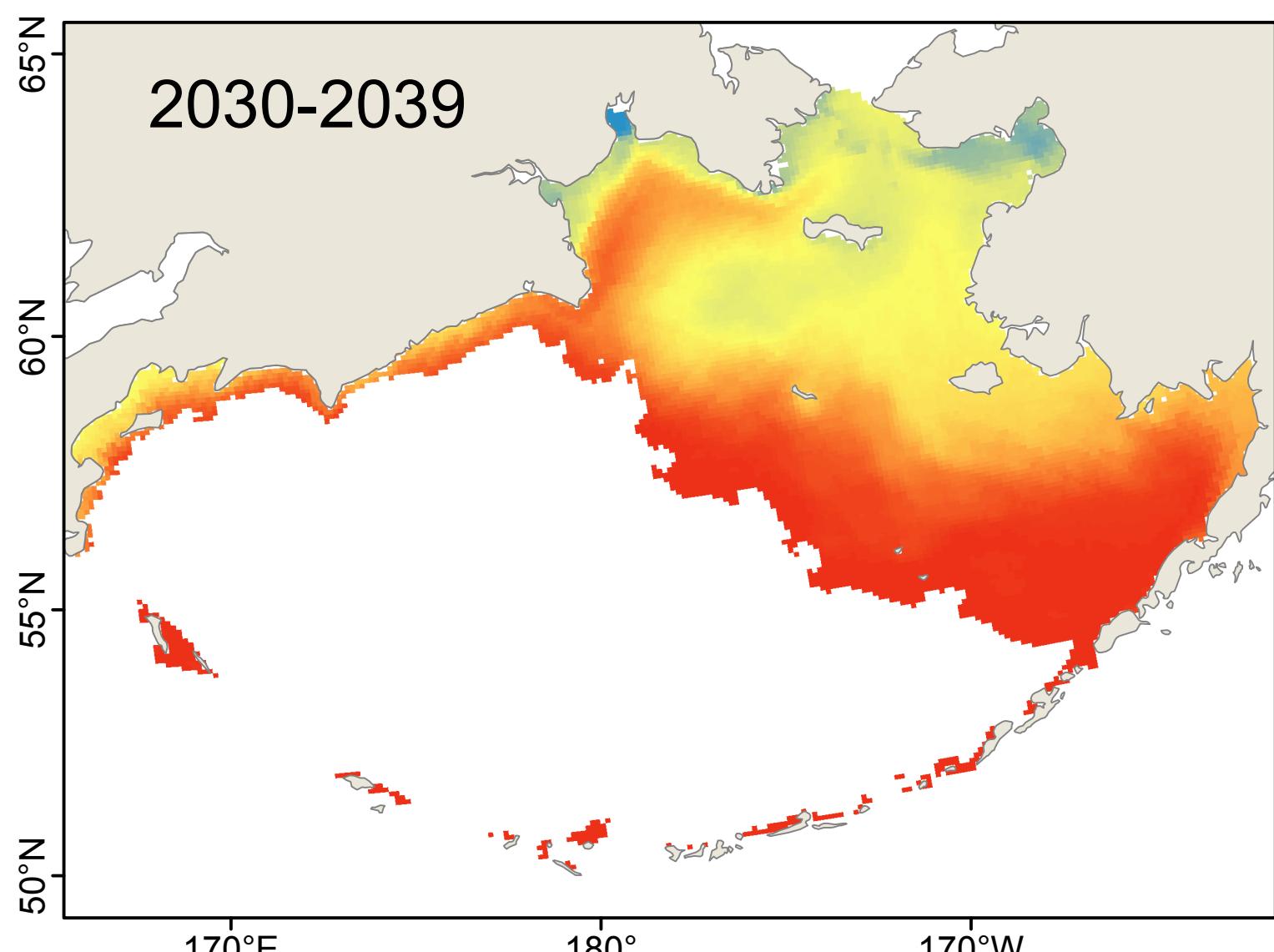
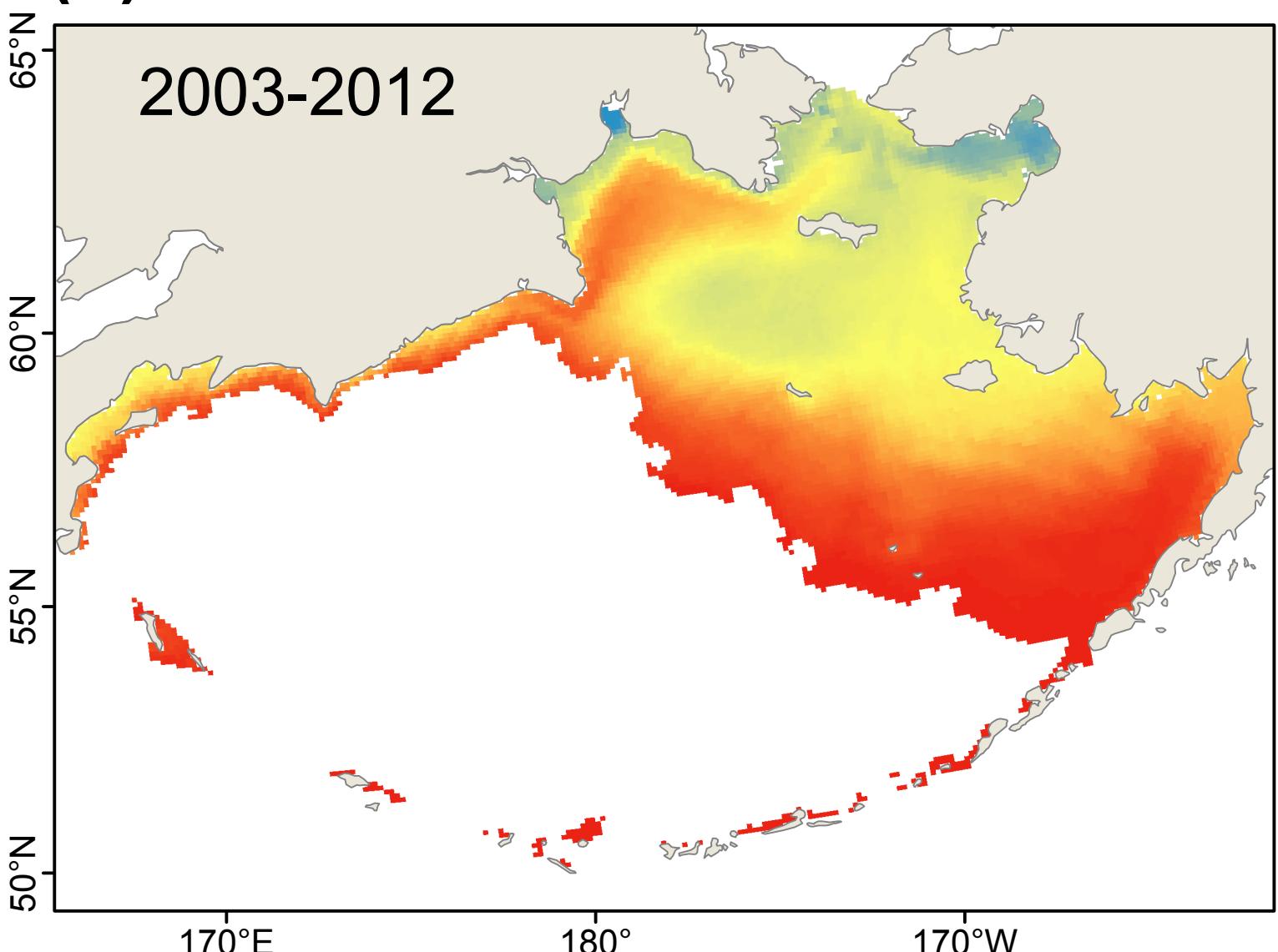
Average number of weeks of suitable habitat



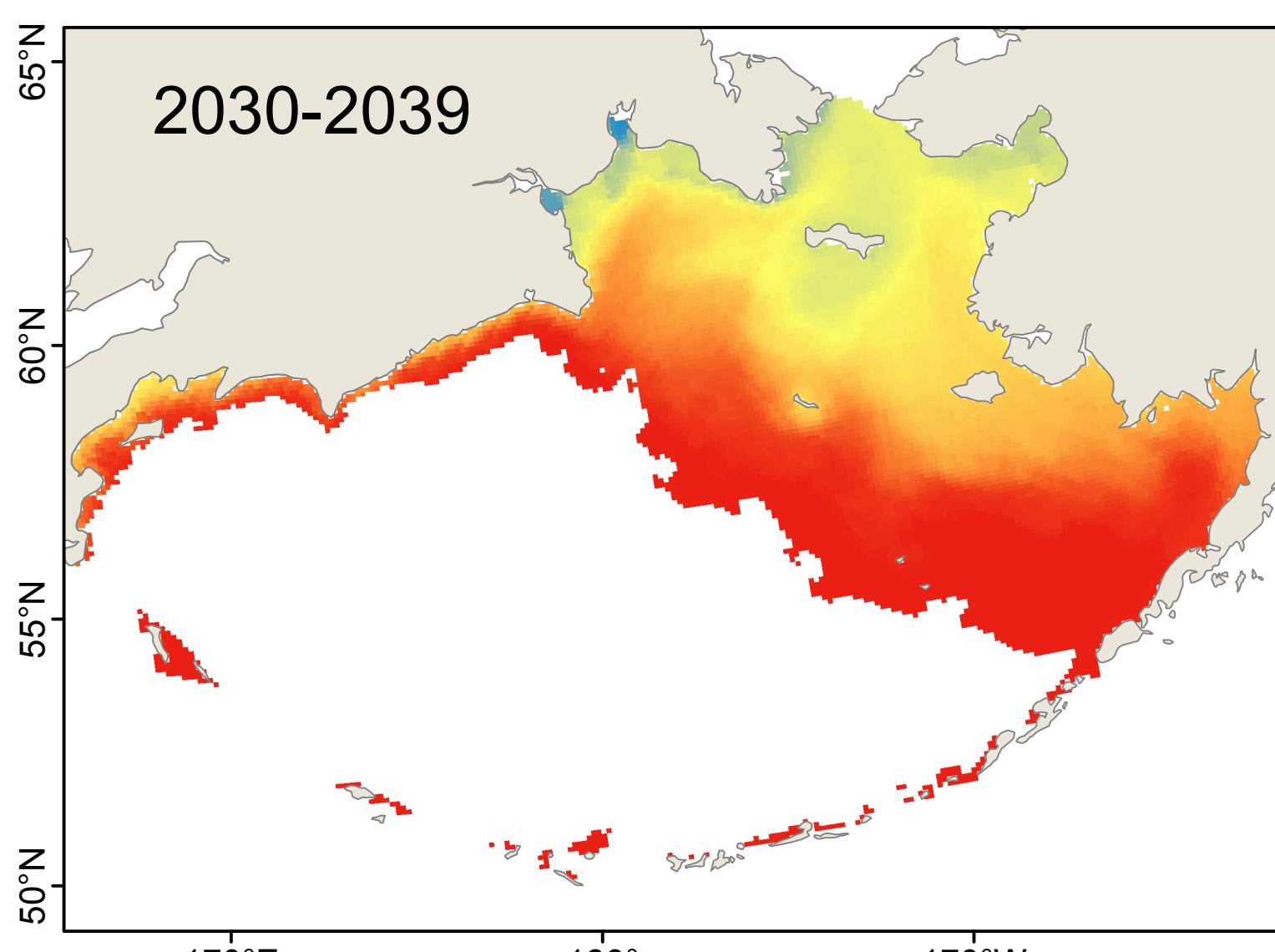
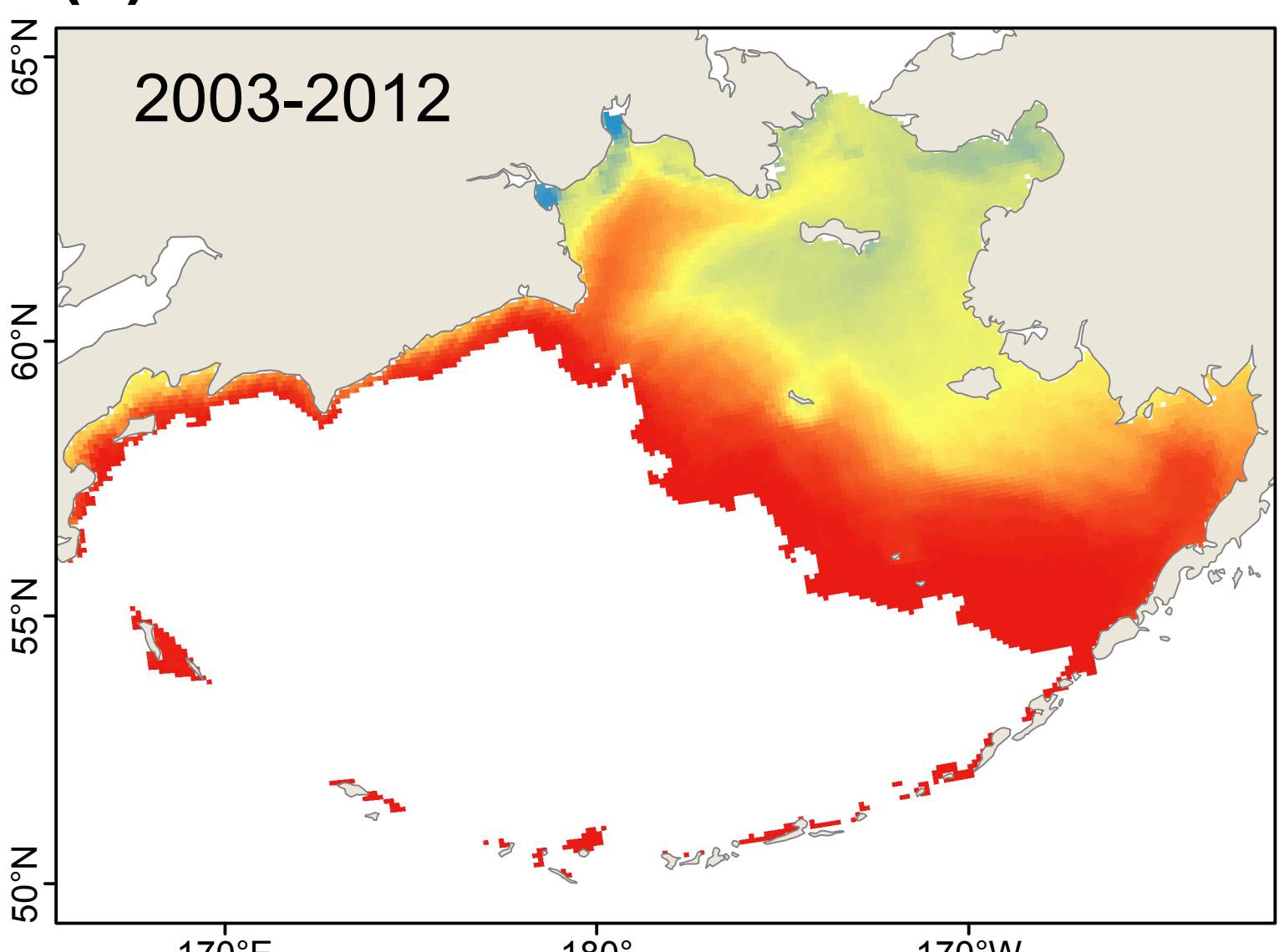
(a) Model: CGCM3-t47



(b) Model: ECHO-G

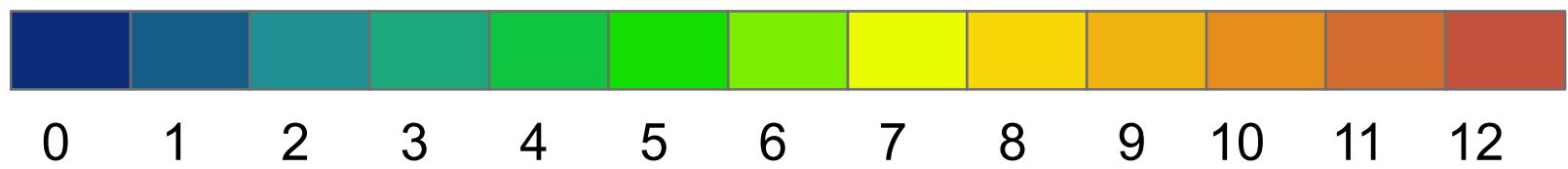


(c) Model: MIROC3.2

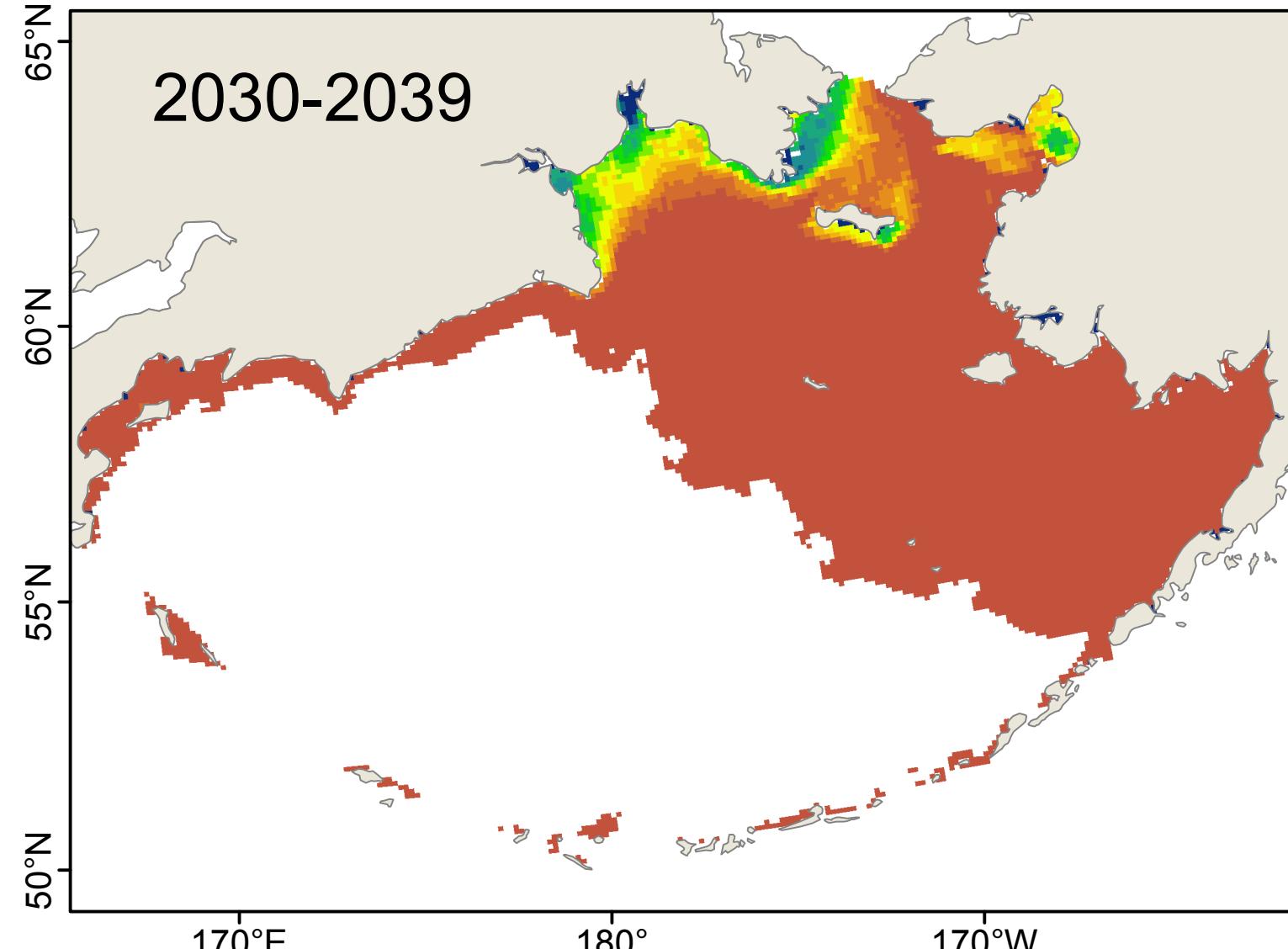
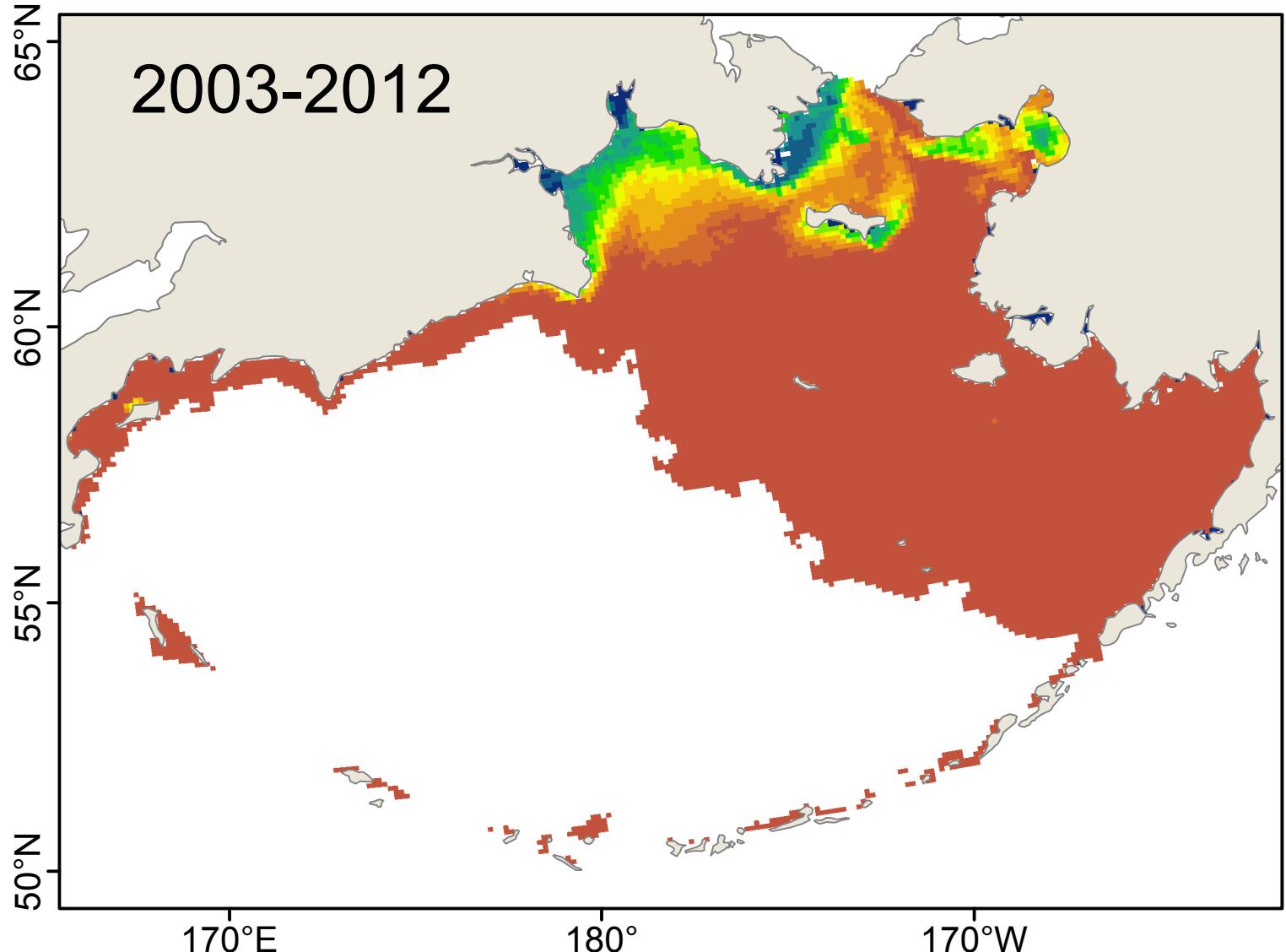


# *Mya arenaria: Reproduction*

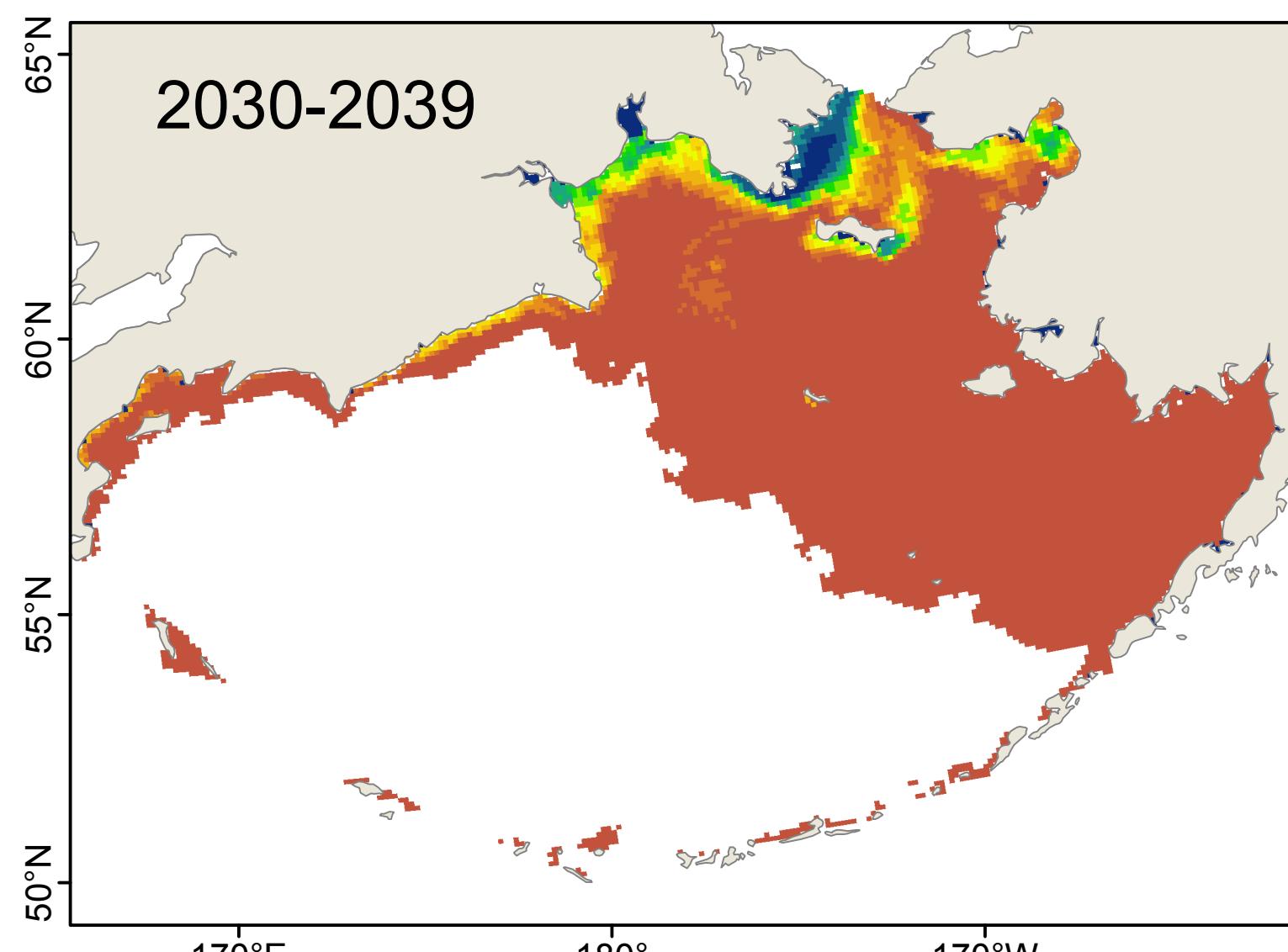
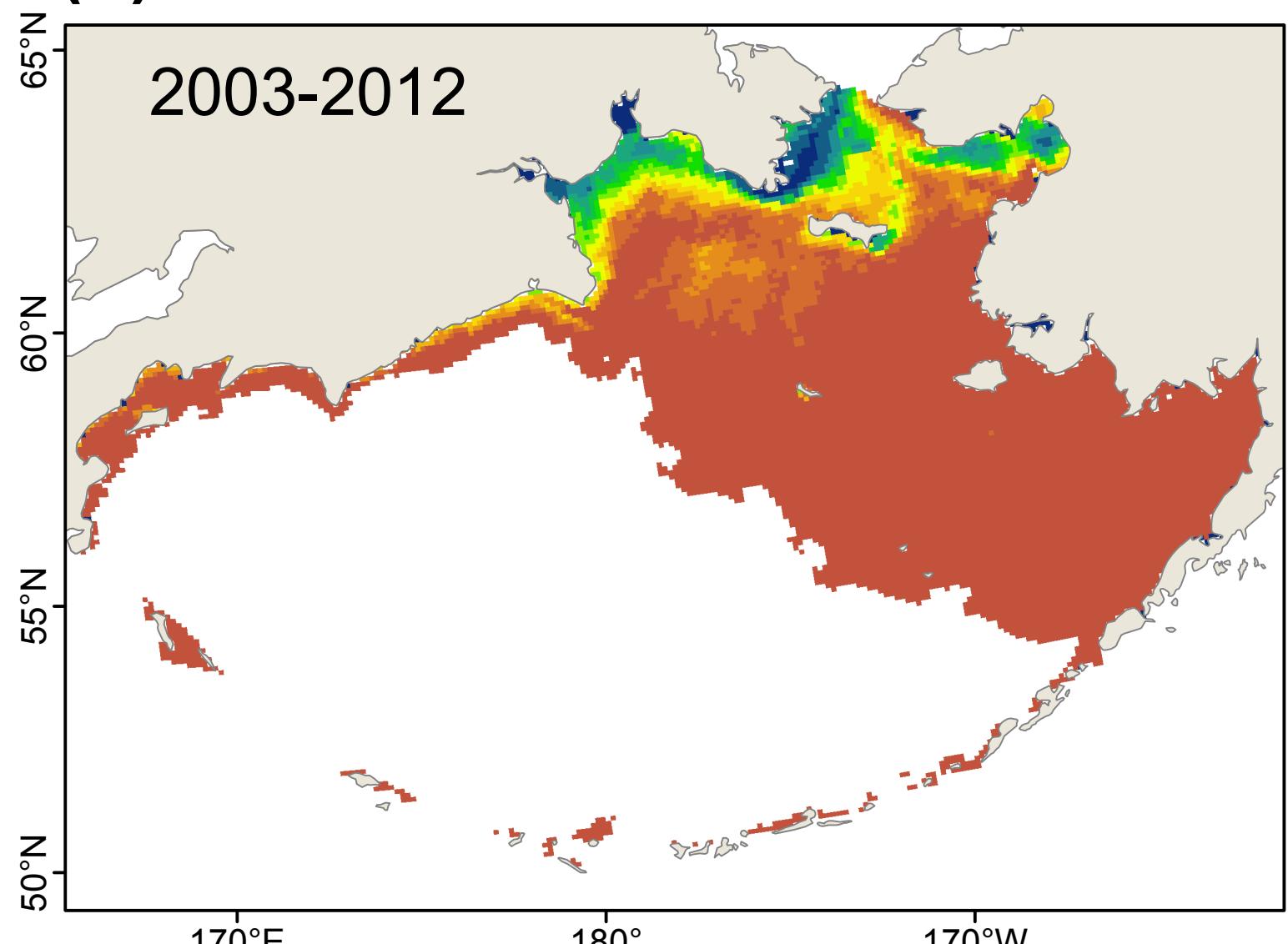
Average number of consecutive weeks of suitable habitat



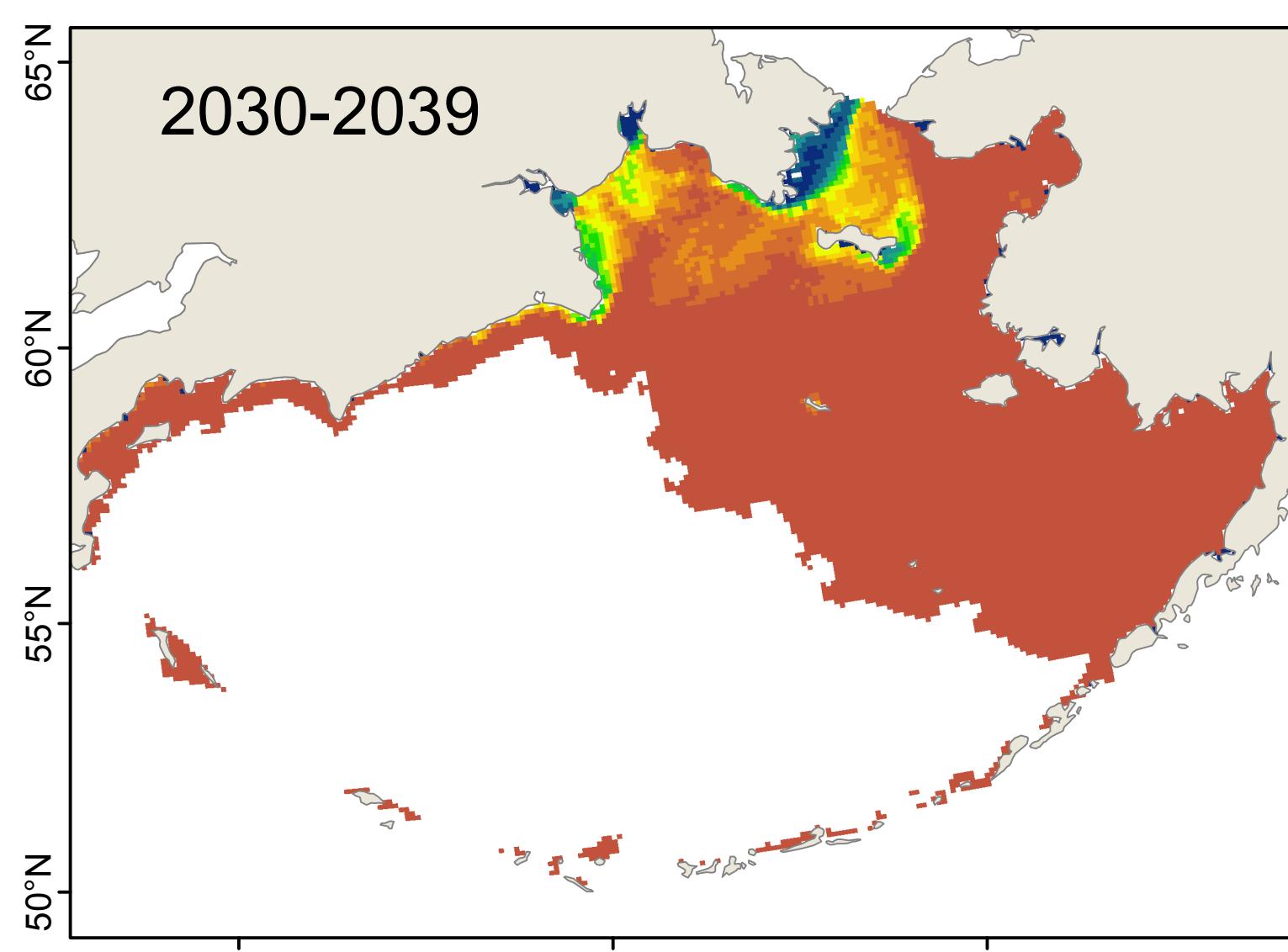
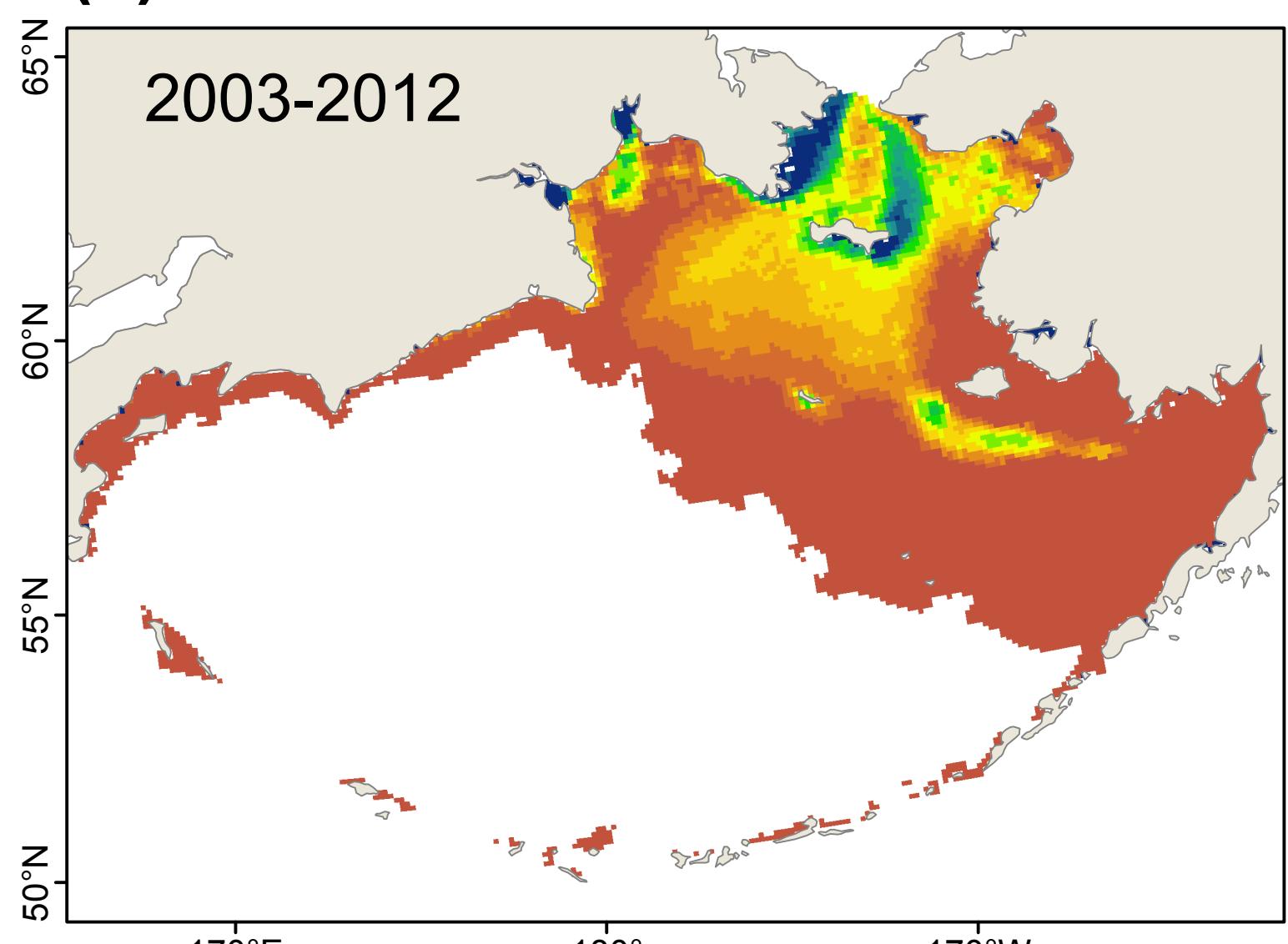
(a) Model: CGCM3-t47



(b) Model: ECHO-G



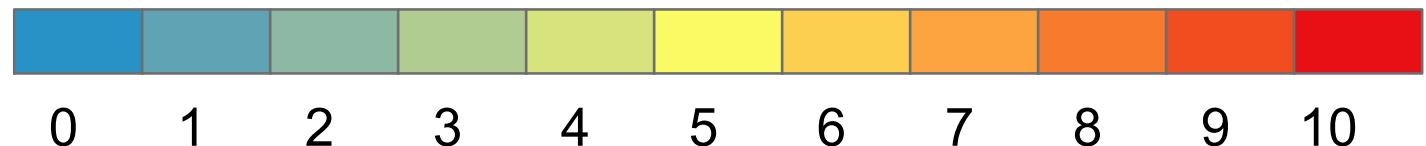
(c) Model: MIROC3.2



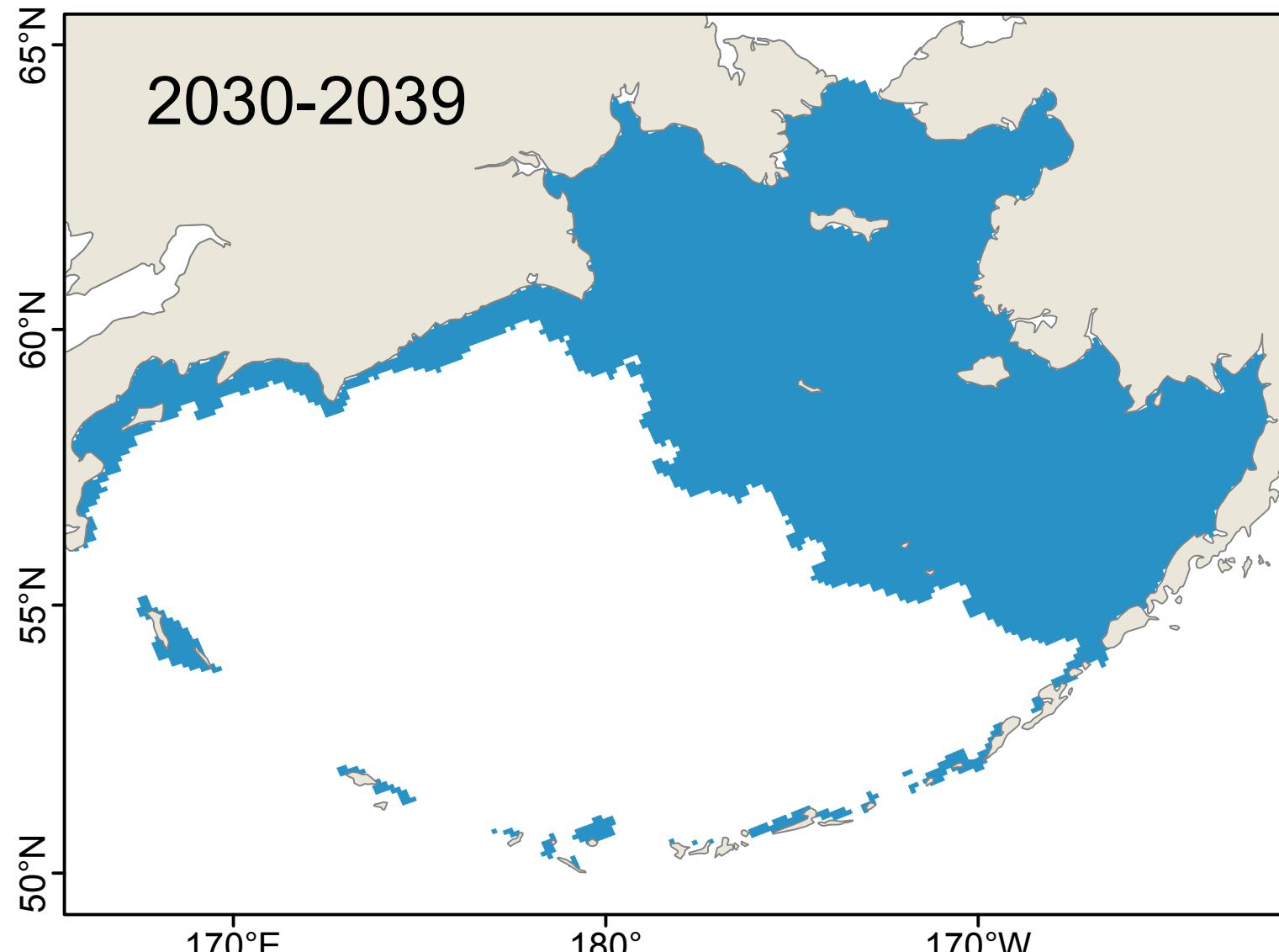
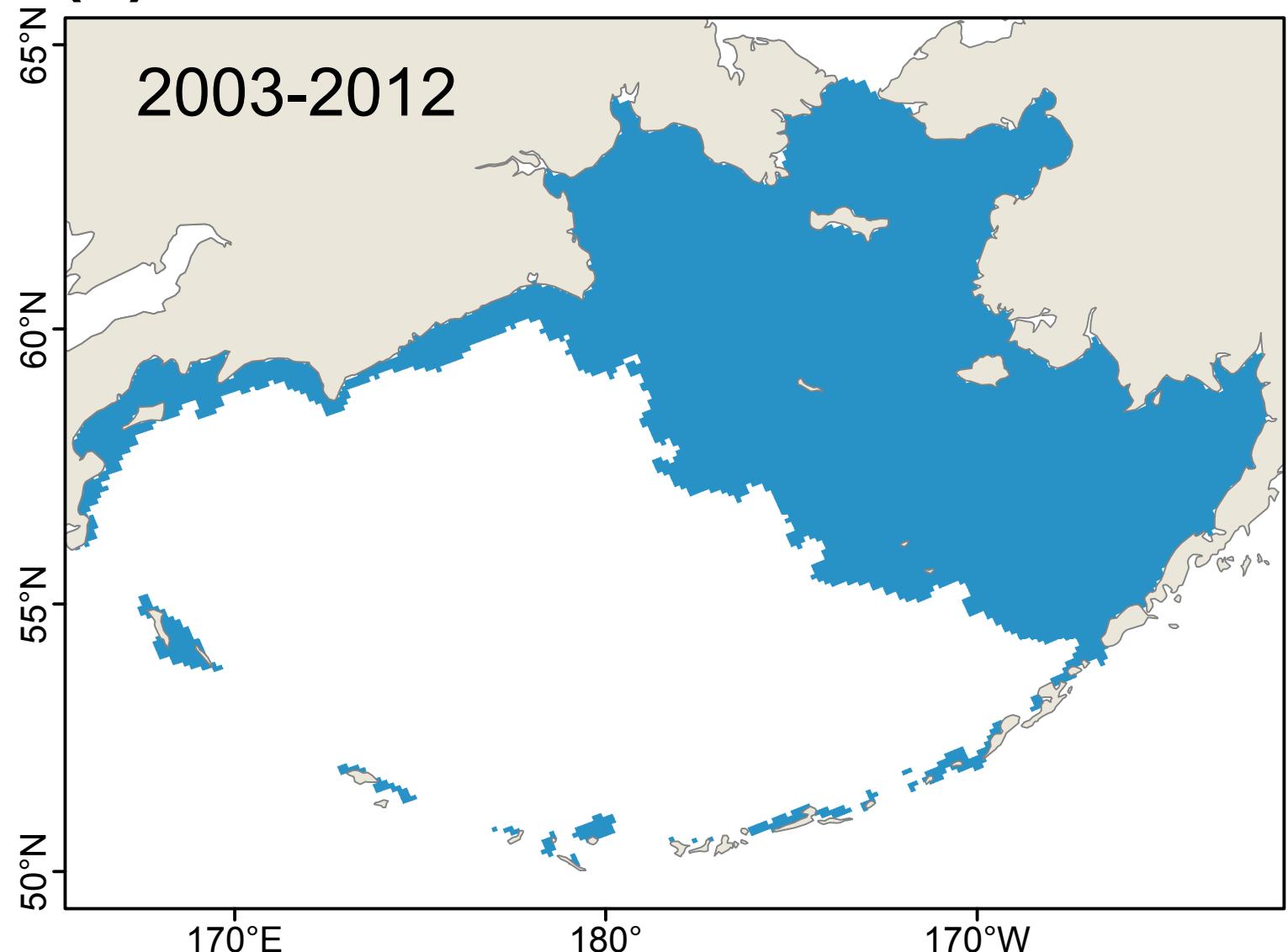
# *Mytilus galloprovincialis*: Year-round Survival

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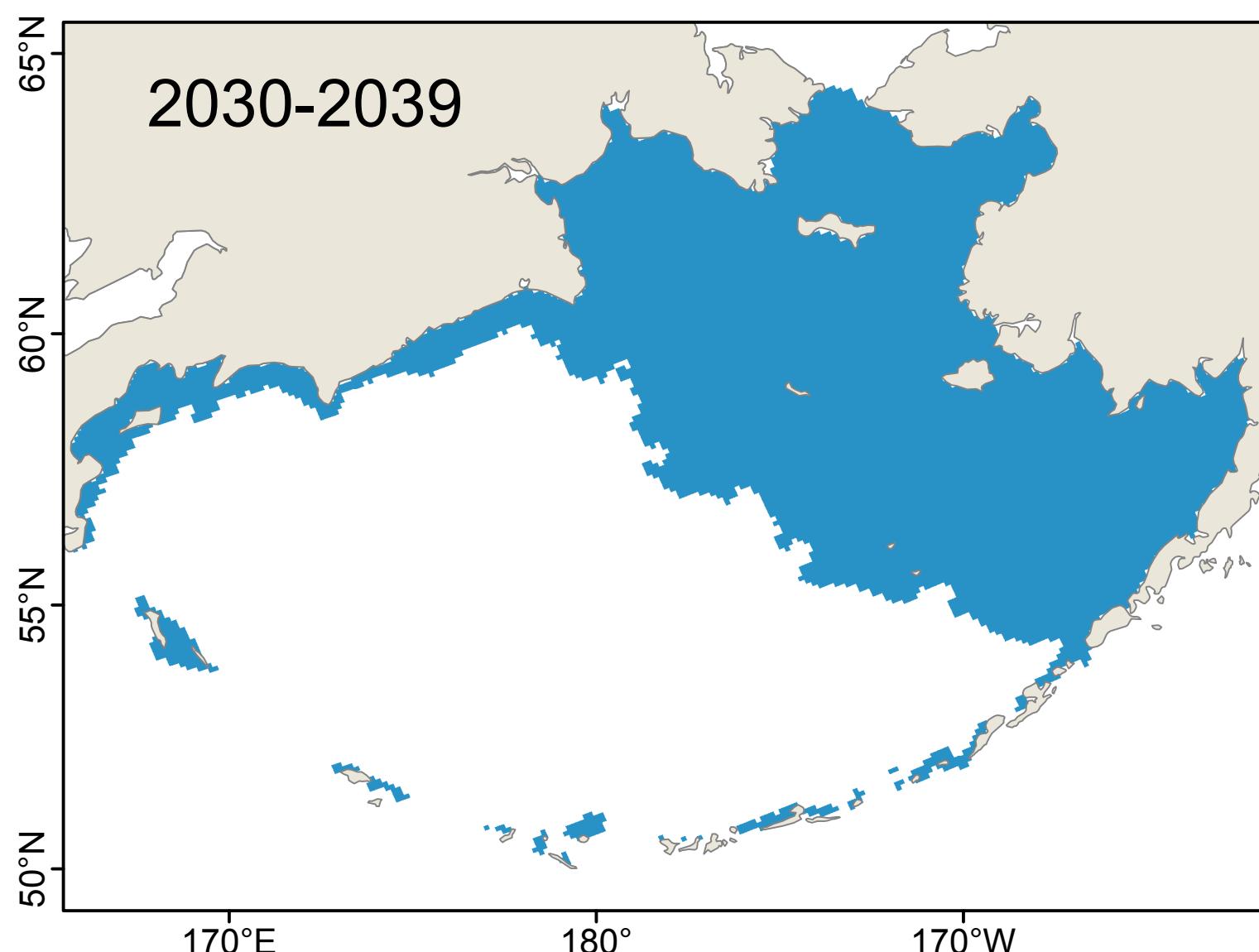
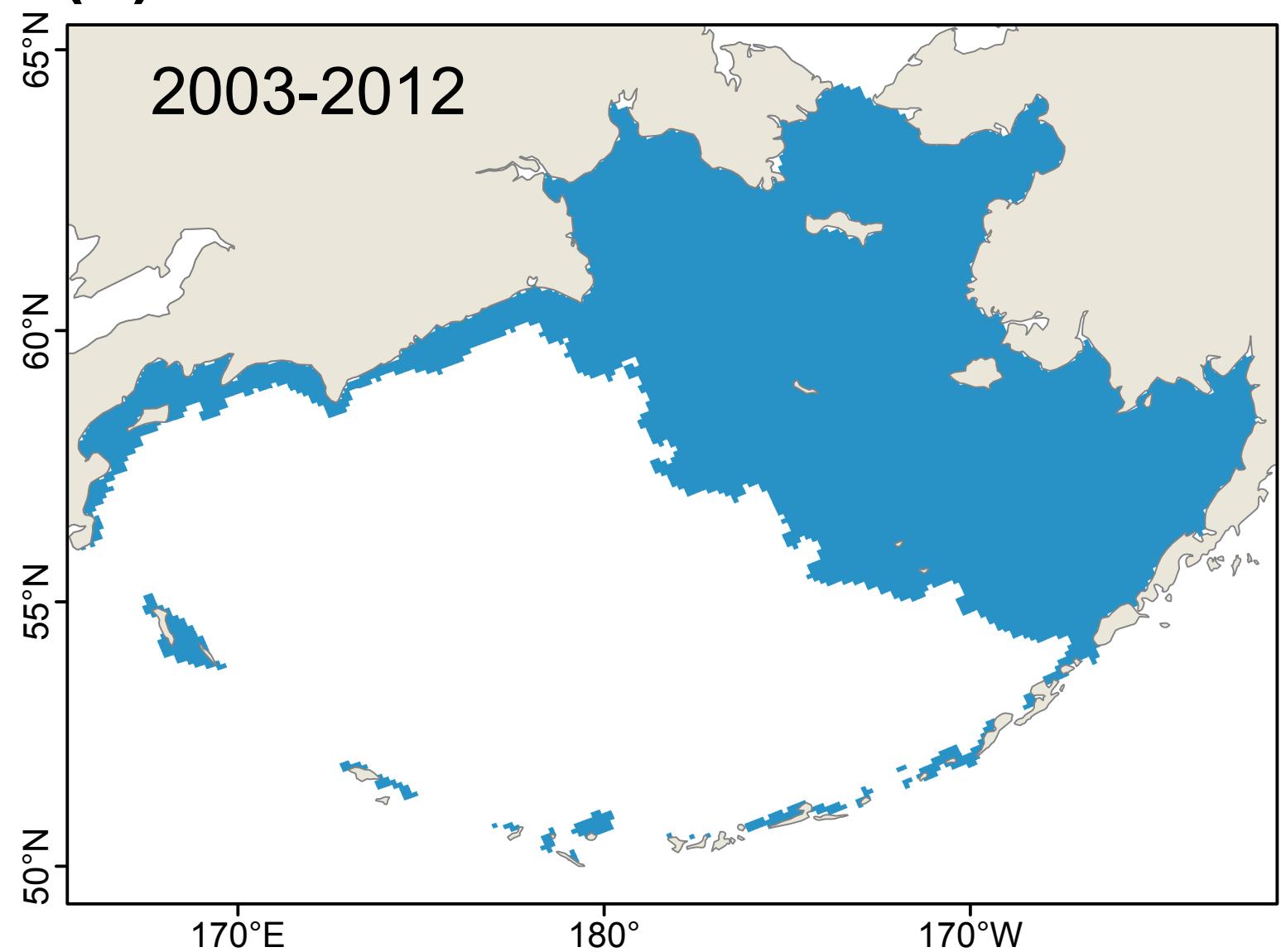
Number of years with suitable habitat



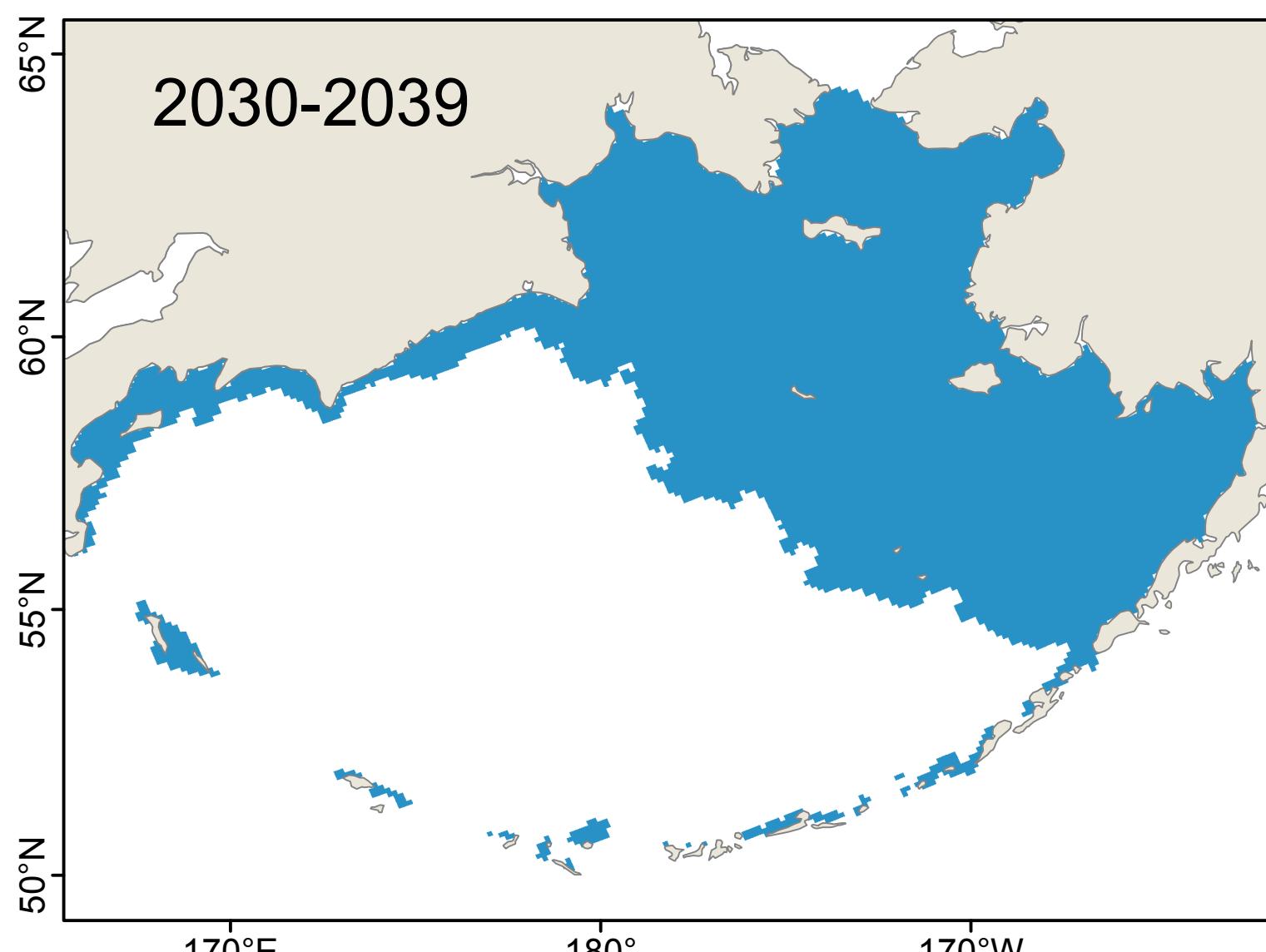
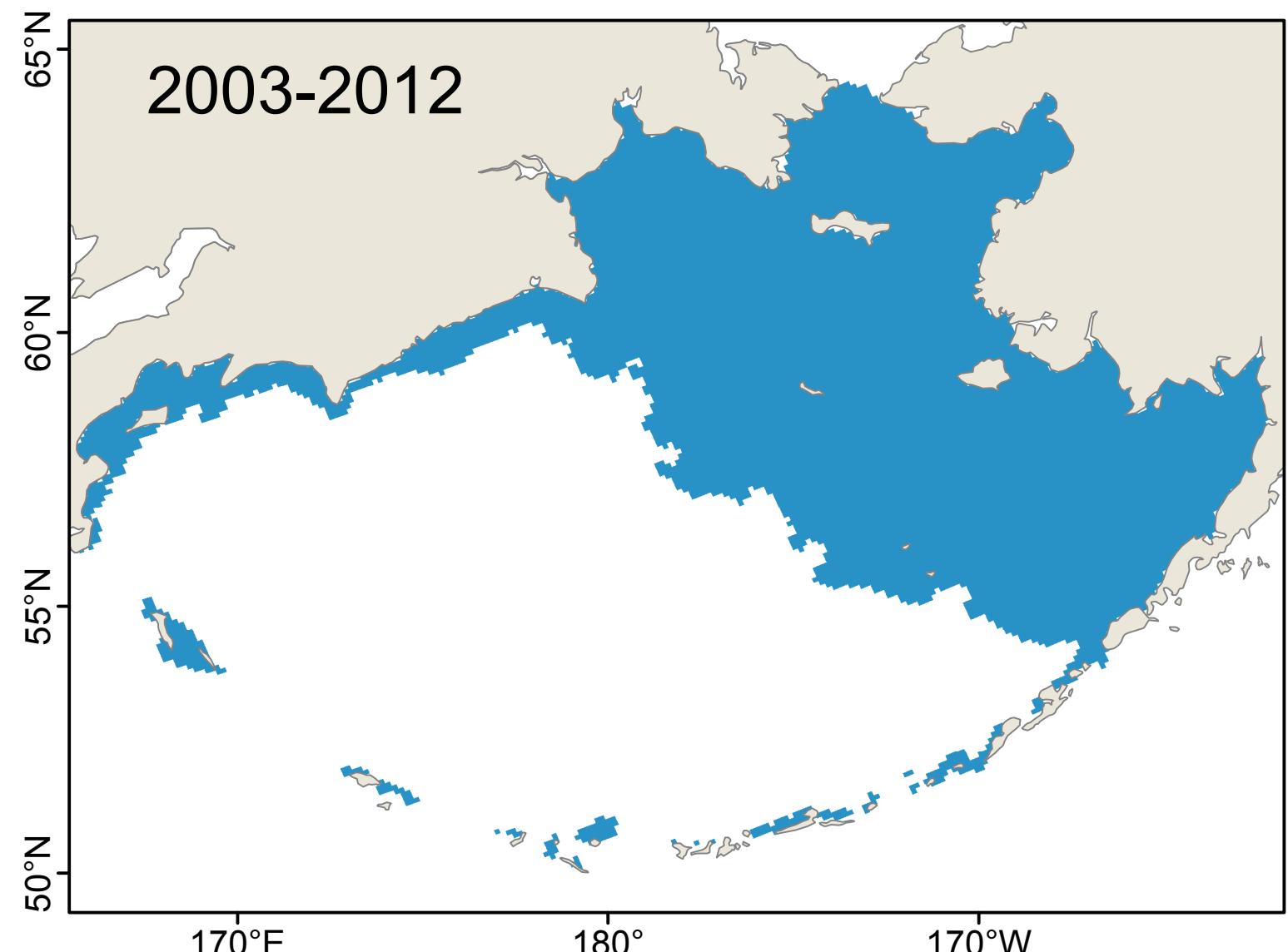
(a) Model: CGCM3-t47



