

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

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SSC, February 7, 2023

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.
- Level 3: Growth, reproduction, or survival rates within habitats.
- Level 4: Production rates by habitat. *[Not available at this time]*

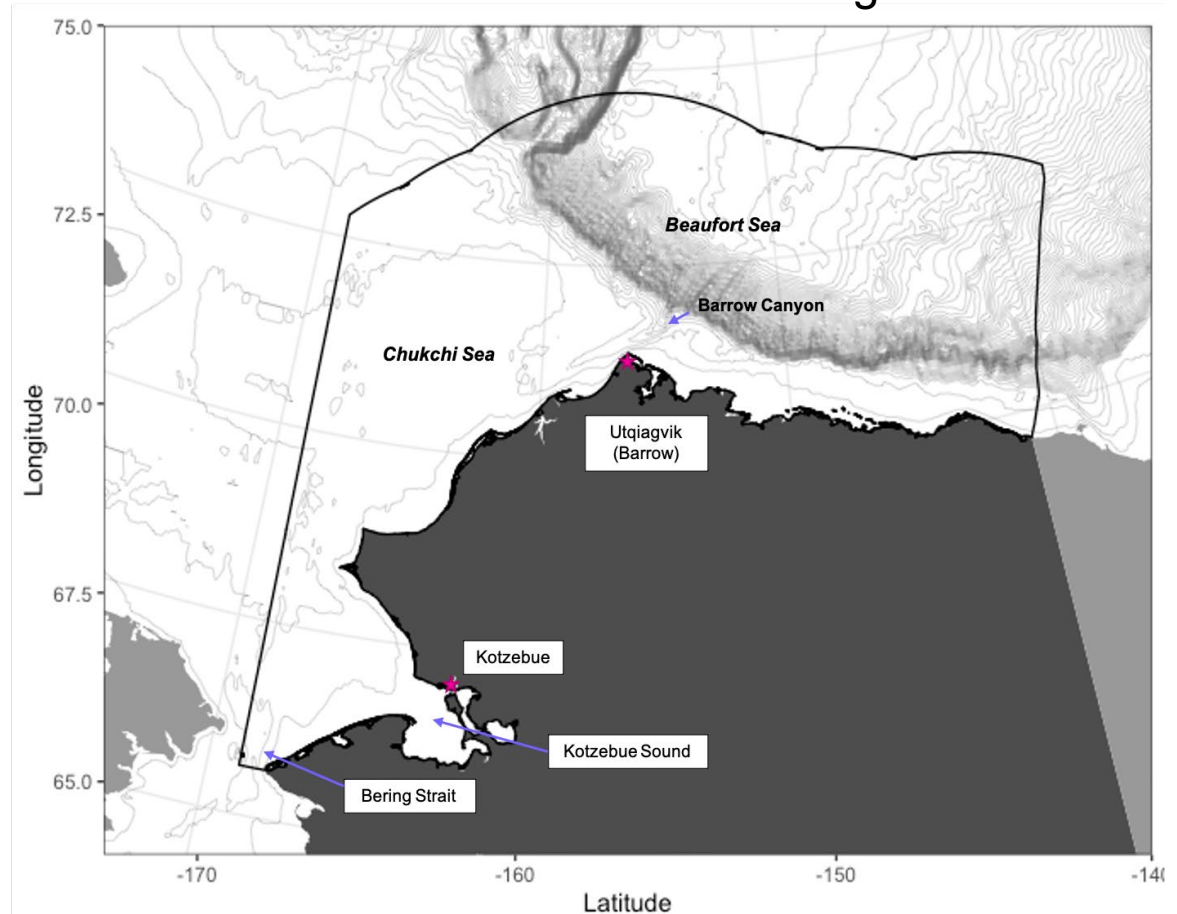
New and revised EFH descriptions and maps for the 2023 Review

- **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

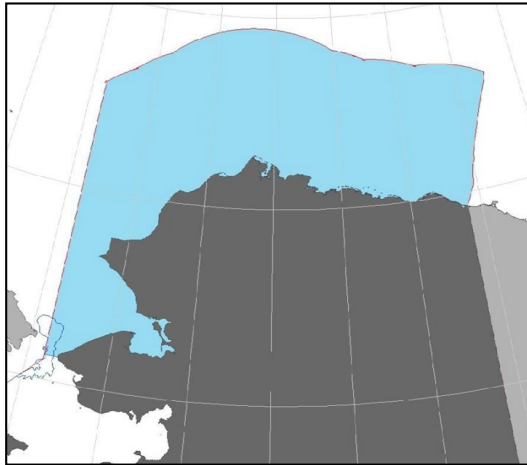
Arctic Management Area



2017 EFH Review



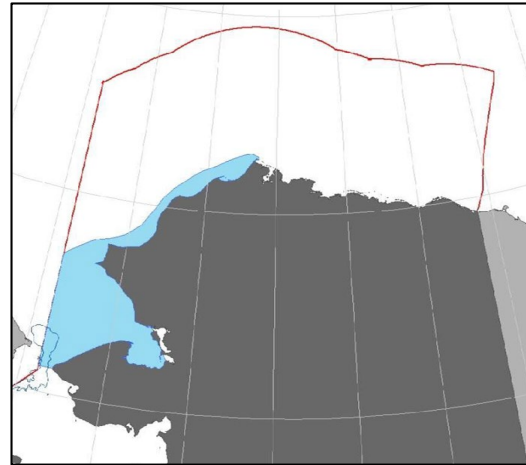
Arctic cod



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



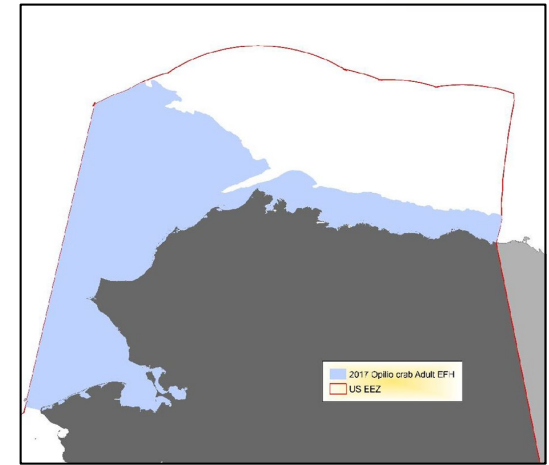
Saffron cod



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



Snow crab



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

Model-based EFH for Arctic Species Life Stages

First SDM EFH maps for Arctic FMP species

- 13 EFH Level 1 maps (habitat-related distribution),

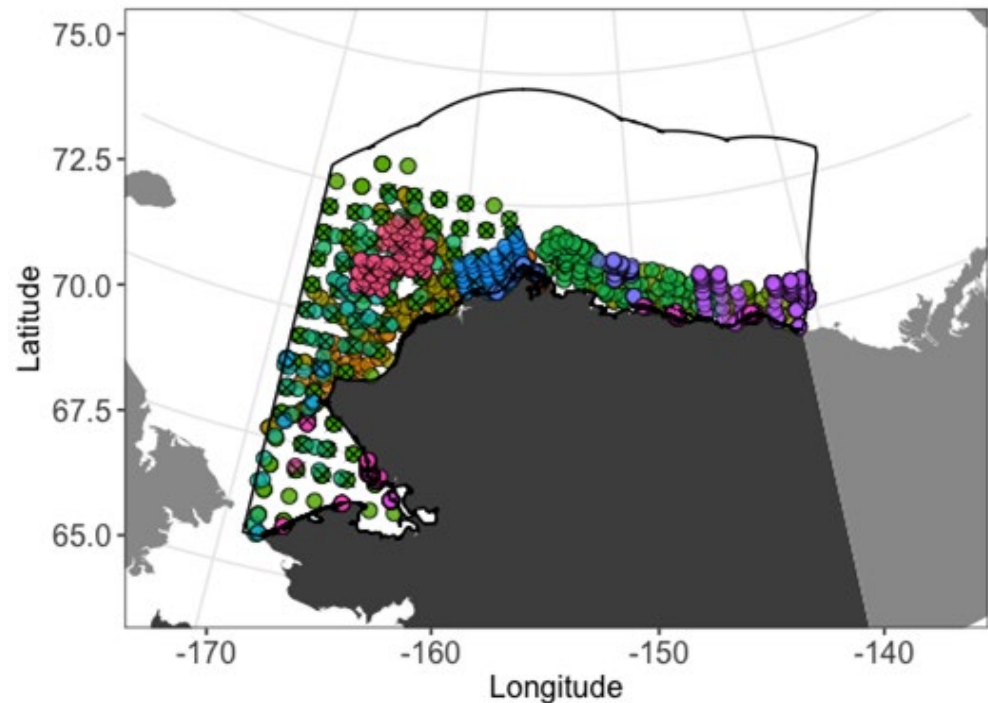
Species	Larvae	Early Juvenile	Late Juvenile	Adult
Arctic cod (Length, mm)	< 30	31 – 70 (age-0)	71 – 120	> 120
Saffron cod (Length, mm)	< 27	28 – 70 (age-0)	71 – 190	> 190
Snow crab (Carapace width, mm)	--	< 34 (immature)	35 – 61 (adolescent male) 35 – 46 (adolescent female)	> 62 (mature male) > 46 (mature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

- EFH Level 3 maps (habitat related vital rates) for three life stages, 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	

