Model-Based Essential Fish Habitat Descriptions for Fish Resources of the Arctic Management Area

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EFH Descriptions and Identification

EFH Component 1 is descriptions and identification (maps)

- Fishery Management Plan (FMP) text and maps
- Maps based on species distribution models (SDMs) were established in the 2017 Review and refined for 2023 Review for the groundfish and crab FMPs.
- SDM maps are new for the Arctic FMP in the 2023 Review.

EFH Component 1 information levels

- Level 1: Distribution data are available for some or all portions of the geographic range of the species.
- Level 2: Habitat-related densities or relative abundance of the species are available.
- Level 3: Growth, reproduction, or survival rates within habitats are available.
- Level 4: Production rates by habitat are available. [Not available at this time]

New and revised EFH descriptions and maps for the 2023 Review

- Arctic FMP EFH Level 1 **expanded** and EFH Level 3 **new**.
- Model-based EFH for the Arctic FMP Marsh et al. In Review

Arctic Fishery Management Plan (2009)

- Prohibits commercial fishing until data indicates a sustainable fishery can be supported.

- Three species were identified as potential commercial stocks, Arctic cod, saffron cod and snow crab:

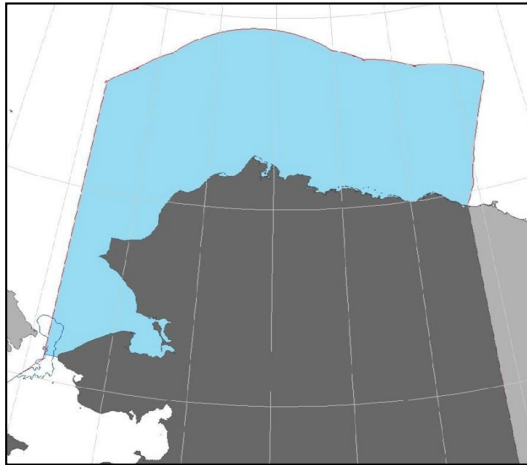 - Preliminary stock assessments
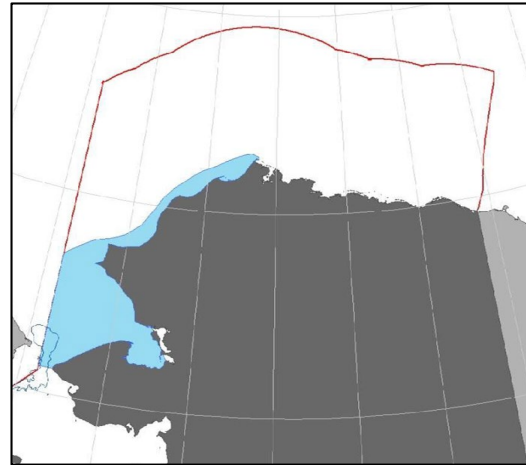 - EFH described and mapped

Arctic Management Area
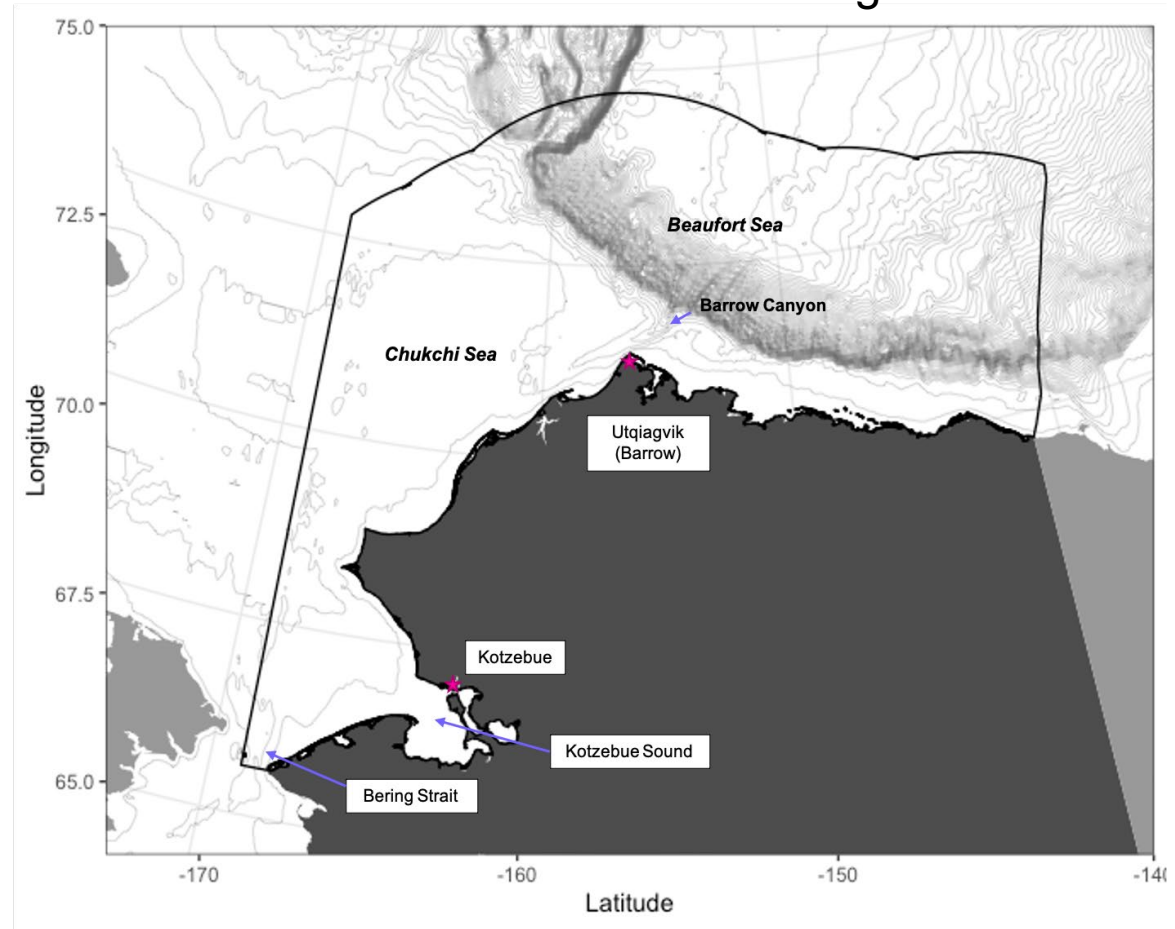
2017 EFH Review

Arctic cod

- Benthic, pelagic and epipelagic waters along entire shelf and upper slope (0-500 m depth)
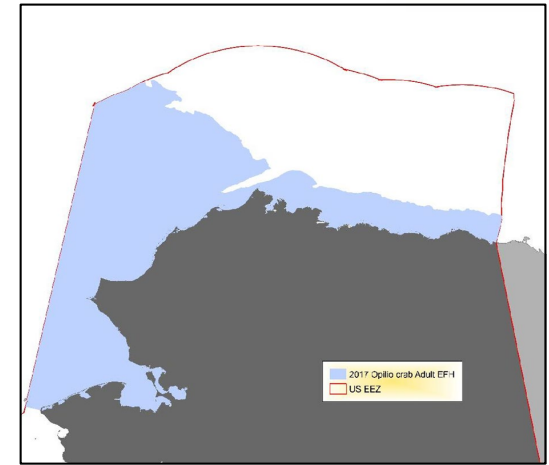- Ice associated

Saffron cod

- Pelagic and epipelagic waters along the coastline (0-50 m depth)
- Substrate(s): sand and gravel

Snow crab

- Epibenthic on the inner and middle shelf (0-100 m depth)
- Substrate: mostly mud

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Model-based EFH Update for Arctic Species Life Stages

First SDM EFH maps for Arctic FMP species
- 13 EFH Level 1 maps (distribution),

Species	Larvae	Early Juvenile	Late Juvenile	Adult
Arctic cod (Length, mm)	< 30	31 – 70 (age-0)	71 – 120	> 120
Saffron cod (Length, mm)	< 27	28 – 70 (age-0)	71 – 190	> 190
Snow crab (Carapace width, mm)	--	< 34 (immature)	35 – 61 (adolescent male) 35 – 46 (adolescent female)	> 62 (mature male) > 46 (mature female)

- 3 EFH Level 3 maps (habitat related vital rates), and
- EFH area comparisons between warm and cold conditions as a first approach to climate-informed EFH mapping.

Species Occurrence Data

- Combined multiple independent surveys using different gear types.

- Arctic study area is difficult to sample; remote, seasonally ice-covered.

- No historic, systematic surveys.

- Species occurrence data from summer months (July –September) for years 2000 – 2018.

Marsh et al. Arctic EFH Maps, section 2.2, page 10
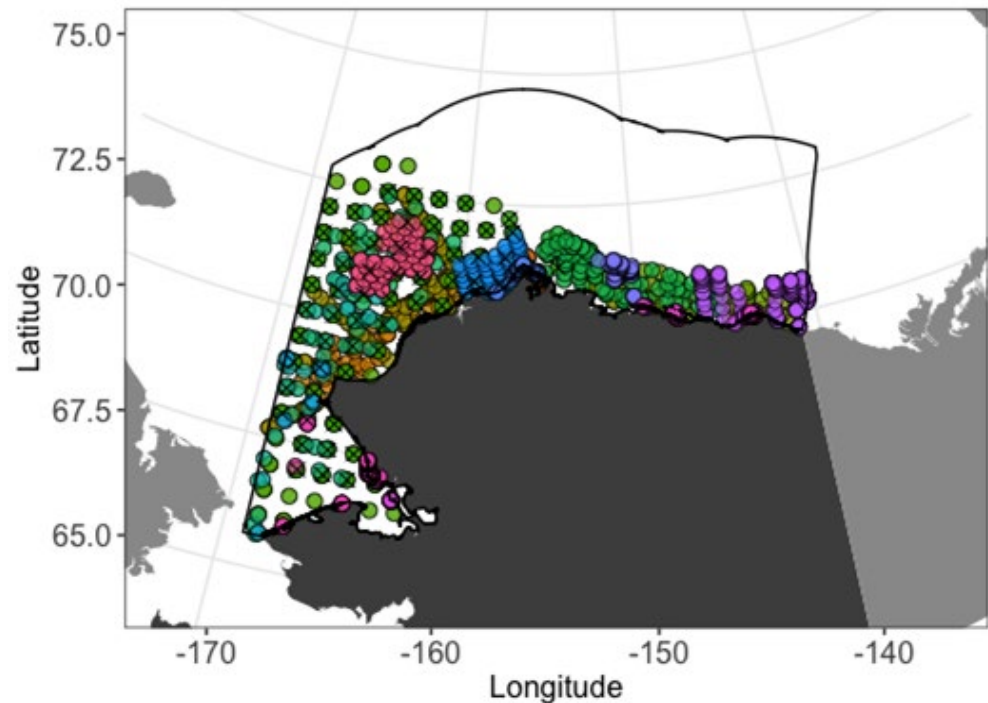
ABLNearshoreTask_Arctic	ANIMIDA_2014	OD0710	SHELFZ13	VonBiela_Arctic
ACES	ANIMIDA_2015	OS180	SYNTHESIS	WCS_ABLP
AFF2015	ArcticEis_2012	OS190	TB_2012	WWW0902
AKCH10	ArcticIES17	RUSALCA_2004	TB_2013	WWW0904
AKCH11	Beau08	RUSALCA_2009	TB_2014	WWW1003
AMBON_2015	BOEM_2011	RUSALCA_2012	USACE_Kaktovik	
AMBON17	COMIDA_2009	SHELFZ	USACE_Kotzebue	