(b) Model: ECHO-G

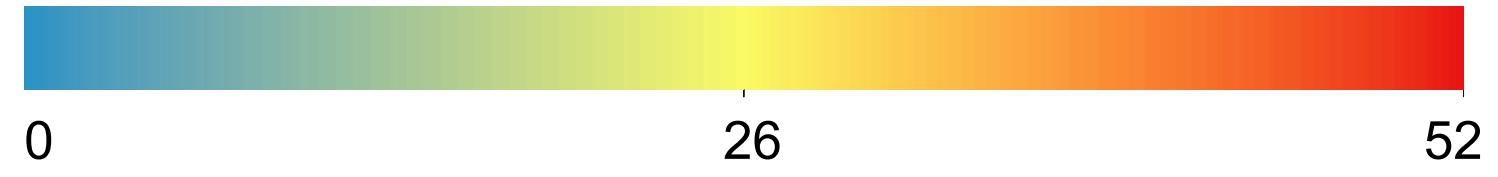


(c) Model: MIROC3.2

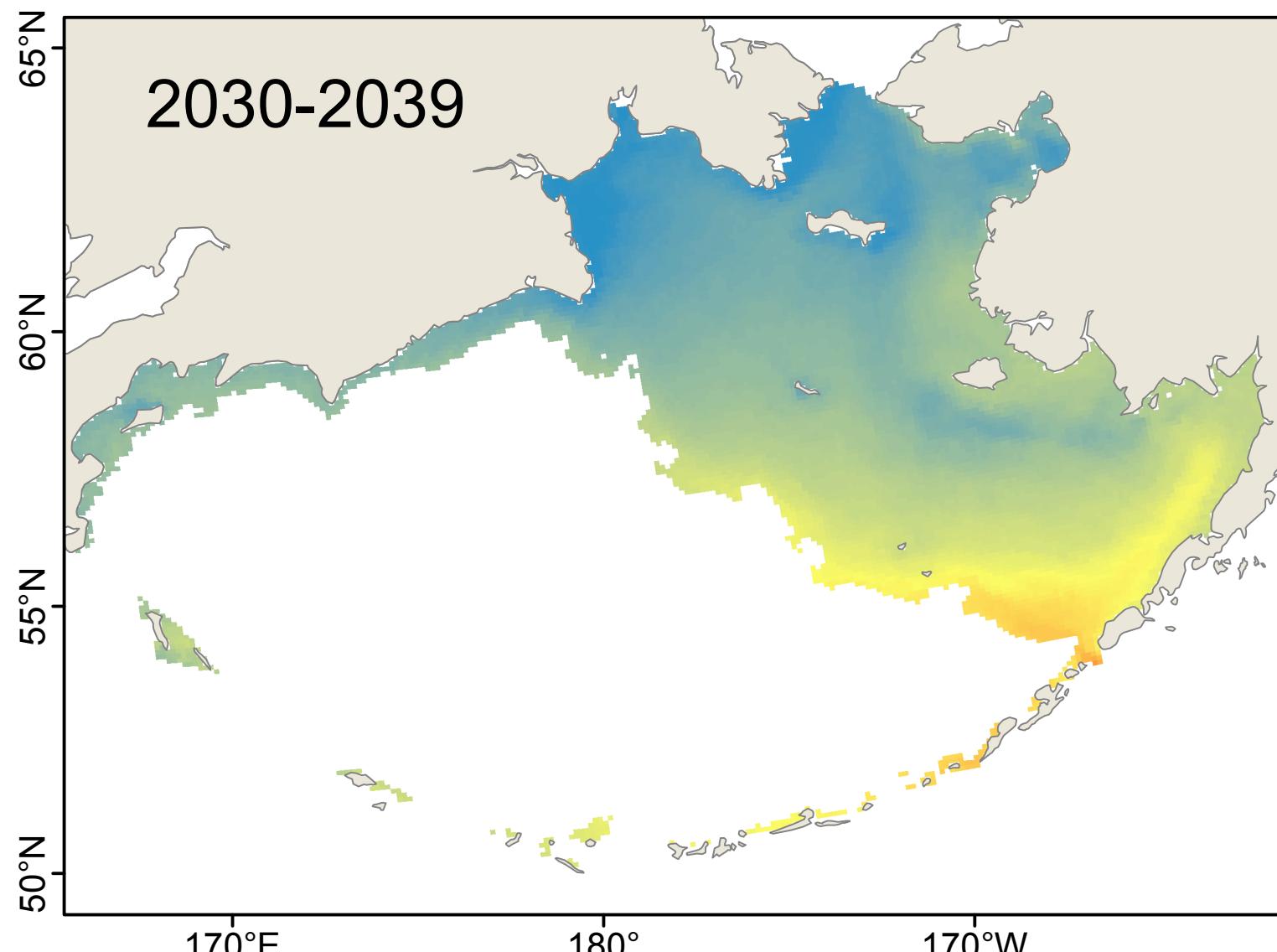
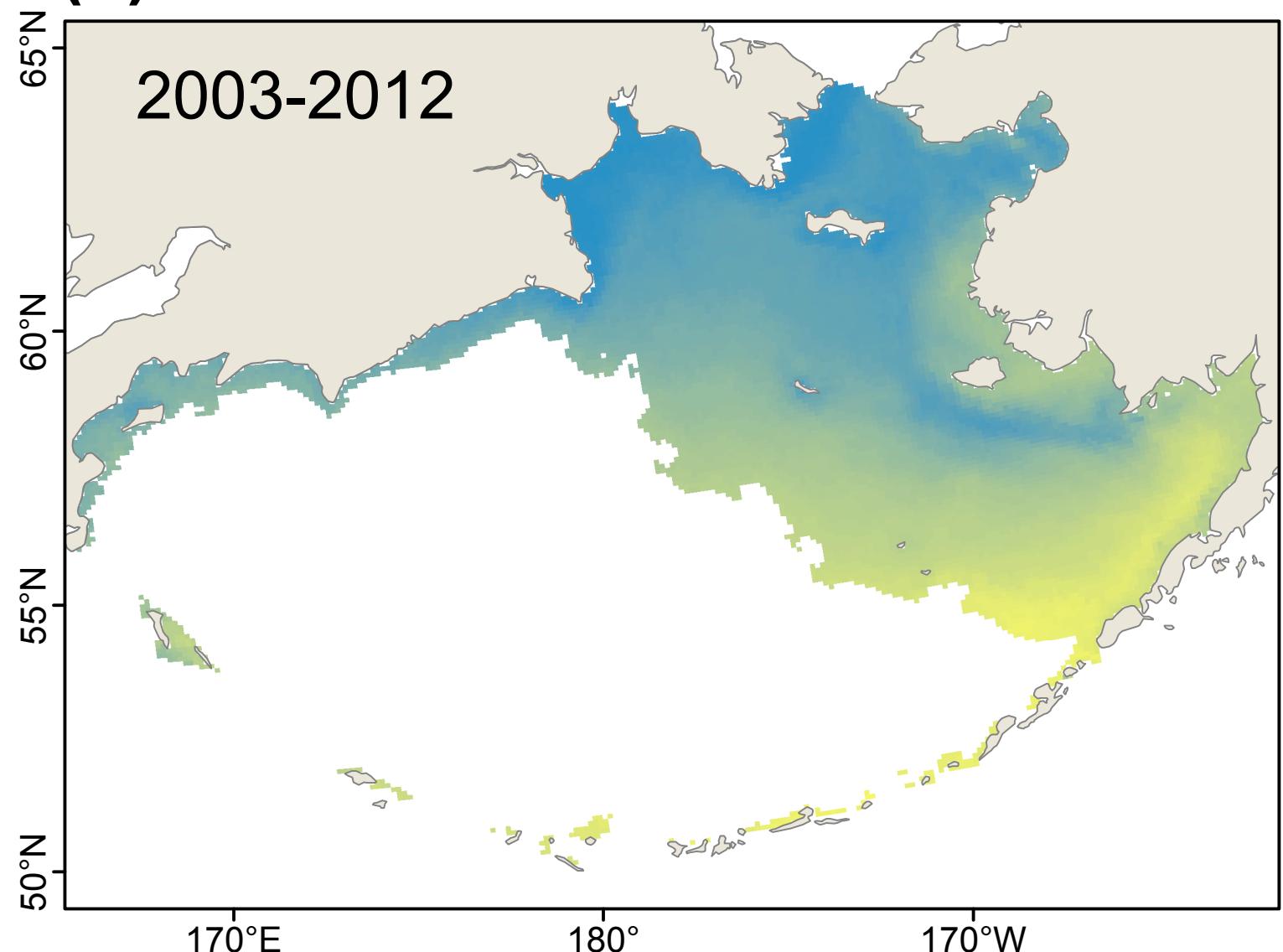


# *Mytilus galloprovincialis: Weekly Survival*

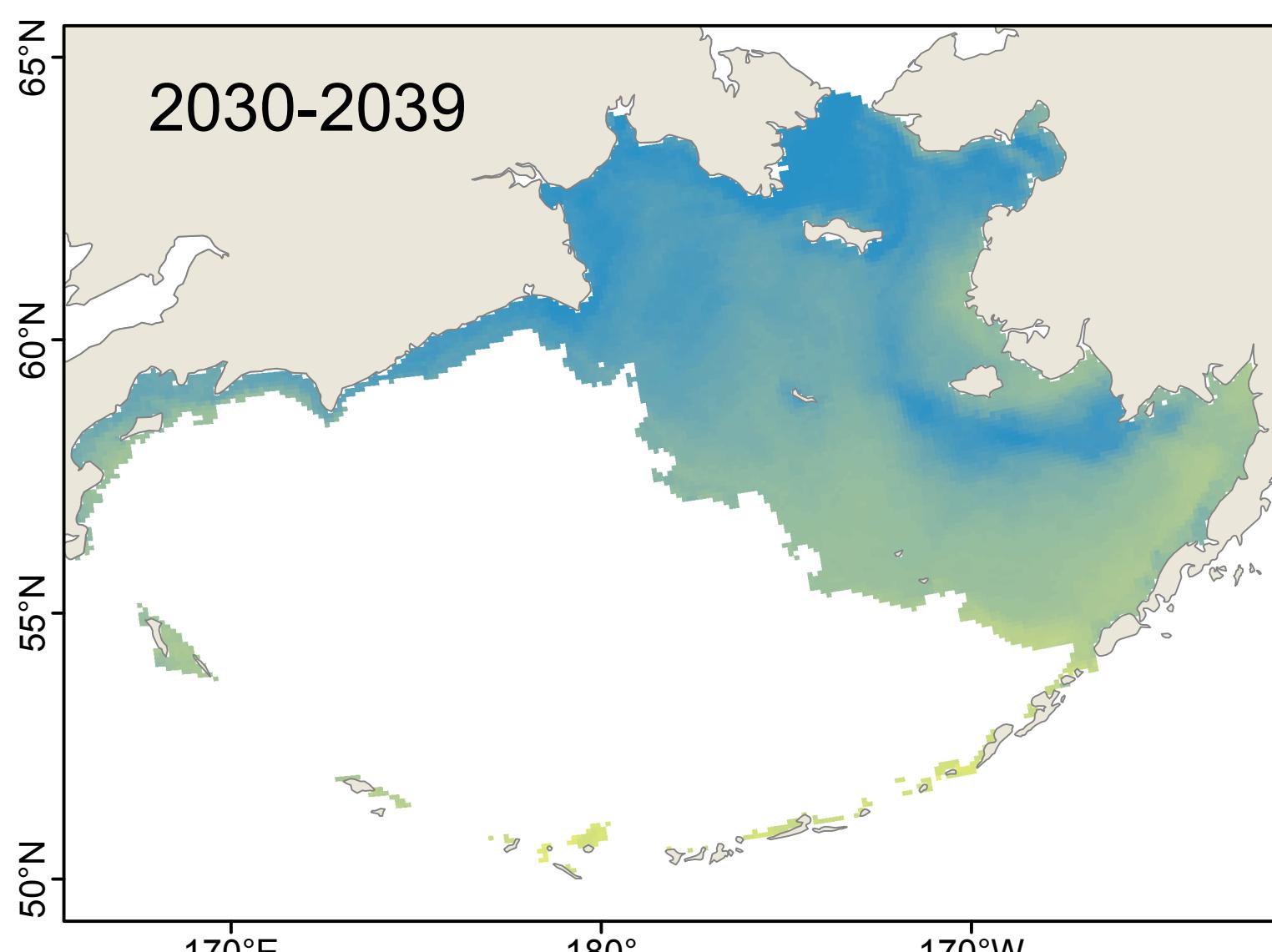
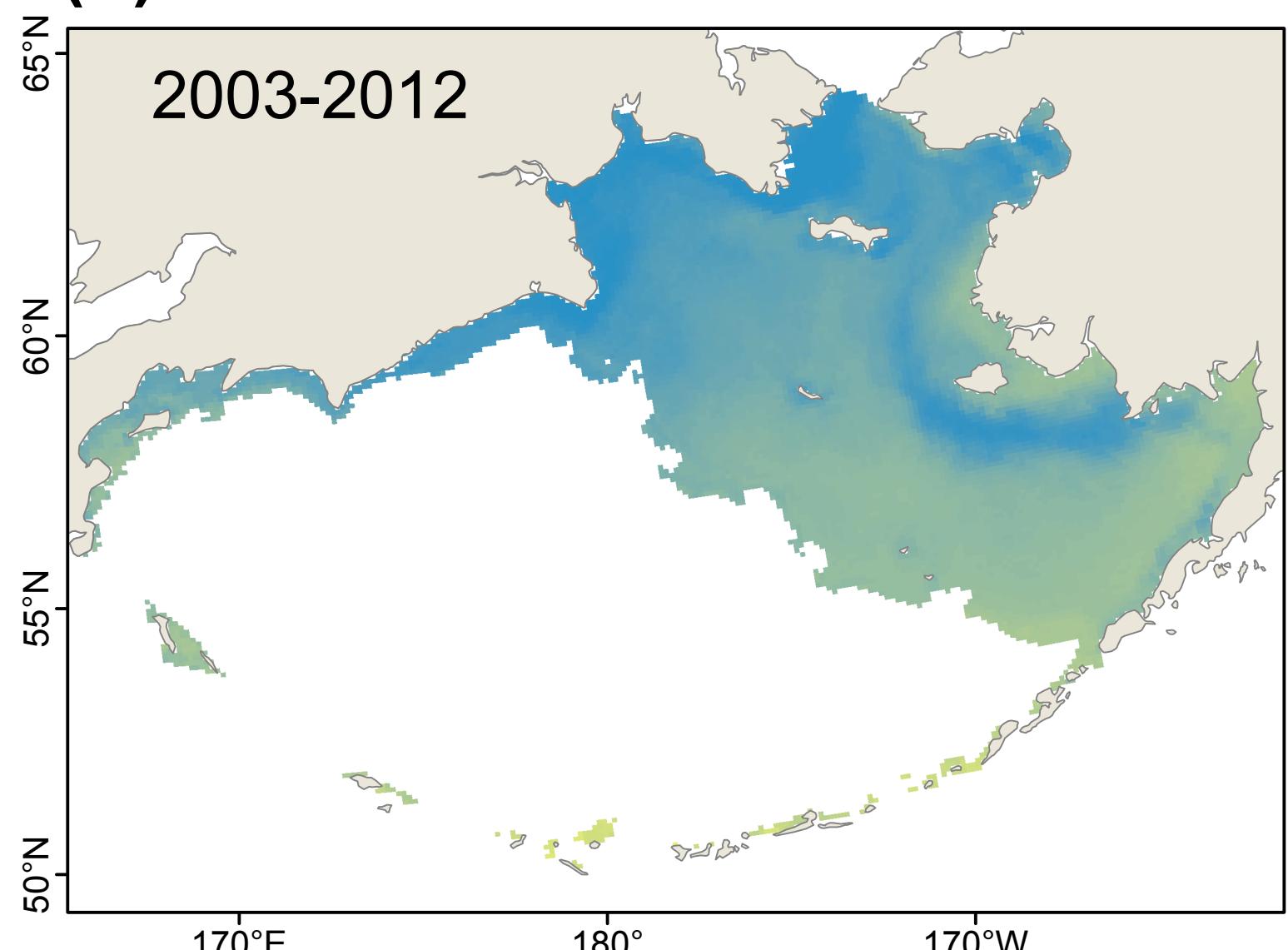
Average number of weeks of suitable habitat



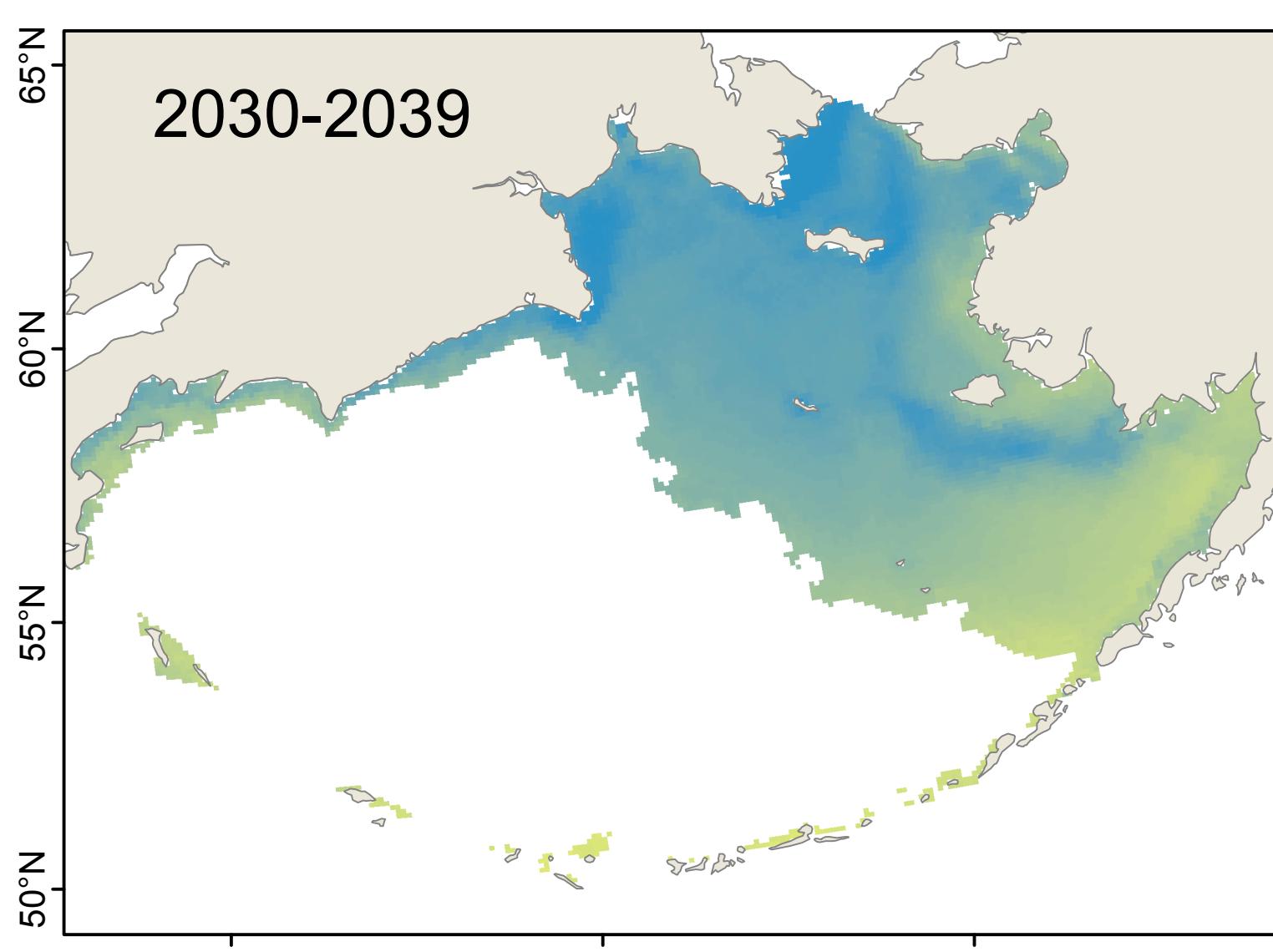
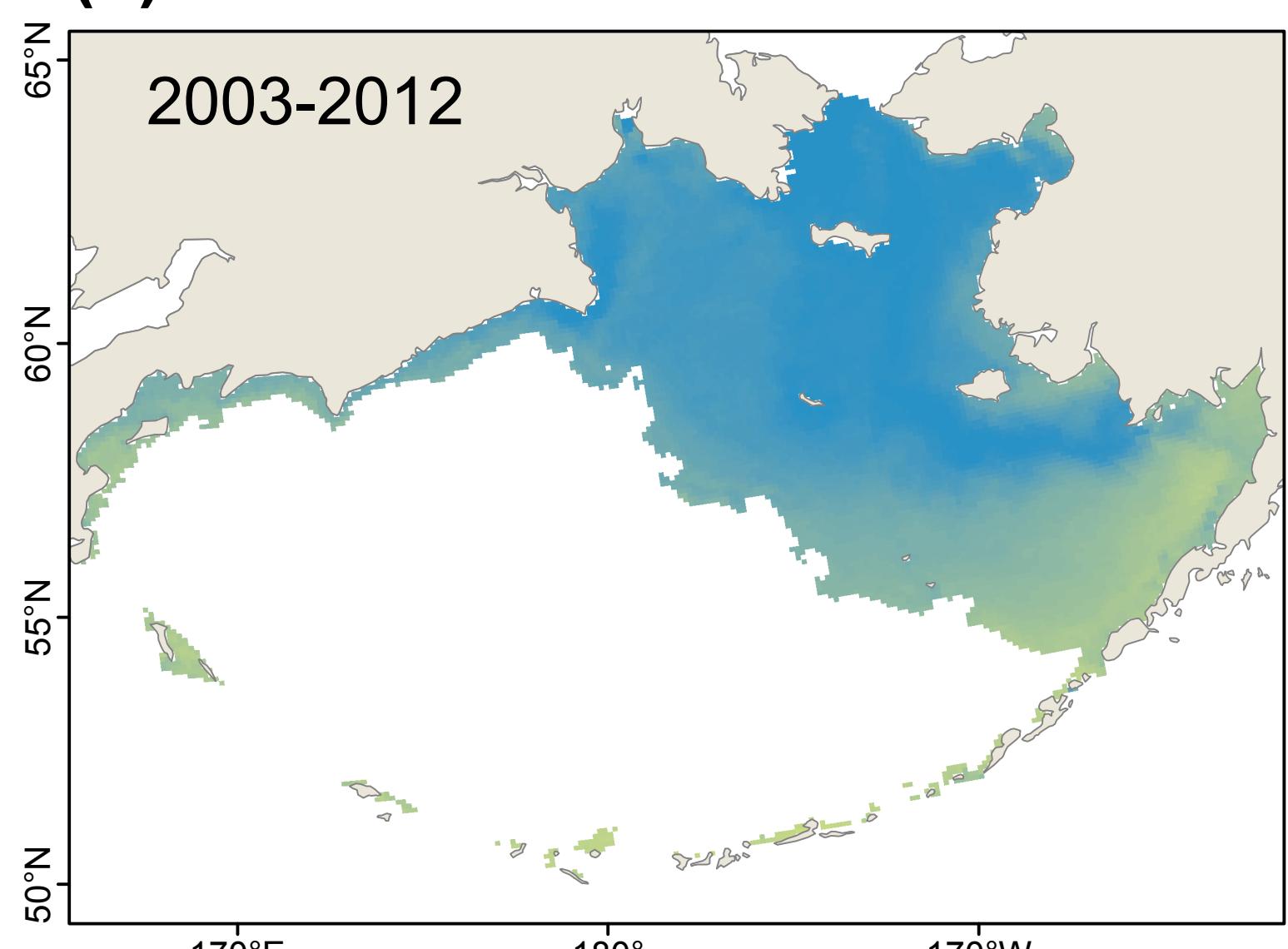
(a) Model: CGCM3-t47



(b) Model: ECHO-G

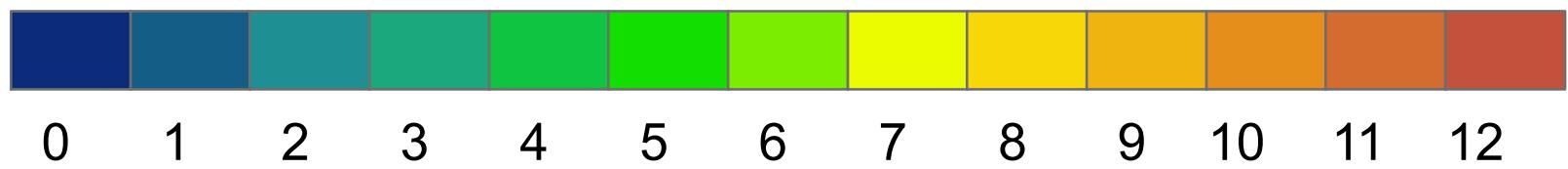


(c) Model: MIROC3.2

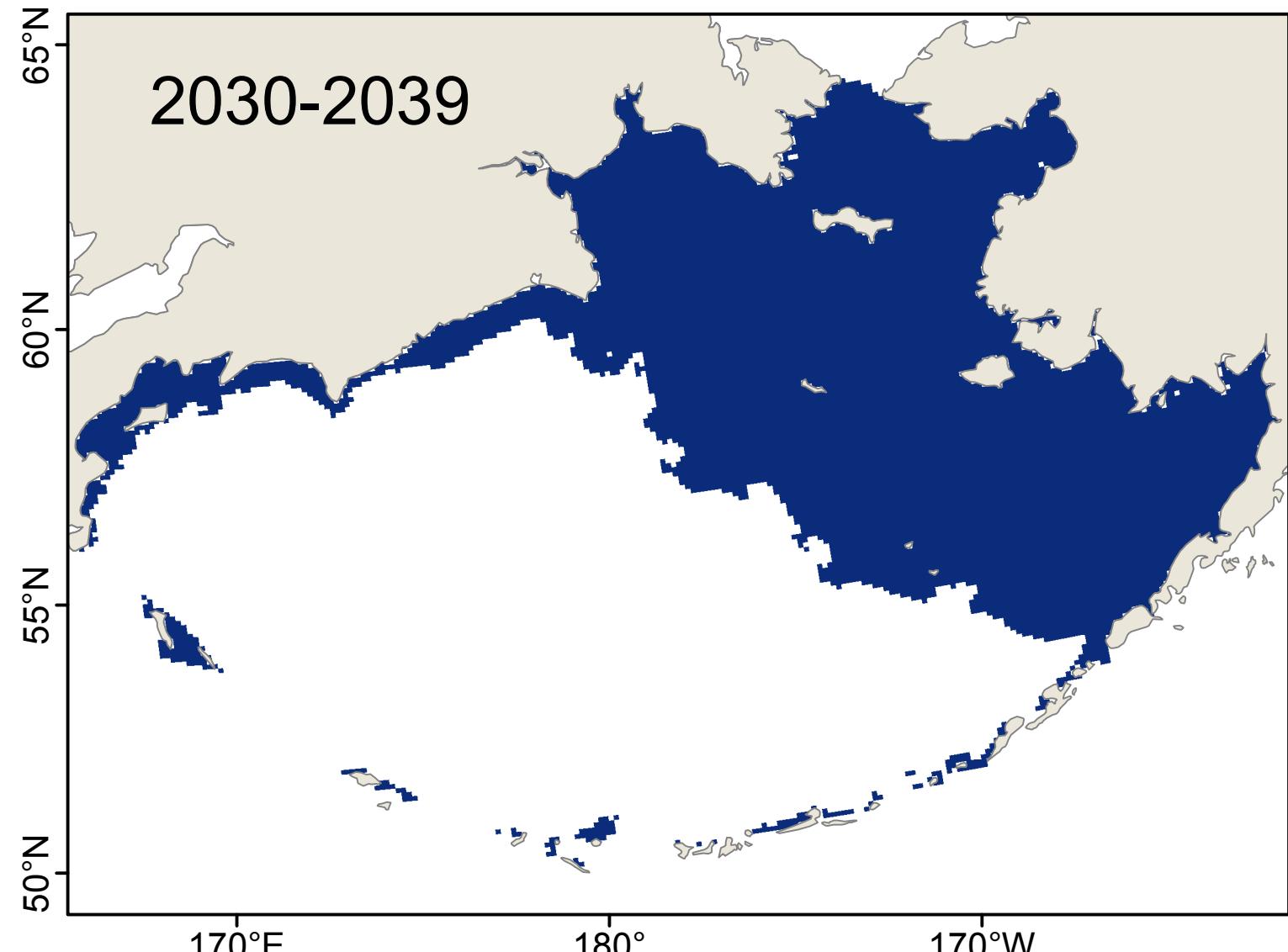
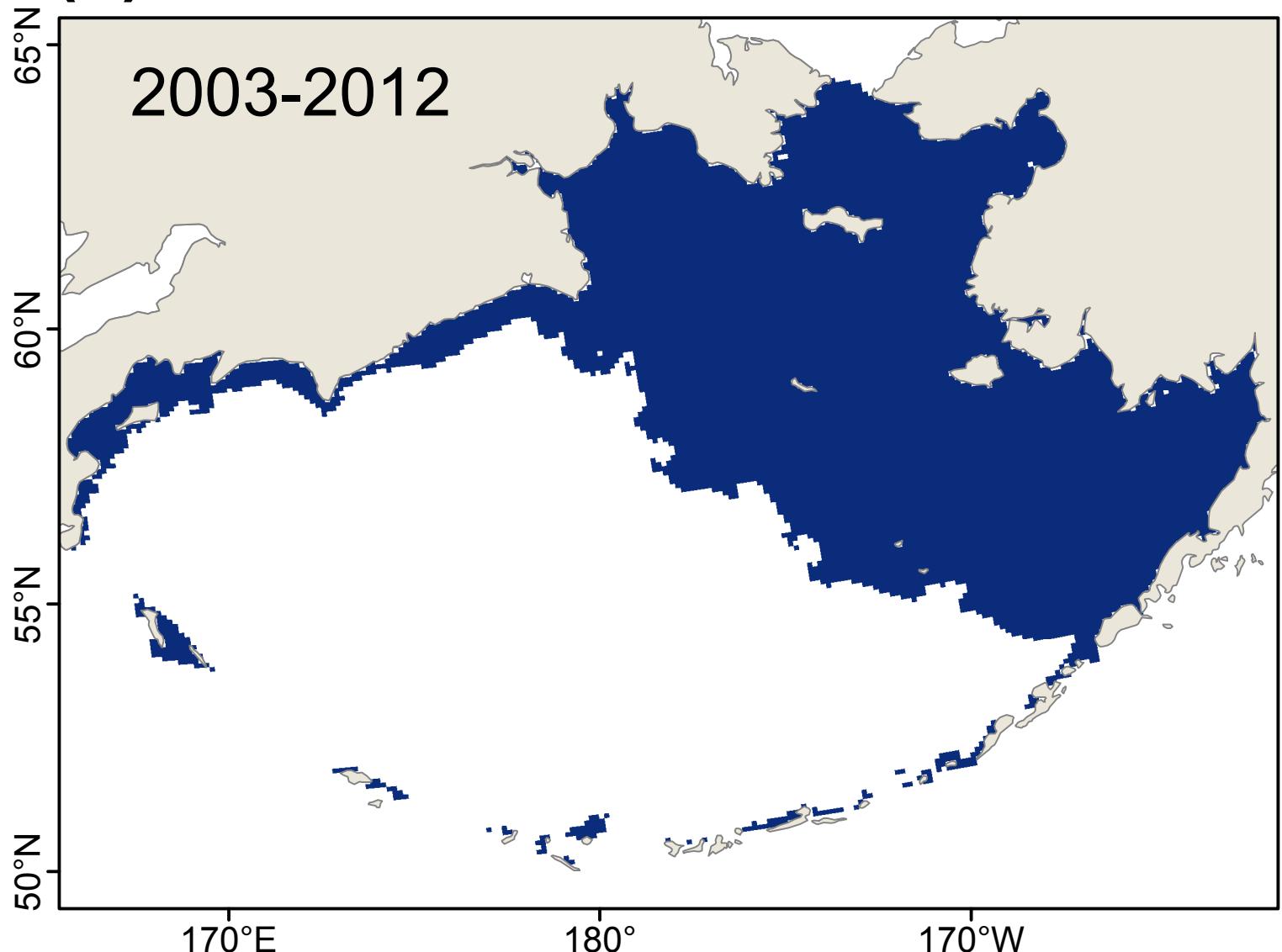


# *Mytilus galloprovincialis: Reproduction*

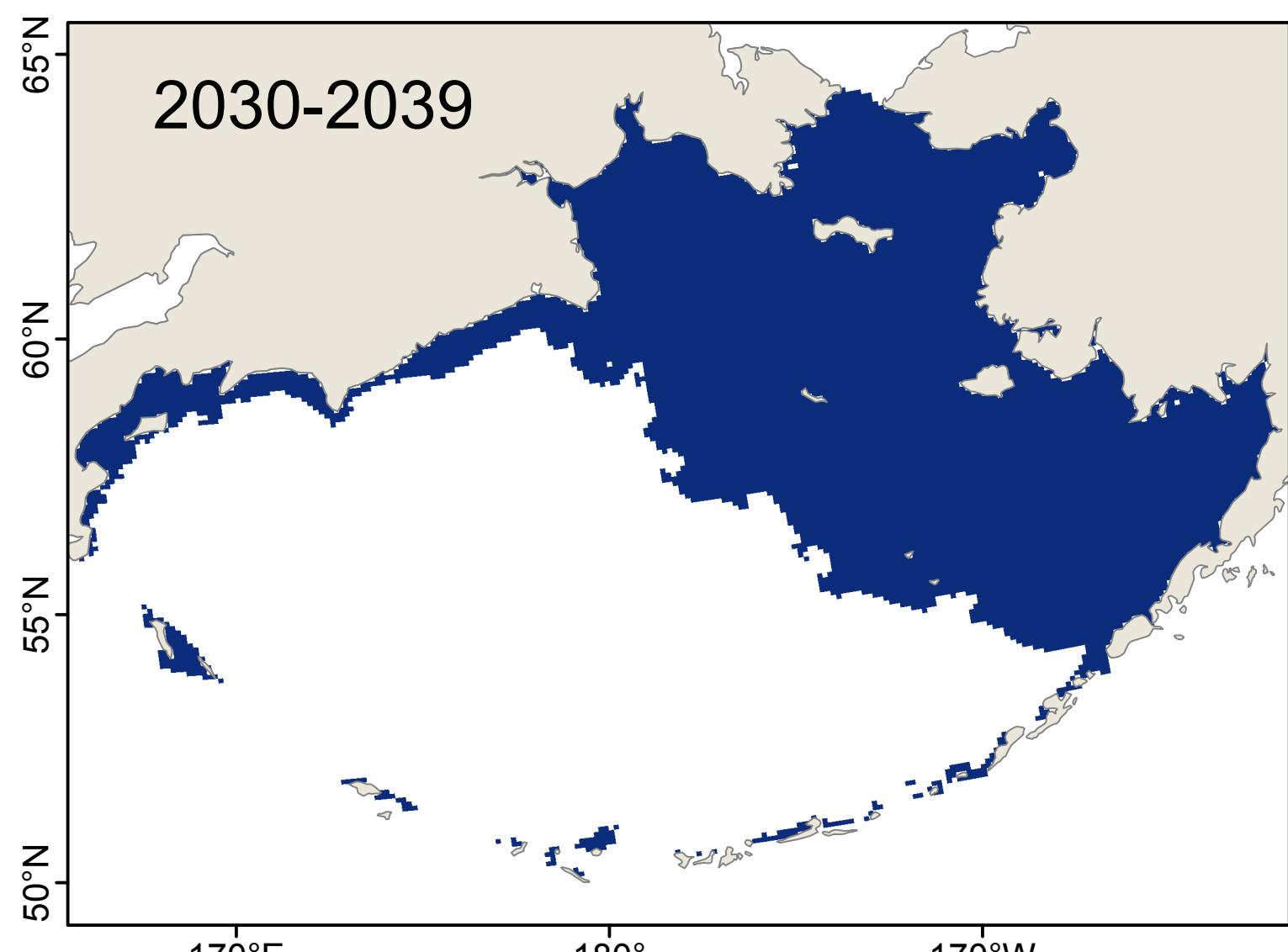
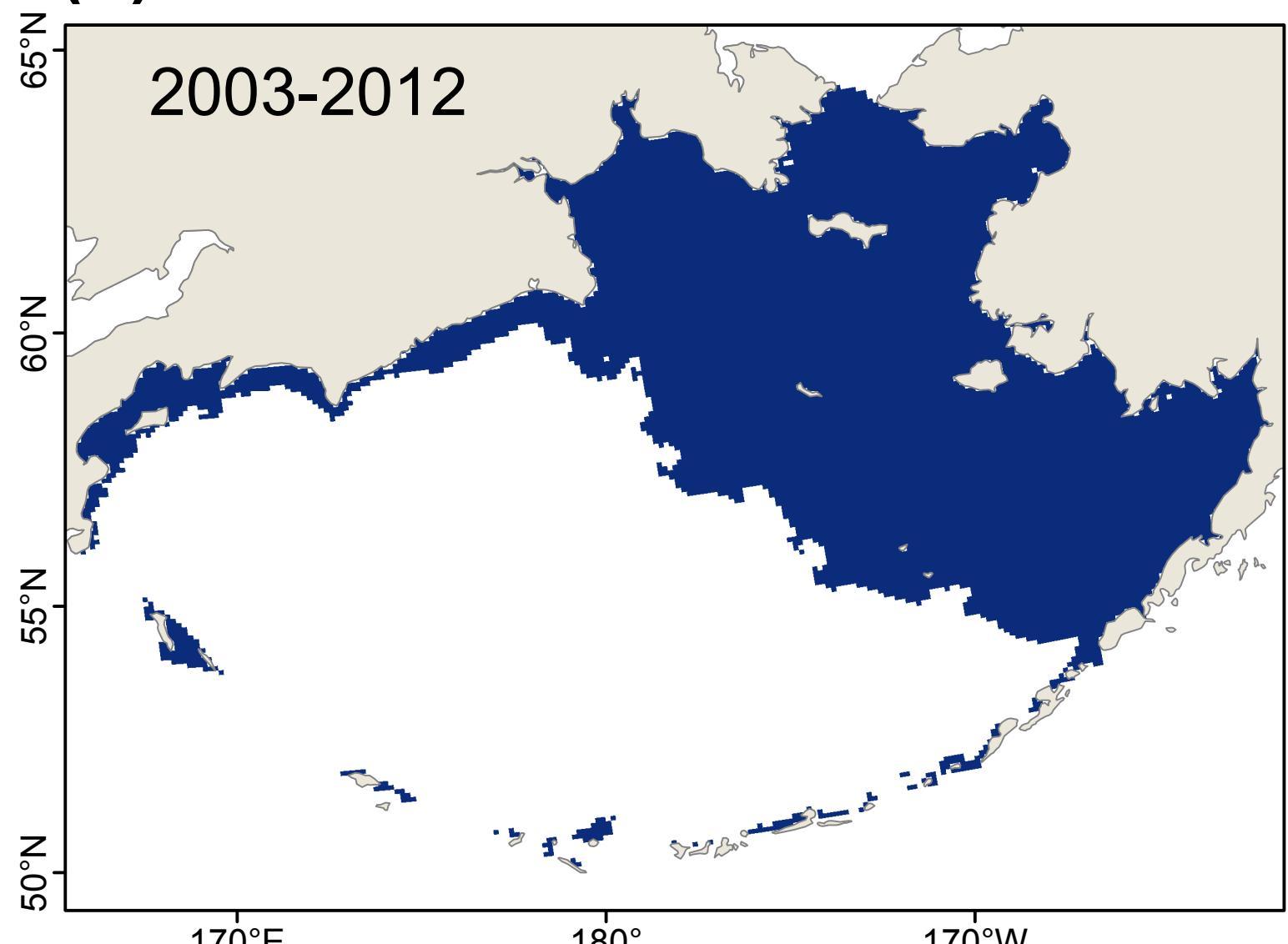
Average number of consecutive weeks of suitable habitat



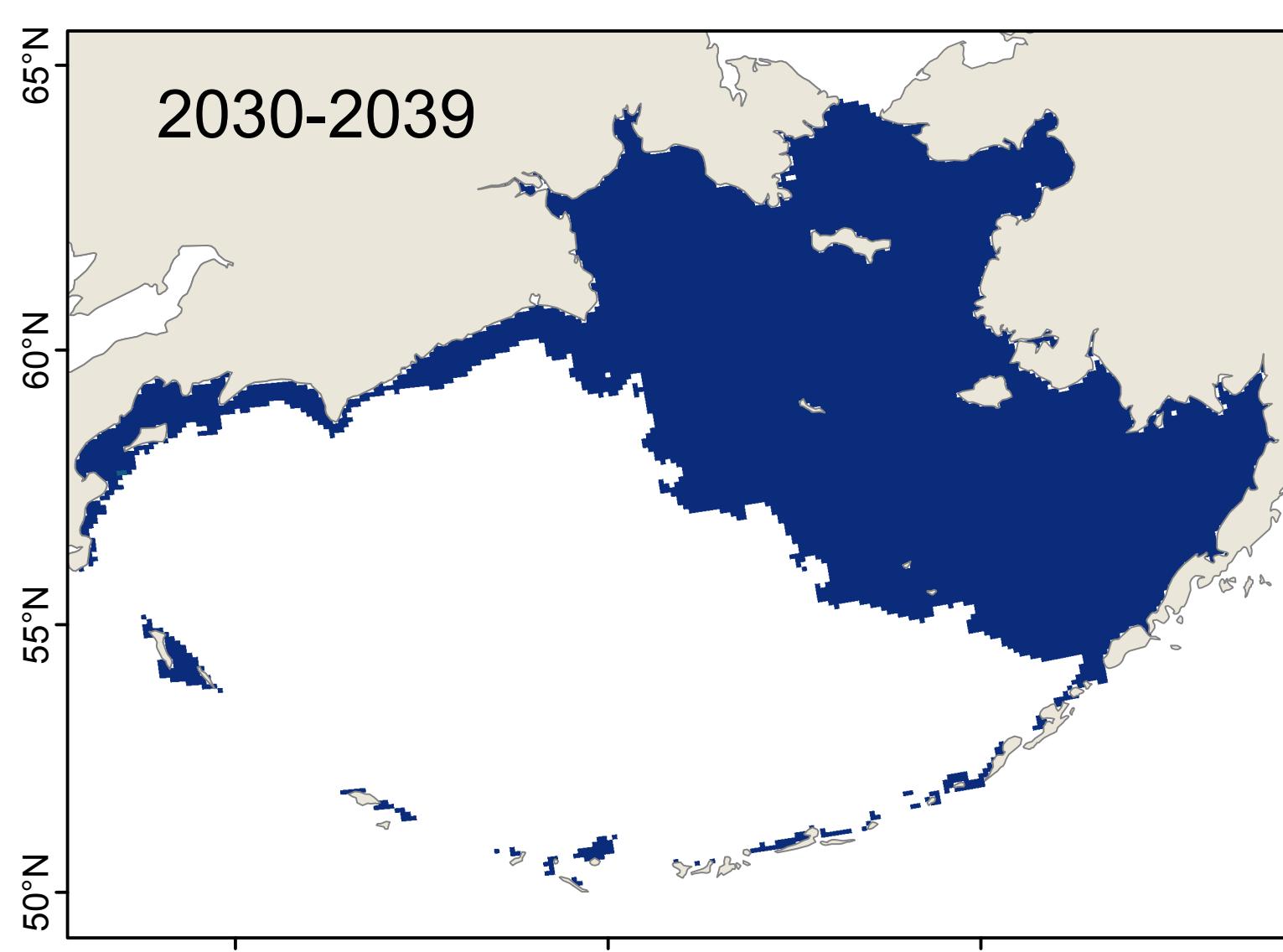
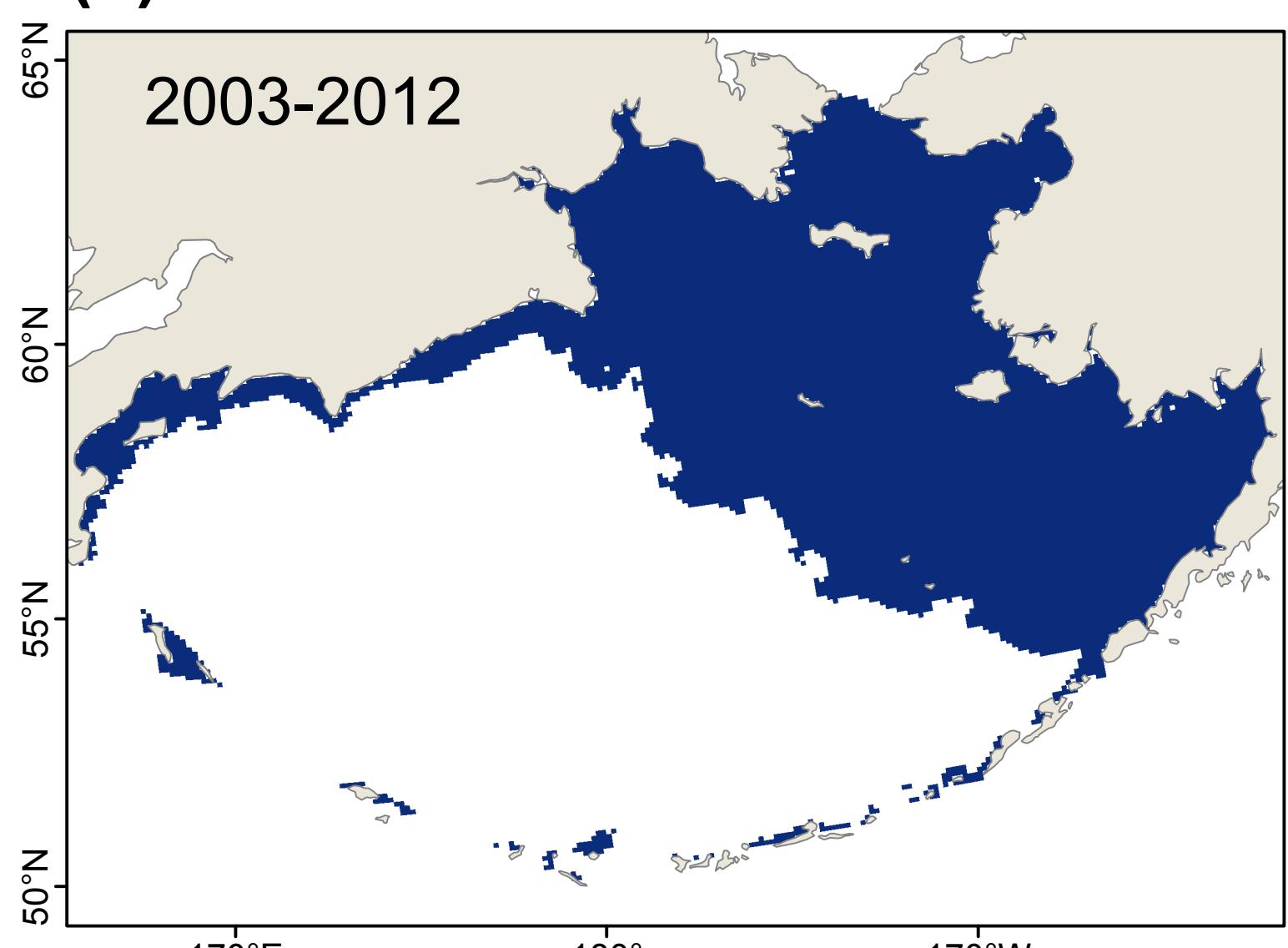
(a) Model: CGCM3-t47



(b) Model: ECHO-G

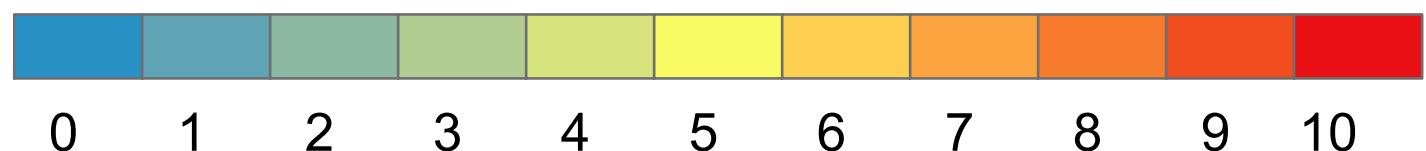


(c) Model: MIROC3.2

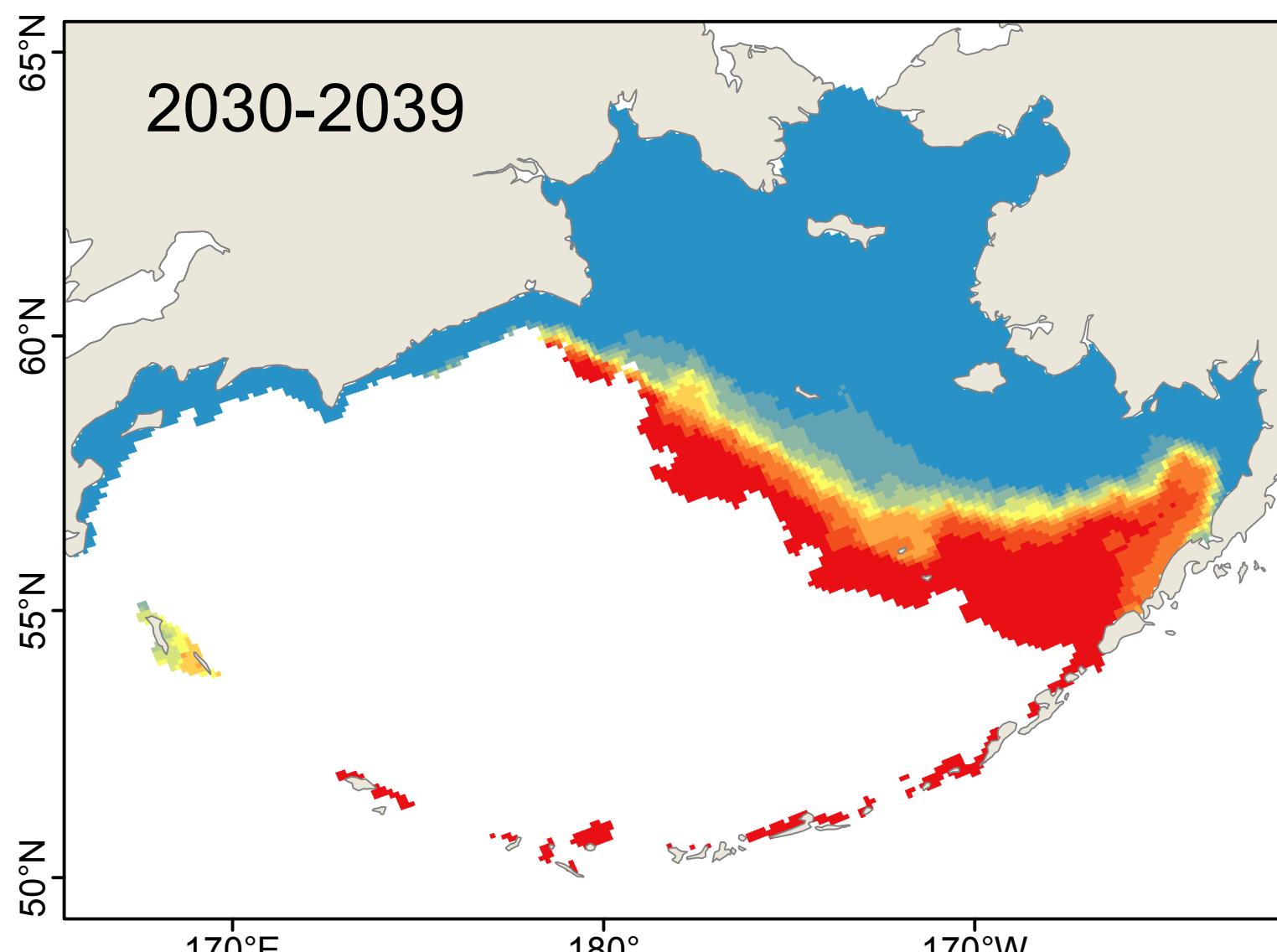
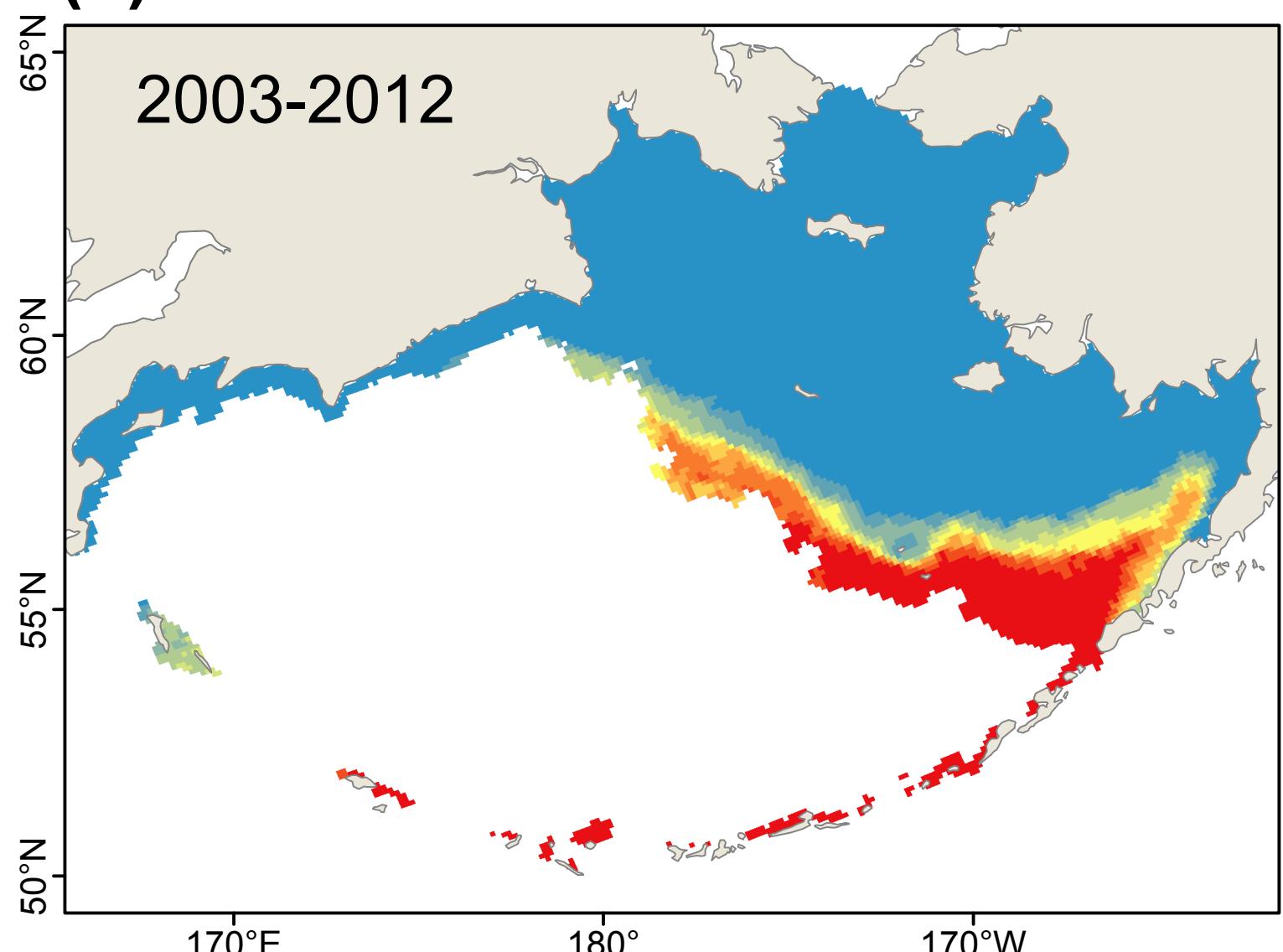