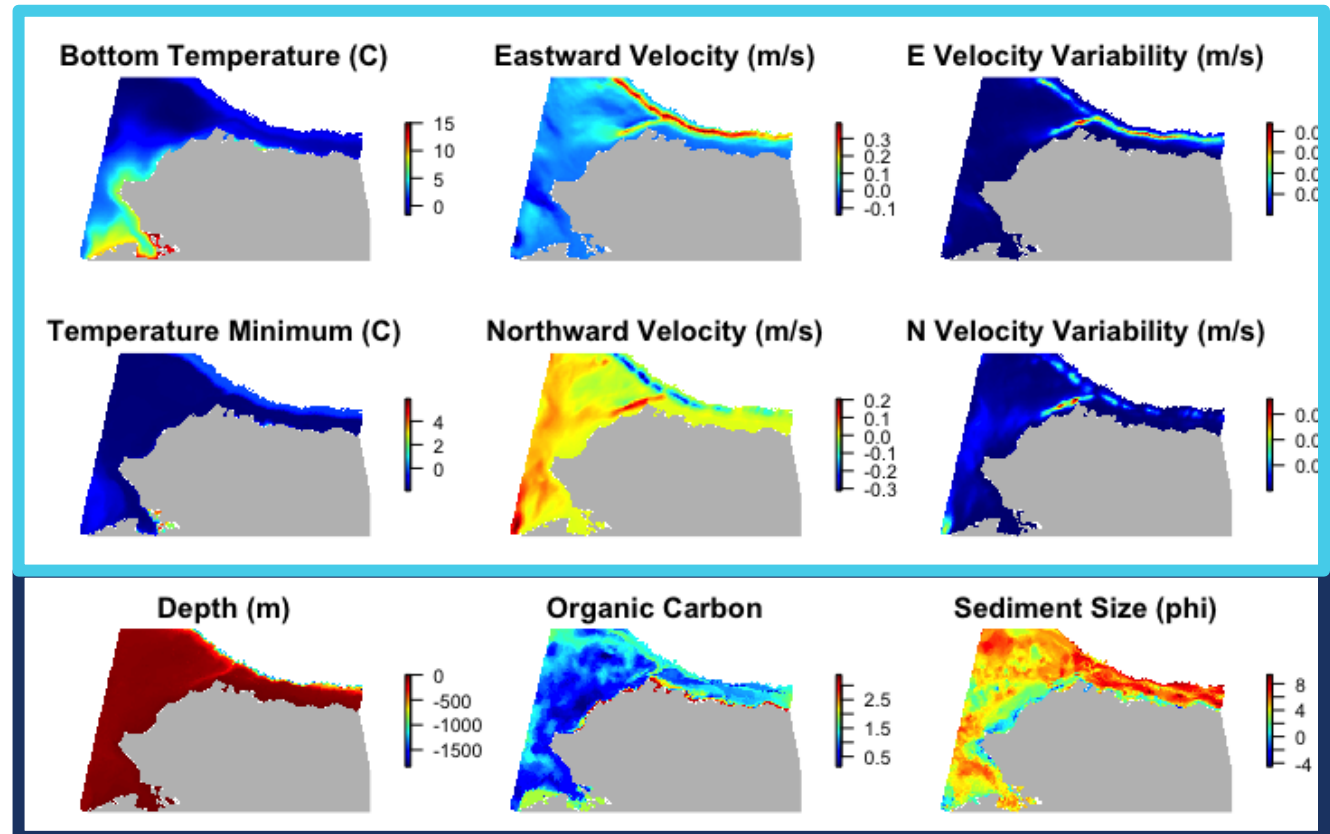
Overview SDM EFH Mapping Methods

- 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 $\geq 5\%$.
- 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 and areas compared.

Habitat Covariates

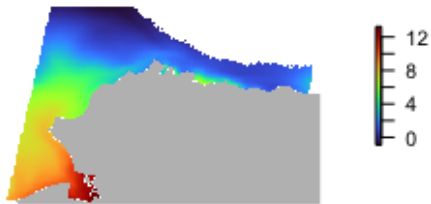
Temporally **dynamic**
and **static** covariates:

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

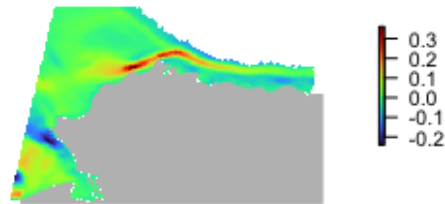


Surface Habitat Covariates

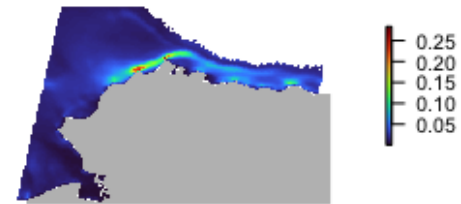
Surface Temperature (C)



Eastward Velocity (m/s)



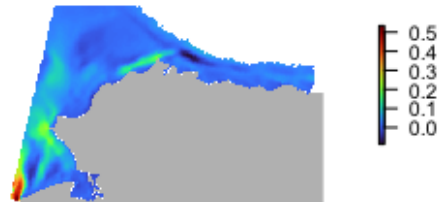
E Velocity Variability



Temperature Minimum (C)



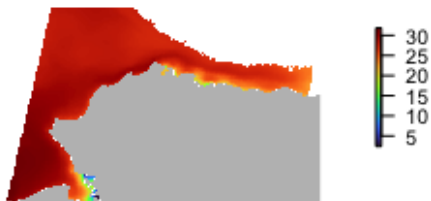
Northward Velocity (m/s)



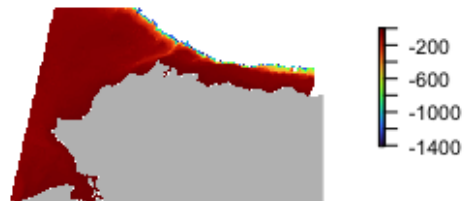
N Velocity Variability



Surface Salinity



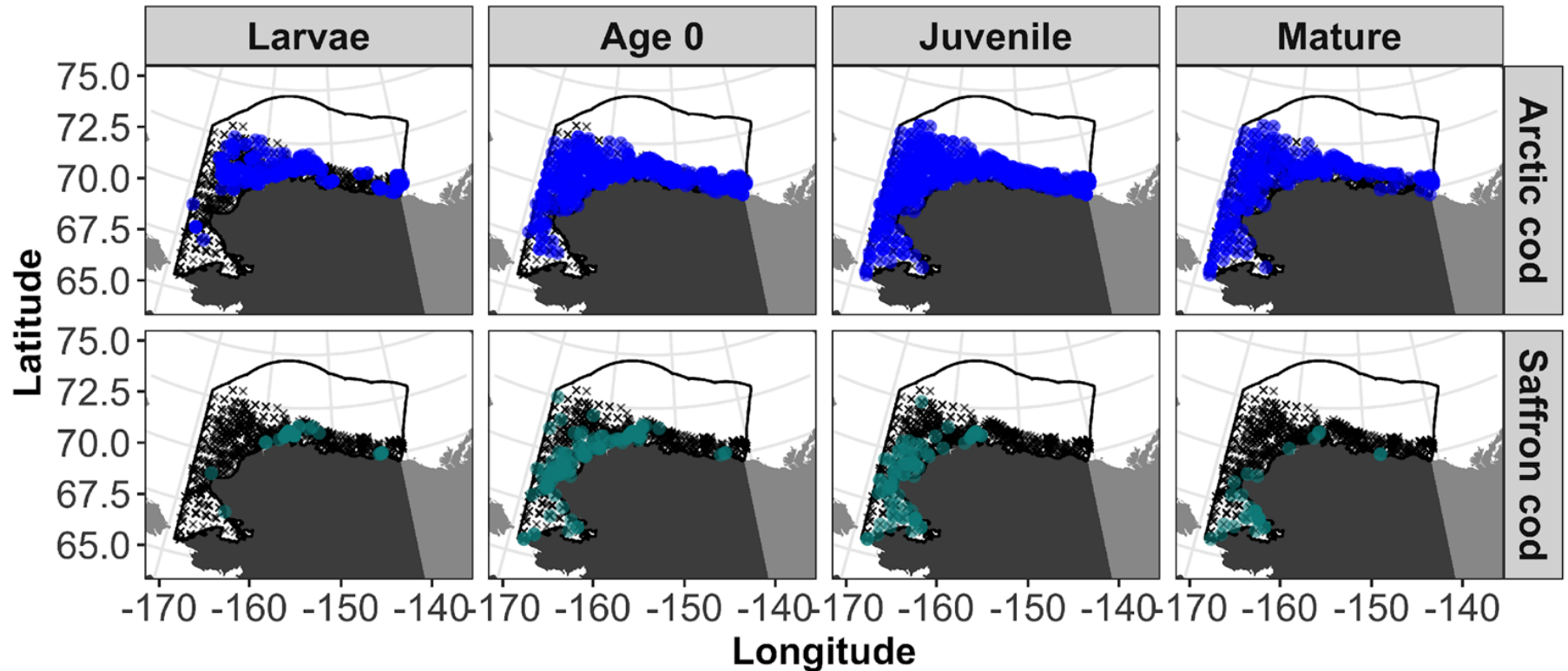
Depth (m)