Overview SDM EFH Mapping Methods

- Maximum Entropy (MaxEnt) models with presence-only data
  - To combine multiple surveys and gear types in a first approach to link habitat characteristics of the study area to species distribution.
  - Methods were co-developed with Laman et al. 2023 Gulf of Alaska groundfish early juvenile life stage EFH Level 1 SDM maps.

- Model Performance Metrics:
  - k-fold cross validation, Beta (L1 regularization multiplier), AUC

- Model Selection Metric:
  - AIC

- EFH Level 1 Maps of Habitat-related Distribution:
  - All locations for a species' life stage with probability of suitable habitat ≥ 5%.

- EFH Level 3 Maps of Habitat-related Vital Rates:
  - Growth rates (Laurel et al. 2016; 2017).
  - Product of temperature-dependent growth potential and probability of suitable habitat.

- Climate-informed EFH Level 1 Maps
  - EFH mapped separately for warm and cold years

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Habitat Covariates

Temporally **dynamic** and **static** covariates:

- Pacific Arctic ROMS (Danielson and Hedstrom)
- Mean of summer values from 2000 – 2018
- Bathymetry (Lewis)
- Sediment (Jenkins)

Marsh et al. Arctic EFH Maps, section 2.3, page 11
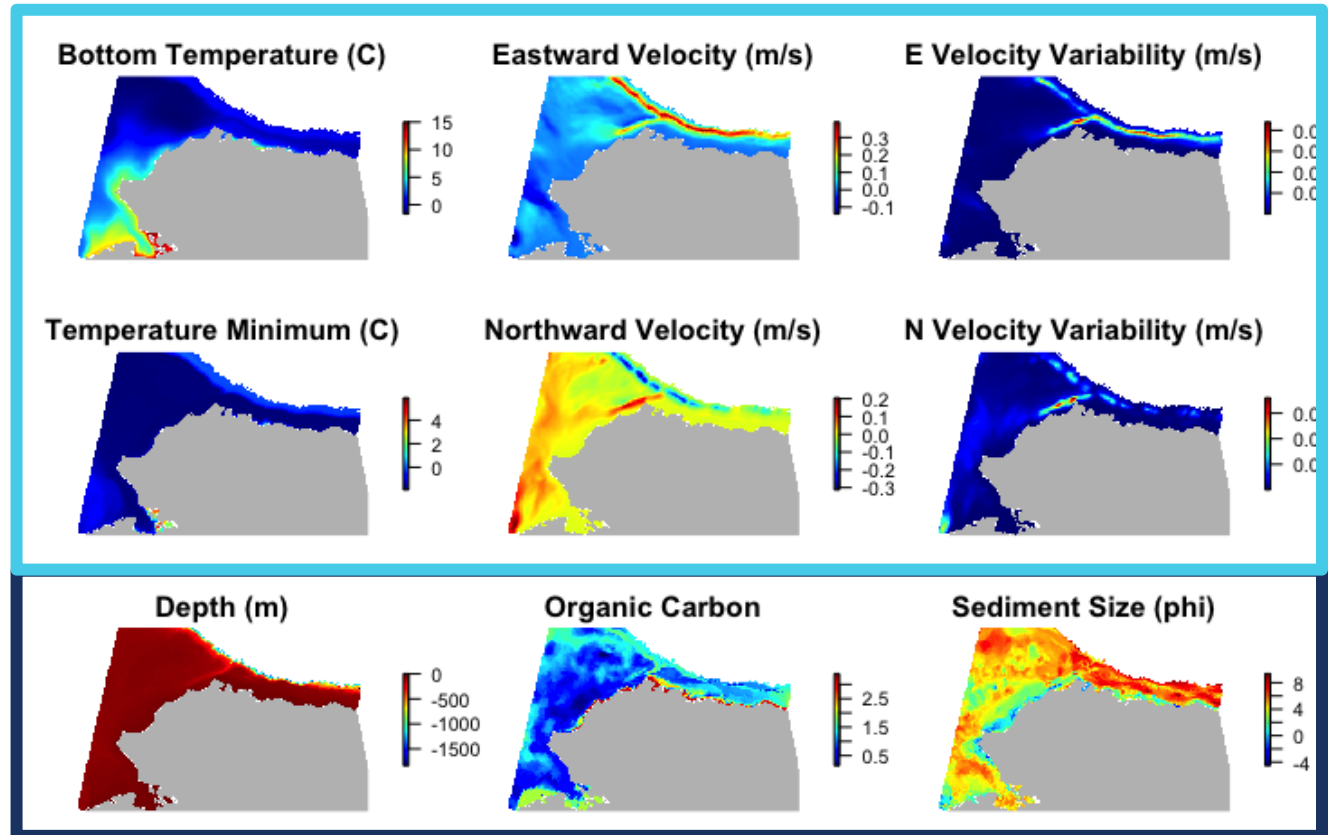
Surface Habitat Covariates
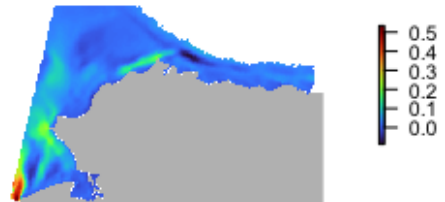
Surface Temperature (C)
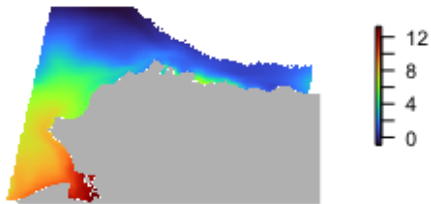
Eastward Velocity (m/s)
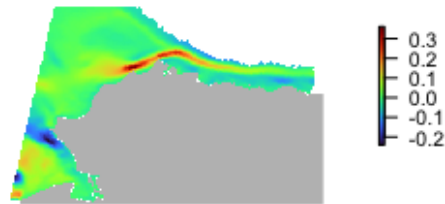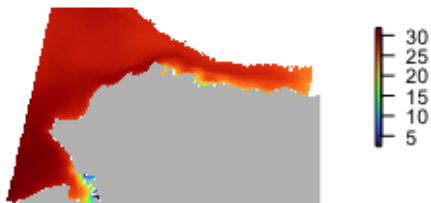
E Velocity Variability
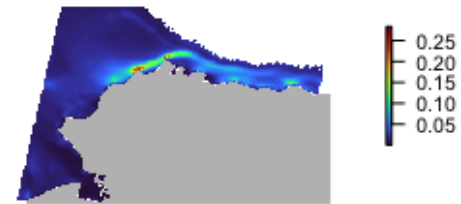
Temperature Minimum (C)

Northward Velocity (m/s)

N Velocity Variability

Surface Salinity

Depth (m)
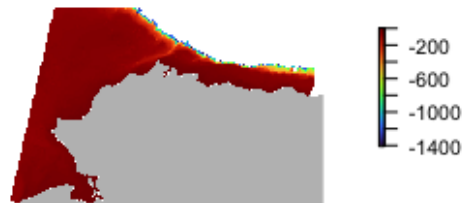
Pelagic life stages:
- Larval Arctic cod
- Age-0 Arctic cod
- Larval saffron cod

