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Model-based Essential Fish Habitat Definitions for Gulf of Alaska Groundfish Species

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ABSTRACT

Defining essential habitats for fishes and crabs is important for managing federally managed species in Alaska waters. Species distribution models have been widely used in conservation biology and terrestrial systems to define the potential habitat for organisms of interest. The models themselves can take a number of forms, from relatively simple frameworks such as generalized linear or additive models to complex modeling frameworks such as boosted regression trees, maximum entropy models, two-stage models, or other formulations. We used a variety of modeling methods and data sets from scientific surveys and commercial fisheries to define essential habitats for more than 40 fishes and 3 crab species from the Gulf of Alaska. Adult, juvenile, larval, and egg stages were modeled in four seasons where data were available. Depth was the dominant variable determining the distribution of most adult and juvenile life history stages. Sea surface temperature was the most important variable for egg and larval stages. Using the models, maps were developed that identified local hot spots for each species and life stage. These maps will be used for marine spatial planning and assessing impacts of anthropogenic activities in Alaska's marine environment.

CONTENTS

INTRODUCTION

The 1996 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) mandates NMFS to identify habitats essential for managed species and conserve habitats from adverse effects of fishing and other anthropogenic activities. Essential Fish Habitat (EFH) is defined under the act as ‘those waters and substrates necessary to fish for spawning, breeding, feeding or growth to maturity.’ As part of this mandate, EFH descriptions for all species listed under a Fisheries Management Plan in Alaskan waters are needed. In addition, these descriptions are routinely revisited on a five-year cycle that reviews and updates EFH information (including species descriptions) with new data and research.

Essential fish habitat descriptions consist of maps of EFH and text descriptions. In Alaska, most EFH descriptions for groundfish have been limited to qualitative statements on the distribution of adult life stages. These are useful, but are relatively easily refined both in terms of spatial extent and life history stage using species distribution models and available data from a variety of sources.

Species distribution models have been widely used in conservation biology and terrestrial systems to define the potential habitat for organisms of interest (e.g. Delong and Collie 2004[1], Lozier et al. 2009, Elith et al. 2011, Sagarese et al. 2014). Recently species distribution models have been developed for coral and sponge species in the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands (Rooper et al. 2014, Sigler et al. 2015, Rooper et al. in review). These models can take a number of forms, from relatively simple frameworks such as generalized linear or additive models to complex modeling frameworks such as boosted regression trees, maximum entropy models, two-stage models, or other formulations. They can be used to predict potential habitat, probability of presence, or even abundance and they all have some features in common: 1) the underlying data consists of some type of independent variables (predictors) and a dependent response variable (presence, presence/absence, or abundance), 2) raster maps of independent variables are used to predict a response map, 3) confidence bounds on the predictions and partitioning of the data can produce test statistics useful for evaluating the model. The outputs of our species distribution models are raster maps that show the predicted abundance

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[1] DeLong, A.K. and J.S. Collie. 2004. Defining Essential Fish Habitat: A Model-Based Approach. Rhode Island Sea Grant, Narragansett, R.I. 4pp.

of a species at each of the raster cells. This type of product is useful for EFH descriptions, as it lends itself to producing maps of low/high abundance areas or hotspots of distribution and the models themselves can be used to generate the required text descriptions.

The goal of the study generating this Data Report was to produce species distribution models of EFH for all major species of groundfish and invertebrates in the Gulf of Alaska. Accompanying Data Reports will be generated for Aleutian Islands and eastern Bering Sea fishes and invertebrates. We attempted to generate models and text descriptions of EFH for each species in the Gulf of Alaska where data exists for egg, larval, juvenile, and adult life history stages in four seasons. From these we generated complementary distribution maps that showed the location of EFH. It is anticipated that this research could form a basis for future updates and integration of new data and studies.

METHODS

Area

The Gulf of Alaska continental shelf and upper continental slope represent a diverse mosaic of benthic habitats stretching from Dixon Entrance (133°W) in the southeastern Gulf of Alaska to Unimak Pass (165°W) in the Aleutian Islands. The continental shelf here ranges in width from 20 km to greater than 200 km and the continental slope is steep and features gullies and submarine canyons extending into the continental shelf (Figure 1). The Alaska Coastal Stream and Alaska Coastal Current flow westward (counter-clockwise) around the Gulf of Alaska from Dixon Entrance to the end of the Aleutian Island chain. This results in downwelling of surface water at the Alaskan coast. Seasonal freshwater discharge results in a highly stratified system in the summer, with nutrient limitation in the photic zone of the water column. The seafloor of the Gulf of Alaska is diverse, with extensive rocky substrate that has been uplifted due to tectonic activity and the retreat of glaciation. Much of the continental shelf is dominated by soft unconsolidated sediments.

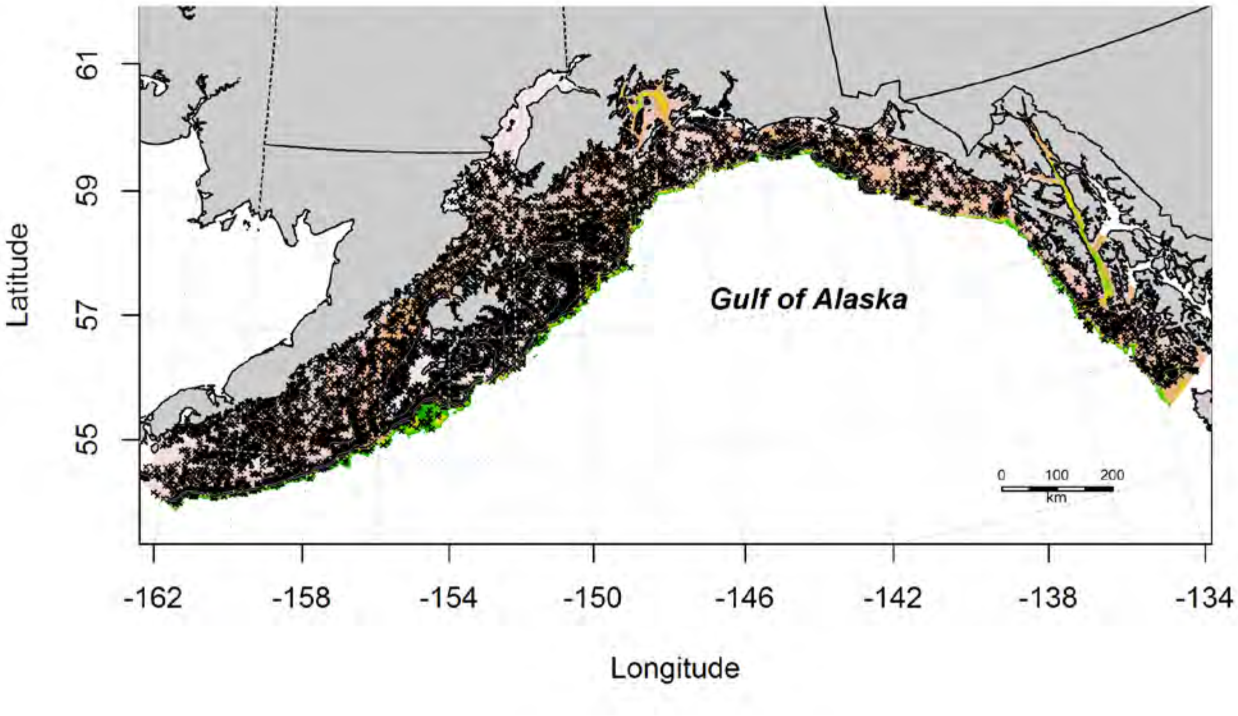

Figure 1. – Gulf of Alaska from Dixon Entrance to Unimak Pass where this modeling study was carried out. Cross-hatches indicate the locations of bottom trawl hauls from the Gulf of Alaska biennial bottom trawl survey (1993-2013).

The species and life stages of fishes and invertebrates examined for this study are included in Table 1. The data available for early life history stages (egg, larval, and early juvenile) was from the Ecosystems and Fisheries-Oceanography Coordinated Investigations (EcoFOCI) ECODAAT database. The summer distributions of late juvenile and adult life history stages were modeled using the RACE Gulf of Alaska bottom trawl survey database (RACEBASE). Seasonal adult distributions were modeled using commercial catch data from the observer Catch in Areas database (CIA). All the data was divided into four seasons for analyses: fall (October-November), winter (December-February), spring (March-May), and summer (June-September).

Table 1. Species and life history stages modeled for the Gulf of Alaska.

Species	Eggs	Larvae	Early juveniles	Late juveniles	Adults
Pollock	🟥	🟥	🟩	🟩	🟩
Pacific cod	⬜	🟥	🟩	🟩	🟩
Sablefish	⬜	🟥	🟥	🟩	🟩
Yellowfin sole	🟥	🟥	🟩	🟩	🟩
Greenland turbot	🟥	🟥	🟥	🟩	🟩
Arrowtooth flounder	🟥 Atheresthes sp. as group		🟥	🟩	🟩
Kamchatka flounder			🟥	🟩	🟩
Southern rock sole	🟥	🟥	🟥	🟩	🟩
Northern rock sole	🟥	🟥	🟩	🟩	🟩
Alaska plaice	🟥	🟥	🟩	🟩	🟩
Rex sole	🟥	🟥	🟥	🟩	🟩
Dover sole	🟥	🟥	🟥	🟩	🟩
Flathead sole	🟥	🟥	🟩	🟩	🟩
Pacific ocean perch	🟥 Sebastes sp. as group			🟩	🟩
Northern rockfish				🟩	🟩
Shortraker rockfish				🟩	🟩
Blackspotted/rougheye rockfish				🟩	🟩
Dusky rockfish				🟩	🟩
Thornyhead rockfish	⬜	⬜	🟩	🟩	🟩
Atka mackerel	⬜	🟥	🟩	🟩	🟩
Great sculpin	⬜	⬜	⬜	⬜	🟩
Yellow Irish lord	⬜	⬜	⬜	⬜	🟩
Bigmouth sculpin	⬜	⬜	⬜	⬜	🟩
Alaska skate	🟥	⬜	🟥	🟩	🟩
Bering skate	🟥	⬜	🟥	🟩	🟩
Aleutian skate	🟥	⬜	🟥	🟩	🟩
Mud skate	⬜	⬜	⬜	⬜	🟩
Pacific giant octopus	⬜	⬜	⬜	⬜	🟩
Red king crab	⬜	🟥	🟥	🟥	🟩
Blue king crab	⬜	🟥	🟥	🟥	🟩
Tanner crab	⬜	🟥	🟩	🟩	🟩
Snow crab	⬜	🟥	🟥	🟥	🟩

⬜ no data available or NA
🟥 Presence or presence absence models
🟩 Density (CPUE) models

Species distribution data – Recruitment processes data

EcoFOCI's ECODAAT database contains historical catches from across the entire Gulf of Alaska (Figure 2). The data considered includes catches from 1991 to 2013. These catches have been collected during a number of different types of surveys with different survey objectives using a variety of different gear types (e.g., bongo, neuston, and Methot nets, egg pumps, and MOCNESS). Because of this, spatial and temporal coverage of sampling across the Gulf of Alaska has been uneven and samples have been collected from a variety of depths in the water column. Ichthyoplankton samples were combined across years for these analyses since data were collected across all months and seasons of the year, although not all month-year combinations occurred in the database. Most of the ichthyoplankton samples originate from the region surrounding Kodiak Island, reflecting the EcoFOCI focus on pollock recruitment mechanism research.

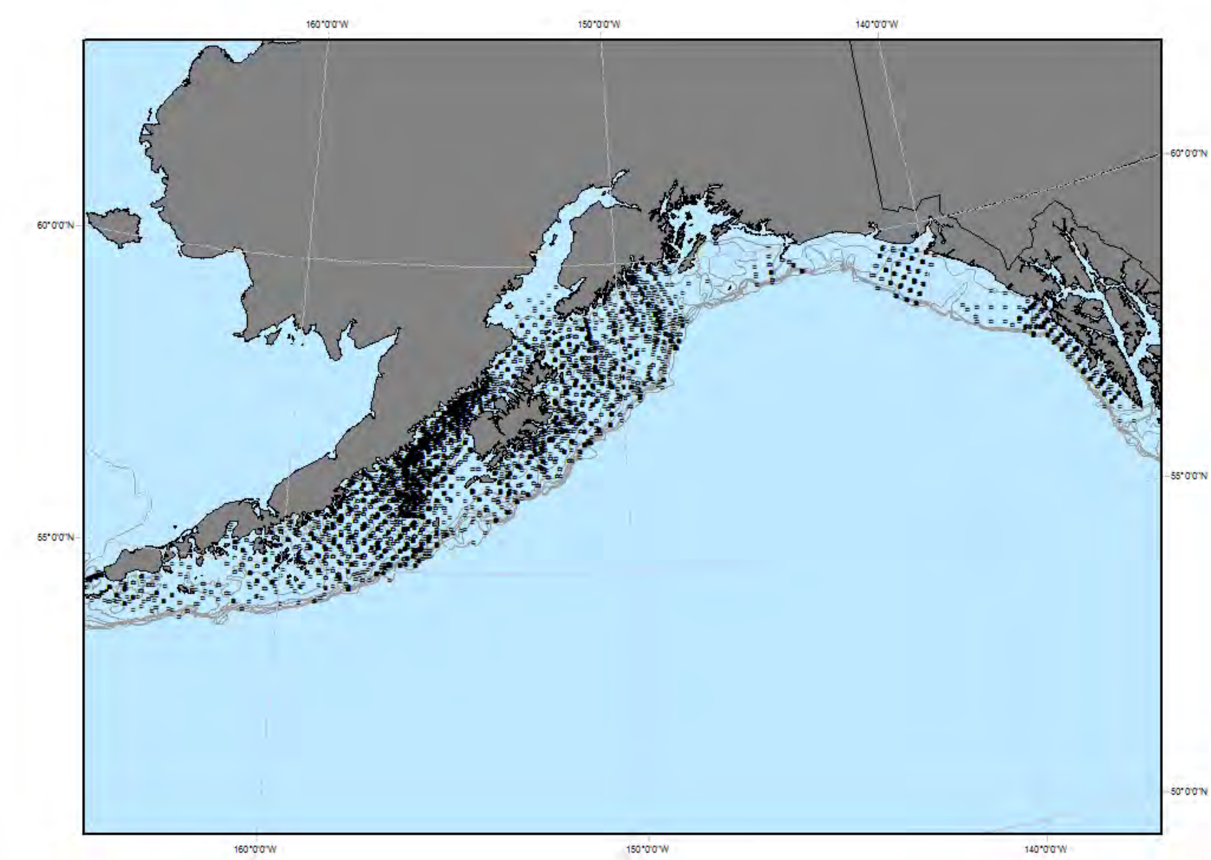

Figure 2. -- Locations (n = 8,753) of ichthyoplankton sampling stations in the Gulf of Alaska (1991-2012) from the EcoFOCI ECODAAT database.

Each species in the ECODAAT data was classified as either egg, larval, or juvenile (we considered all juveniles to be early juvenile stages, as they were collected from the water column rather than the benthos). We used these data for presence-only models where the number of presence observations in a species' life stage and season combination exceeded 50. The numbers of catches for each species, season, and life stage are shown in Table 2.

An important caveat to the species distribution models developed using the ECODAAT database is that these data were not collected over the entire area of the Gulf of Alaska. Typically, these data were collected from a smaller regional survey grid, rather than conducted over a regular grid. The distribution of sampling effort should be considered when drawing conclusions from maps produced from these data.

Table 2. Numbers of presence records for species and life history stages available in the ECODAAT database from the Gulf of Alaska. Some species were grouped by genus where the species were not individually identifiable. Maximum entropy modeling was conducted for species, season, and life history stages where the number of presence observations exceeded 50.

		Fall			Spring			Summer			Winter	
Species	Eggs	Larvae	Early juveniles	Eggs	Larvae	Early juveniles	Eggs	Larvae	Early juveniles	Eggs	Larvae	Early juveniles
Alaska plaice (*Pleuronectes quadrituberculatus*)	--	--	--	493	218	--	12	54	--	--	--	--
Atheresthes sp.	--	--	--	4	1136	1	--	228	7	39	52	--
Atka mackerel (*Pleurogrammus monopterygius*)	--	--	--	--	6	1	--	--	--	--	9	--
Dover sole (*Microstomus pacificus*)	--	--	--	1539	133	--	277	125	--	6	--	--
Greenland turbot (*Reinhardtius hippoglossoides*)	--	--	--	--	3	--	--	--	--	--	--	--
Hemitripterus sp.	--	--	--	--	220	17	--	28	4	--	8	--
Hippoglossoides sp.	1	--	--	3833	2699	--	340	610	9	1	--	--
Yellowfin sole (*Limanda aspera*)	--	--	--	15	2	--	92	41	--	--	--	--
Pacific cod (*Gadus macrocephalus*)	--	--	--	9	2174	--	2	223	74	--	--	--
Pollock (*Gadus chalcogramma*)	8	--	--	2996	4283	2	181	569	122	3	1	--
Rex sole (*Glyptocephalus zachirus*)	2	--	--	1472	182	--	331	172	--	--	--	--
Rock sole (*Lepidopsettia* sp.)	--	3	--	--	2010	--	--	663	1	--	1	--
Sablefish (*Anoplopoma fimbria*)	--	--	--	3	302	1	1	50	1	8	--	--
Rockfish (*Sebastes* sp.)	--	6	--	--	1567	--	--	1382	18	--	--	--
Thornyhead (*Sebastolobus* sp.)	--	--	--	31	4	--	15	26	--	--	--	--

Species distribution data – Groundfish bottom trawl surveys

The modeling analyses also included data collected during bottom-trawl surveys of the Gulf of Alaska ecosystem. These data were the most comprehensive and useful of the three types of data analyzed, as they are all from the summer season and are conducted with a rigorous statistical design. The National Marine Fisheries Service (NMFS), Alaska Fisheries Science Center (AFSC), has conducted standard bottom-trawl surveys in these ecosystems since 1984 (von Szalay et al. 2012, von Szalay et al. 2014). We used surveys that were conducted triennially between 1993 and 1999 and biennially thereafter until 2013 (n = 11 surveys). The Gulf of Alaska survey is conducted on a 5 km by 5 km grid superimposed over the survey area. Each year of the survey between 401-753 grid cells were randomly chosen and a bottom trawl haul was placed within the 5 km by 5 km boundaries of the selected grid cell. In the Gulf of Alaska, grid cells are chosen according to a stratified random sampling protocol and include a random mix both previously sampled and unsampled grid cells. For this analysis, AFSC bottom-trawl data in the Gulf of Alaska region (Unimak Pass to Dixon Entrance) from 1993 to 2013 were combined across years. The 1993 bottom-trawl survey was the first for which accurate temperature and depth data were available for calculating water-column properties used in the modeling.

The Gulf of Alaska bottom trawl survey utilizes a poly Nor'Eastern high-opening bottom trawl with 24.2 m roller gear constructed with 36 cm rubber bobbins separated by 10 cm rubber disks (Stauffer 2004). Trawl tows were conducted at a target speed of 5.6 km h–1 (3 knots) for 15 (since 1996) or 30 min (prior to 1996). Bottom contact and net dimensions were recorded throughout each trawl using net mensuration equipment. The net width averaged 15.9 m across all bottom trawl hauls. For these analyses, records were only used if trawl performance was satisfactory and if the distance fished, geographic position, average depth, and water temperature were recorded. Tows were deemed satisfactory if the net opening was within a predetermined normal range, the roller gear maintained contact with the seafloor, and the net suffered little or no damage during the tow. Data from a total of 7,314 bottom-trawl tows were used for this analysis. In 504 of these trawl hauls, no net width was recorded and modeled value was substituted.

All fishes and invertebrates captured during a survey tow were sorted either by species or into larger taxonomic groups and the total weight in the catch was determined. Catch per unit effort (CPUE; number$\cdot$ha^{-1}) for each taxonomic group was calculated using the area swept which was computed from the net width for each tow multiplied by the distance towed recorded with a GPS. For some species both juvenile and adult sizes were captured during the bottom trawl survey. In these cases an approximate length at first maturity was used to partition the catches proportionally into juvenile and adult stages (Table 3). For some species only a subset of years was used in the modeling due to taxonomic changes that have occurred throughout the time series. For example, dusky and dark rockfishes were considered one species prior to the 1996 survey, so only data from surveys beginning in this year were used to model these two species.

Table 3. Species modeled using bottom trawl survey data. Years included in each of the modeling efforts, the percentage of positive catches (frequency of occurrence) in the bottom trawl hauls for juvenile and adult life history stages, and the maximum size considered to be the juvenile stage is shown.

Species	Years modeled	Percent positive catches - Juveniles	Percent positive catches - adults	Maximum juvenile length (cm)
Alaska plaice (*Pleuronectes quadrituberculatus*)	All	0.5	5.1	28
Alaska skate (*Bathyraja parmifera*)	1990-	1.2	1.0	92
Aleutian skate (*Bathyraja aleutica*)	1990-	6.6	1.8	132
Arrowtooth flounder (*Atheresthes stomias*)	1993-	75.6	85.9	35
Atka mackerel (*Pleurogrammus monopterygius*)	All	0.4	9.8	27
Bering skate (*Bathyraja interrupta*)	1990-	5.0	4.6	69
Bigmouth sculpin (*Hemitripterus bolini*)	All	1.4	2.8	51
Black rockfish (*Sebastes melanops*)	All	0.2	0.6	40
Blackspotted rockfish (*Sebastes melanostictus*)	2007-	4.7	2.5	43
Canary rockfish (*Sebastes pinniger*)	All	0.3	0.5	47
Dark rockfish (*Sebastes ciliatus*)	1996-	0.9	0.5	42
Darkblotched rockfish (*Sebastes crameri*)	All	0.5	0.3	38
Dover sole (*Microstomus pacificus*)	All	34.7	38.9	38
Dusky rockfish (*Sebastes variabilis*)	1996-	1.5	12.0	29
Flathead sole (*Hippoglossoides elassodon*)	All	38.1	49.2	29
Great sculpin (*Myoxocephalus polyacanthocephalus*)	All	3.8	3.9	51
Greenland turbot (*Reinhardtius hippoglossoides*)	All	--	0.0	65
Greenstriped rockfish (Sebastes elongatus)	All	0.7	1.3	23
Harlequin rockfish (*Sebastes variegatus*)	All	3.1	5.0	23
Kamchatka flounder (*Atheresthes evermanni*)	1993-	0.1	0.2	52
Longspine thornyhead (*Sebastolobus altivelis*)	All	--	1.1	
Mud skate (*Bathyraja taranetzi*)	1990-	0.0	--	62
Northern rock sole (*Lepidopsetta polyxystra*)	2001-	21.9	26.2	30
Northern rockfish (*Sebastes polyspinis*)	All	3.2	15.1	26
Octopus sp. (*Octopus dofleini*)	All	--	4.4	
Pacific cod (*Gadus macrocephalus*)	All	29.7	56.7	42
Pacific ocean perch (*Sebastes alutus*)	All	24.2	33.0	25
Pollock (*Gadus chalcogramma*)	All	49.5	51.4	37
Pygmy rockfish (*Sebastes wilsoni*)	All	--	0.8	
Quillback rockfish (*Sebastes maliger*)	All	0.2	0.7	29
Redbanded rockfish (*Sebastes babcocki*)	All	8.6	3.2	42
Redstripe rockfish (*Sebastes proriger*)	All	1.0	2.3	28
Rex sole (*Glyptocephalus zachirus*)	All	28.1	59.5	24
Rosethorn rockfish (*Sebastes helvomaculatus*)	All	1.5	2.0	21
Rougheye rockfish (*Sebastes aleutianus*)	2007-	7.4	3.3	43
Sablefish (*Anoplopoma fimbria*)	All	6.8	35.9	40
Sharpchin rockfish (*Sebastes zacentrus*)	All	5.8	4.8	25
Shortraker rockfish (*Sebastes borealis*)	All	2.6	8.1	44
Shortspine thornyhead (*Sebastolobus alascanus*)	All	19.4	23.6	21
Silvergray rockfish (*Sebastes brevispinis*)	All	1.7	5.5	40
Southern rock sole (*Lepidopsetta bilineata*)	2001-	23.2	34.2	30
Splitnose rockfish (*Sebastes diploproa*)	All	0.4	0.0	27
Widow rockfish (*Sebastes entomelas*)	All	0.0	0.3	36
Yellow Irish lord (*Hemilepidotus jordani*)	All	2.5	12.5	22
Yelloweye rockfish (*Sebastes ruberrimus*)	All	0.8	2.0	45
Yellowfin sole (*Limanda aspera*)	All	3.4	5.8	25
Yellowtail rockfish (*Sebastes flavidus*)	All	0.1	0.6	39
	Standard GAM model			
	Hurdle GAM model			
	Maximum entropy model			

Species distribution data – Commercial catch (observer) data

Data from the CIA observer database was used to model adult life history stages of fishes caught in commercial catches during the non-summer seasons (Table 4). The CIA data was provided by John V. Olson and Steve Lewis (AKRO). The data from observed hauls regardless of the type of fishing gear were combined across years for analysis. We used the observations of catch by species in the data for MaxEnt (presence-only) models where the number of presence observations in a species exceeded 50. The numbers of catches for each species and season are shown in Table 4. All of these fish and invertebrates were assumed to be adult life history stages. Only the fall, winter, and spring seasons were considered, as the summer distributions were modeled using bottom trawl survey data.