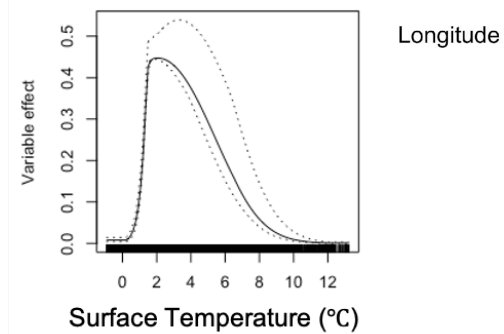
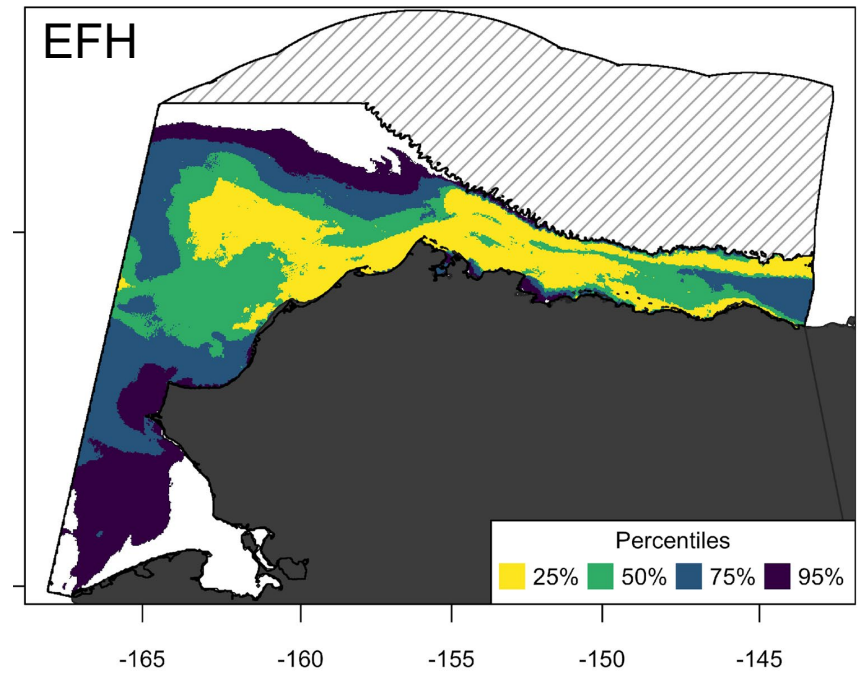
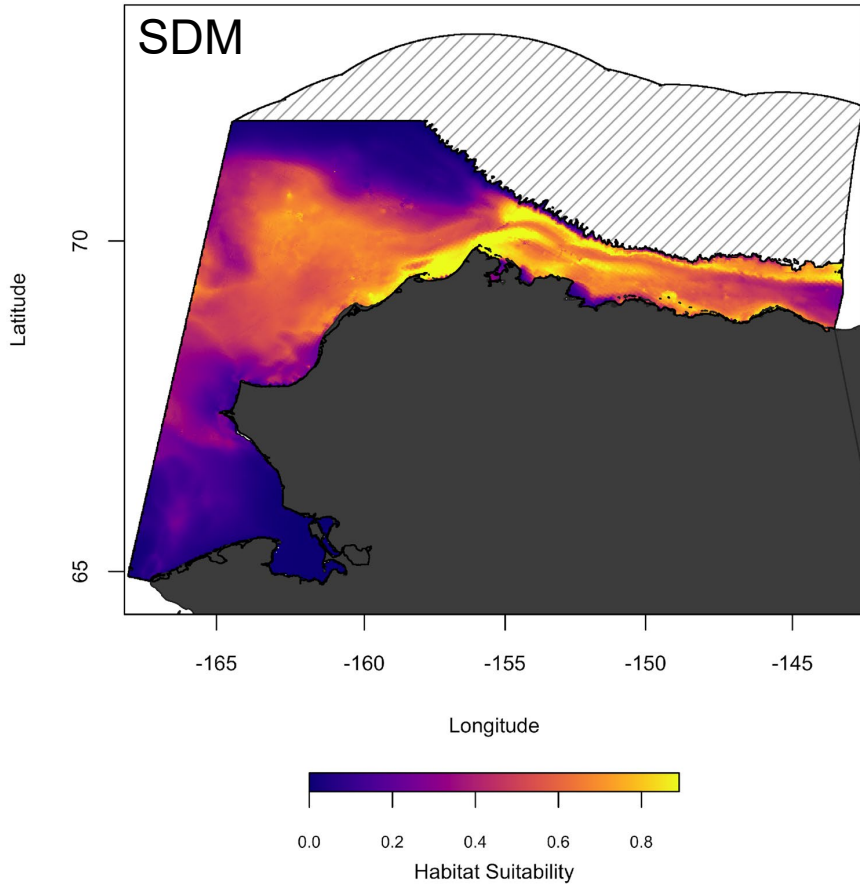
Pelagic life stages:

- Larval Arctic cod
- Age-0 Arctic cod
- Larval saffron cod

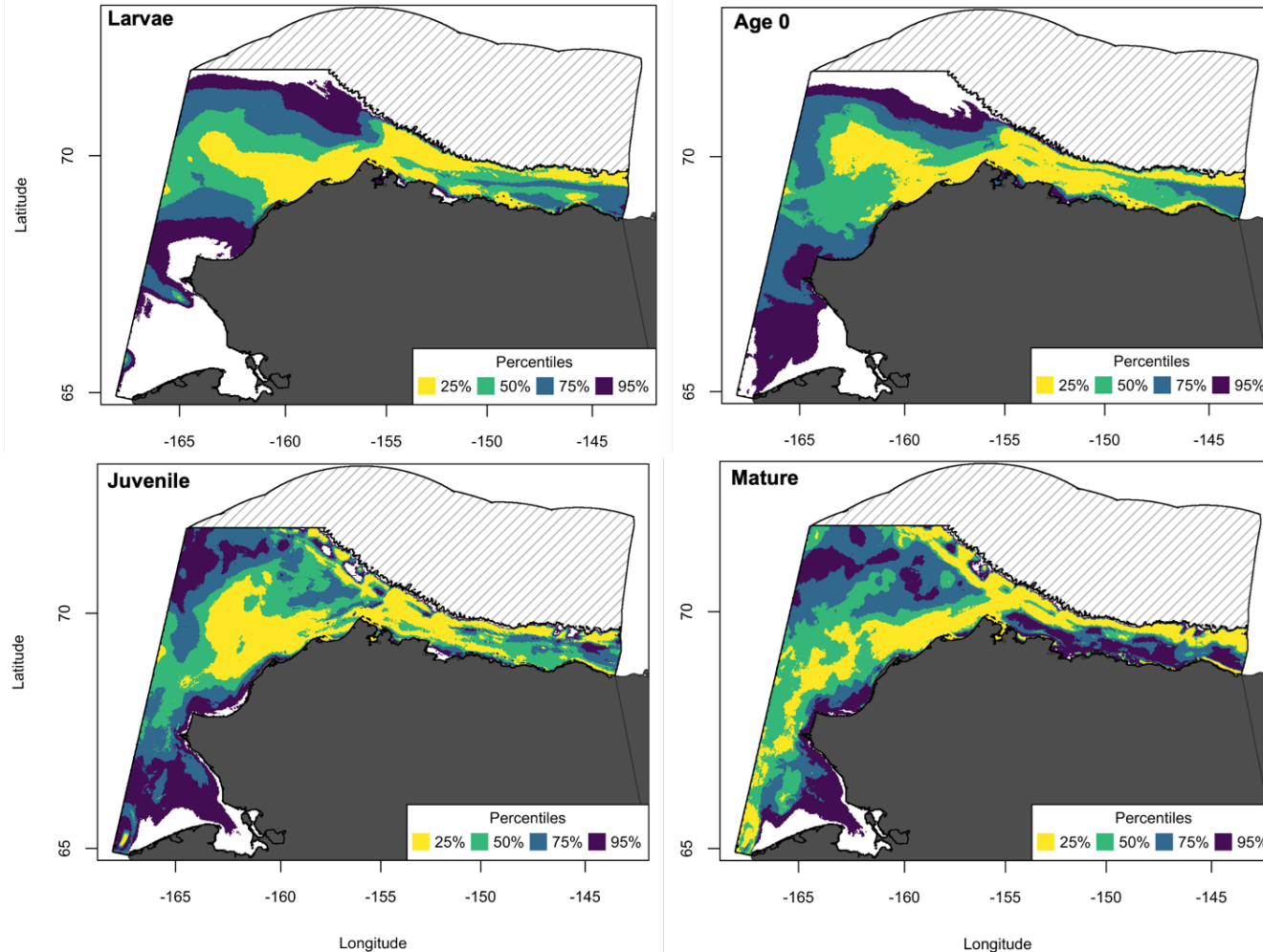
Occurrence Data for Arctic Cod and Saffron Cod



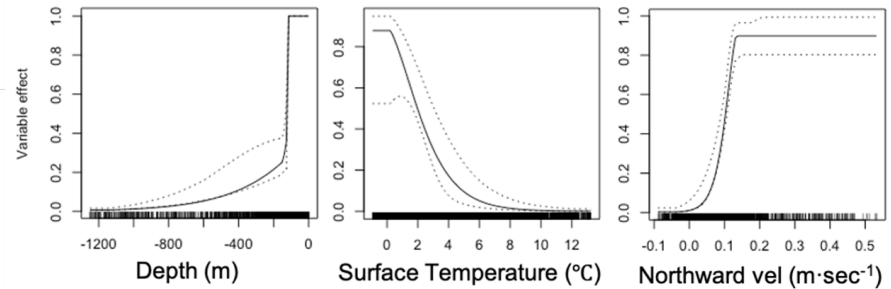
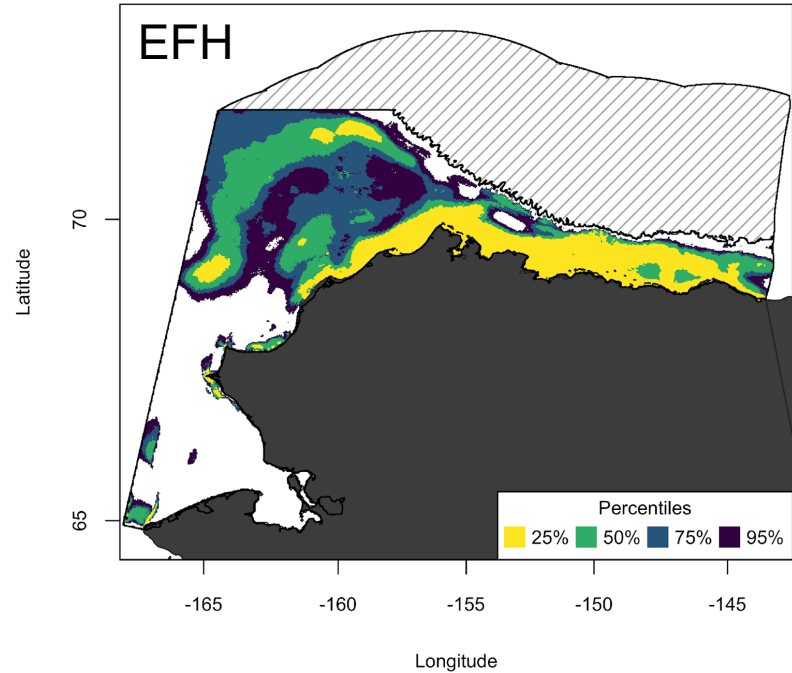
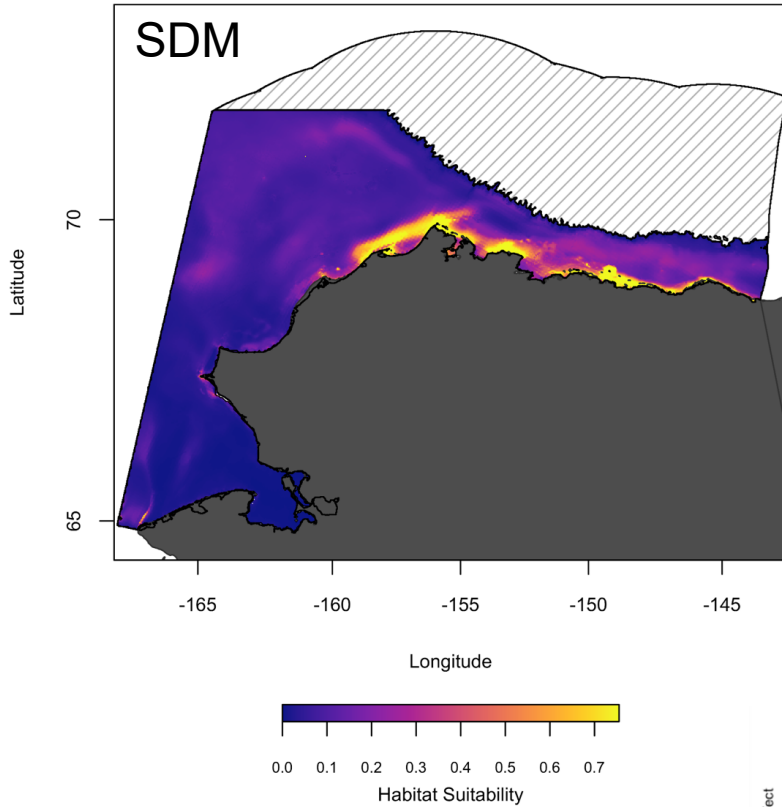
Age-0 Arctic Cod