Marsh et al. Arctic EFH Maps, section 2.3, page 11

Occurrence Data for Arctic Cod and Saffron Cod

Marsh et al. Arctic EFH Maps, section 3.1, page 28
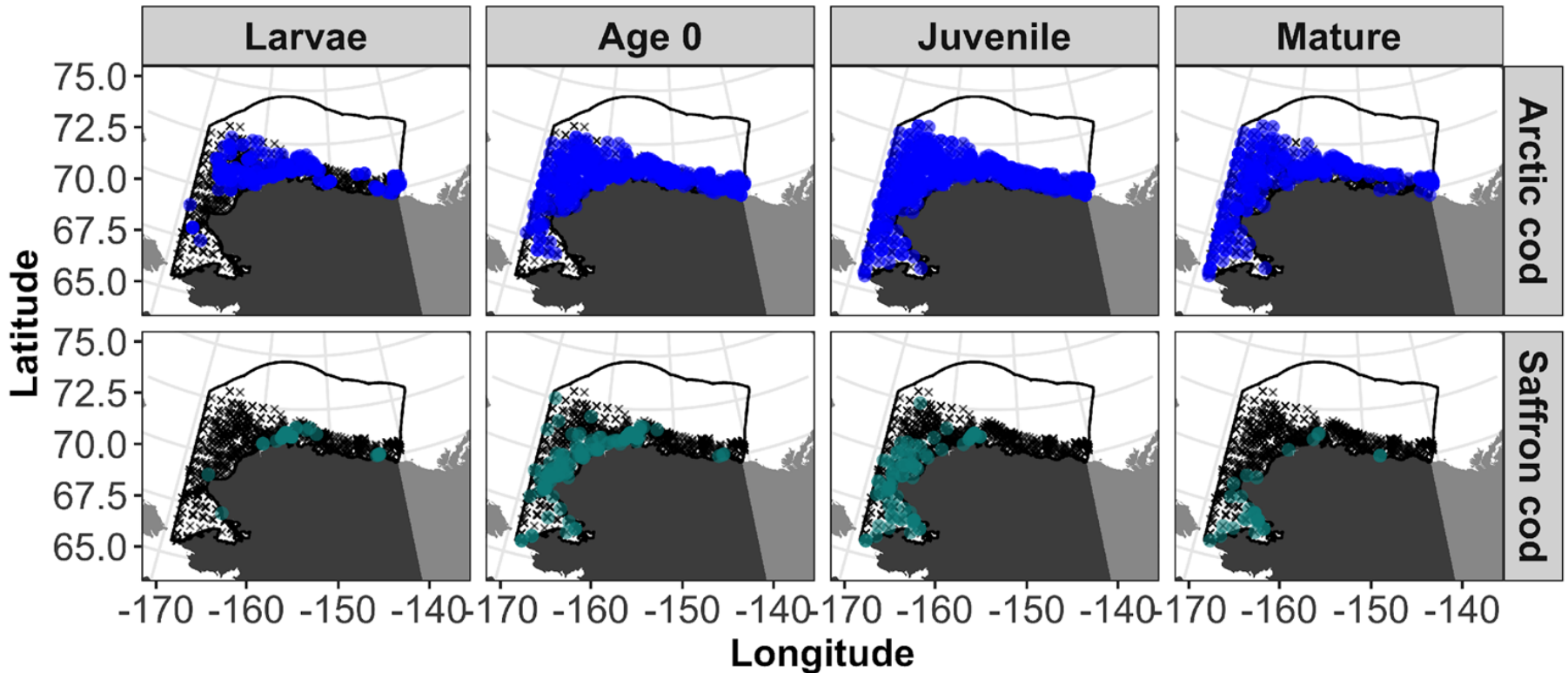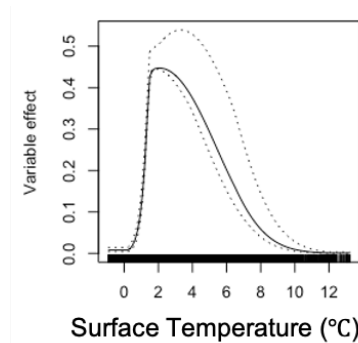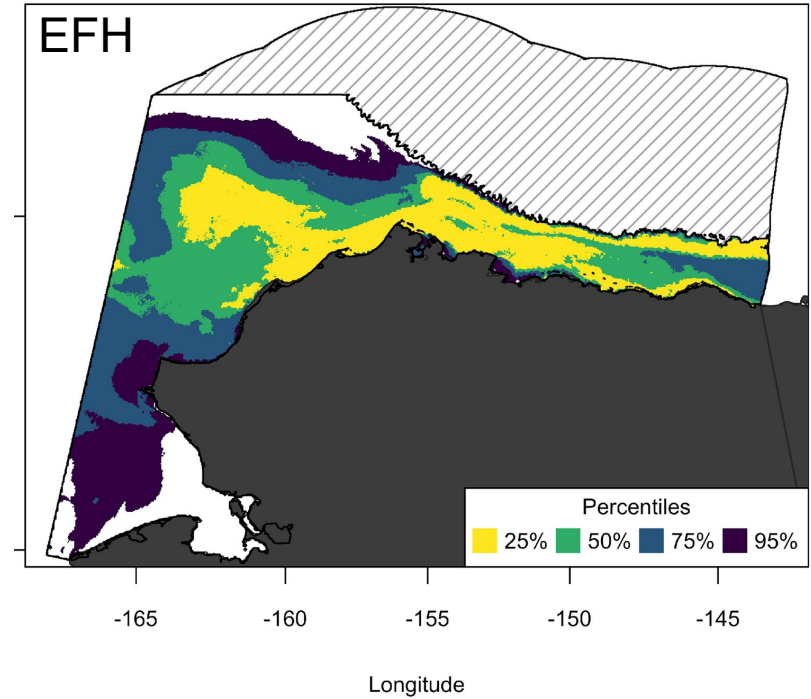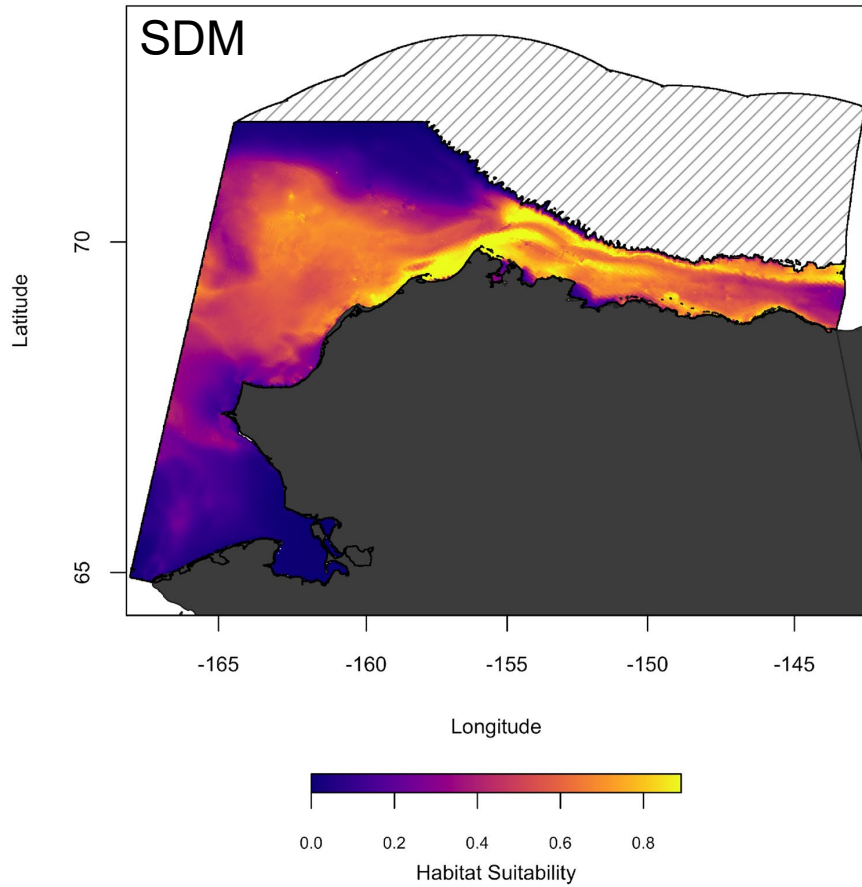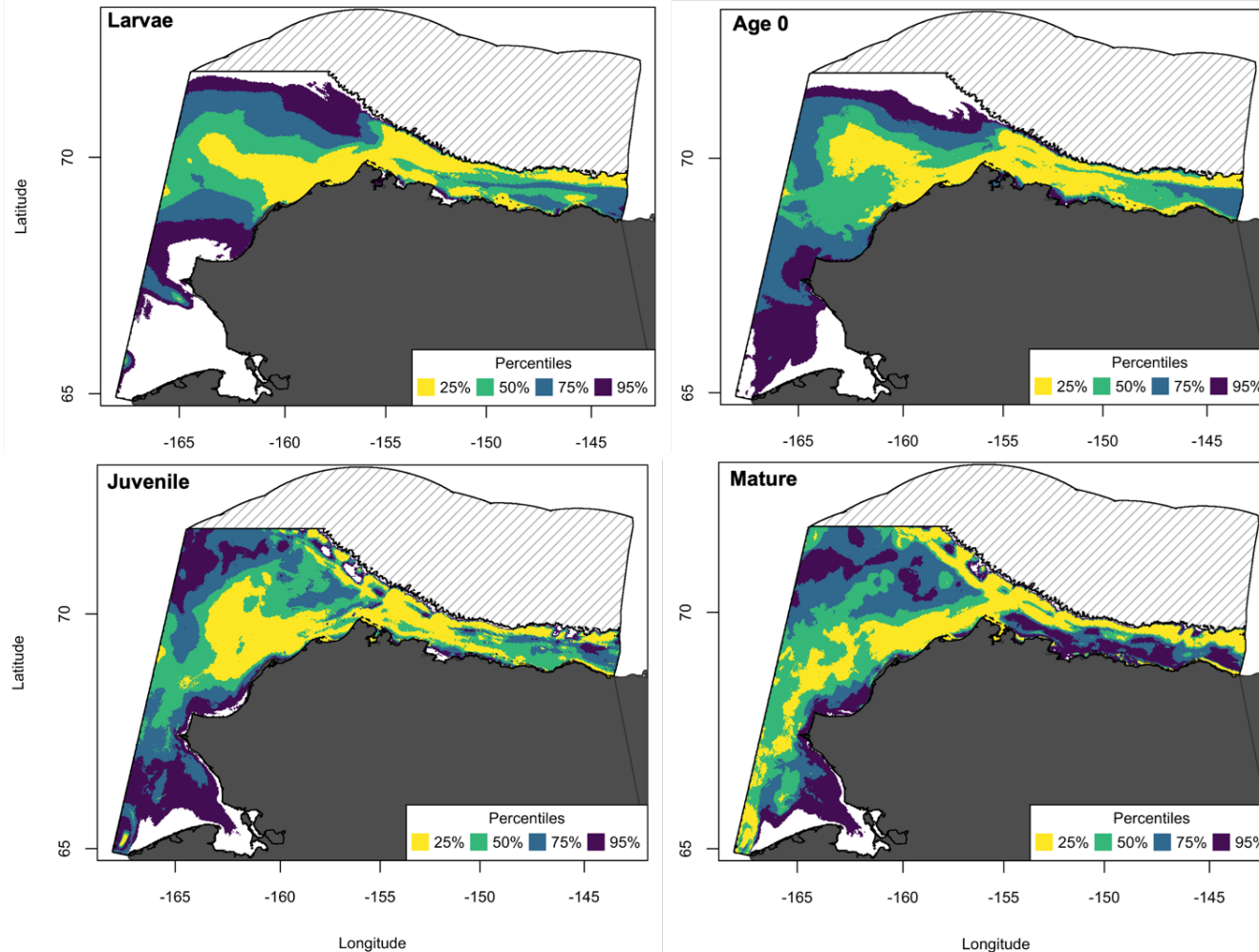
Age-0 Arctic Cod