# *Petricolaria pholadiformis*: Year-round Survival

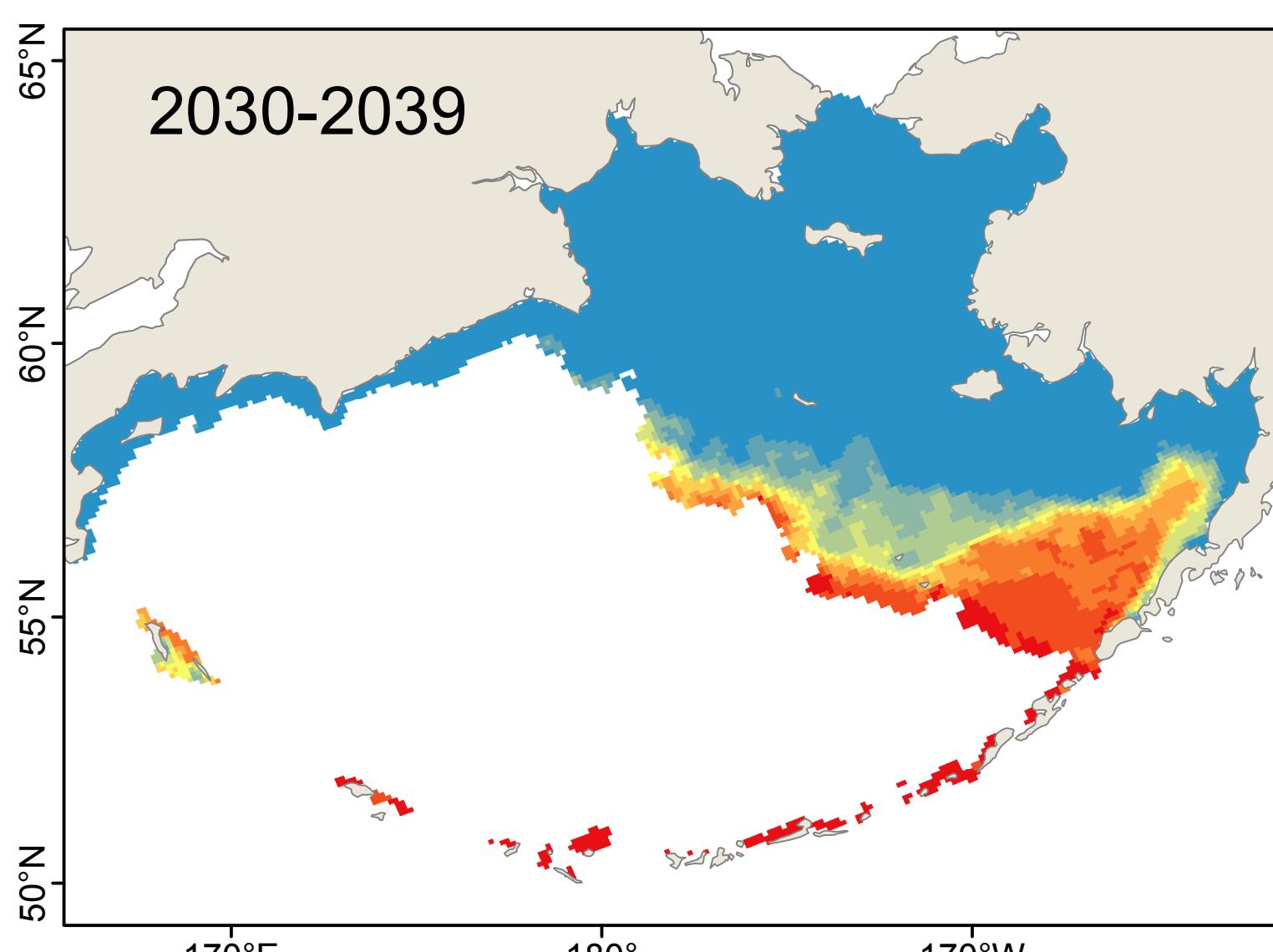
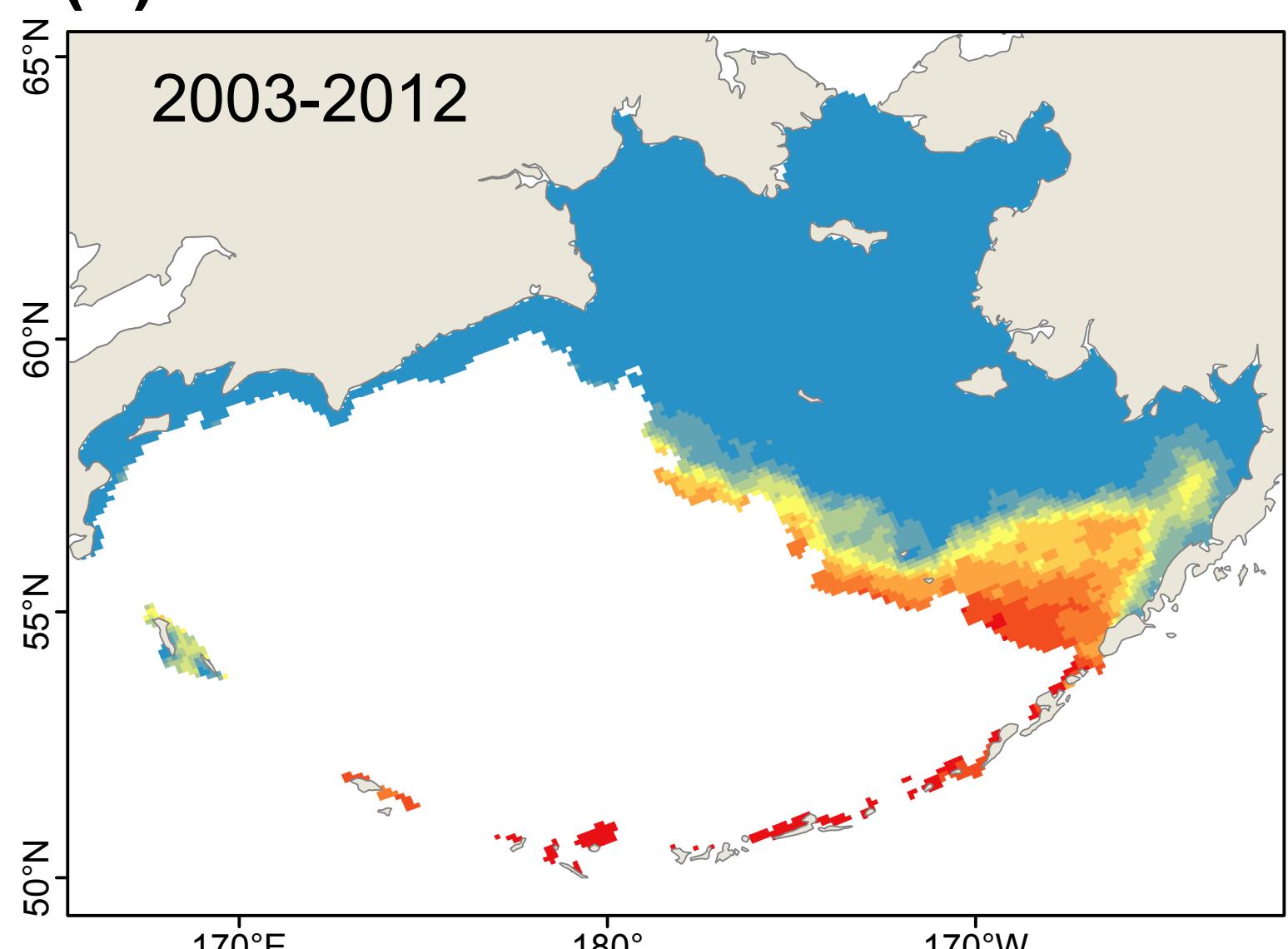
Number of years with suitable habitat



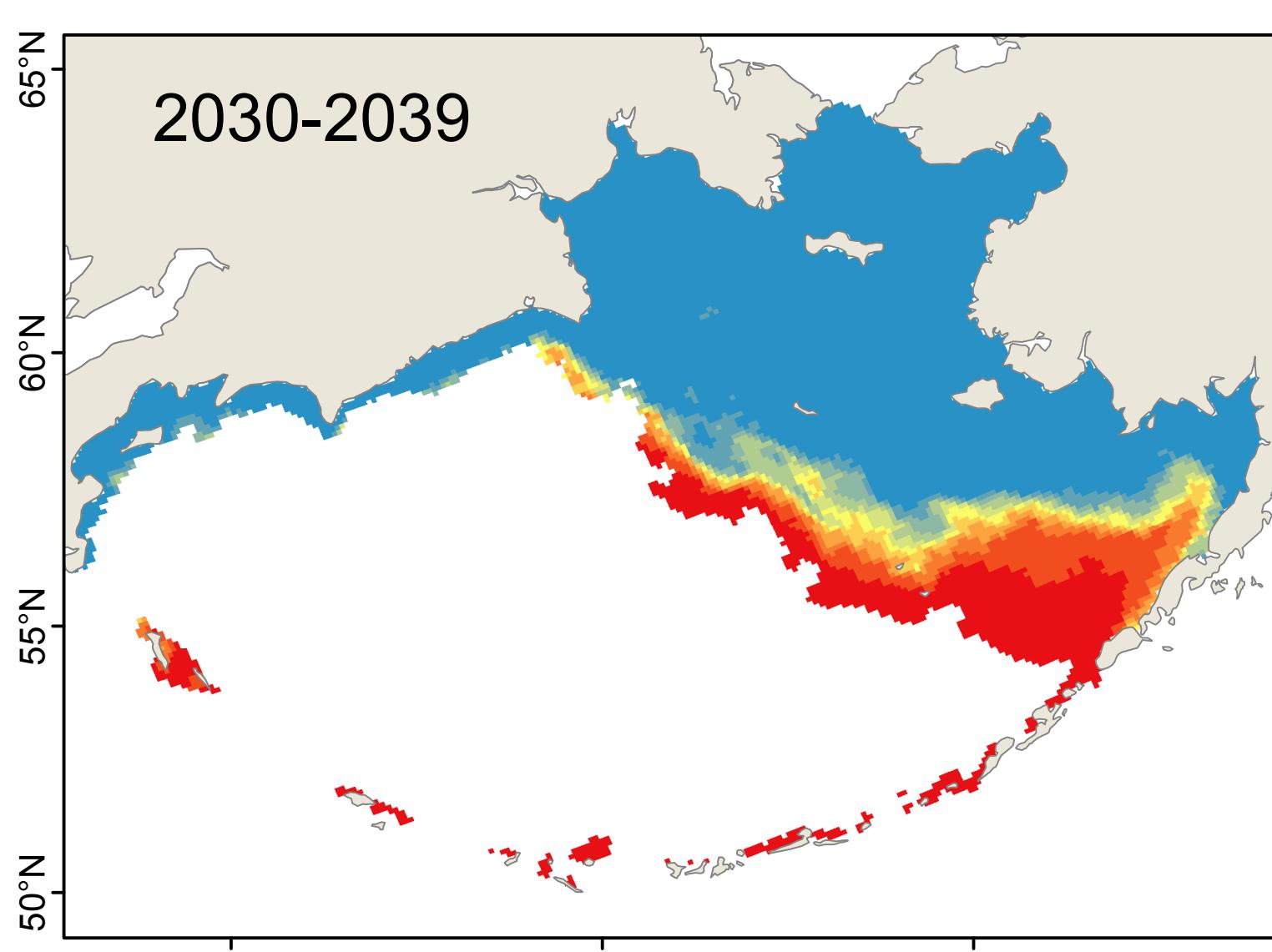
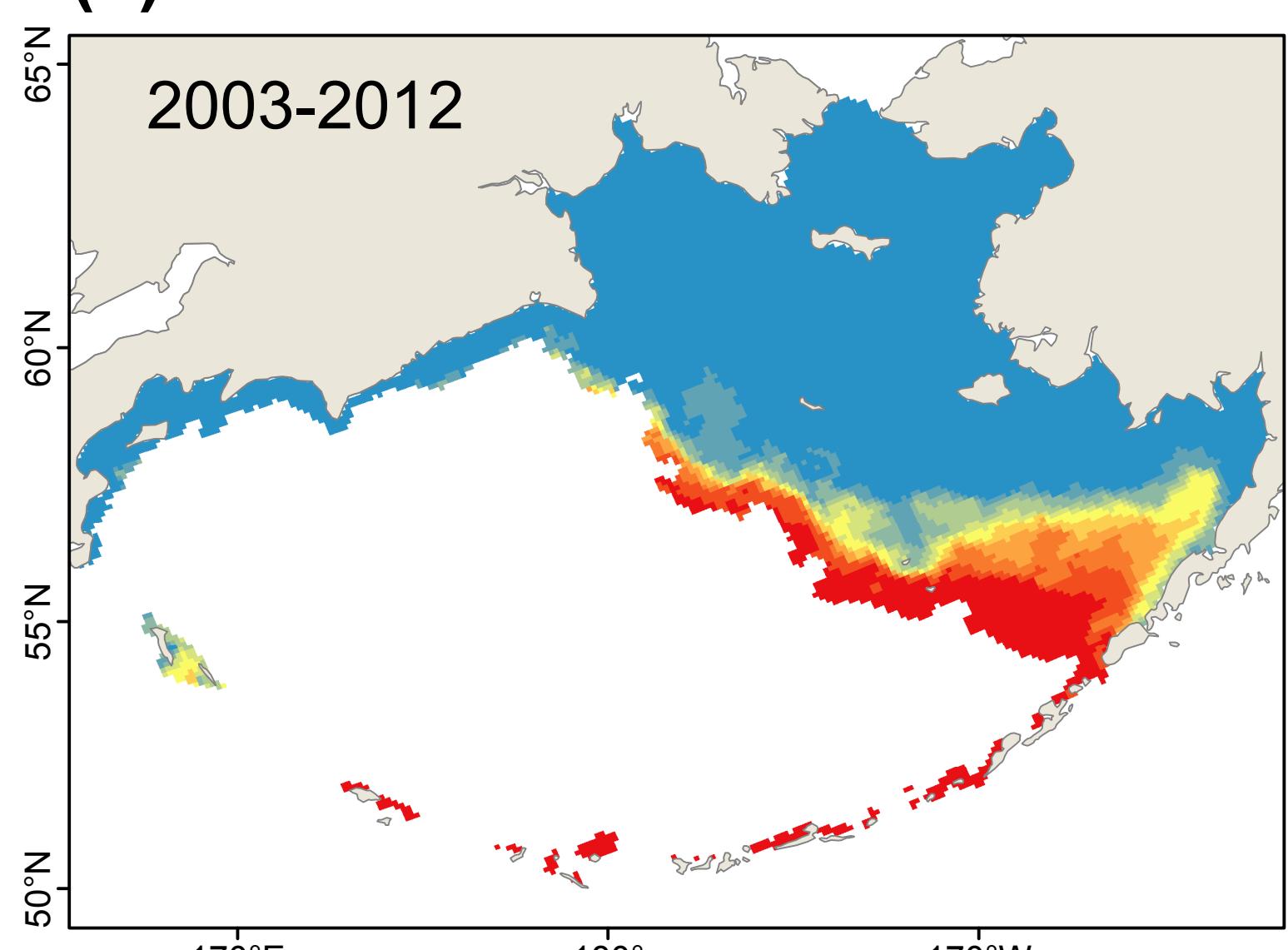
(a) Model: CGCM3-t47



(b) Model: ECHO-G

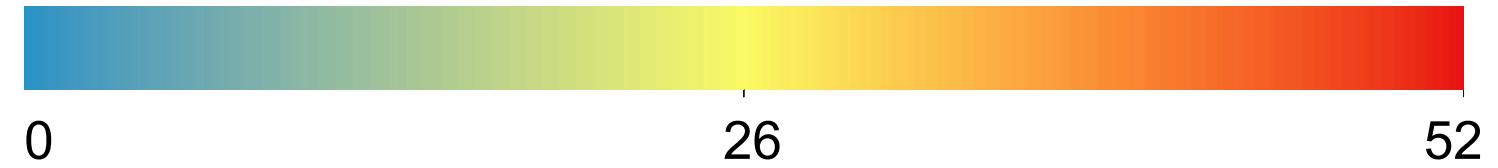


(c) Model: MIROC3.2

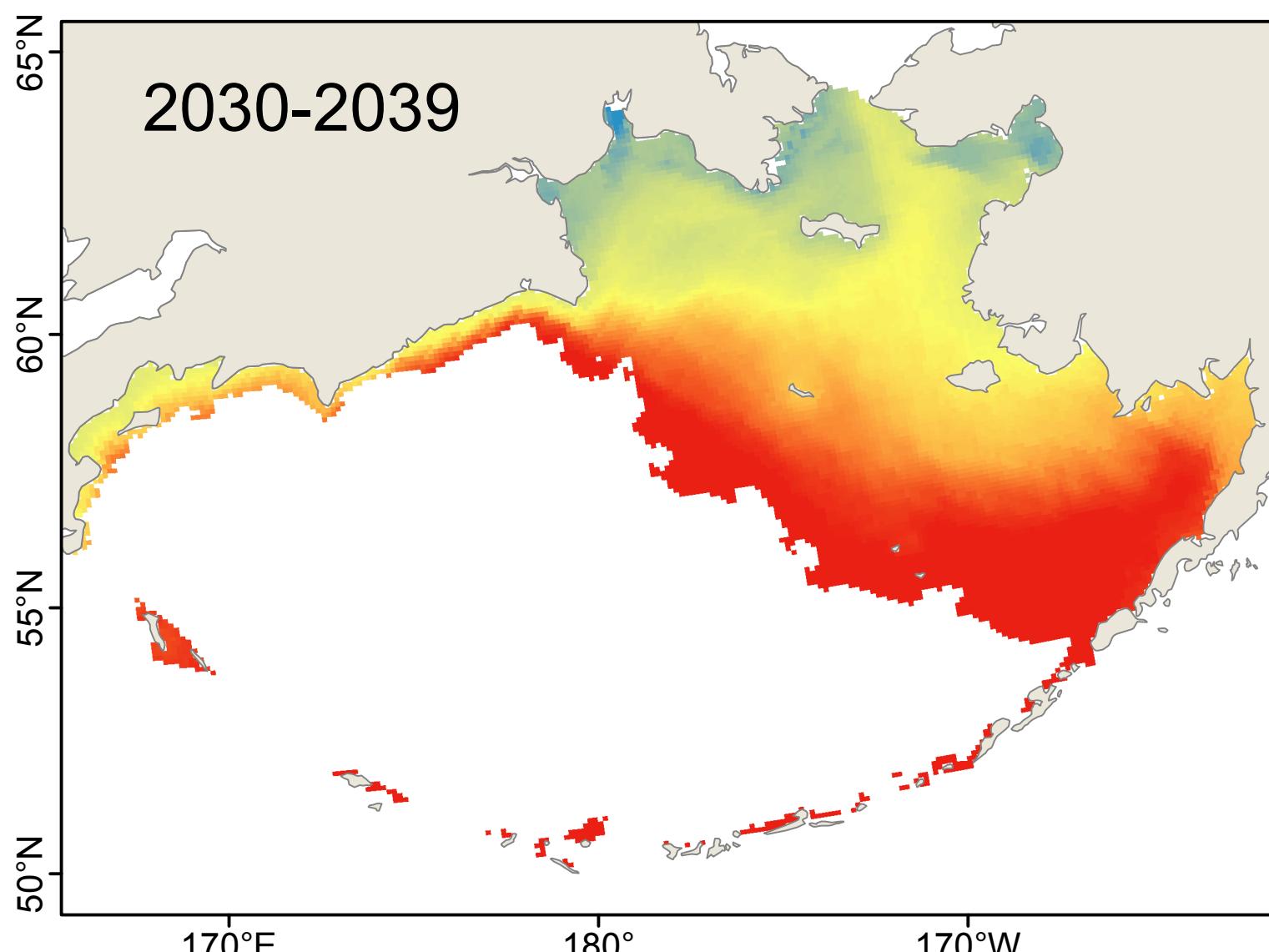
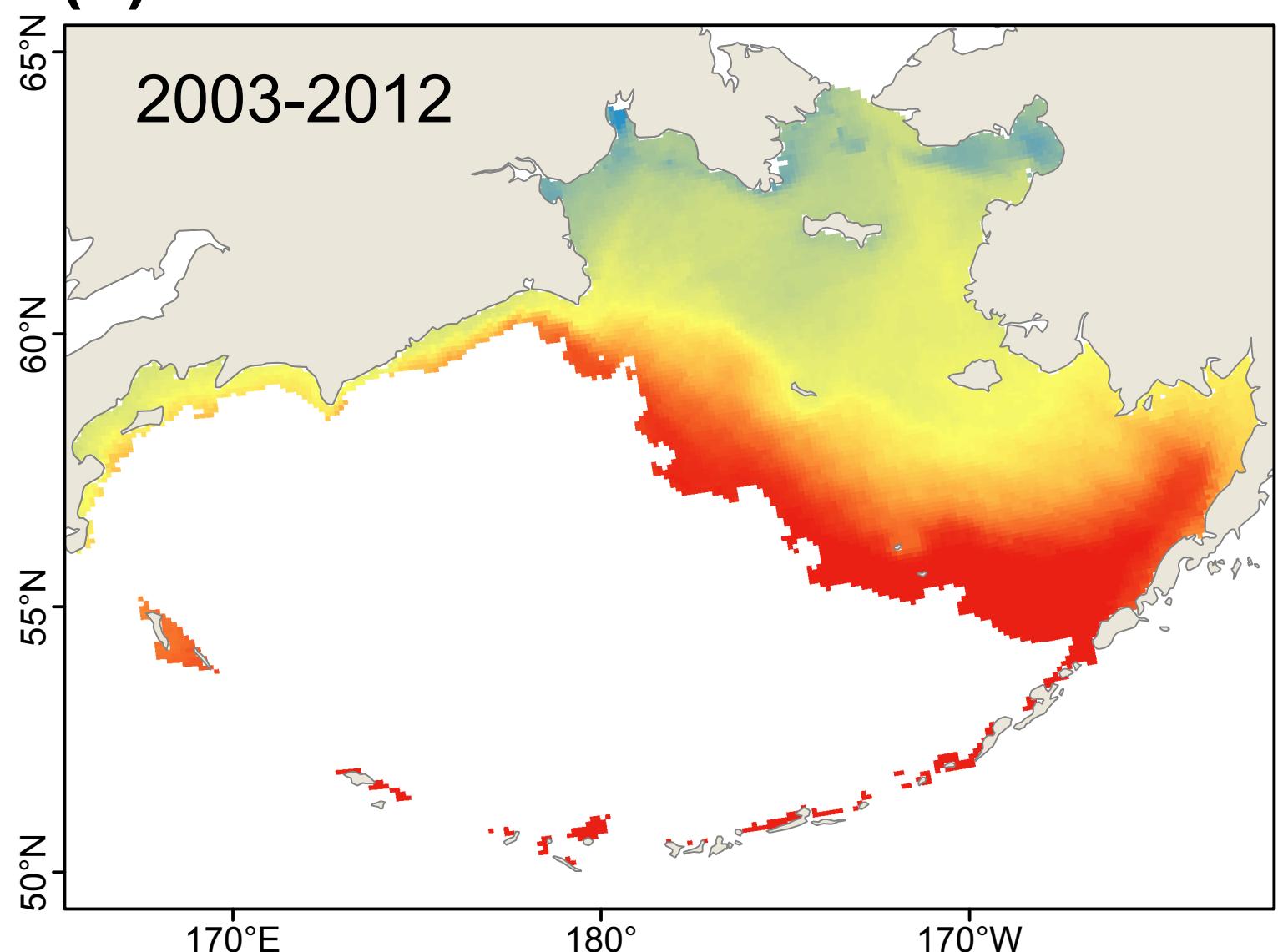


# *Petricolaria pholadiformis: Weekly Survival*

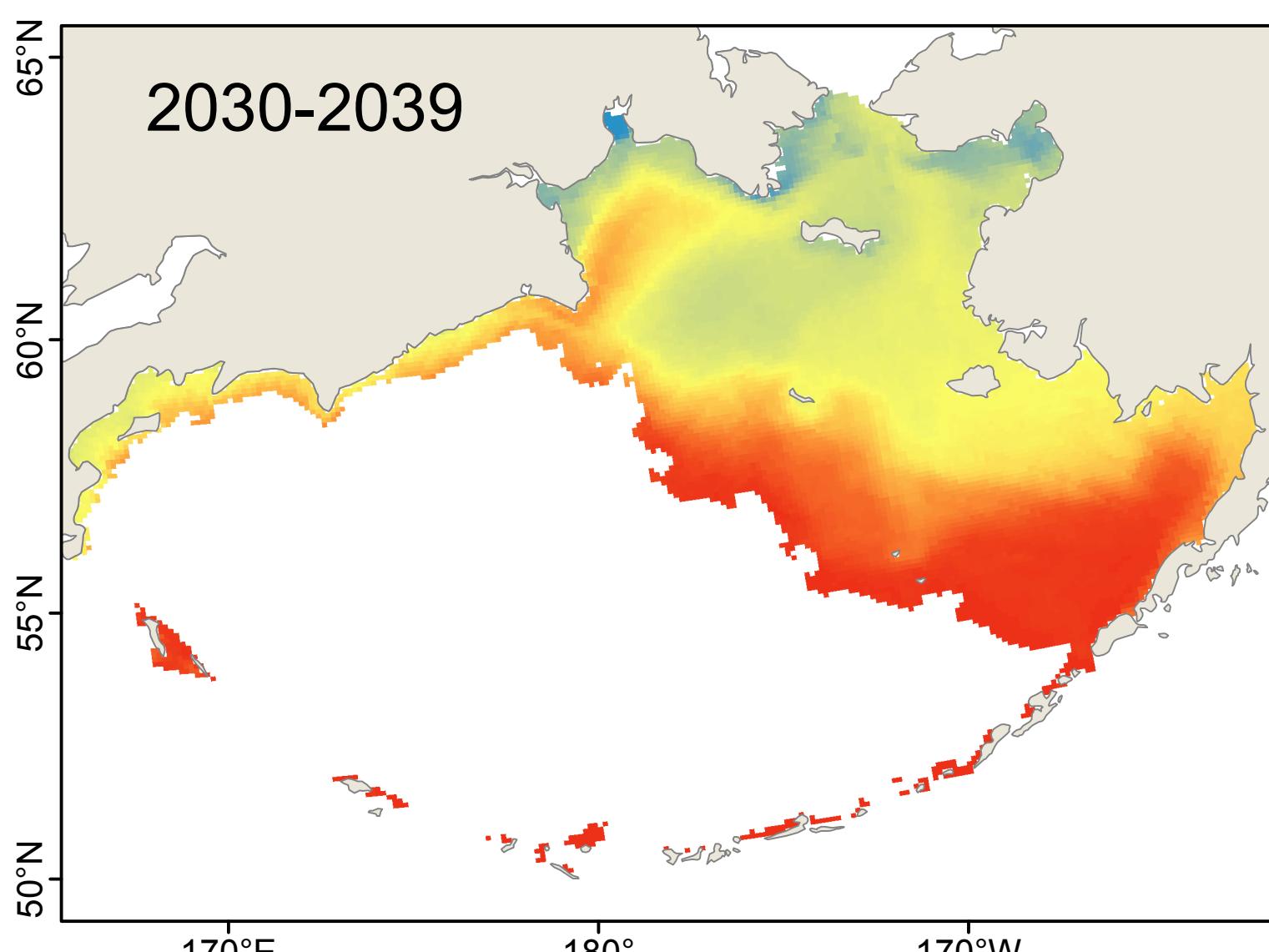
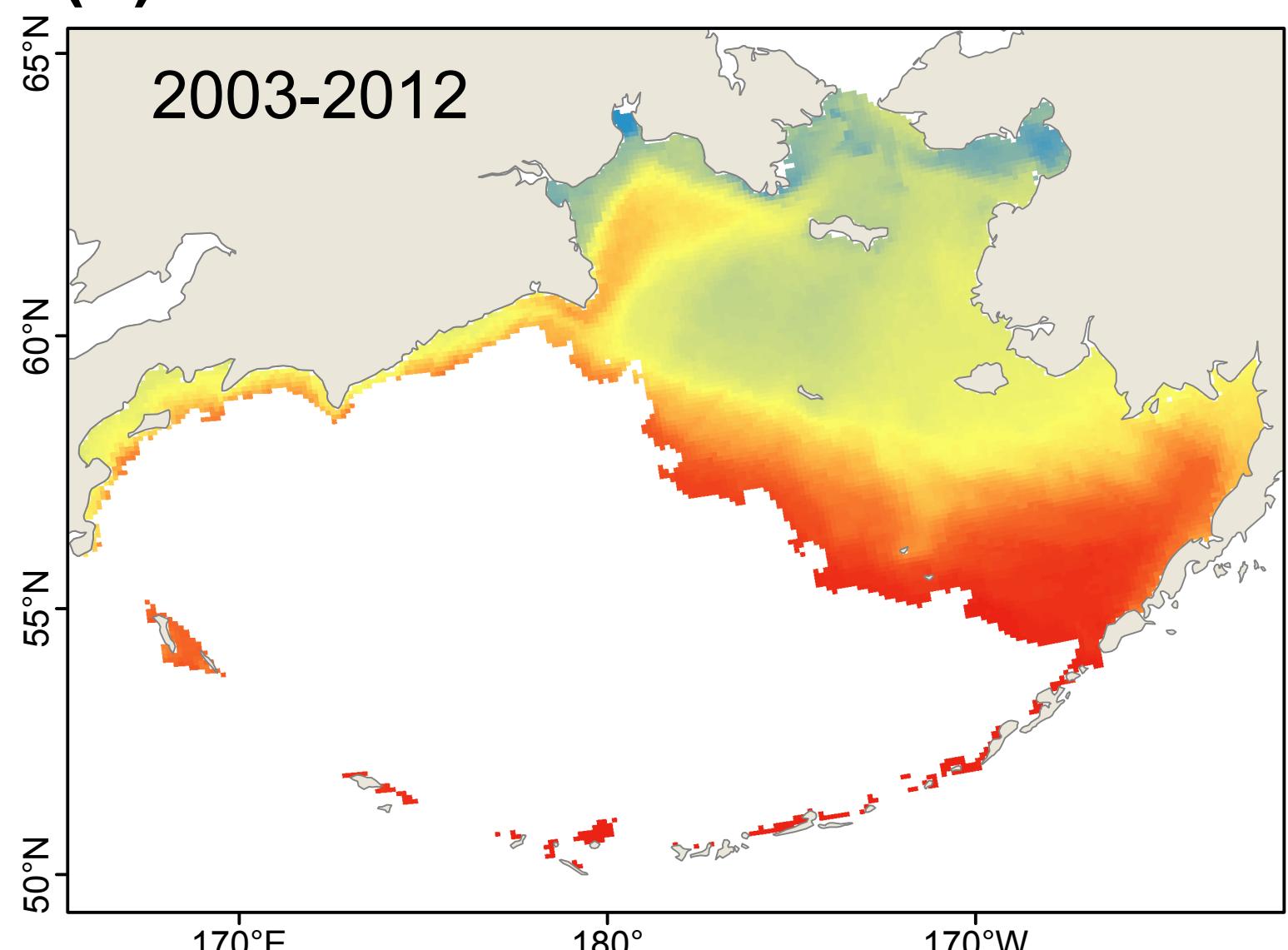
Average number of weeks of suitable habitat



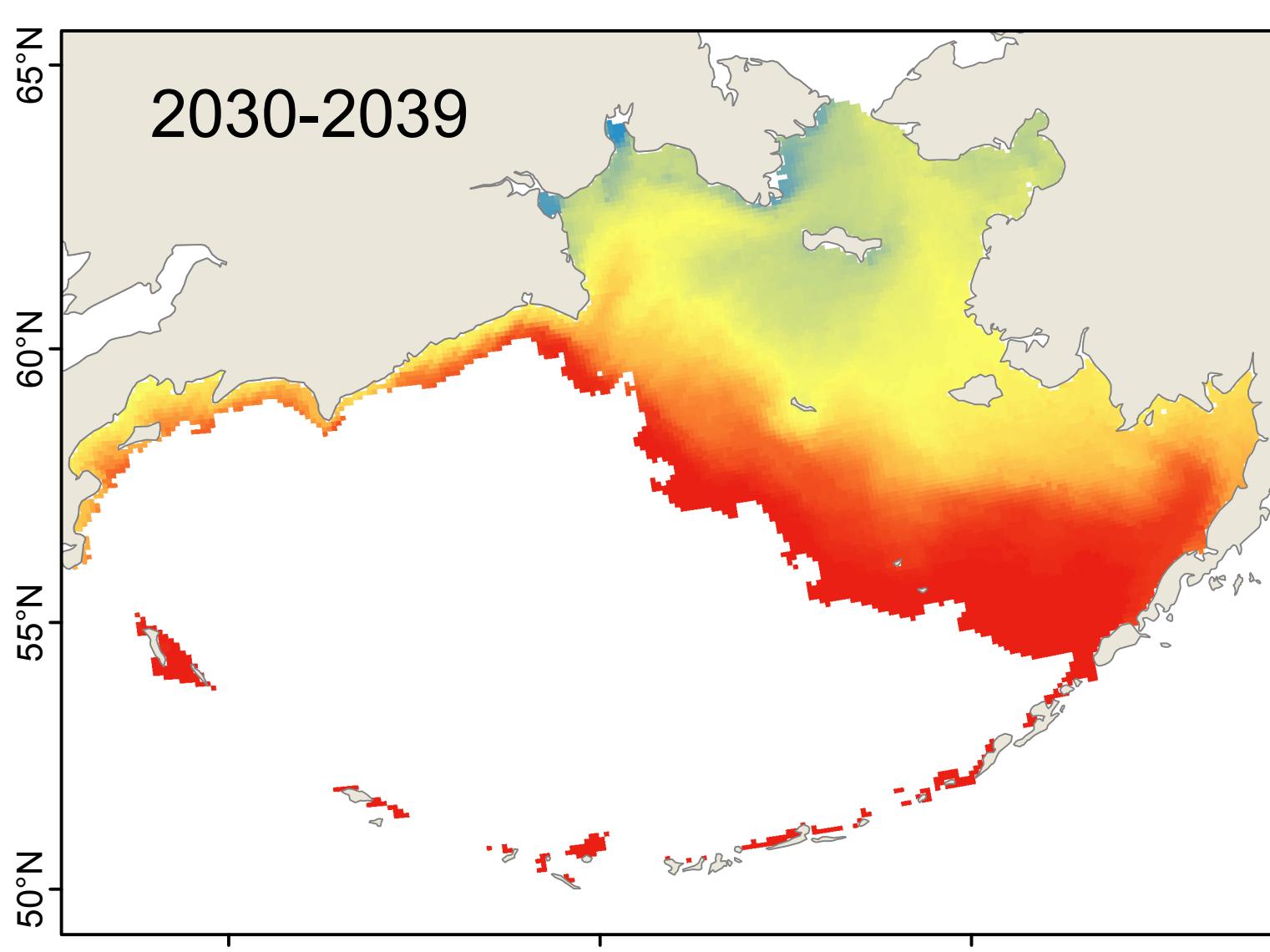
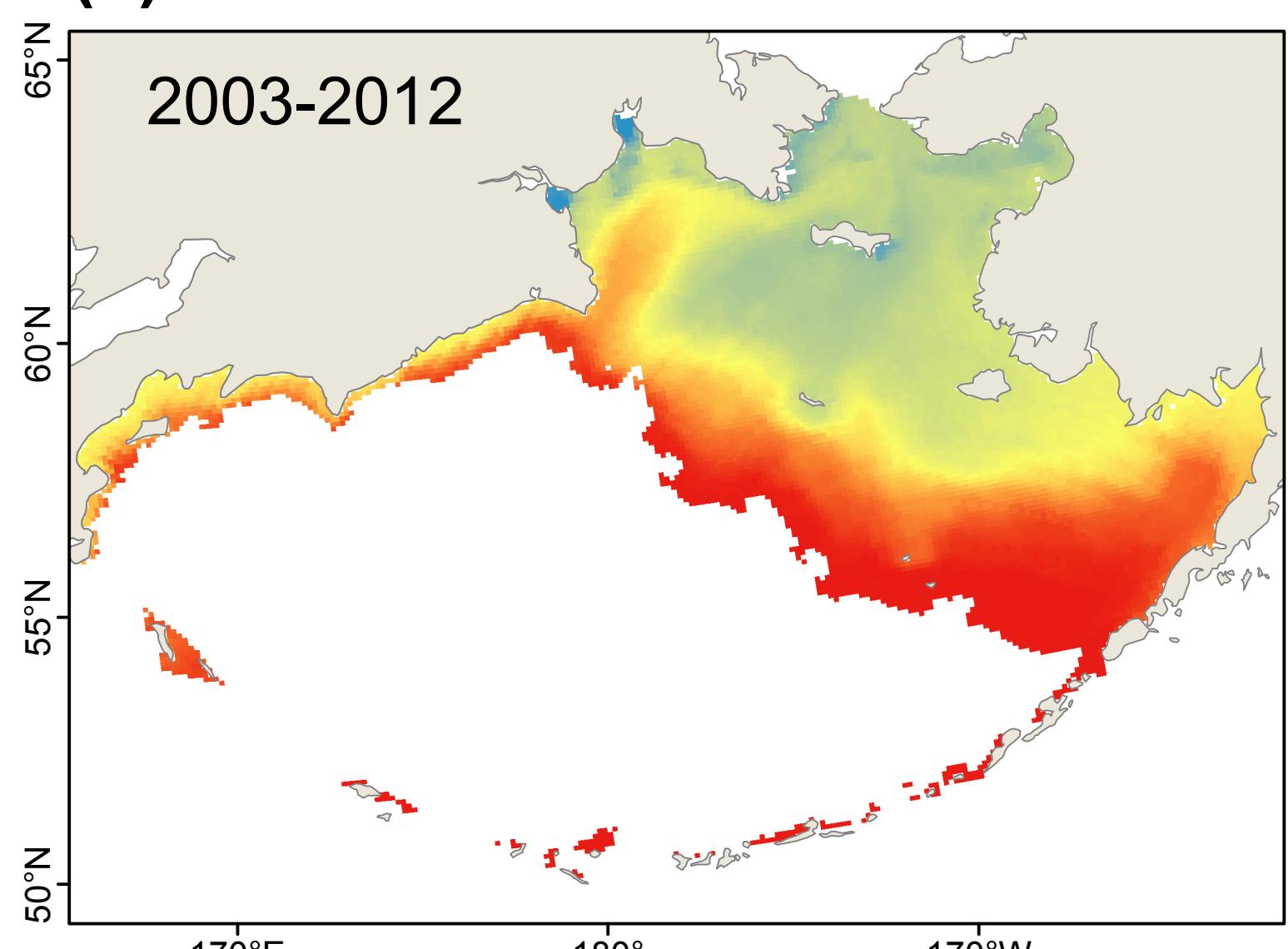
(a) Model: CGCM3-t47



(b) Model: ECHO-G

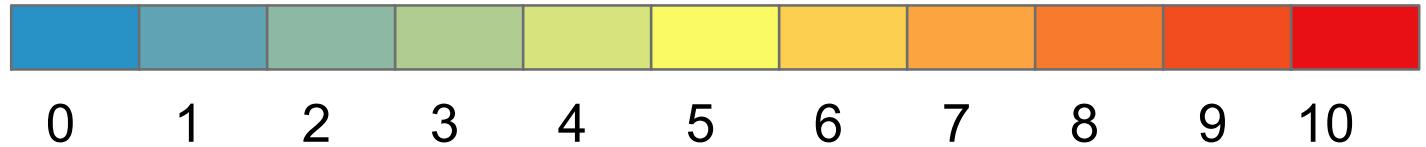


(c) Model: MIROC3.2

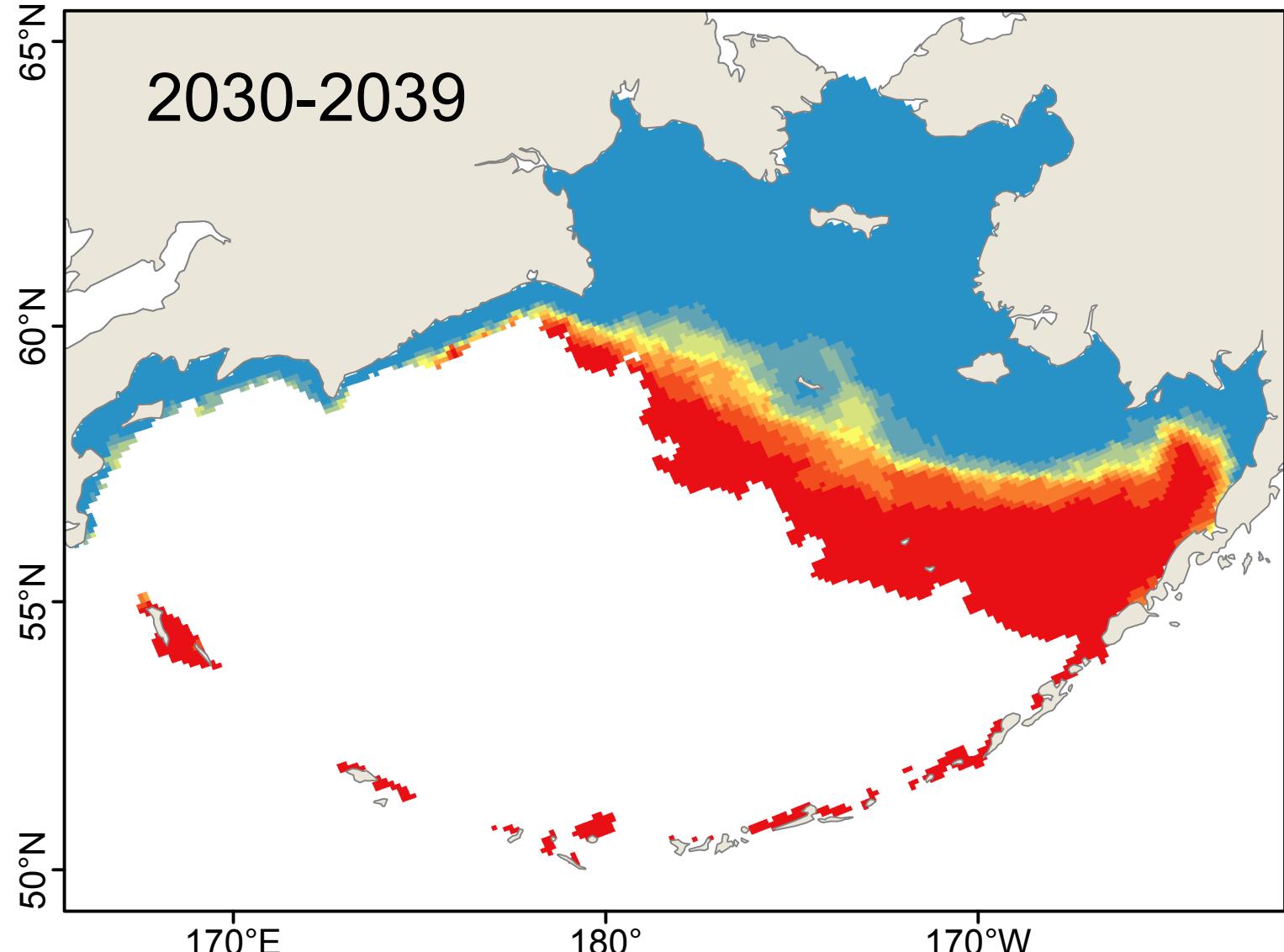
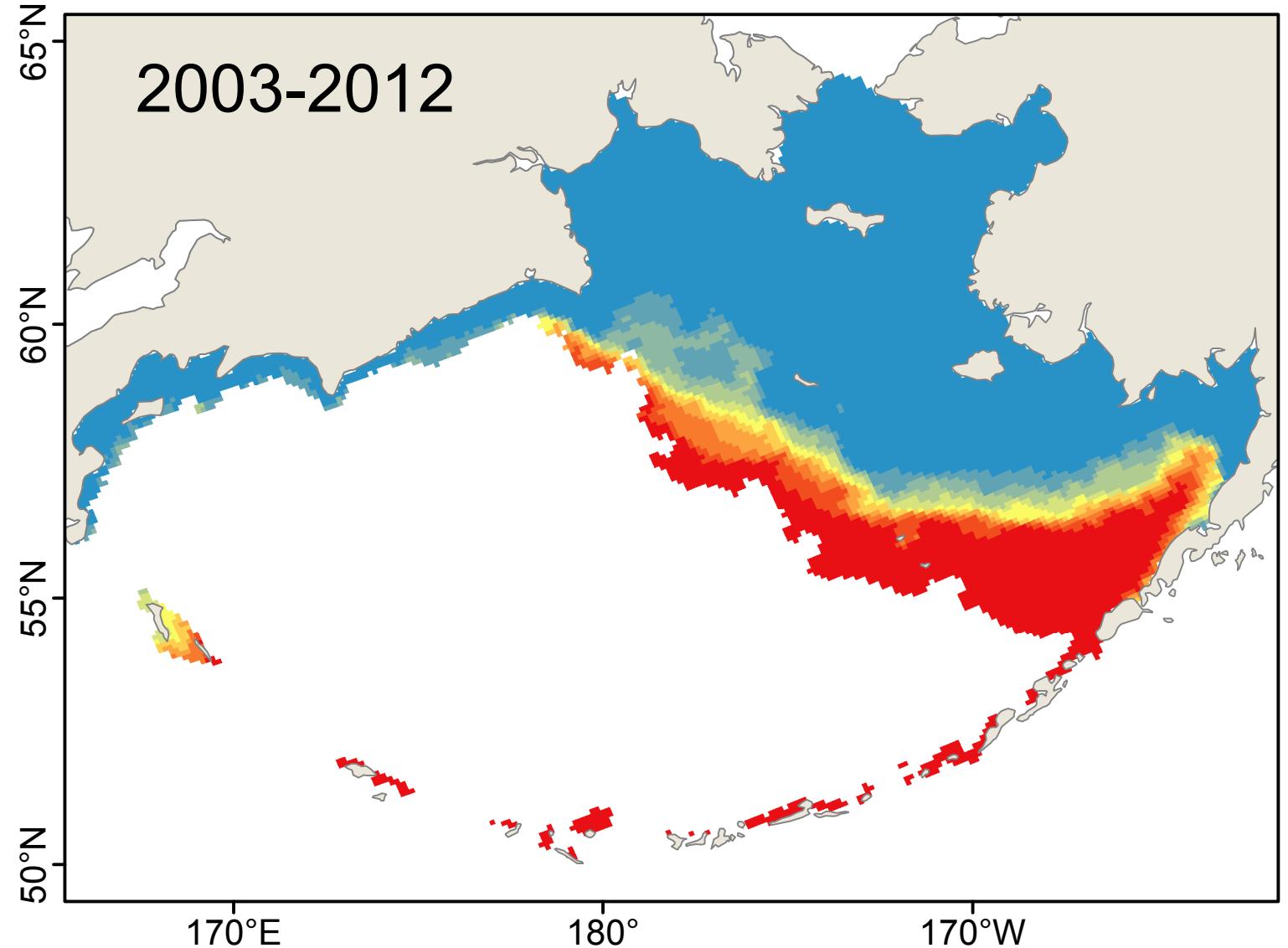


# *Teredo navalis*: Year-round Survival

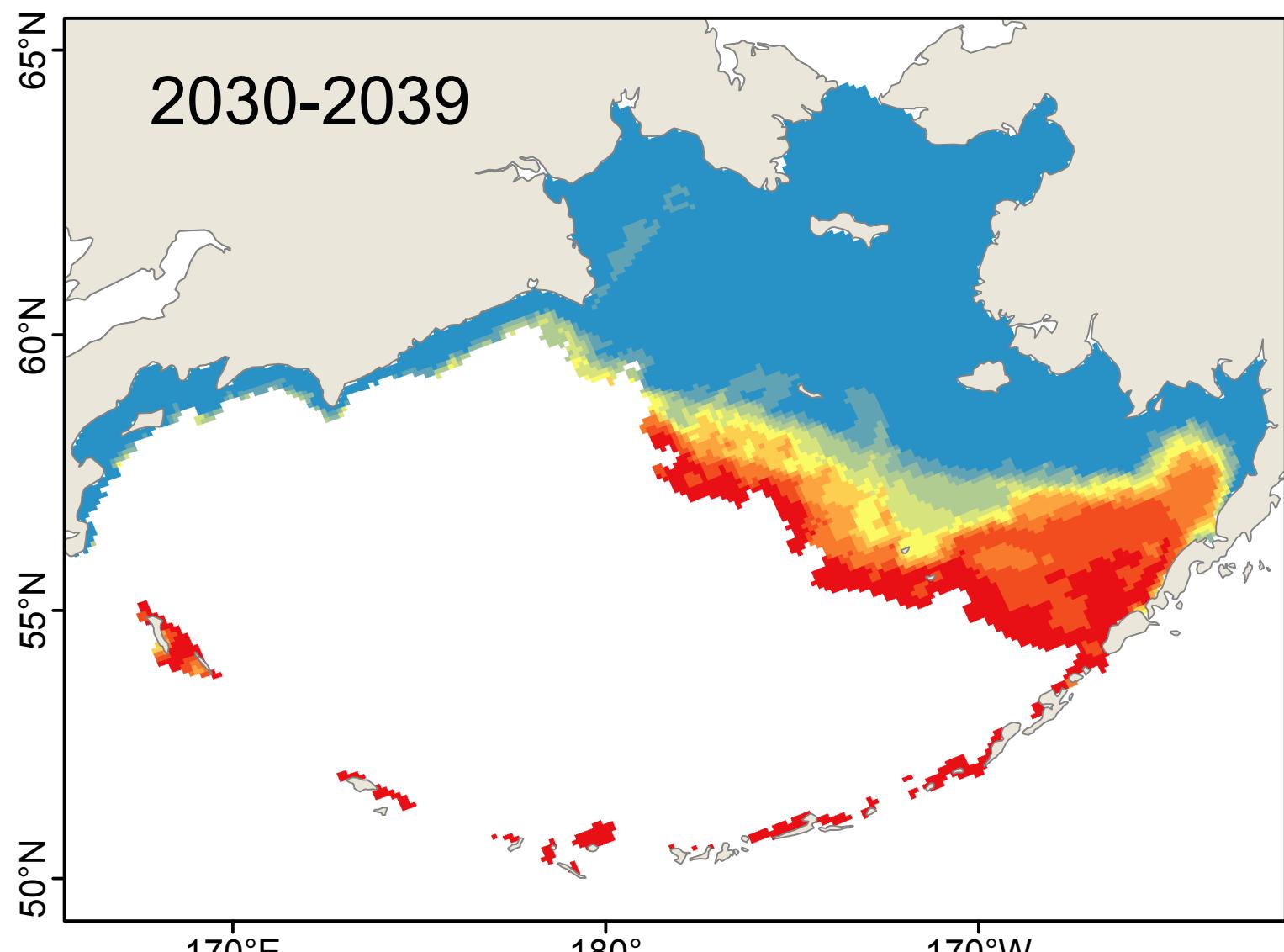
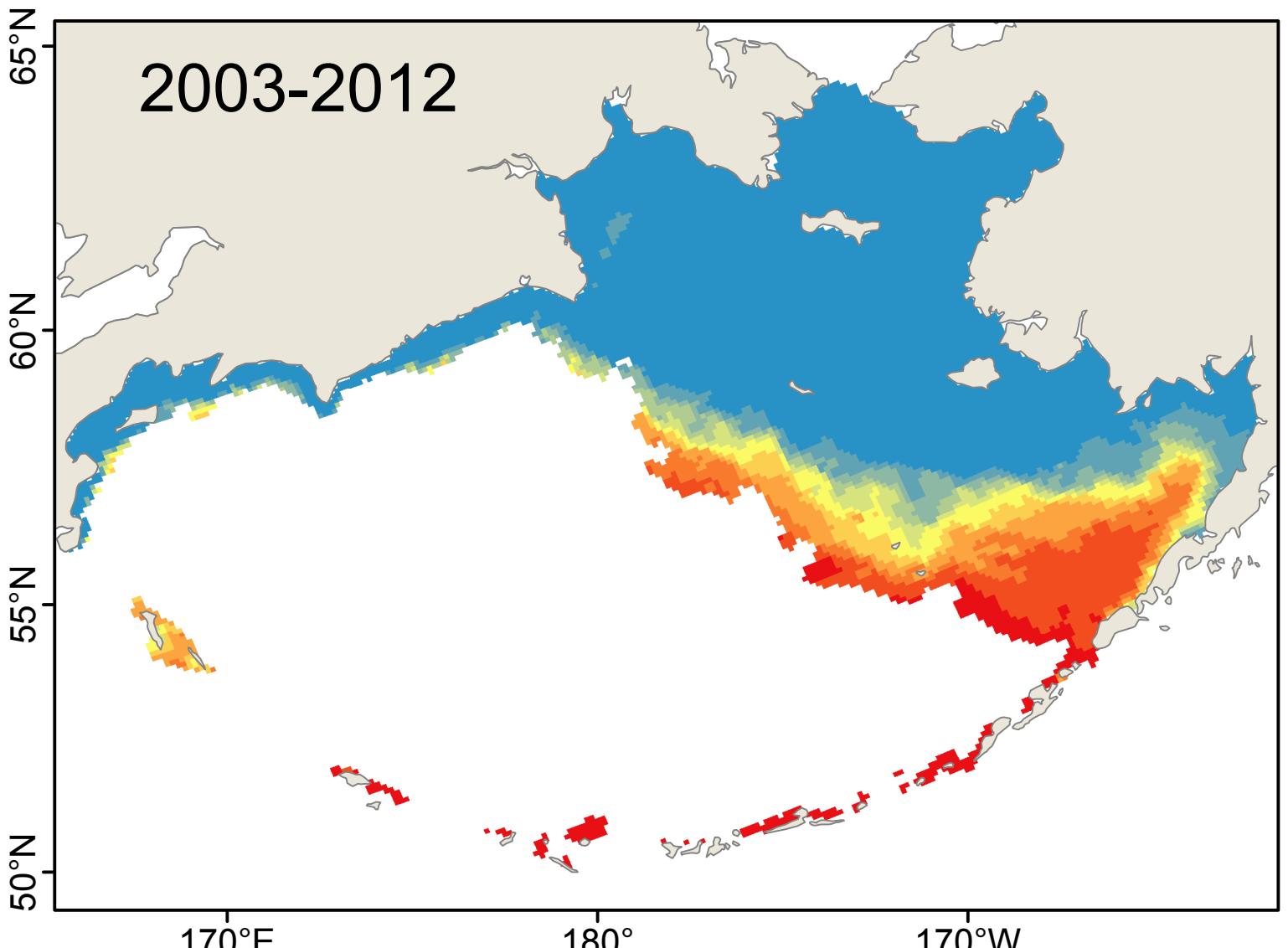
Number of years with suitable habitat



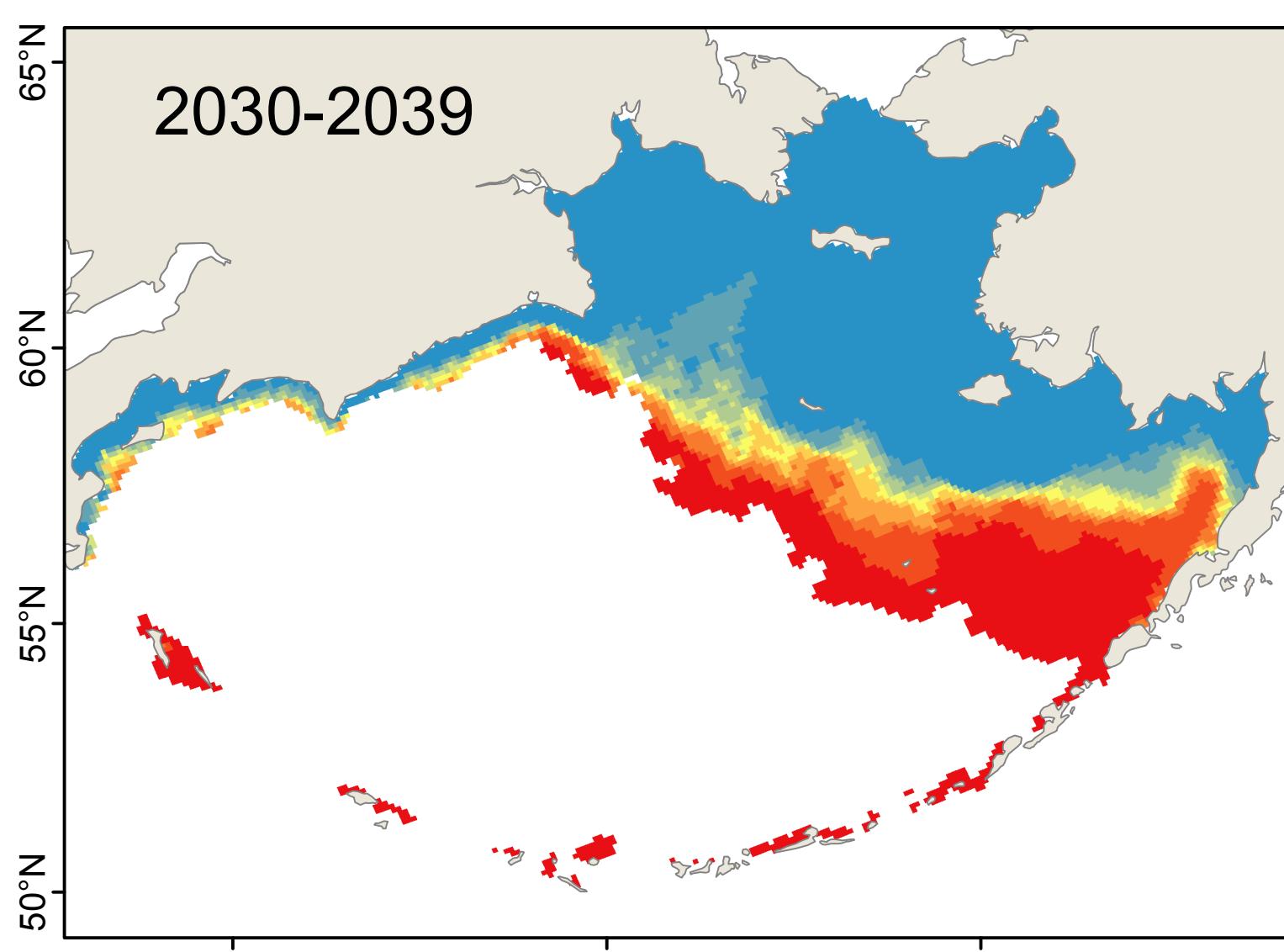
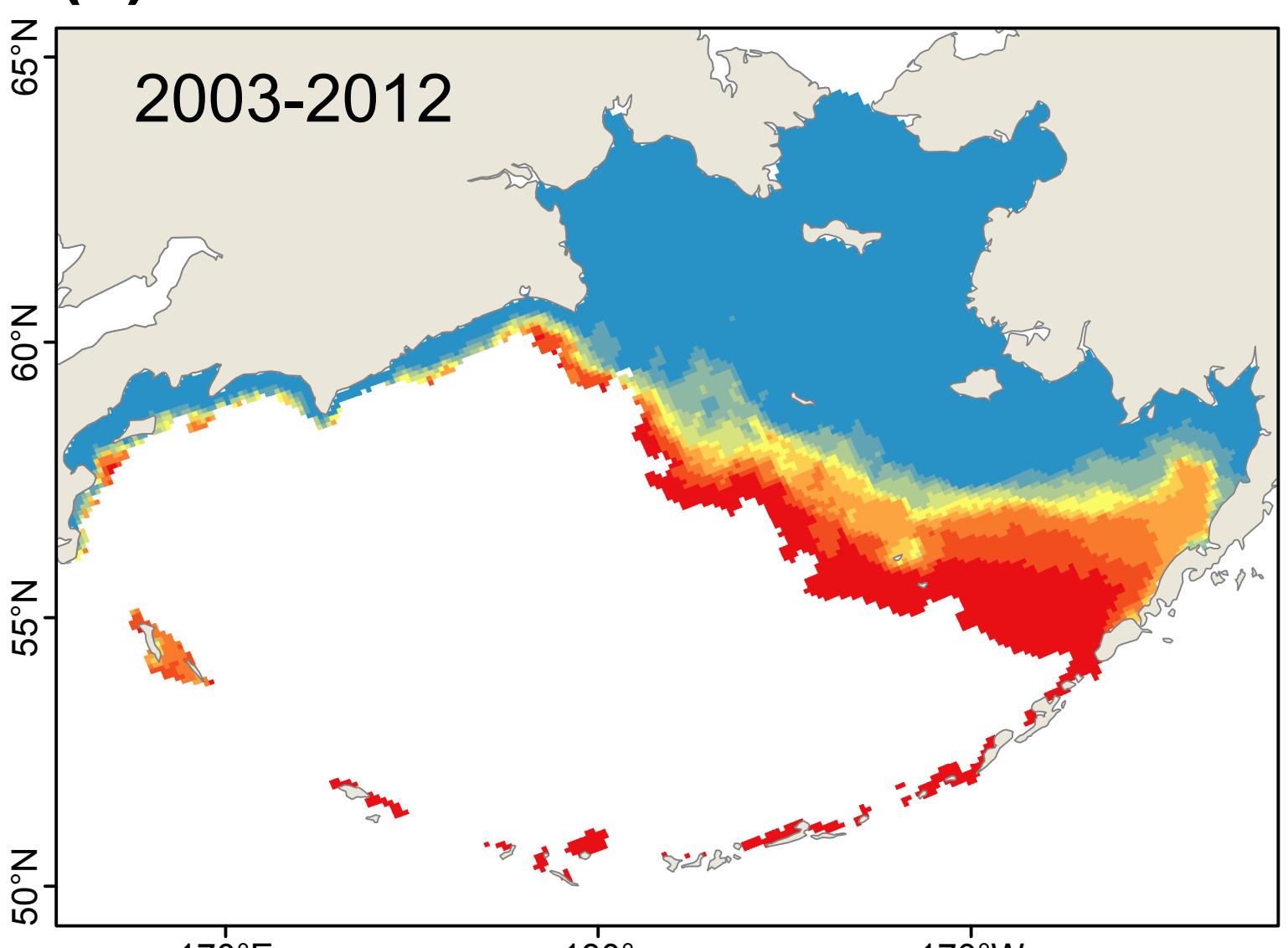
(a) Model: CGCM3-t47