Arctic Cod EFH Maps

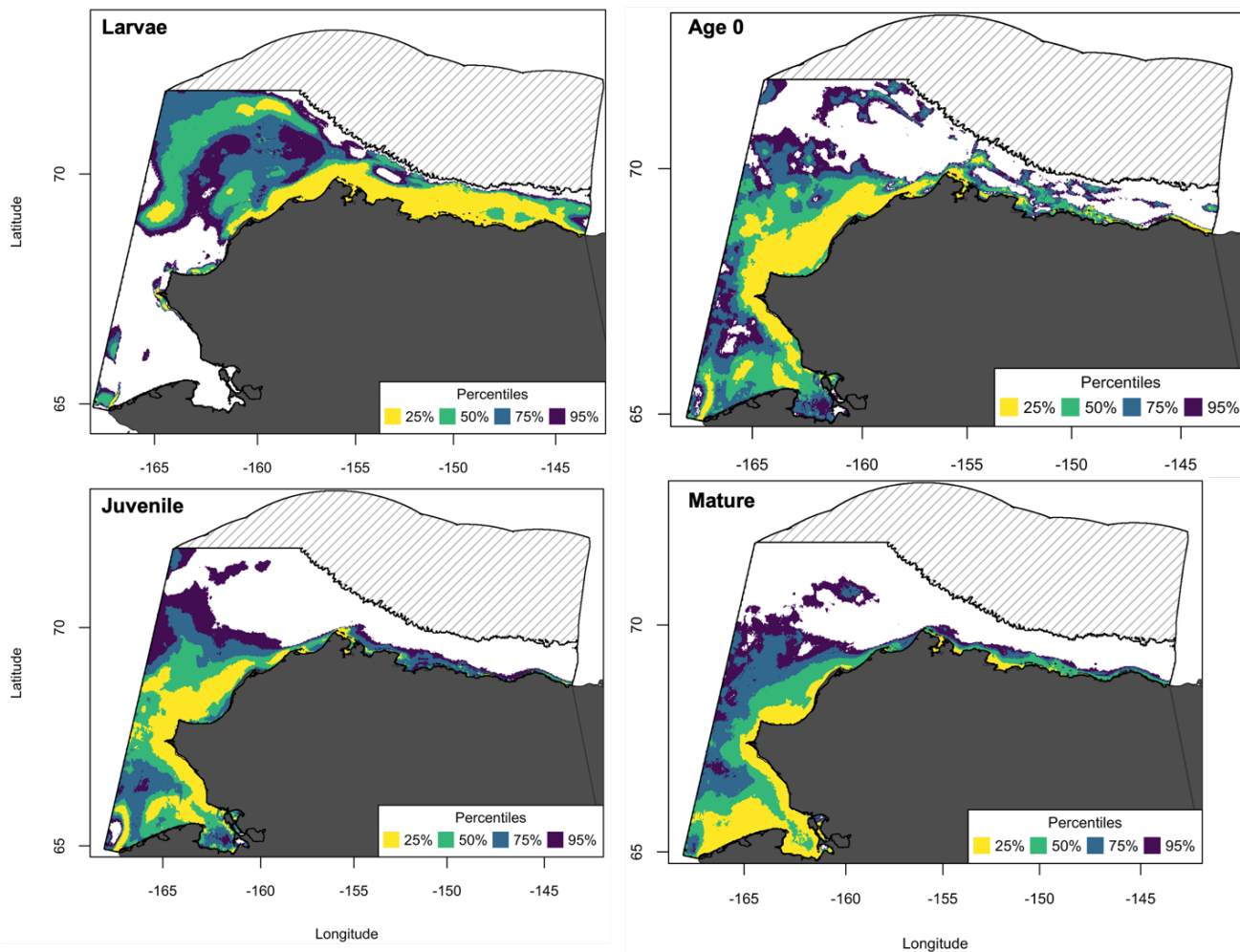


Larval Saffron Cod

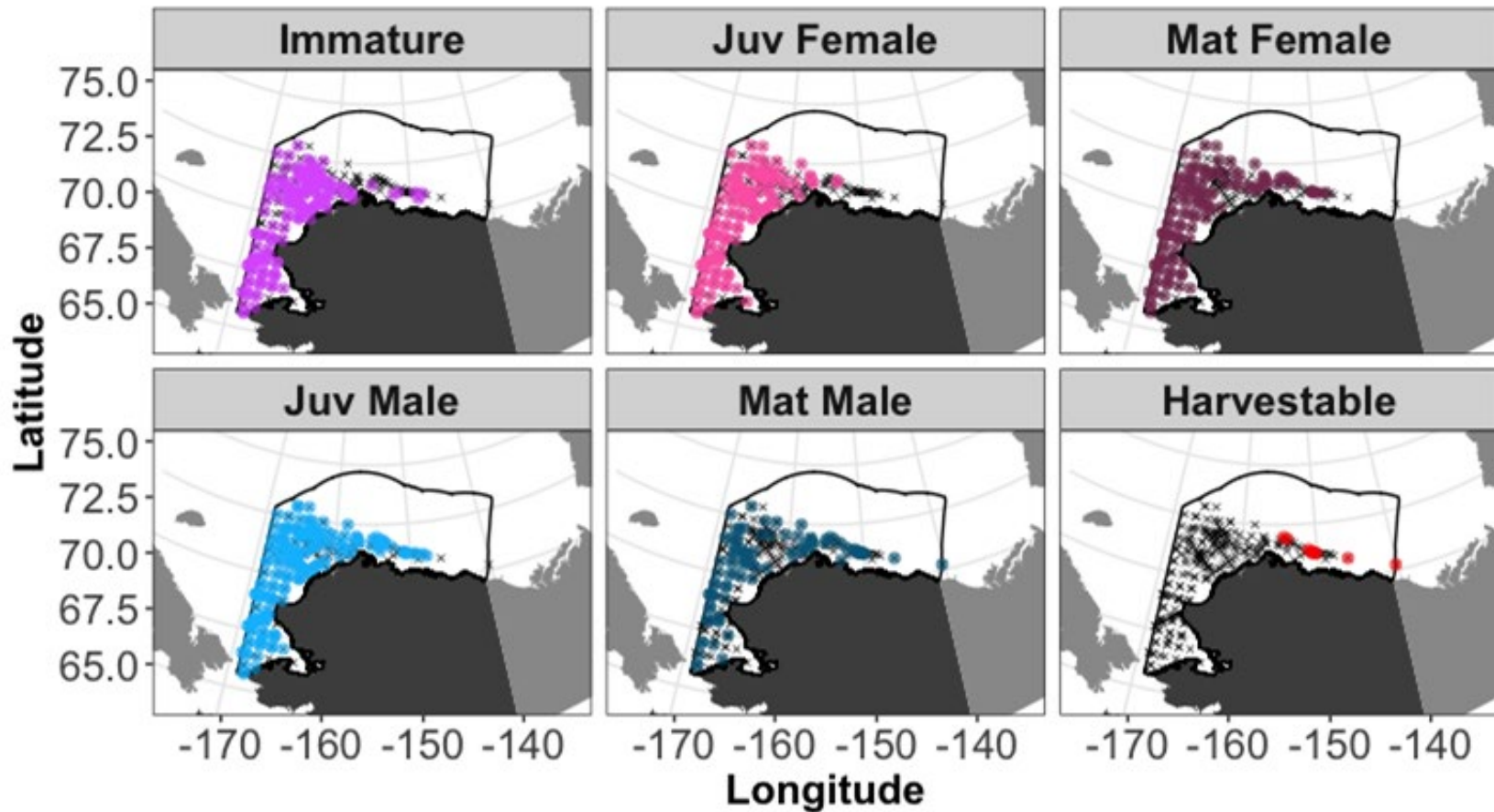


Marsh et al. Arctic EFH Maps, section 3.2.1, page 34

Saffron Cod EFH Maps

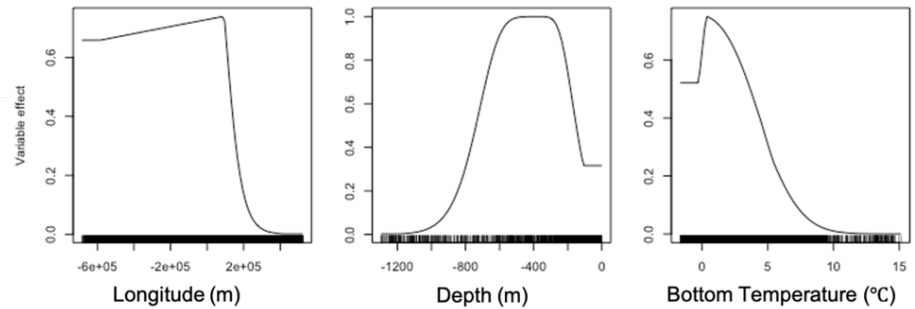