An important caveat to the species distribution models developed using the CIA database is that for most species, the distribution of catches represents the distribution of fishing activity. So, instead of being a regular survey conducted over a regular grid, these observations are typically clustered around areas of high catches for target species. As such, they should be viewed with some caution compared to the bottom trawl survey distribution maps.

Table 4. Numbers of presence records by species available from the CIA database in the Gulf of Alaska. Maximum entropy modeling was conducted for species and season where the number of presence observations exceeded 50.

Species	Fall	Winter	Spring
Alaska plaice (*Pleuronectes quadrituberculatus*)	2	15	37
Alaska skate (*Bathyraja parmifera*)	289	178	149
Aleutian skate (*Bathyraja aleutica*)	574	363	993
Arrowtooth flounder (*Atheresthes stomias*)	1623	1315	5678
Atka mackerel (*Pleurogrammus monopterygius*)	275	104	283
Bigmouth sculpin (*Hemitripterus bolini*)	36	74	68
Black rockfish (*Sebastes melanops*)	12	21	34
Blackspotted, rougheye rockfish (*Sebastes aleutianus, S. melanostictus*)	182	98	2006
Blue king crab (*Paralithodes platypus*)	--	--	5
Canary rockfish (*Sebastes pinniger*)	3	1	12
Dark rockfish (*Sebastes ciliatus*)	49	24	33
Darkblotched rockfish (*Sebastes crameri*)	--	3	13
Dover sole (*Microstomus pacificus*)	400	103	1337
Dusky rockfish (*Sebastes variabilis*)	369	223	462
Flathead sole (*Hippoglossoides elassodon*)	889	849	2403
Golden king crab (*Lithodes aequispina*)	1	--	25
Great sculpin (*Myoxocephalus polyacanthocephalus*)	3	38	25
Greenland turbot (*Reinhardtius hippoglossoides*)	7	3	67
Harlequin rockfish (*Sebastes variegatus*)	47	8	65
Kamchatka flounder (*Atheresthes evermanni*)	38	5	124
Longspine thornyhead (*Sebastolobus altivelis*)	--	--	62
Mud skate (*Bathyraja taranetzi*)	6	2	6
Northern rock sole (*Lepidopsetta polyxystra*)	296	417	733
Northern rockfish (*Sebastes polyspinis*)	383	261	610
Octopus sp. (*Octopus dofleini*)	107	292	137
Pacific cod (*Gadus macrocephalus*)	1643	2277	2708
Pacific ocean perch (*Sebastes alutus*)	245	153	965
Pollock (*Gadus chalcogramma*)	1084	1039	2137
Pygmy rockfish (*Sebastes wilsoni*)	--	--	2
Quillback rockfish (*Sebastes maliger*)	6	2	5
Red king crab (*Paralithodes camtschaticus*)	3	--	8
Redbanded rockfish (*Sebastes babcocki*)	41	20	313
Redstripe rockfish (*Sebastes proriger*)	28	3	14
Rex sole (*Glyptocephalus zachirus*)	490	481	2083
Rosethorn rockfish (*Sebastes helvomaculatus*)	4	--	14
Sablefish (*Anoplopoma fimbria*)	645	127	4833
Sharpchin rockfish (*Sebastes zacentrus*)	10	1	54
Shortraker rockfish (*Sebastes borealis*)	215	65	2173
Shortspine thornyhead (*Sebastolobus alascanus*)	249	62	4169
Silvergray rockfish (*Sebastes brevispinis*)	7	14	15
Snow crab (*Chionoecetes opilio*)	1	9	6
Southern rock sole (*Lepidopsetta bilineata*)	290	703	790
Splitnose rockfish (*Sebastes diploproa*)	--	4	--
Tanner crab (*Chionoecetes tanneri*)	141	329	576
Widow rockfish (*Sebastes entomelas*)	--	--	2
Yellow Irish lord (*Hemilepidotus jordani*)	73	170	126
Yelloweye rockfish (*Sebastes ruberrimus*)	321	59	201
Yellowfin sole (*Limanda aspera*)	1	59	24
Yellowtail rockfish (*Sebastes flavidus*)	1	--	2

Habitat-related variables

Independent variables for modeling included the standard suite of habitat variables typically collected on the bottom trawl survey as well as a few derived and modeled variables (Table 5). These variables were chosen for their availability and potential value to describe the distribution of crabs and fishes from historical studies.

Early life history stages of fishes were generally collected in pelagic waters. Therefore, surface water temperature, surface current speed, and surface current direction were chosen as potential variables to explain early life history stage distributions. In addition, surface current direction variability was used as an indication of potential eddy vorticity or other current variability processes that might be present. These variables were derived from ROMS model runs from 1969-2005 provided by A. Hermann (Danielson et al. 2011). The monthly data values were originally on a 10 km by 10 km grid. These values were interpolated to a 1 km by 1 km grid via inverse distance weighting and used for modeling by season. Additional variables used for modeling the early life history stages of fish species included the depth, slope, color, and tidal current.

A bathymetry raster for the entire Gulf of Alaska region was produced from data provided by Zimmermann and Prescott (2014) and Zimmermann (unpublished data; Figure 3). Bathymetric point data were derived from soundings (n > 2.1 million soundings) on NOS smooth sheets that were digitized and compiled according to the methods in Zimmermann and Benson (2013). These point data were linearly interpolated from a triangular irregular network (TIN) layer to a 100 m by 100 m raster grid. The interpolation was conducted using the Spatial Analyst package in ArcGIS software (ESRI 2009). Slope was derived from the 100 m by 100 m bathymetry raster for each raster grid cell and was computed as the maximum difference between the depth of a cell and its surrounding cells. The computation of slope was completed using the *raster* package[2] in R software (R Core Development Team 2013). For the analysis of early life history data, each of these two layers was averaged to a 1 km by 1 km grid.

To reflect average ocean productivity (g C m^{-2} day^{-1}) at each of the bottom trawl survey sites, we used MODIS ocean color data for five months (May-September) encompassing the spring and summer phytoplankton blooms over eight years (2003-2011) in the Gulf of Alaska region (Behrenfeld and Falkowski 2007). These data were downloaded from the Oregon State University Ocean Productivity website[3] and were averaged by cell and by month and then averaged again by cell and by year to account for differences in the number of samples within each cell. The averages were then interpolated to a 1 km by 1 km raster grid using inverse distance weighting (Figure 3).

Tidal speeds were estimated for 368 consecutive days (e.g., January 1st, 2009 to January 3rd, 2010) using a tidal inversion program parameterized for the Gulf of Alaska and Aleutian Islands on a 1 km by 1 km grid (Egbert and Erofeeva 2002). This tidal prediction model was used to produce a series of one lunar year of tidal currents for spring and neap cycles at each bottom trawl survey location. The annual maximum of the series of predicted tidal current was then extracted for the position of each bottom trawl survey haul. This value was used as a habitat variable in the modeling. Maximum tidal currents at each bottom trawl survey site were also interpolated to the entire Gulf of Alaska using ordinary kriging and an exponential semi-variogram. When evaluated using leave-one-out cross-validation, the kriging model fit the observations well (n = 3,051, mean squared error = 407, $R^2 = 0.93$). The kriging model was used

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[2] R v3.0.1; Hijams, R.J., J. van Etten, M. Mattiuzzi, M. Sumner, J.A. Greenberg, O.P., Lamigueiro, A. Bevan, E.B. Racine, and A. Shortridge. 2015. Geographic data analysis and modeling: package ‘raster’ version 2.3-24. 232 pages.

[3] http://www.science.oregonstate.edu/ocean.productivity/

to interpolate a raster of maximum current values on a 1 km by 1 km cell size that was used for modeling early life history stages (Figure 3).

For modeling late juvenile and adult fish distribution from bottom trawl survey hauls, the surface data derived from the ROMS models were not used. Additionally, the raster used for prediction was the smaller 100 m by 100 m grid for the depth, slope, maximum tidal current, and ocean color variables.

Haul position and depth were collected during each bottom trawl haul. A start and end position for the vessel during the on-bottom portion of the trawl haul were collected using the vessel-mounted GPS receiver. Vessel position was corrected for the position of the bottom trawl itself by triangulating how far the net was behind the vessel (based on the seafloor depth and the wire out) and subtracting this distance from the vessel position in the direction of the bottom trawl haul. We assumed that the bottom trawl was directly behind the vessel during the tow and that all bottom trawl tows were conducted in a straight line from the beginning to the end point. The mid-point of the start and end positions of the net was used as the location variable in the modeling. The longitude and latitude data for each tow (and all other geographical data including the raster layers described below) were projected into Alaska Albers Equal Area Conic projection (center latitude = 50°N and center longitude = 154°W) and degrees of latitude and longitude were transformed into 100 m by 100 m square grids of eastings and northings for modeling. The location variable was used to capture any significant spatial trends across the Gulf of Alaska region in coral and sponge bottom trawl survey catches.

The depth for each bottom trawl haul was measured with a SeaBird SBE-39 microbathythermograph attached to the headrope of the net and added to the measured net height. Mean depth during the on bottom portion of the trawl haul was calculated for inclusion as an explanatory variable in the modeling. A bathymetry raster for the entire Gulf of Alaska region was also produced for this analysis (Zimmermann and Prescott 2014, Zimmermann, unpublished data). This raster was used for prediction, but not for parameterizing the models. Bathymetric point data was derived from soundings (n > 2.1 million soundings) on NOS smooth sheets that were digitized and compiled according to the methods in Zimmermann and Benson (2013). This point data was linearly interpolated from a triangular irregular network (TIN) layer to a 100 m by 100 m raster grid. This interpolation was conducted using the Spatial Analyst package in ArcGIS software (ESRI 2009).

Slope was derived from the 100 m by 100 m bathymetry raster. Slope for each raster grid cell was computed as the maximum difference between the depth at a cell and its surrounding cells. Slope was computed using the *raster* package in R software (R Core Development Team 2013). The mean slope underneath each bottom trawl tow path was used as habitat variables in the modeling. The 100 m by 100 m raster layer of slope (Figure 3) was used for prediction.

The average summer temperature at each site was estimated from data collected during Gulf of Alaska bottom trawl surveys from 1996-2013. Bottom temperatures are collected during each bottom trawl tow using the SBE-39 attached to the headrope of the net. Mean bottom temperatures for each haul were interpolated to the 100 m by 100 m grid for the entire Gulf of Alaska region. These data were interpolated using ordinary kriging (Venables and Ripley 2002) with an exponential semi-variogram model. This resulted in a single temperature raster layer that reflects the average temperature conditions in surveys from 1996-2013 (Figure 3). When evaluated using leave-one-out cross-validation, the kriging model was a statistically significant fit to the observations (n = 2,814, mean squared error = 0.19, R^2 = 0.38), capturing the spatial trend in the temperature data. The temperature data used in our models were primarily designed to reflect long-term averages that could be compared spatially to the distribution of corals and sponges. Mean bottom temperature underneath each bottom trawl tow path was used as a habitat variable in the modeling. The 100 m by 100 m raster layers of average temperature were used for prediction.

Two measures of water movement and its potential interaction with the seafloor were used as habitat variables in modeling and prediction. The first variable was the maximum tidal speed at the site of each bottom trawl haul. Tidal speeds were estimated for 368 consecutive days (January 1st, 2009 to January 3rd, 2010) using a tidal inversion program parameterized for the Gulf of Alaska and Aleutian Islands on a 1 km by 1 km grid (Egbert and Erofeeva 2002). This tidal prediction model was used to produce a one lunar year series of tidal currents for spring and neap cycles at each bottom trawl survey location. The maximum of the series of predicted tidal current was then extracted for the position of each bottom trawl survey haul. This maximum value was used as a habitat variable in the modeling. Maximum tidal current at each bottom trawl survey site were also interpolated to the entire Gulf of Alaska using ordinary kriging and an exponential semi-variogram. When evaluated using leave-one-out cross-validation, the kriging model fit the observations very well (n = 3051, mean squared error = 407, R^2 = 0.93). The kriging model was then used to interpolate a raster of maximum current values on a 100 m by 100 m cell size that was used for prediction (Figure 3).

The second water movement variable was the predicted bottom water layer current speed from ROMS model runs from 1969-2005 (Danielson et al. 2011). This long-term current speed and direction were available as points on a 10 km by 10 km grid. The ROMS model was based on a three-dimensional grid with 60 depth tiers for each grid cell. For example, a point at 60 m water depth would have 60 depth bins at 1 m intervals, while a point at 120 m depth would have 60 depth bins at 2 m depth intervals, etc. The current speed and direction for the deepest depth bin at each point (closest to the seafloor) was used in this analysis. This regularly spaced data was interpolated to a 100 m by 100 m cell size raster covering the entire Gulf of Alaska using inverse distance weighting (Figure 3). The values from this raster at each of the bottom trawl survey haul locations were extracted and the mean value computed for the path of each bottom trawl survey tow to be used for model prediction.

To reflect average ocean productivity (g C m^{-2} day^{-1}) at each of the bottom trawl survey sites, we used MODIS ocean color data for five spring-summer months (May-September) that encompass the spring and summer phytoplankton blooms over eight years (2003-2011) for the Gulf of Alaska region (Behrenfeld and Falkowski 2007). These data were downloaded from the Oregon State University Ocean Productivity website. These data were averaged by cell and by month and then averaged again by cell and by year (to account for differences in the number of samples within each cell). The averages were then interpolated to 100 m by 100 m raster grids using inverse distance weighting (Fig. 2). The mean value in this grid underlying each bottom trawl survey tow was extracted from this raster. The raster was used for prediction.

The final variables included in the modeling of bottom trawl survey data were the catches of structure forming invertebrates (corals, sponges and pennatulaceans). The presence of each of these categories of invertebrates was a binomial (presence or absence) term in the model. The prediction was accomplished by using the prediction surfaces from distribution models for each of these species (Rooper et al. unpublished manuscript).

For commercial catch data (observer data), the same variables as were used for the bottom trawl survey models (with the exception of the structure forming invertebrate layers; Table 5).

There was some collinearity in the habitat variables included in the model (Table 6). The largest correlations were between latitude and longitude (r = 0.60) and slope and depth (r = 0.53). The remaining pairwise correlations among variables were < 0.5. Variance inflation factors were calculated using the method of Zaur et al. (2009) for each of the variables to be included in the modeling, resulting in values ranging from 1.1 to 3.9. These values were all acceptable (below 5.0) allowing inclusion of all variables in the modeling. Thus, the habitat variables were all included in the models of habitat suitability, presence or absence and abundance of the coral and sponge groups.

Table 5. Variables used in modeling the distributions of fishes and invertebrates in the Gulf of Alaska.

Variable	Unit	Definition	Interpolation method	Source	
Position	eastings, northings	Latitude and longitude of bottom trawl hauls in Alaska Albers projection corrected for the position of the trawl net relative to the vessel	--	DGPS collected at bottom trawl hauls	
Depth	m	Bathymetry of the seafloor based on digitized and position corrected NOS charts	Linear interpolation	Mean depth of bottom trawl hauls (modeling), Zimmermann, M, unpublished data (prediction)	
Slope	percent	Maximum difference between a depth measurement and its adjoining cells	--	Zimmermann, M, unpublished data	
Bottom temperature	°C	Mean summer bottom temperature for the region measured during bottom trawl surveys from 1996-2010	Ordinary kriging	Temperature data collected at bottom trawl hauls	
Surface temperature	°C	Ocean current speed predicted from the ROMS model during the years 1970-2004 and averaged on a 10 km by 10 km grid	Inverse distance weighting	Danielson et al. 2011	1
Ocean color	Carbon*m^{-2}*day^{-1}	Net primary production in surface waters in May to September averaged by 1080 by 2160 grid cells then averaged across years (2002-2011)	Inverse distance weighting	Behrenfeld and Falkowski 1997	
Mean bottom ocean current	m*sec^{-1}	Seafloor ocean current speed predicted from the ROMS model during the years 1970-2004 and averaged on a 10 km by 10 km grid	Inverse distance weighting	Danielson et al. 2011	
Maximum tidal current	cm*sec^{-1}	Maximum of the predicted tidal current at each bottom trawl location over a 1-year cycle	Ordinary kriging	Egbert and Erofeeva 2000	
Mean surface ocean current speed	m*sec^{-1}	Surface ocean current speed predicted from the ROMS model during the years 1970-2004 and averaged on a 10 km by 10 km grid	Inverse distance weighting	Danielson et al. 2011	1
Mean surface ocean current direction	angle	Surface ocean current direction predicted from the ROMS model during the years 1970-2004 and averaged on a 10 km by 10 km grid	Inverse distance weighting	Danielson et al. 2011	1
Surface ocean current direction variability	--	Variability in surface ocean current direction predicted from the ROMS model during the years 1970-2004 and averaged on a 10 km by 10 km grid	Inverse distance weighting	Danielson et al. 2011	1
Coral presence or absence	--	Coral presence or absence in bottom trawl catch and raster of predicted presence or absence of coral	--	Catch data from bottom trawl hauls (modeling), Rooper et al. (in review) (prediction)	2
Sponge presence or absence	--	Sponge presence or absence in bottom trawl catch and raster of predicted presence or absence of Sponge	--	Catch data from bottom trawl hauls (modeling), Rooper et al. (in review) (prediction)	2
Pennatulacean presence or absence	--	Pennatulacean presence or absence in bottom trawl catch and raster of predicted presence or absence of Pennatulacean	--	Catch data from bottom trawl hauls (modeling), Rooper et al. (in review) (prediction)	2

[1] Used to model egg, larval and early juvenile stages only

[2] Used to model bottom trawl survey data only

Table 6. Cross-correlations among explanatory variables and variance inflation factors for Gulf of Alaska data.

			Fall	Winter	Spring	Summer
Variable	Variance Inflation Factor (Trawl survey data)	Variance Inflation Factor (CIA data)	Variance Inflation Factor (FOCI data)	Variance Inflation Factor (FOCI data)	Variance Inflation Factor (FOCI data)	Variance Inflation Factor (FOCI data)
Depth	1.90	1.89	1.66	1.60	1.63	1.76
Slope	1.58	1.56	1.53	1.55	1.54	1.54
Temperature	1.54	1.53				
Ocean color	1.17	1.16	1.34	1.12	1.21	1.37
Current speed	1.28	1.28				
Tidal current	1.28	1.25	1.24	1.27	1.22	1.17
Coral	1.04					
Sponge	1.08					
Sea whips	1.01					
Surface temperature			2.81	1.78	1.22	1.42
Surface current speed			1.10	1.11	1.16	1.44
Surface current variability			2.54	1.84	1.16	1.48

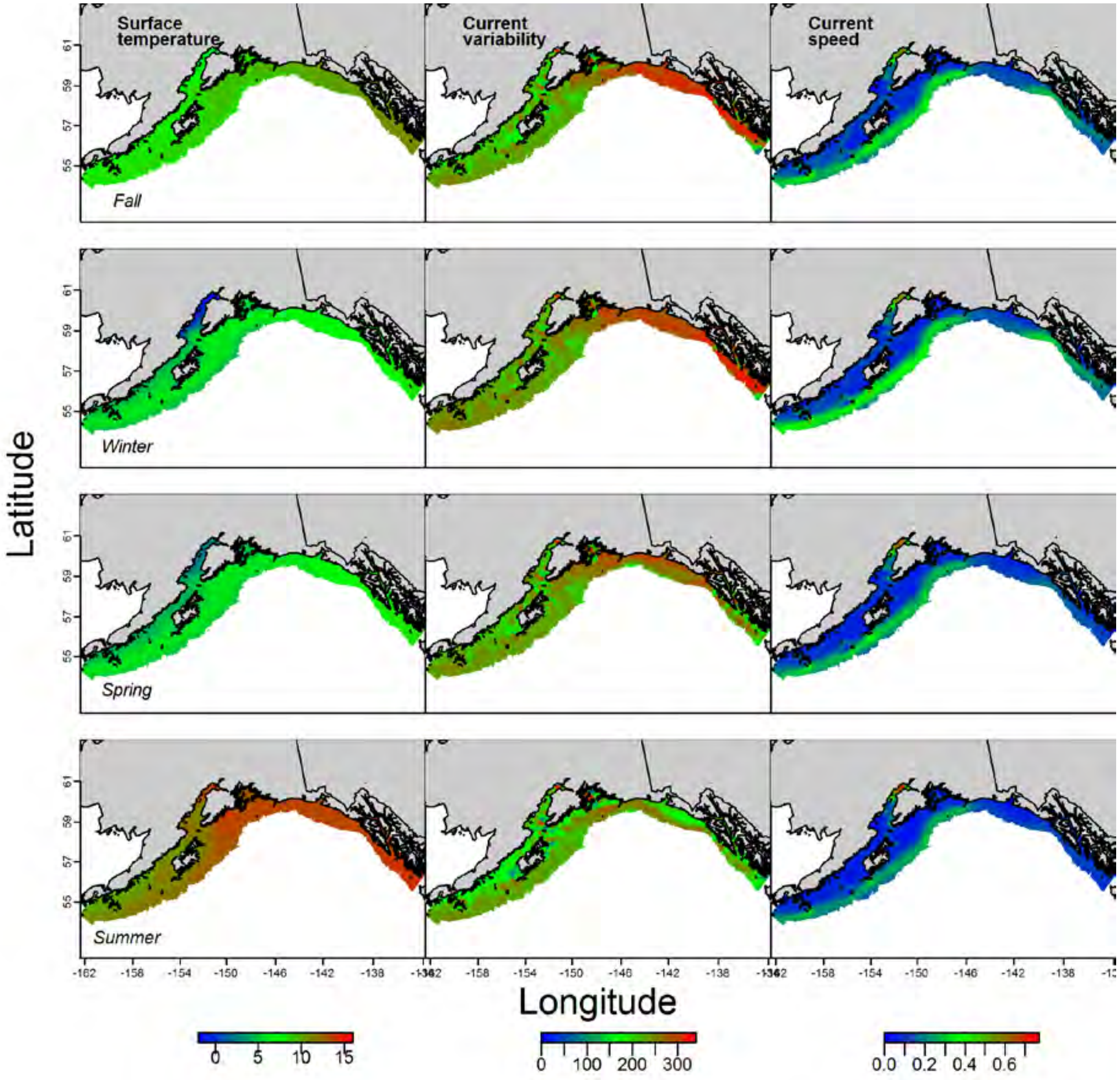
Surface temperature
Current variability
Current speed
Fall
Winter
Spring
Summer
Latitude
55
57
59
61
Longitude
-162
-158
-154
-150
-146
-142
-138
0
5
10
15
0
100
200
300
0.0
0.2
0.4
0.6

Figure 3. -- Seasonal habitat covariate rasters from EcoFOCI ichthyoplankton surveys of early life history stages of fishes in the Gulf of Alaska.