(b) Model: ECHO-G

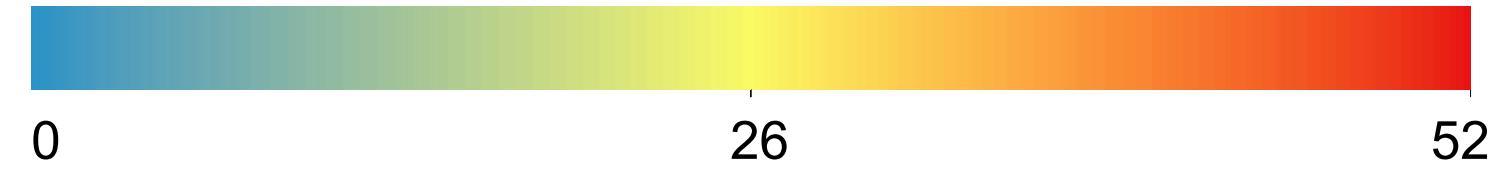


(c) Model: MIROC3.2

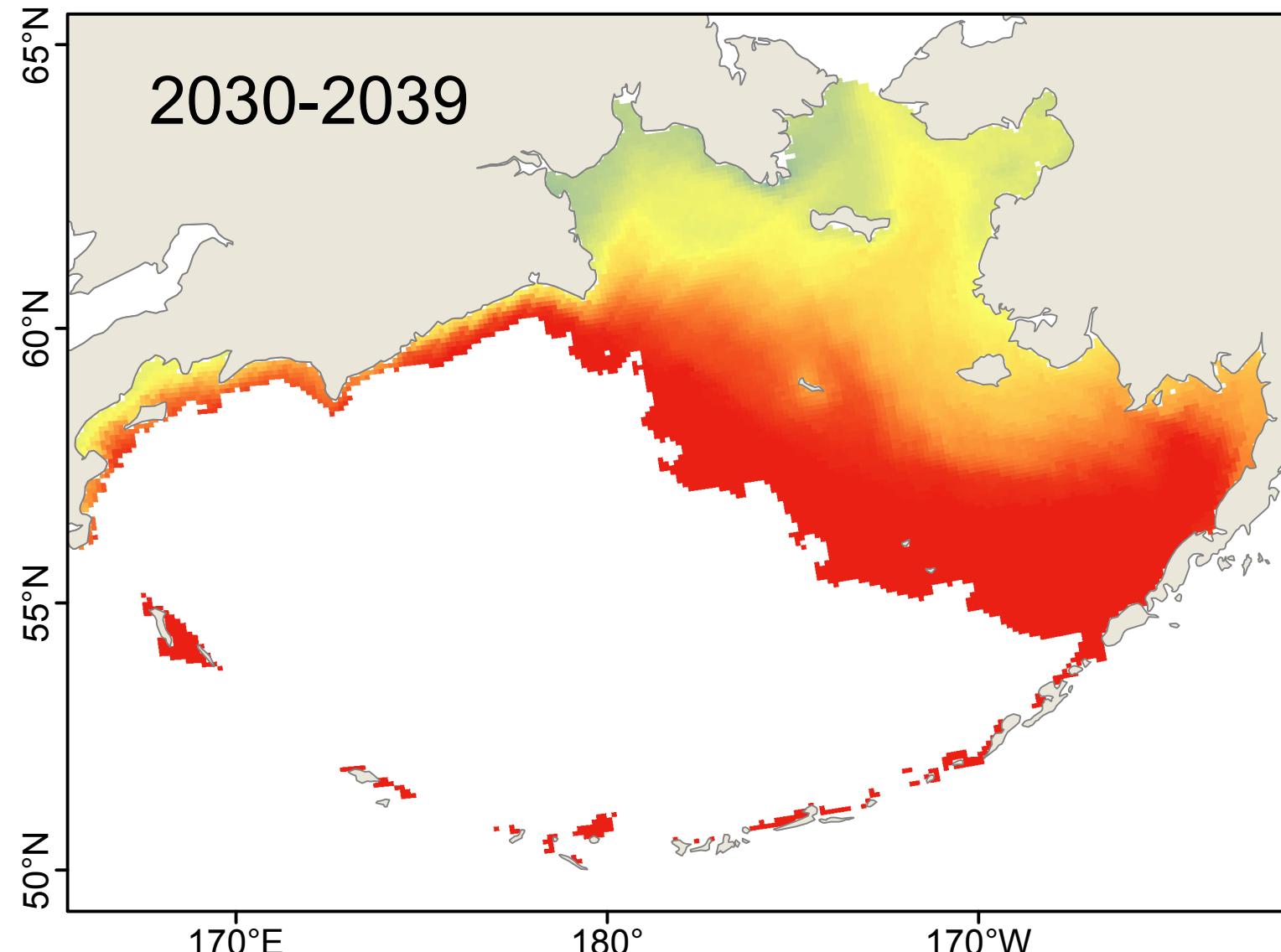
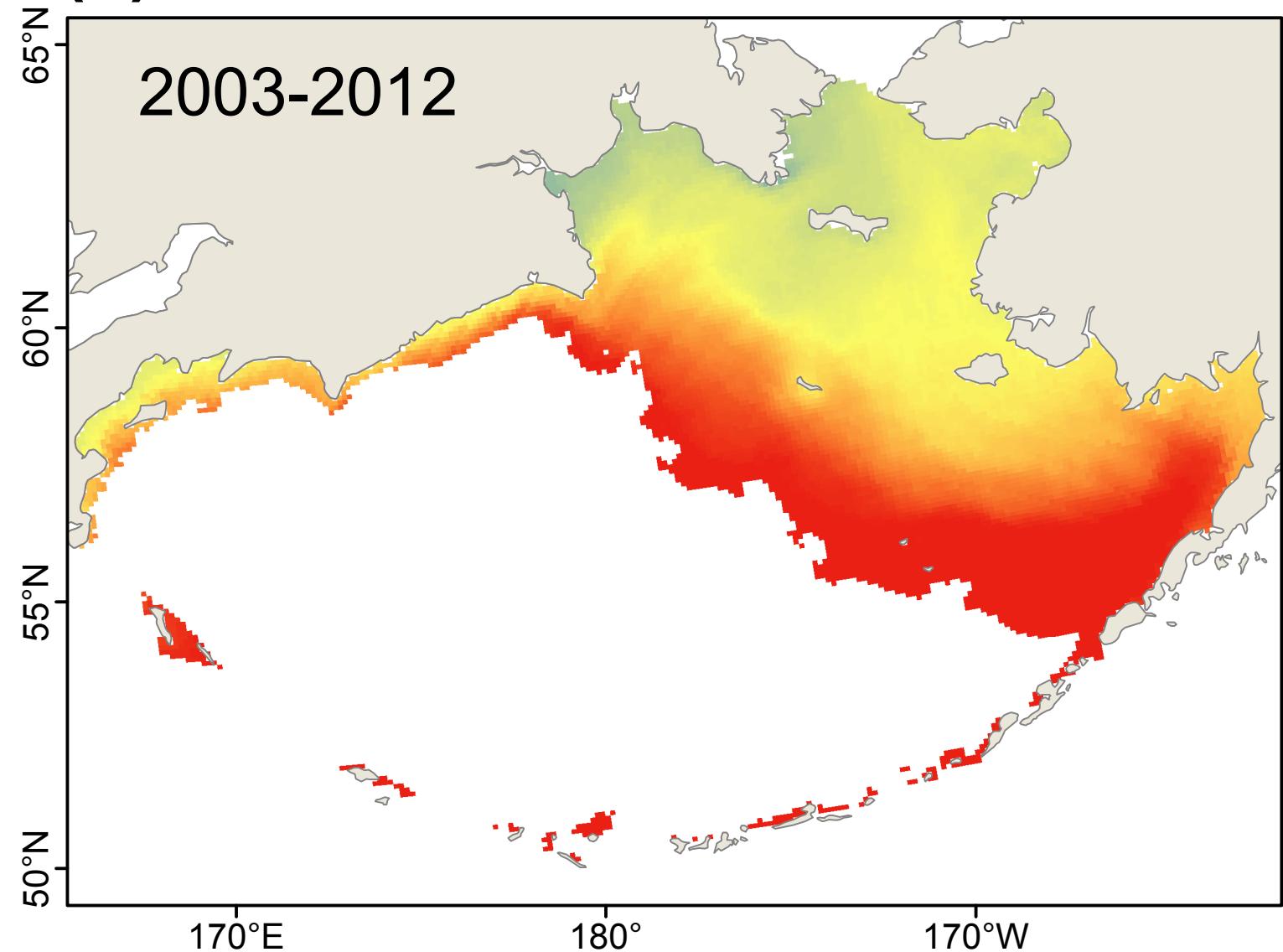


# *Teredo navalis*: Weekly Survival

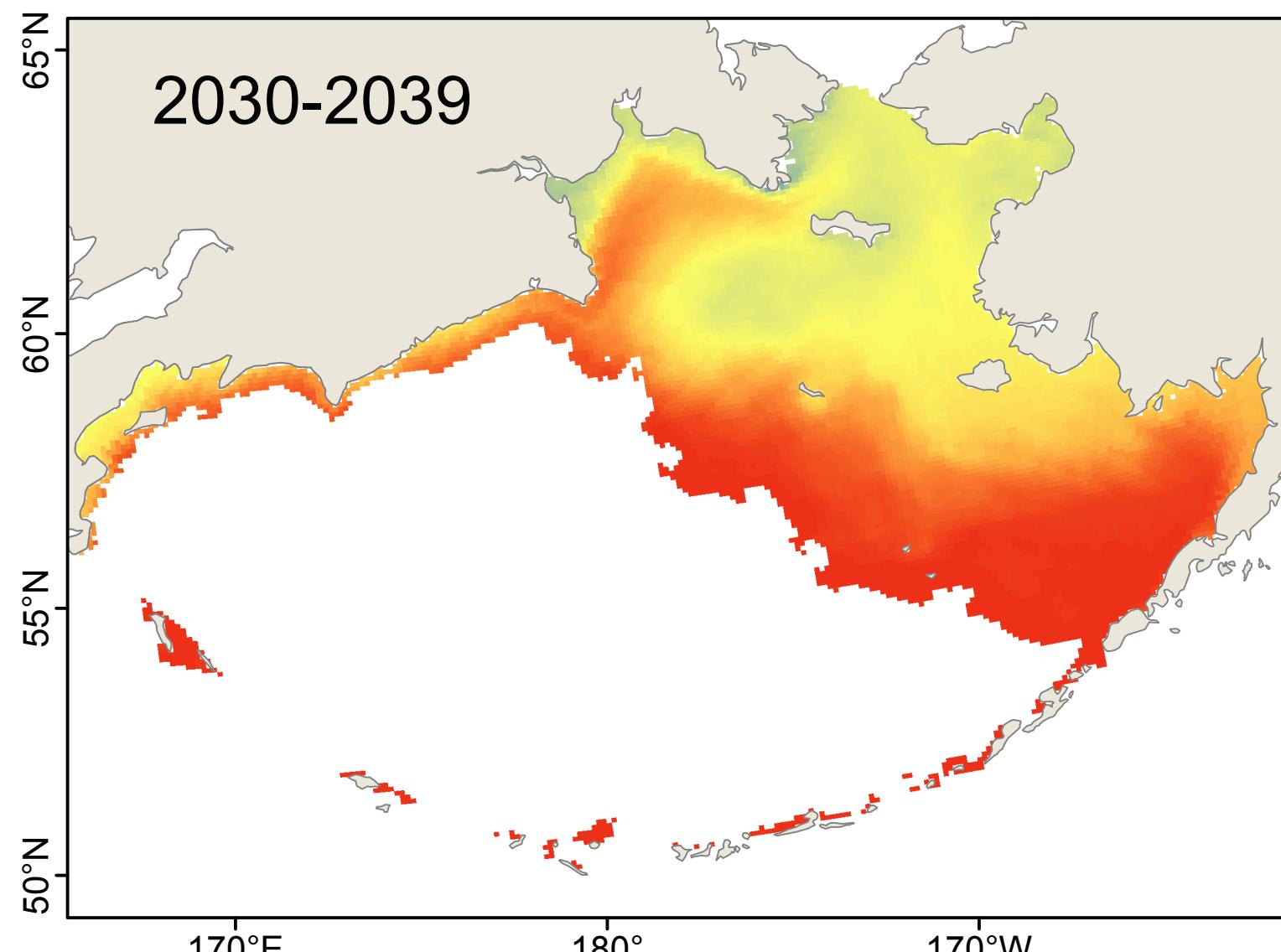
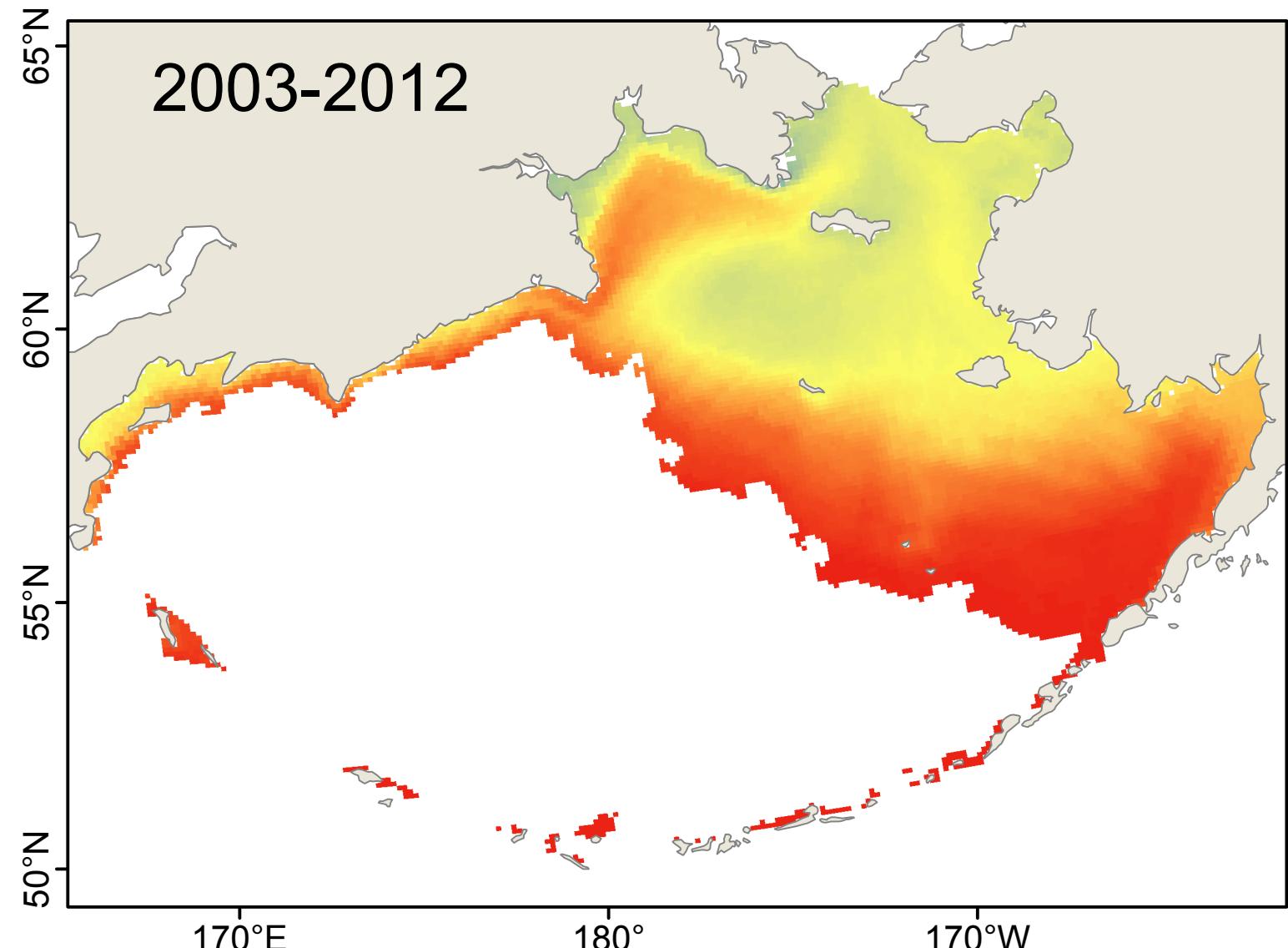
Average number of weeks of suitable habitat



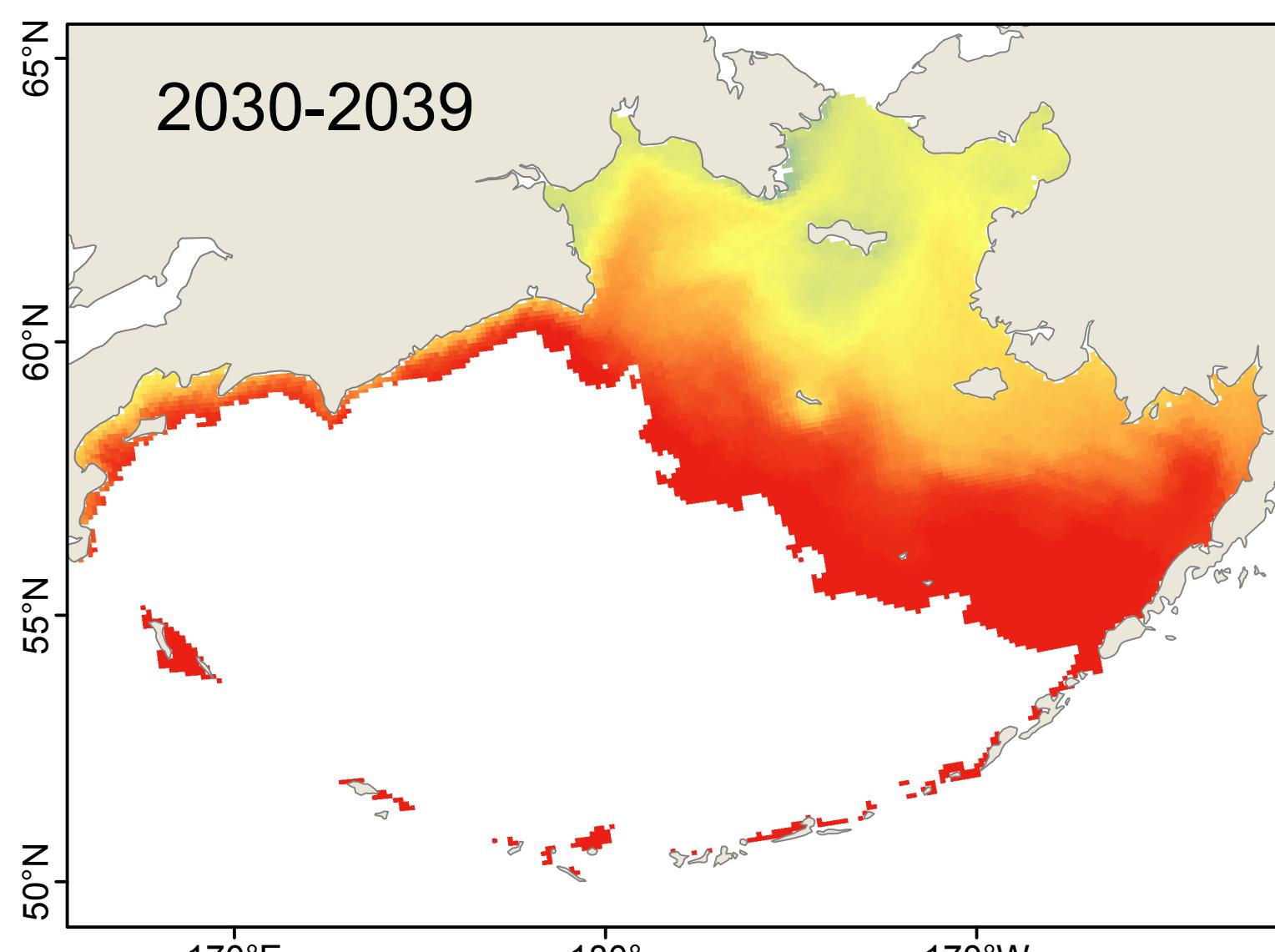
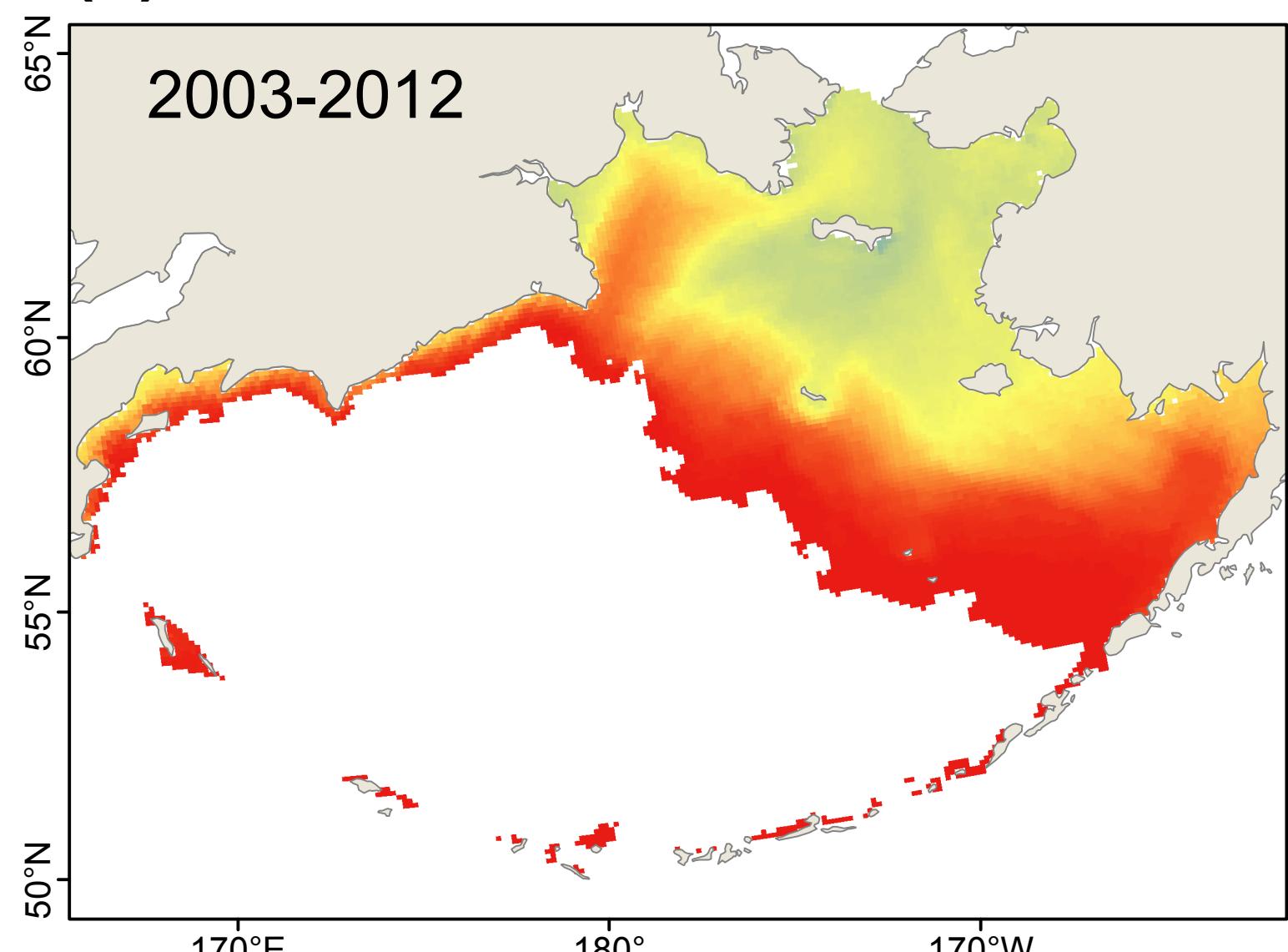
(a) Model: CGCM3-t47



(b) Model: ECHO-G

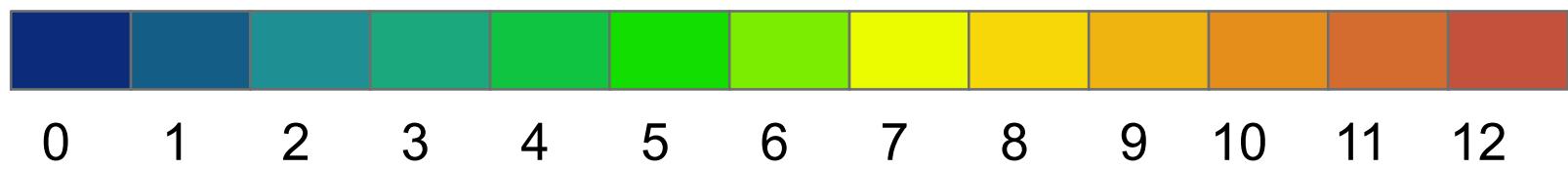


(c) Model: MIROC3.2

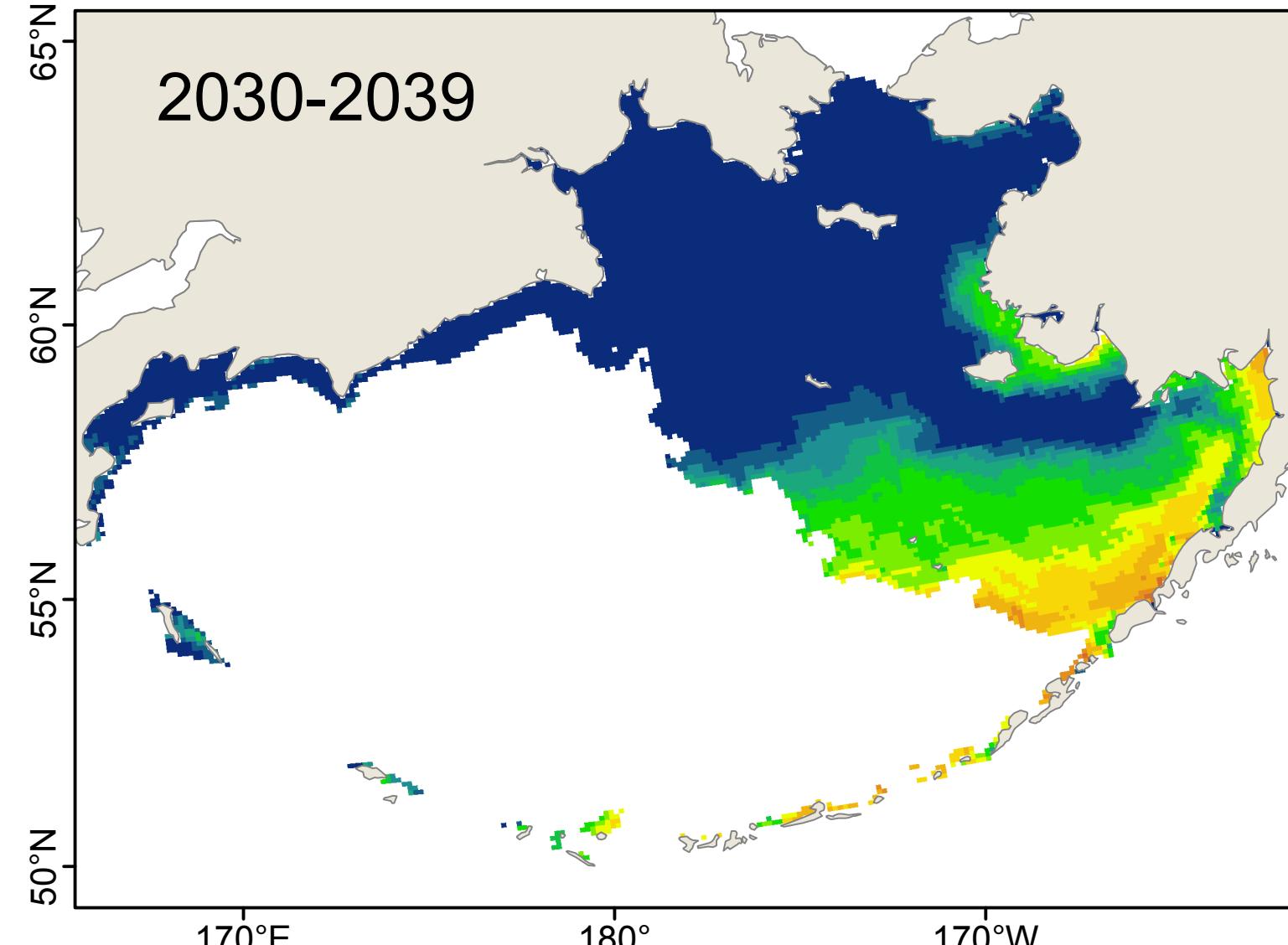
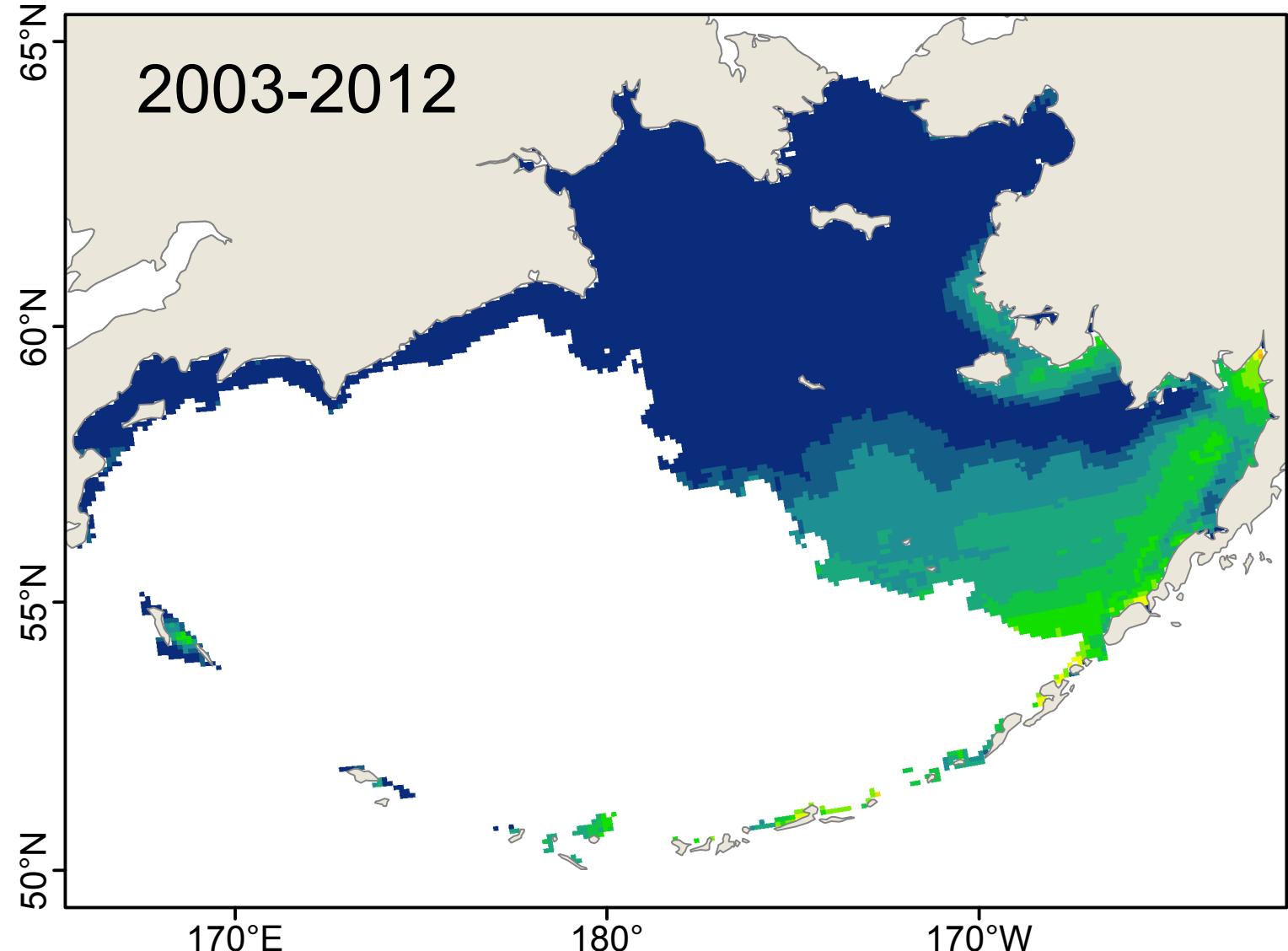


# *Teredo navalis: Reproduction*

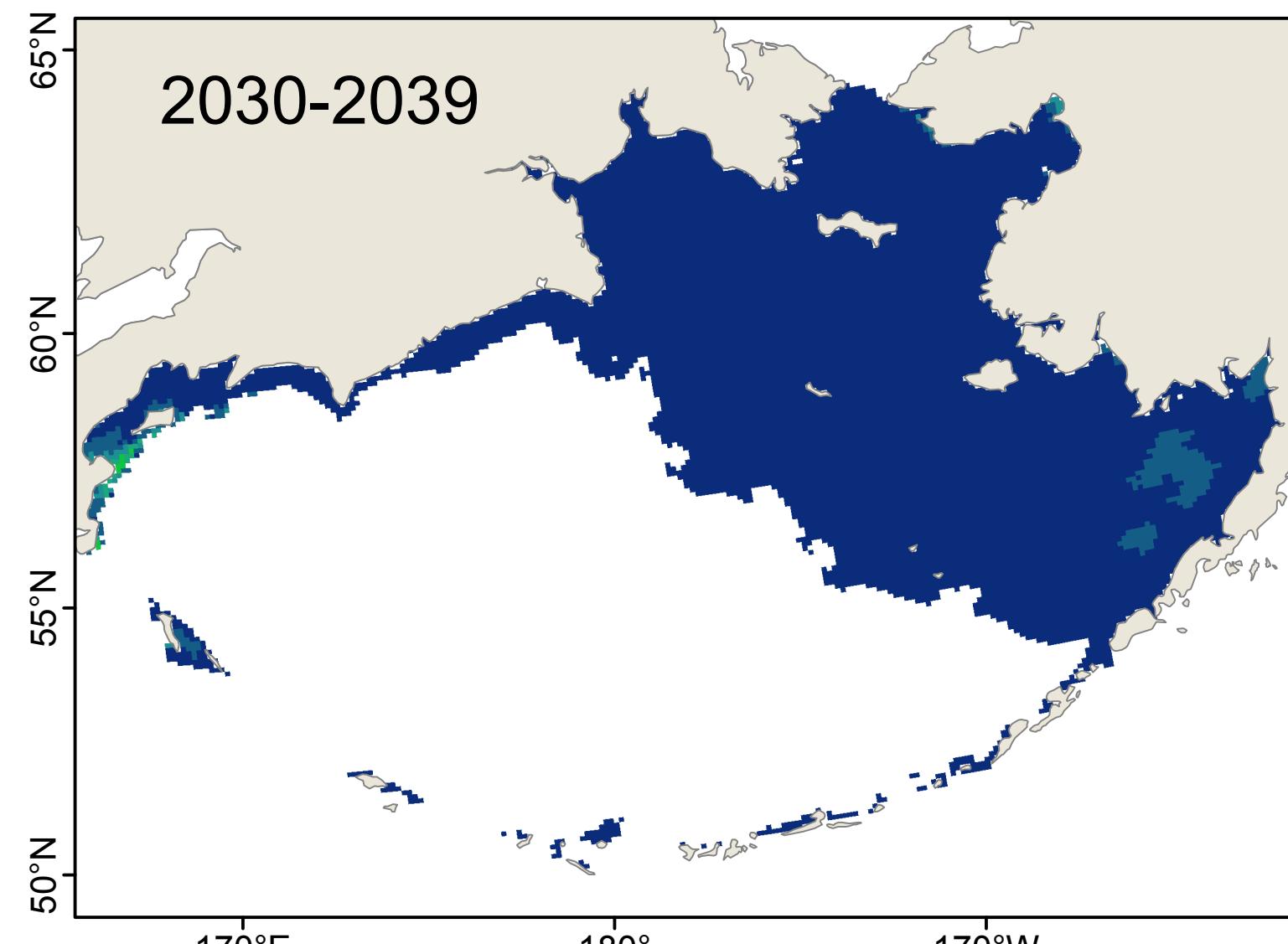
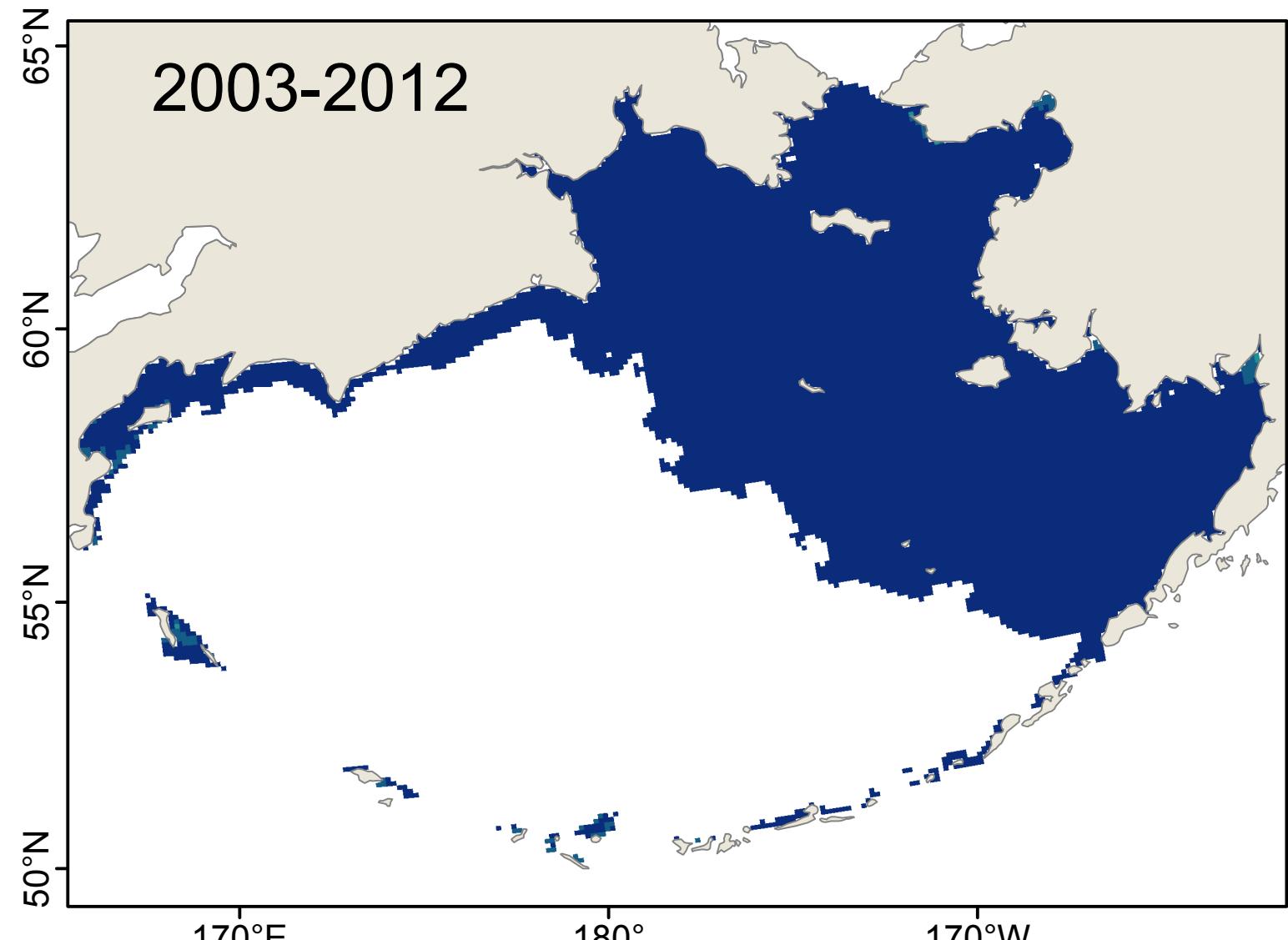
Average number of consecutive weeks of suitable habitat



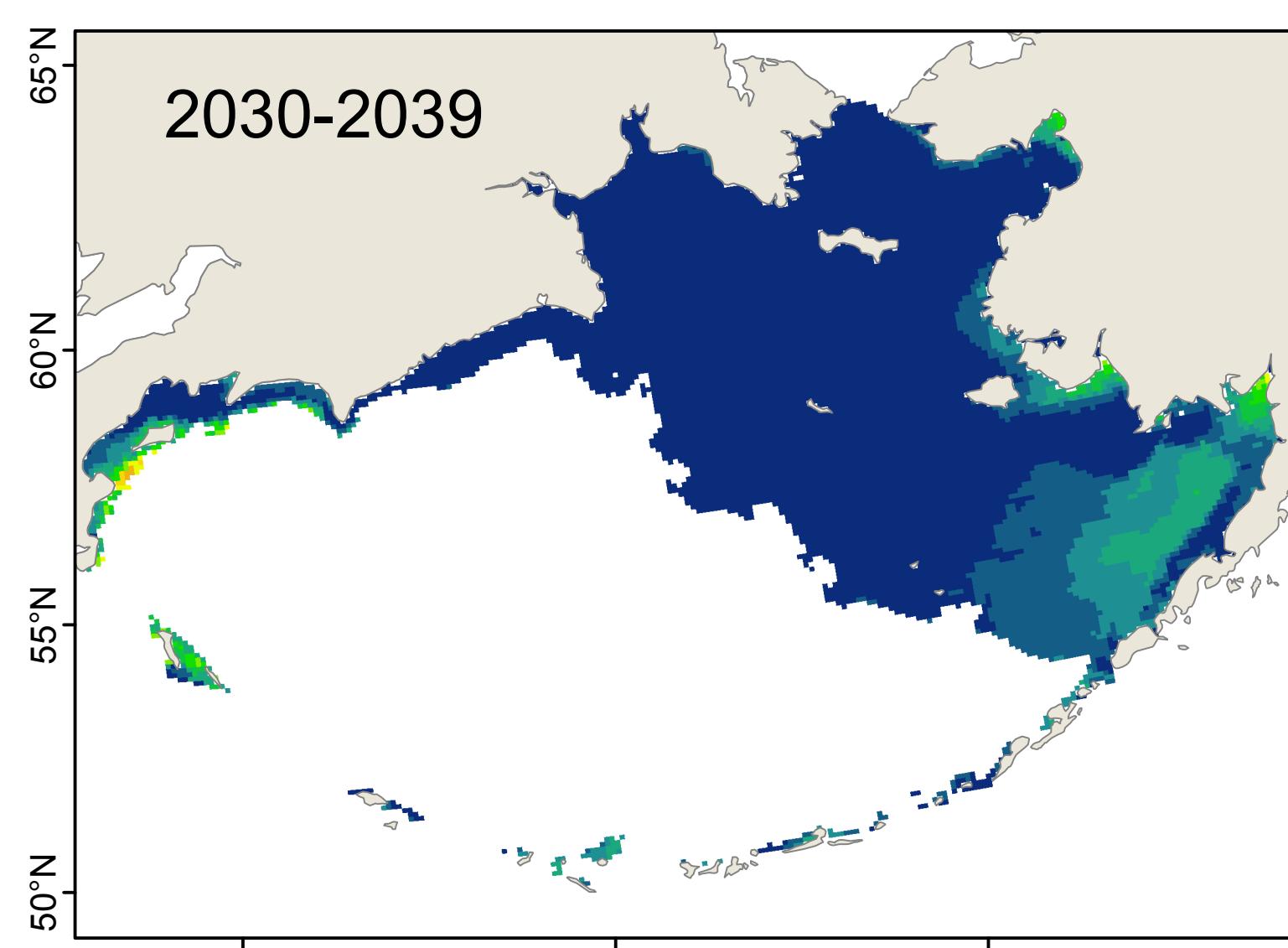
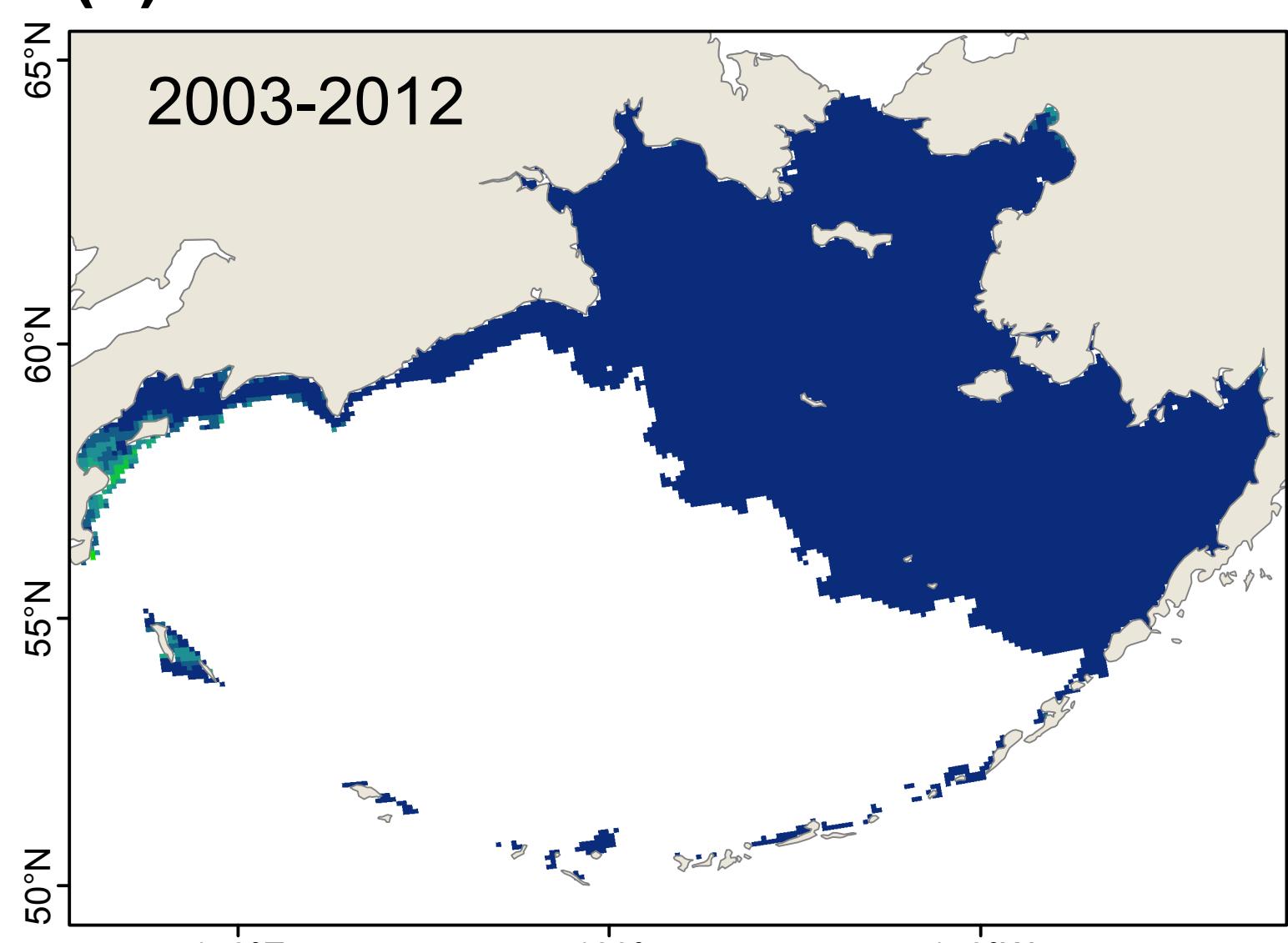
(a) Model: CGCM3-t47



(b) Model: ECHO-G



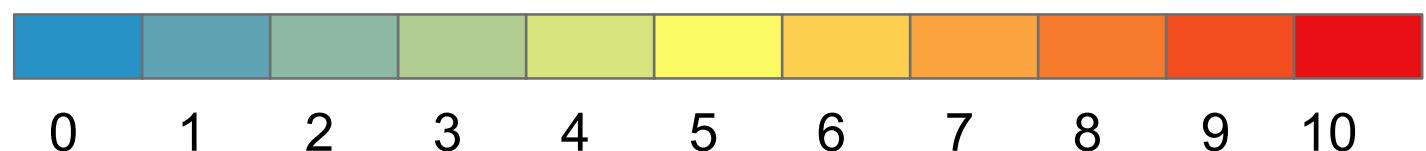
(c) Model: MIROC3.2



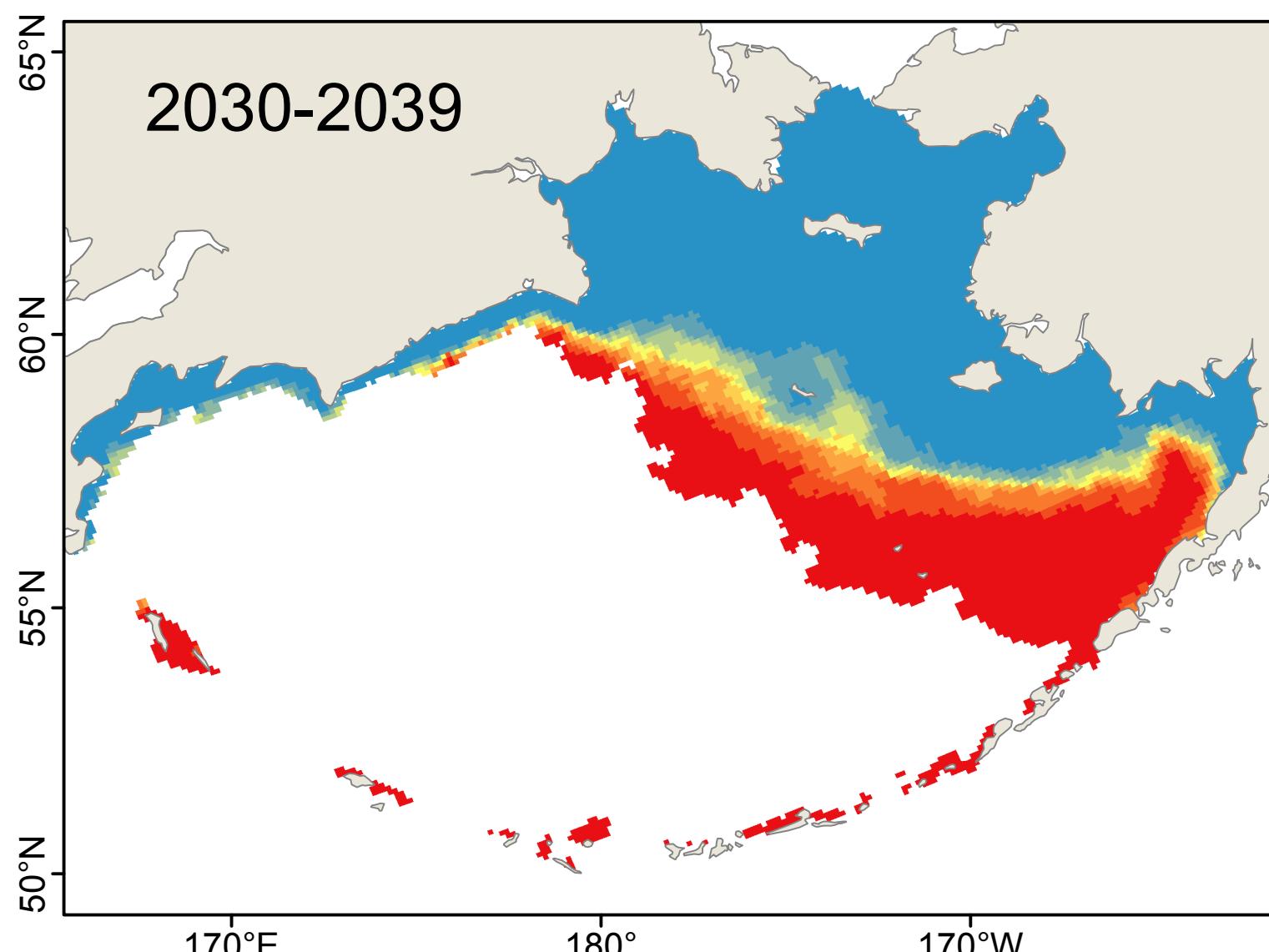
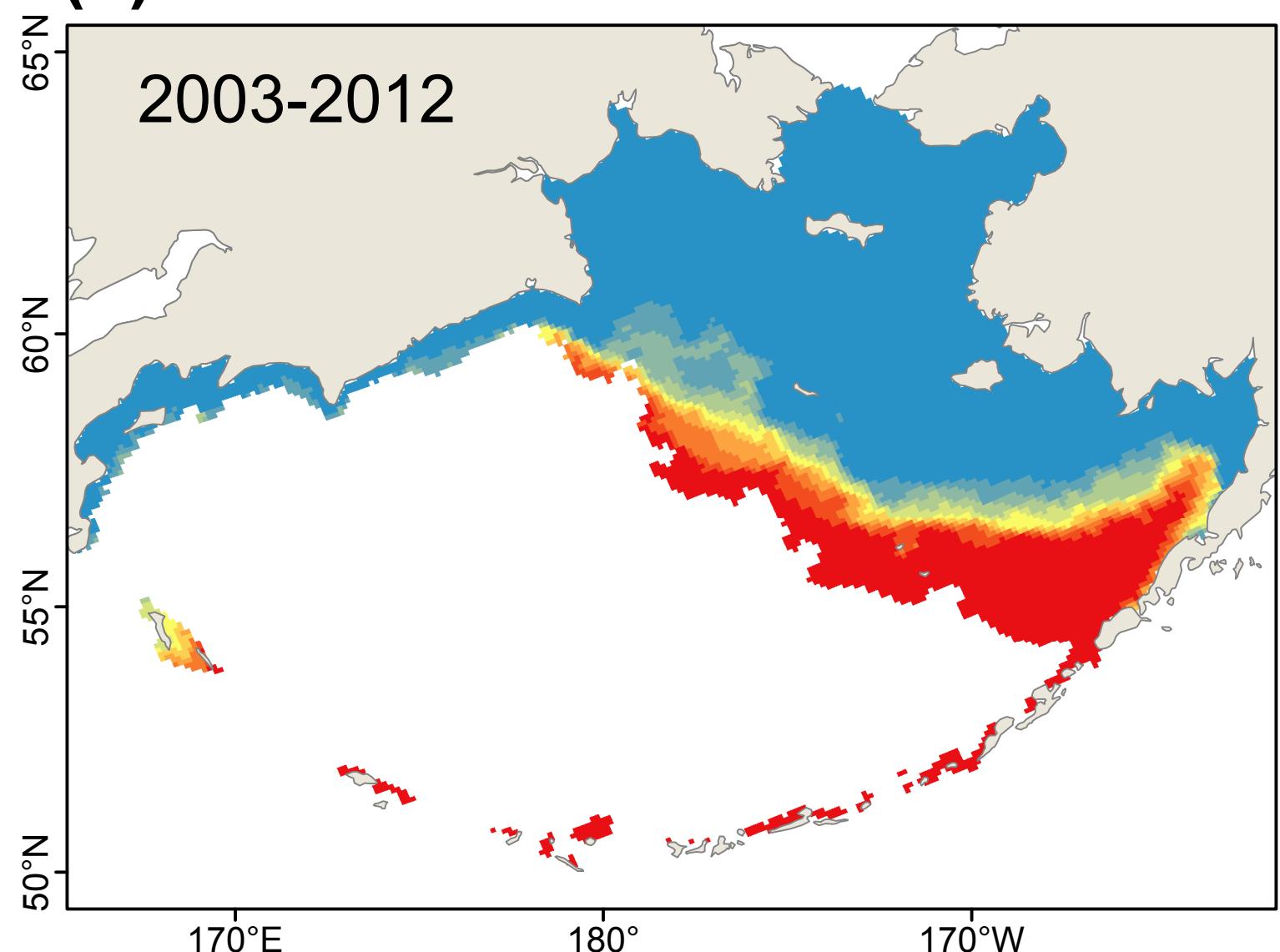
# *Venerupis philippinarum*: Year-round Survival

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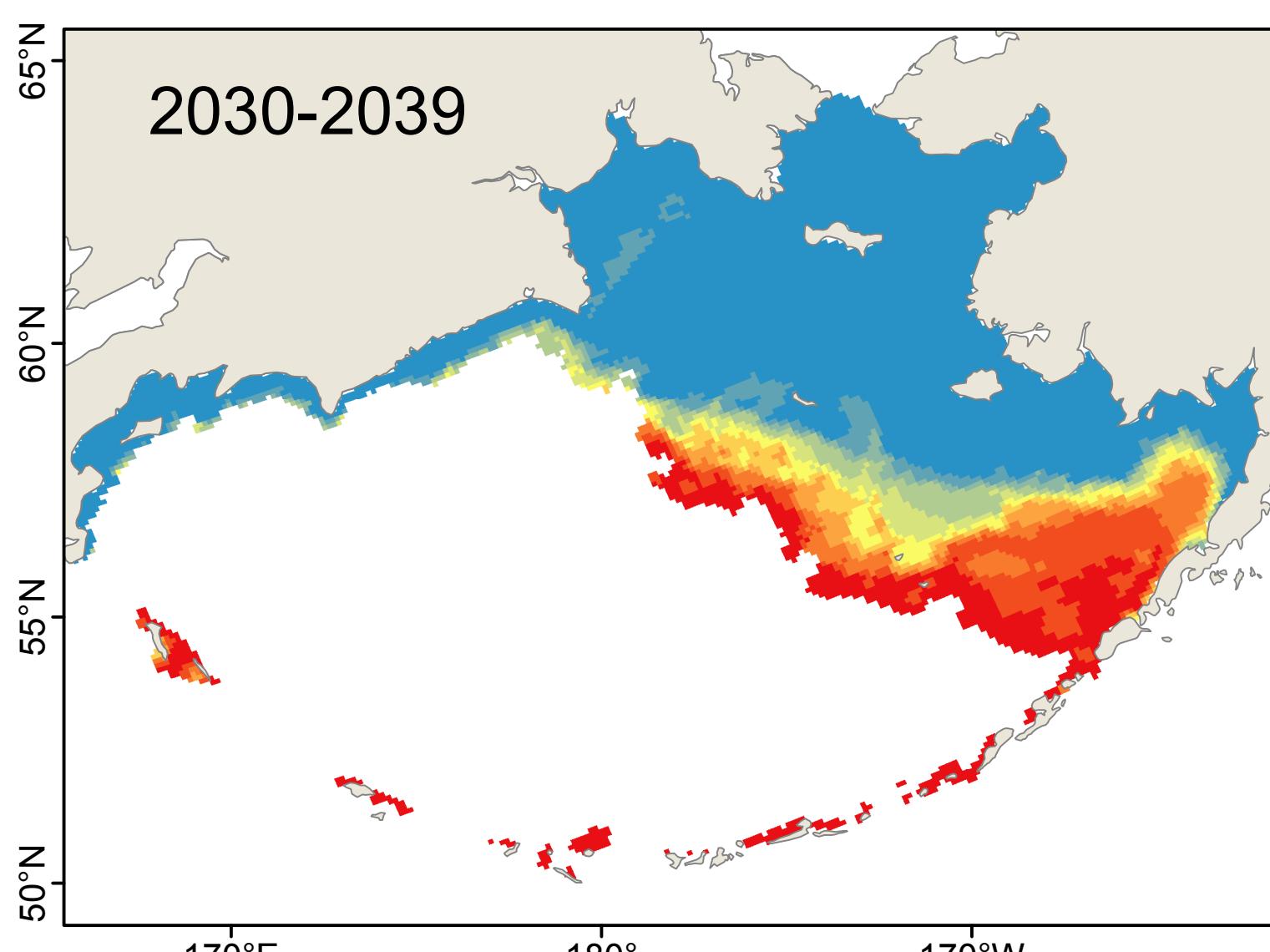
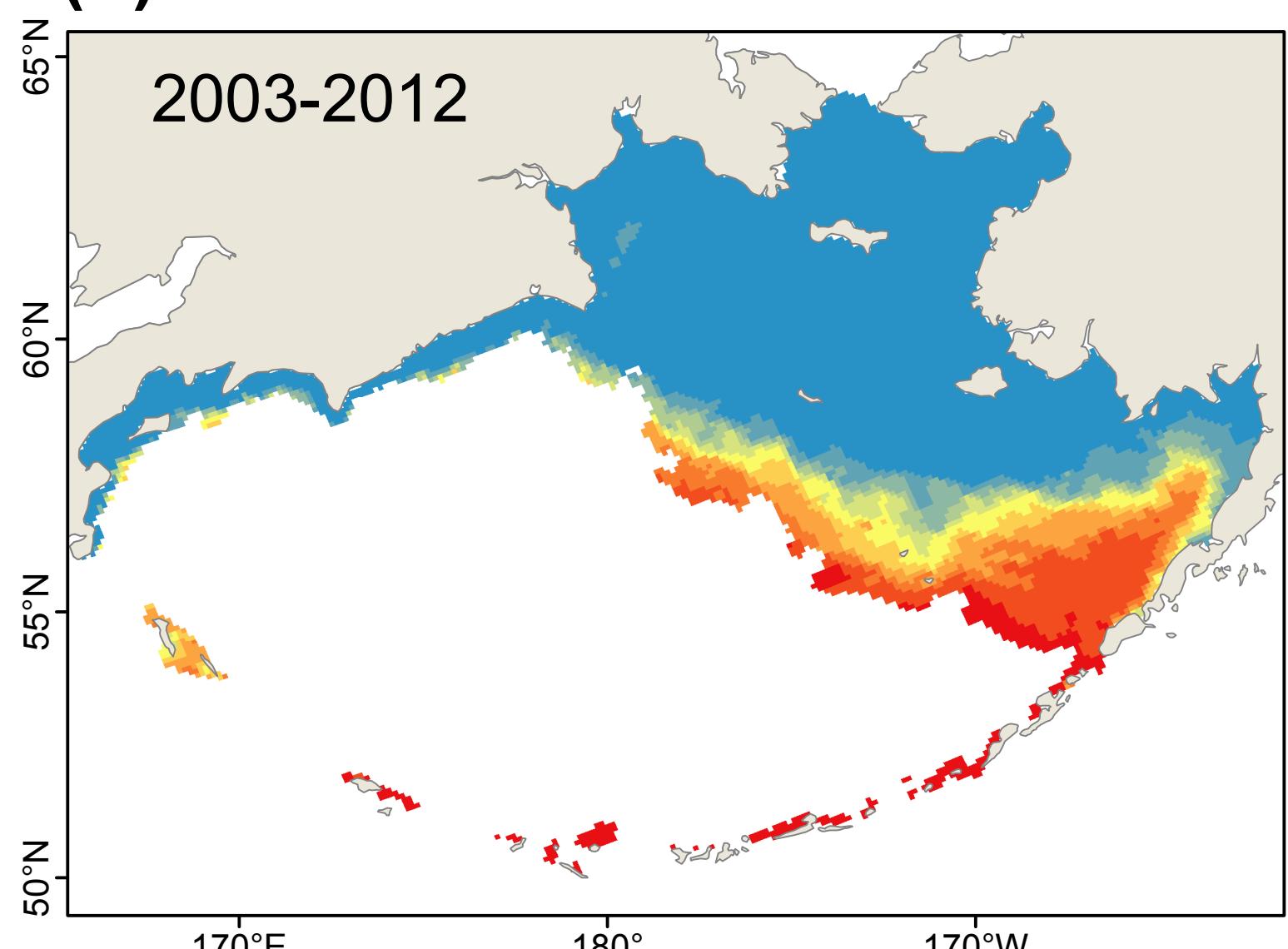
Number of years with suitable habitat