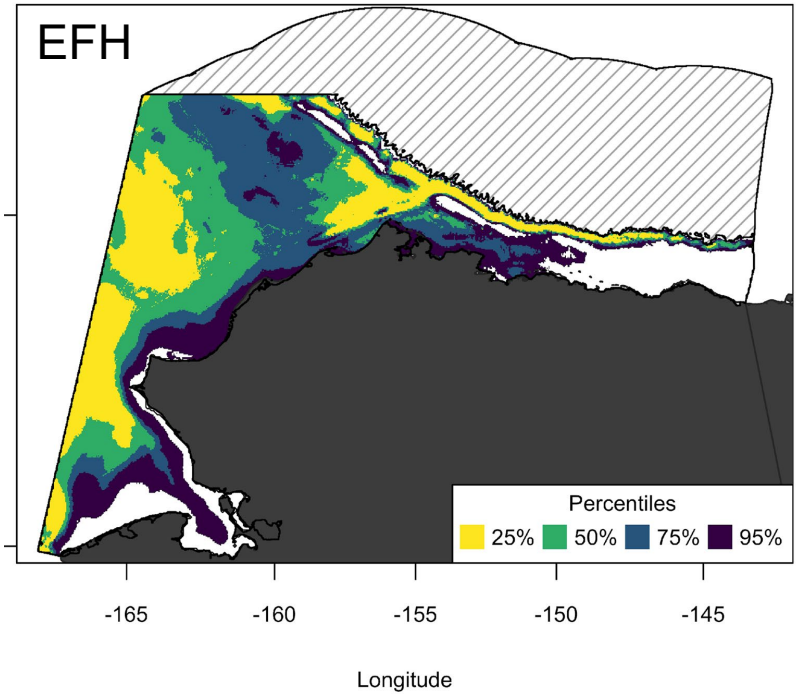
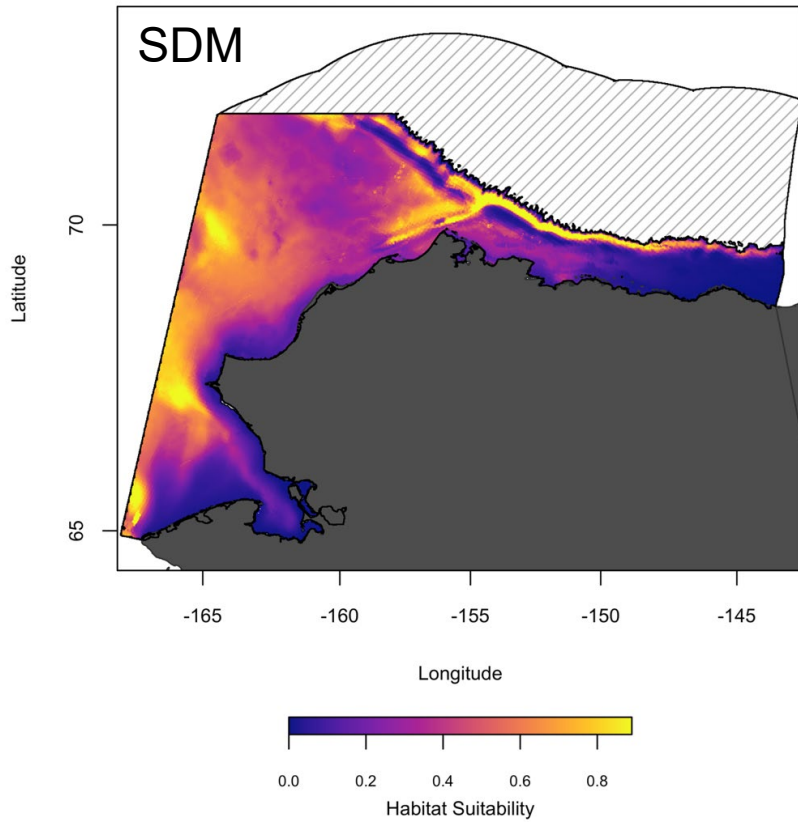


Snow Crab Occurrence by Life Stage



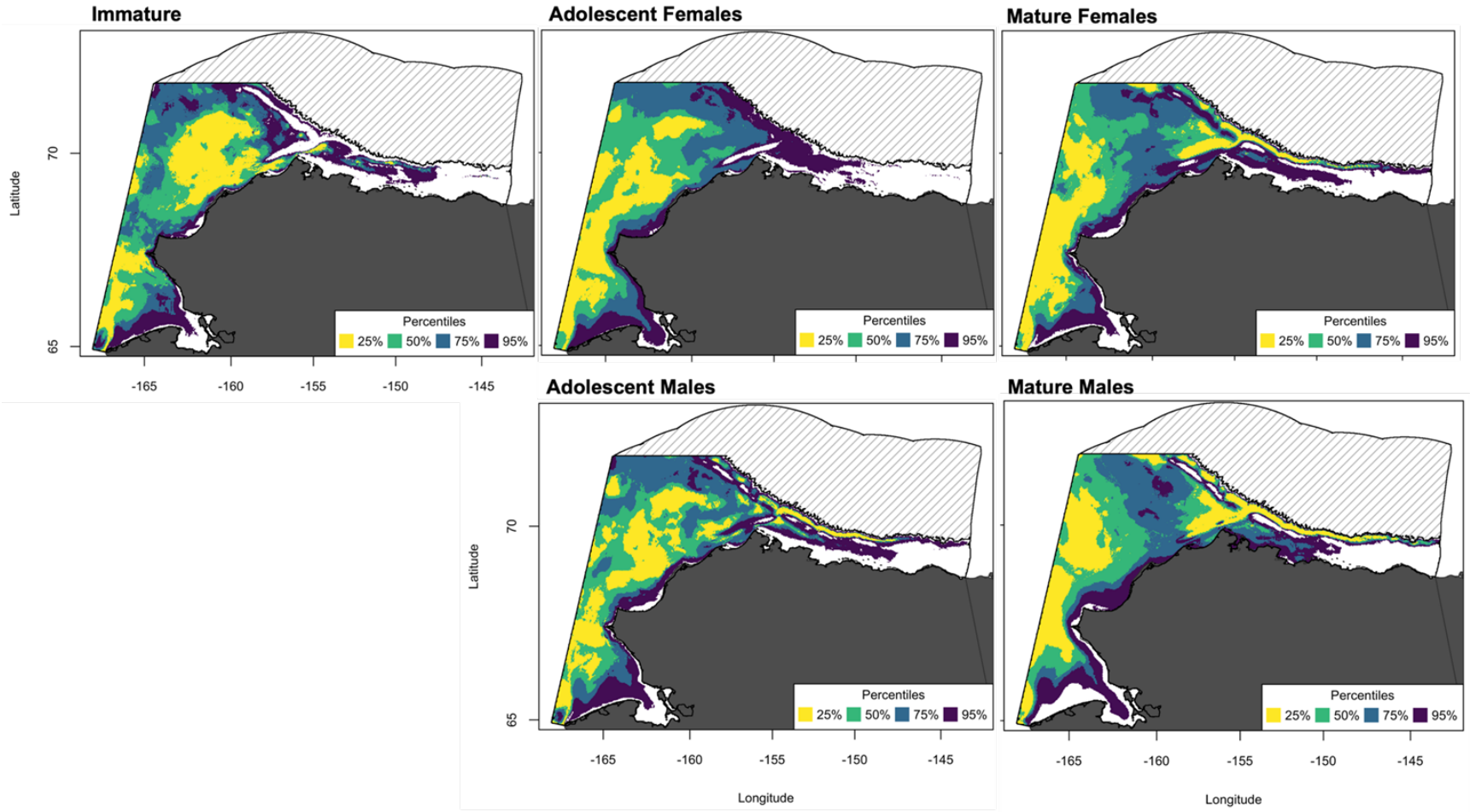
Marsh et al. Arctic EFH Maps, section 3.3, page 45