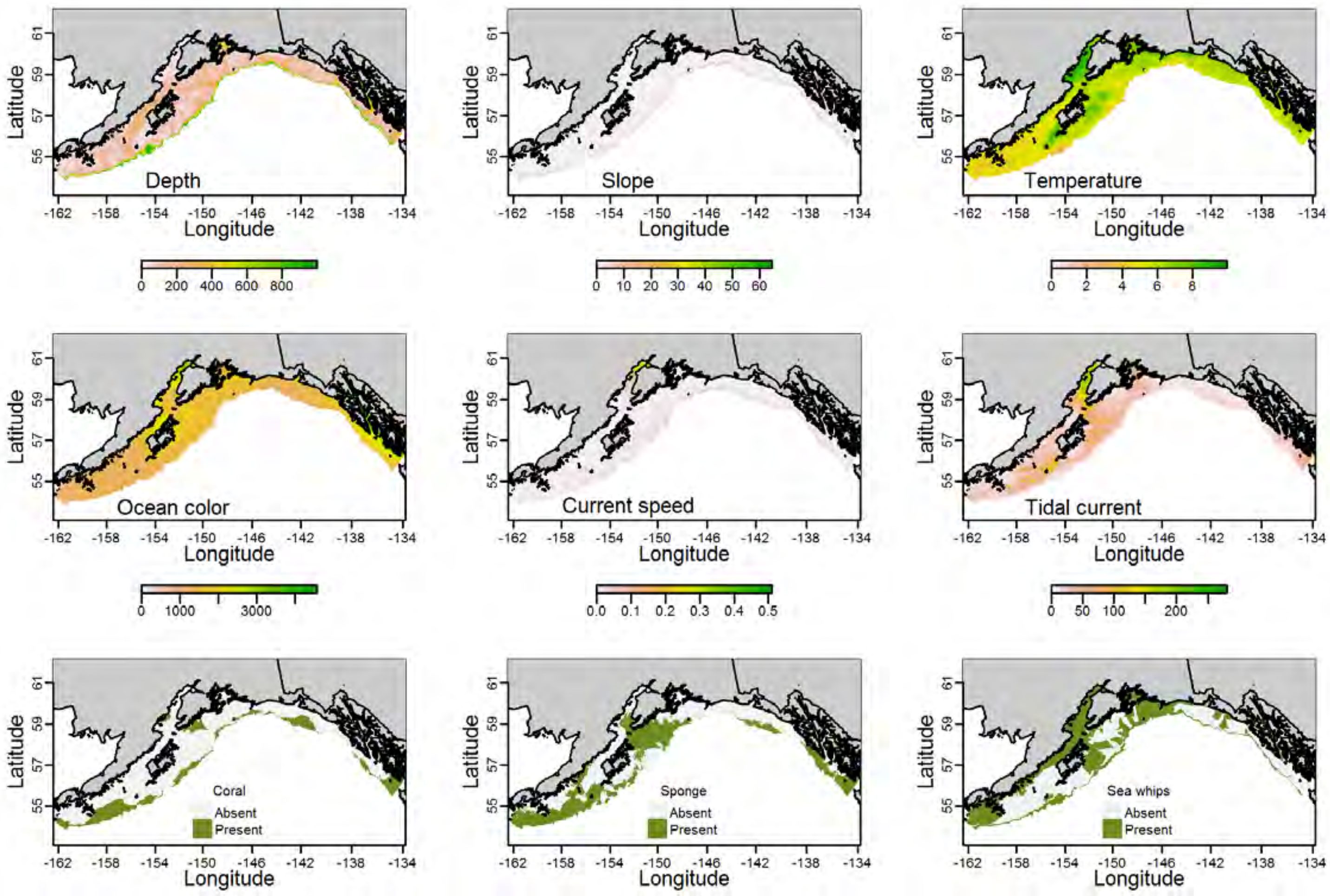

Figure 4. -- Habitat covariate rasters used to parameterize species distribution models in the Gulf of Alaska.

Modeling Methods – Recruitment processes data

The maximum entropy (MaxEnt) modeling method was used for estimating species distribution for early life history stages in the ECODAAT database (Phillips et al. 2006, Elith et al. 2011). It was implemented in R software using the *dismo* package[4]. MaxEnt models use only presence observations and are based on raster grids of explanatory variables (habitat variables) and point observations of presence. The model predicts the probability of suitable habitat based on habitat related variables (i.e. given the depth, temperature, slope and current speed at each grid cell – what is the probability that this is suitable for a canary rockfish?), not probability of presence. Separate training (80%) and testing (20%) data were randomly selected for MaxEnt model developed in order to assess model performance.

Modeling Methods – Bottom trawl survey data

Three types of distribution modeling were used for the bottom trawl survey data based on the frequency of occurrence for each species in the catch. For species that occurred in > 30% of bottom trawl hauls, such as arowtooth flounder (Table 3), a standard Generalized Additive Modeling (GAM) method was used to produce maps of predicted density. Generalized additive models (Hastie and Tibshirani 1990) using the *mgcv* package[5] in R software (R Core Development Team 2013) were used to predict the dependent variables with the suite of untransformed habitat variables included. In each case the basis degrees of freedom used in the smoothing function was limited to ≤ 4 for univariate variables and ≤ 30 for the bivariate term

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[4] R, v3.0.1; Hijams, R.J., S. Phillips, J. Leathwick, and J. Elith. 2014. Species distribution modeling: package ‘dismo’ version 1.0-5. 65 pages.

[5] R, v3.0.1; Wood, S. 2014. Mixed GAM computation vehicle with GCV/AIC/REML smoothness estimation: package ‘mgcv’ version 1.8-4. 243 pages.

(location). Insignificant terms were sequentially removed. In this case model terms were removed until there was no reduction in the Akiake Information Criterion (AIC) values (Wood 2006). For each species, the model with the lowest AIC score was deemed the best fitting model and used for further prediction and model validation. For the standard GAM's, the CPUE was fourth-root transformed prior to analyses.

For species where frequency of occurrence was between 10% and 30% a hurdle model (Cragg 1971, Potts and Elith 2006) predicting spatial distribution of fishes was used (Table 3). Hurdle models predict the spatial distribution of abundance (or in this case abundance and height) in three stages: 1) probability of presence is predicted from presence-absence data using a GAM and binomial distribution for each species; 2) a threshold presence probability is determined that defines presence or absence of the species; 3) a separate GAM is constructed that predicts abundance by modeling the forth-root transformed CPUE data from the bottom trawl survey where the species was present in the catch. As for the standard GAM's above, the number of inflection points were limited and insignificant terms were sequentially removed to determine the best-fitting model.

For species with < 10% frequency of occurrence, but > 50 presence observations, the MaxEnt methodology was used to develop suitable habitat models, as for the EcoFOCI data above.

For all models, separate training (80%) and testing (20%) data were randomly selected from the total available trawl hauls for assessing the performance of each type of modeling (Figure 3). The training and testing data sets were the same across all species for the analysis of bottom trawl survey data.

Modeling Methods – Commercial catch (observer) data

The maximum entropy (MaxEnt) modeling method was used for estimating species distribution for commercial catch data in the CIA database (Phillips et al. 2006, Elith et al. 2011). It was implemented in R software using the *dismo* package. MaxEnt models use only presence observations and are based on raster grids of explanatory variables (habitat variables) and point observations of presence. As with the other models, separate training (80%) and testing (20%) data were randomly selected for MaxEnt model developed in order to assess model performance.

Modeling Methods – Model validation

To test the performance of the best-fitting models, the predictions were compared to the observations. For presence and presence-absence models the area under the curve (AUC) was computed to judge model performance. The AUC calculates the probability that a randomly chosen presence observation would have a higher probability of presence than a randomly chosen absence observation using rank data. We used the scale of Hosmer & Lemeshow (2005), where AUC value > 0.5 is estimated to be better than chance, a value > 0.7 is estimated to be acceptable, and values > 0.8 and 0.9 are excellent and outstanding, respectively. Confidence intervals for the AUC (95%) were calculated according to the methodology of DeLong et al (1988). For abundance models the performance was directly tested by correlating the predictions with the observations. Model testing was also performed on the 20% of the data withheld at random, using the same metrics. Because of space limitations, figures showing the model validation results are generally not shown. Where appropriate, deviations from model assumptions or models with very poor predictive ability relative to the testing data are highlighted. Where these occur, the results of the modeling may not be robust.

Modeling Methods – Essential Fish Habitat Maps

Maps of essential fish habitat based on model predictions were developed for each species and life history stage. These maps were produced as population quantiles from predictions of the distribution of suitable habitat (for species where maximum entropy modeling was used) or predictions of the distribution of abundance (for species where CPUE was modeled using either a GAM or hurdle GAM). For each map of model predictions 300,000 points were randomly sampled from the raster surface. These values were then ordered by cumulative distribution and zero abundance values were removed. Four population quantiles were selected from these cumulative distributions (5%, 25%, 50% and 75%). These quantiles were then used as break points to translate the model predictions (maps of suitable habitat or abundance) to map the distribution of categories of the amount of the species abundance or suitable habitat. For example, if the 5% quantile of species A was 0.024 individuals/ha, this meant that 95% of the population occurred at values higher than 0.024. Similarly, a 75% quantile of species A at 2.1 individuals/ha meant that values above 2.1 represented the top 25% of the population proportion, or the predicted highest abundance areas. The four categories for each species, life history stage, and season were mapped to show the distribution of the areas containing 95%, 75%, 50% and 25% of the population. It is important to note that these values were chosen somewhat arbitrarily (except 95% which is the current definition of EFH in Alaska), and other values could be equally appropriate.

RESULTS

Flatfishes

arrowtooth flounder (*Atheresthes stomias*)

Arrowtooth flounder occur over most of the shelf in the Gulf of Alaska. They occur down to 700 m depth, but are most abundant between 100-500 m depth (von Szalay et al., 2010).

Seasonal distribution of early life history stages of *Atheresthes* spp. in the Gulf of Alaska -- The early life history stages of arrowtooth flounder were not able to be consistently distinguished from those of Kamchatka flounder (*Atheresthes evermanni*), as a result the two species were analyzed together at the genus level, *Atheresthes* spp.

Eggs and larvae of *Atheresthes* spp. were collected during ichthyoplankton surveys of the Gulf of Alaska. There were 43 observations of *Atheresthes* spp. eggs in the EcoFOCI database. Most of these occurred in the winter, and all but one occurred along the shelf break off Kodiak Island or the Alaska Peninsula (Figure 5). *Atheresthes* spp. larvae were observed during the winter, spring, and summer (Figure 6).

The seasonal probability of suitable larval *Atheresthes* spp. larval habitat in the eastern Bering Sea was predicted using maximum entropy modeling (Figure 7). During the winter, the most important variable in modeling larval distribution was surface current surface speed (relative importance 35.5). The AUC was 0.98 for the training data and 0.95 for the testing data, indicating an excellent model fit for both. The percent of correctly classified observations was 93% for the training data and 95% for the test data. During the winter, larvae were predicted to occur along the shelf break off Kodiak Island and the Alaska Peninsula. During the spring, the best-fitting *MaxEnt* model indicated that depth and current variability were the most important variables predicting habitat suitability (relative importance 40.2 and 17.6, respectively). The AUC was 0.86 for the training data, indicating a good model fit. The AUC for the testing data was 0.77, indicating a fair model fit. The percent of the observations correctly classified was 77% for both the training and testing data. During the spring, *Atheresthes* spp. larvae were predicted to over most of the shelf in the western GOA, particularly in deeper areas such as Shelikof and Shumagin Gullies off the Alaska Peninsula, and Amatuli Trough off the Kenai Peninsula. During the summer, the most important variables predicting *Atheresthes* spp. larval distribution were depth and surface temperature (relative importance 27.2 and 22, respectively). The AUC was 0.85 for the training data, indicating a good model fit; and 0.71 for the testing data, indicating a fair model fit. The percentage correctly classified observations was 78% for the training and 78% testing data. High suitability larval habitats were predicted to occur over much of the shelf in the western GOA, particularly from the Semidi Islands west to the Shumagin Islands.

There were only 8 observations of early juvenile *Atheresthes* spp. in the EcoFOCI database (Figure 8). A single observation occurred during the spring, west of Shelikof Strait. The other seven occurred during the summer in the western gulf.

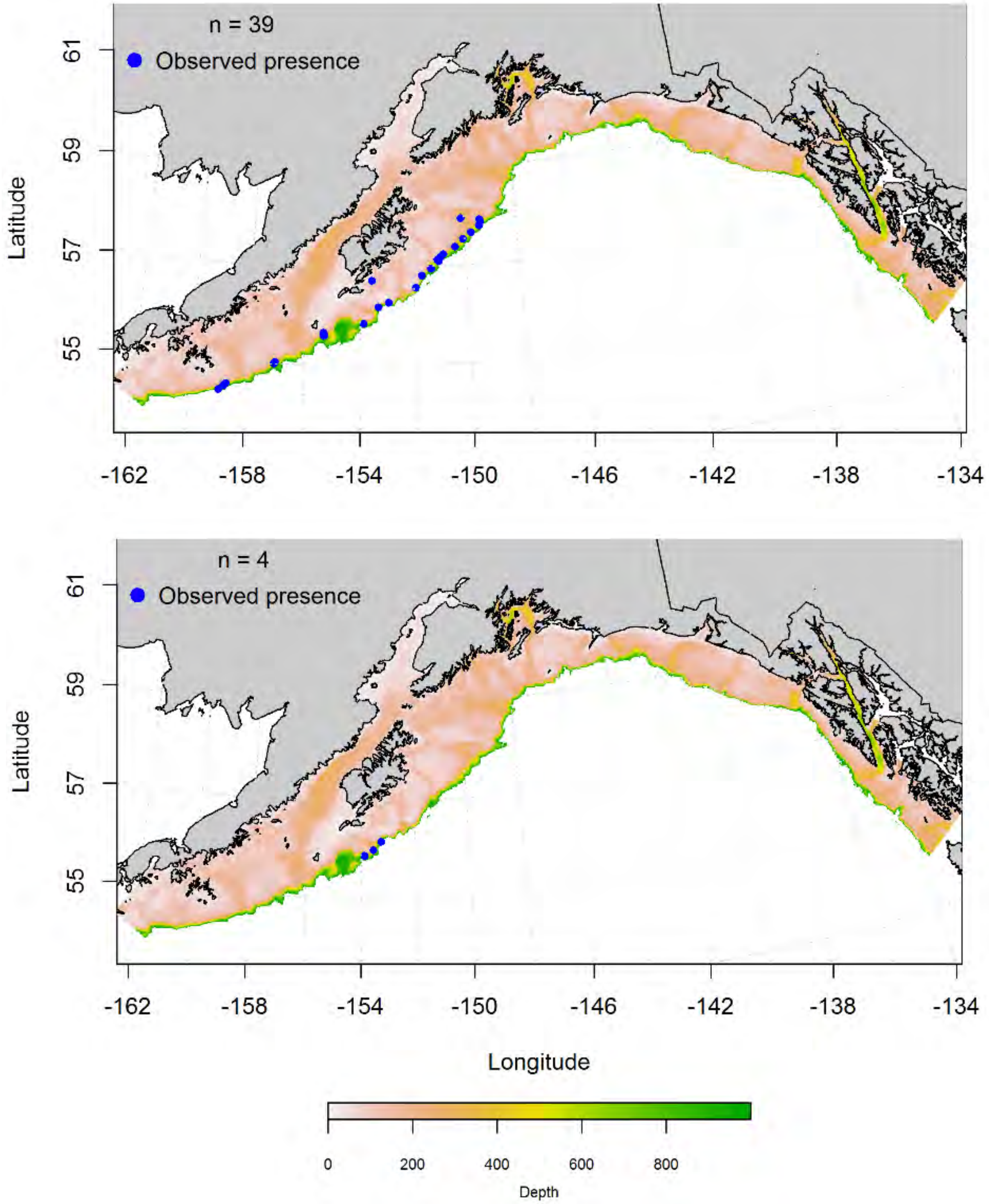


Figure 5.-- Winter and spring (top and bottom panel) observations of *Atheresthes* spp. eggs from the Gulf of Alaska.

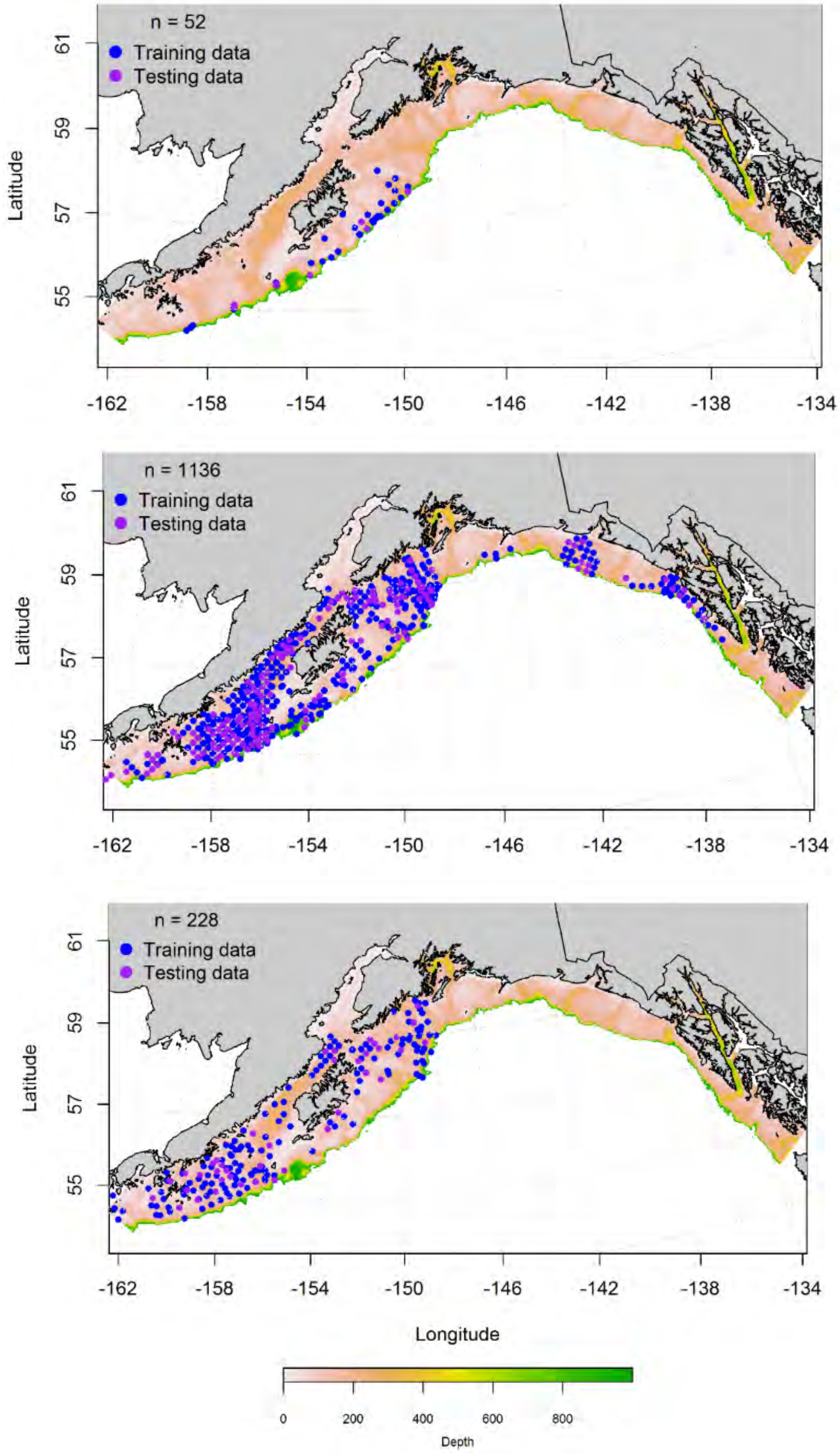


Figure 6.-- Winter, spring, and summer observations (top, middle, and bottom panel, respectively) of larval *Atheresthes* spp. from the Gulf of Alaska.

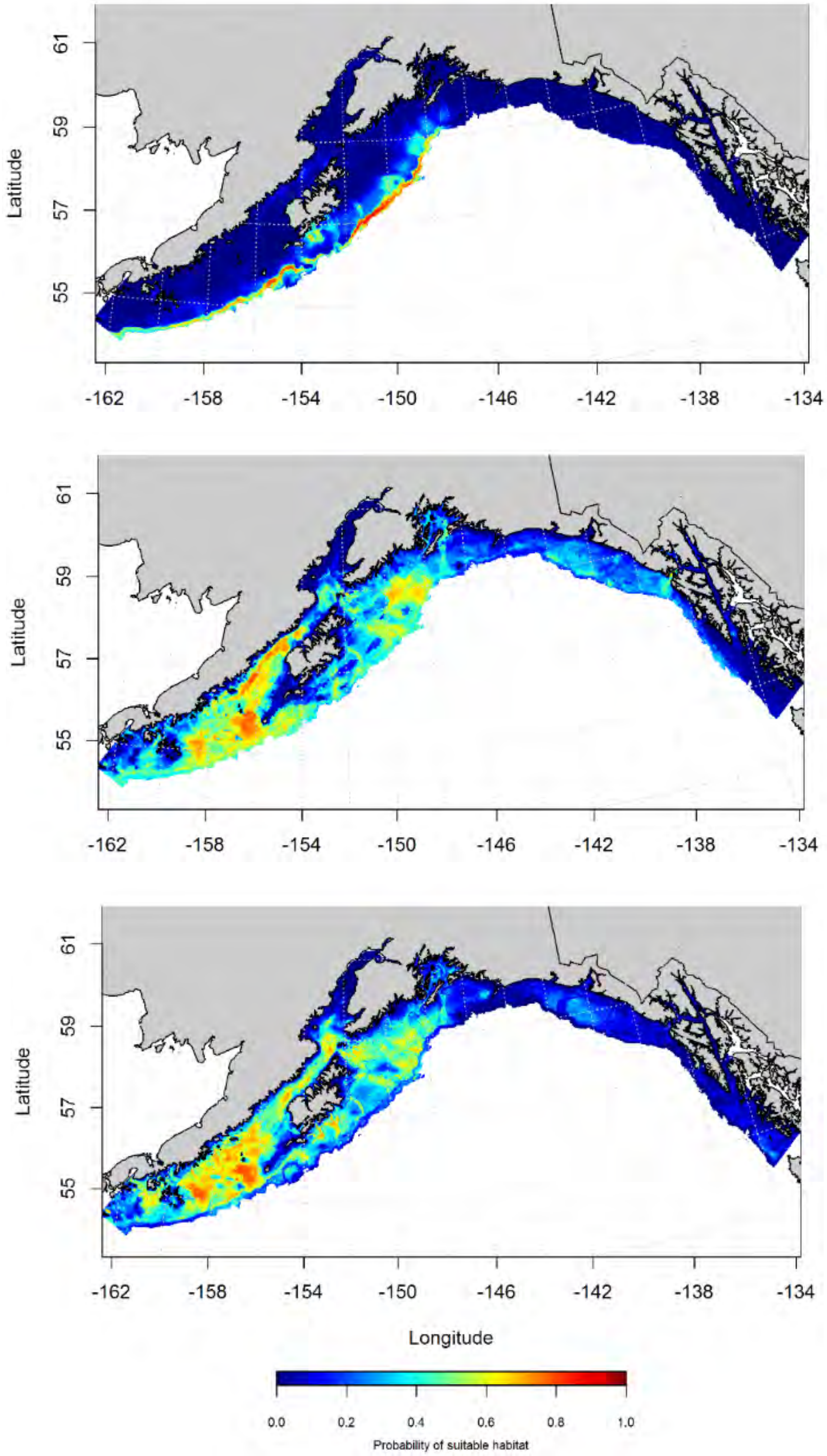


Figure 7. -- Predicted probability of suitable habitat for winter, spring, and summer observations (top, middle, and bottom panel, respectively) of larval *Atheresthes* spp. from maximum entropy modeling of the Gulf of Alaska.