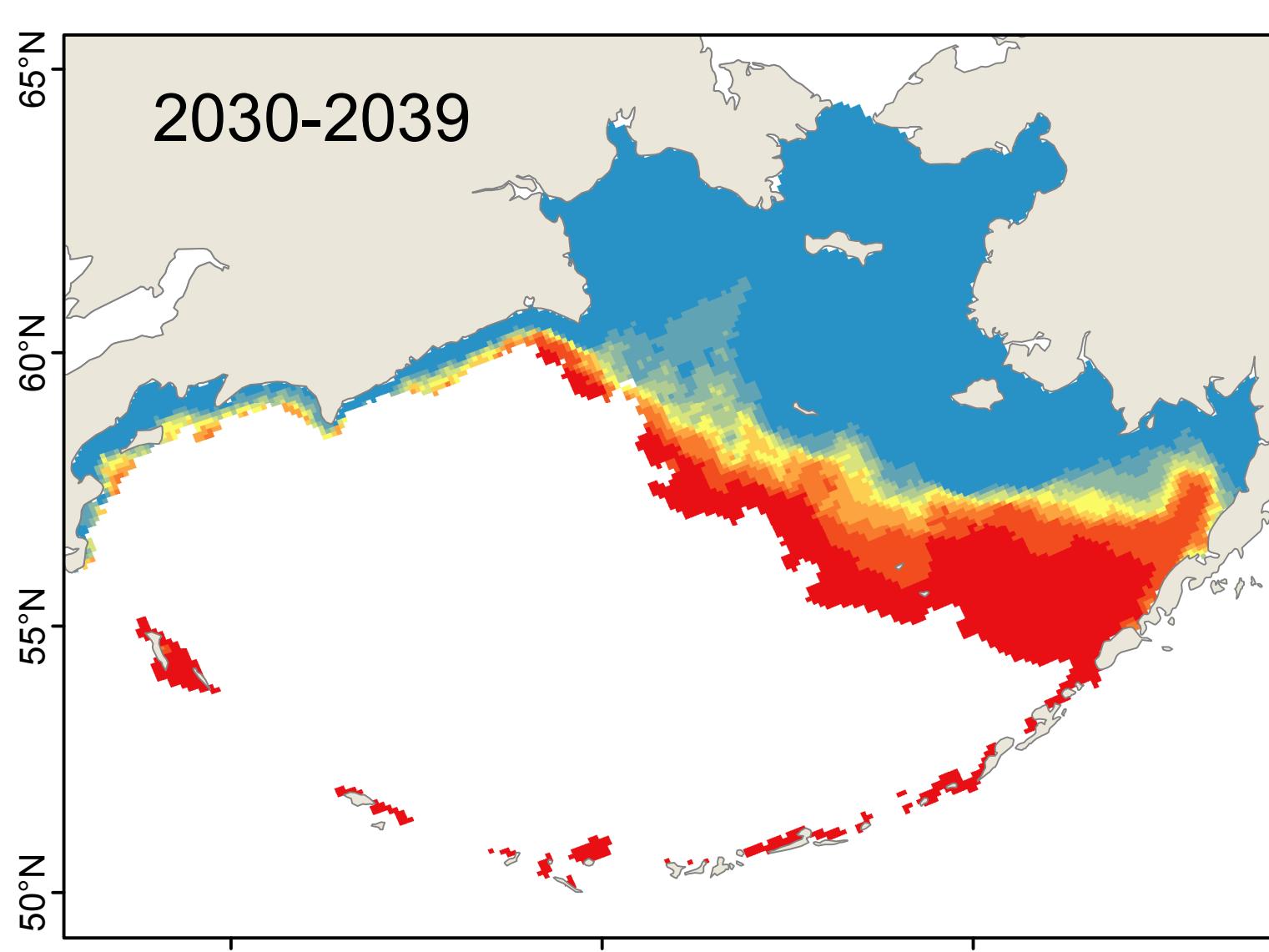
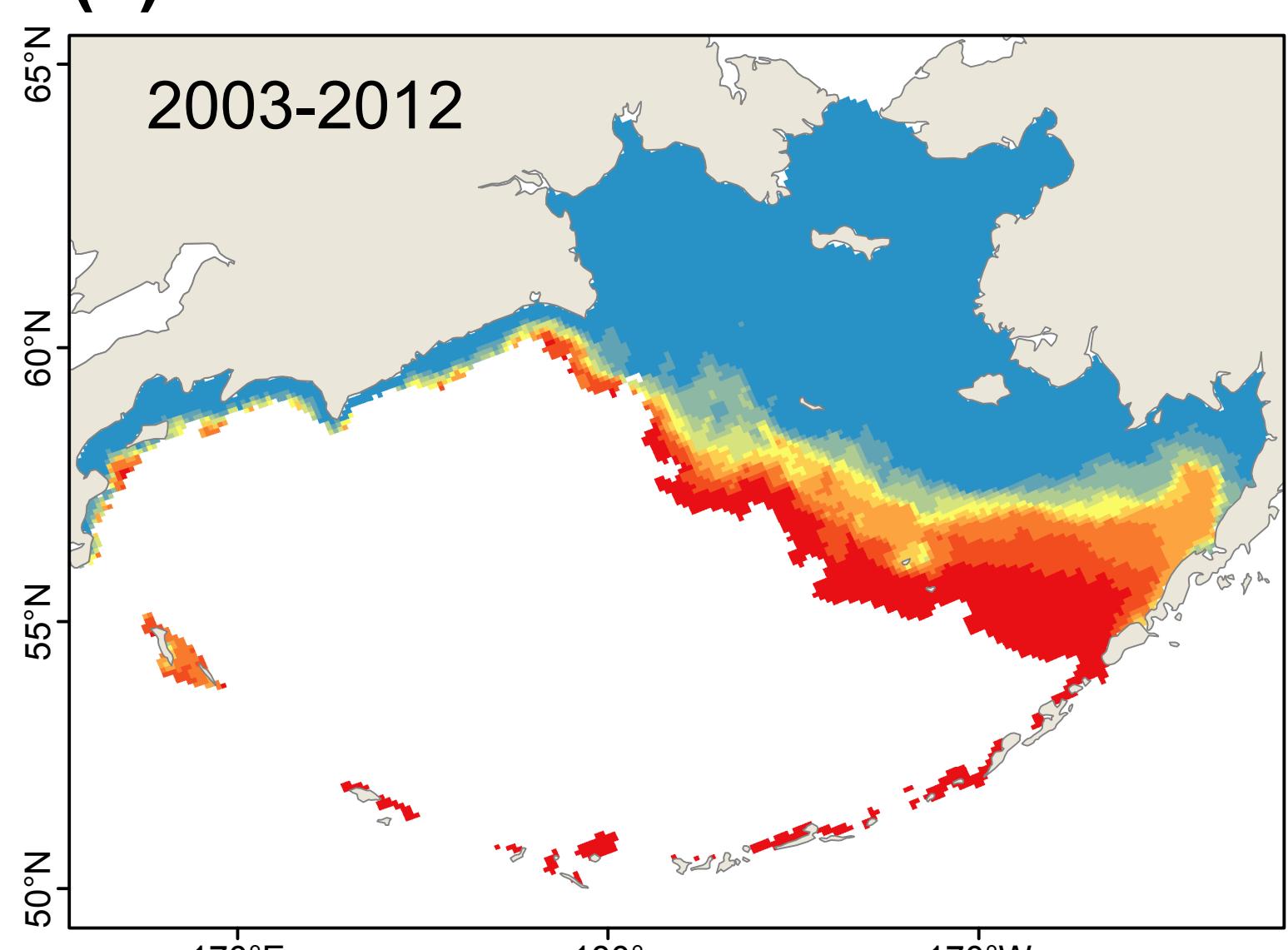
(a) Model: CGCM3-t47



(b) Model: ECHO-G

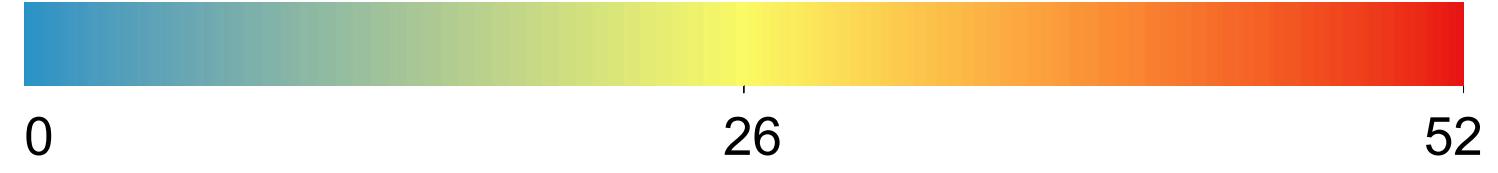


(c) Model: MIROC3.2

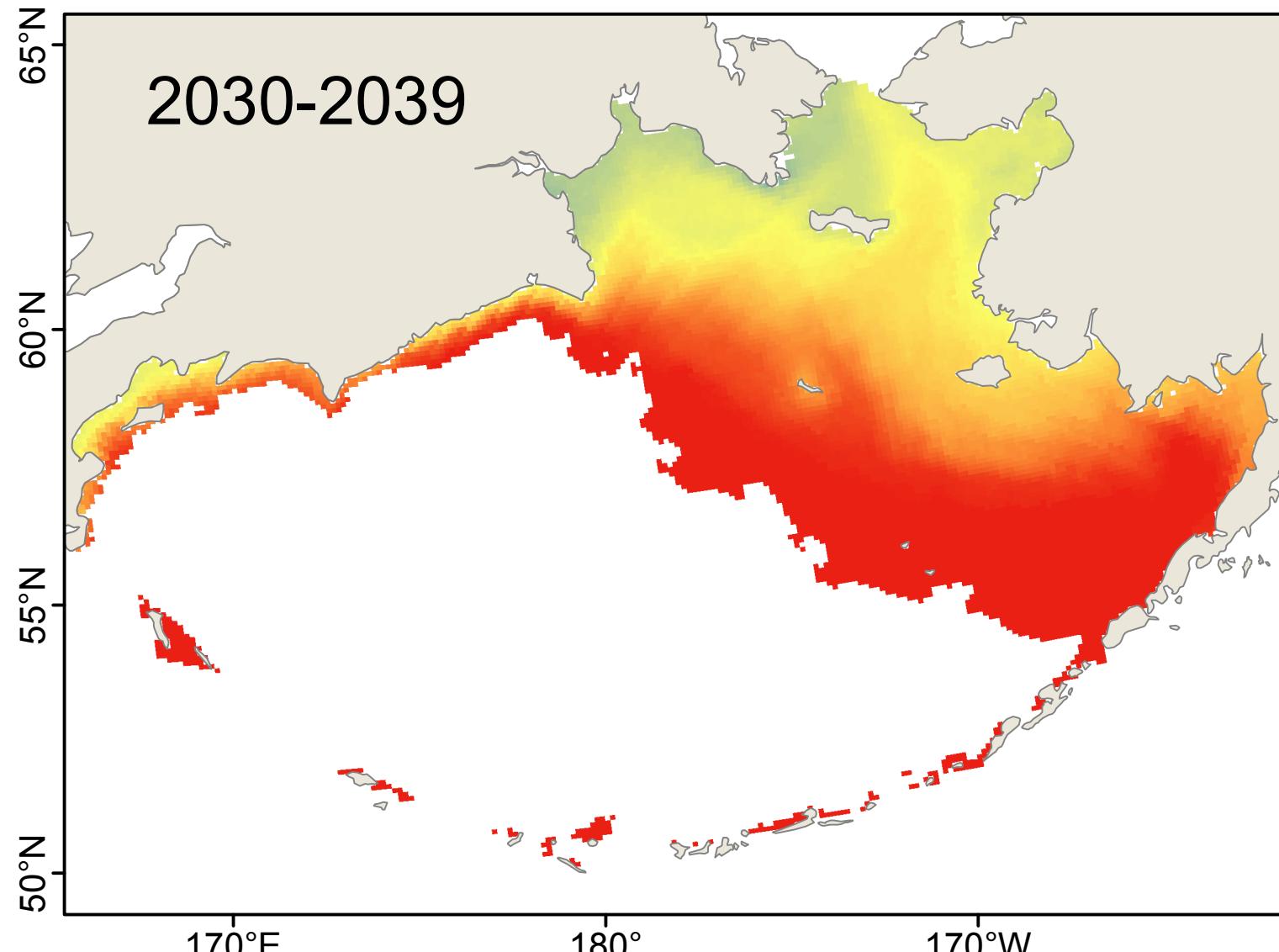
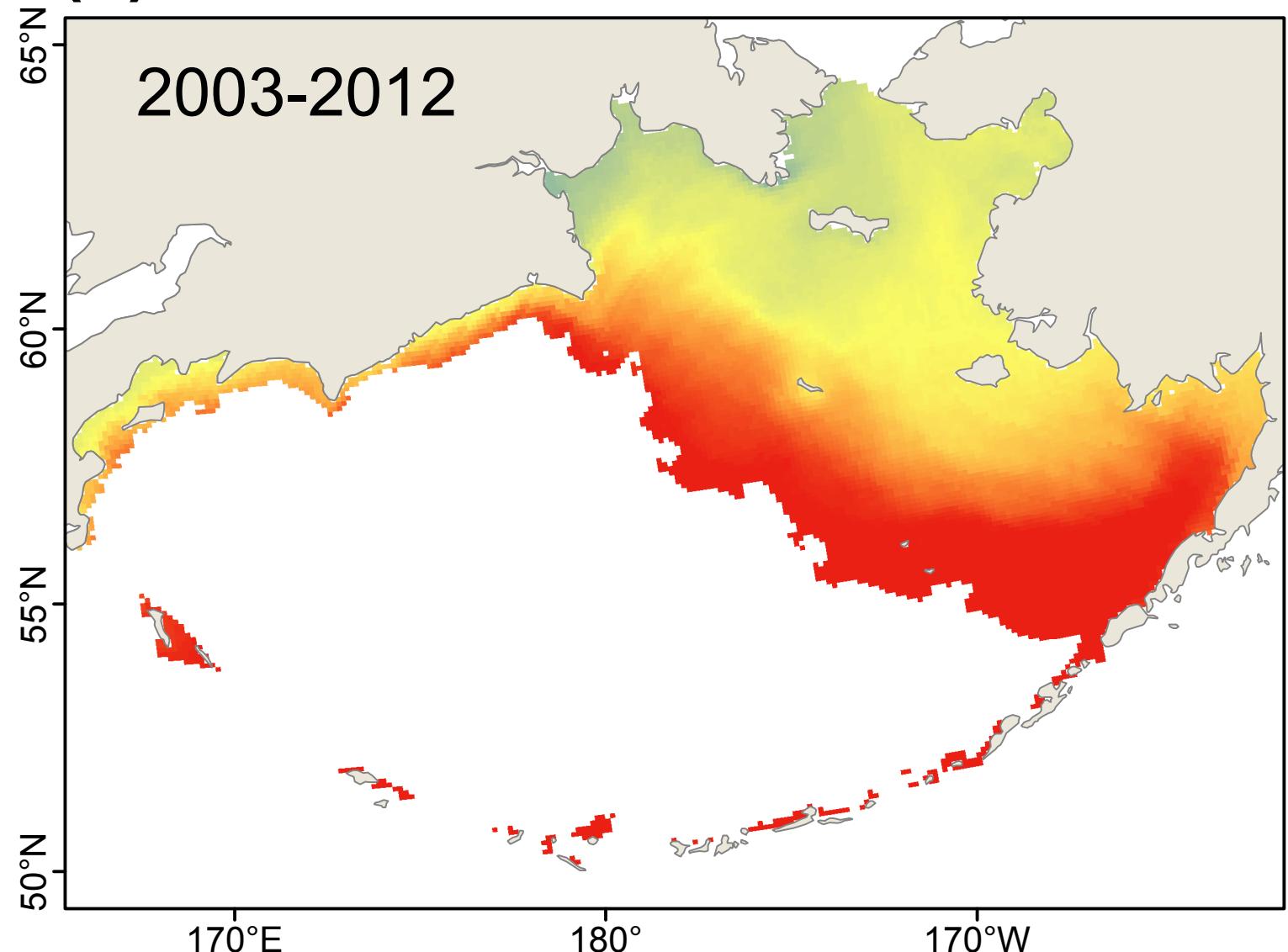


# *Venerupis philippinarum: Weekly Survival*

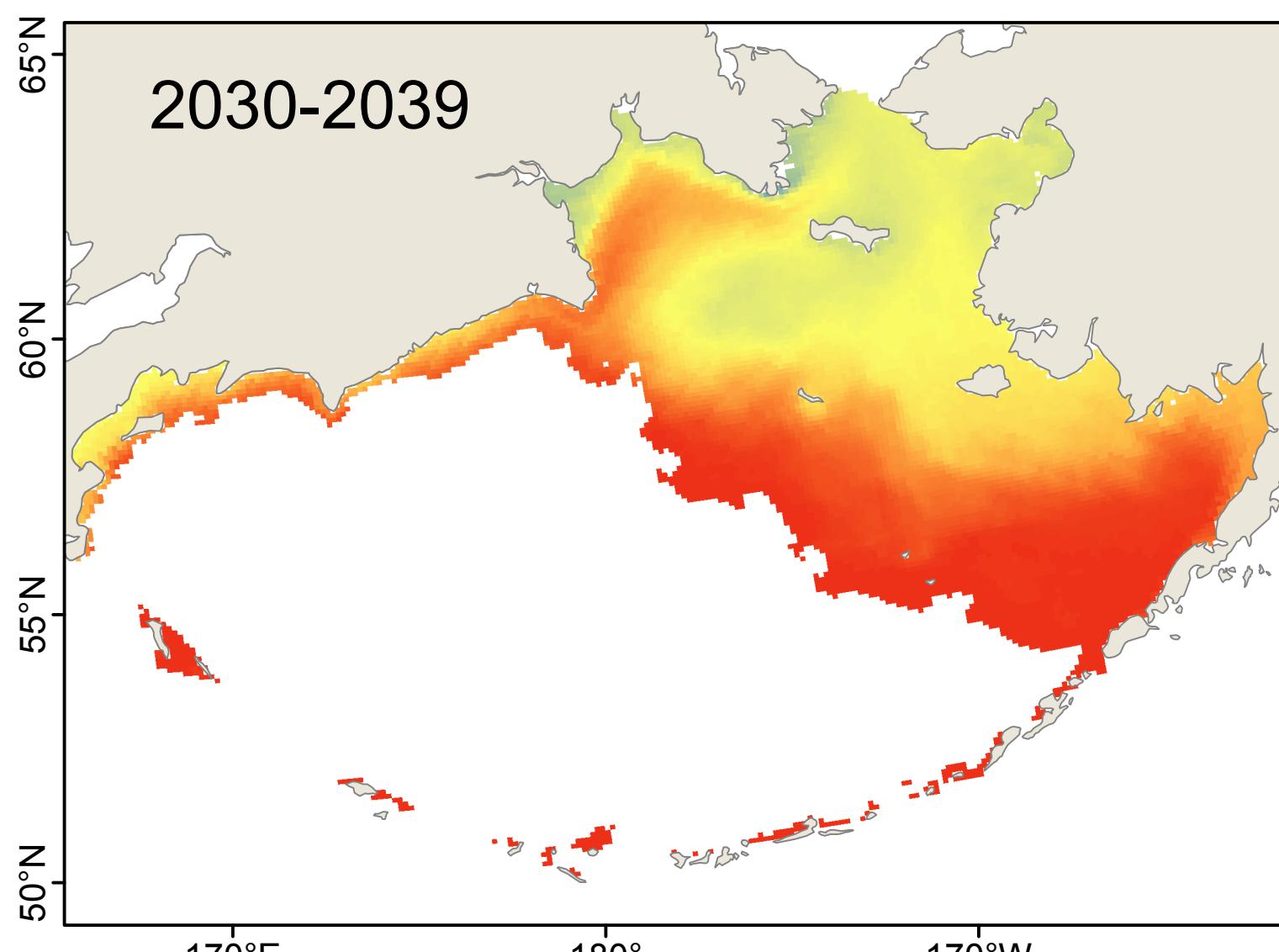
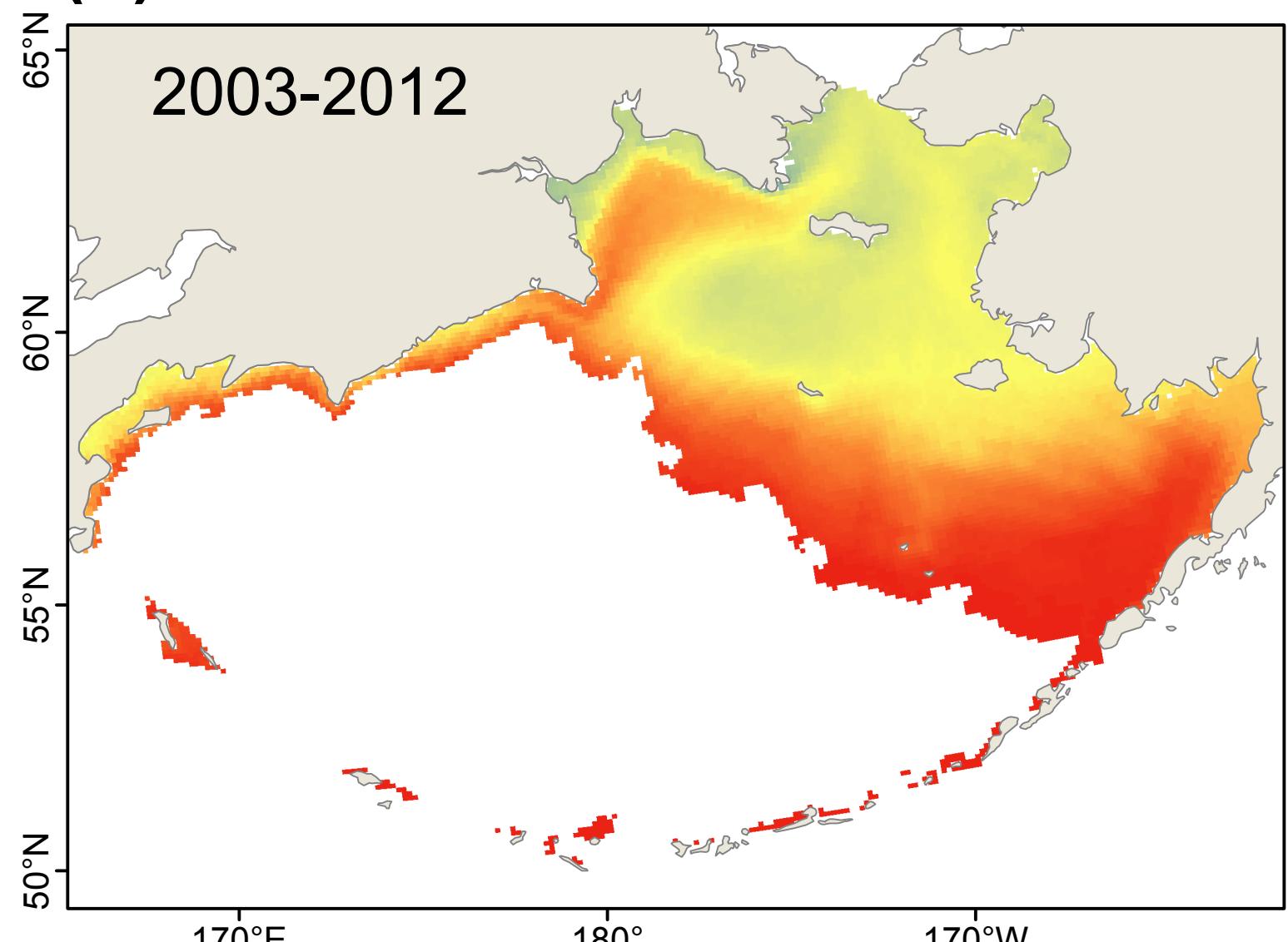
Average number of weeks of suitable habitat



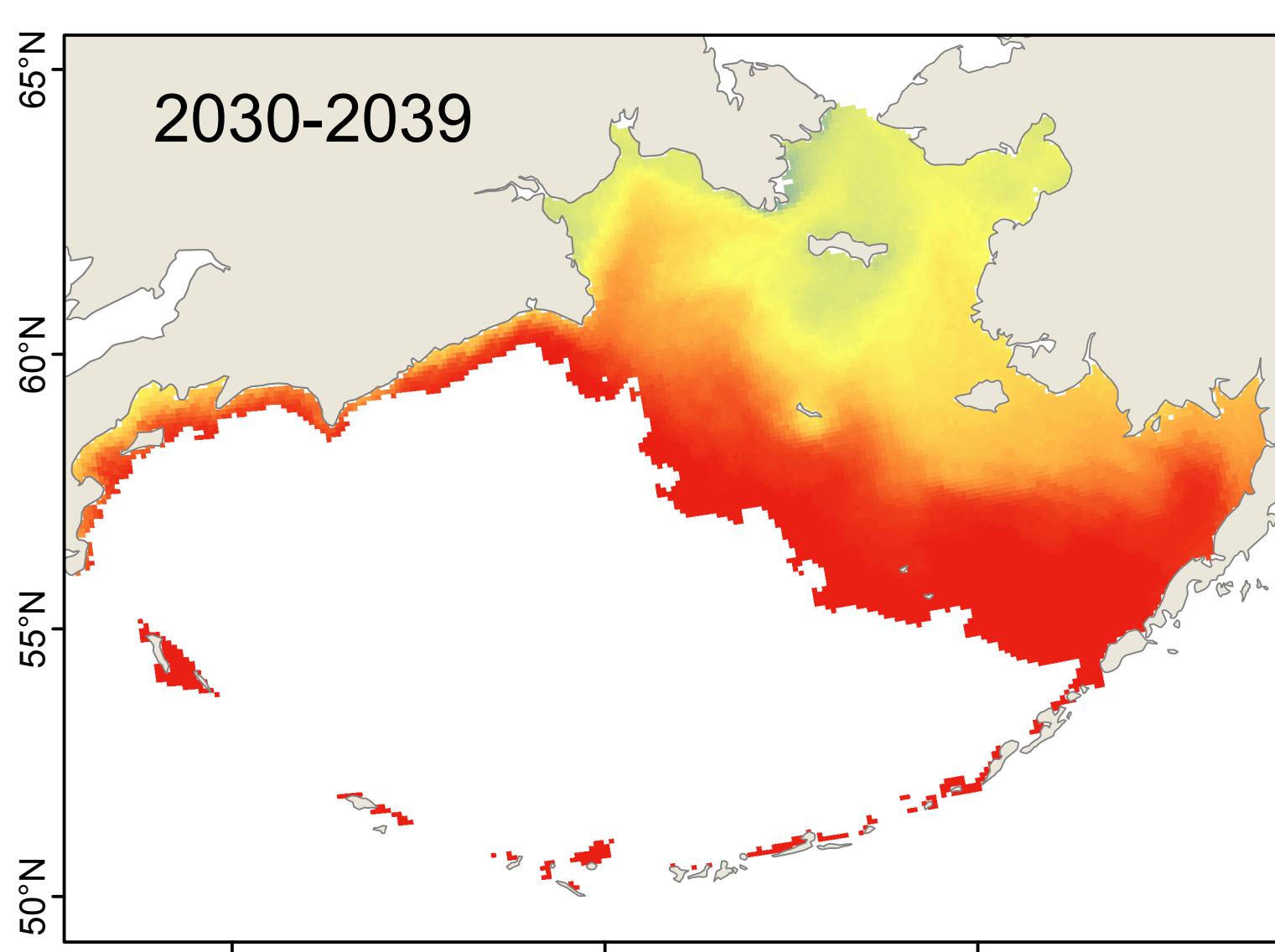
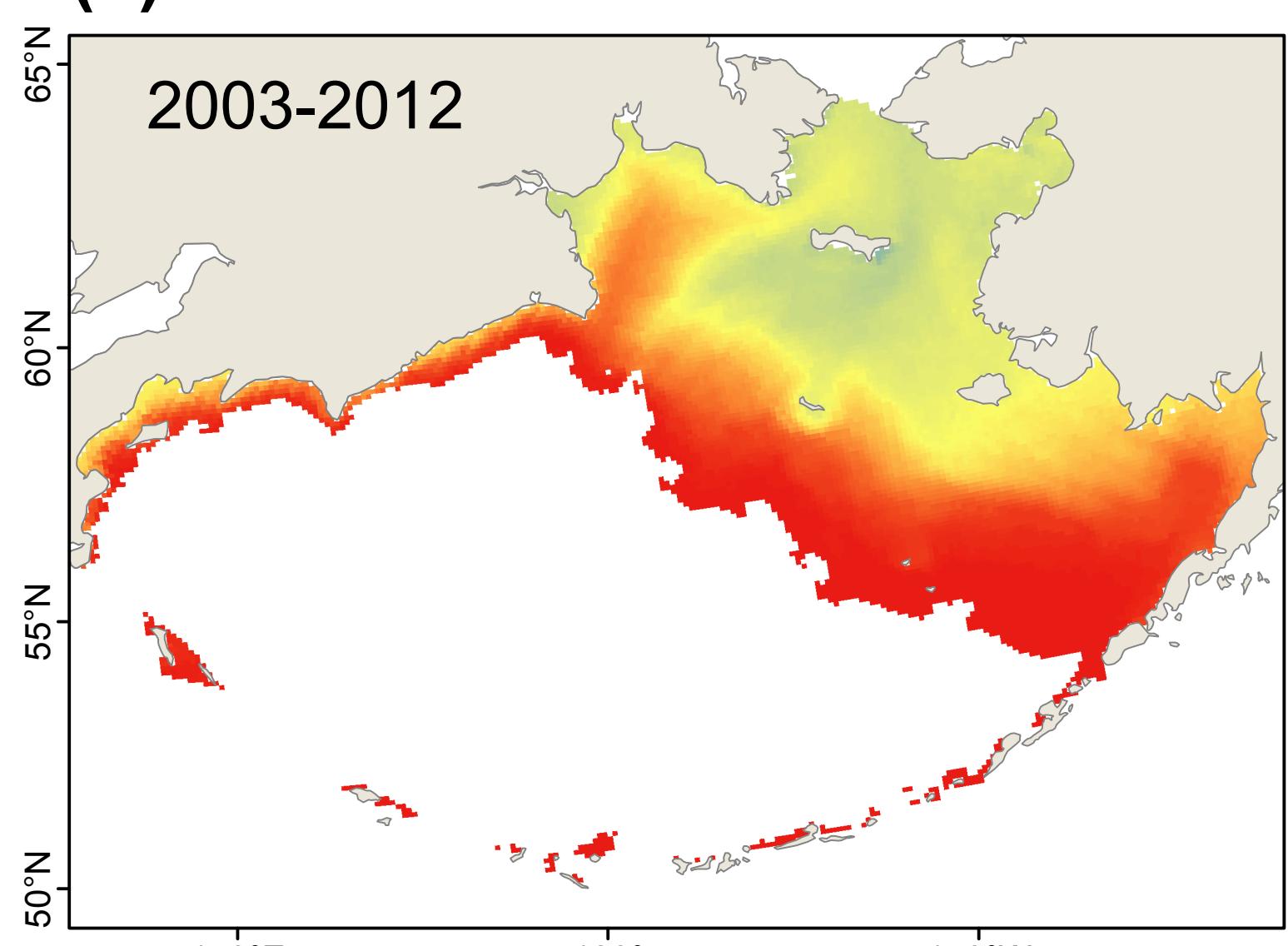
(a) Model: CGCM3-t47



(b) Model: ECHO-G

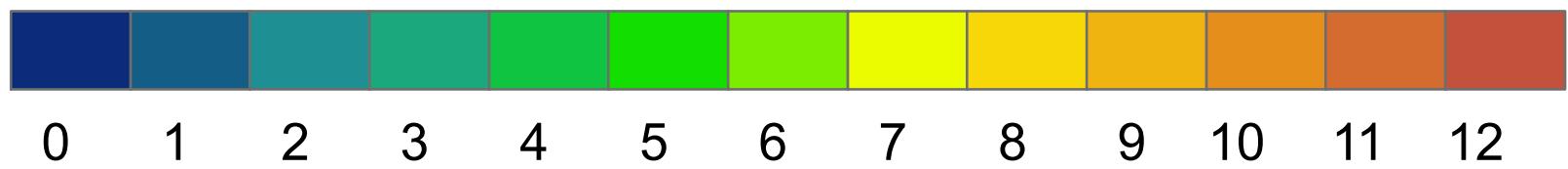


(c) Model: MIROC3.2

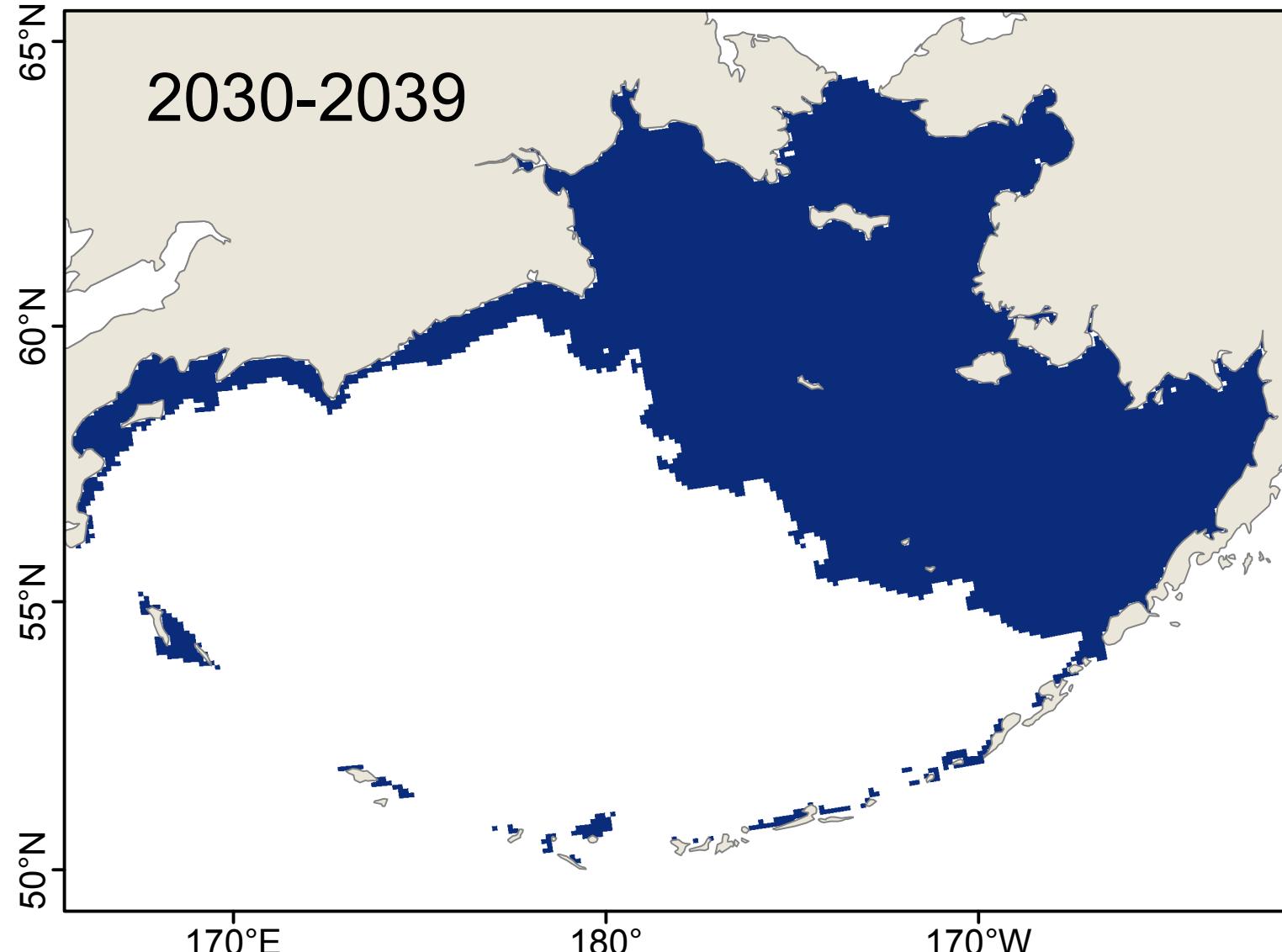
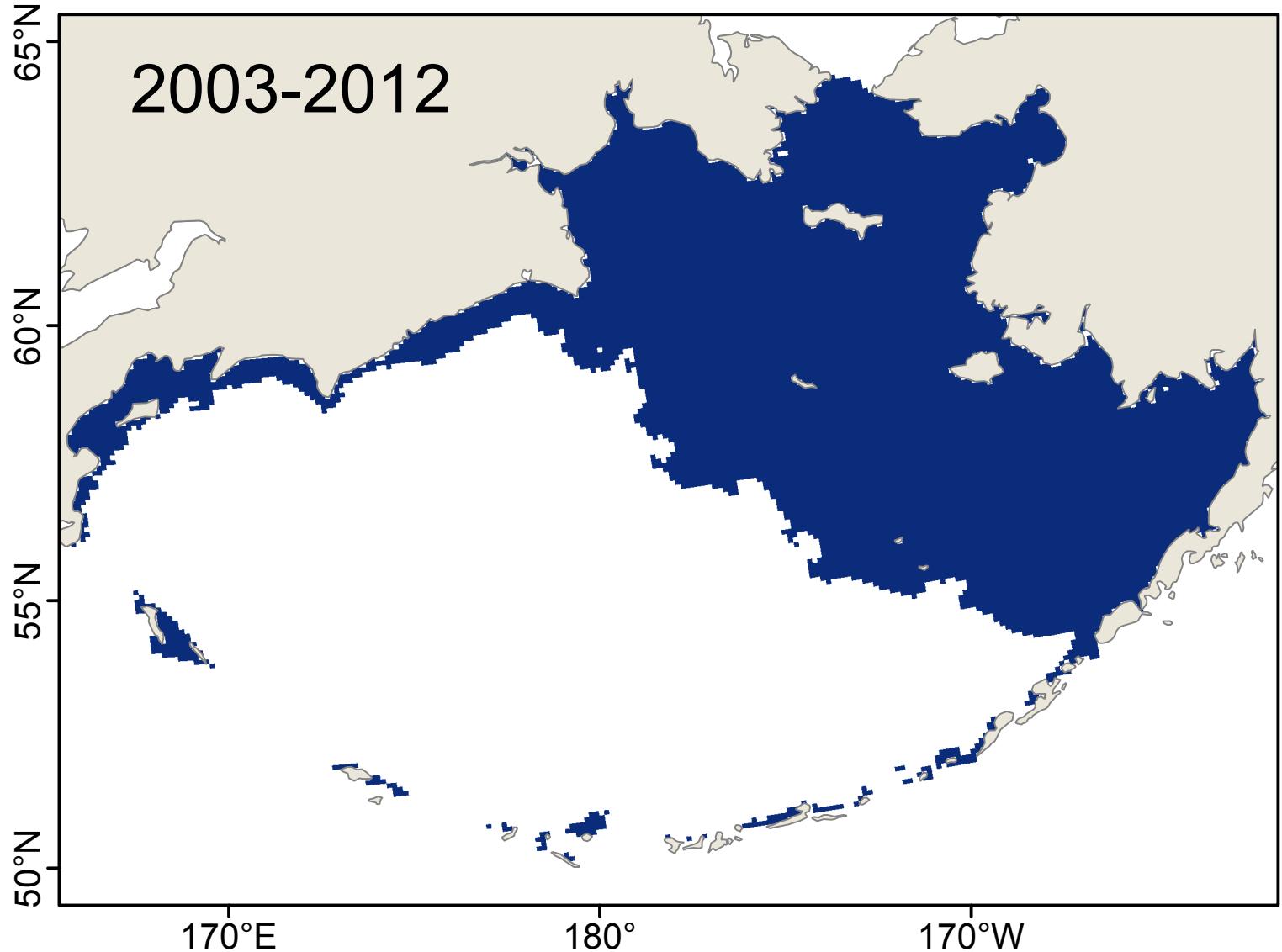


# *Venerupis philippinarum: Reproduction*

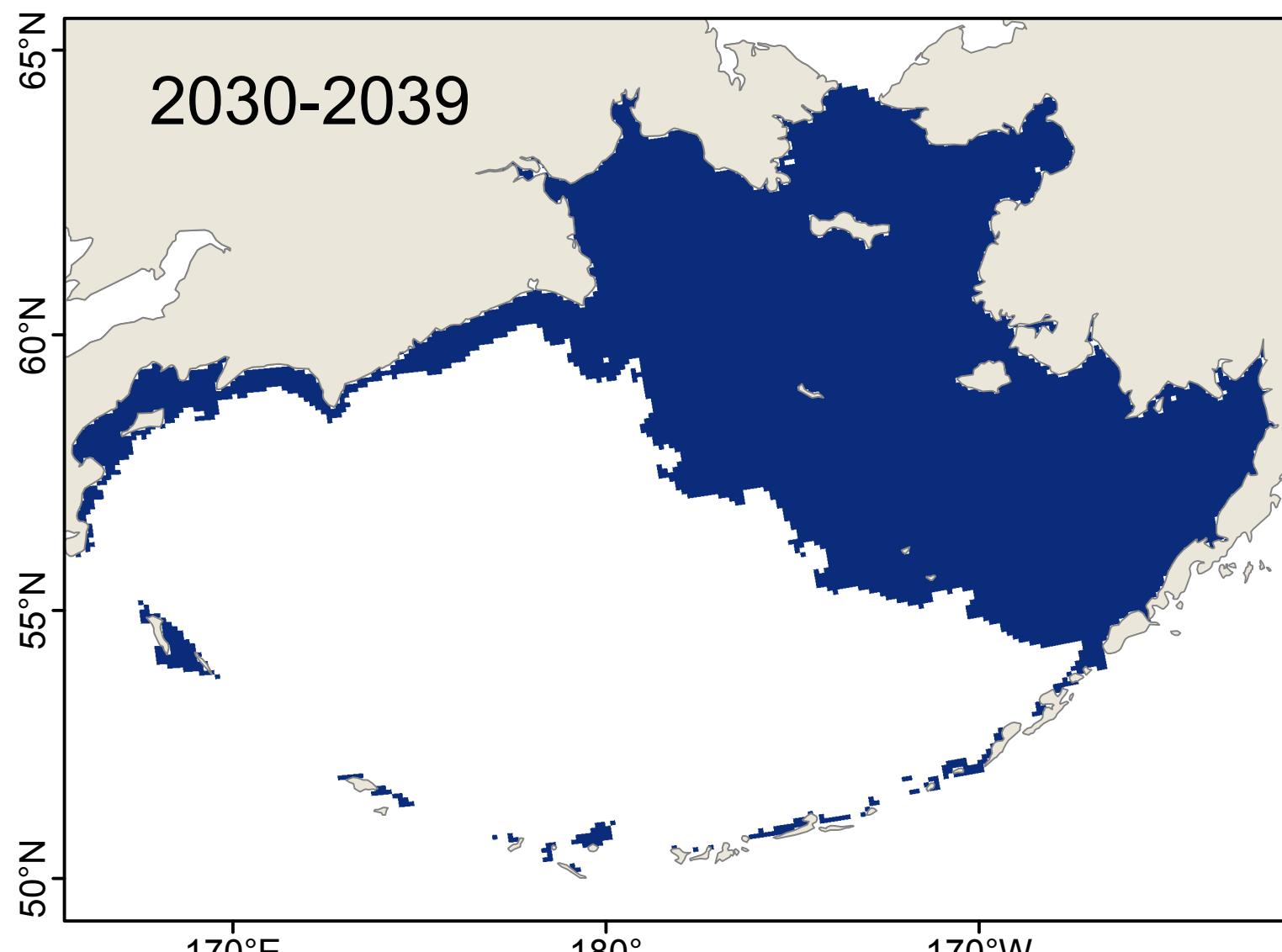
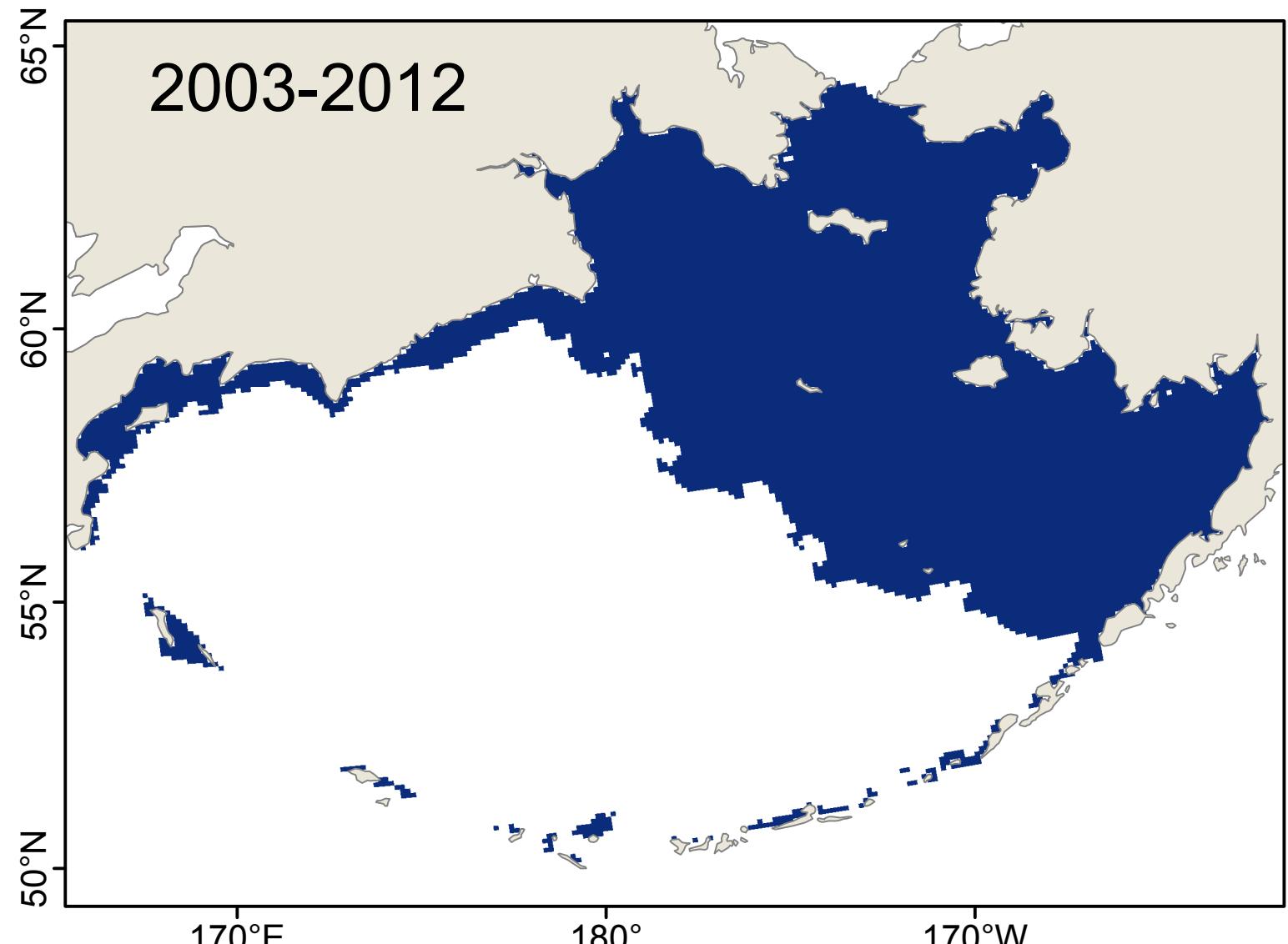
Average number of consecutive weeks of suitable habitat



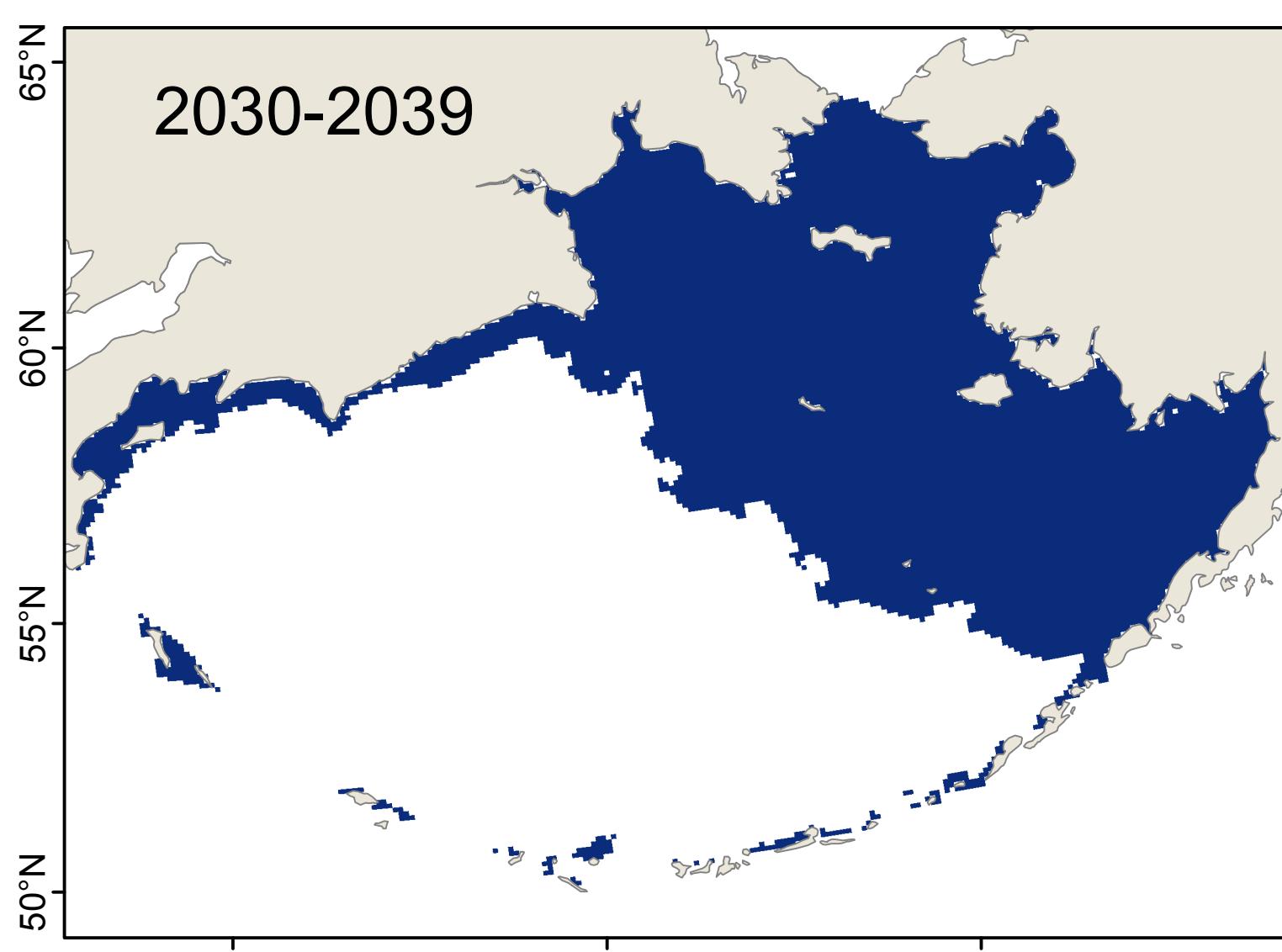
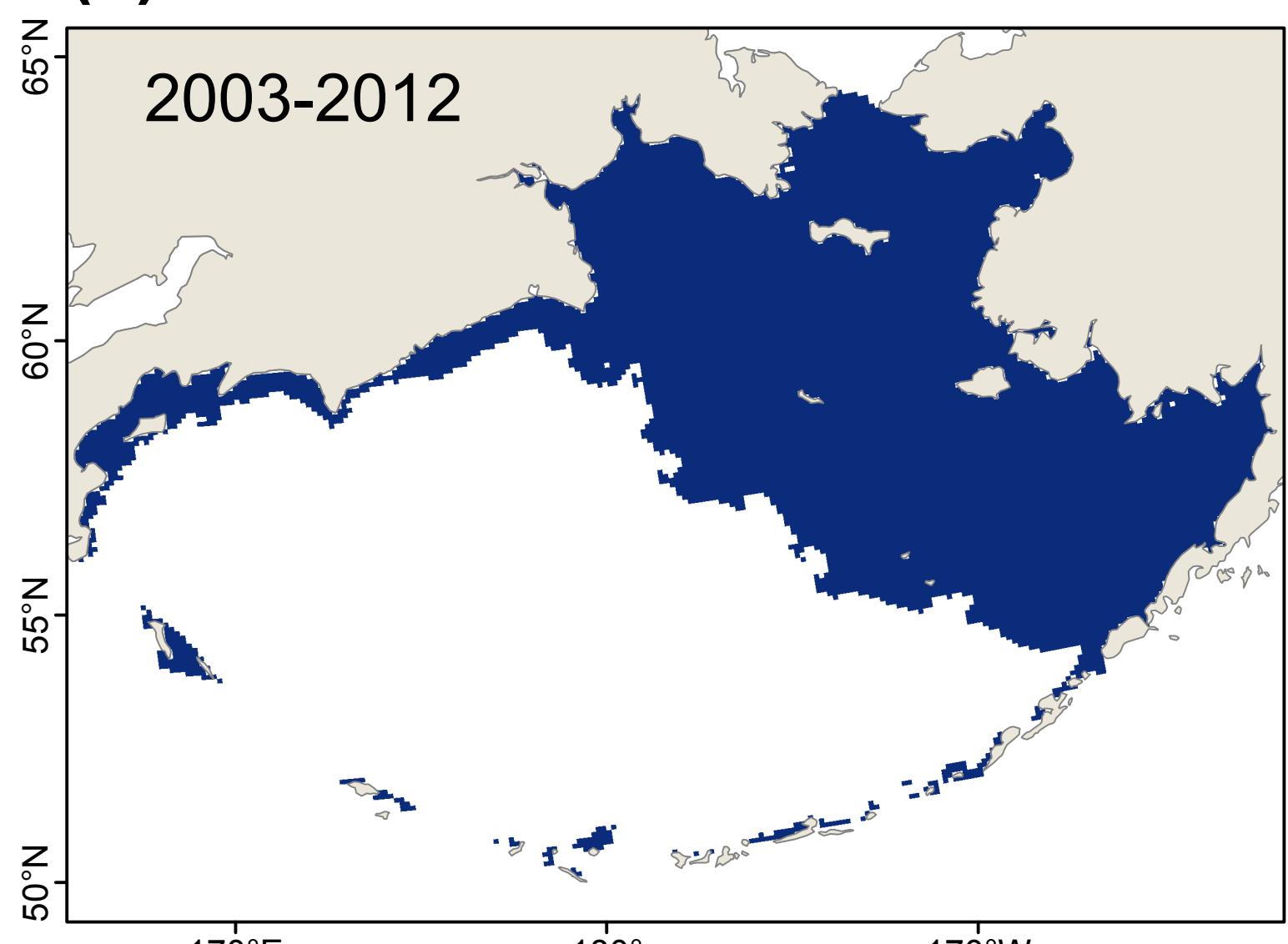
(a) Model: CGCM3-t47