Mature Male Snow Crab



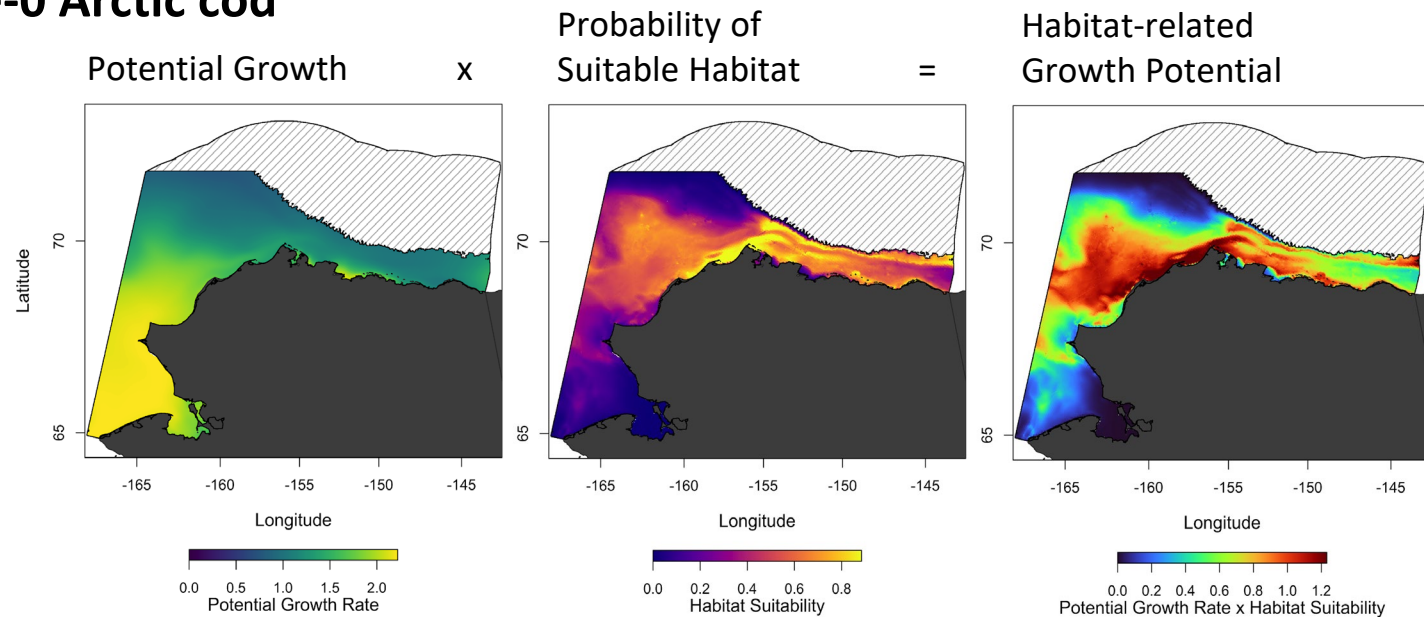
Marsh et al. Arctic EFH Maps, section 3.3.5, page 43

Snow Crab EFH Maps



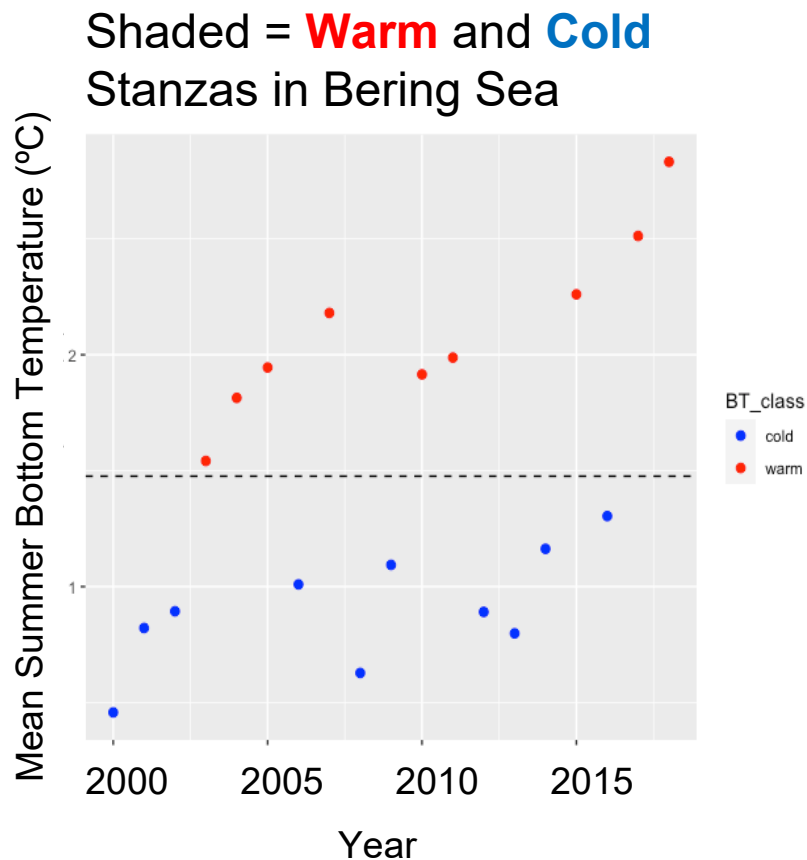
EFH Level 3 Maps

Age-0 Arctic cod

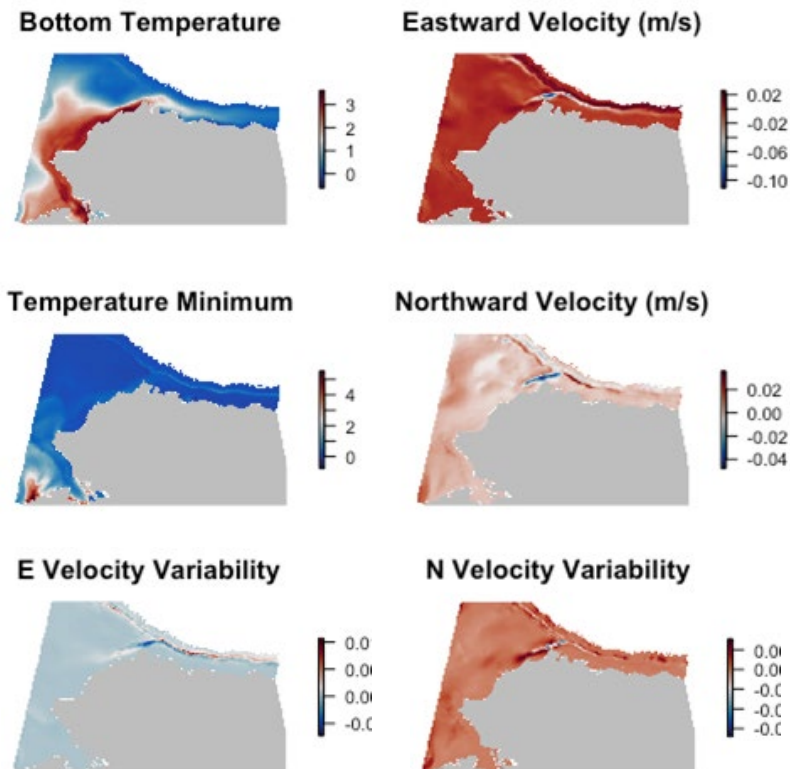


- EFH Level 3 maps of habitat-related vital rates.
- Product of temperature-dependent growth rates by Laurel et al. 2016, and 2017 and the SDM maps of the probability of suitable habitat for Arctic cod age-0 and Arctic cod and saffron cod juveniles.
- Methods co-developed with Laman et al. study for BSAI and GOA groundfish.

Warm and Cold Conditions

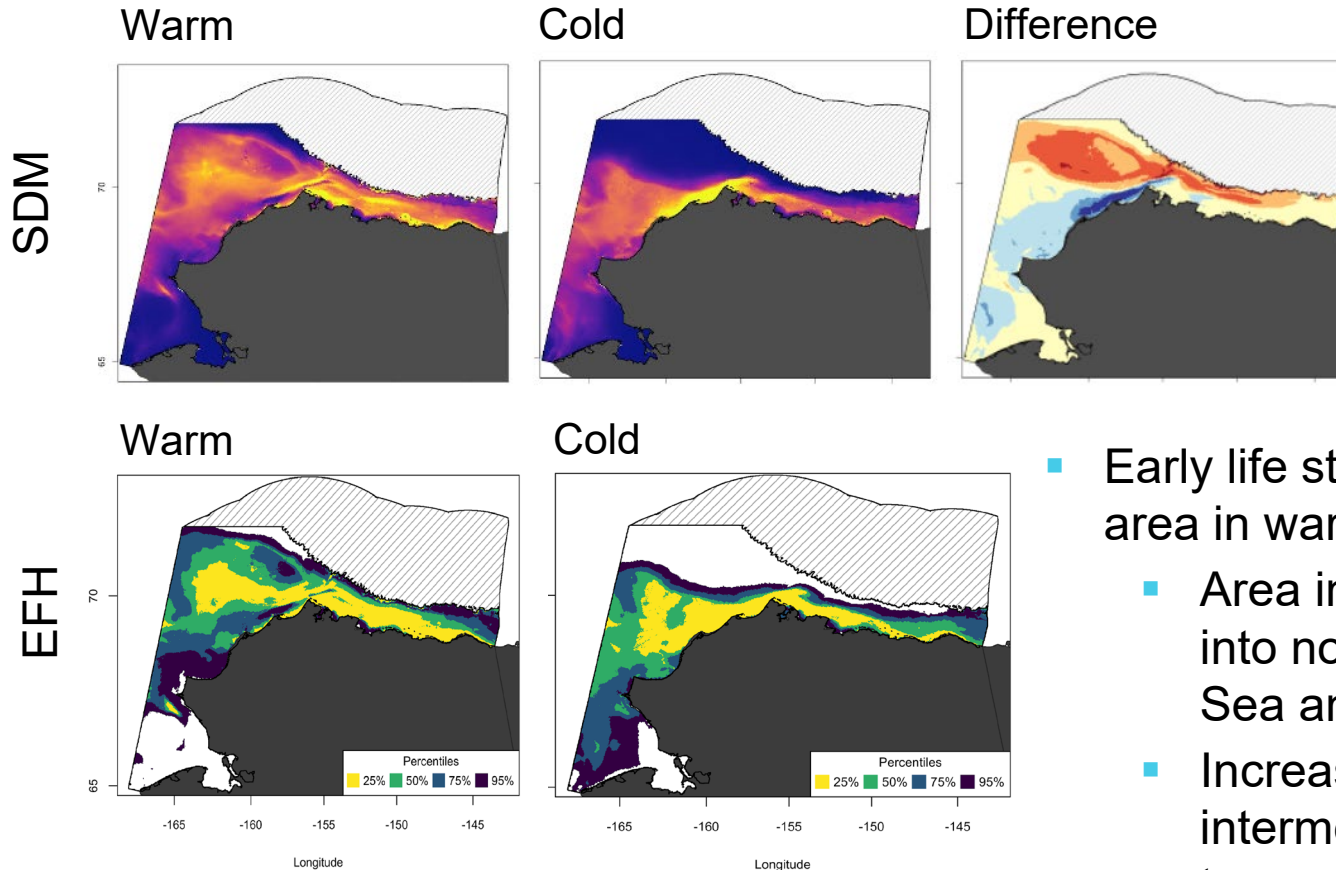


Marsh et al. Arctic EFH Maps, section 2.7,
page 13



Difference in SDM dynamic covariates
between warm and cold stanzas in the
Bering Sea.