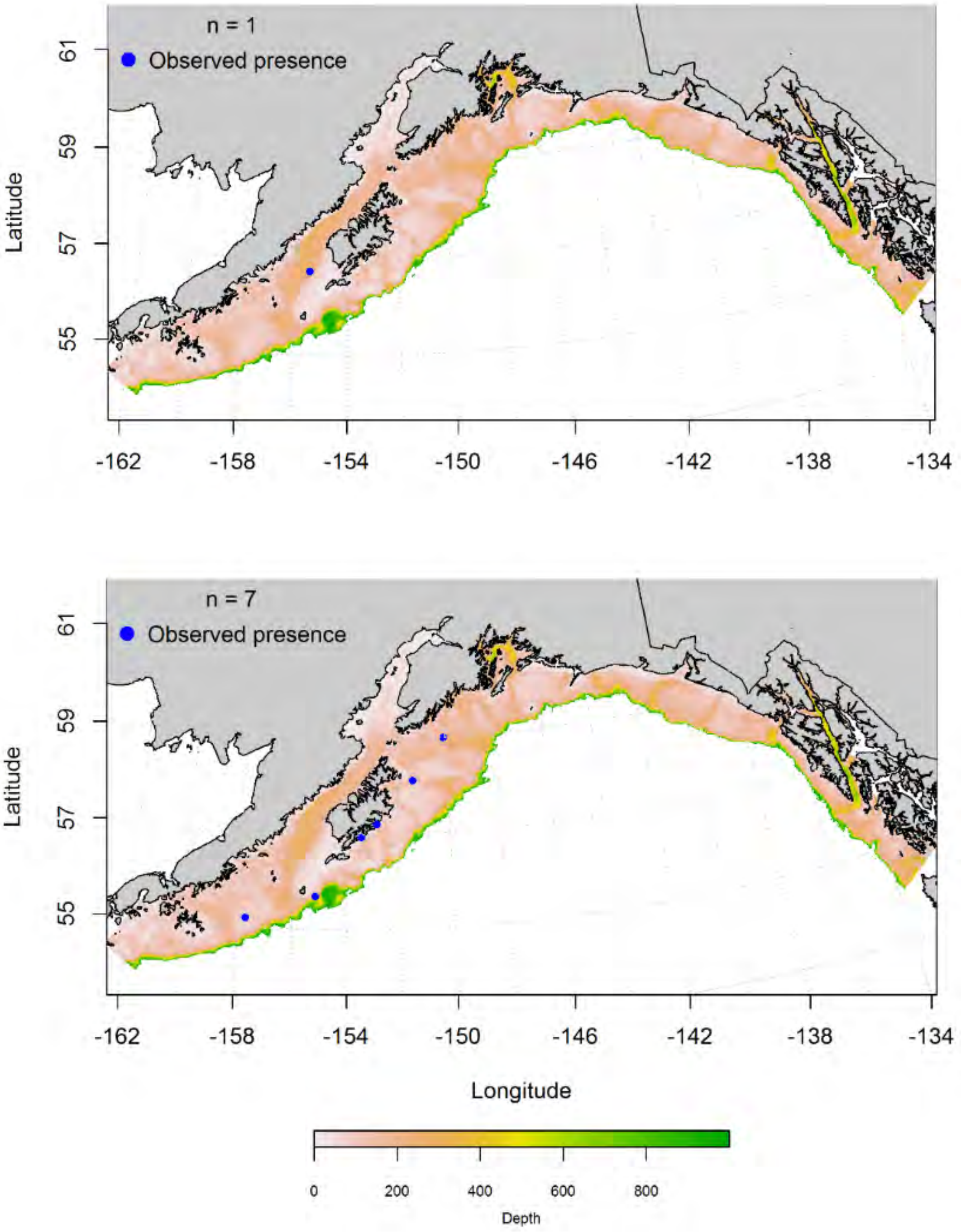
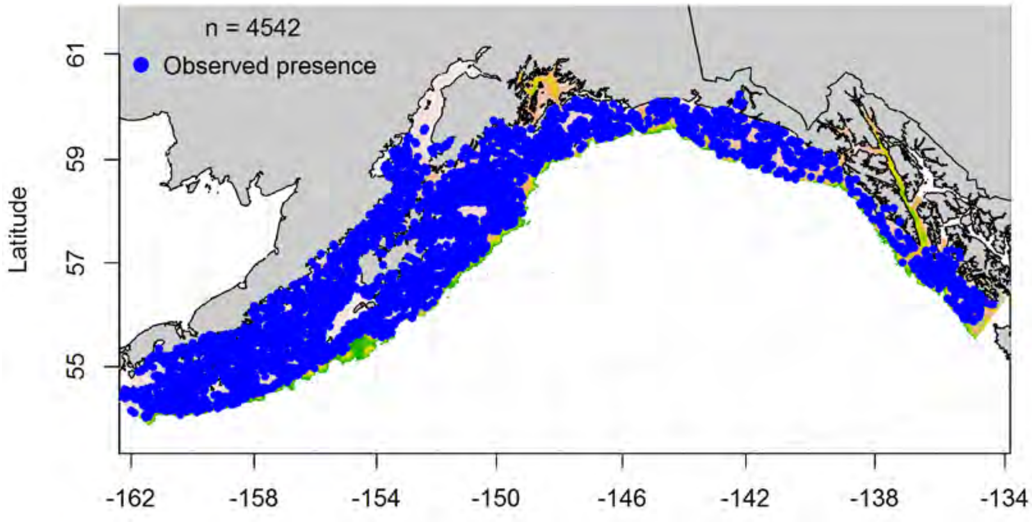


Figure 8. -- Spring and summer catches (top and bottom) of early juvenile *Atheresthes* spp. in the Gulf of Alaska.

Juvenile and adult *A. stomias* from bottom trawl surveys of the Gulf of Alaska – Juvenile and adult arrowtooth flounder were distributed throughout the Gulf of Alaska survey area (Figure 9).

The best-fitting GAM indicated that depth, temperature and tidal current were the most important variables predicting juvenile arrowtooth distribution. The model explained 32% of the variability in the training data CPUE, and 28% of variability in the test data CPUE. The predicted areas of highest abundance occurred along the inner-shelf of the Alaska Peninsula (Figure 10).

Summer bottom trawl survey data also indicated that adult arrowtooth flounder are broadly distributed across much of the Gulf of Alaska. The best-fitting GAM indicated that depth, latitude and longitude, and temperature were the most important factors predicting adult arrowtooth distributions. The model explained 32% of the variability in the training data CPUE, and 28% of variability in the test data CPUE. Low abundances of adult arrowtooth flounder were predicted to be occur across much of the shelf in the GOA (Figure 11).



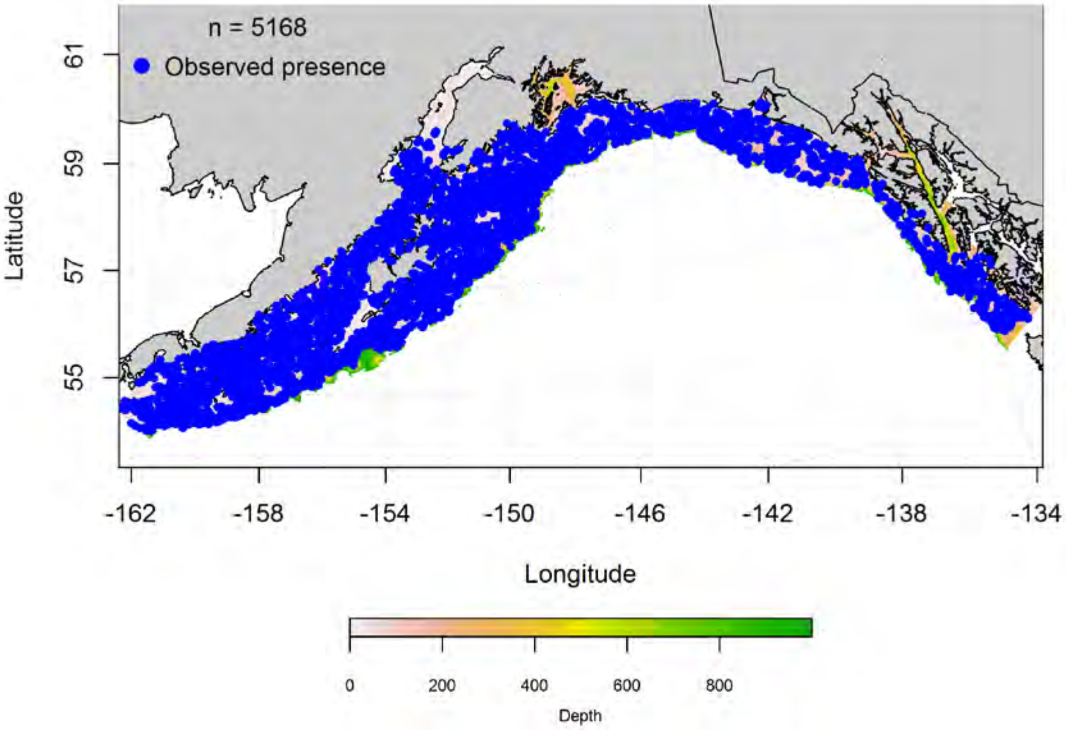


Figure 9. -- Locations of catches of juvenile and adult *A. stomias* (top and bottom) from summer bottom trawl surveys of the Gulf of Alaska.

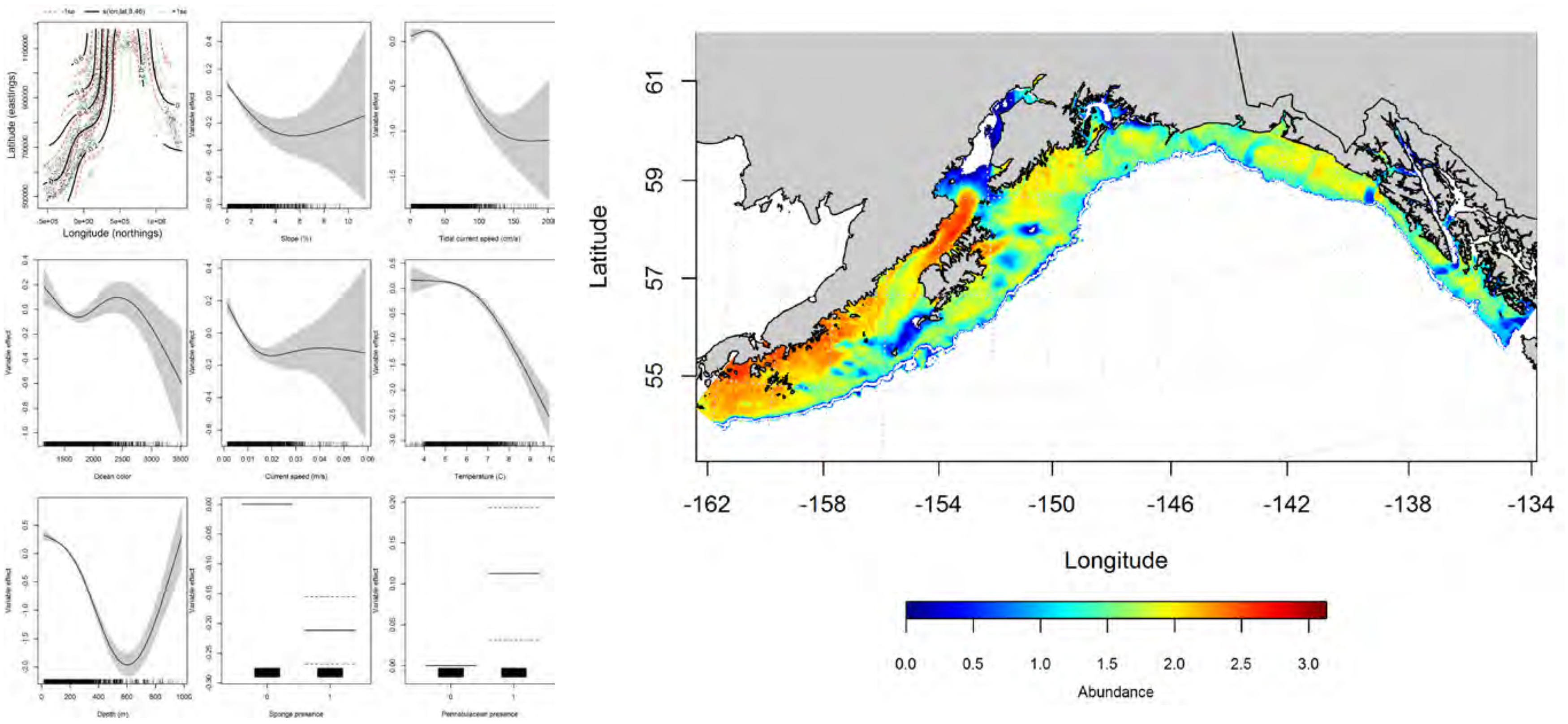


Figure 10. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of juvenile *A. stomias* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted juvenile *A. stomias* abundance (right panel).

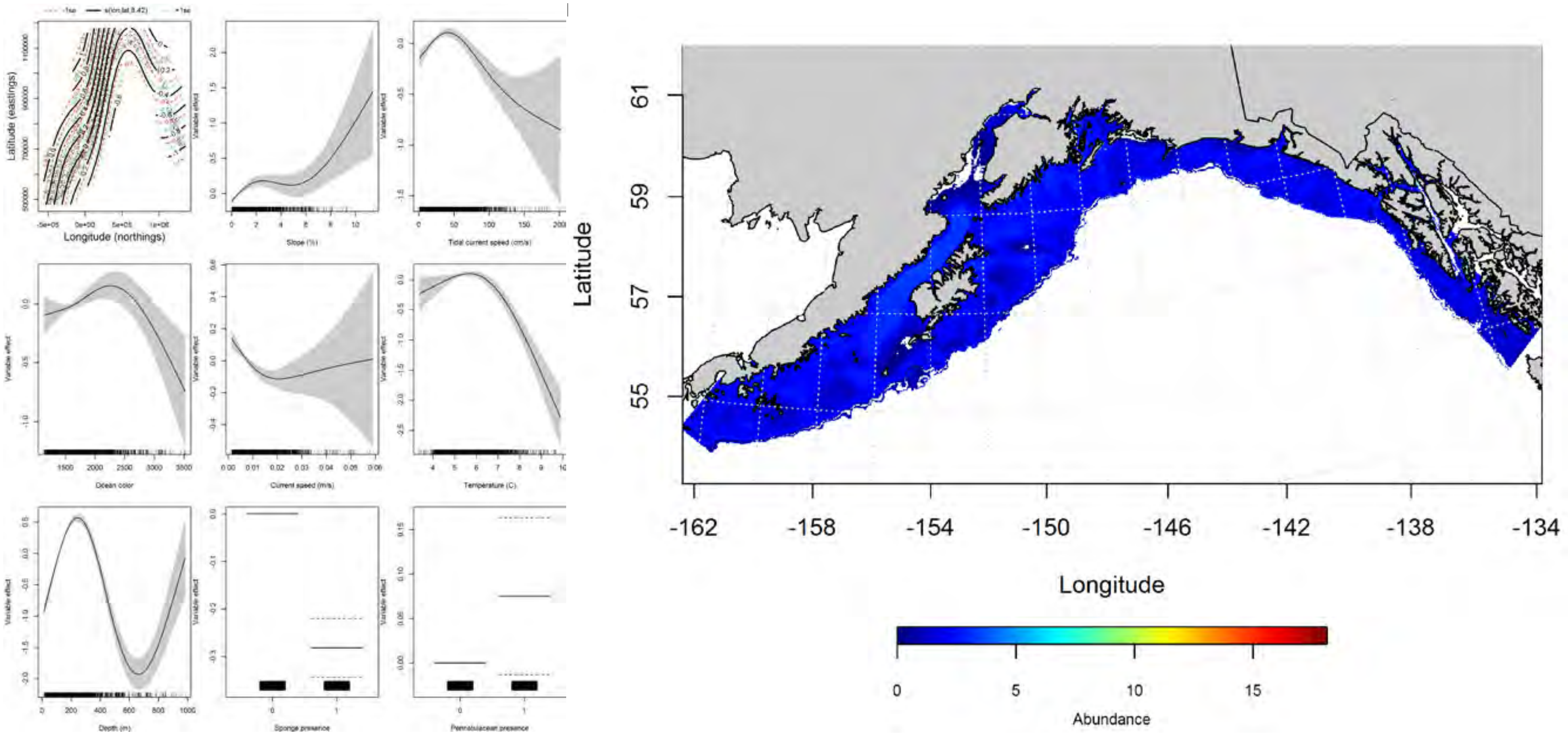


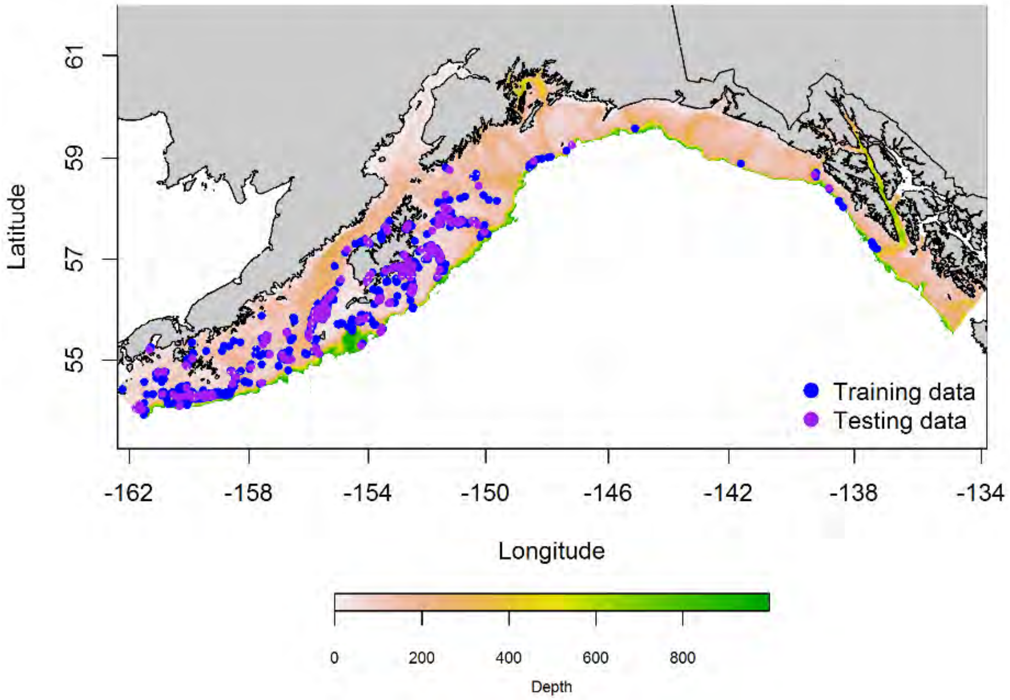
Figure 11. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *A. stomias* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *A. stomias* abundance (right panel)

Check for scaling issue

Seasonal distribution of commercial fisheries catches of adult *A. stomias* in the Gulf of Alaska – Commercial catch data indicate arrowtooth flounder are broadly distributed across much of the western Gulf of Alaska. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables (relative importance = 30.1 and 25.7) predicting their distribution. The AUC of the best fitting fall model was 0.84 for the training data indicating a good model fit. The AUC for the test data was 0.75, indicating only a fair model fit. In both cases >75% of the test and training data sets were correctly predicted. During the fall high suitability habit was predicted to occur across much of middle-shelf in the western gulf, particularly in the deeper troughs and gullies around Kodiak Island and the Alaskan Peninsula (Figure 12).

In the winter, depth and ocean color were the most important variables predicting the distribution of arrowtooth flounder (relative importance = 31.4 and 28.0 respectively). The AUC of the training data was 0.85, representing a good model fit. The AUC for the test data was 0.79, representing only a fair model fit. For 79% of observations in the training and testing data were classified correctly. During the winter, high suitability habits were predicted to occur across much of the middle-and inner-shelf between Kodiak Island and Cape St. Elias, including Albatross and Portlock Banks (Figure 13).

In the spring, depth and current speed were the most important variables predicting the distribution of arrowtooth flounder (relative importance = 51.4 and 24.6 respectively). The AUC for the training data was 0.86, indicating a good model fit. The AUC for the test data was 0.78, indicating a fair model fit. In both cased, the models correctly classified ≥77% of the observations correctly. High suitability habitats were predicted to occur along the shelf break and deeper portions of the middle-shelf, such as Shelikof Strait (Figure 14).



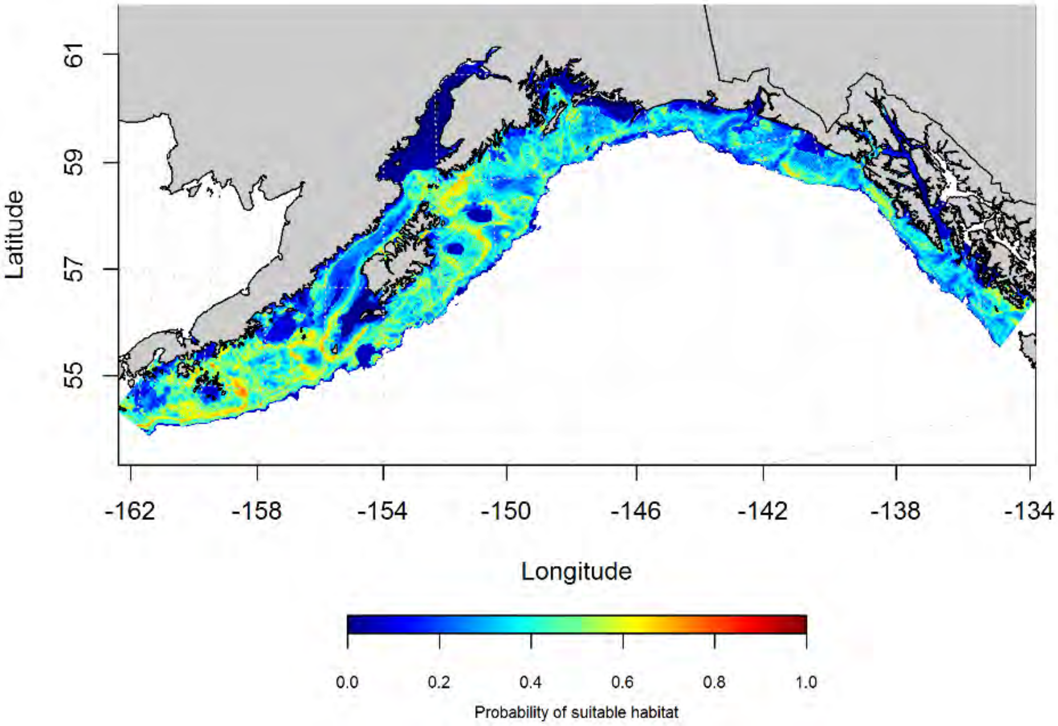


Figure 12. -- Locations of fall (September-November) commercial fisheries catches of *A. stomias* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *A. stomias* commercial catches (bottom panel) and the purple points were used to test the model.

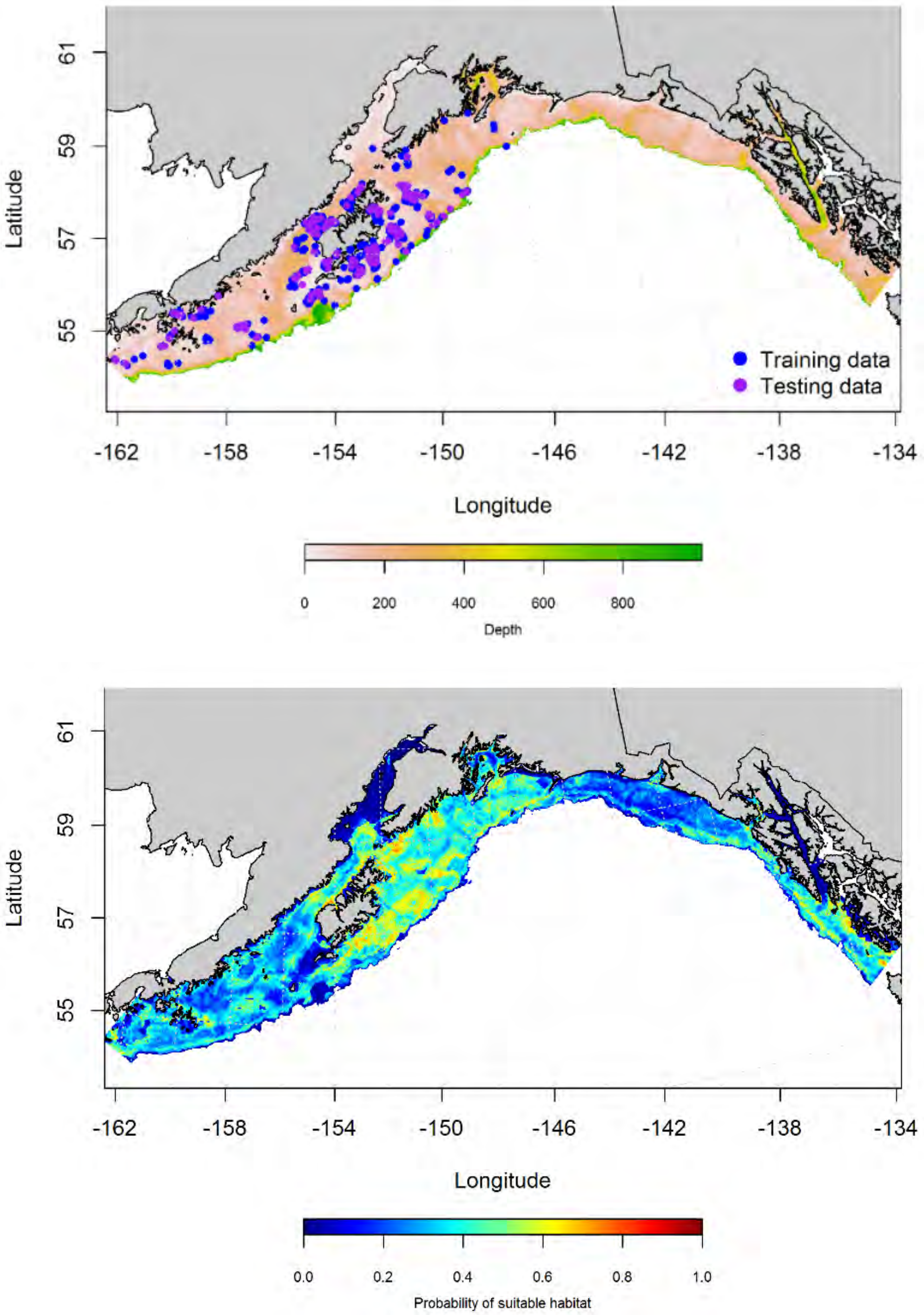


Figure 13. -- Locations of winter (December-February) commercial fisheries catches of *A. stomias* (top panel). Blue points were used to train the maximum entropy model predicting the

probability of the winter distribution of *A. stomias* commercial catches (bottom panel) and the purple points were used to test the model.