(b) Model: ECHO-G

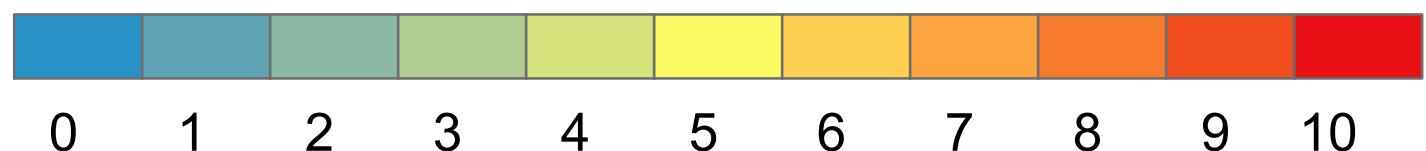


(c) Model: MIROC3.2

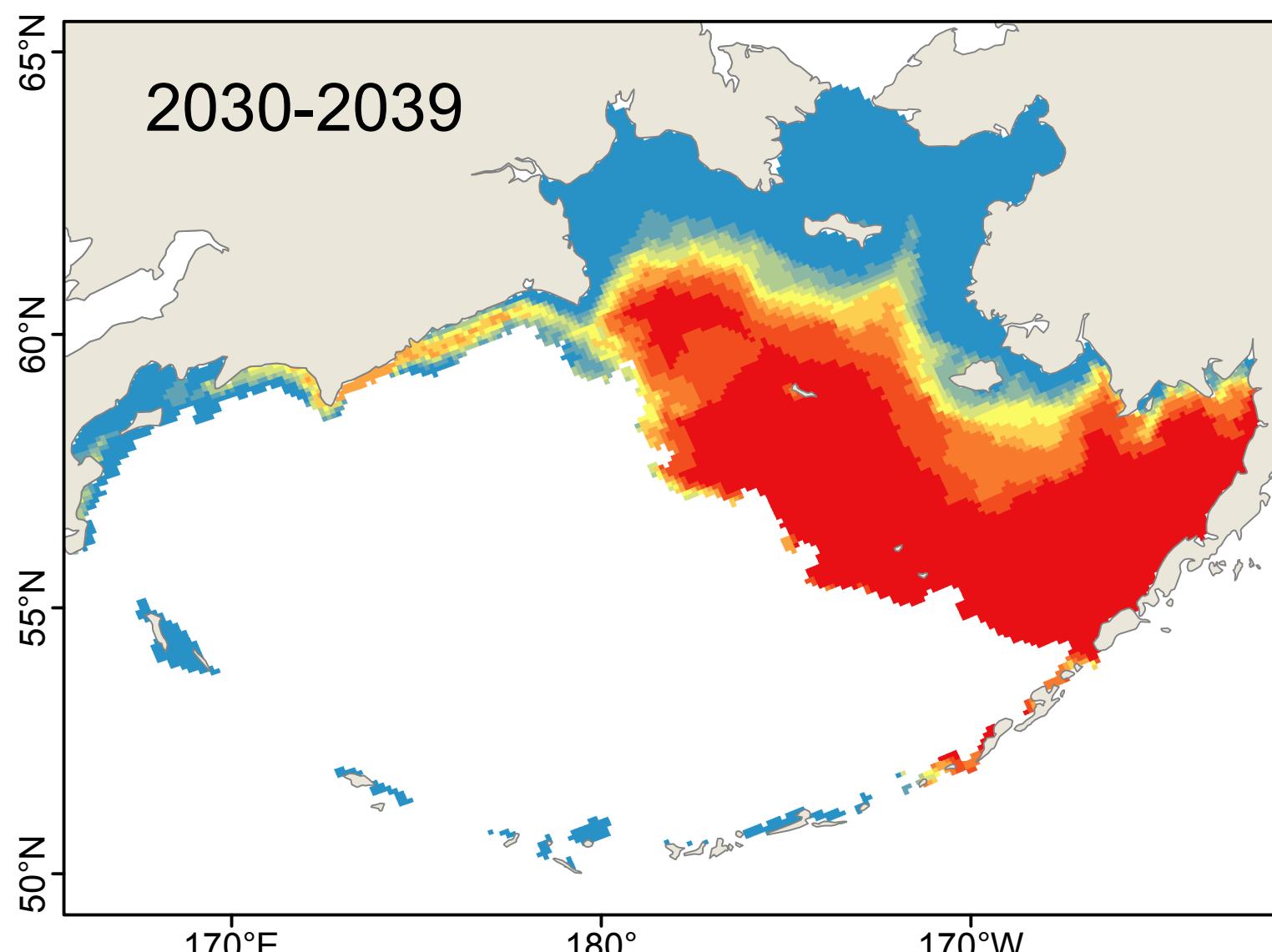
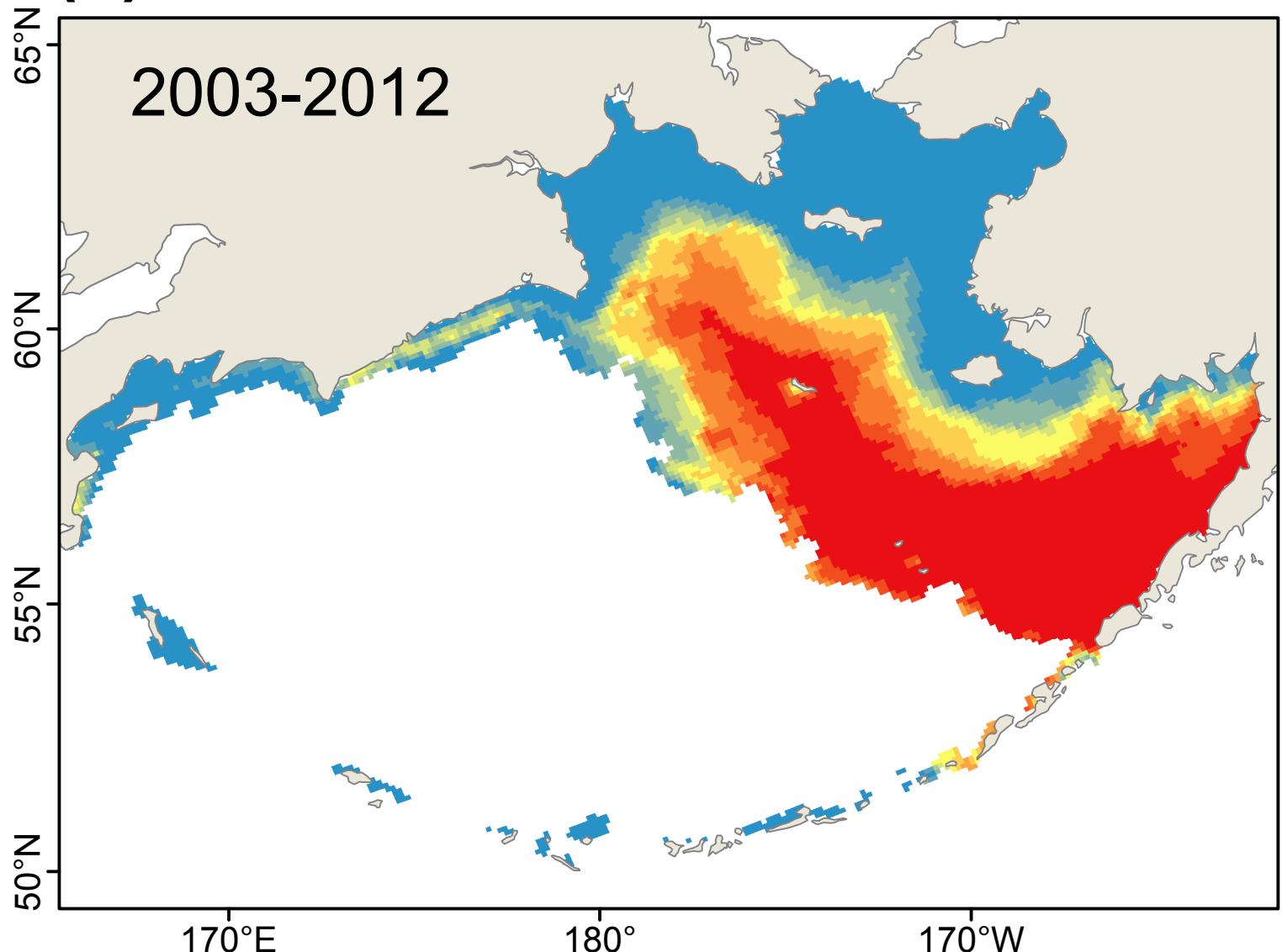


# *Batillaria attramentaria: Year-round Survival*

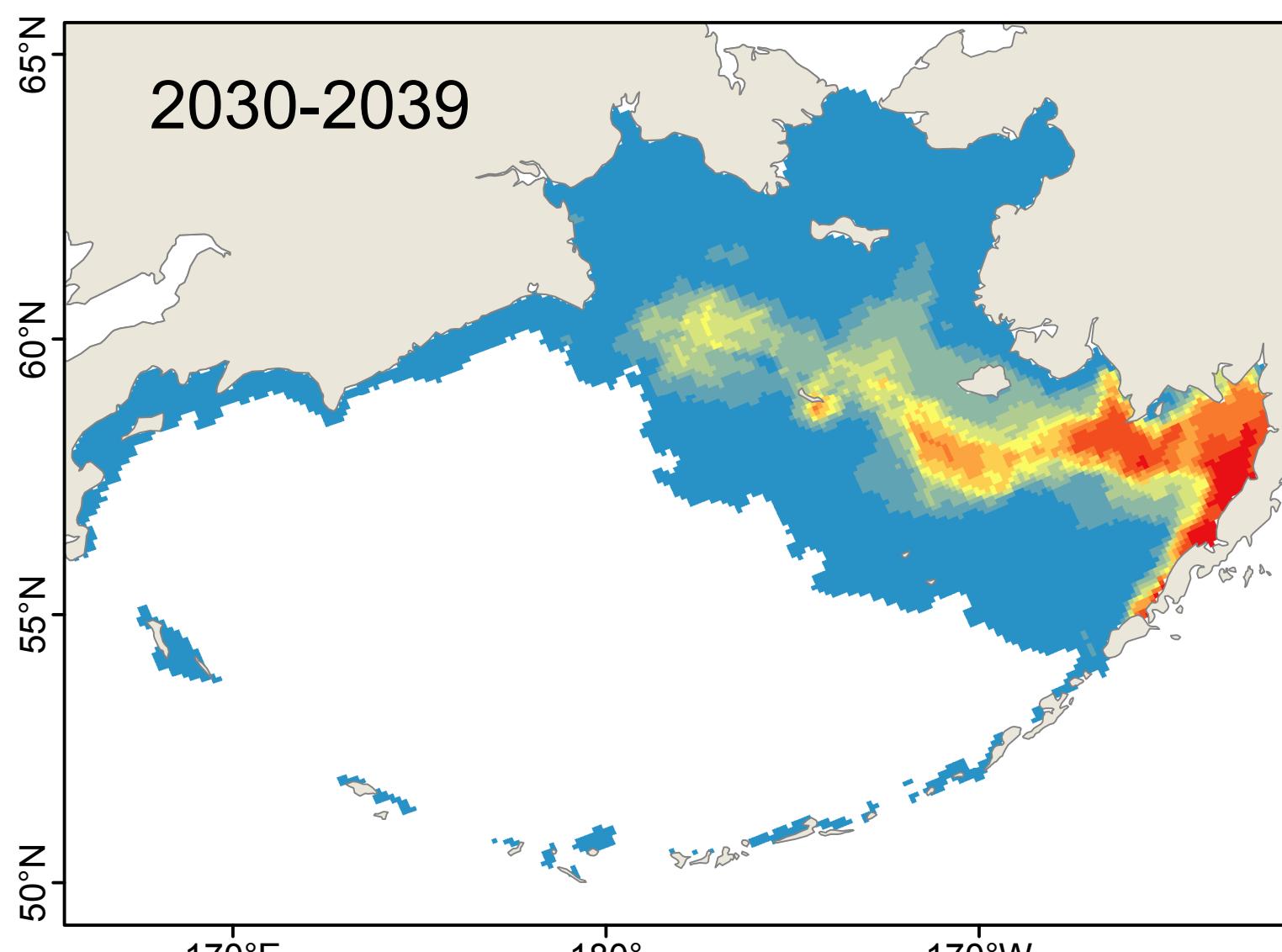
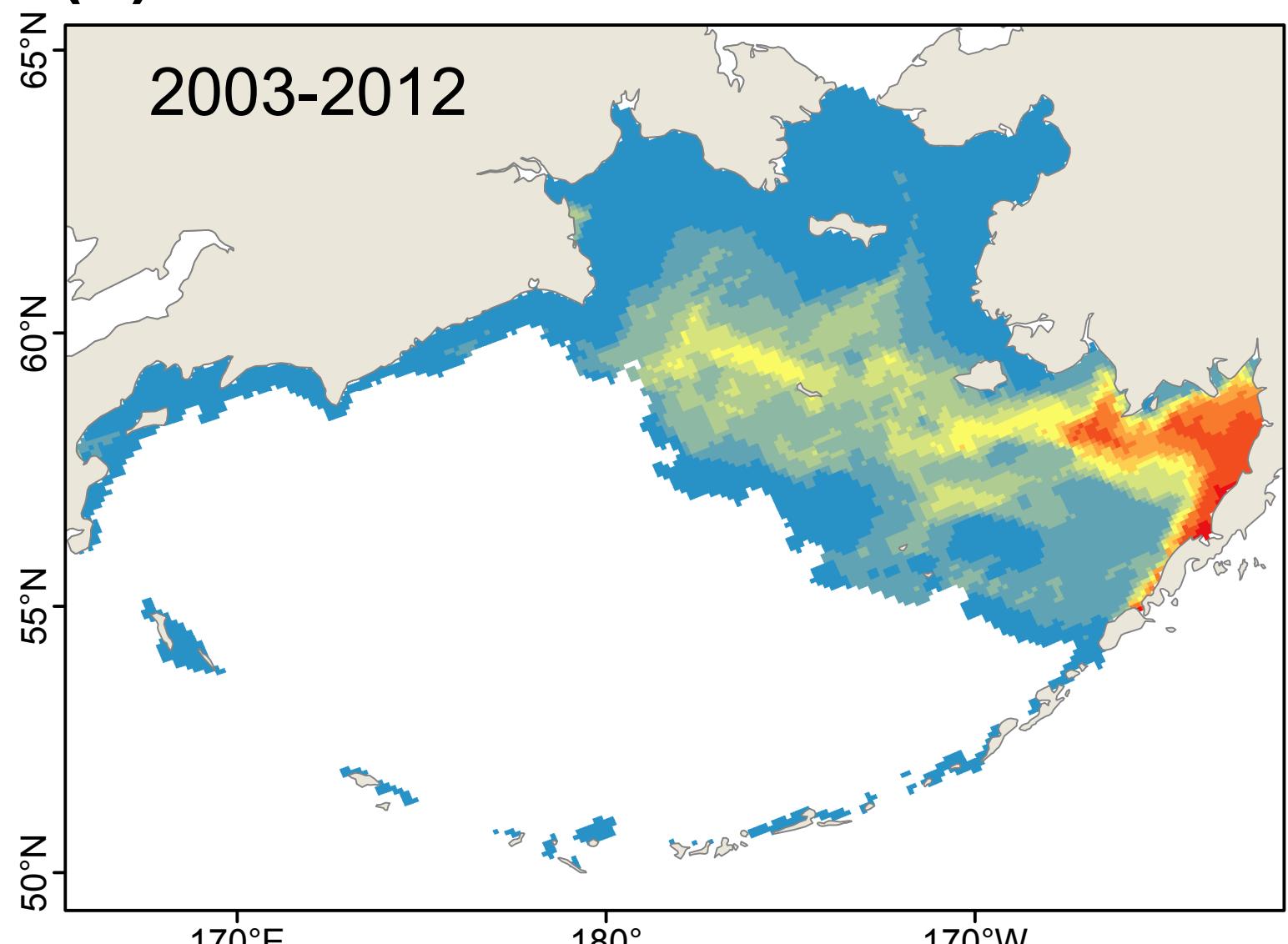
Number of years with suitable habitat



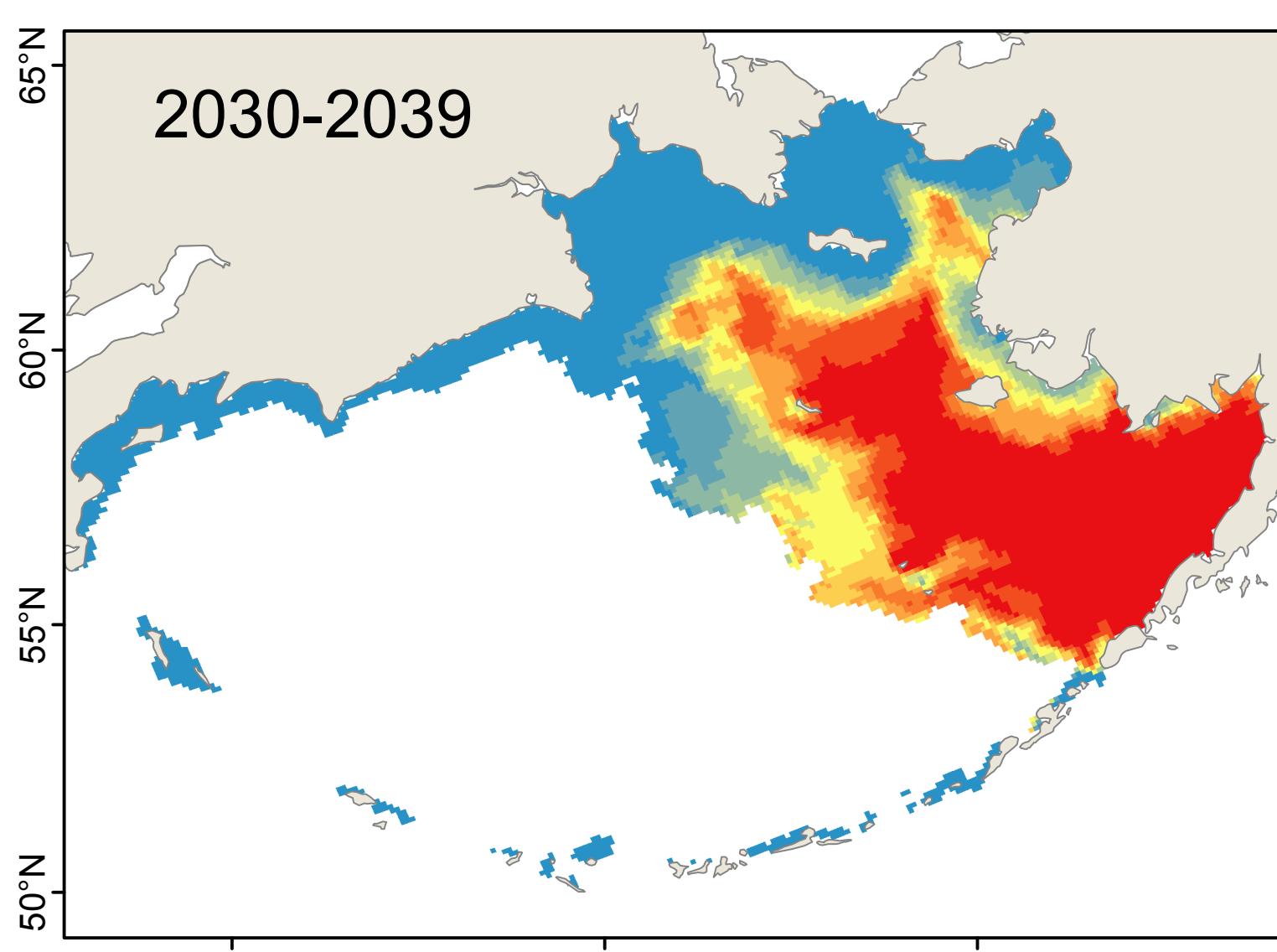
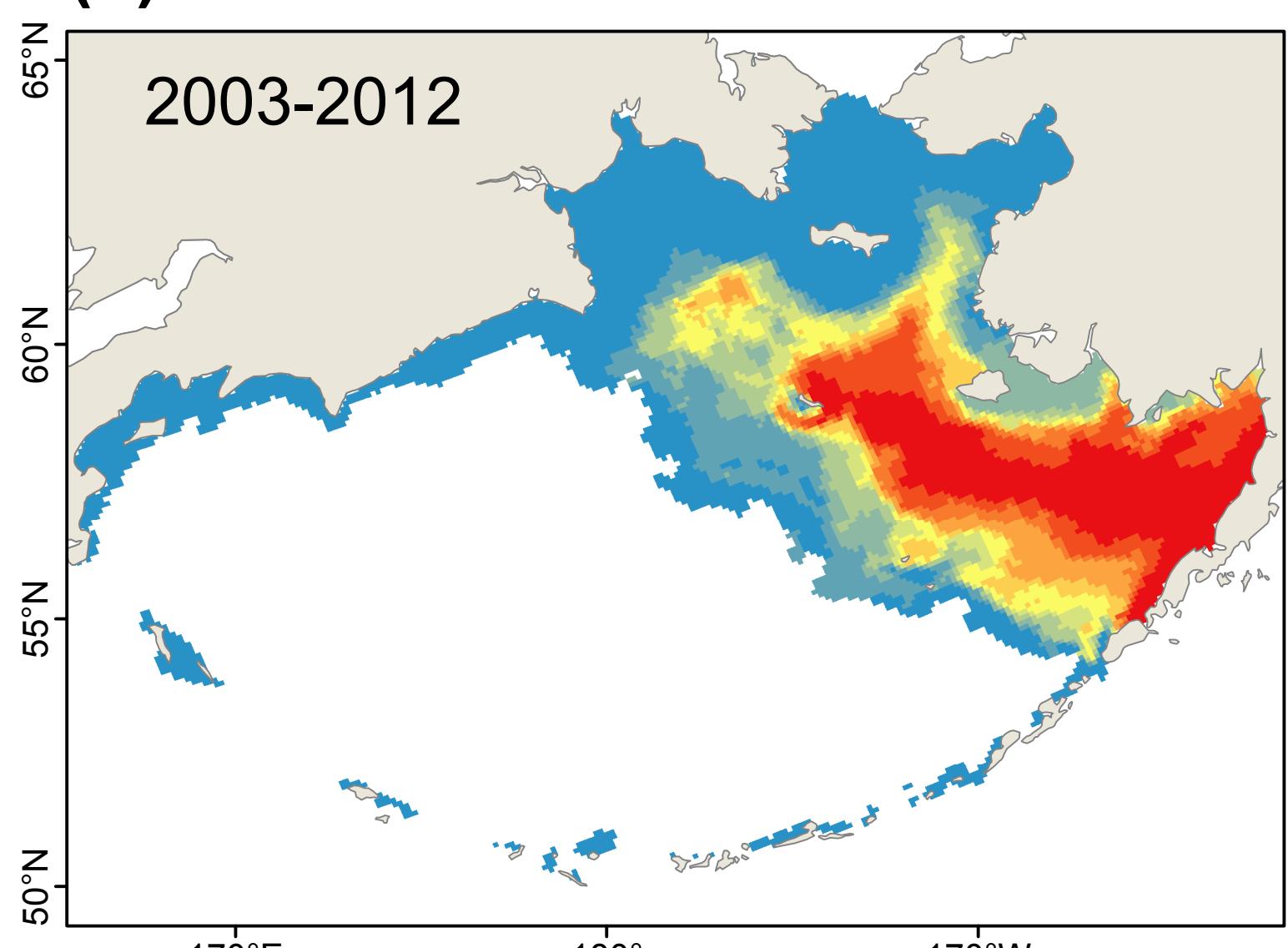
(a) Model: CGCM3-t47



(b) Model: ECHO-G

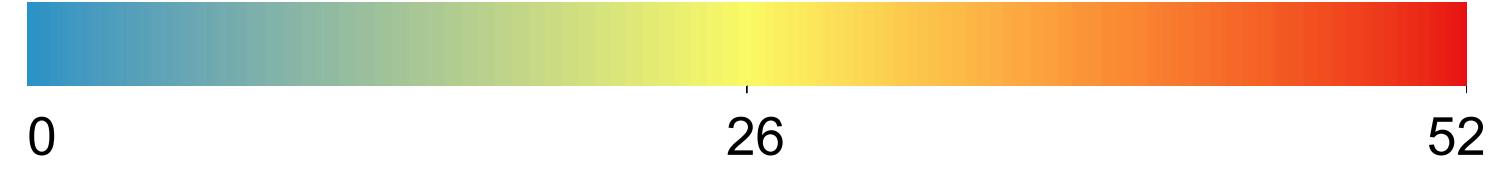


(c) Model: MIROC3.2

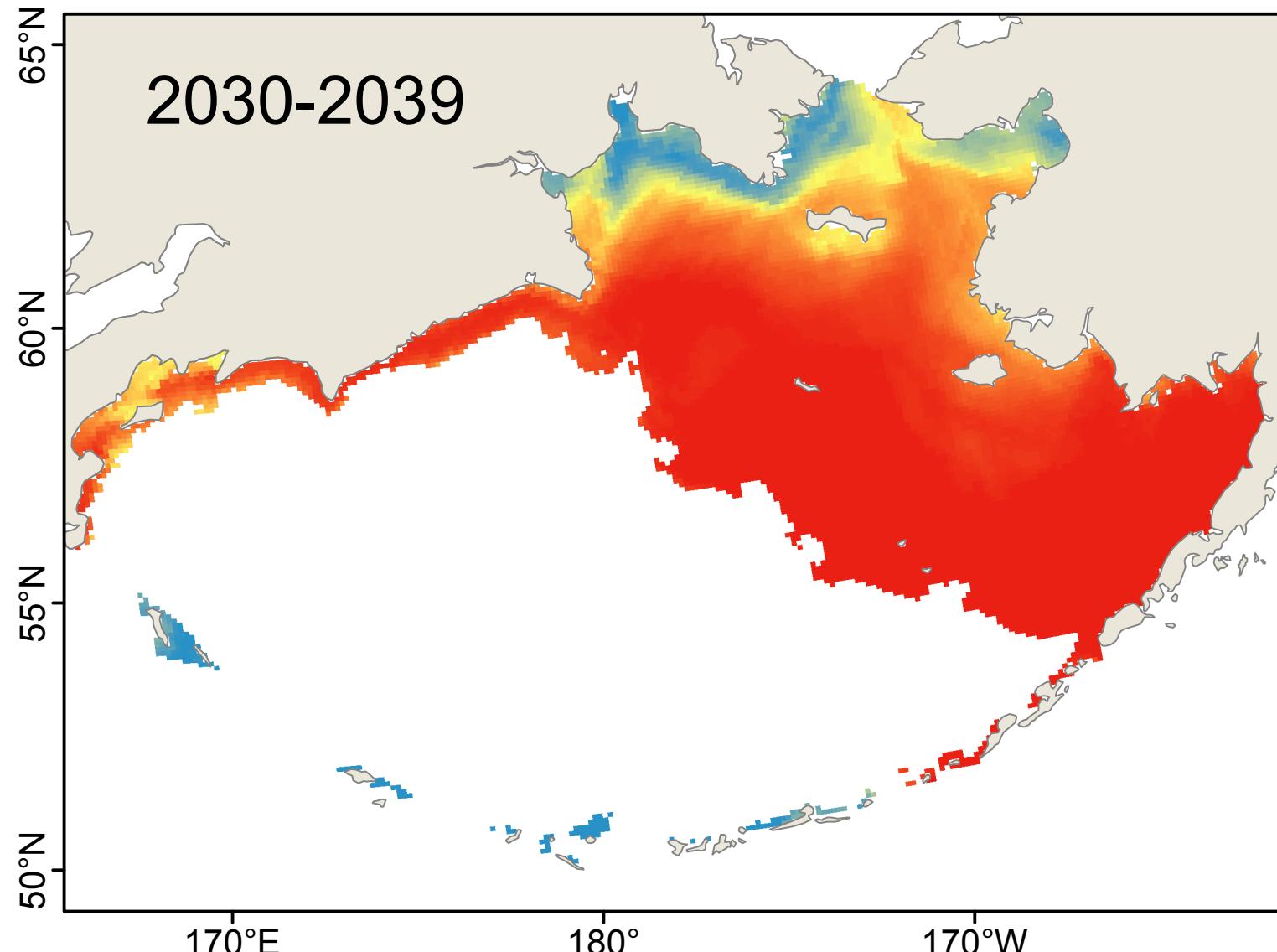
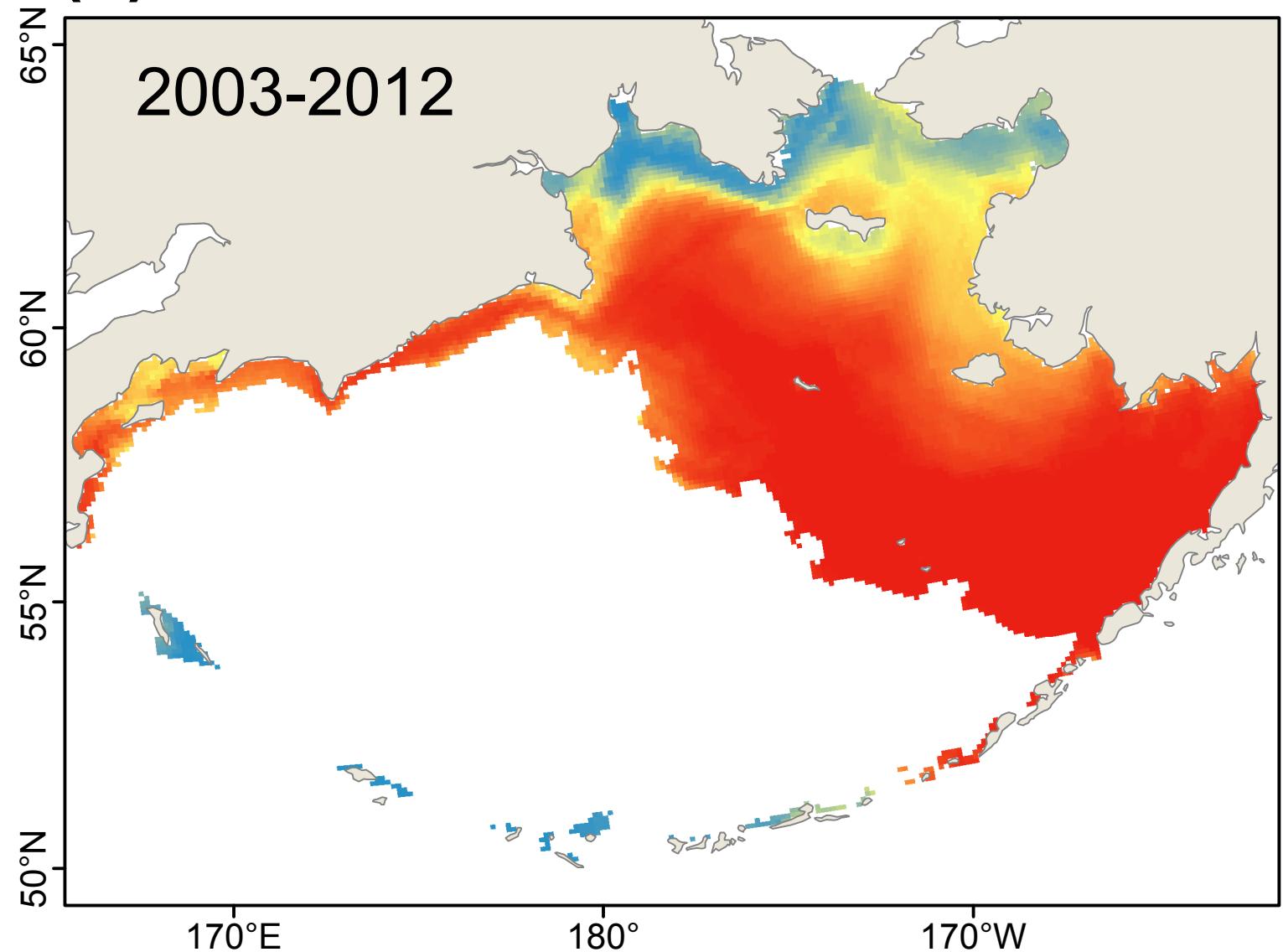


# *Batillaria attramentaria: Weekly Survival*

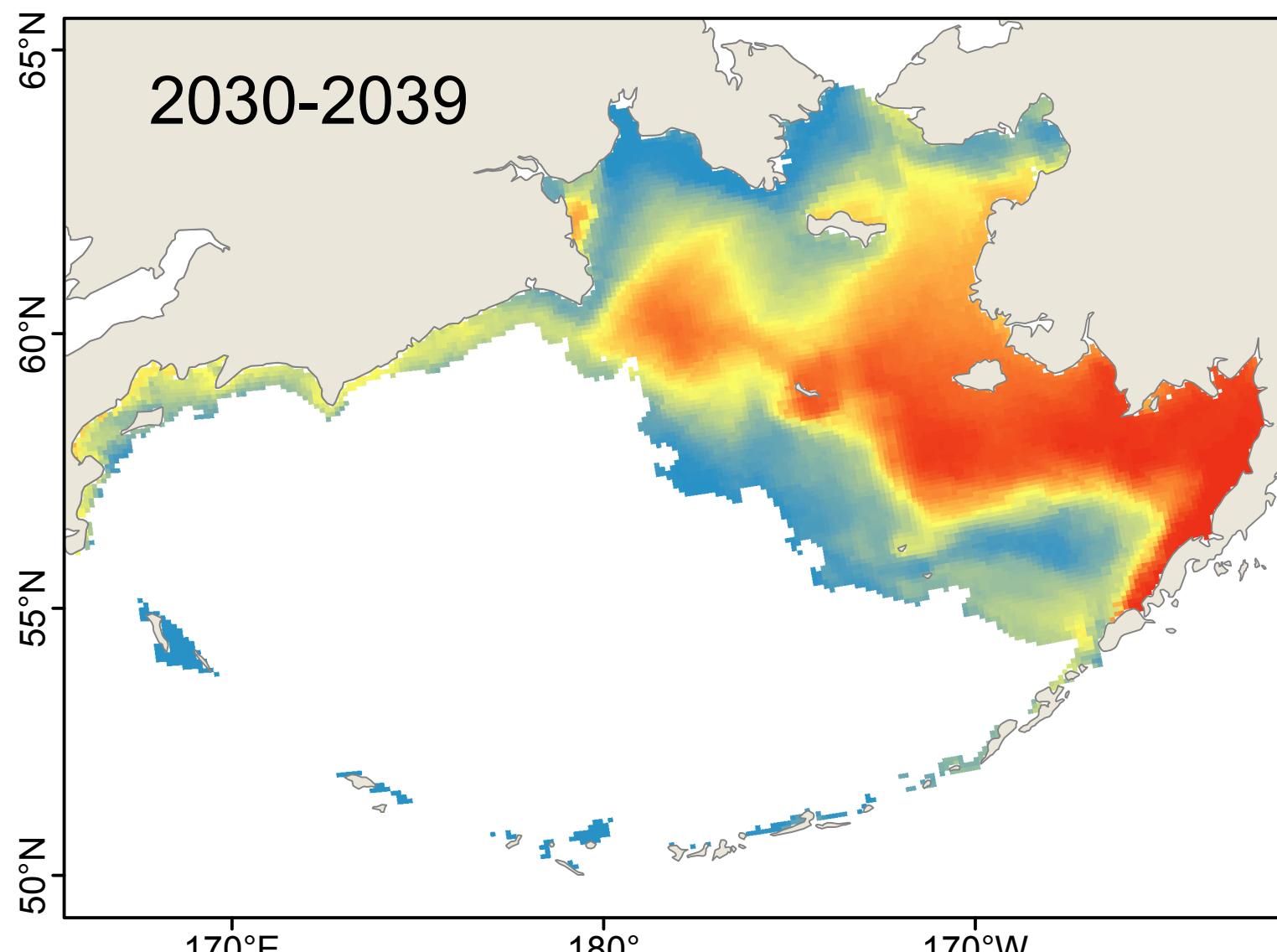
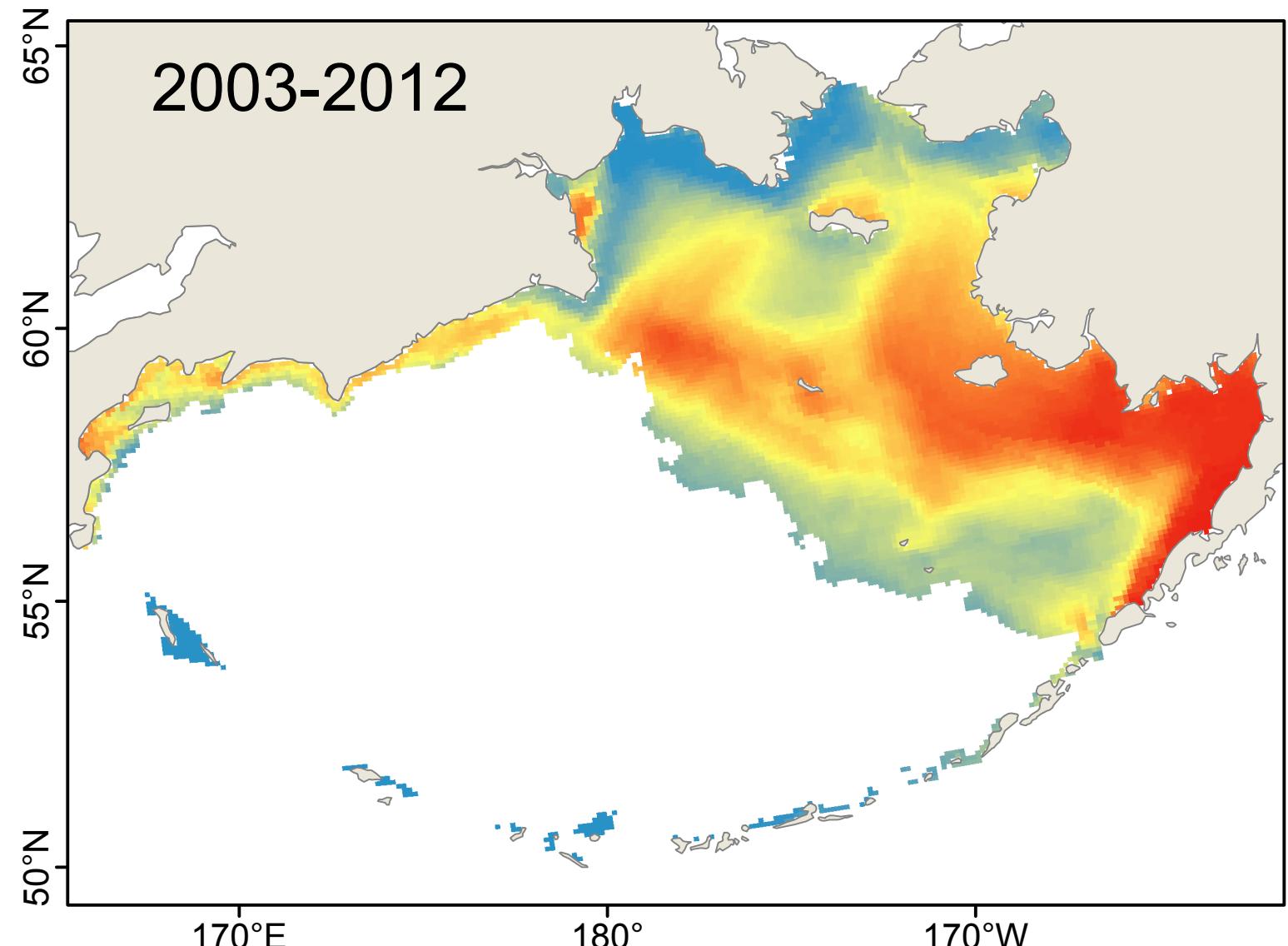
Average number of weeks of suitable habitat



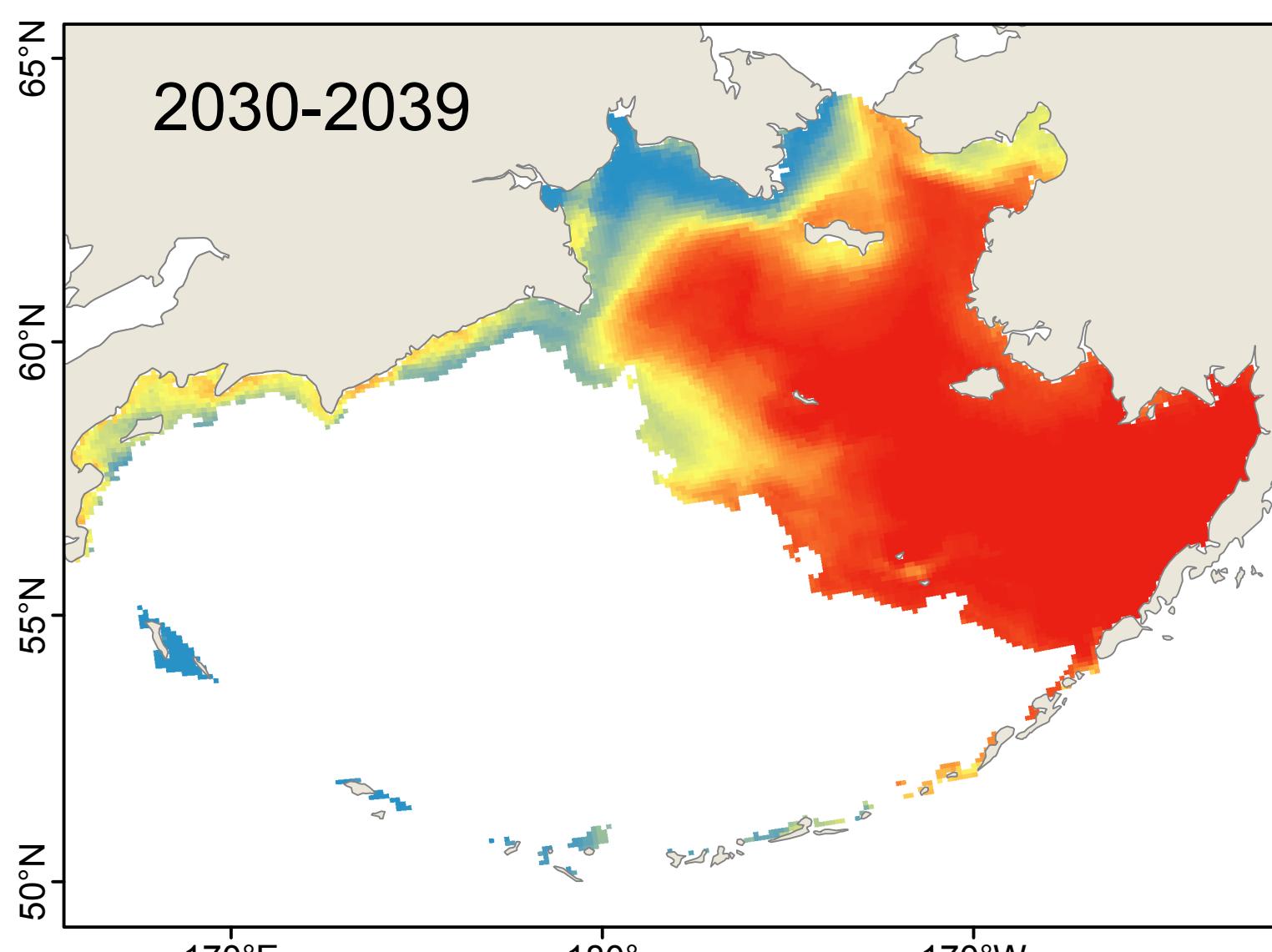
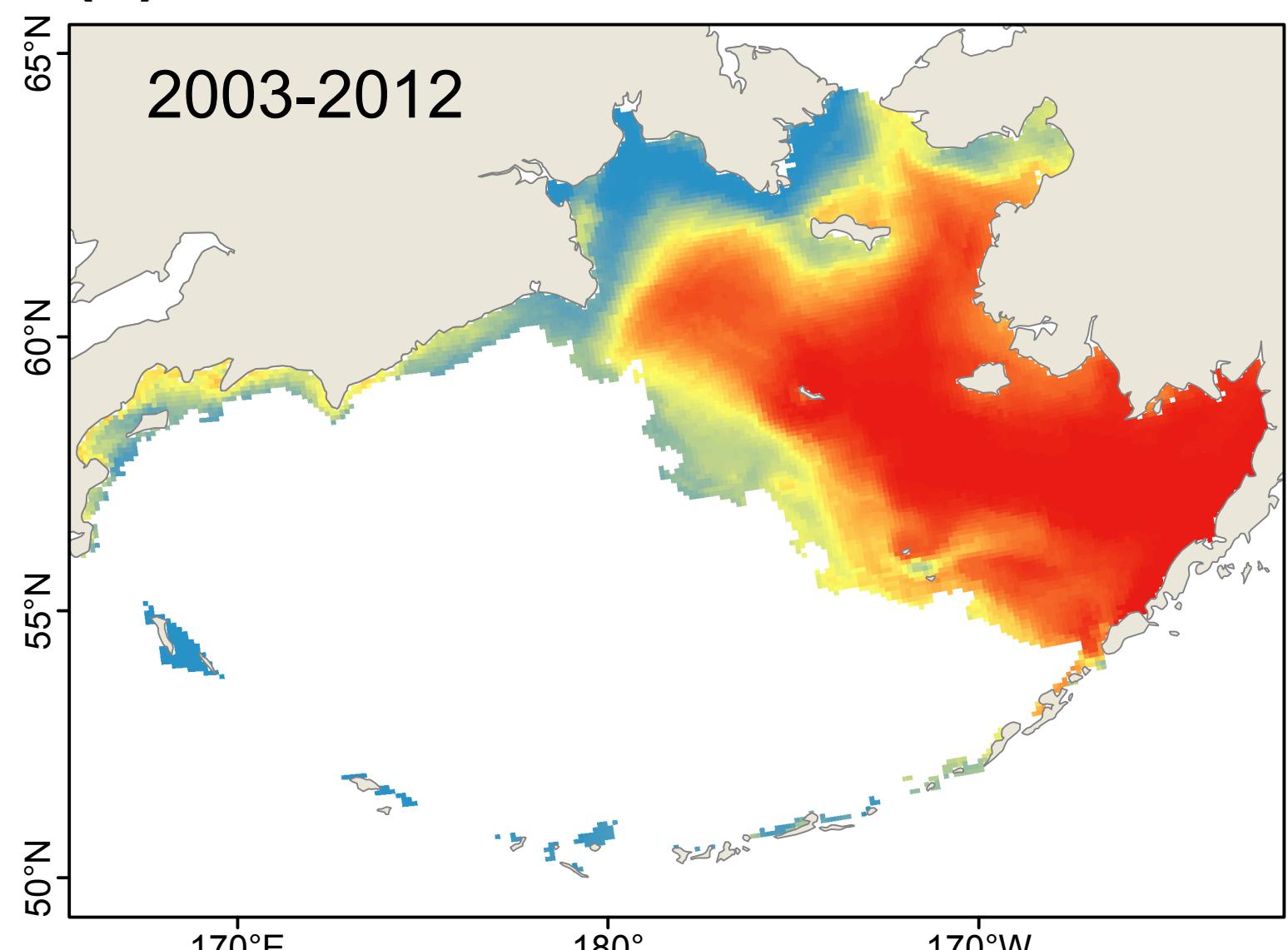
(a) Model: CGCM3-t47



(b) Model: ECHO-G

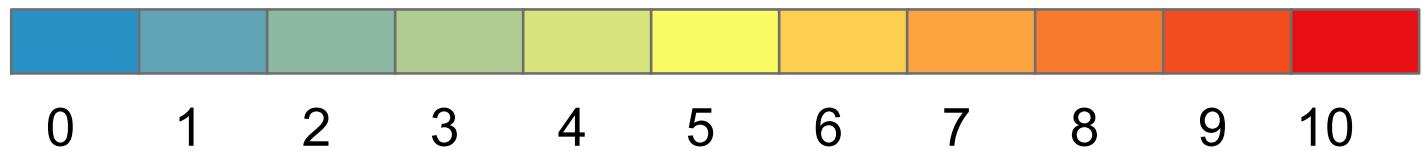


(c) Model: MIROC3.2

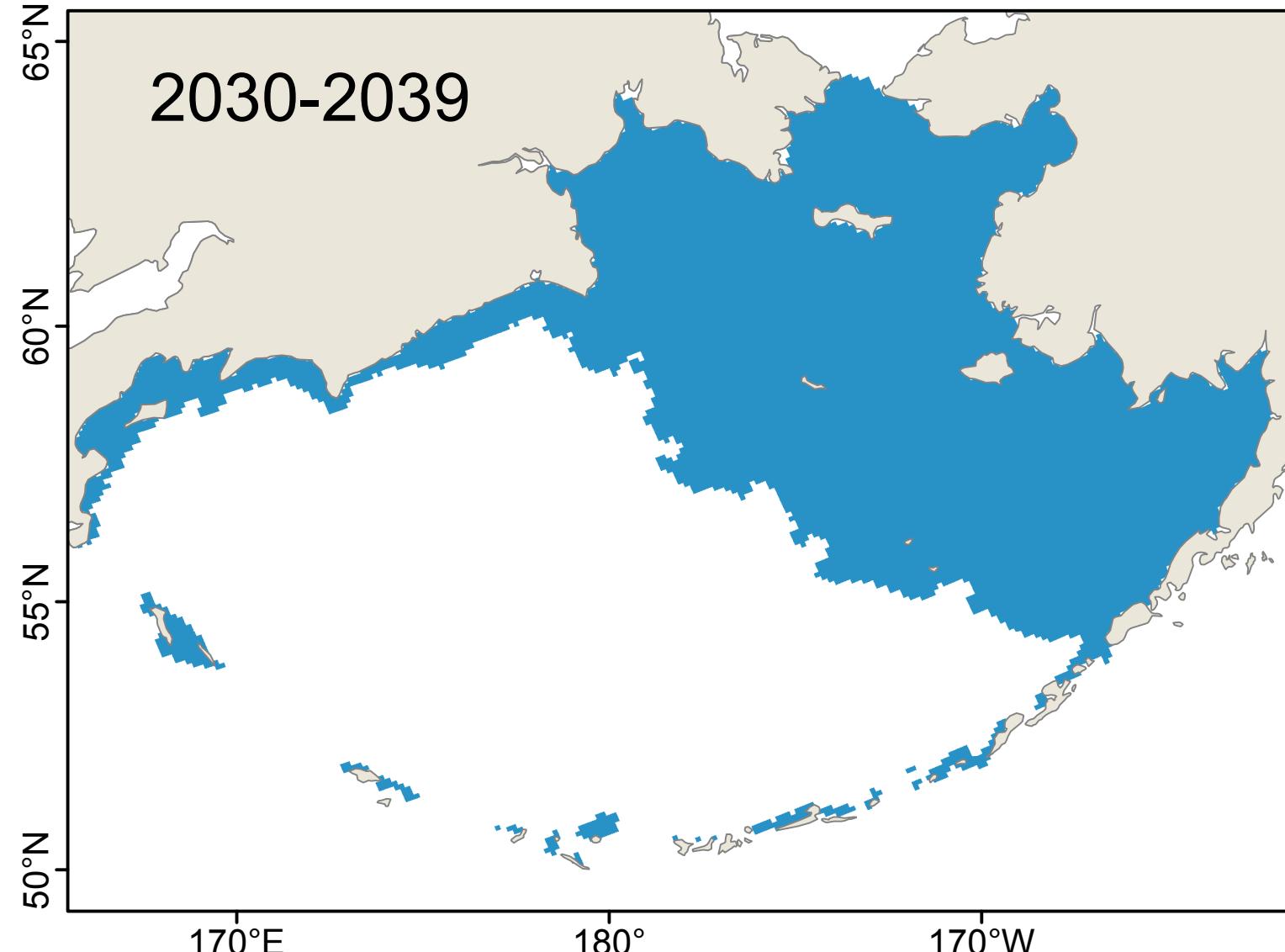
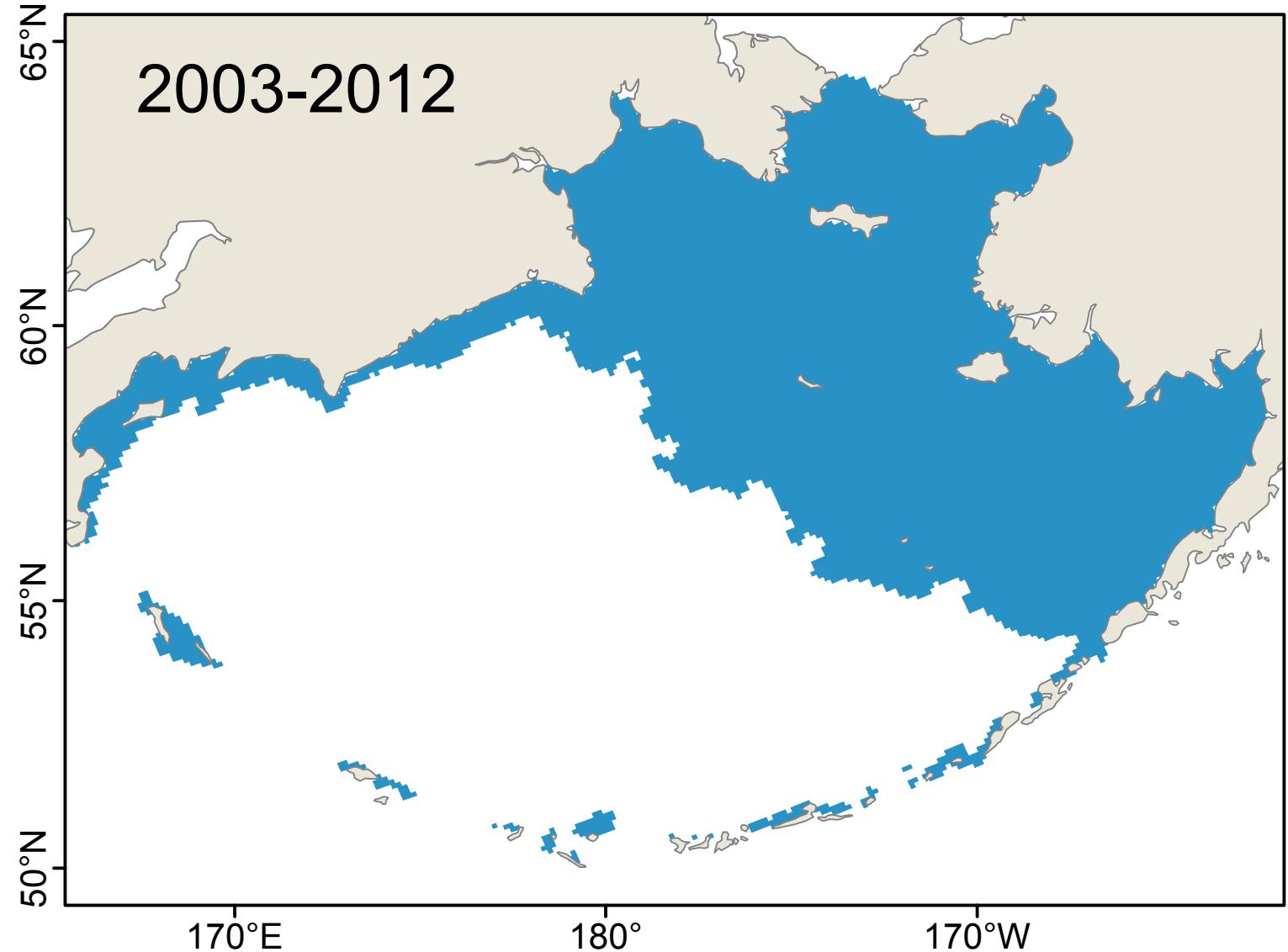


# *Crepidula onyx: Year-round Survival*

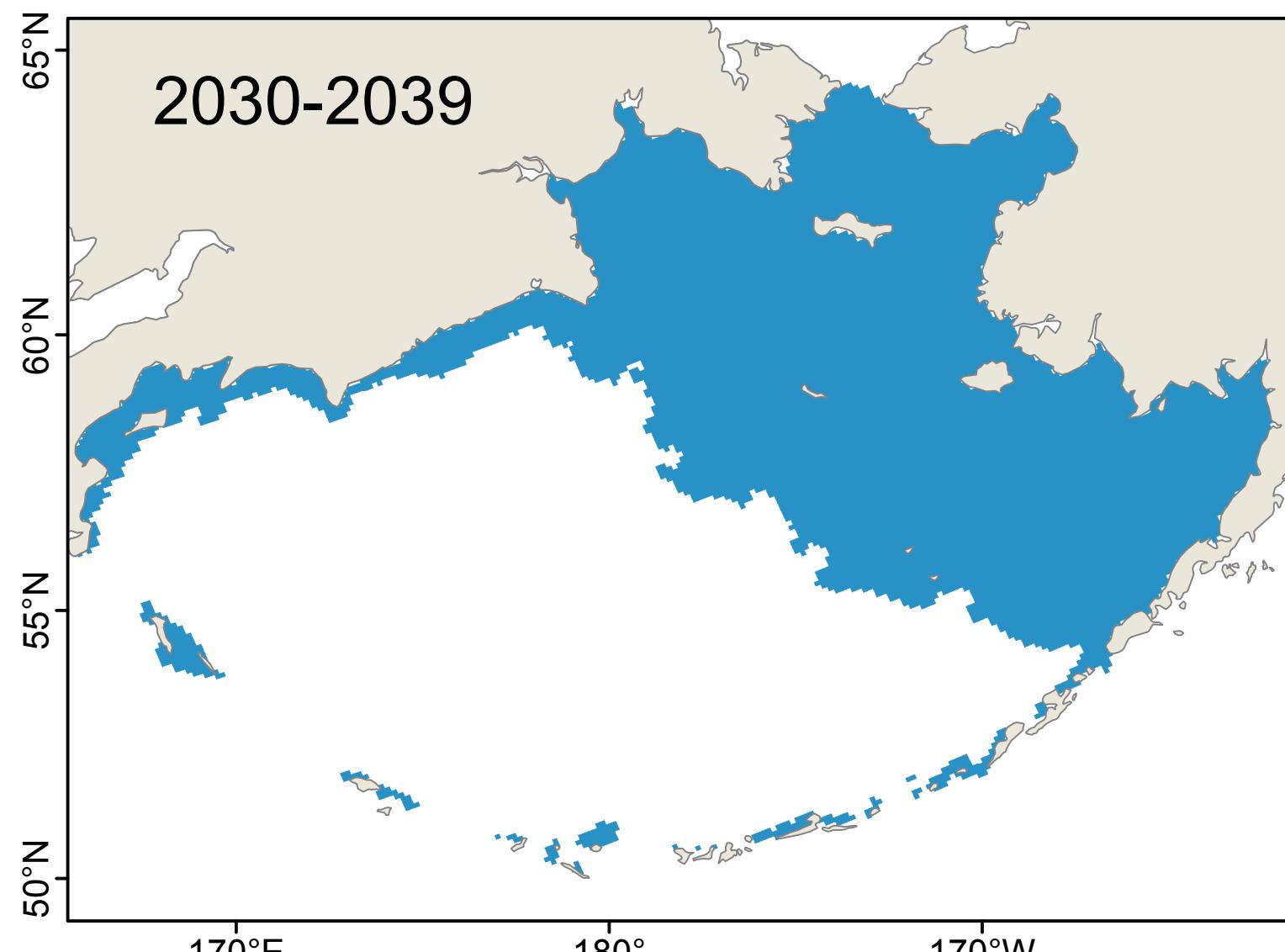
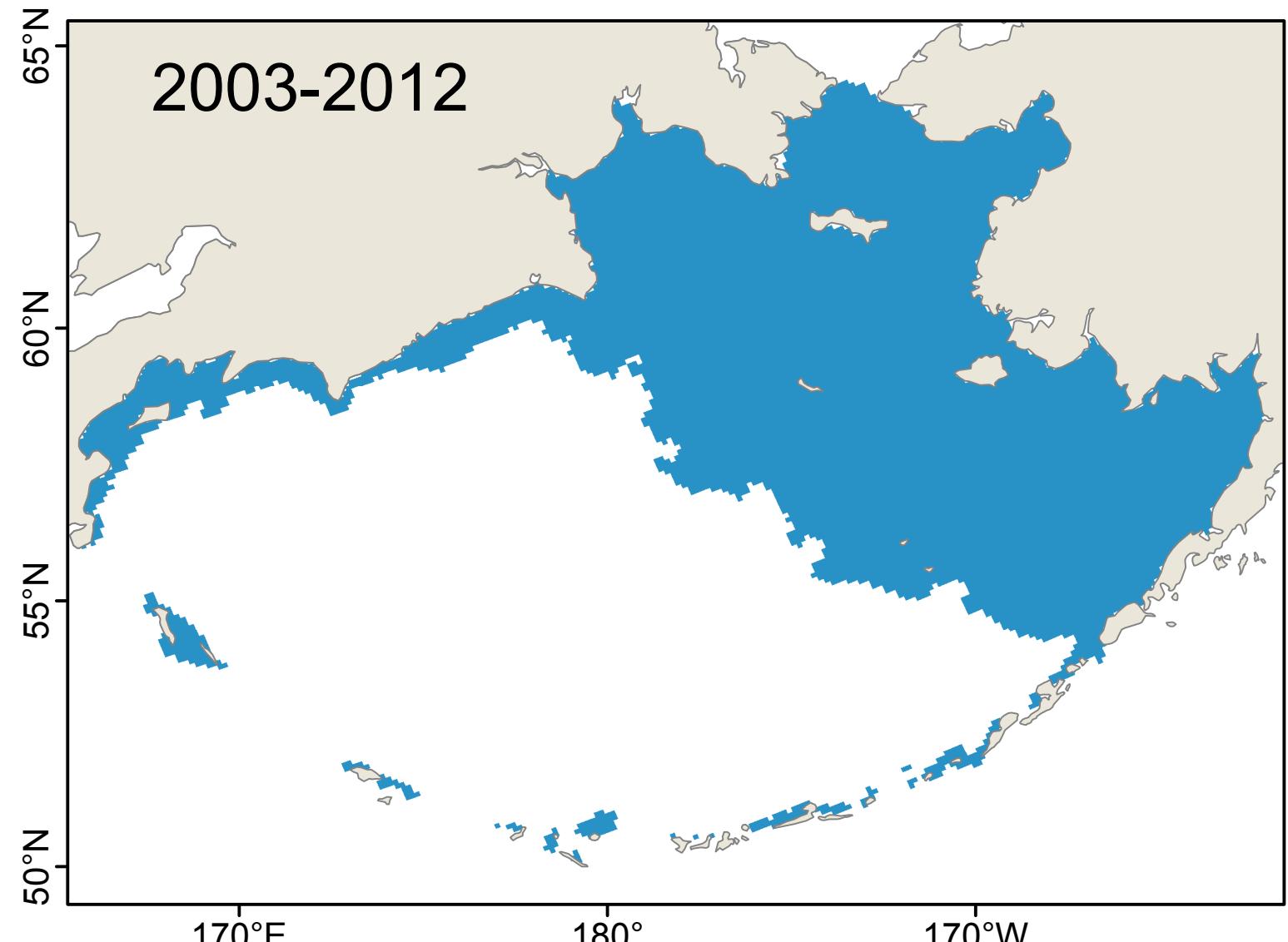
Number of years with suitable habitat