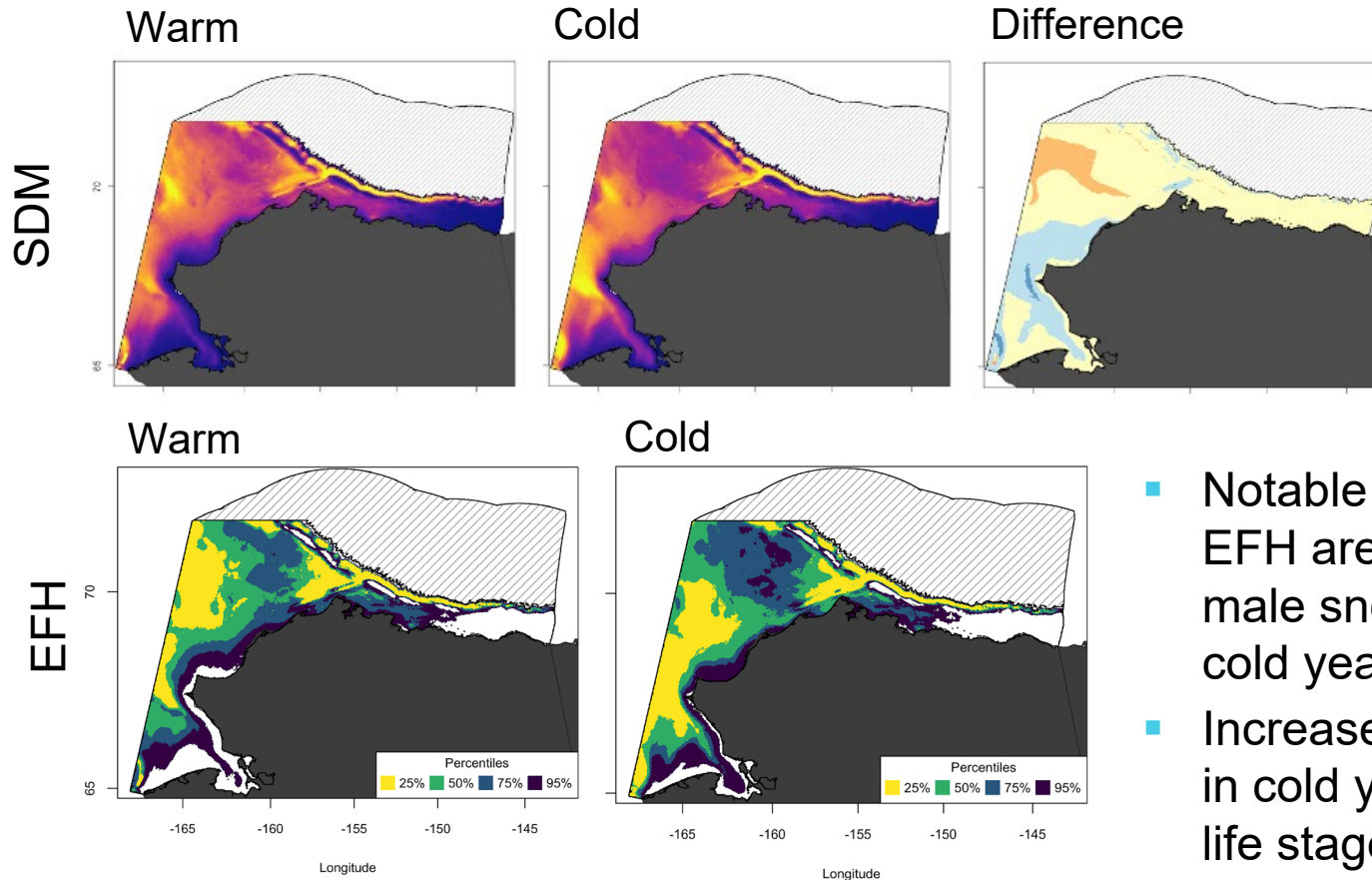
Age-0 Arctic Cod – Warm Cold Comparison



- Early life stages larger EFH area in warm years
 - Area increase and shift into northern Chukchi Sea and Beaufort Sea.
 - Increased growth at intermediate temperatures (Laurel et al. 2016, 2017).

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

Mature Male Snow Crab – Warm Cold Comparison



- Notable increase in EFH area for mature male snow crab in cold years.
- Increase in EFH area in cold years for all life stages.

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 available data 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 differences in EFH spatial distribution and area support fitting separate models by life stage for these species.
- Temperature was an important habitat covariate for predicting the probability of suitable habitat for many of the life-stage species combinations.
- 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 species and environmental data become available.
- Consider other covariates such as predator, prey, and competitor fields.
- Move towards temporally dynamic models.
- Explore alternative modeling methods to predict abundance.

THANK YOU



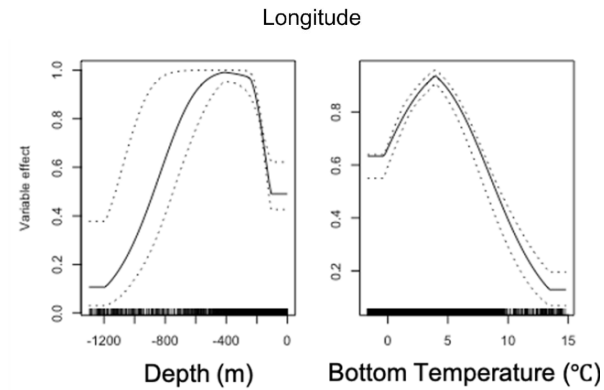
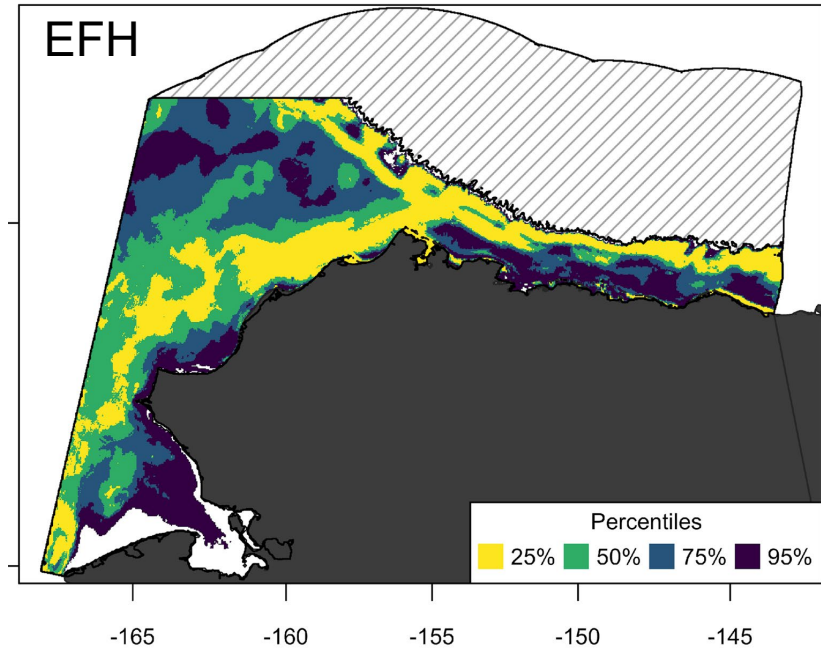
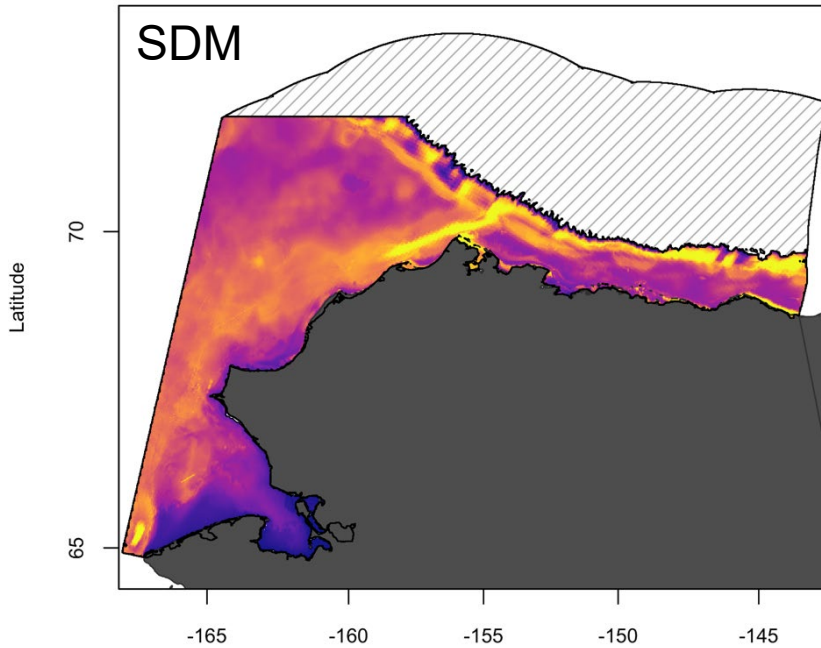
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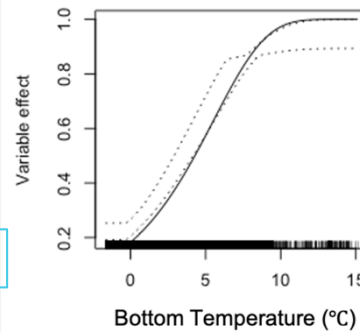
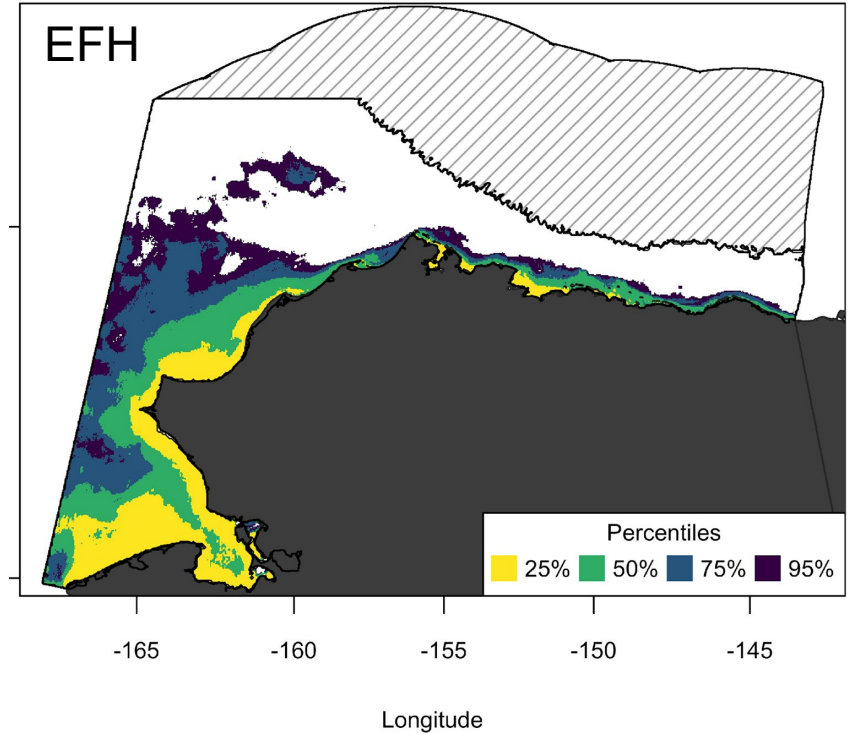
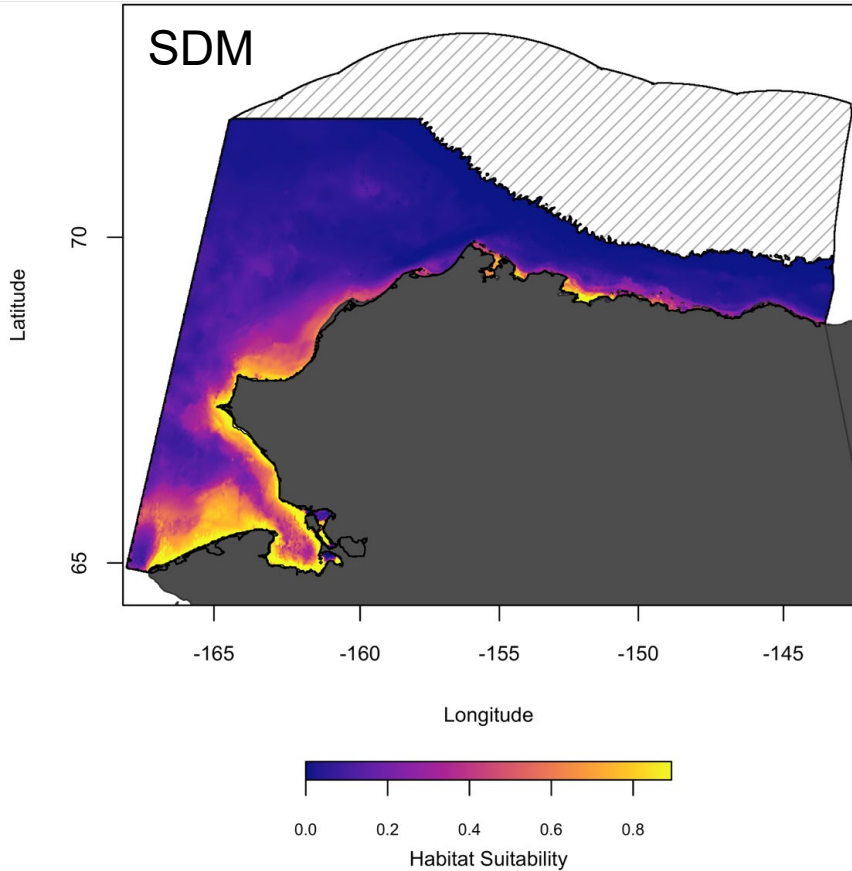
jodi.pirtle@noaa.gov