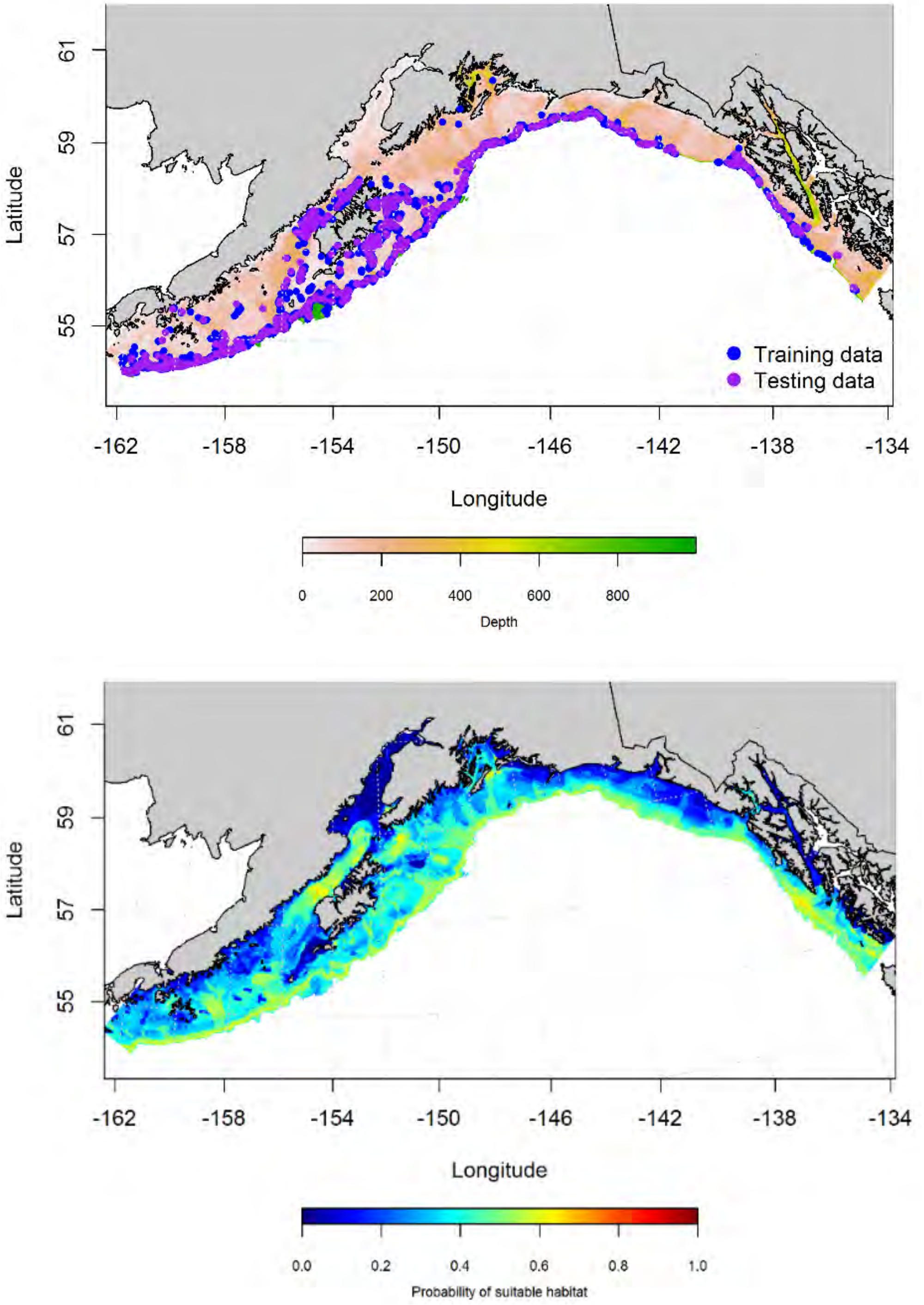


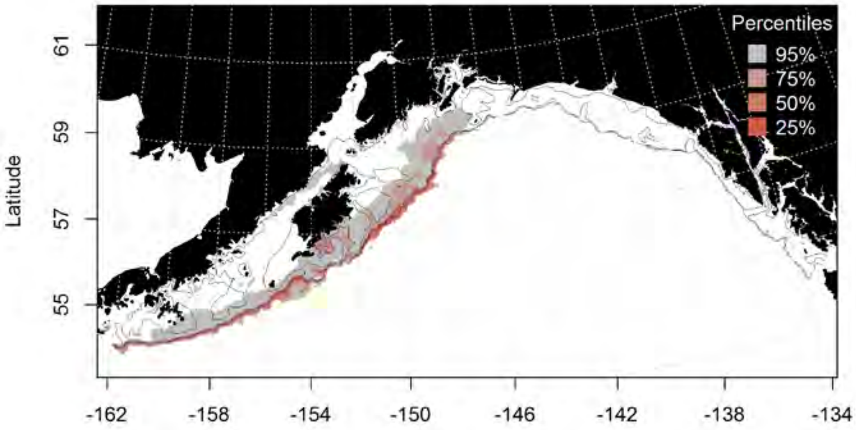
Figure 14. -- Locations of spring (March-May) commercial fisheries catches of *A. stomias* (top panel). Blue points were used to train the maximum entropy model predicting the probability of

the spring distribution of *A. stomias* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *A. stomias* Essential Fish Habitat Maps and Conclusions – Essential fish habitat for arrowtooth flounder predicted to be extensively distributed across much of the Gulf of Alaska. EFH for larval arrowtooth flounder during the winter, spring, and summer were predicted to include much of the shelf in the western gulf (Figure 15). It was not possible to predict EFH for arrowtooth flounder eggs or early juvenile stages.

Summer EFH for juvenile and adult arrowtooth flounder, based on trawl survey data, include much of the shelf in the GOA (Figure 16).

EFH for adult arrowtooth flounder, based on commercial fisheries data, were predicted to include much of the shelf during the fall and winter (Figure 17). During the spring, the EFH for adult arrowtooth flounder also included large areas of the shelf, but with higher suitability habitats largely occurring along the shelf break.



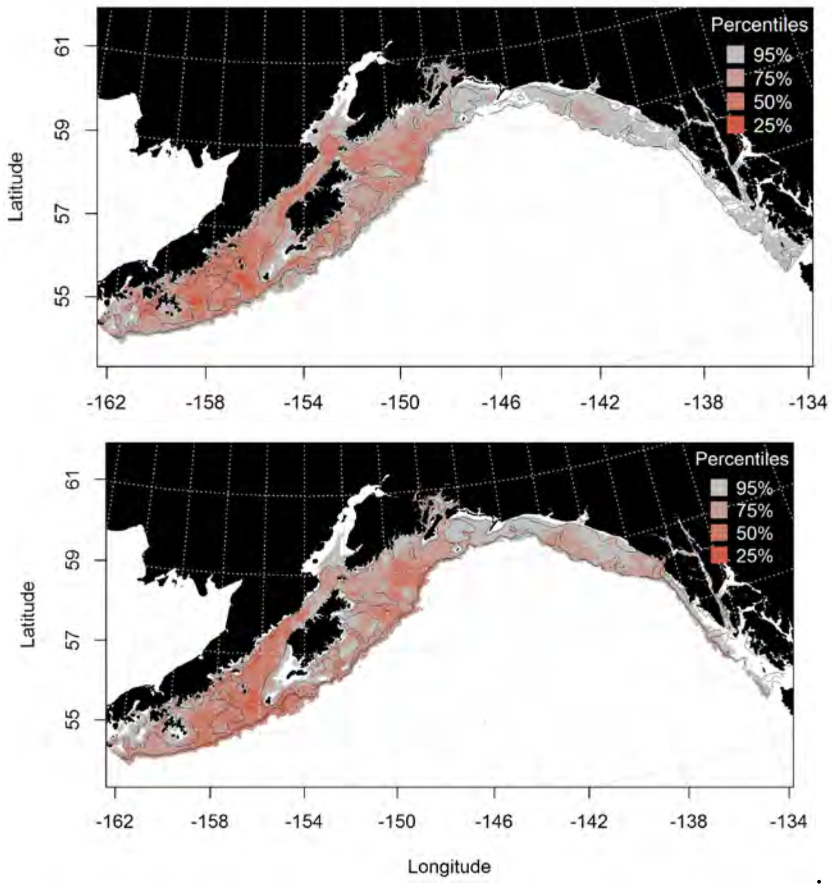
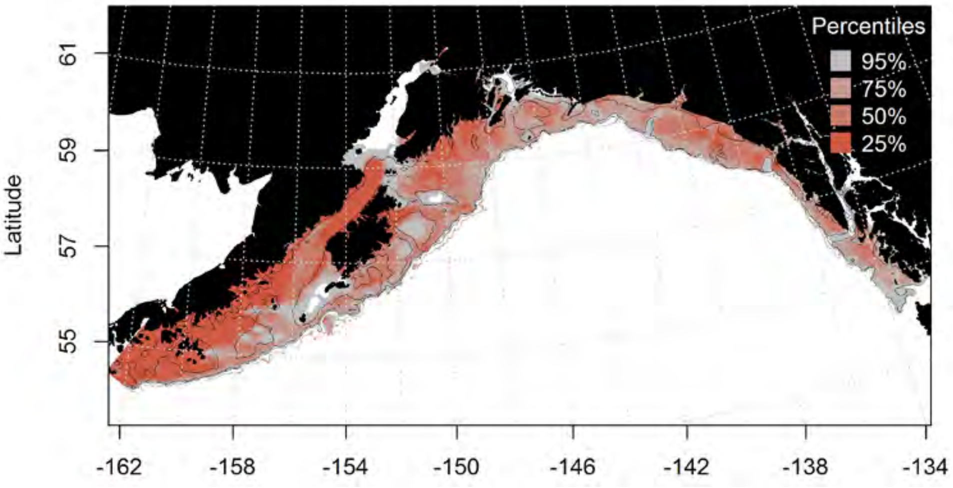


Figure 15. -- Winter, spring, and summer essential fish habitat predicted for larval *A. stomias* (top and bottom panel, respectively) from EcoFOCI database.



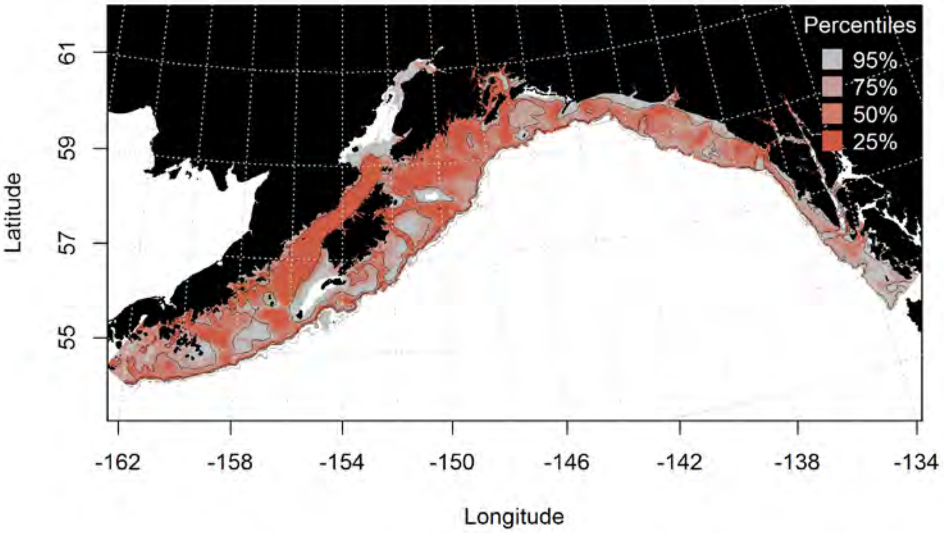
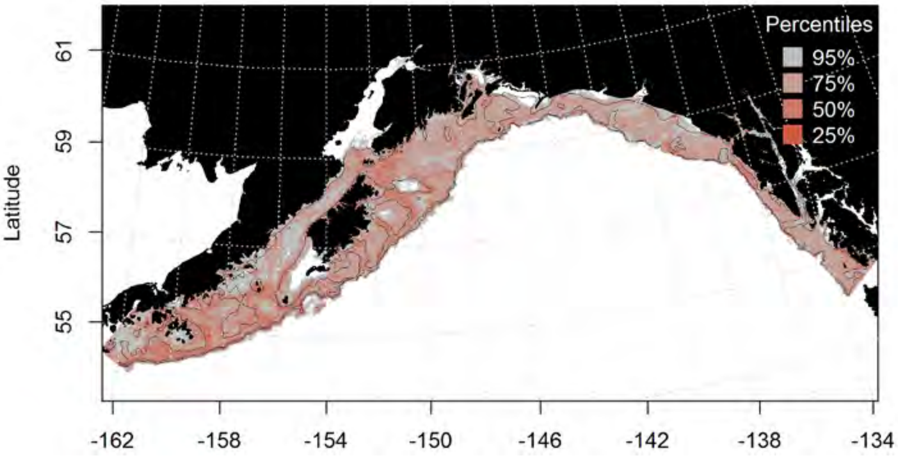


Figure 16. -- Predicted summer essential fish habitat for *A. stomias* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.



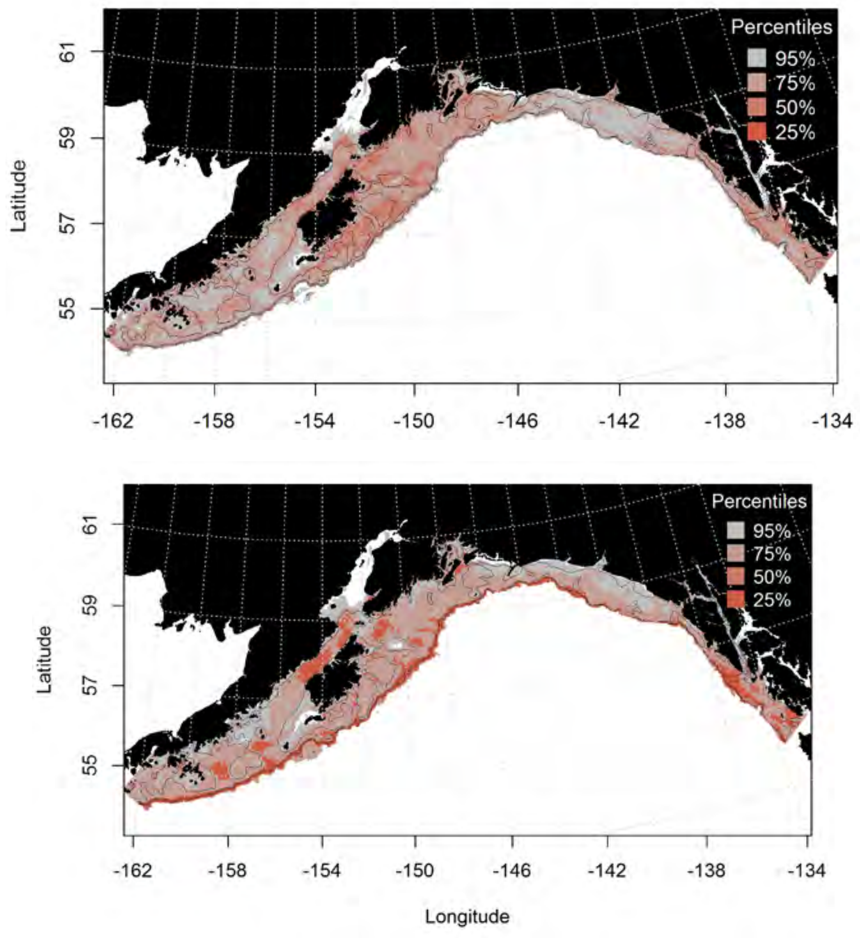


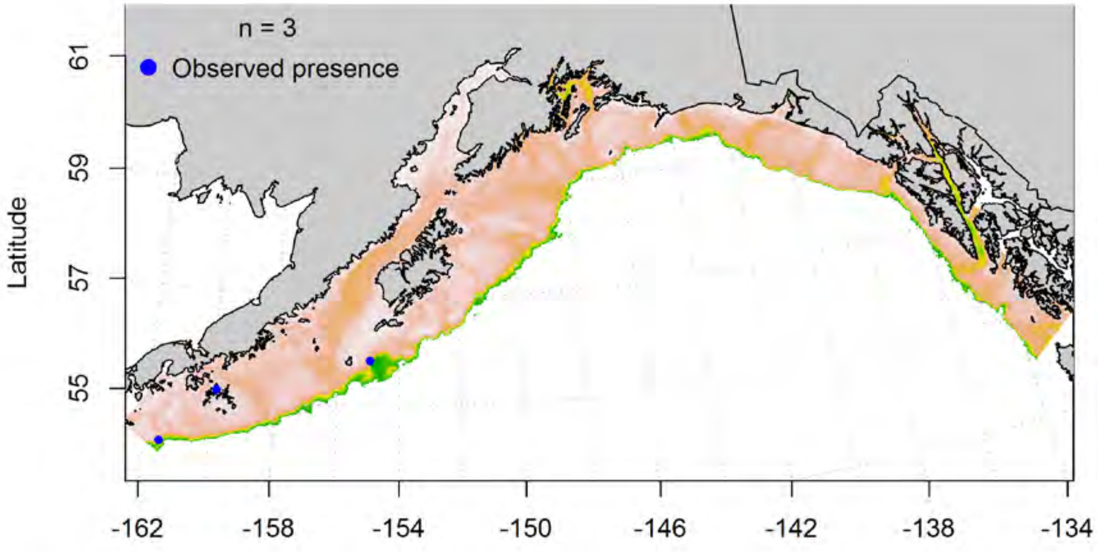
Figure 17. -- Essential fish habitat predicted for adult *A. stomias* during fall (top panel), winter (middle panel), and spring (bottom panel) from commercial catches.

Kamchatka flounder (*Atheresthes evermanni*)

Kamchatka flounder are relatively rare in the Gulf of Alaska and are largely restricted western gulf, occurring as far east as Shelikof Strait (Allen and Smith 1988).

Seasonal distribution of early life history stages of *A. evermanni* in the Gulf of Alaska -- The early life history stages of Kamchatka flounder were not able to be consistently distinguished from those of arrowtooth flounder (*Atheresthes stomias*), as a result observations of the two species were analyzed together at the genus level, *Atheresthes* spp. Please refer to the arrowtooth flounder section of this report for a description of the early life history of *Atheresthes* spp.

Juvenile and adult *A. evermanni* from bottom trawl surveys of the Gulf of Alaska – Summer bottom trawl survey data indicates juvenile and adult Kamchatka flounder largely occur in the western Gulf of Alaska. Only three juvenile, and four adult Kamchatka flounder were observed. A majority of these observations occurred along the shelf break along the Alaska Peninsula (Figure 18). There was insufficient data to predict the distribution of either juvenile or adult Kamchatka flounder.



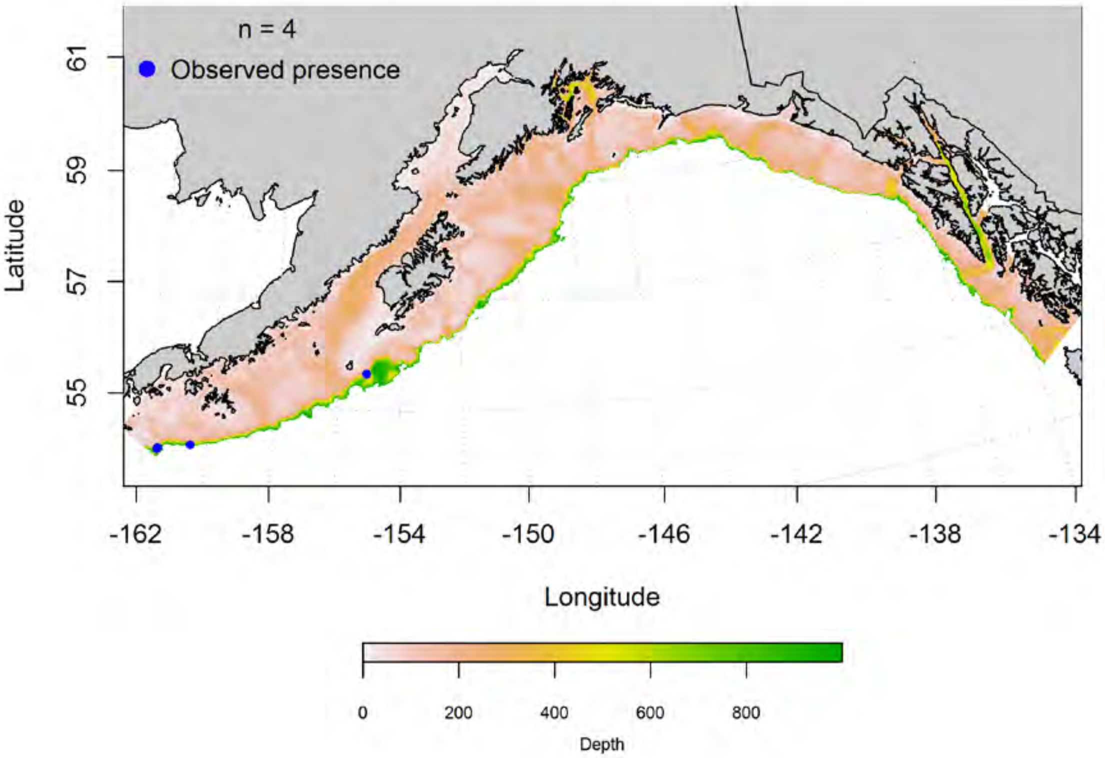


Figure 18. -- Locations of catches of juvenile and adult *A. evermanni* (top and bottom) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *A. evermanni* in the Gulf of Alaska – Commercial catch data of adult Kamchatka flounder were available only during the spring. The best-fitting *MaxEnt* model indicated that depth and slope were the most important variables predicting the distribution of Kamchatka flounder (relative importance = 54.2 and 21.9 respectively). The AUC for the training data was 0.97, and 0.94 for the test data, indicated the fit was excellent for both models. The areas with highest predicted habitat suitability for Kamchatka flounder occurred along the shelf break along the Alaska Peninsula. In addition a localized area of high suitability also occurred in the Yakutat Valley (Figure 19).