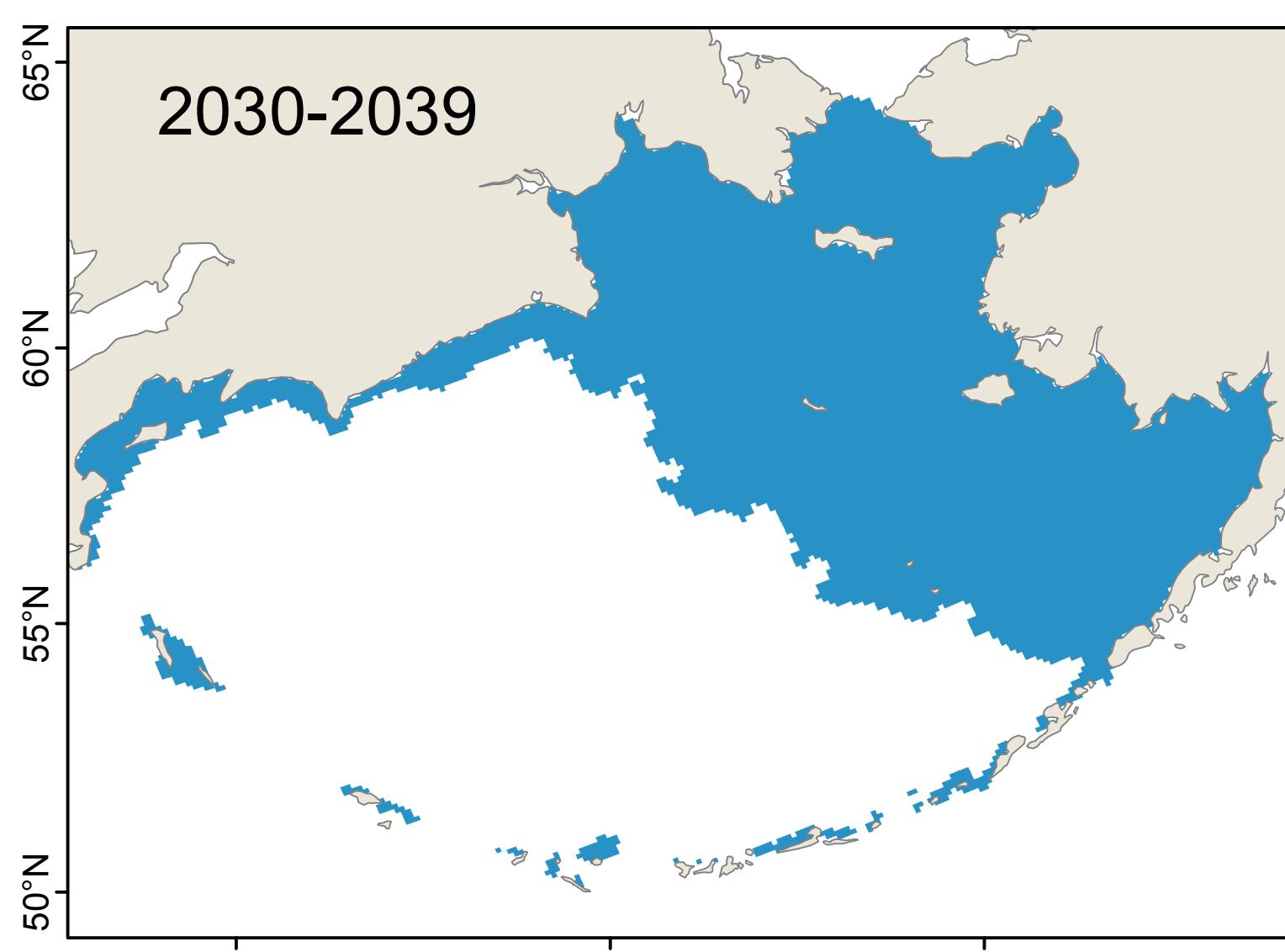
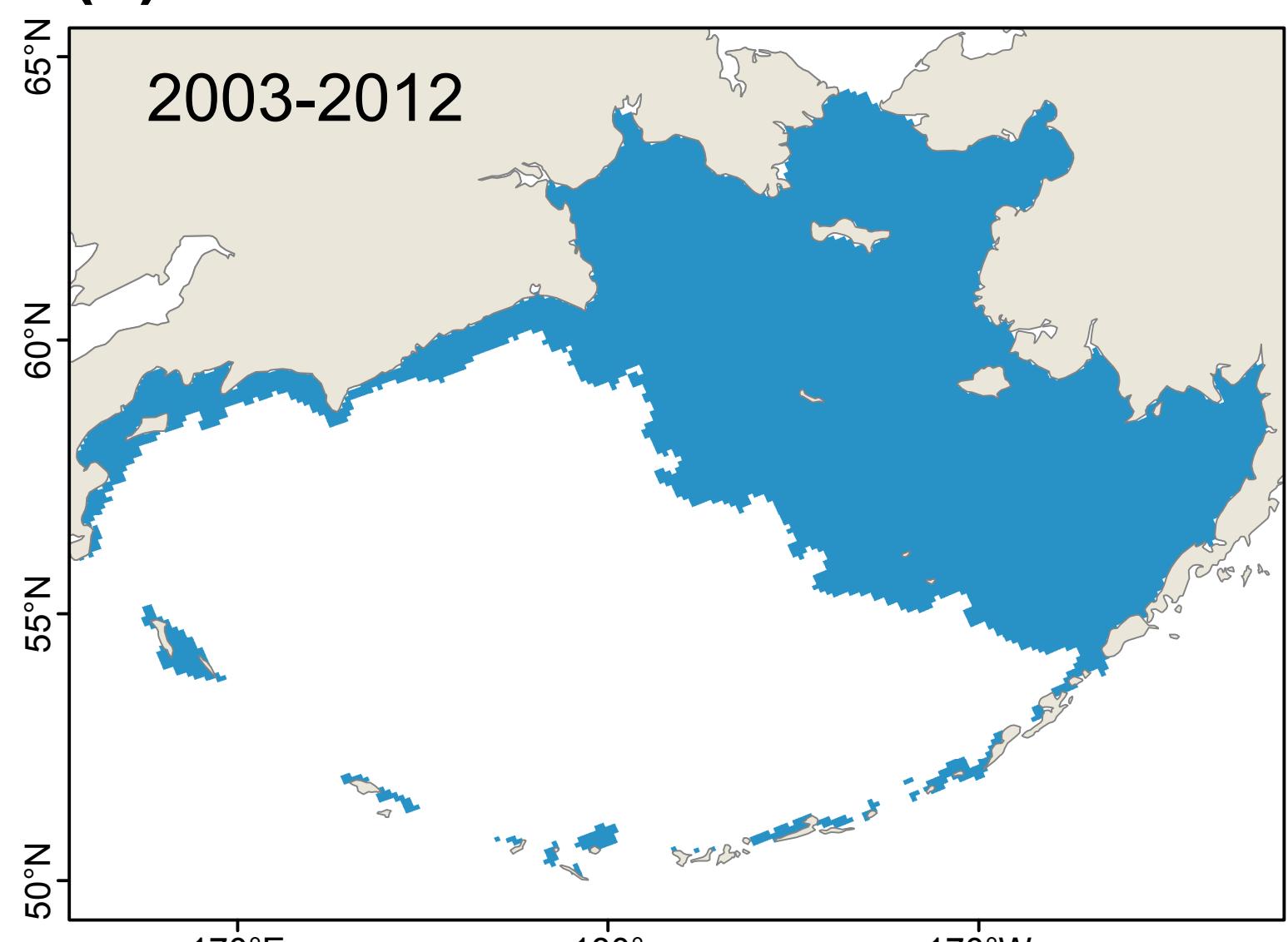
**(a) Model: CGCM3-t47**



**(b) Model: ECHO-G**

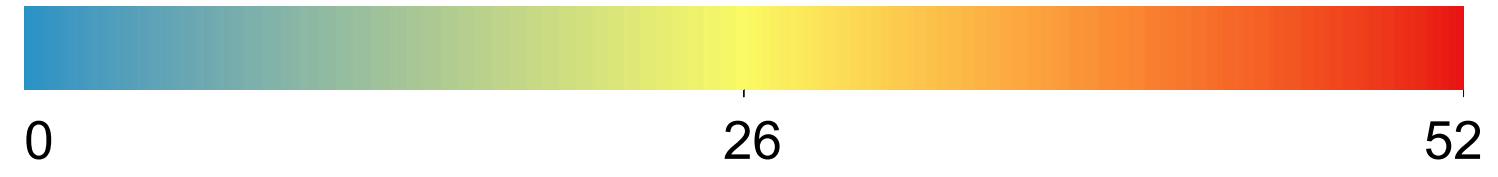


**(c) Model: MIROC3.2**

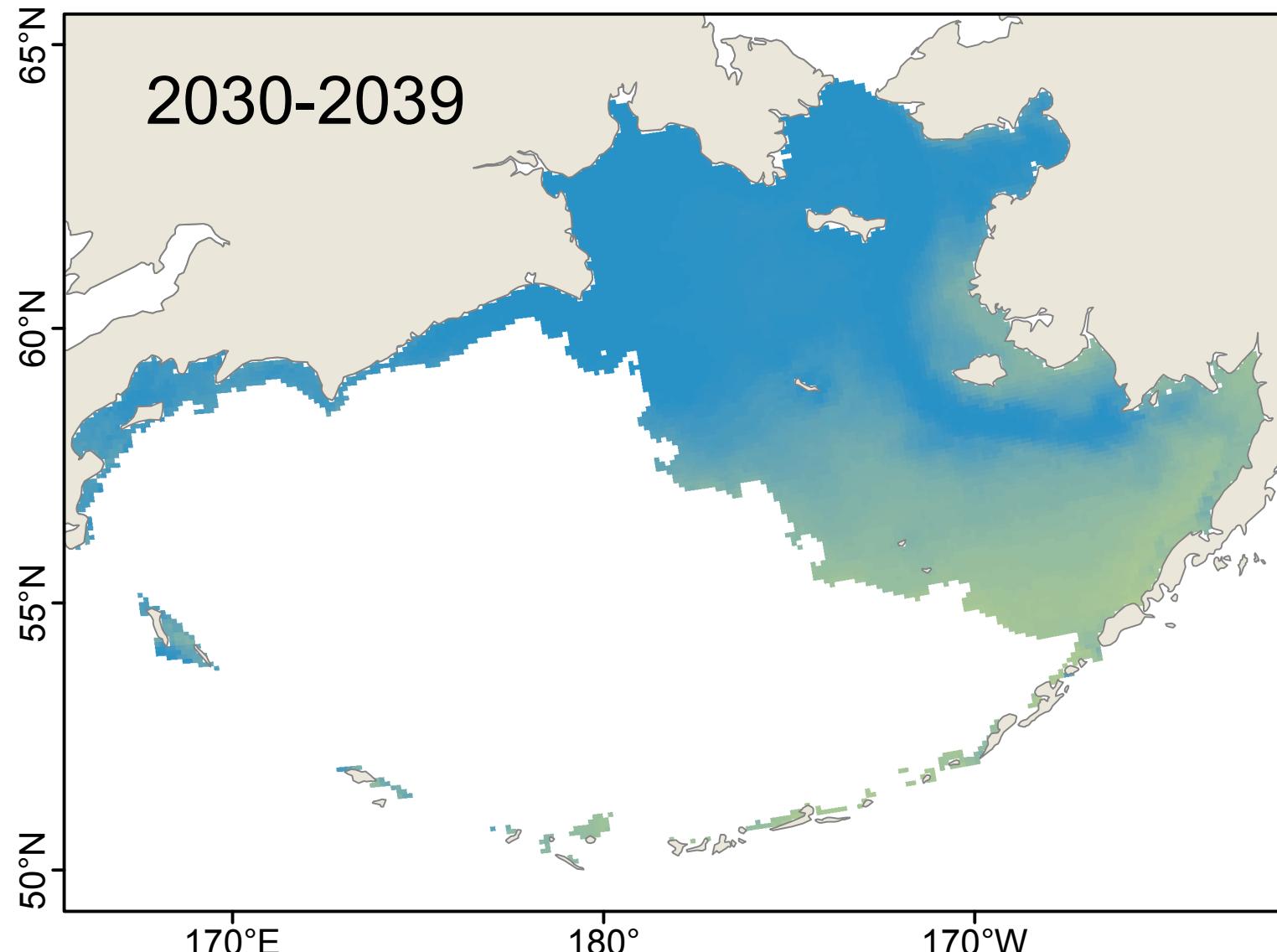
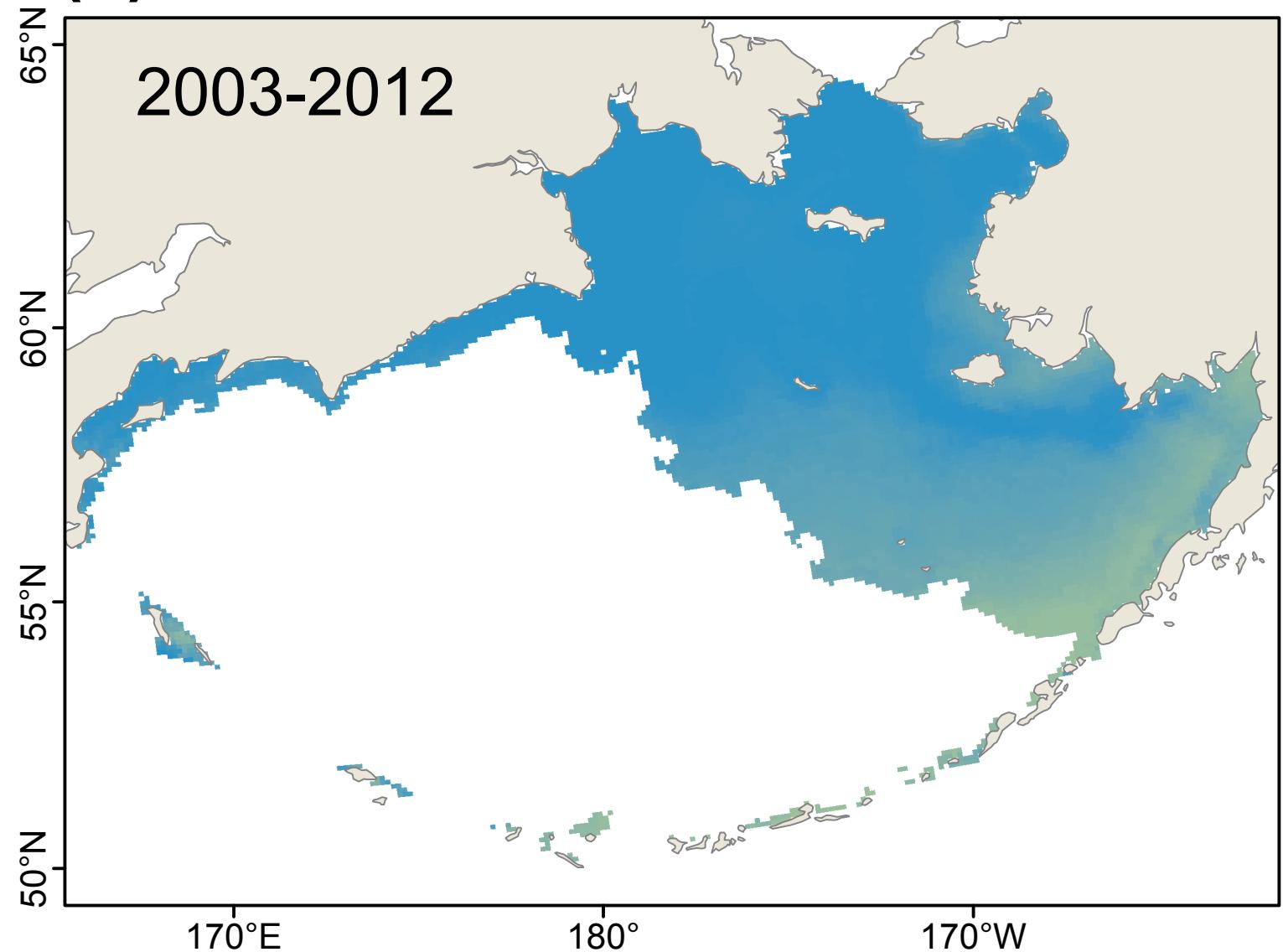


# *Crepidula onyx: Weekly Survival*

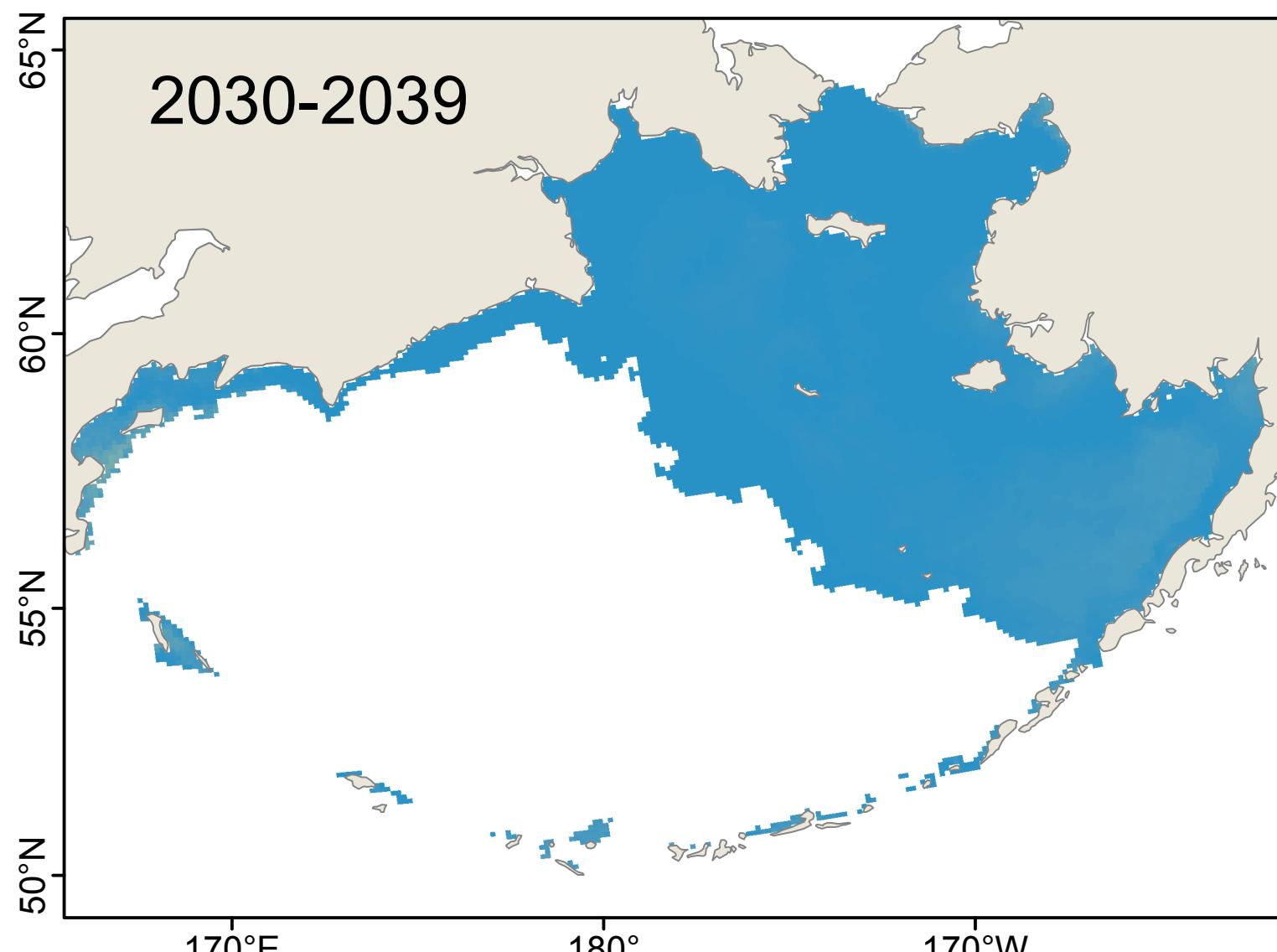
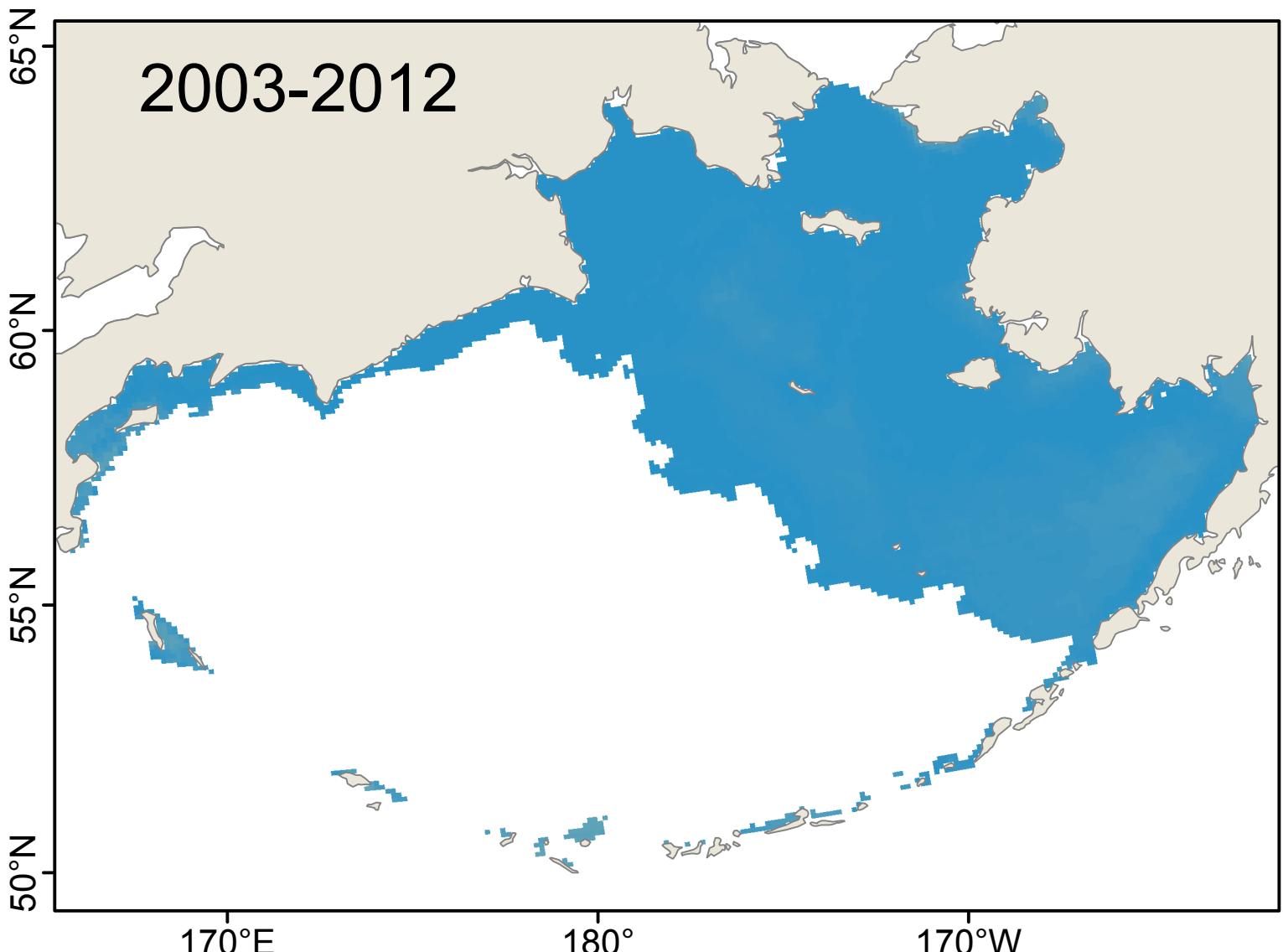
Average number of weeks of suitable habitat



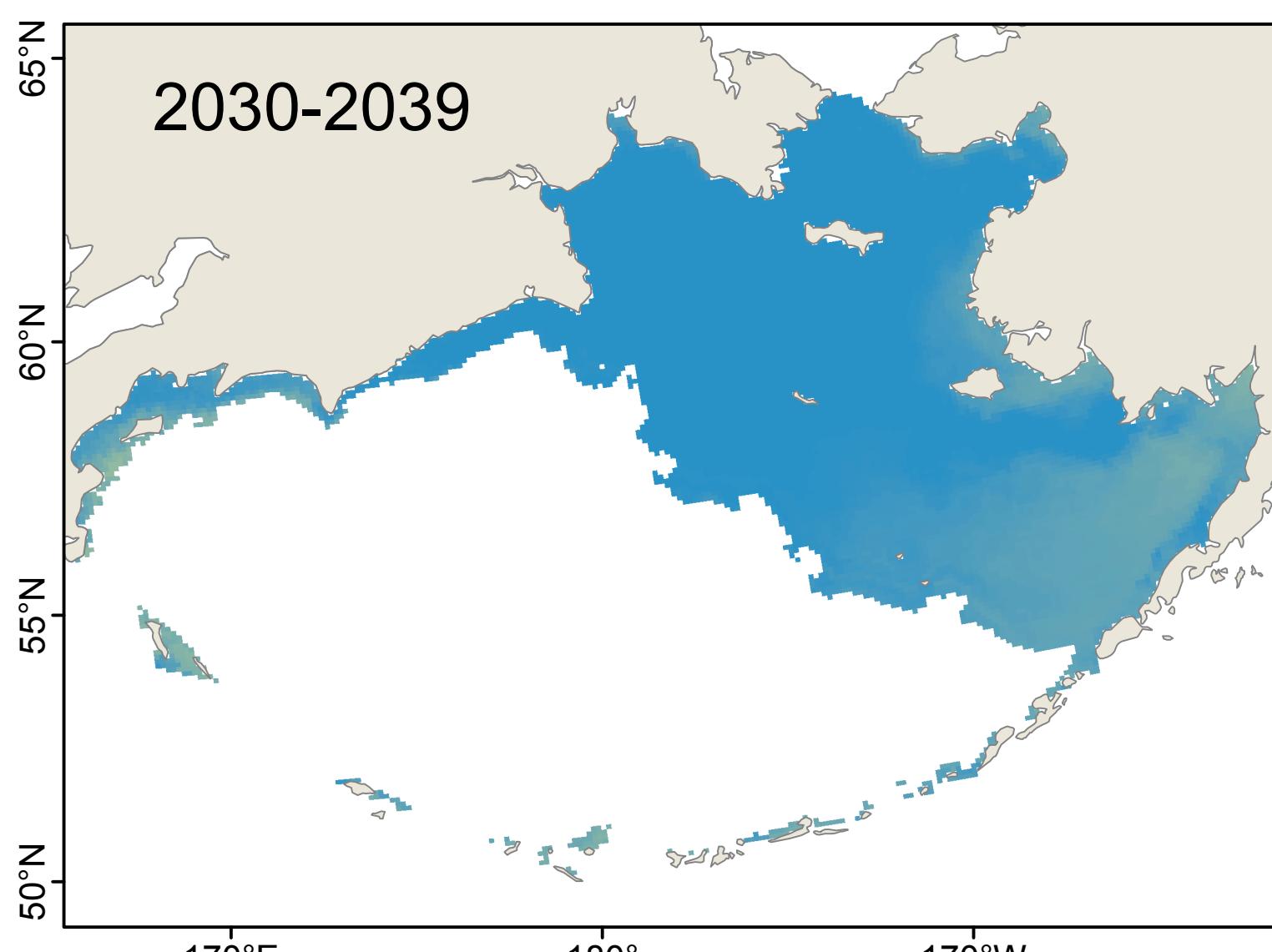
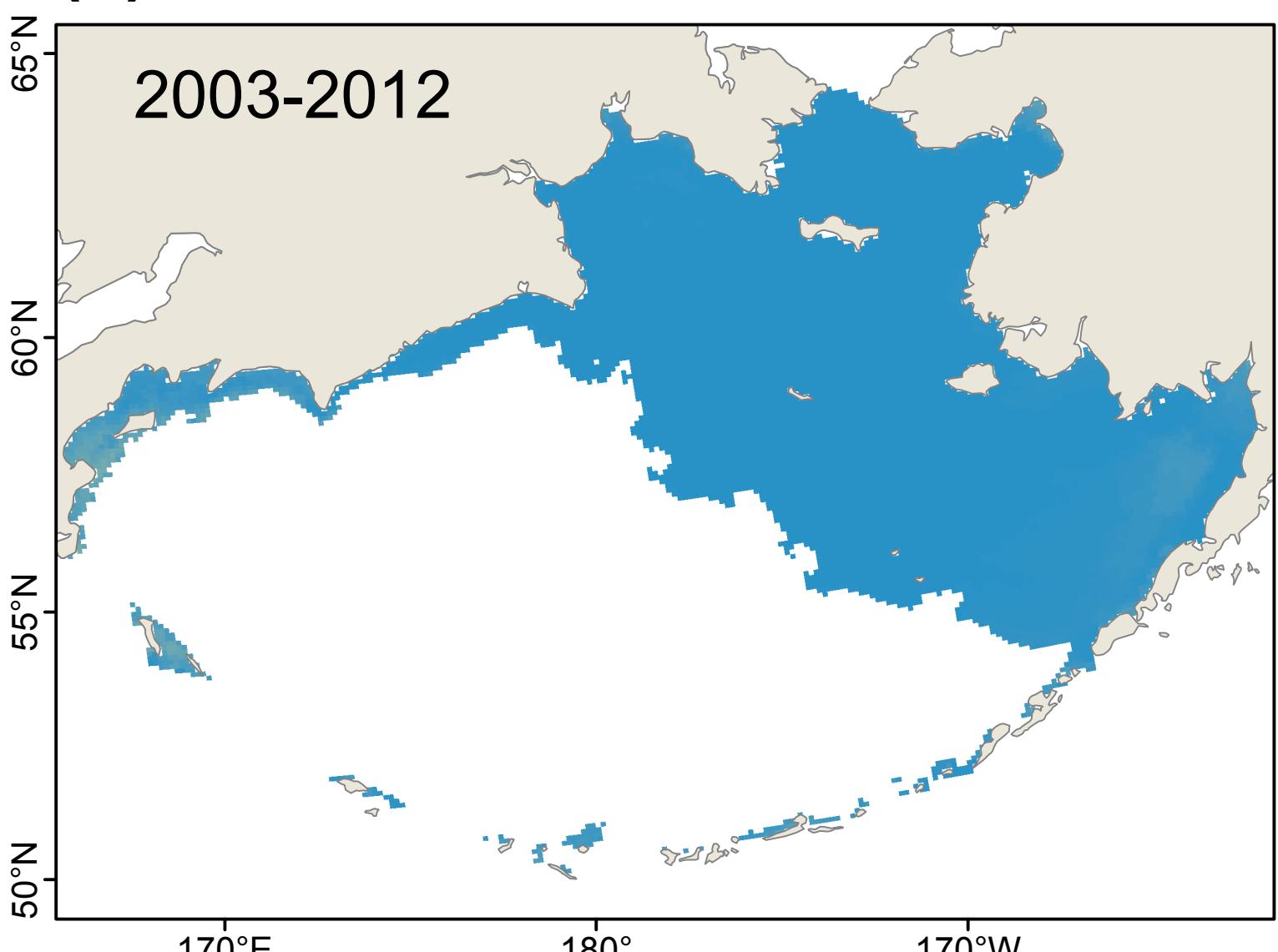
(a) Model: CGCM3-t47



(b) Model: ECHO-G

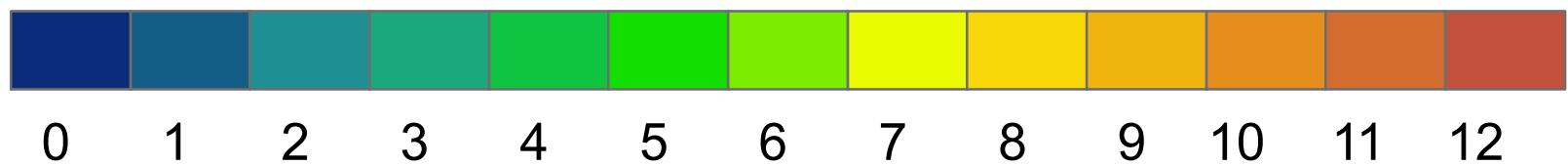


(c) Model: MIROC3.2

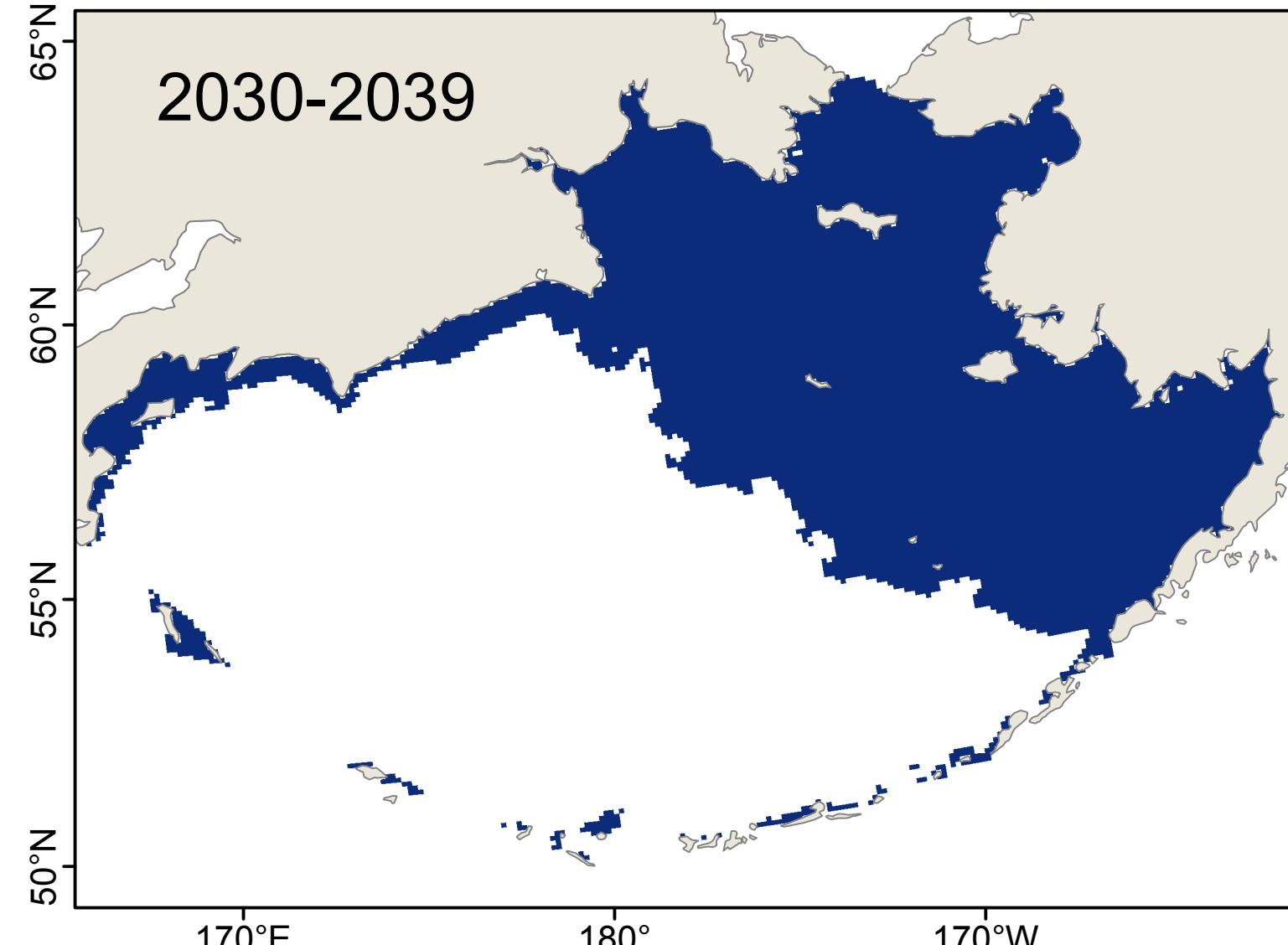
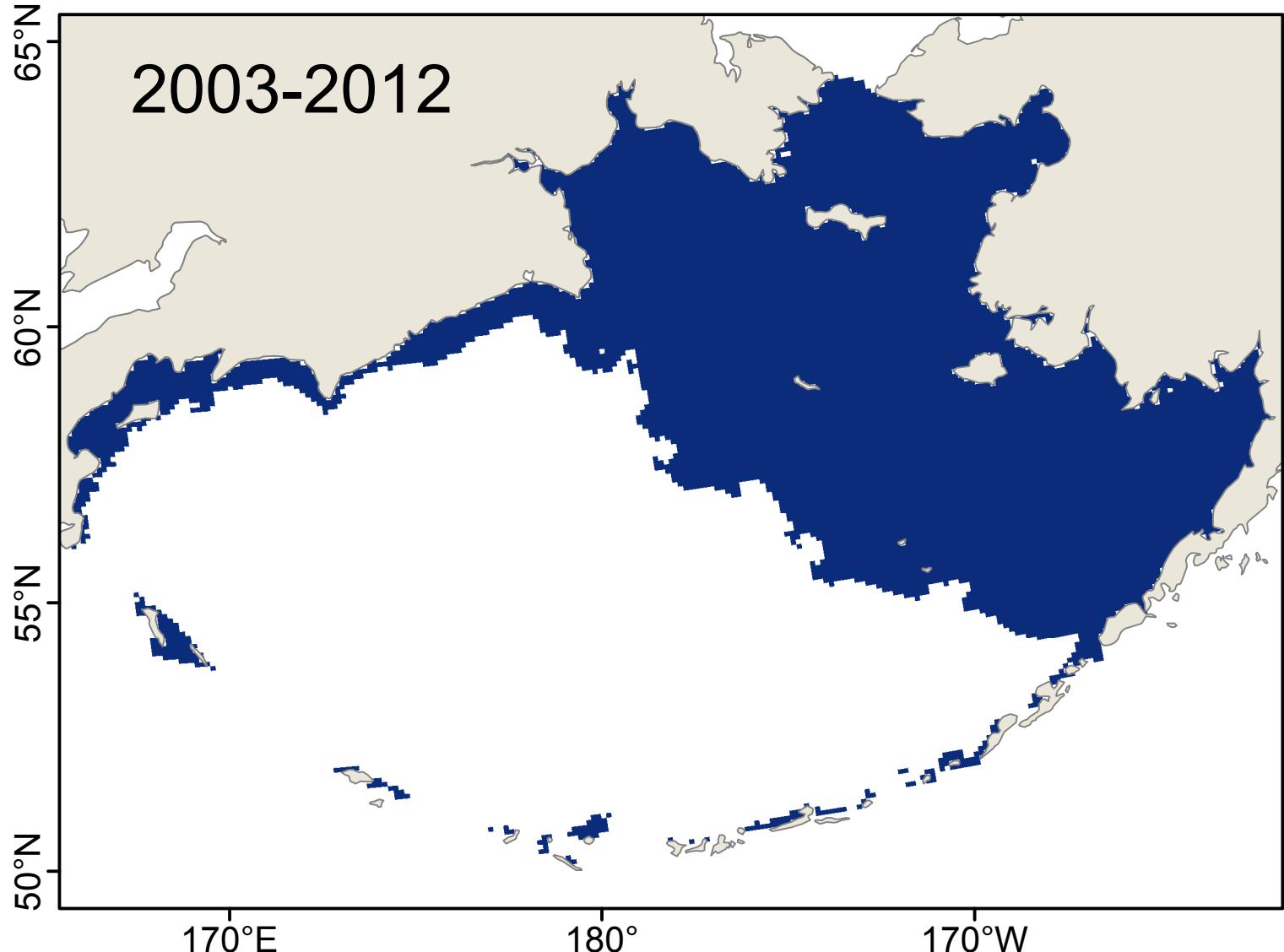


# *Crepidula onyx: Reproduction*

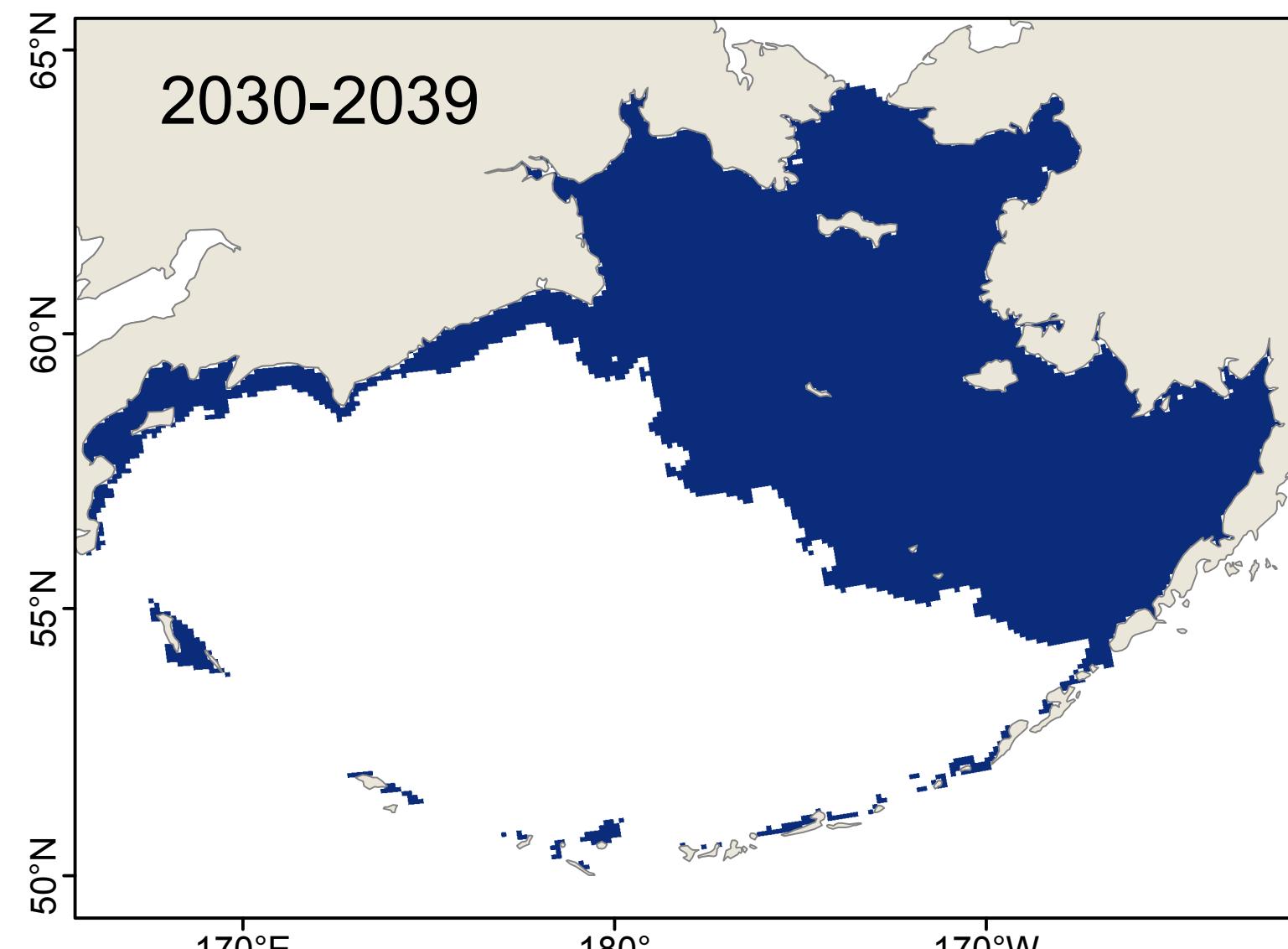
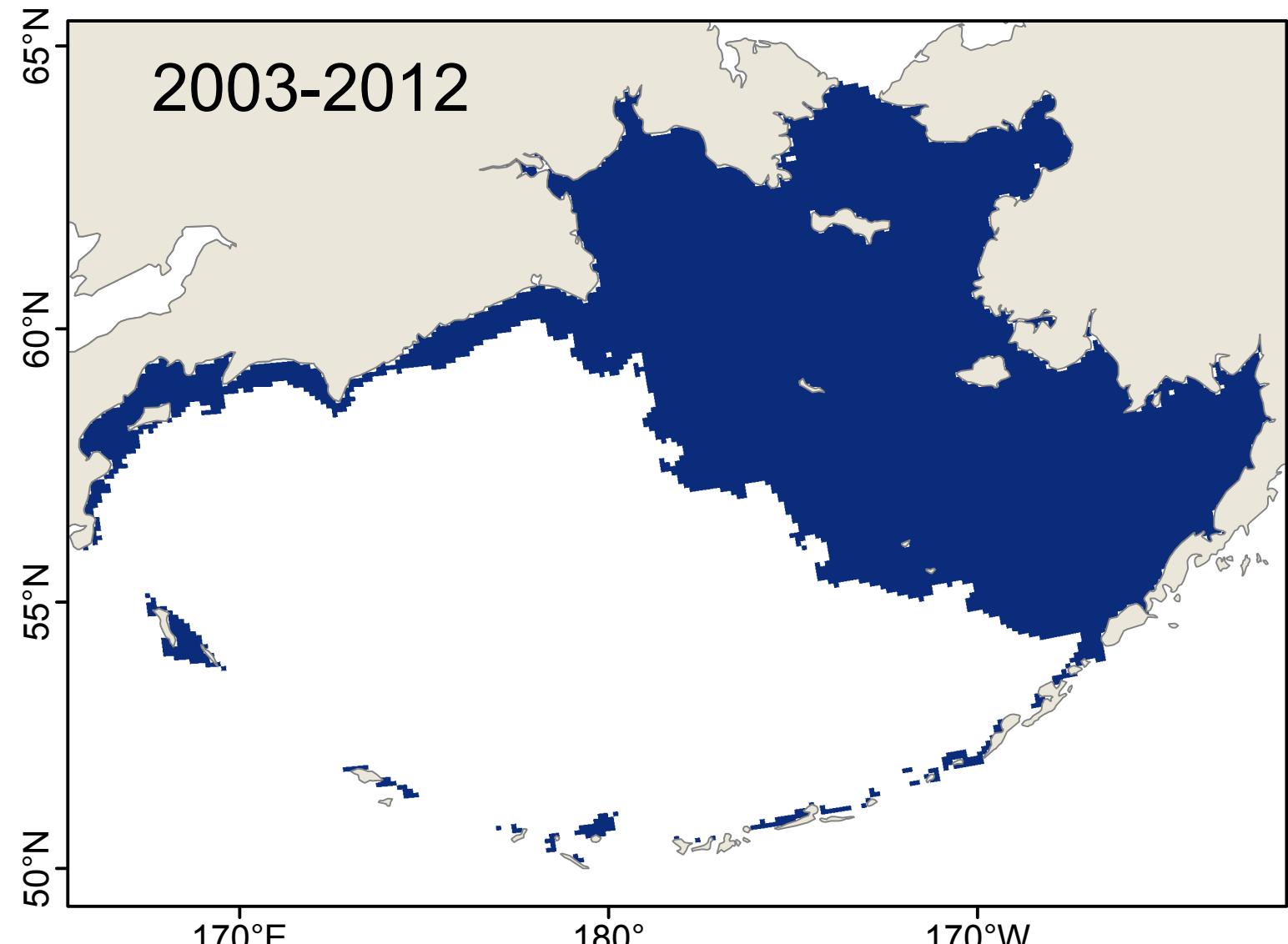
Average number of consecutive weeks of suitable habitat



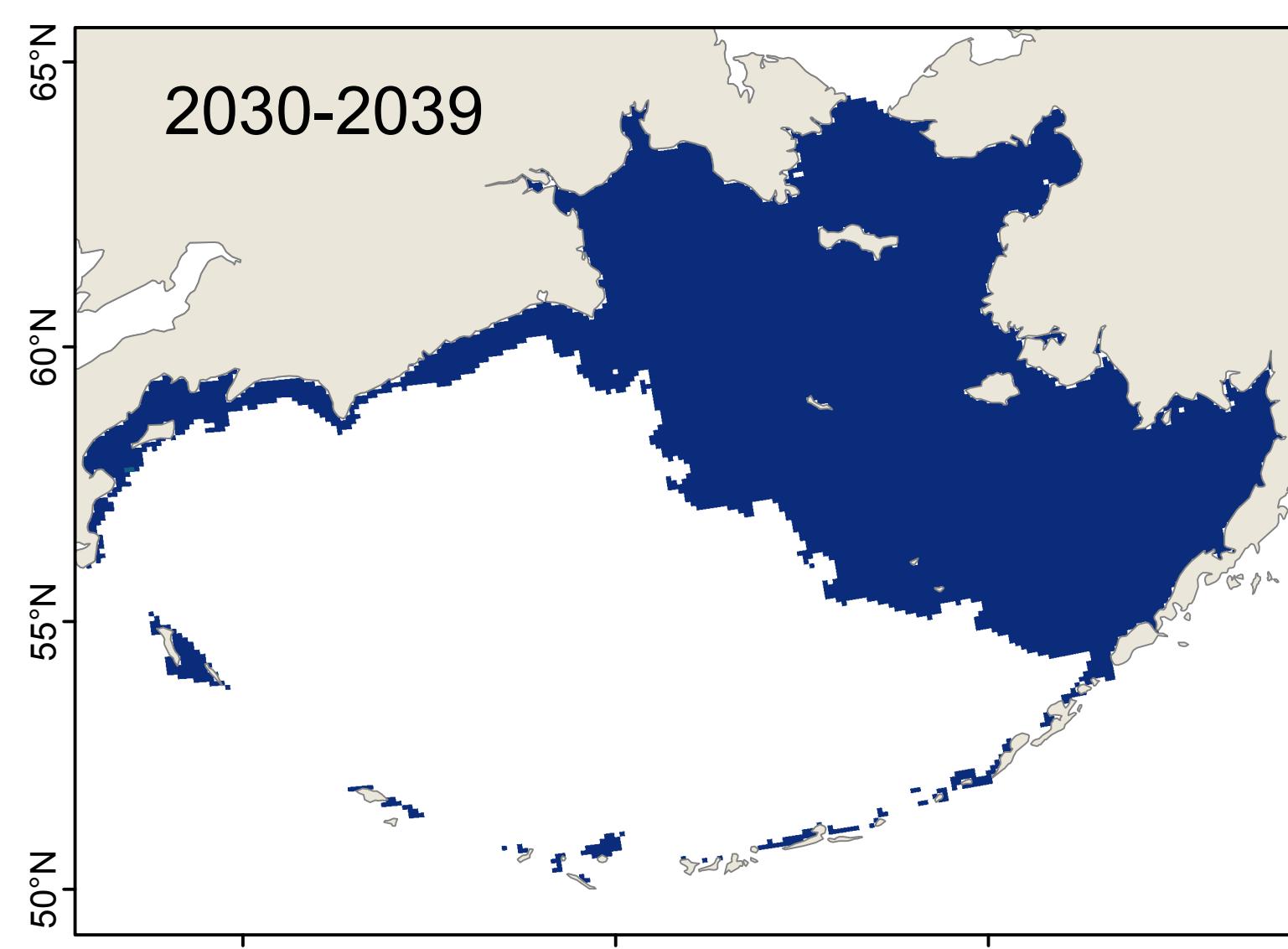
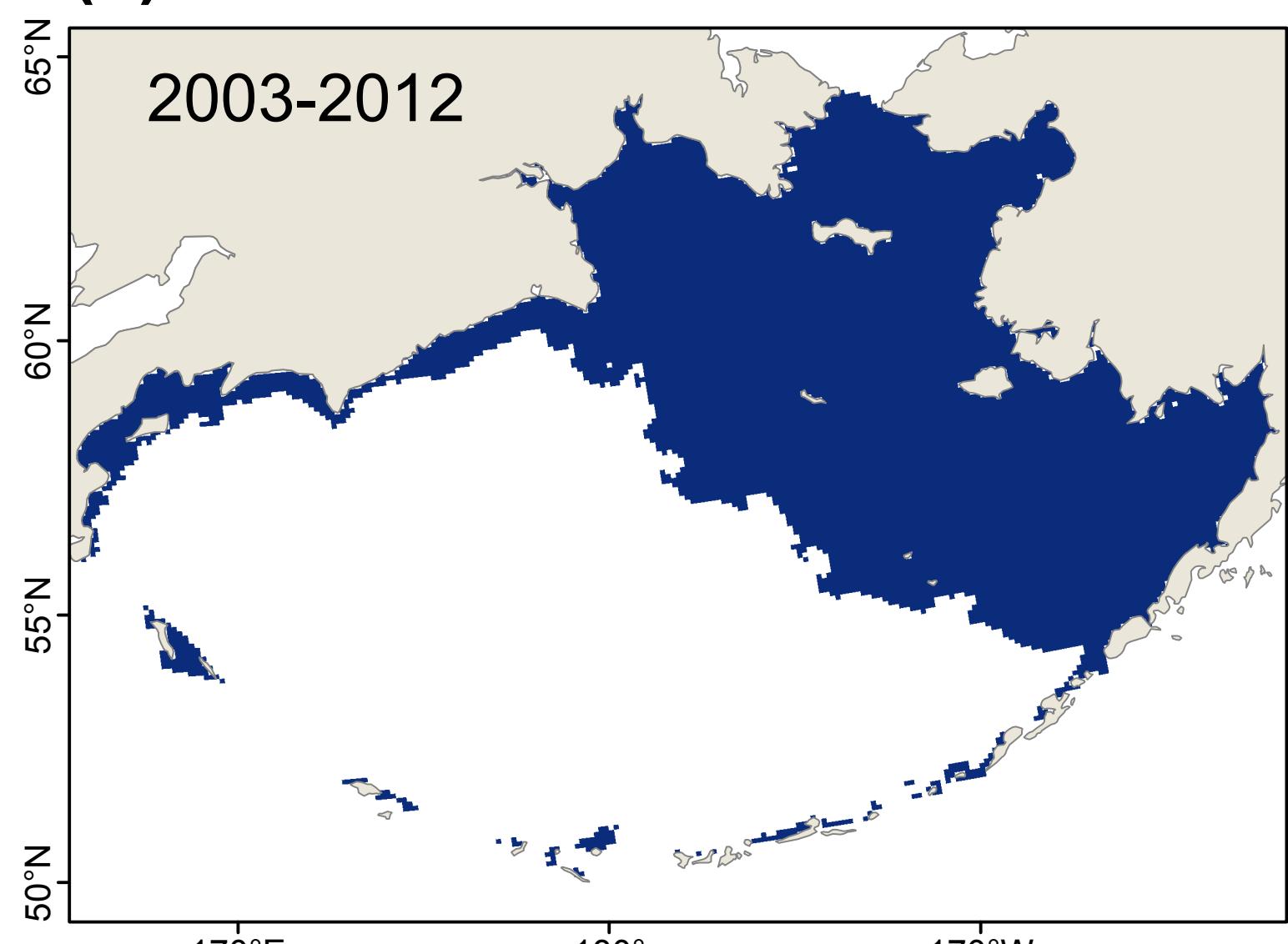
(a) Model: CGCM3-t47