Marsh et al. Arctic EFH Maps, section 3.1.2, page 24
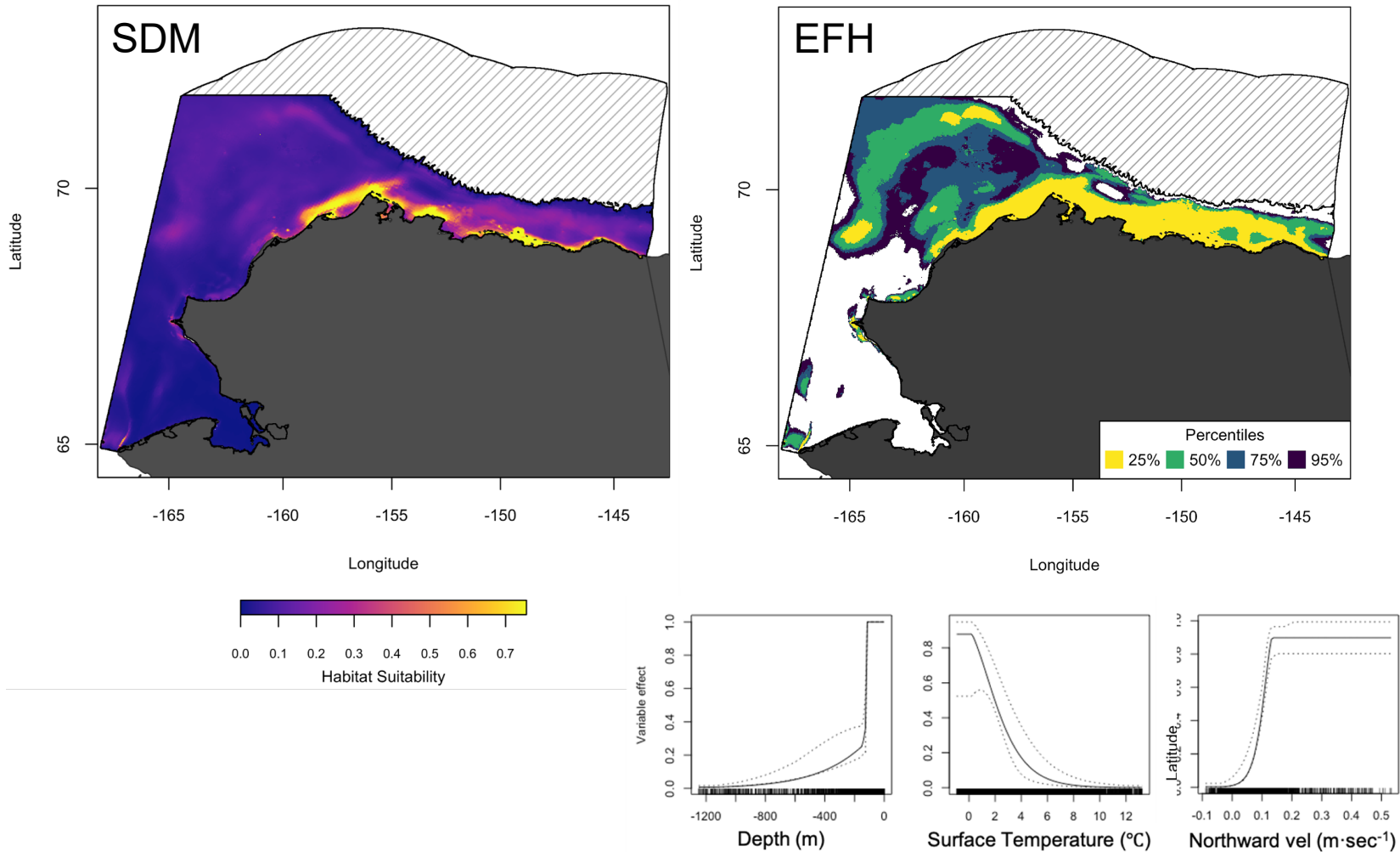
Mature Arctic Cod
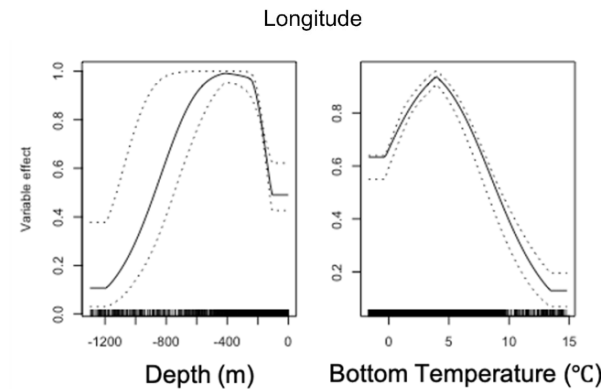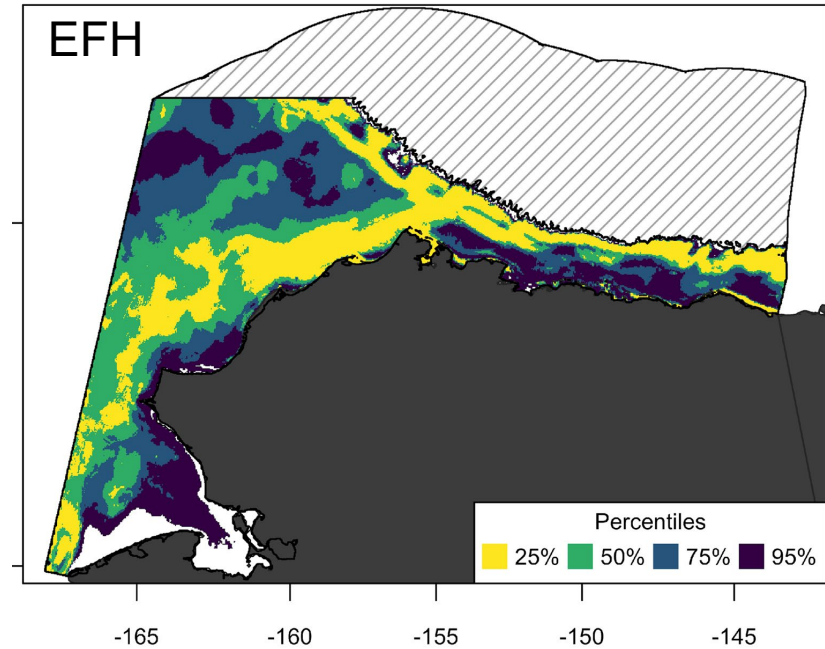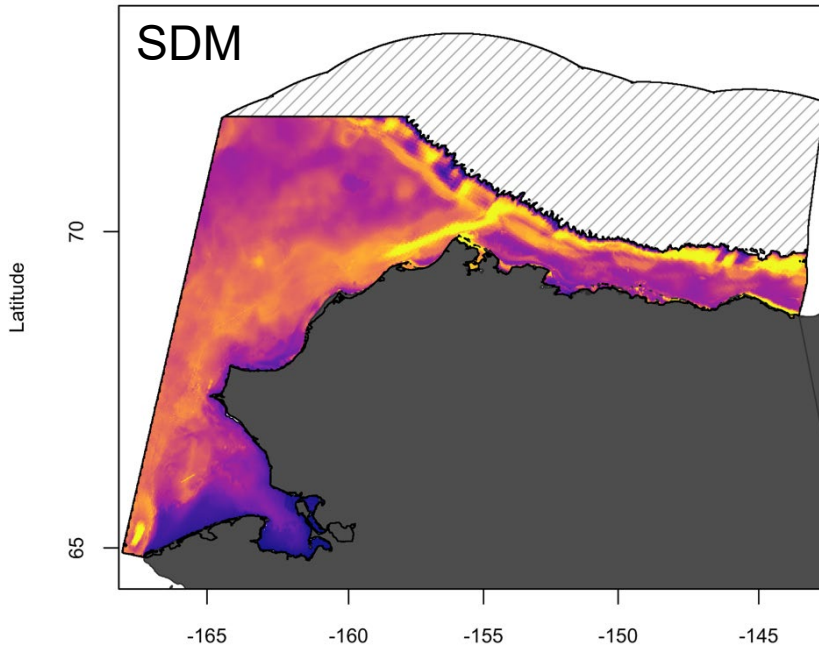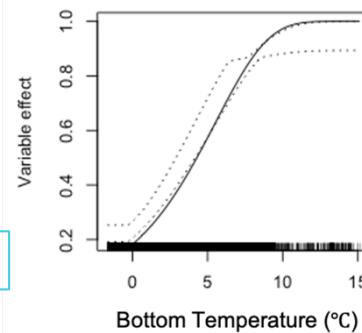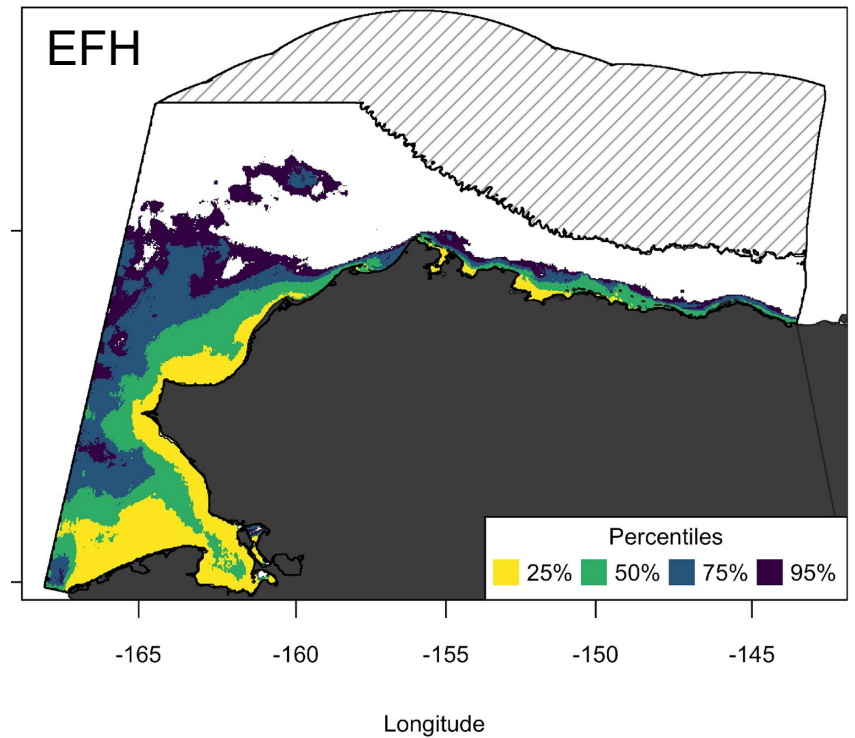