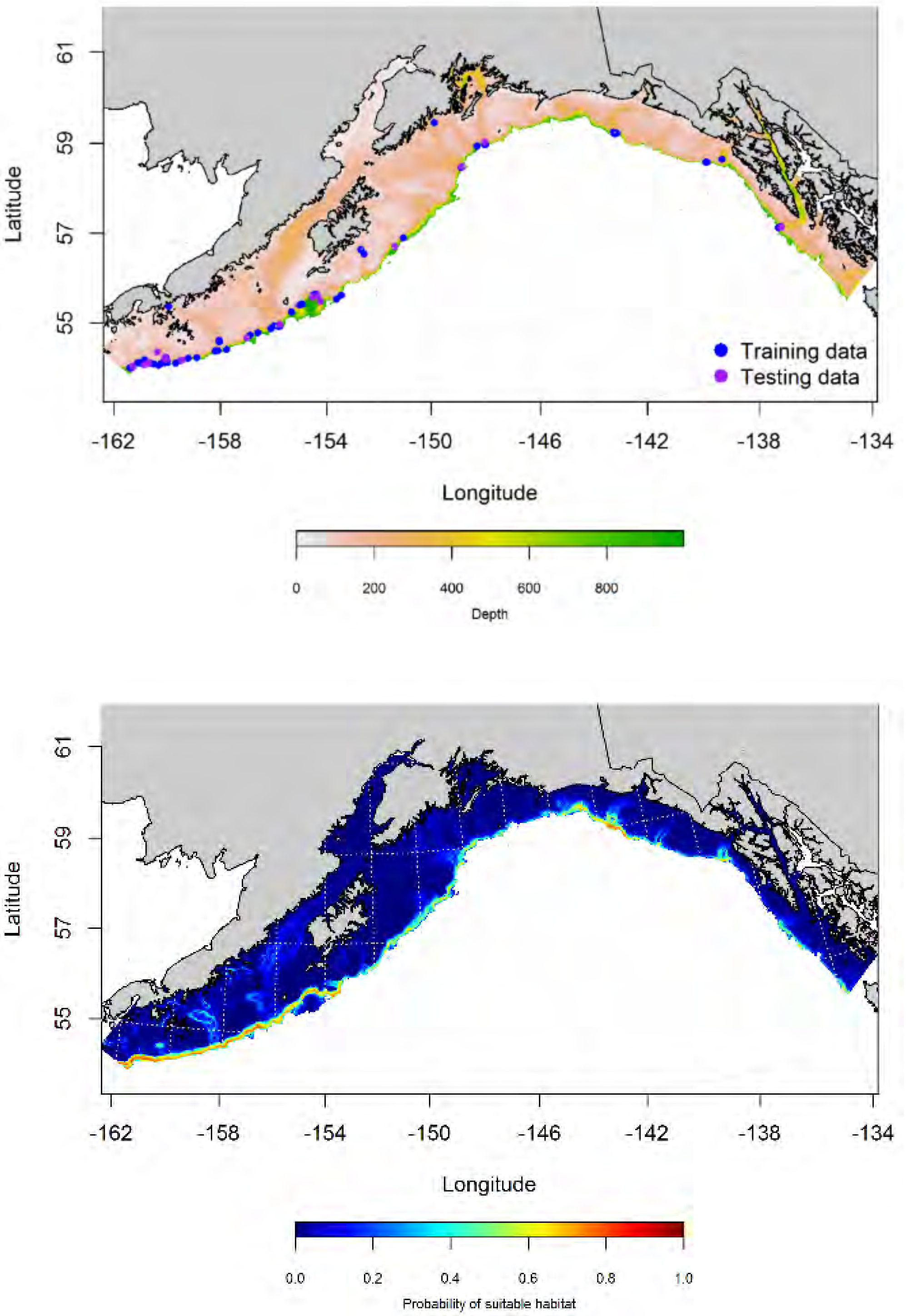


Figure 19. -- Locations of spring (March-May) commercial fisheries catches of *A. evermanni* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *A. evermanni* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *A. evermanni* Essential Fish Habitat Maps and Conclusions -- There was insufficient data to predict EFH for either egg or early juvenile stages of Kamchatka flounder. EFH for larval *Atheresthes* spp. during the winter, spring, and summer were predicted to include much of the shelf in the western GOA (Figure 15); however, these predictions were based on observations that also included larval arrowtooth flounder (*Atheresthes stomias*). Therefore, the results likely over predict the actual EFH for larval Kamchatka flounder.

Predictions of summer EFH for juvenile and adult Kamchatka flounder, based on bottom trawl surveys data, were not possible. Spring EFH for Kamchatka flounder, based on commercial fisheries observations, was predicted to occur along the shelf break throughout the GOA (Figure 20).

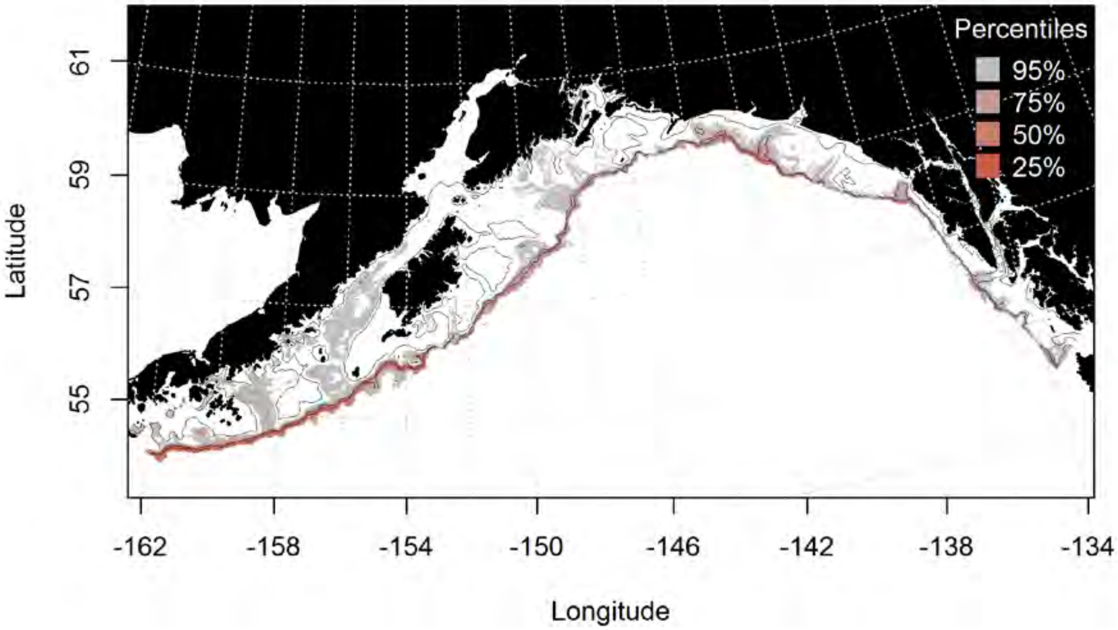


Figure 20. -- Essential fish habitat predicted for *A. evermanni* during spring commercial catches.

rex sole (*Glyptocephalus zachirus*)

Rex sole occur throughout the Gulf of Alaska, typically at less than 700 m depth; however, large catches of this species are rare (von Szalay et al., 2010).

**Seasonal distribution of early life history stages of *G. zachirus* in the Gulf of Alaska – **Throughout much of their early life history rex sole occur predominantly in the western Gulf of Alaska. Rex sole eggs were observed winter, spring, and summer (Figure 21). In the winter, there were only two observations of eggs, both occurred in the western gulf. There were insufficient data to model the distribution of rex sole eggs during the winter. During the spring, rex sole eggs were much more prevalent.

The best-fitting *MaxEnt* model indicated that depth and ocean color were the most important variables (relative importance 20.3 and 18.7) predicting the habitat suitability for rex sole eggs. The AUC was 0.9 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.69, indicating a poor model. The percent of the observations correctly classified in the training data was 81% and 69% for the test data. Rex sole eggs were predicted to occur along much of the middle-shelf in the western gulf, particularly between in Shelikof Gull west to the Shumagin Islands (Figure 22). During the summer, the best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables (relative importance 31.5 and 31.2 respectively) predicting the habitat suitability for rex sole eggs. The AUC was 0.89 for the training data, indicating a good model fit. The AUC for the testing data was 0.76, indicating a fair model fit. The percent of the observations correctly classified in the training data was 79% and 76% for the test data. Rex sole eggs were predicted to occur around

Kodiak Island, with high suitability habitat predicted across much of the shelf east of Kodiak Island including Marmot Gully and the entrance to Cook Inlet, as well as to the west of Kodiak in the vicinity of Chirikof Island.

Larval rex sole were abundant across much of the shelf in the western GOA. Larval rex sole were observed during the spring and the summer (Figure 23).

During the spring, the best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables (relative importance 20.3 and 18.7 respectively) predicting the habitat suitability for rex sole larvae. The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.69, indicating a poor model fit. The percent of the observations correctly classified in the training data was 81% and 69% for the test data. Rex sole larvae were predicted to be occur over much of the inner- and middle-shelf west of Kodiak Island, from Shelikof Strait to the Shumagin Islands (Figure 24). During the summer, the most important variables predicting rex sole larval habitat suitability were surface temperature and depth (36.0 and 33.0). The AUC was 0.85 for the training data, indicating a good model fit. The AUC for the testing data was 0.63, indicating a poor model fit. The percent of the observations correctly classified in the training data was 77% and 63% for the test data. Rex sole larvae were predicted to be occur over much of the shelf in the western gulf. High suitability habitat was predicted to occur around much of Kodiak Island, west to the Shumagin Islands.

No observations of early juvenile stage rex sole occurred in the EcoFOCI database.

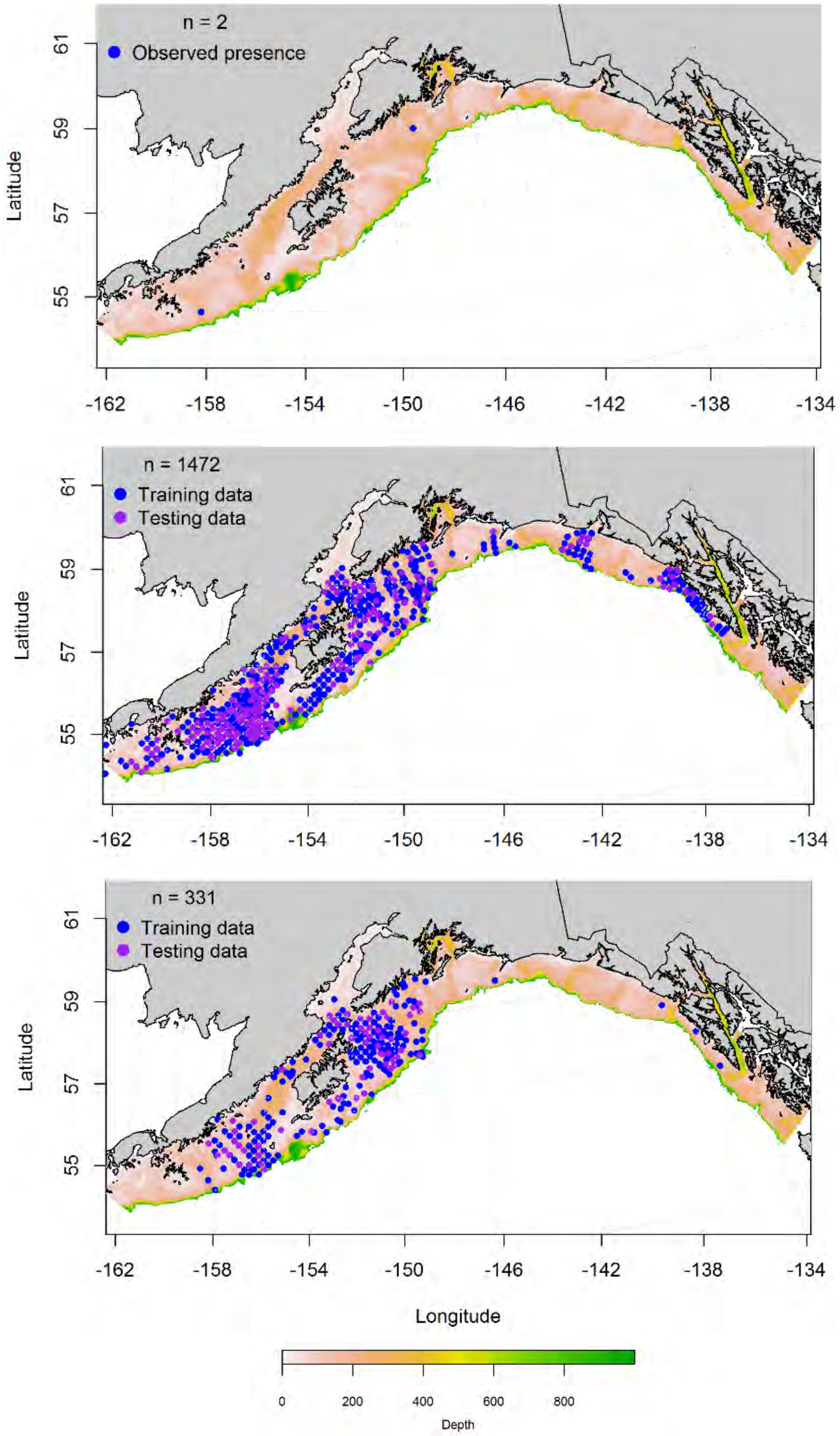


Figure 21. -- Fall, spring, and summer (top, middle, and bottom panel, respectively) observations of *G. zachirus* eggs from the Gulf of Alaska.

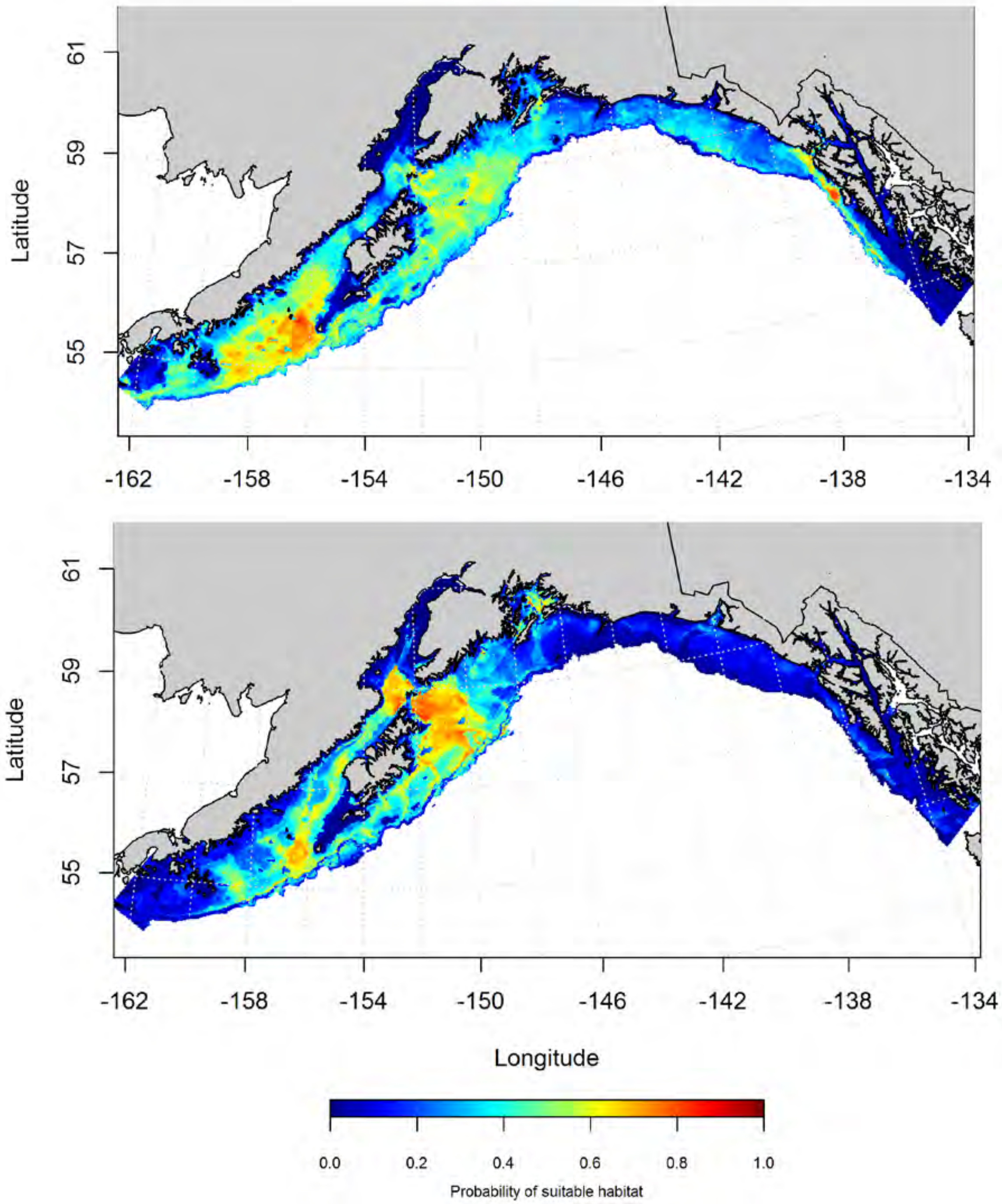


Figure 22. -- Predicted probability of suitable habitat spring and summer observations (top and bottom panel, respectively) of *G. zachirus* eggs from maximum entropy modeling of the Gulf of Alaska.

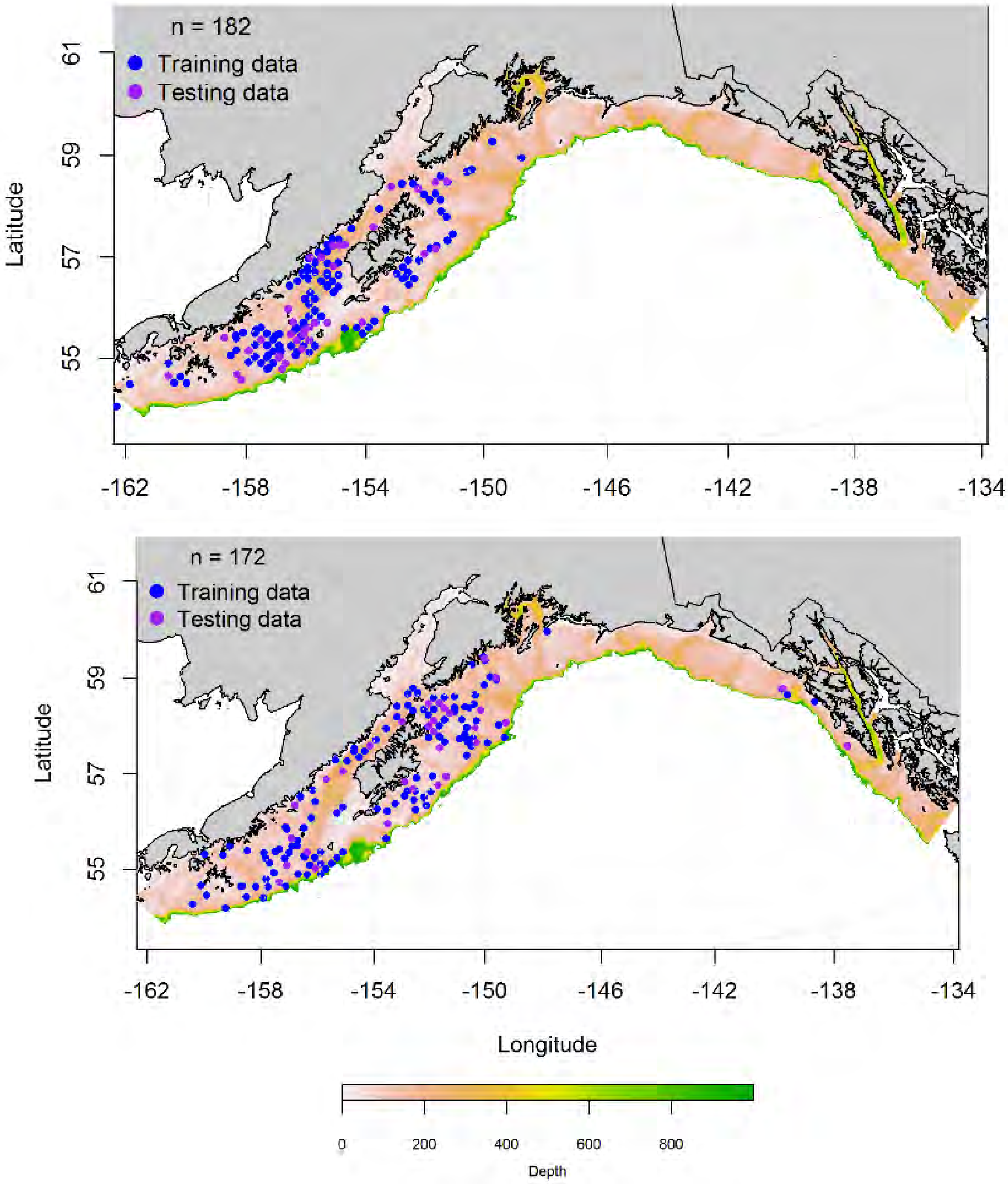


Figure 23. -- Spring and summer (top and bottom panel, respectively) of larval *G. zachirus* from the Gulf of Alaska.

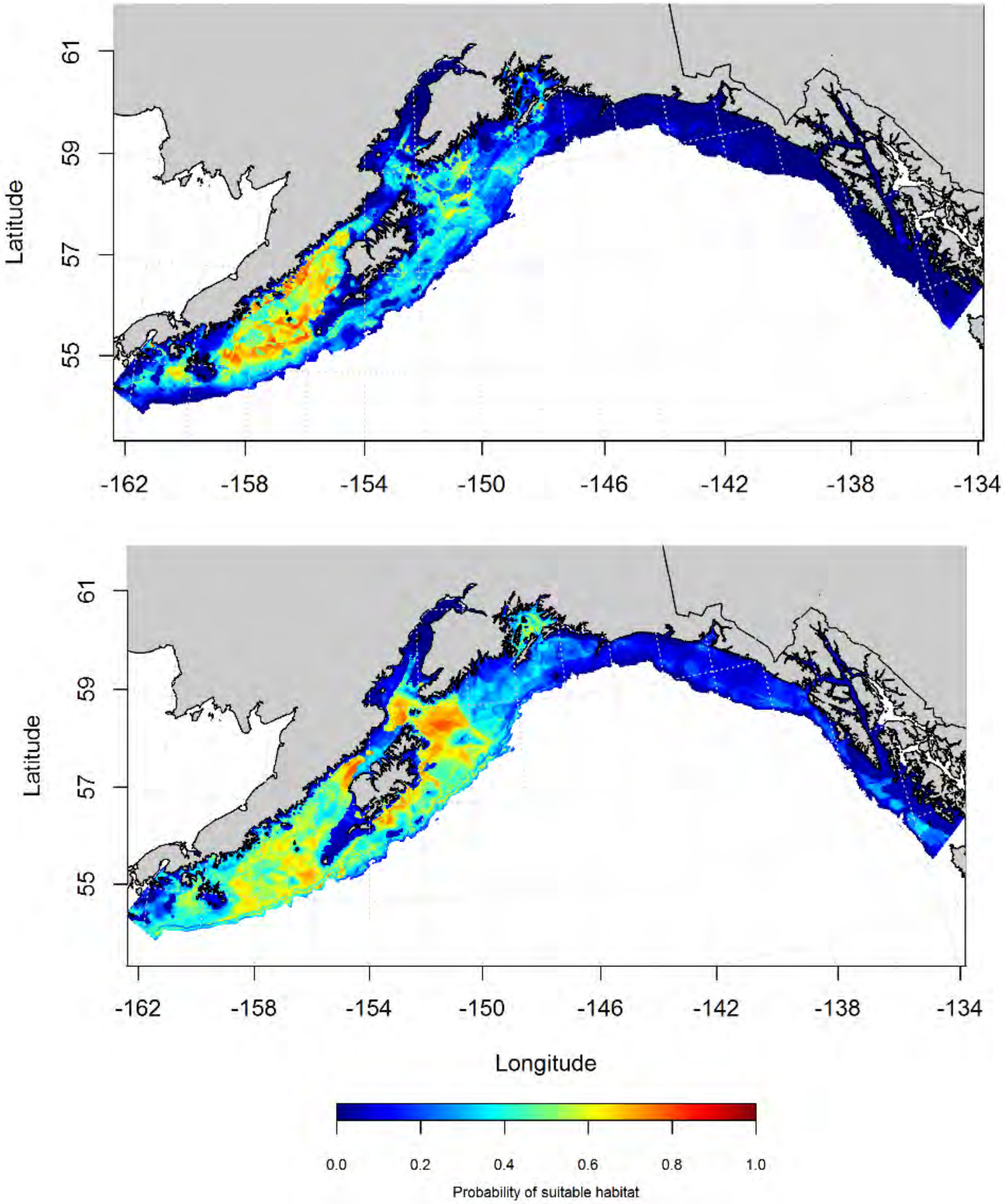


Figure 24. -- Predicted probability of suitable habitat spring and summer observations (top and bottom panel, respectively) of larval *G. zachirus* from maximum entropy modeling of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *G. zachirus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile rex sole are broadly distributed across much of the shelf in the Gulf of Alaska (Figure 25).

The best-fitting GAM indicated that depth, latitude and longitude, and coral presence were the best predictors of juvenile rex sole distributions. The AUC was 0.79 for both the training and test data sets, indicating a fair model fit. The optimum threshold was 0.26. The percent of observations correctly classified was 70% for the training data set, and 73% for the test data set. The most important variables predicting the abundance of juvenile rex sole were latitude and latitude, tidal current, and depth. The best-fitting GAM explained just 6% of the variability in CPUE in the training data and 18% of the variability in the test data. The predicted distribution of juvenile rex sole included much of inner-shelf in the GOA; however, predicted areas of high abundances were much more localized. They included portions of the inner-shelf from Kenai Peninsula to Cape St. Elias and inshore waters off Prince of Wales Island (Figure 26). The model also predicted high abundances of juvenile rex sole in Prince William Sound and the inside waters of southeast Alaska; however, these predictions were not supported by any observations.

Summer bottom trawl survey data indicate adult rex sole are also broadly distributed across much of the shelf in the GOA (Figure 27). The best-fitting GAM indicated that depth, latitude and longitude, and sponge presence were the most important variables predicting the distribution of adult rex sole. The model explained 33% of the variability in CPUE for both the training and testing data. Adult rex sole were predicted to occur at low abundances across much of the shelf, particularly in the deeper channels and depressions.