Mature Arctic Cod

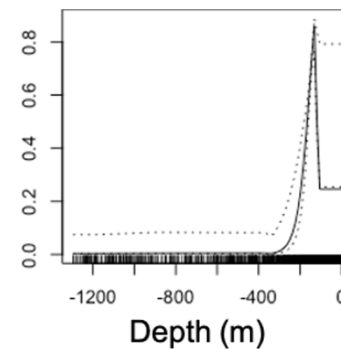
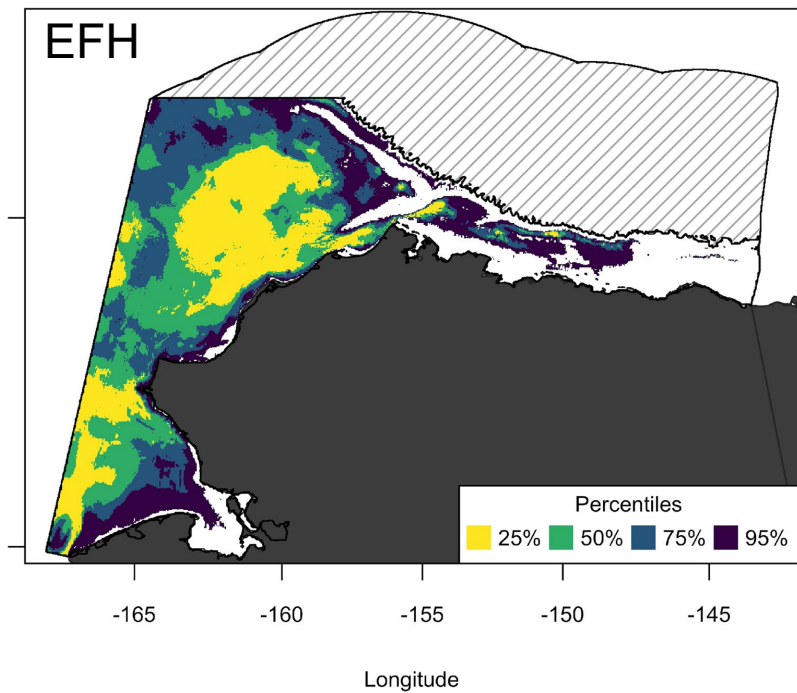
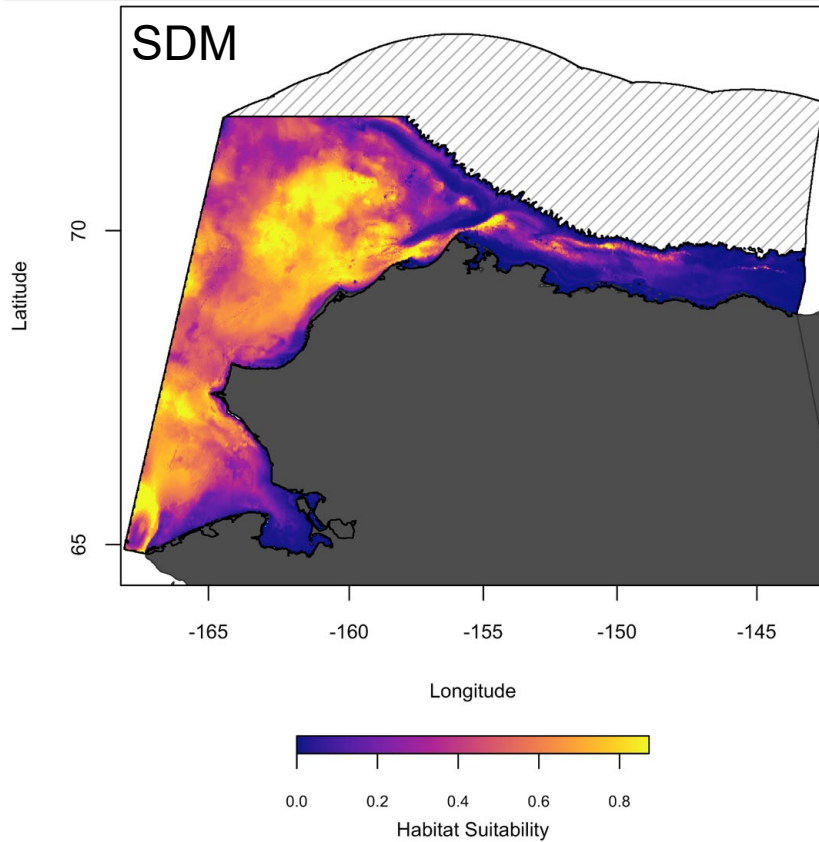


Marsh et al. Arctic EFH Maps, section 3.1.4, page 25

Mature Saffron Cod



Immature Snow Crab (Males and Females)



Narrow depth range
~ 100 – 250m.

EFH Area and Differences in Warm and Cold Years

Table 8. Model-based estimates of EFH area (km²) during warm and cold years and the difference in area (parentheses indicate an increase in area).

Species - Life stage	Warm Years EFH Area (km ²)	Cold Years EFH Area (km ²)	Difference EFH Area (km ²)
Arctic cod – Larvae	215,284	185,208	30,076
Arctic cod – Age-0	232,133	197,371	34,762
Arctic cod – Juvenile	262,200	265,769	(3,569)
Arctic cod – Mature	269,458	271,955	(2,497)
Saffron cod – Larvae	167,872	208,107	(40,235)
Saffron cod – Age-0	160,931	175,222	(14,291)
Saffron cod – Juvenile	162,924	161,206	1,718
Saffron cod – Mature	163,412	148,162	15,250
Snow crab – Immature	226,955	226,325	(1,425)
Snow crab – Adolescent Female	237,200	238,227	(1,027)
Snow crab – Adolescent Male	240,032	241,253	(1,221)
Snow crab – Mature Female	238,068	241,142	(3,074)
Snow crab – Mature Male	233,088	248,007	(14,919)