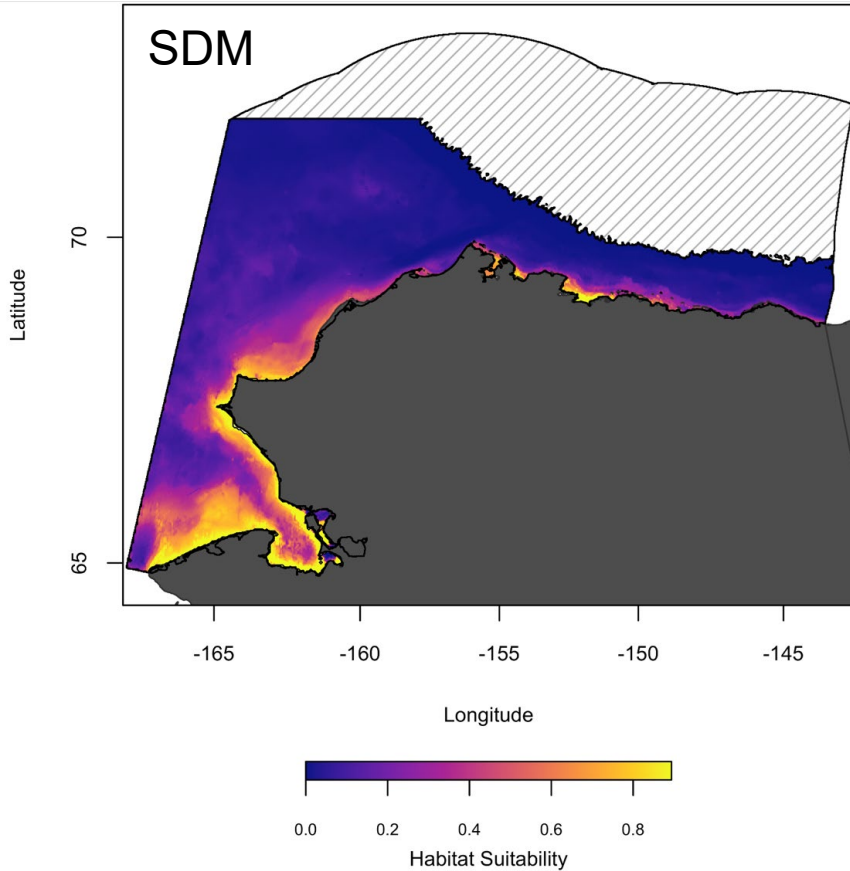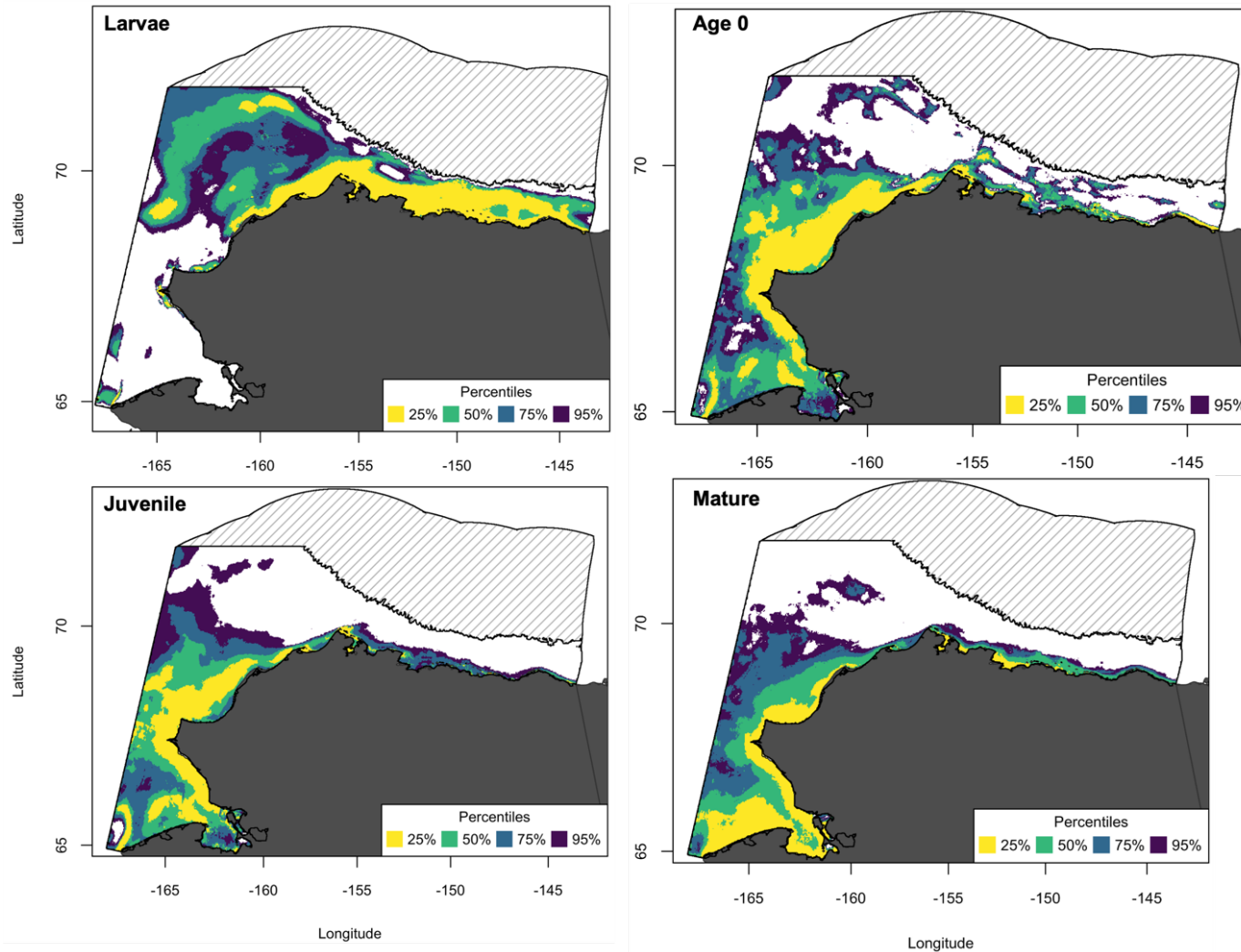Marsh et al. Arctic EFH Maps, section 3.1.4, page 25

Arctic Cod EFH Maps

Marsh et al. Arctic EFH Maps, section 3.1.5, page 25

Larval Saffron Cod

Marsh et al. Arctic EFH Maps, section 3.2.1, page 34

Mature Saffron Cod

Marsh et al. Arctic EFH Maps, section 3.2.4, page 35

Saffron Cod EFH Maps

Marsh et al. Arctic EFH Maps, section 3.2.5, page 35

Snow Crab Occurrence by Life Stage

Marsh et al. Arctic EFH Maps, section 3.3, page 45
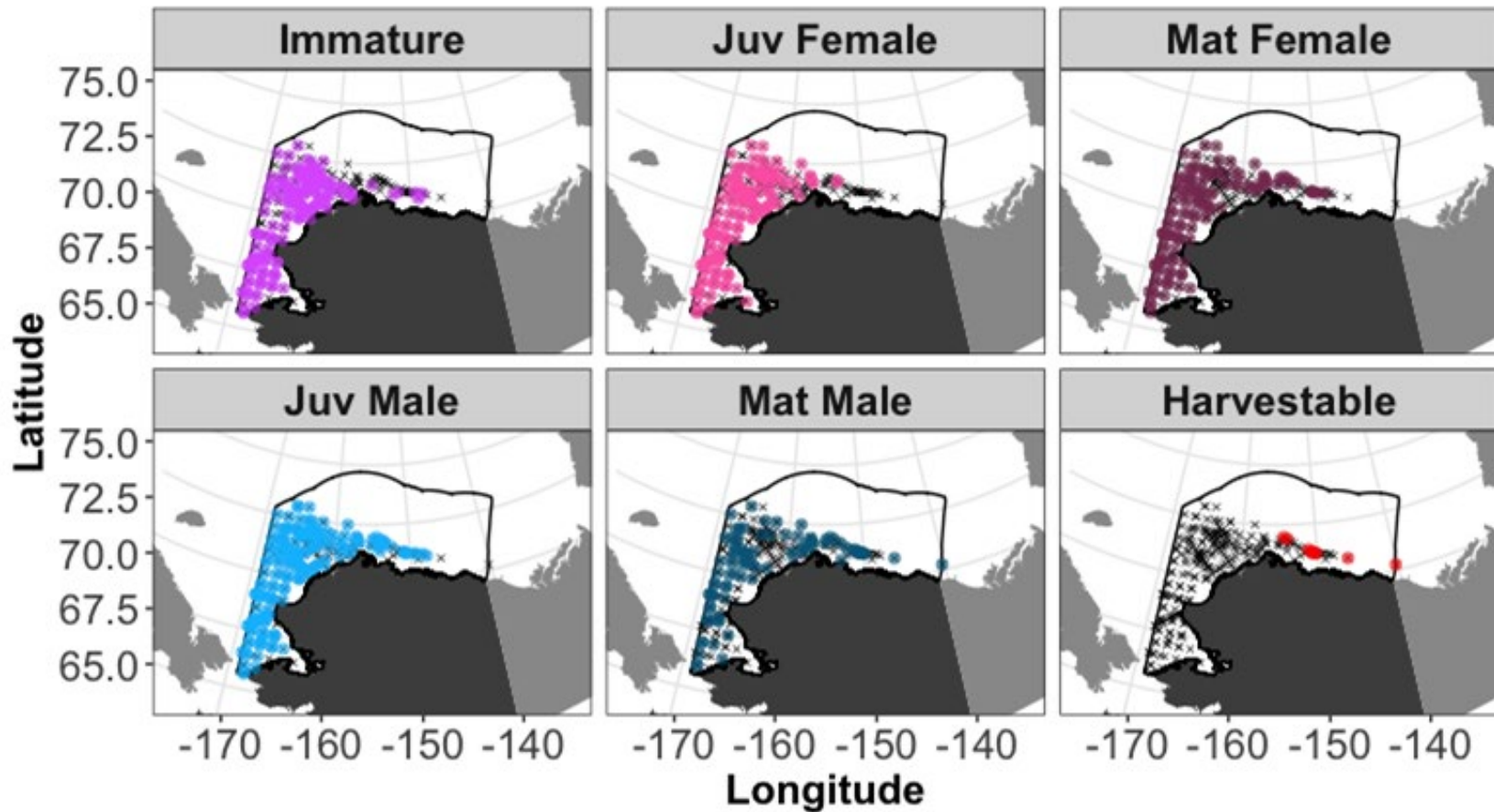
Immature Snow Crab (Males and Females)