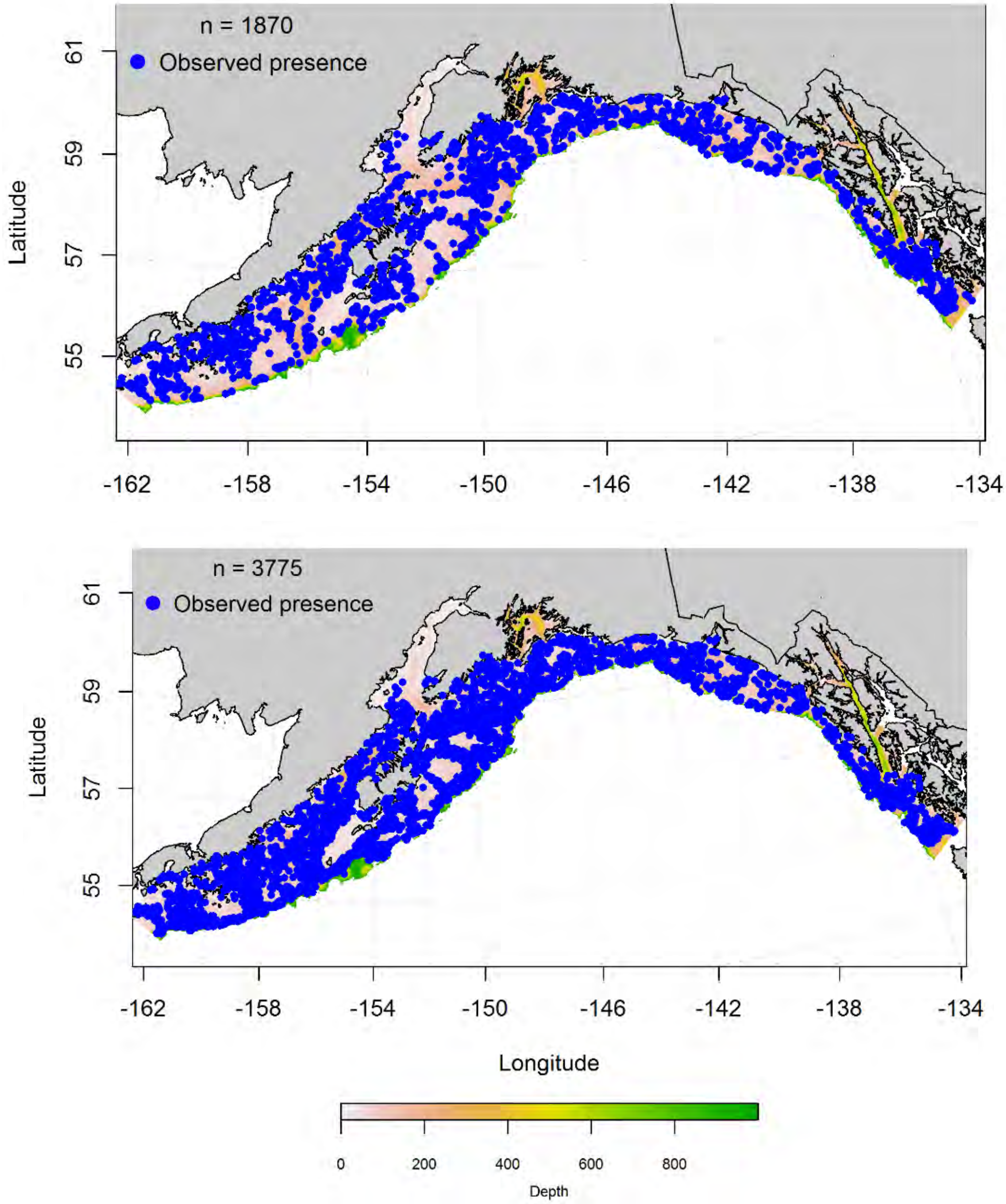


Figure 25. -- Locations of catches of juvenile and adult *G. zachirus* (top and bottom) from summer bottom trawl surveys of the Gulf of Alaska.

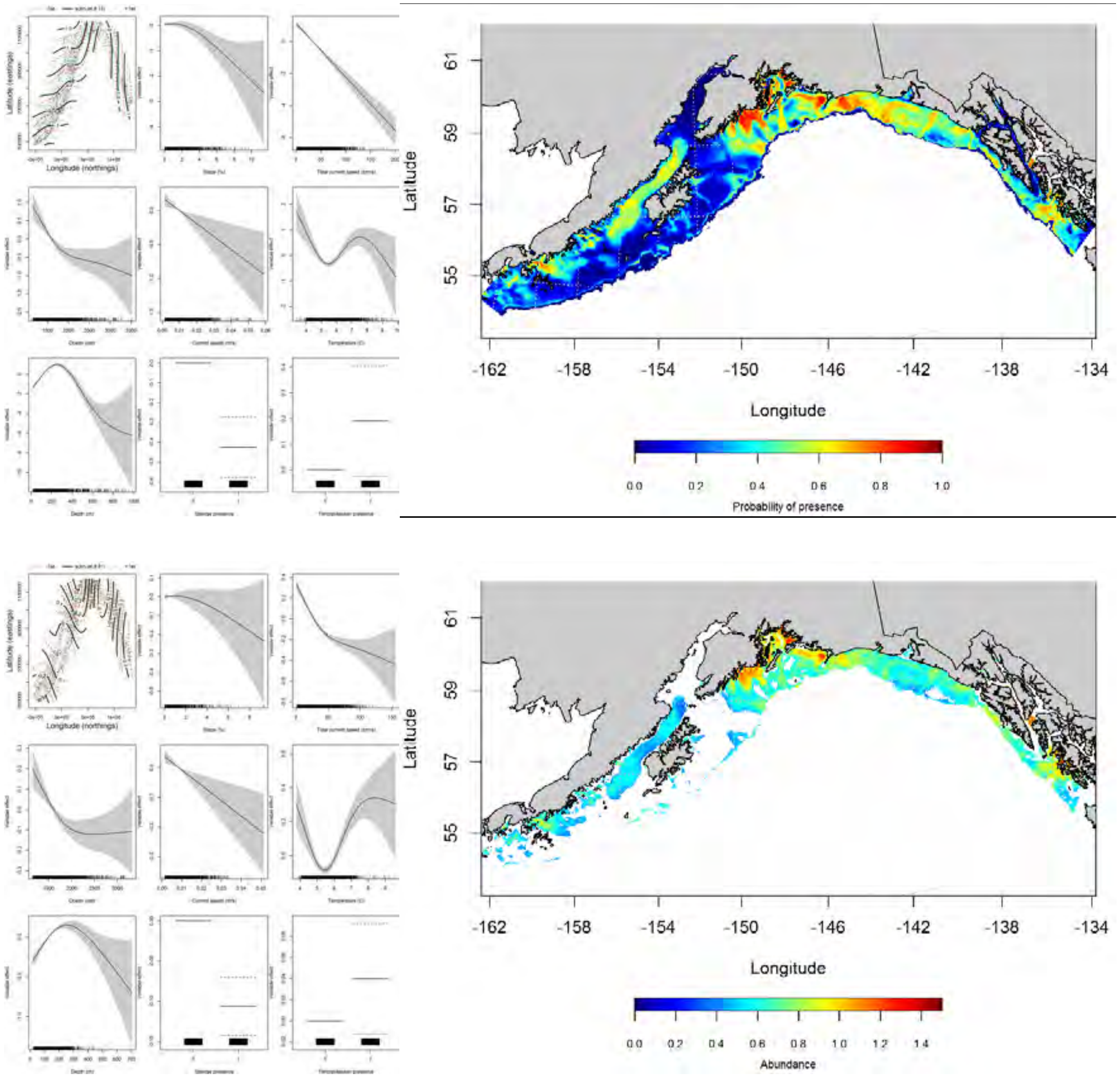


Figure 26. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *G. zachirus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

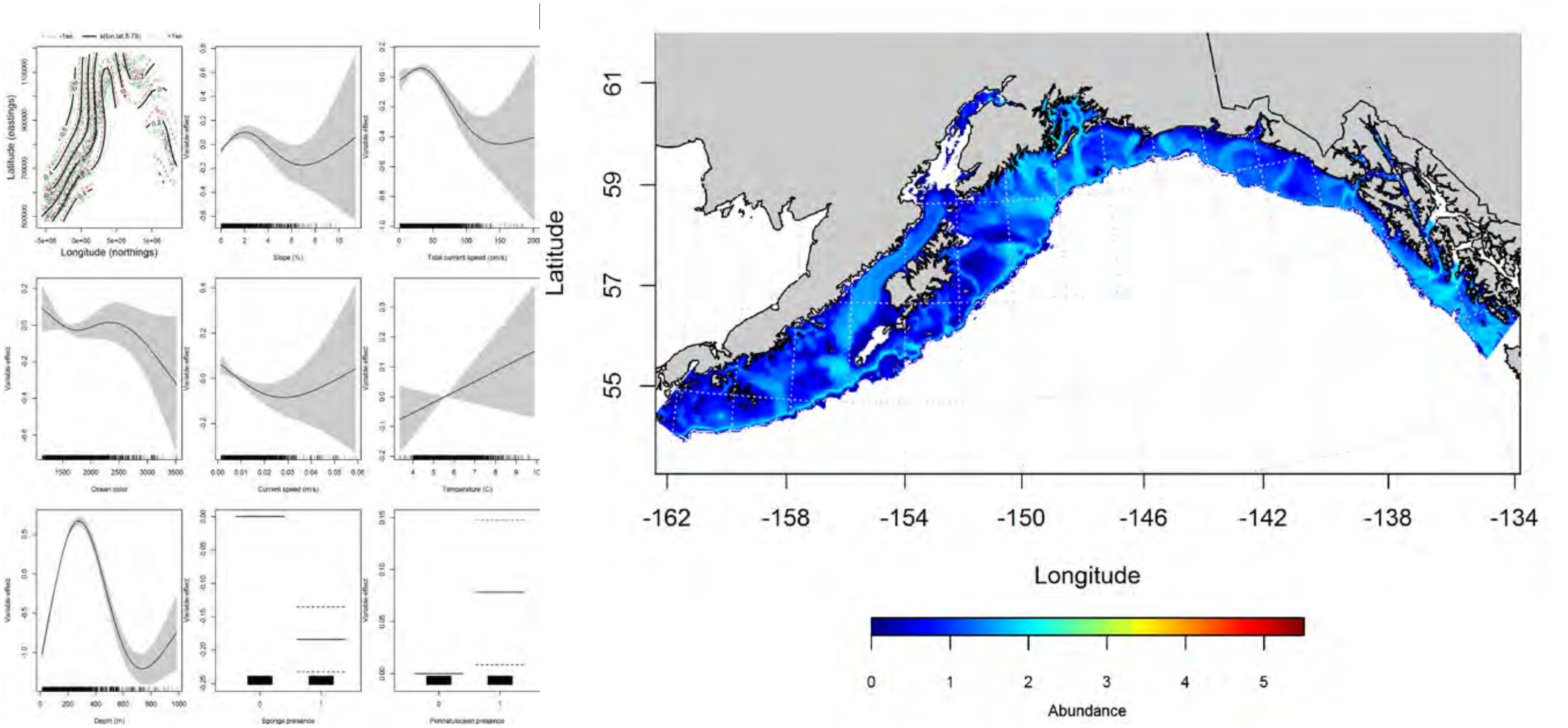


Figure 27. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *G. zachirus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *G. zachirus* abundance (right panel)

Seasonal distribution of commercial fisheries catches of adult *G. zachirus* in the Gulf of Alaska -- Commercial catch data indicate rex sole they largely occurs around Kodiak Island and the shelf in the western GOA. In the fall, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of rex sole (relative importance = 37.4 and 28.6). The AUC for the training data 0.94, indicating an excellent model fit. The AUC for the test data was 0.80, indicating a good model fit. The percent of observations correctly classified for the training data was 86%, and it was 80% for the test data. In the fall, the habitat with the highest predicted suitability for rex sole occurred along the edges of banks around Kodiak Island, particularly Chirikof, Albatross, and Portlock Banks (Figure 28).

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables determining the distribution of rex sole (relative importance = 25.6 and 21.6). The AUC was 0.91 for the training data, indicating an excellent model fit. The AUC for the test data was 0.82, indicating a good model fit. The percent of observations correctly classified was 85% and 82% respectively, for the training and test data. In the winter, the habitat with the highest predicted suitability for rex sole occurred on the around Kodiak Island, practically around Albatross and Portlock Banks, and to a lesser extent off the Kenai Peninsula (Figure 29).

In the spring, *MaxEnt* modeling determined that depth and tidal current were the most important variables determining the distribution of rex sole (relative importance = 52.64 and 28.7). The AUC was 0.91 for the training data, indicating an excellent model fit. It was 0.84 for the test data, indicating a good model fit. During the spring, high suitability habitat for rex sole were predicted to be more dispersed and generally deeper than was observed during either the fall or the winter. High suitability habits were predicted to occur across much of the middle and outer-shelf in the GOA, with localized concentration occurring along the Alaska Peninsula (Shumagin and Shelikof Gullies), in Shelikof Strait, and off Prince of Wales Island in southeast Alaska. (Figure 30).

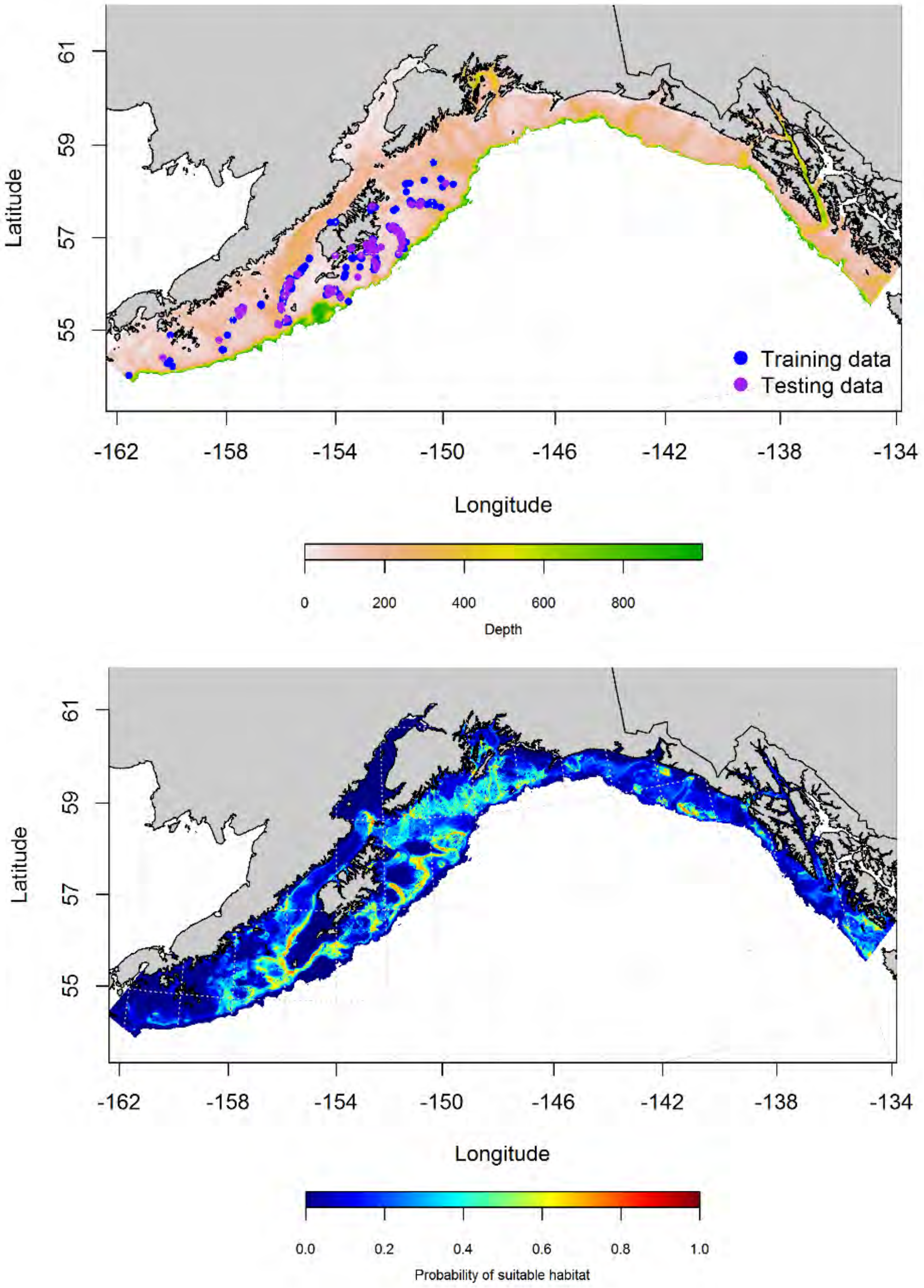
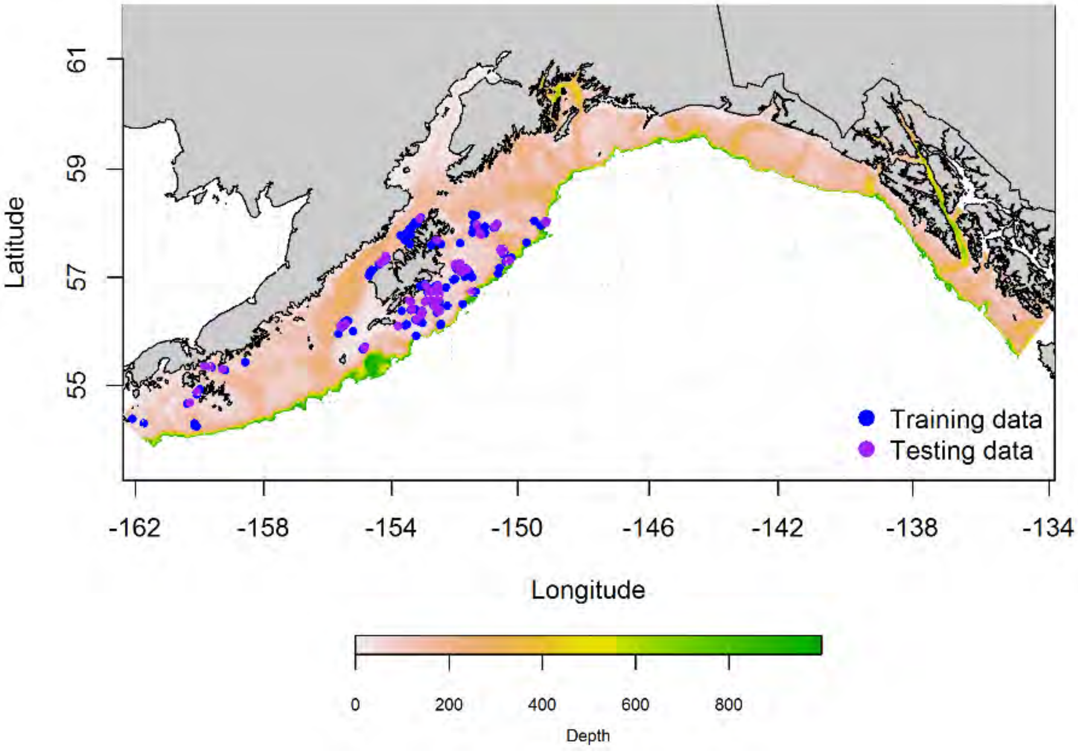


Figure 28. -- Locations of fall (September-November) commercial fisheries catches of *G. zachirus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *G. zachirus* commercial catches (bottom panel) and the purple points were used to test the model.



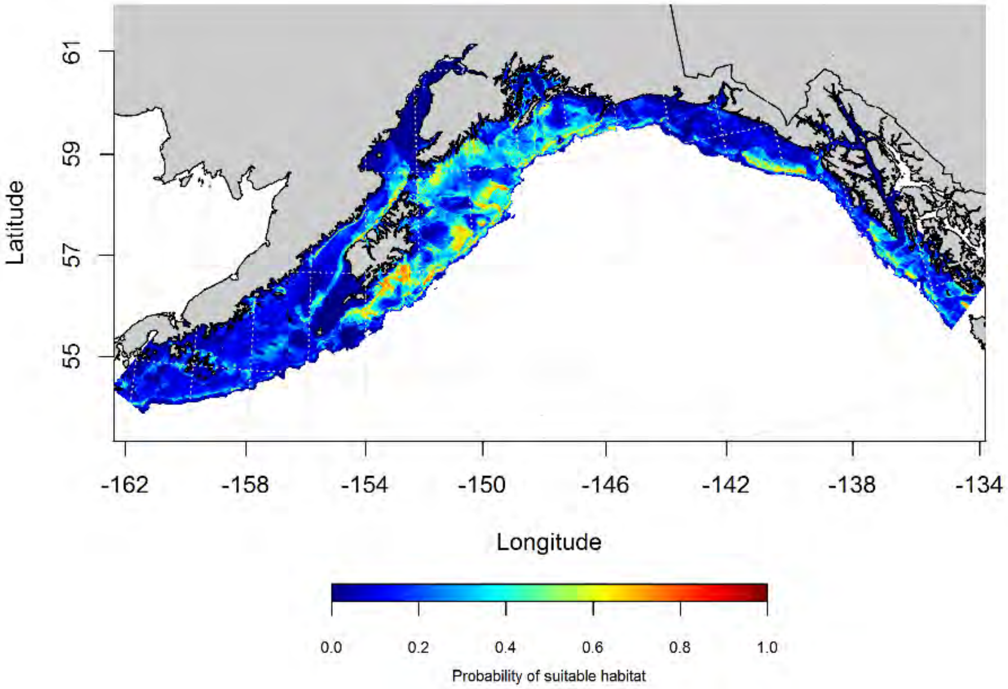


Figure 29. -- Locations of winter (December-February) commercial fisheries catches of *G. zachirus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *G. zachirus* commercial catches (bottom panel) and the purple points were used to test the model.

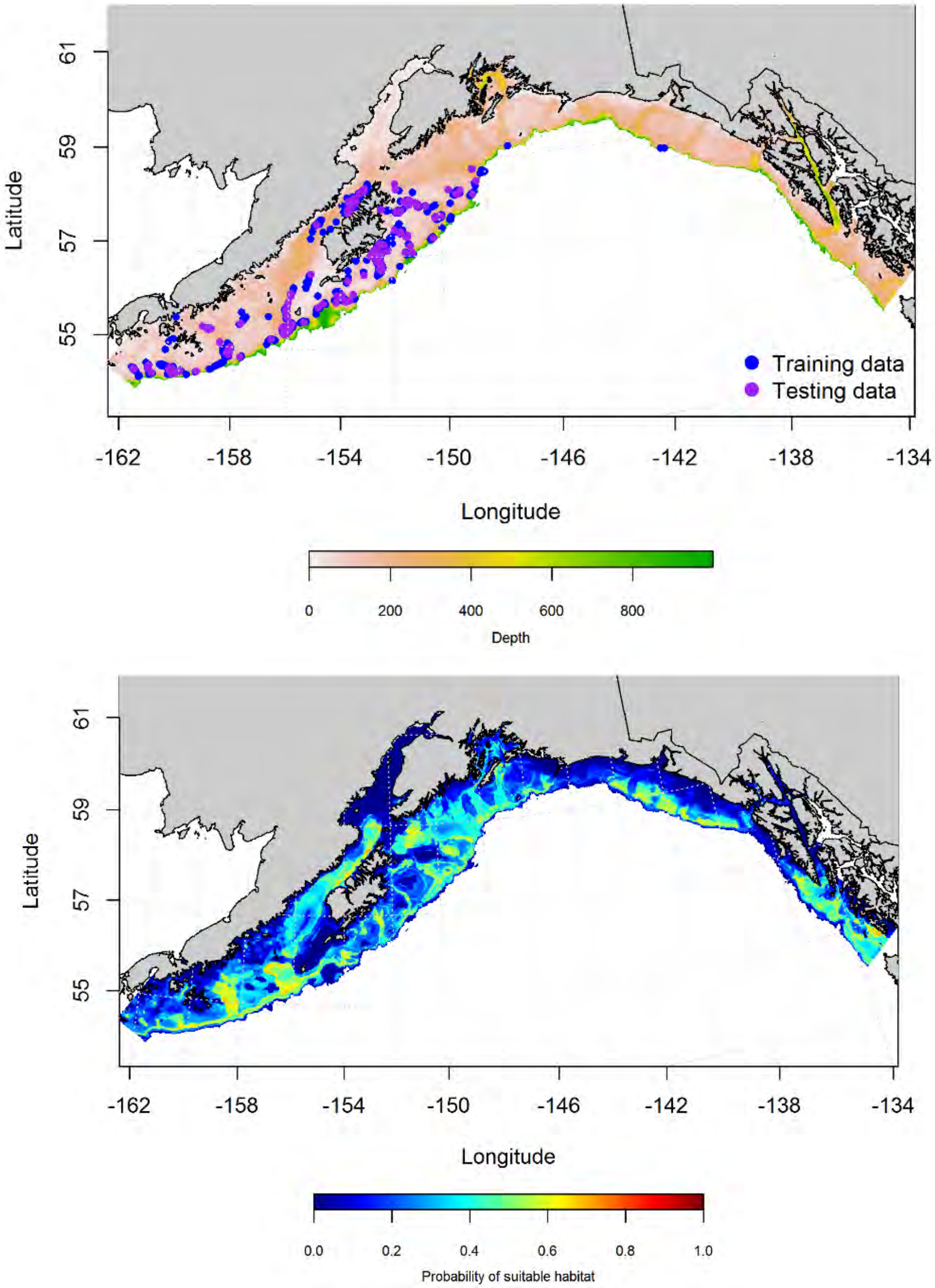


Figure 30. -- Locations of spring (March-May) commercial fisheries catches of *G. zachirus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *G. zachirus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *G. zachirus* Essential Fish Habitat Maps and Conclusions -- Rex sole essential fish habitat predicted by modeling is extensively distributed across much of the shelf in the Gulf of Alaska. EFH for rex sole eggs in the spring was predicted to include most of the shelf in the GOA. During the summer, EFH for rex sole eggs was more restricted and included most of the shelf in the western gulf (Figure 31). EFH for larval stages predicted in the spring and summer included much of the shelf in the western GOA. Early juvenile EFH could not be predicted.