(b) Model: ECHO-G

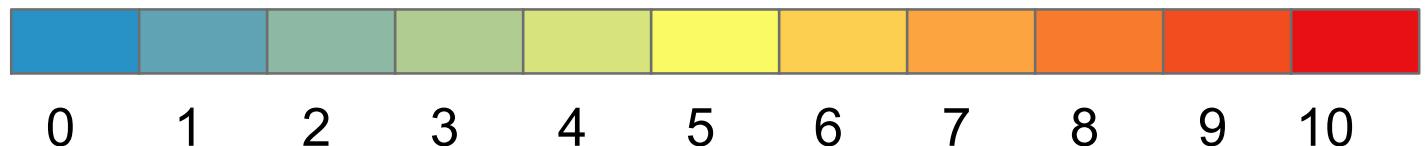


(c) Model: MIROC3.2

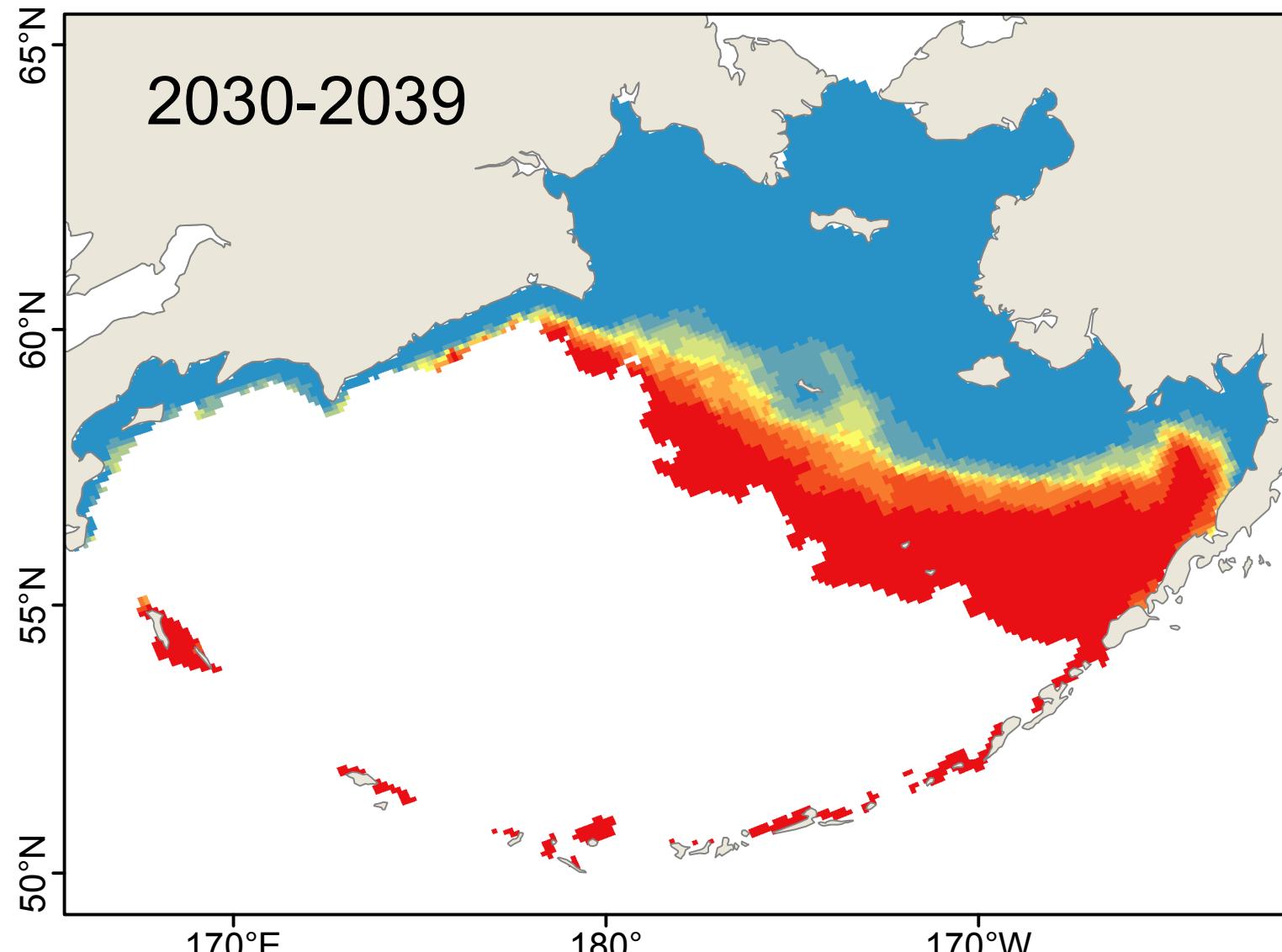
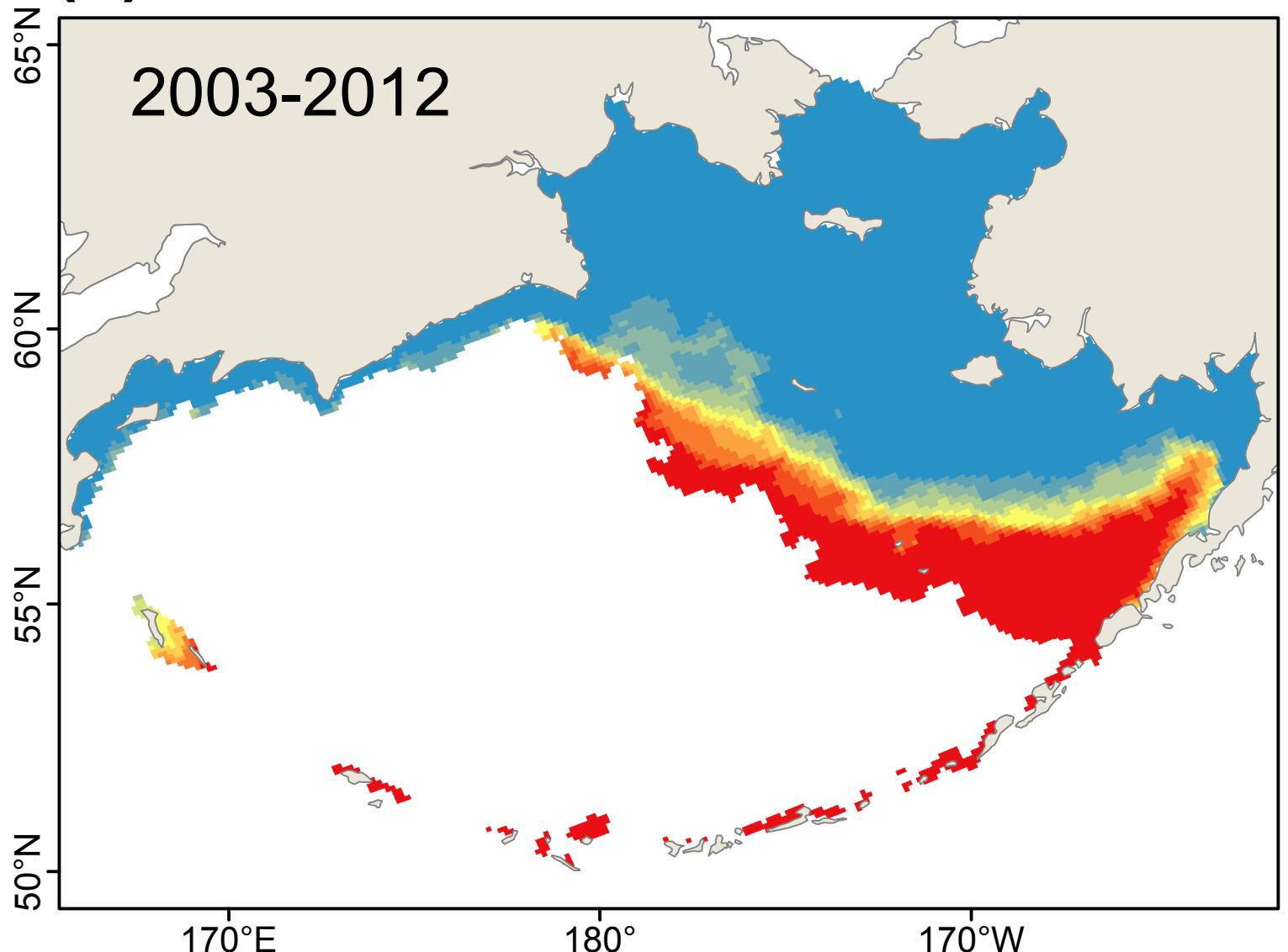


# *Ilyanassa obsoleta: Year-round Survival*

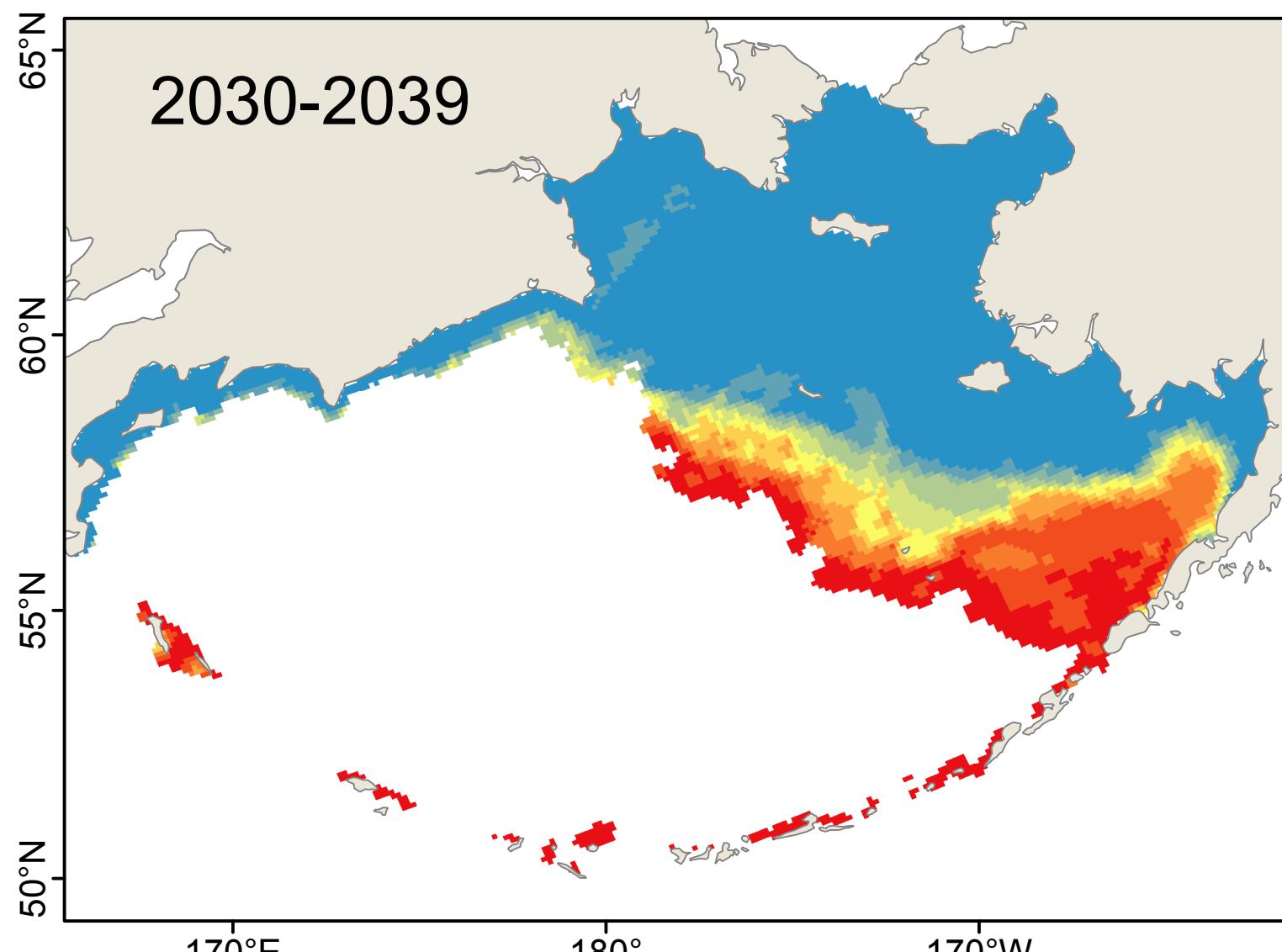
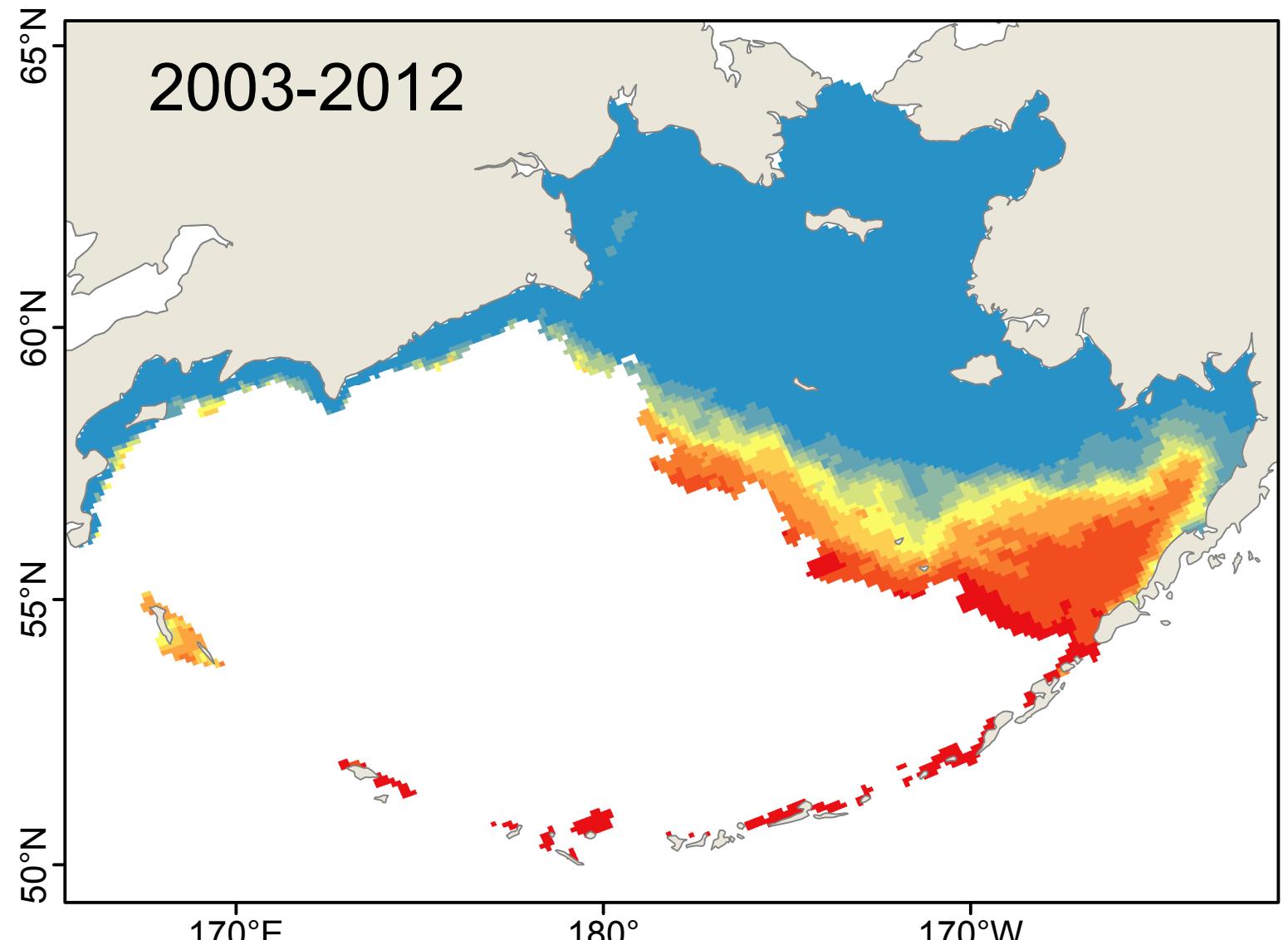
Number of years with suitable habitat



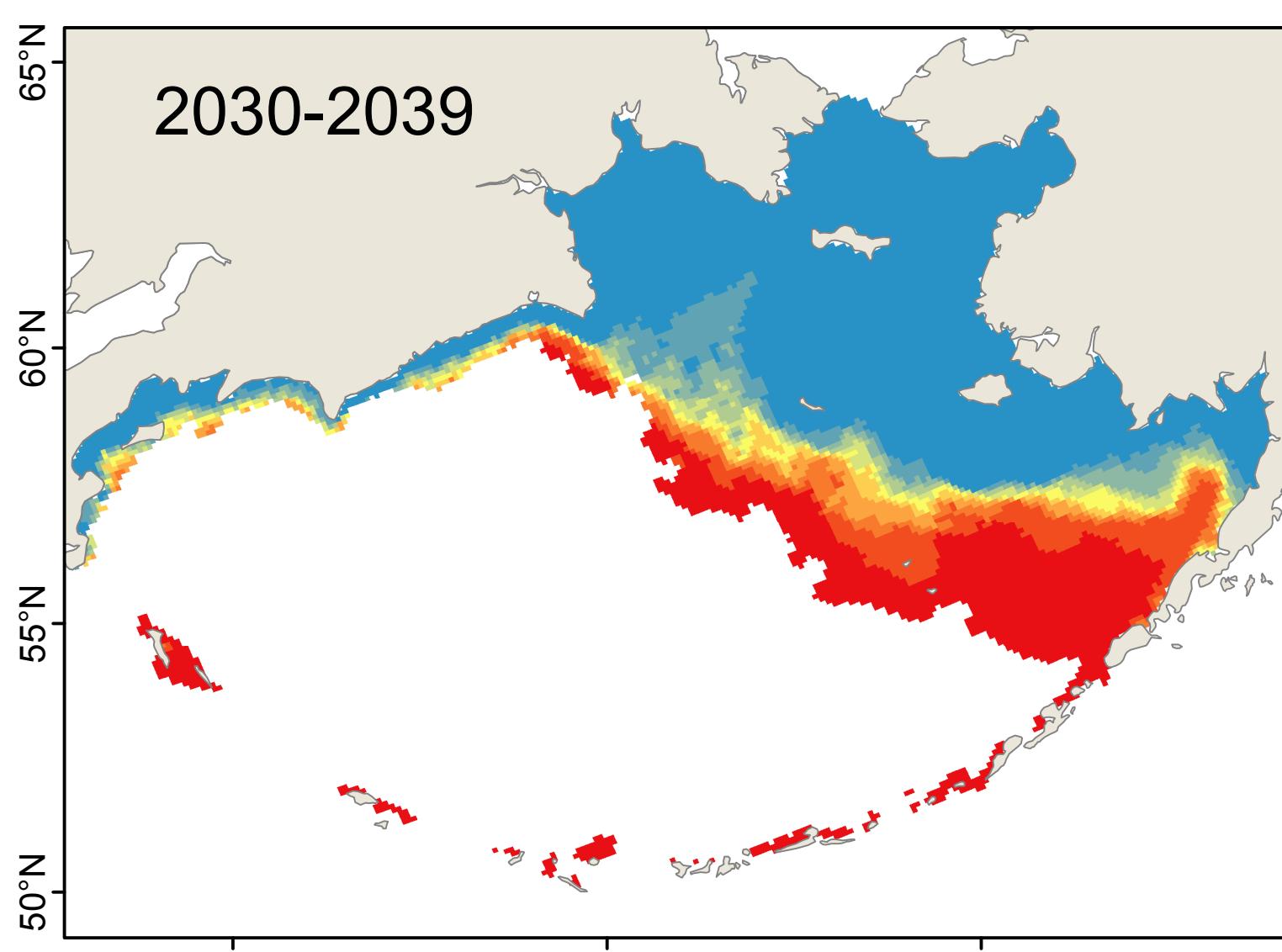
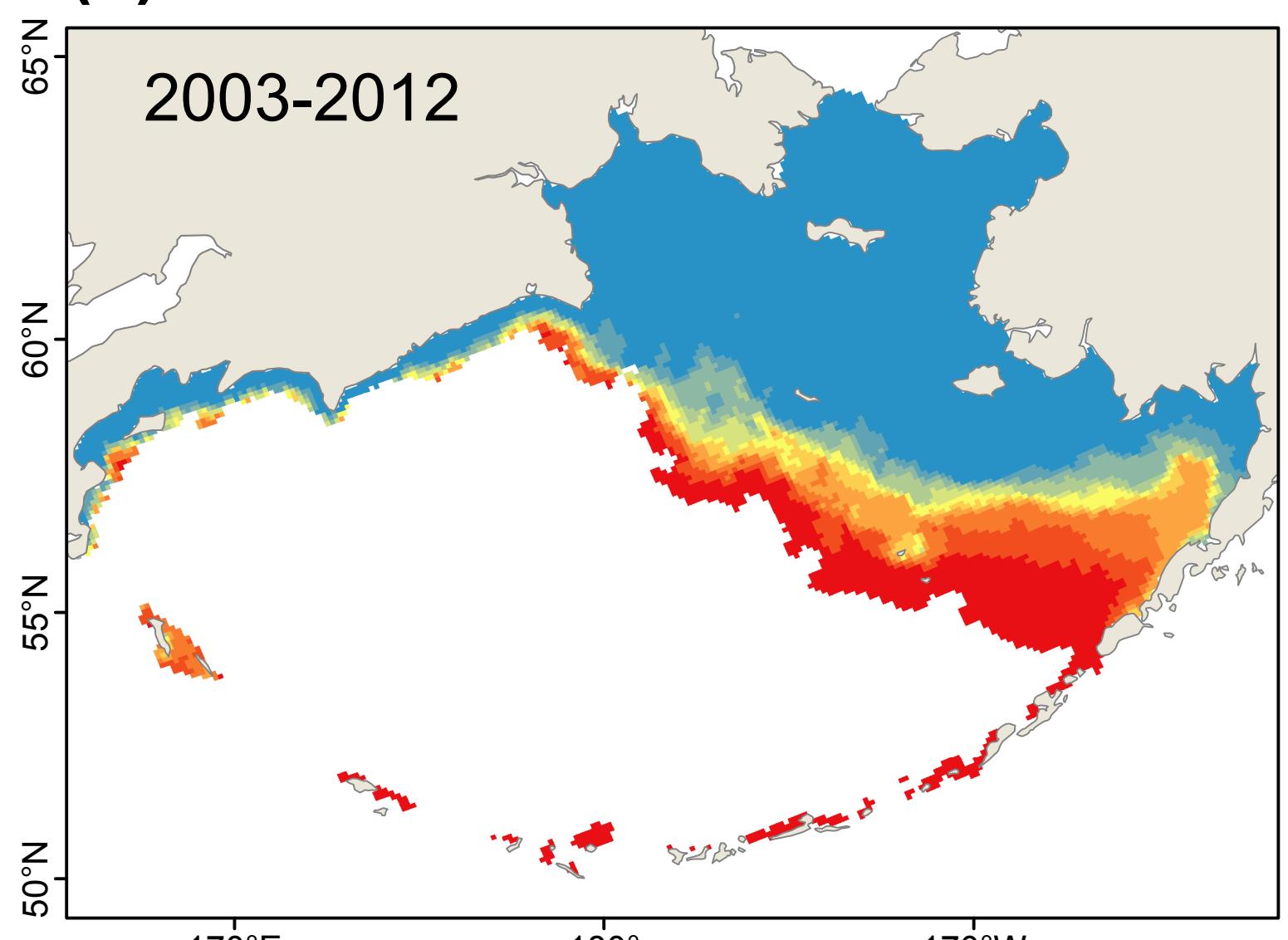
(a) Model: CGCM3-t47



(b) Model: ECHO-G

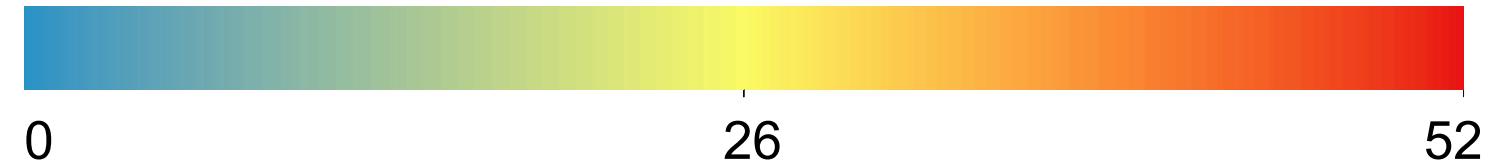


(c) Model: MIROC3.2

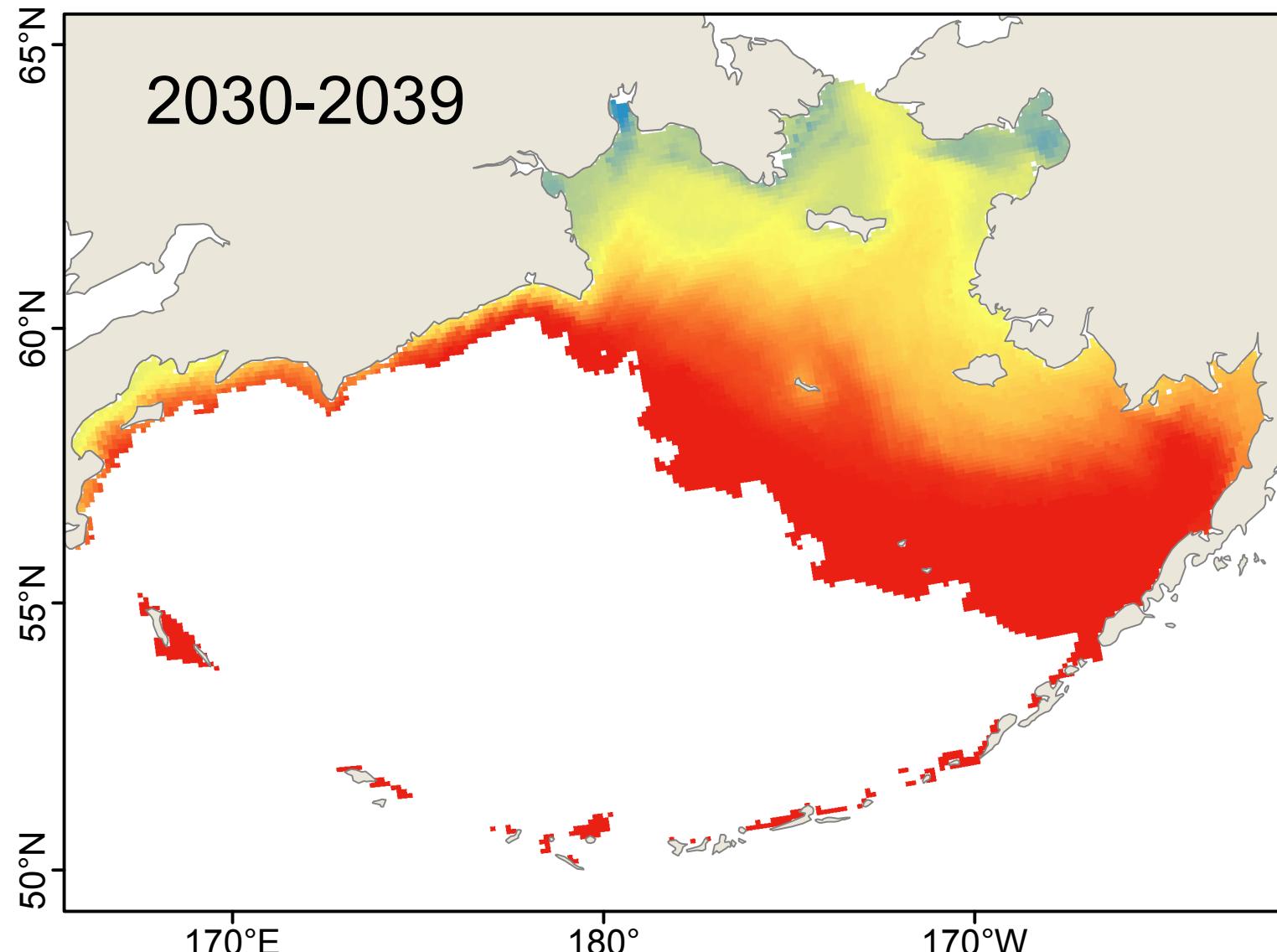
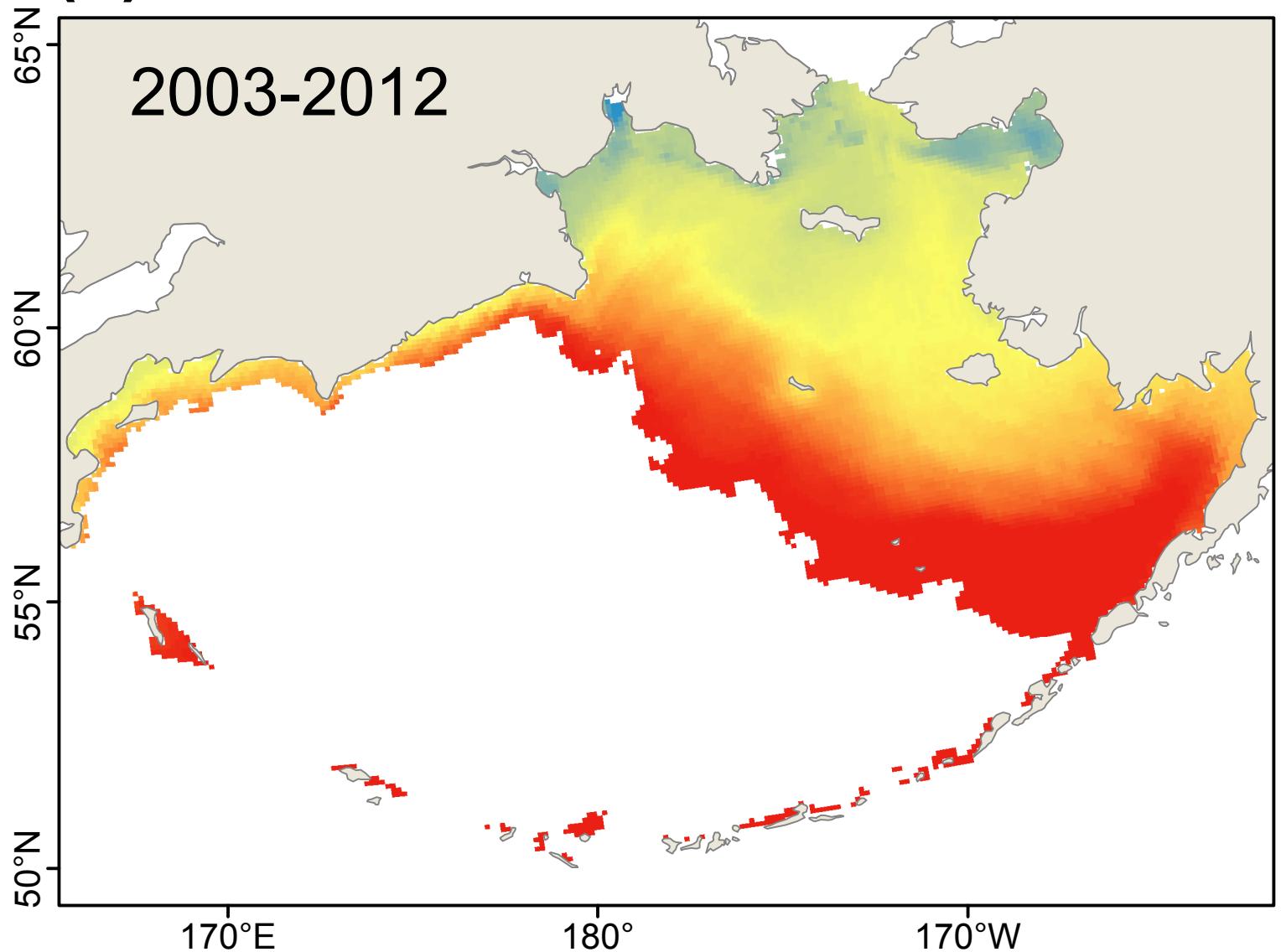


# *Ilyanassa obsoleta: Weekly Survival*

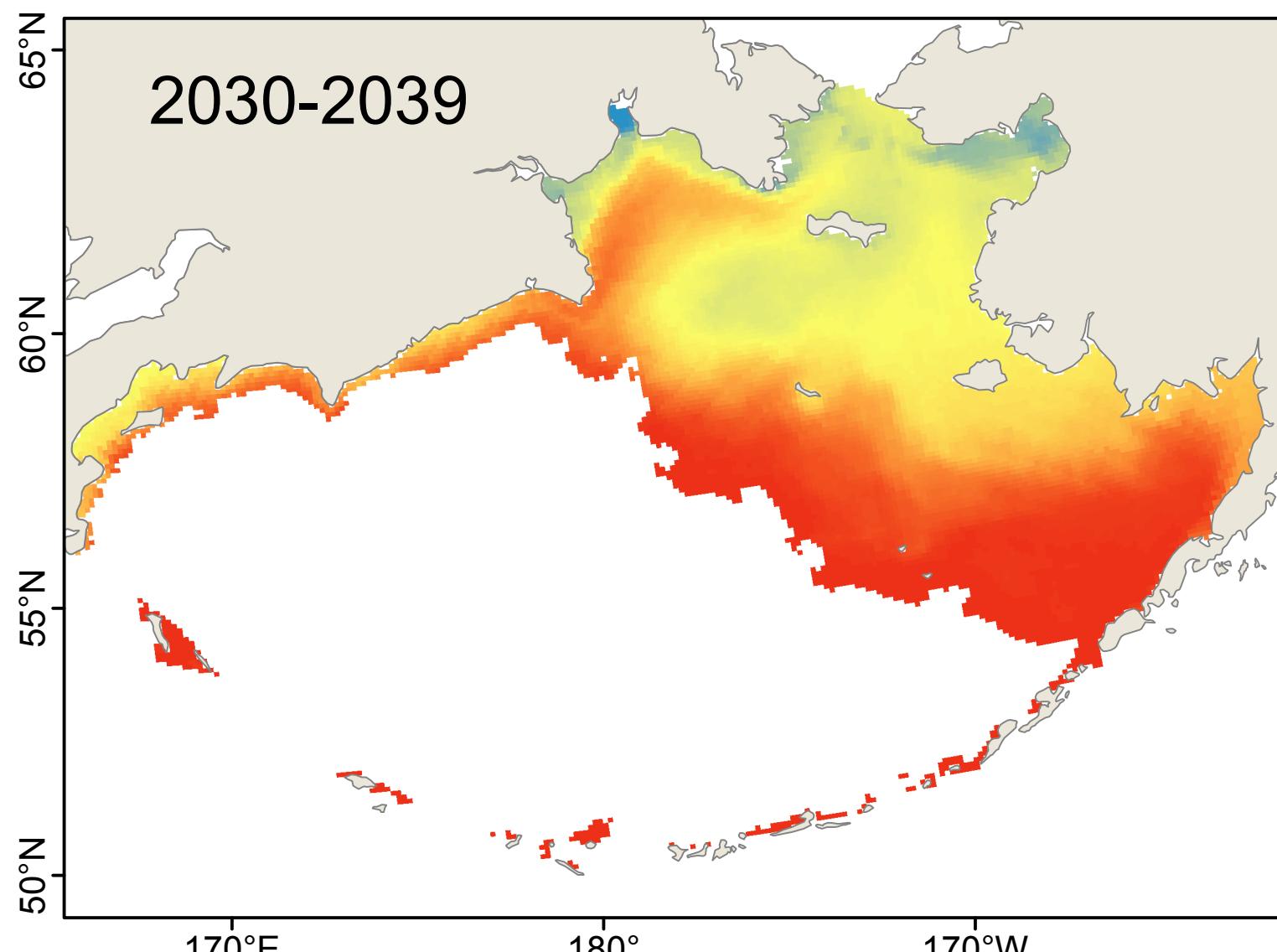
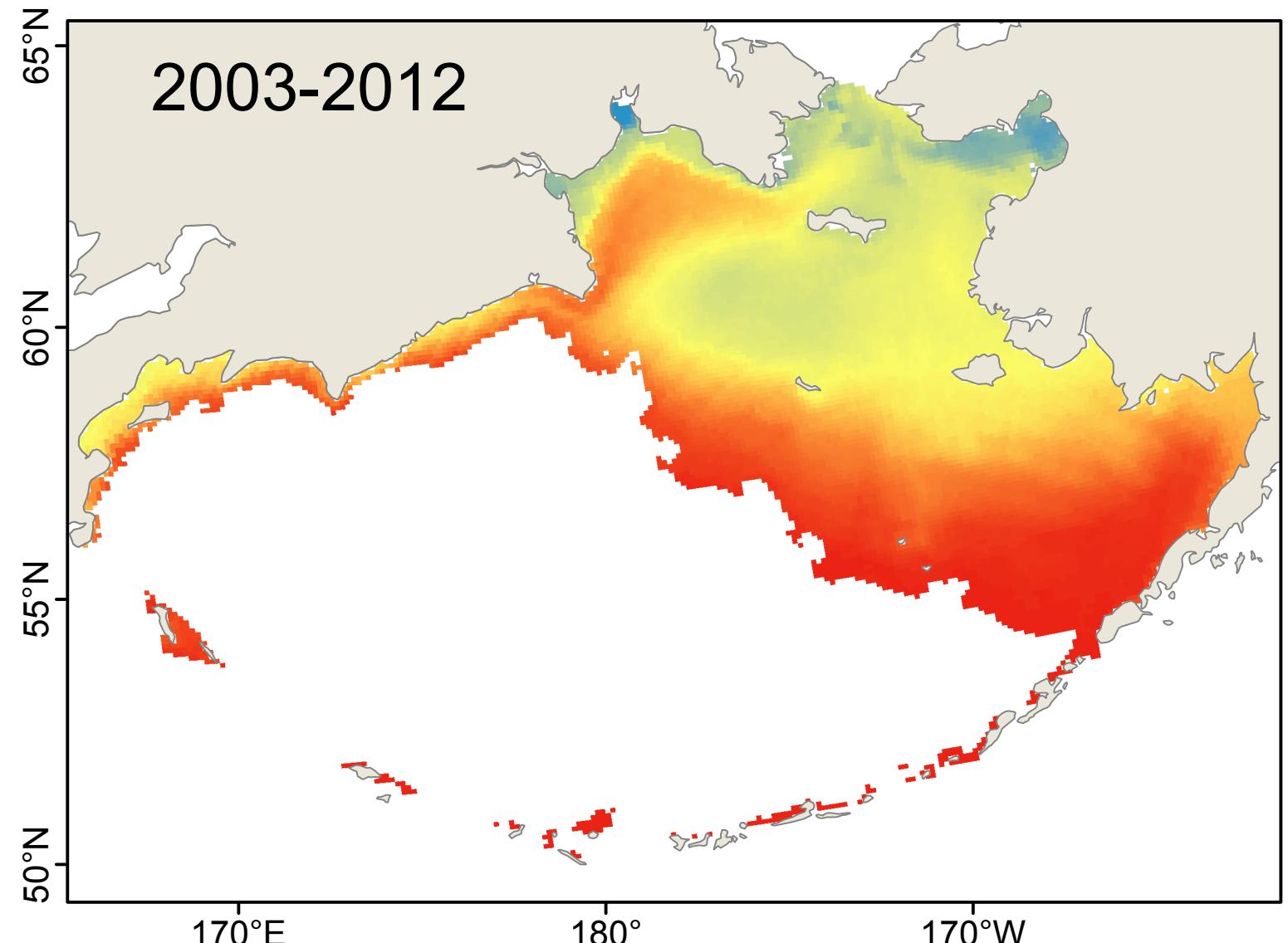
Average number of weeks of suitable habitat



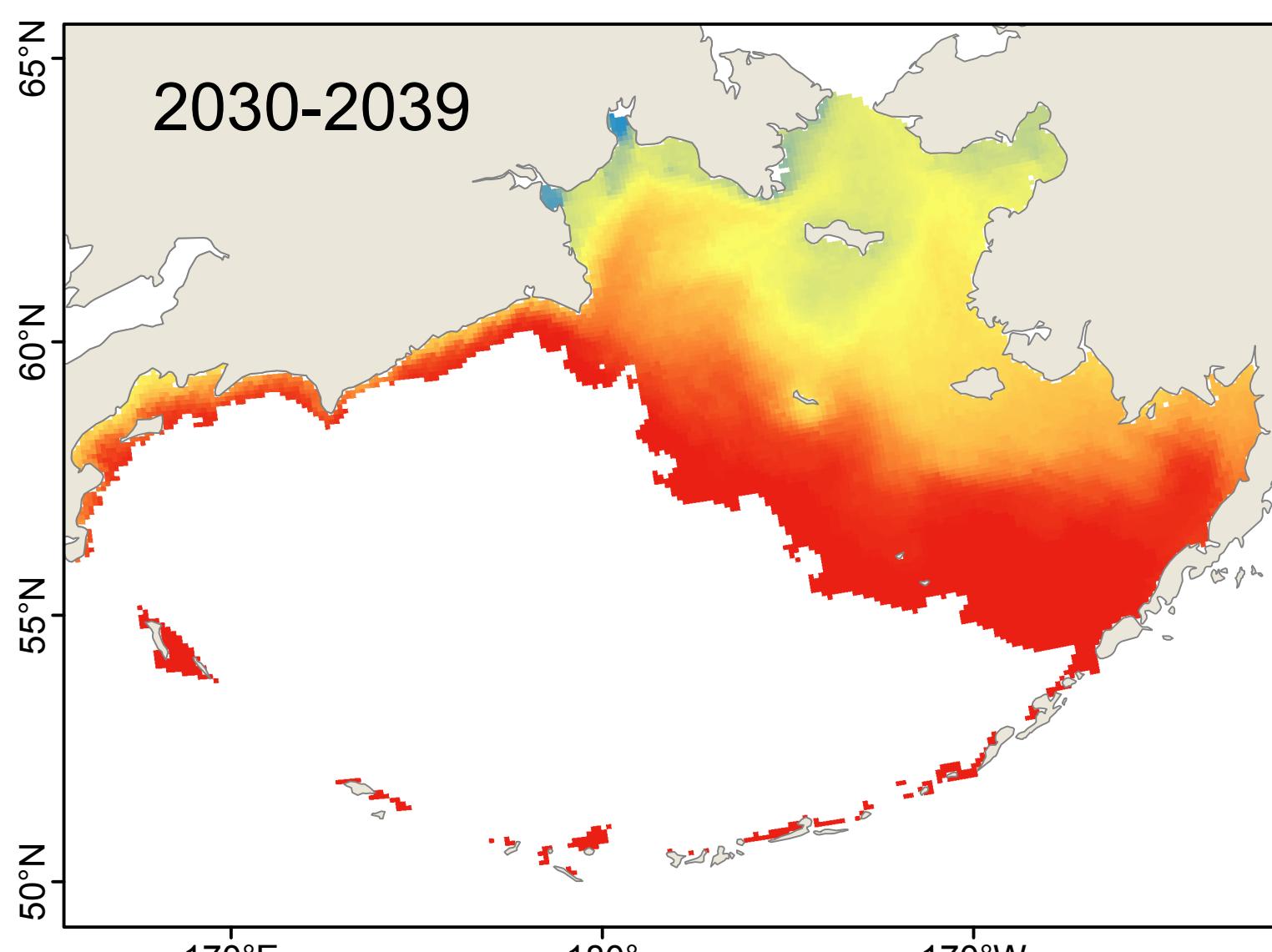
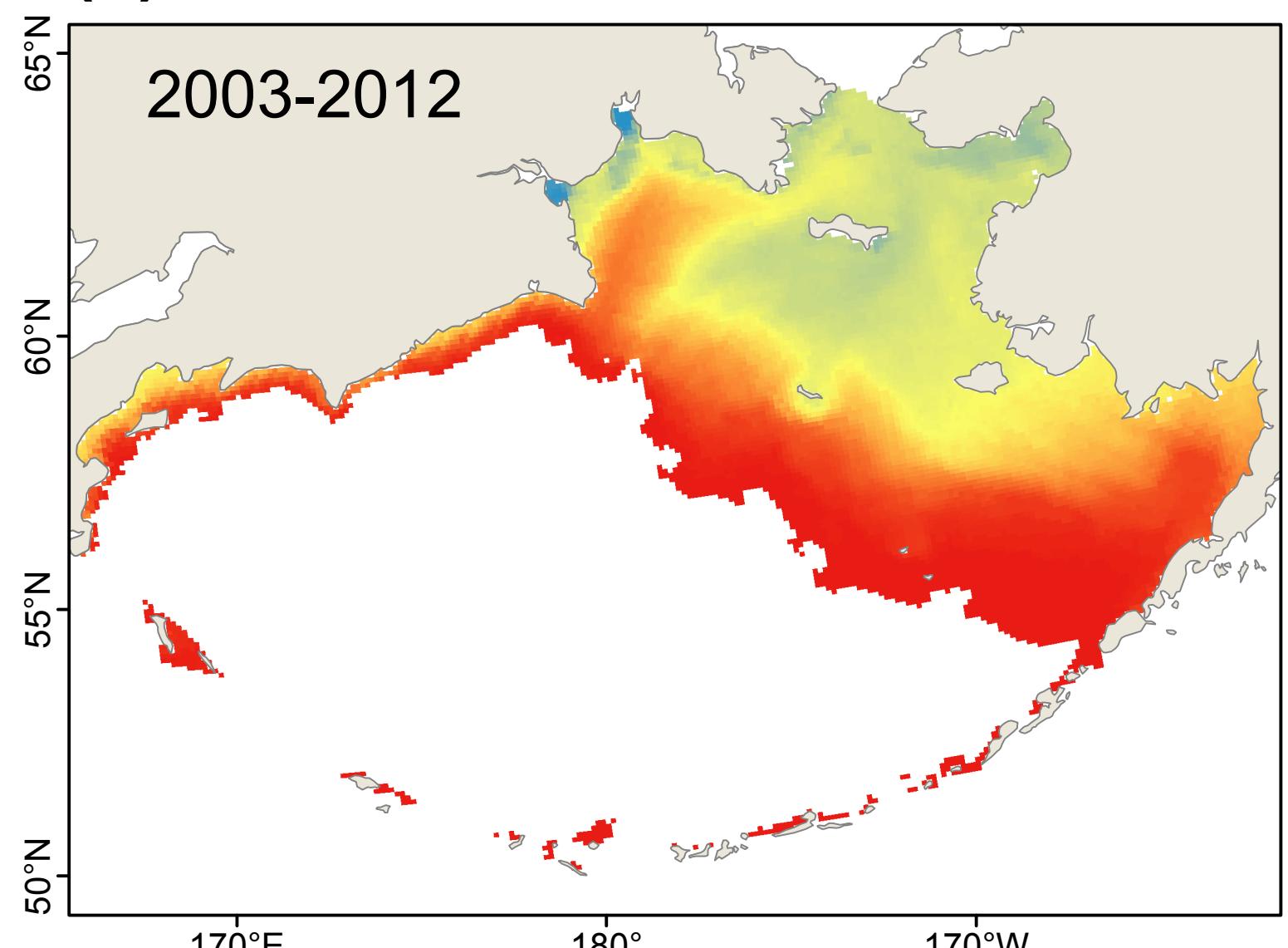
(a) Model: CGCM3-t47



(b) Model: ECHO-G

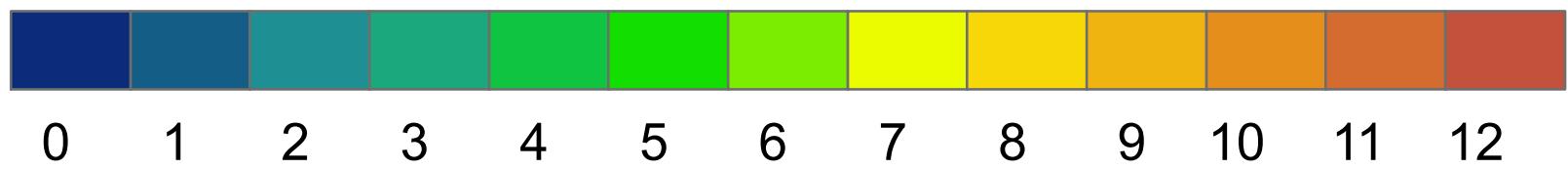


(c) Model: MIROC3.2

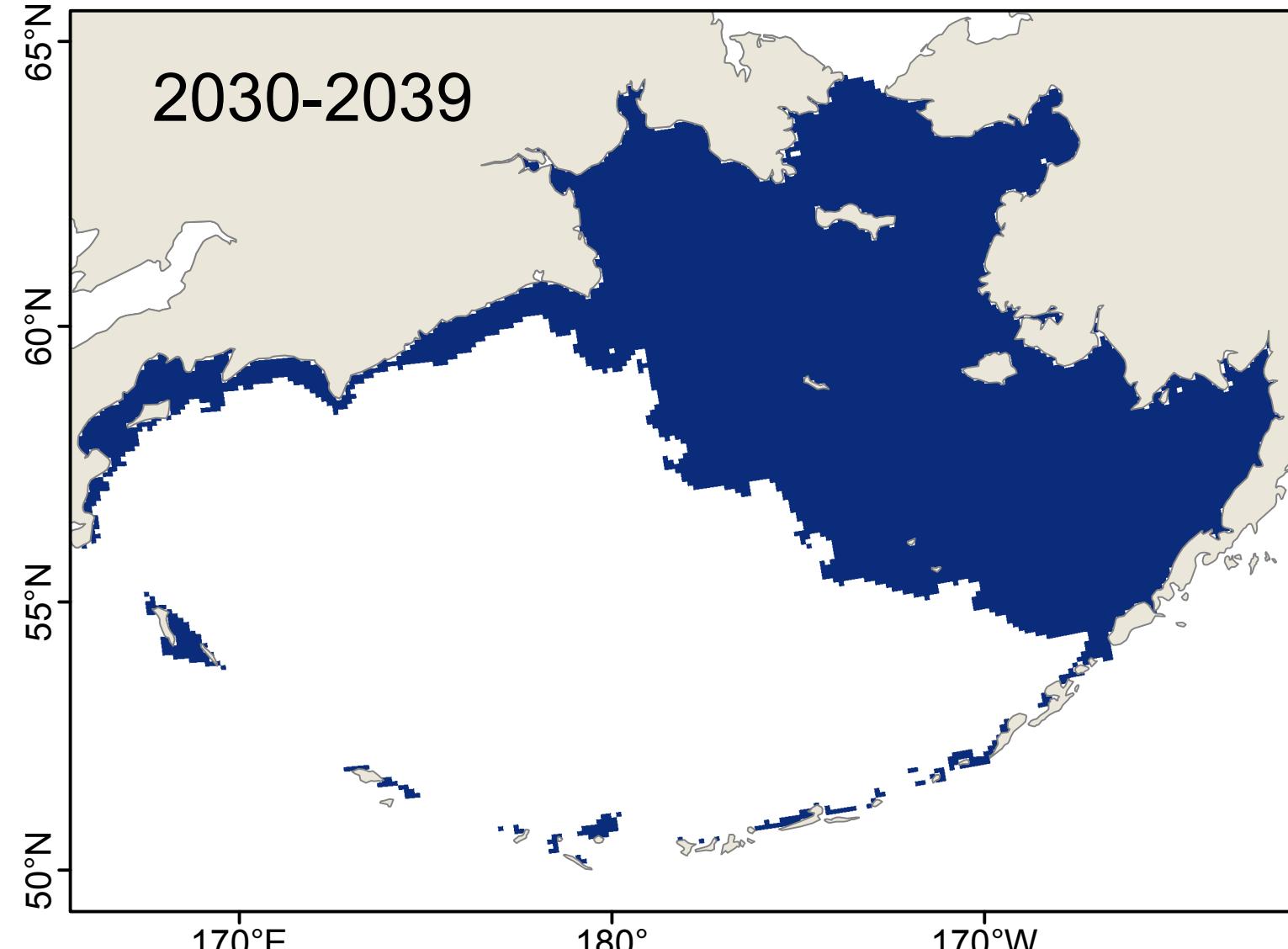
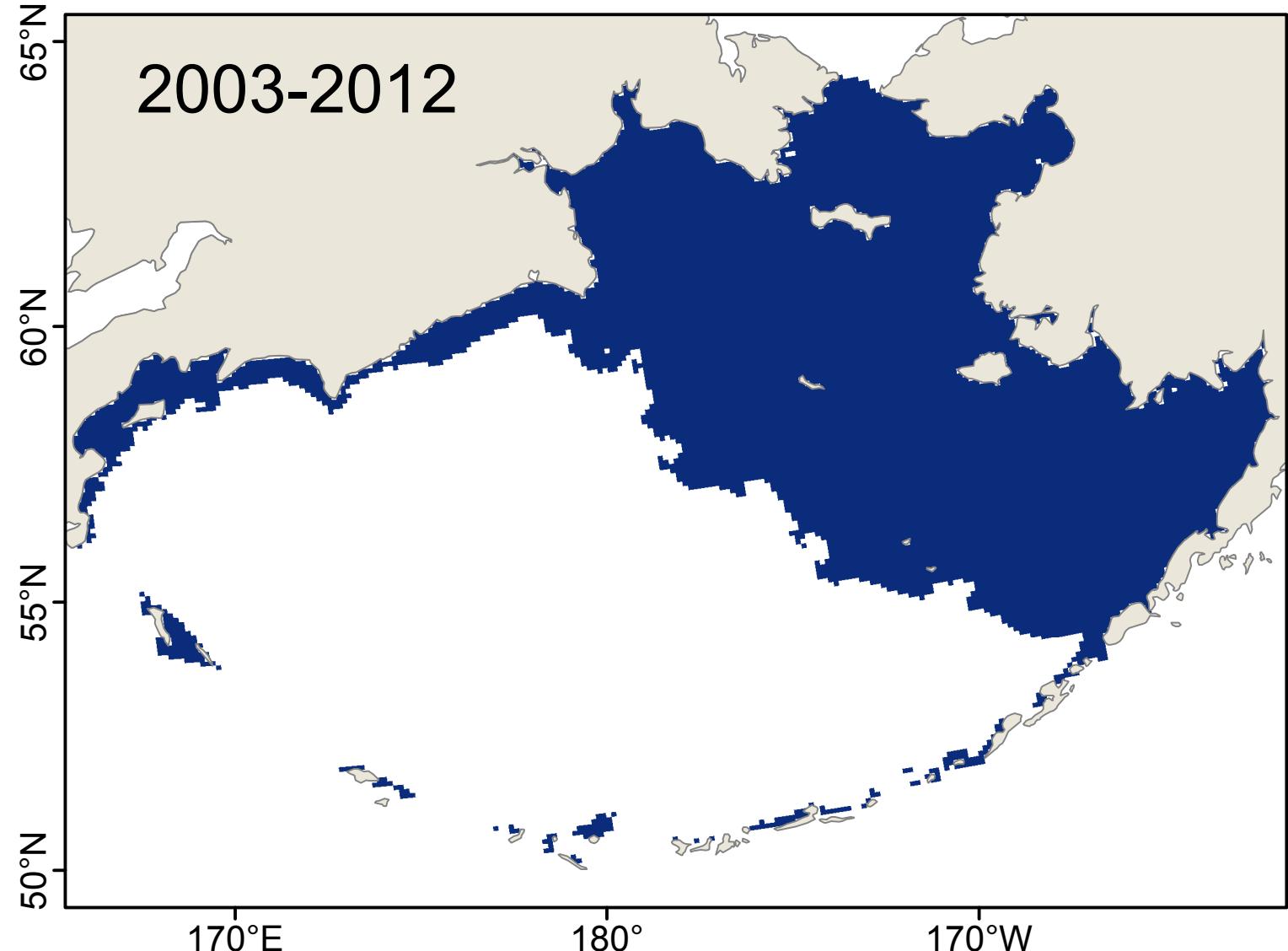


# *Ilyanassa obsoleta: Reproduction*

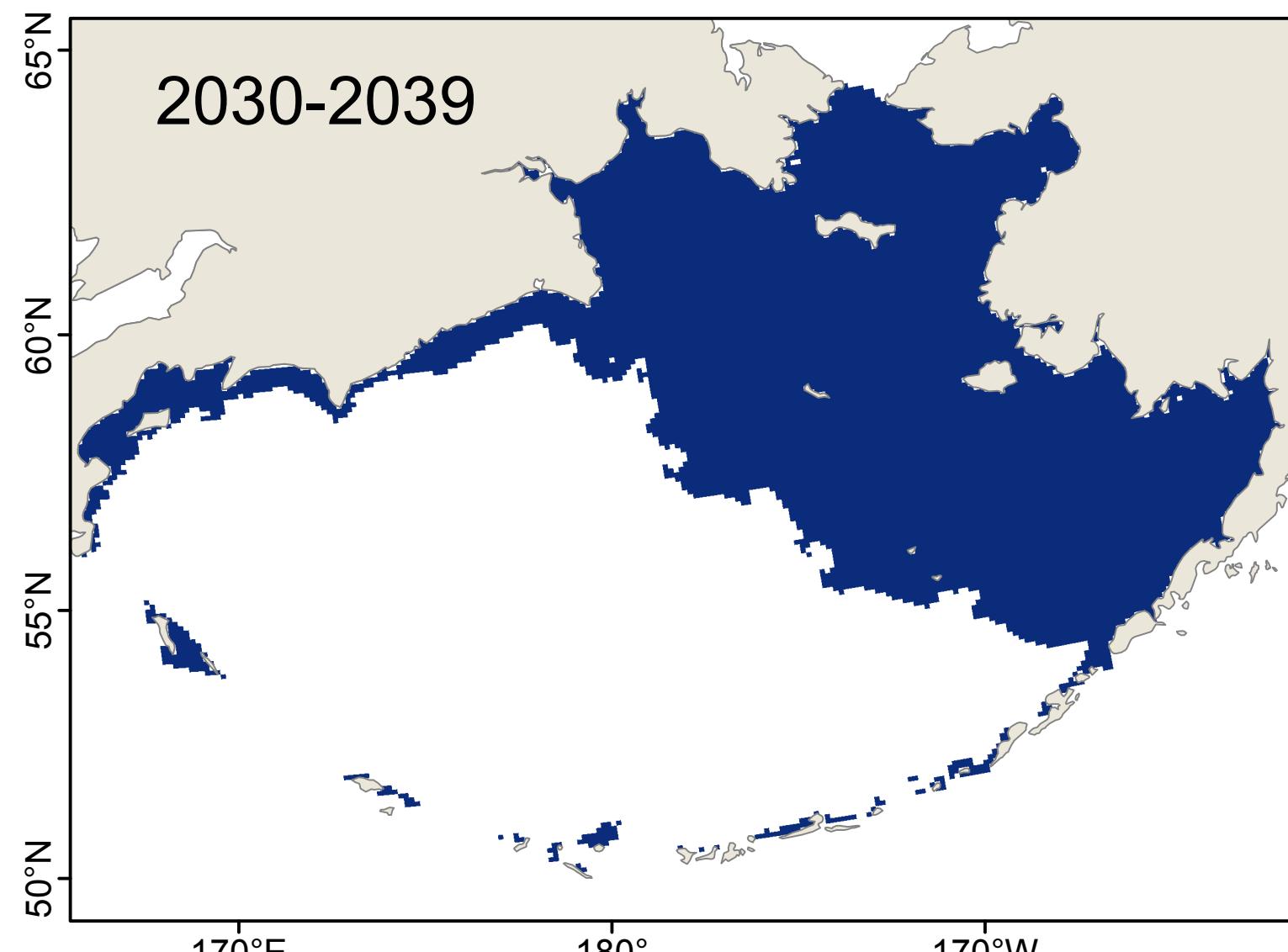
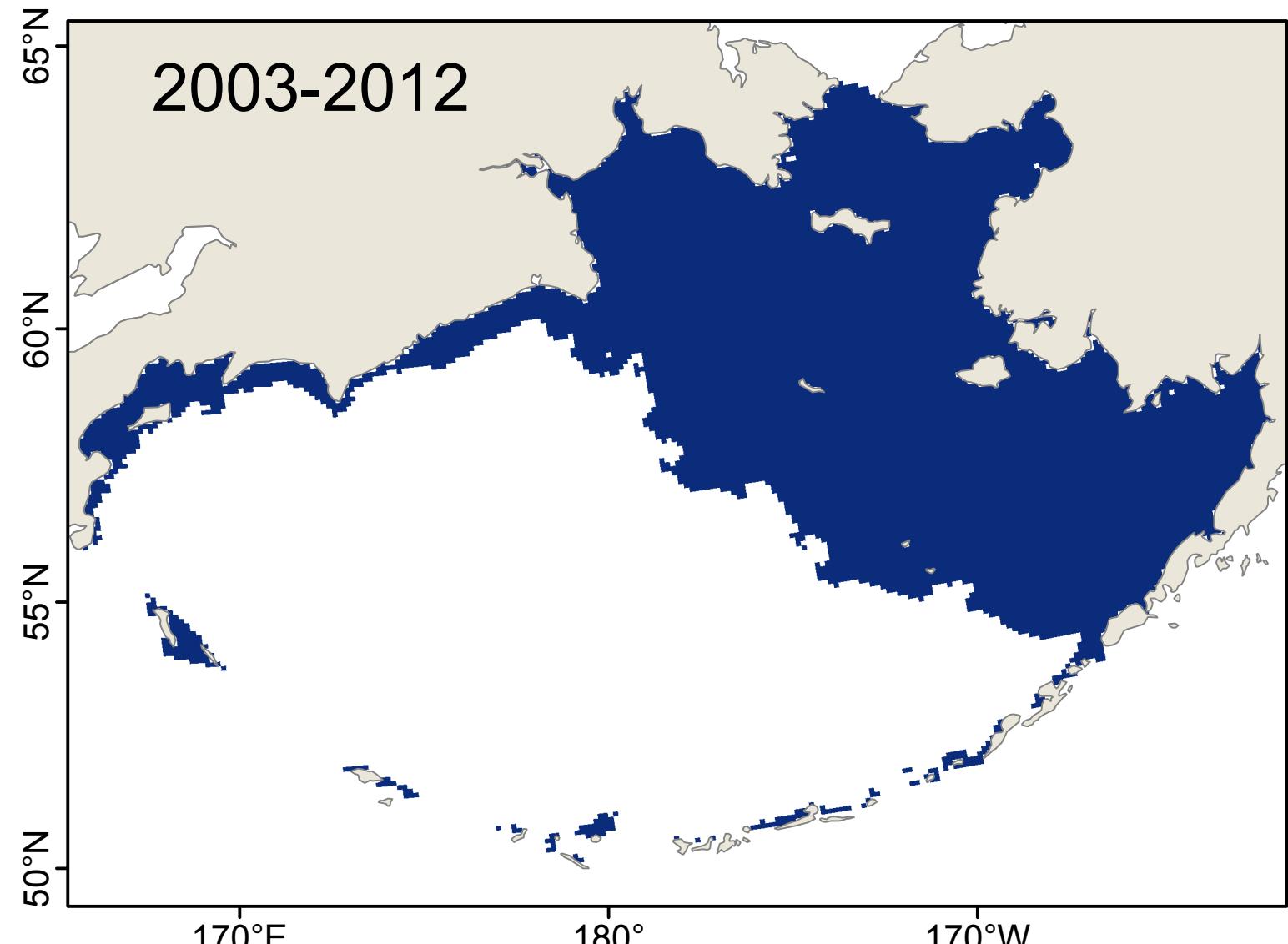
Average number of consecutive weeks of suitable habitat



(a) Model: CGCM3-t47



(b) Model: ECHO-G



(c) Model: MIROC3.2