SDM

EFH

Percentiles
25% 50% 75% 95%

Habitat Suitability
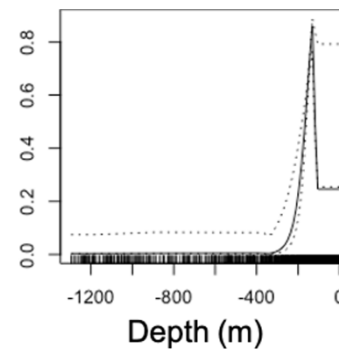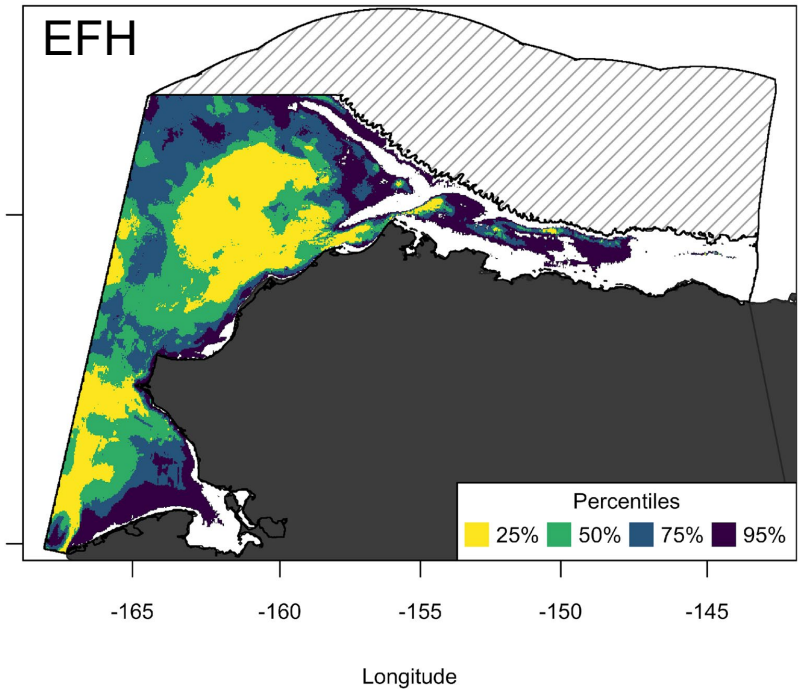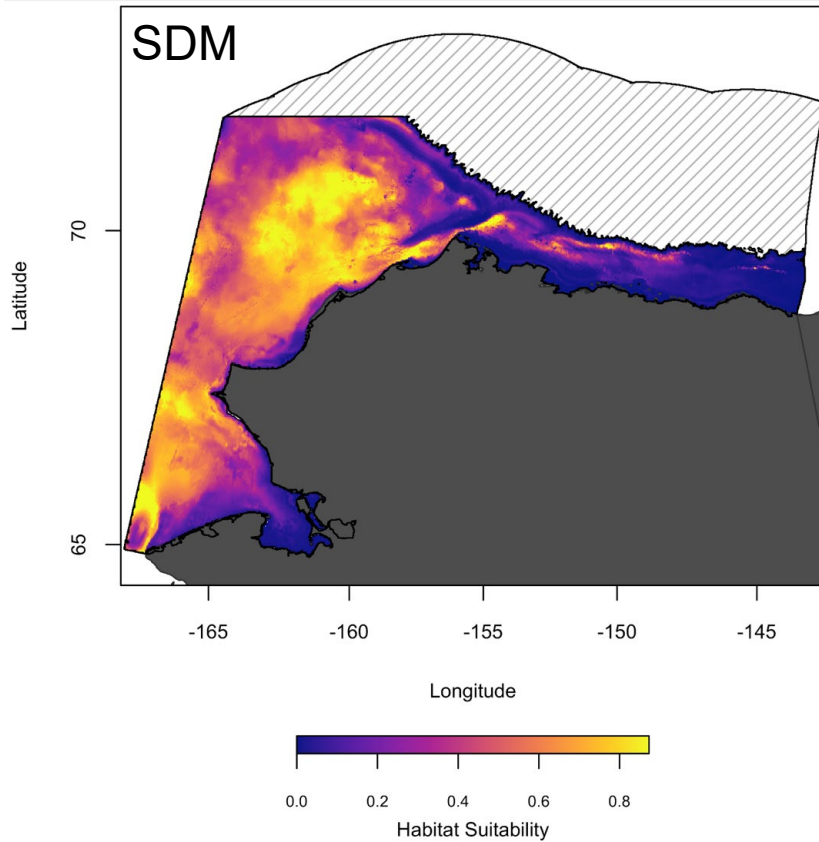
Narrow depth range
~ 100 – 250m.

Depth (m)

Marsh et al. Arctic EFH Maps, section 3.3.1, page 42

Mature Male Snow Crab

Marsh et al. Arctic EFH Maps, section 3.3.5, page 43
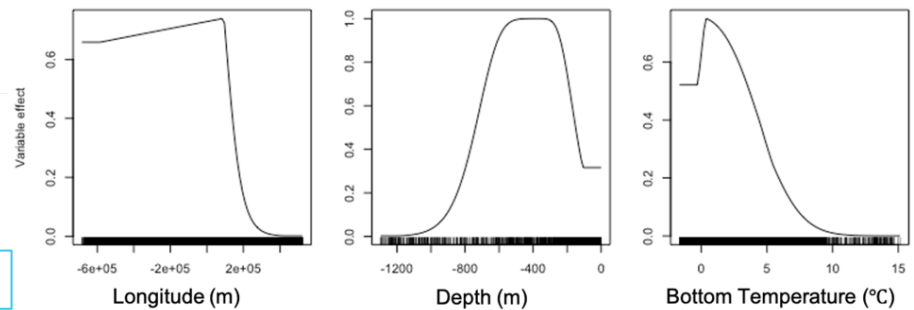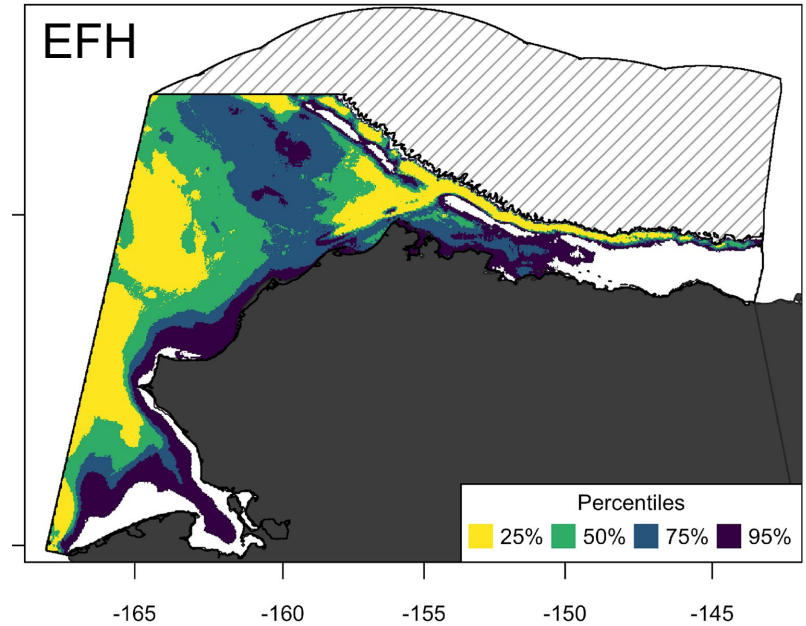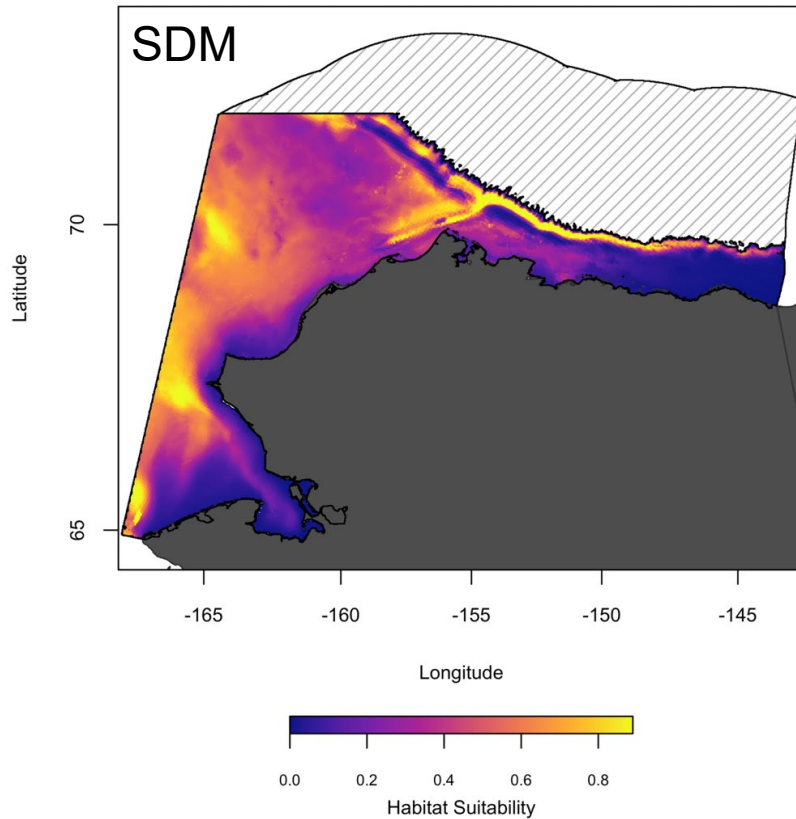
Snow Crab EFH Maps
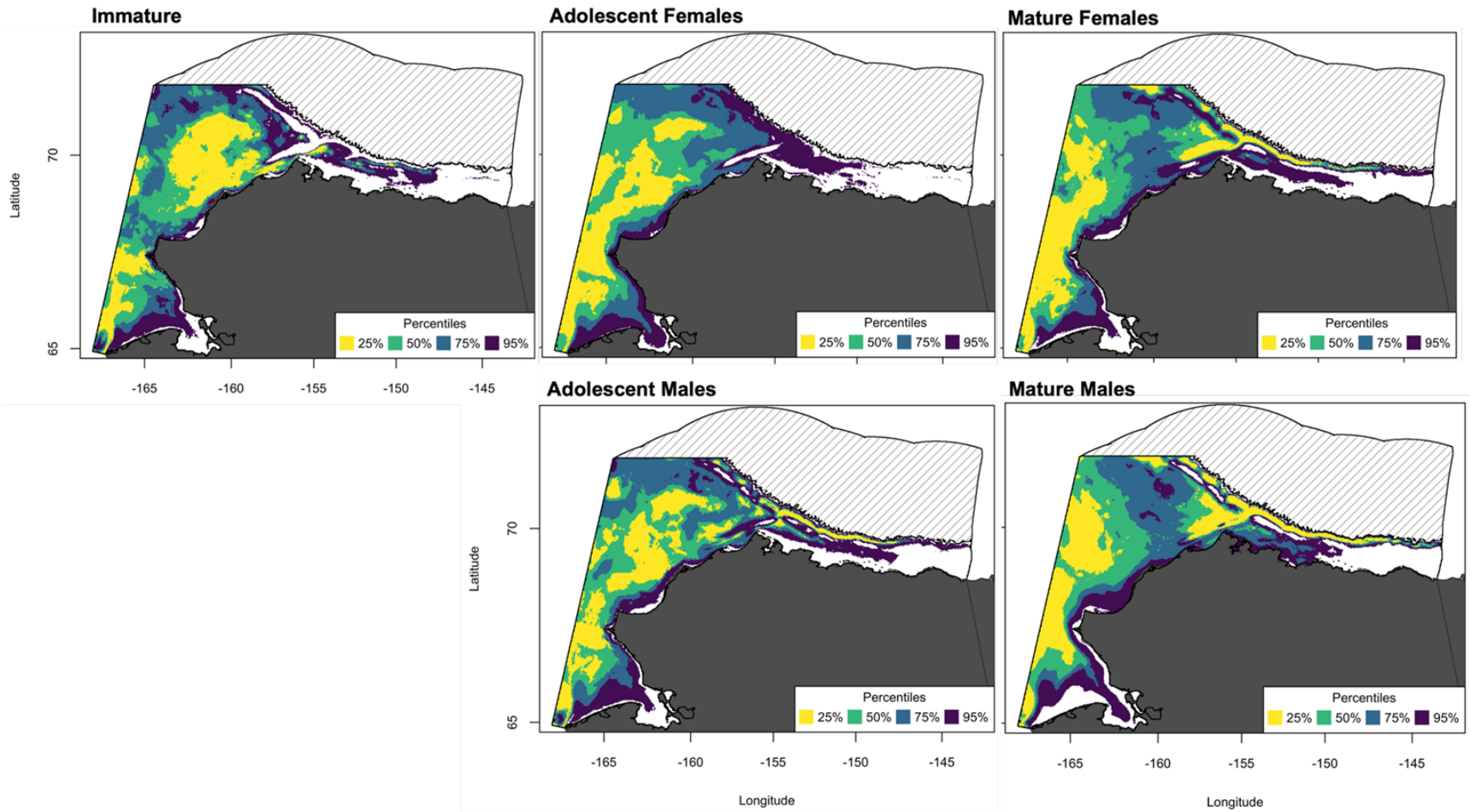
Marsh et al. Arctic EFH Maps, section 3.3.6, page 43

EFH Level 3 Maps

Age-0 Arctic cod

Potential Growth   x   Probability of Suitable Habitat   =   EFH Level 3 Map
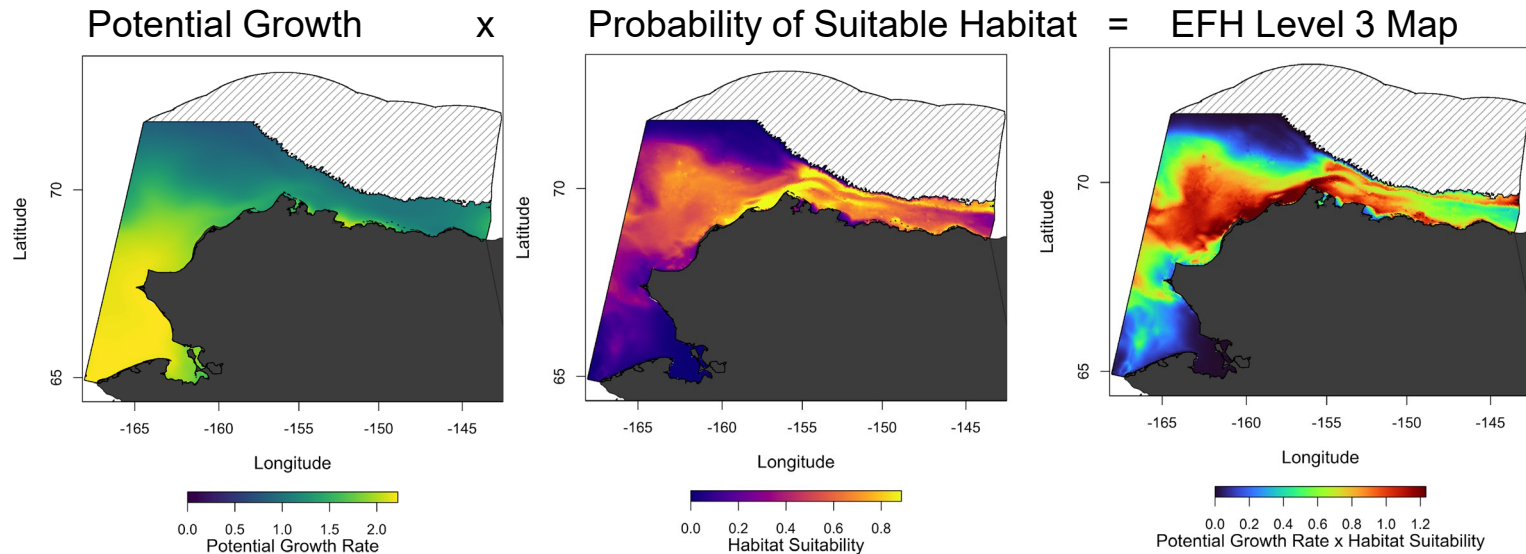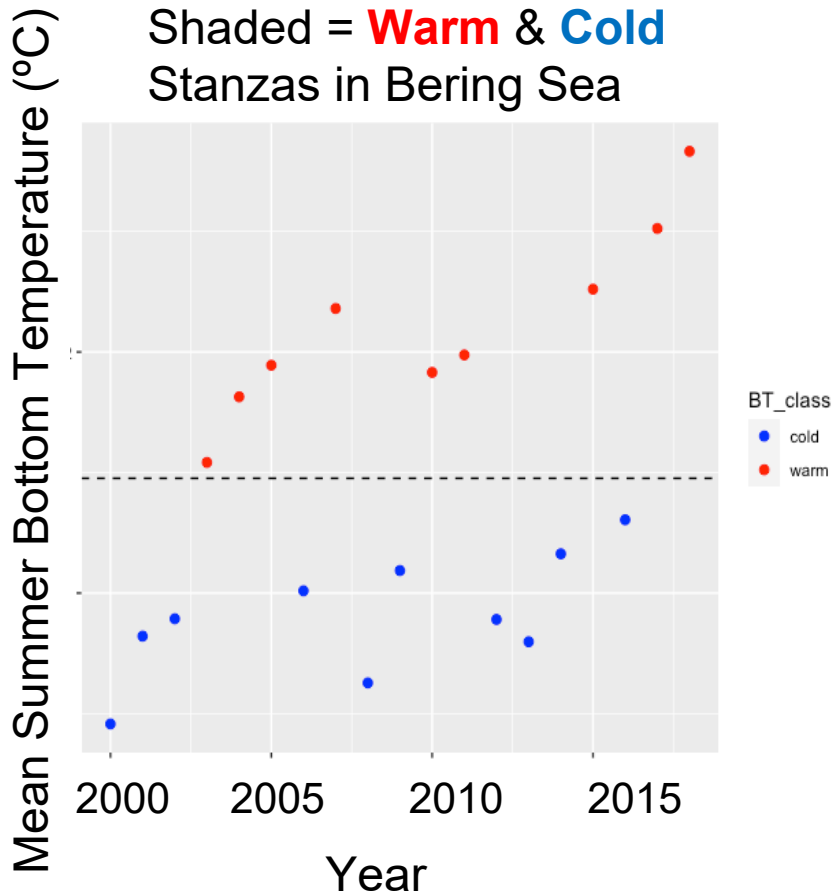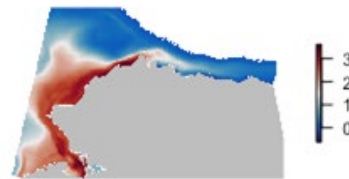
- EFH Level 3 maps of habitat-related vital rates for Arctic cod age-0 and juveniles, and saffron cod juveniles.
- Product of published temperature-dependent growth rates (Laurel et al. 2016; 2017) and SDM maps of the probability of suitable habitat.
- Methods co-developed with Laman et al. study for groundfish.

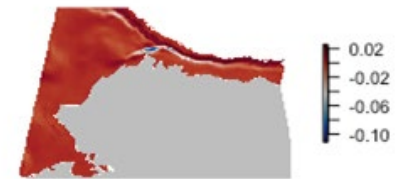Marsh et al. Arctic EFH Maps, section 2.6, page 13
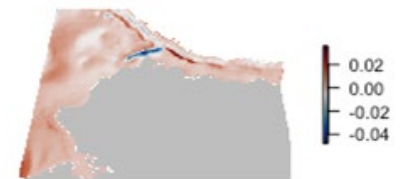
Warm and Cold Conditions

Shaded = **Warm** & **Cold** Stanzas in Bering Sea

Difference among dynamic covariates in warm and cold conditions.

Marsh et al. Arctic EFH Maps, section 2.7, page 13

Age-0 Arctic Cod – Warm Cold Comparison

Warm Cold Difference

SDM

Warm Cold

EFH
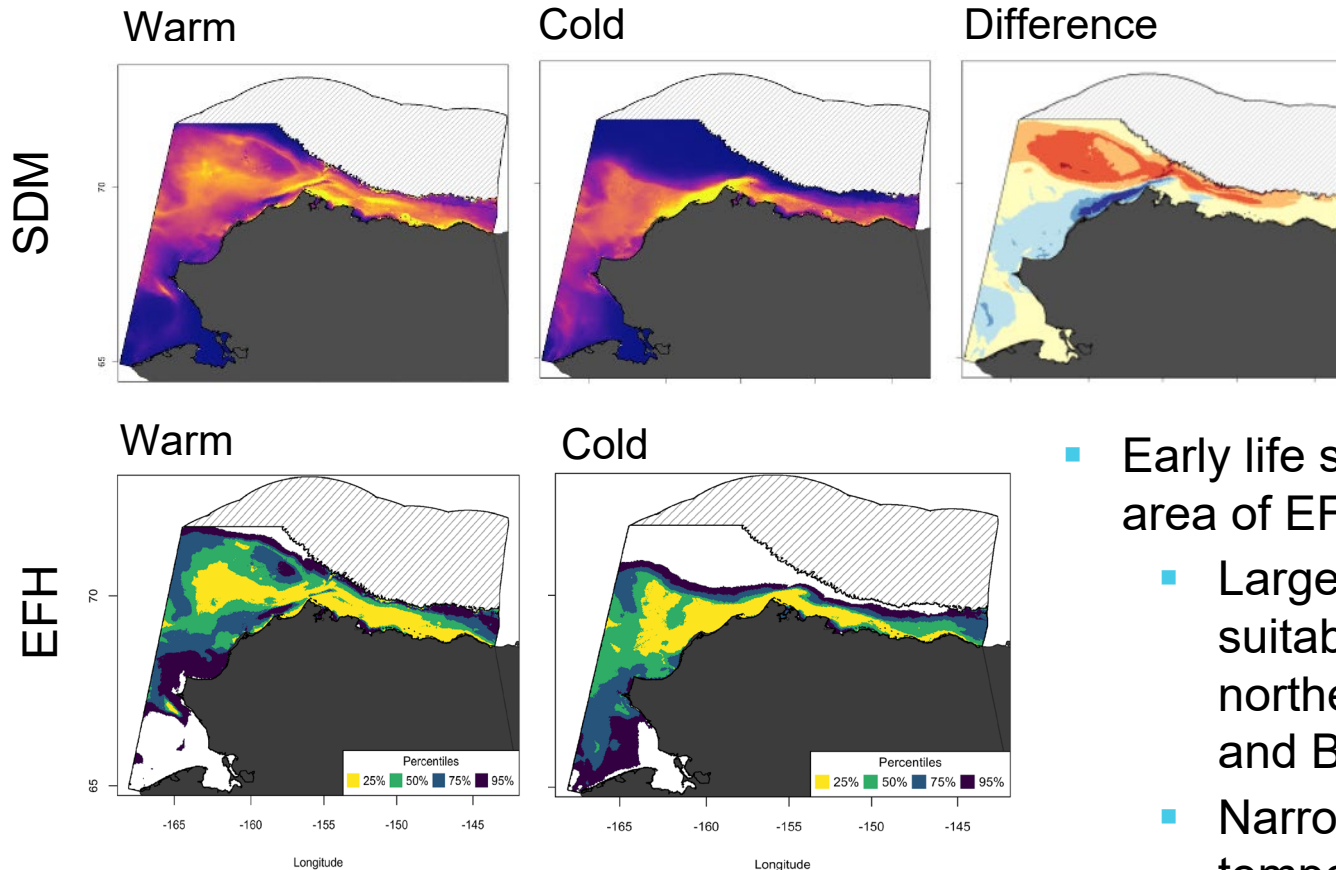
- Early life stages larger area of EFH in warm years
  - Larger area of suitable habitat in northern Chukchi Sea and Beaufort Sea.
  - Narrow preferred temperature range.

Marsh et al. Arctic EFH Maps, section 3.5.1, page 56, and Appendix 2, page 80

Mature Male Snow Crab – Warm Cold Comparison

Warm   Cold   Difference

SDM

Warm   Cold

EFH
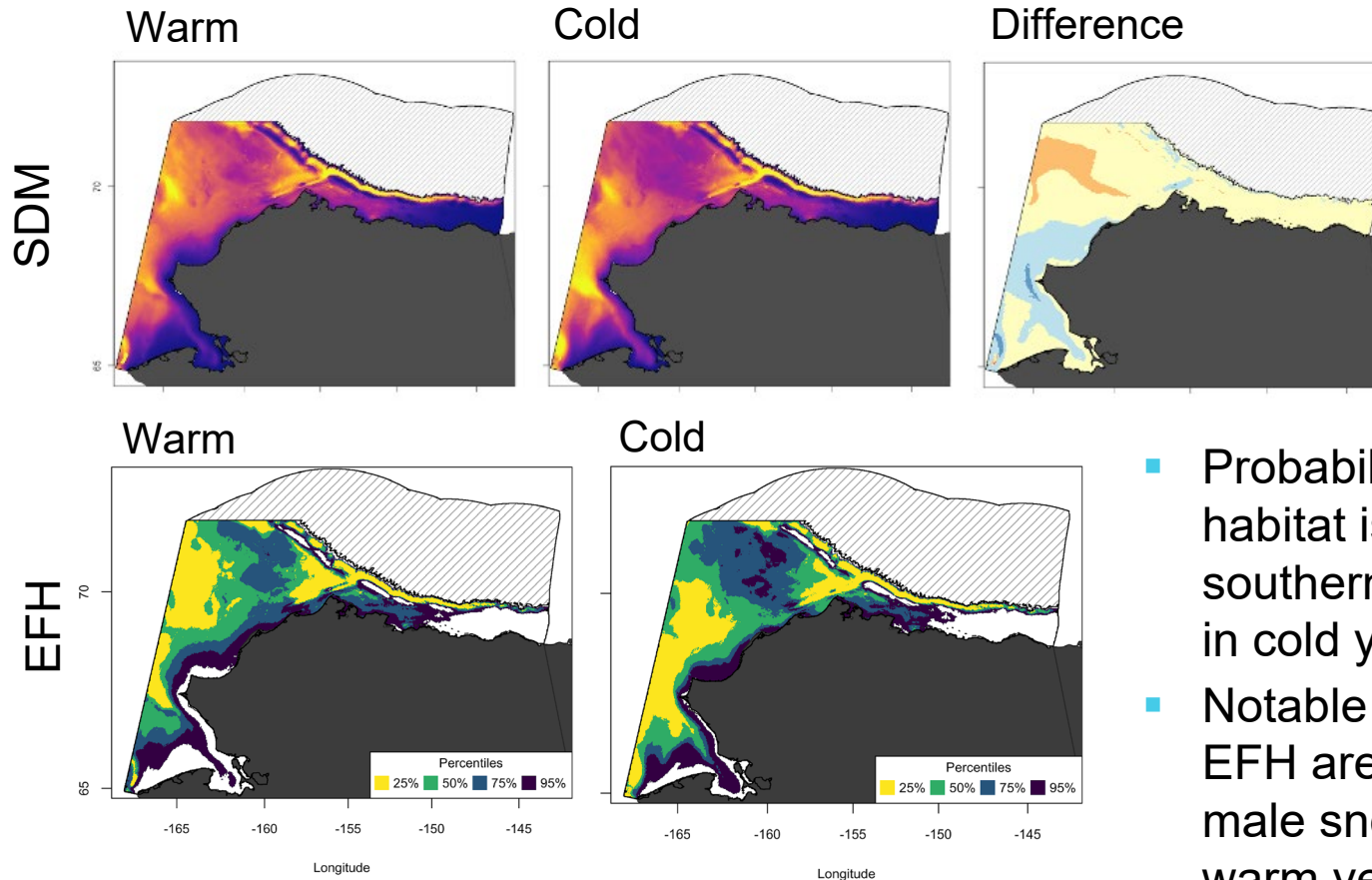
- Probability of suitable habitat is higher in the southern Chukchi Sea in cold years.

- Notable decrease in EFH area for mature male snow crab in warm years.

Marsh et al. Arctic EFH Maps, section 3.5.3, page 58, and Appendix 2, page 85

Conclusions and Future Recommendations

Conclusions:

- NMFS recommends updating the EFH sections of the Arctic FMP to include the revised text descriptions and maps from this study, including the new climate-informed EFH maps.
- Increases in data availability and SDM methods advances allowed us to update and substantially refine the Arctic EFH descriptions and maps.
  - Model performance was good to acceptable in all cases.
- Ontogenetic distribution shifts support fitting separate life stage models.
- Separate models for warm and cold conditions was a first step in temporally dynamic, climate-informed SDM EFH mapping.

Future research recommendations:

- Continue to refine models as new survey data becomes available;
- Consider other covariates such as predator, prey, and competitor fields;
- Move towards temporally dynamic models; and
- Explore alternative modeling methods to predict abundance.

THANK YOU

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