Larval *G. zachirus* paragraph…(Figure 32)

ADULTS NEED TO BE SUMMARIZED HERE AS WELL FOR (Figure 33). Summer EFH for juvenile rex sole, based on trawl survey observations, was predicted to include much of shelf in the central and eastern gulf (Figure 33). This potential mismatch, in the distribution of EFH for early life history stages and juveniles may have the result of high-salinity bottom being drawn onto the shelf during the summer, influencing the transport of young rex sole (Weingartner 2005). Alternatively, it may have been due to a sampling artifact.

During the fall and spring, EFH for adult rex sole included of the middle and outer-shelf in the GOA. During the winter, EFH for adult rex sole was predicted to be more restricted in extent, and was largely centered in deeper gullies and troughs east of Kodiak Island (Figure 34).

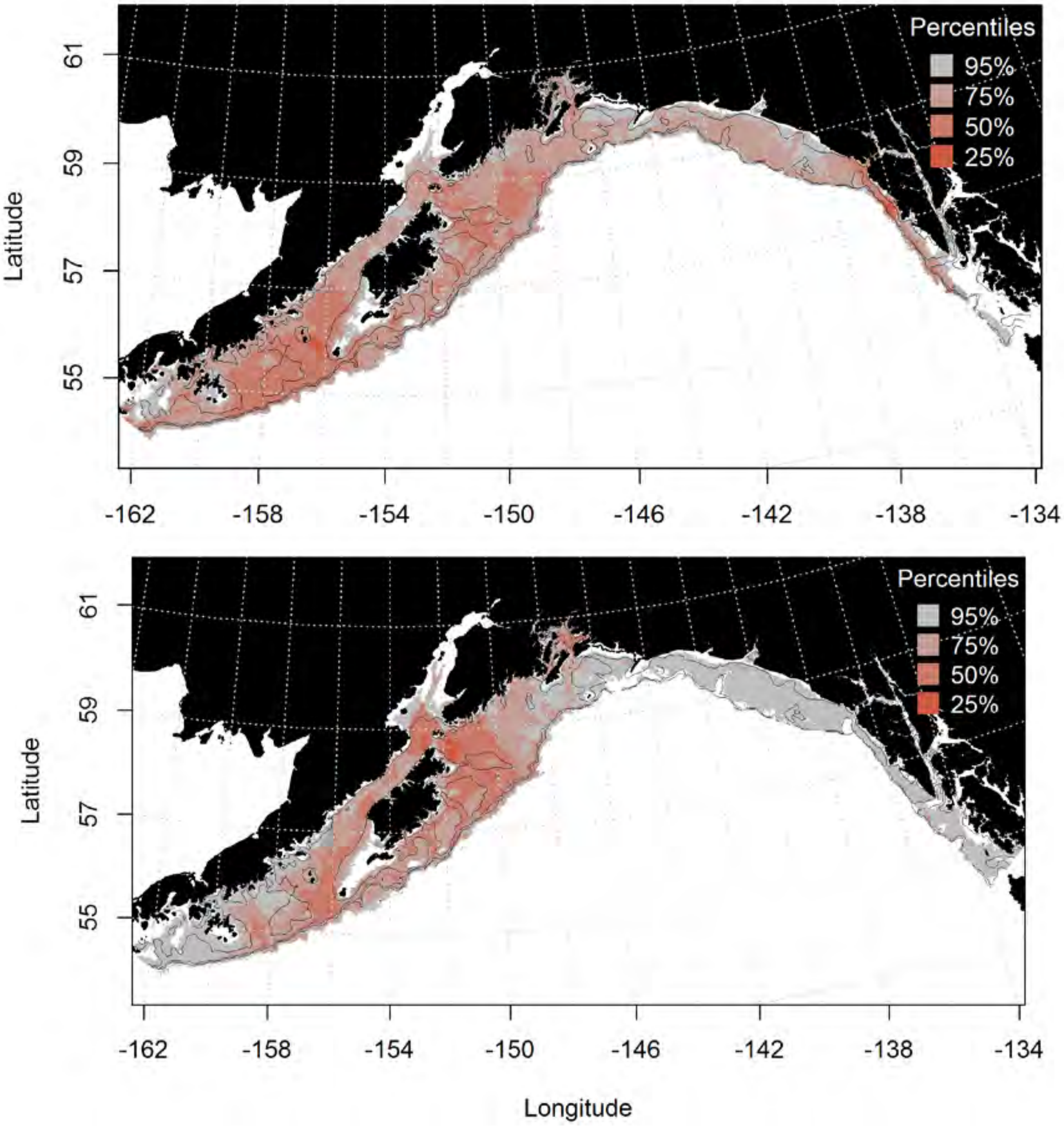


Figure 31. -- Spring and summer essential fish habitat predicted for *G. zachirus* eggs (top and bottom panel) from the EcoFOCI database.

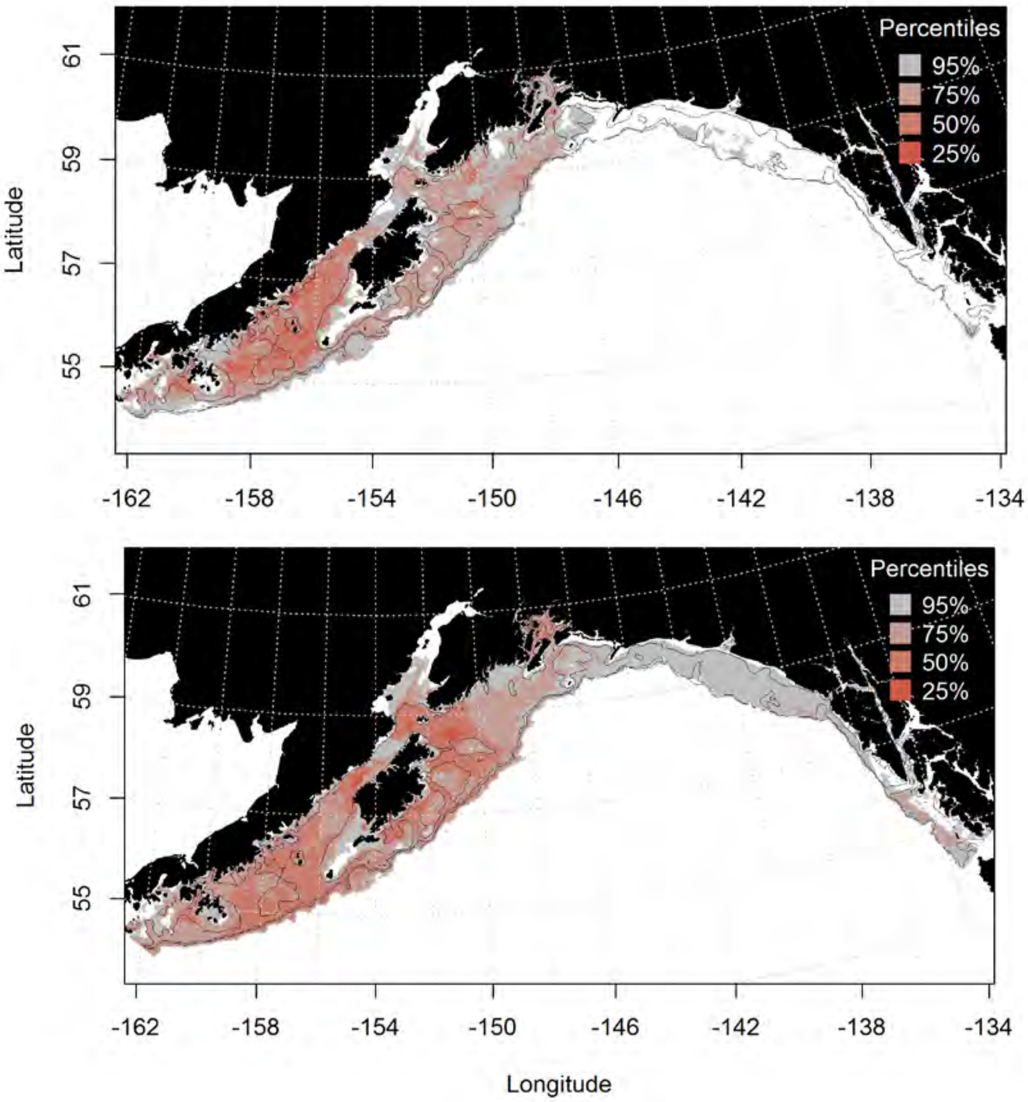


Figure 32. -- Spring and summer essential fish habitat predicted for larval *G. zachirus* (top and bottom panel) from the EcoFOCI database.

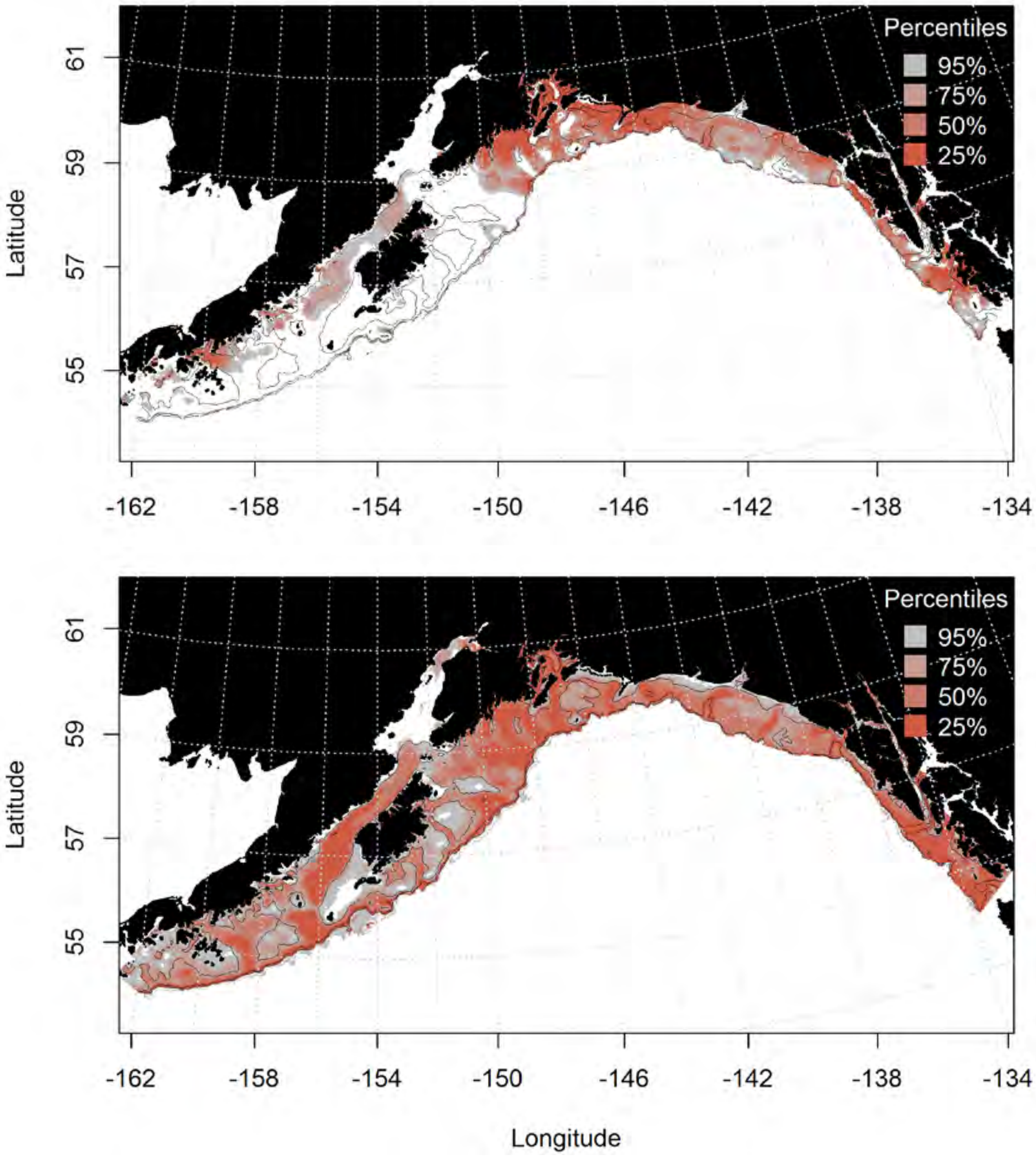


Figure 33. -- Predicted summer essential fish habitat for *G. zachirus* juveniles and adults (top and bottom panel) from summer bottom trawl surveys.

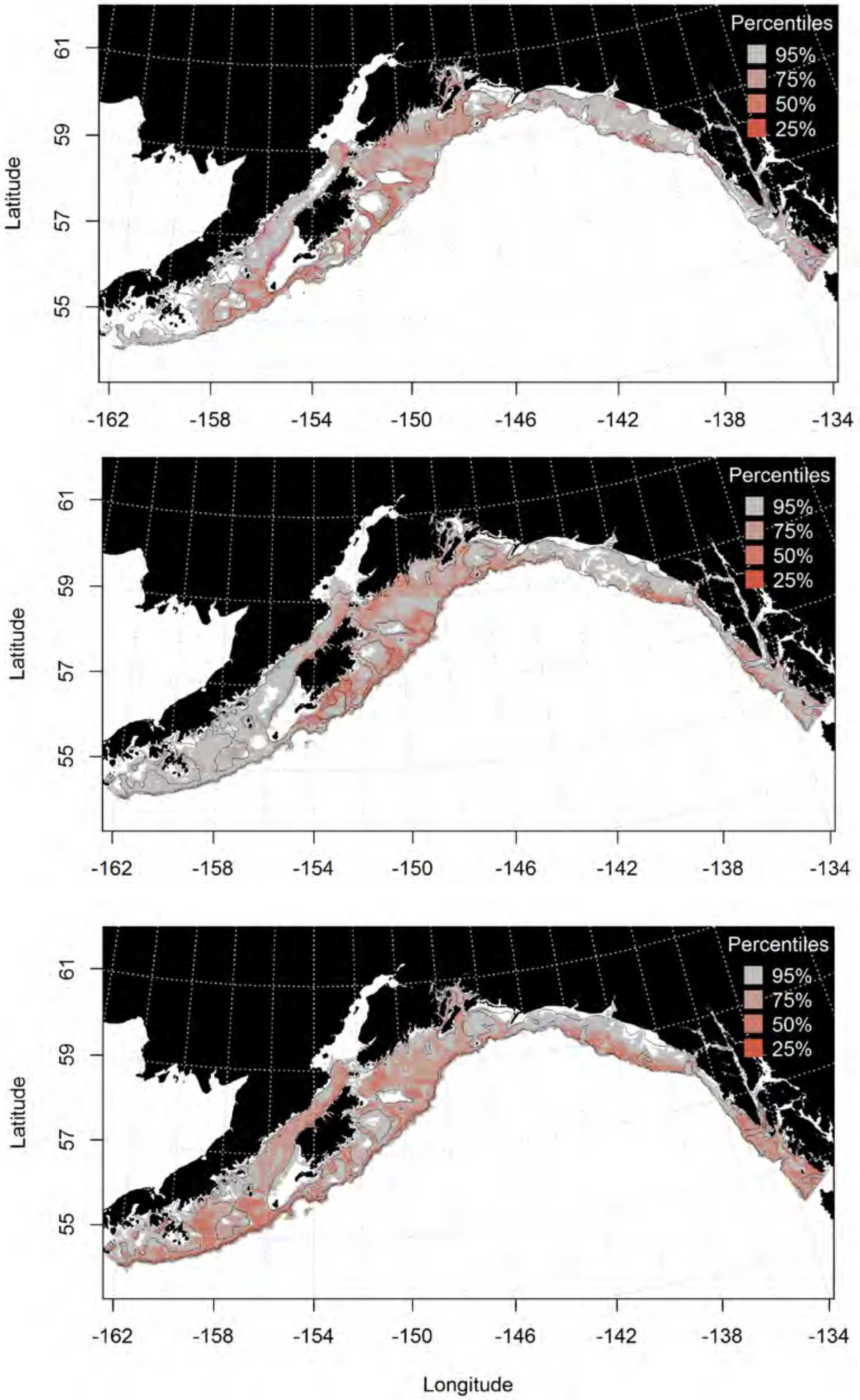


Figure 34. -- Essential fish habitat predicted for *G. zachirus* during fall (top panel), winter (middle panel), and spring (bottom panel) from commercial catches.

Dover sole (*Microstomus pacificus*)

Dover sole occur throughout much of the Gulf of Alaska, primarily in waters deeper than 200 m (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *M. pacificus* in the Gulf of Alaska -- Throughout much of their early life history Dover sole appear to occur in the western Gulf of Alaska. Dover sole eggs were observed during the winter, spring, and summer (Figure 35). In the winter, there were only six observations of Dover sole, all of which occurred along the shelf break in the western GOA.

During the spring Dover sole eggs were much more abundant. The best-fitting *MaxEnt* model indicated that depth and current variability (relative importance 42.7 and 23.1 respectively) were the most important variables habitat suitable. The AUC for the training data was 0.81, indicating an excellent model fit. The AUC for the testing data was 0.76, indicating a fair model fit. The percent of the observations correctly classified in the training data was 73% and 76% for the test data. The predicted distribution of Dover sole eggs occurred across much of the shelf in western GOA, from Prince William Sound to the Shumagin Islands (Figure 36). The highest suitability habits occurred at the foot of Shelikof Gully in the vicinity of Chirikof Island. Dover sole eggs were also abundant during the summer. The best-fitting *MaxEnt* model indicated that depth and surface temperature (relative importance 32.2 and 32.1) were the most important variables habitat suitable. The AUC for the training data was 0.89, indicating a good model fit. The AUC for the testing data was 0.67, indicating a poor model fit. The percent of the observations correctly classified in the training data was 80% and 67% for the test data. Dover sole eggs were predicted to occur around Kodiak Island, including Marmot Gully and Shelikof Strait to the east, and Shelikof Gully to the west (Figure 36).

Larval Dover sole were observed during the spring and the summer (Figure 37).

During the spring, the best-fitting *MaxEnt* model indicated that depth and current variability (relative importance 25.4 and 24.2 respectively) were the most important variables habitat suitable. The AUC was 0.92 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.56, indicating the model failed. The percent of the observations correctly classified in the training data was 42% and 56% for the test data. During the spring, Dover sole larval habitat was predicted to be occur around Kodiak Island, particularly along Shelikof Strait and Shelikof Gully (Figure 38). During the summer, larval Dover sole were also abundant around Kodiak Island. The most important variables predicting larval habitat suitability were surface temperature and depth (43.7 and 23.5, respectively). The AUC was 0.92 for the training data, indicating an excellent model fit. Model over fitting resulted in a reduced AUC score (0.66) for the testing data, indicating a poor model fit. The percent of the observations correctly classified in the training data was 86% and 66% for the test data. During the summer, Dover sole larval habitat was predicted to be largely occur east of Kodiak Island, in Shelikof Strait and Marmot Gully (Figure 38).

No records of early juvenile Dover sole occurred in the EcoFOCI database.

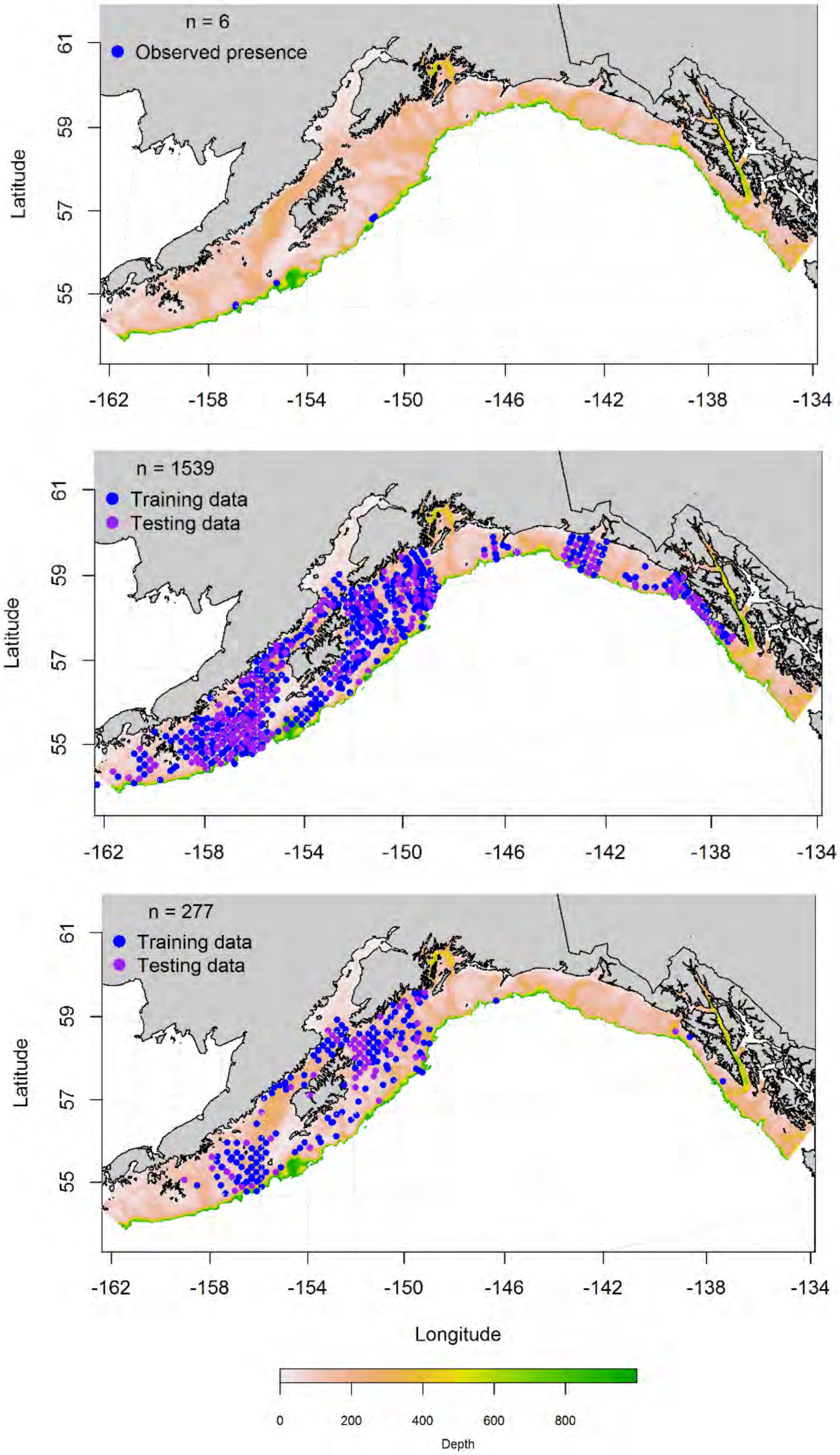


Figure 35. -- Winter, spring, and summer (top, middle, and bottom panel, respectively) observations of *M. pacificus* eggs from the Gulf of Alaska.

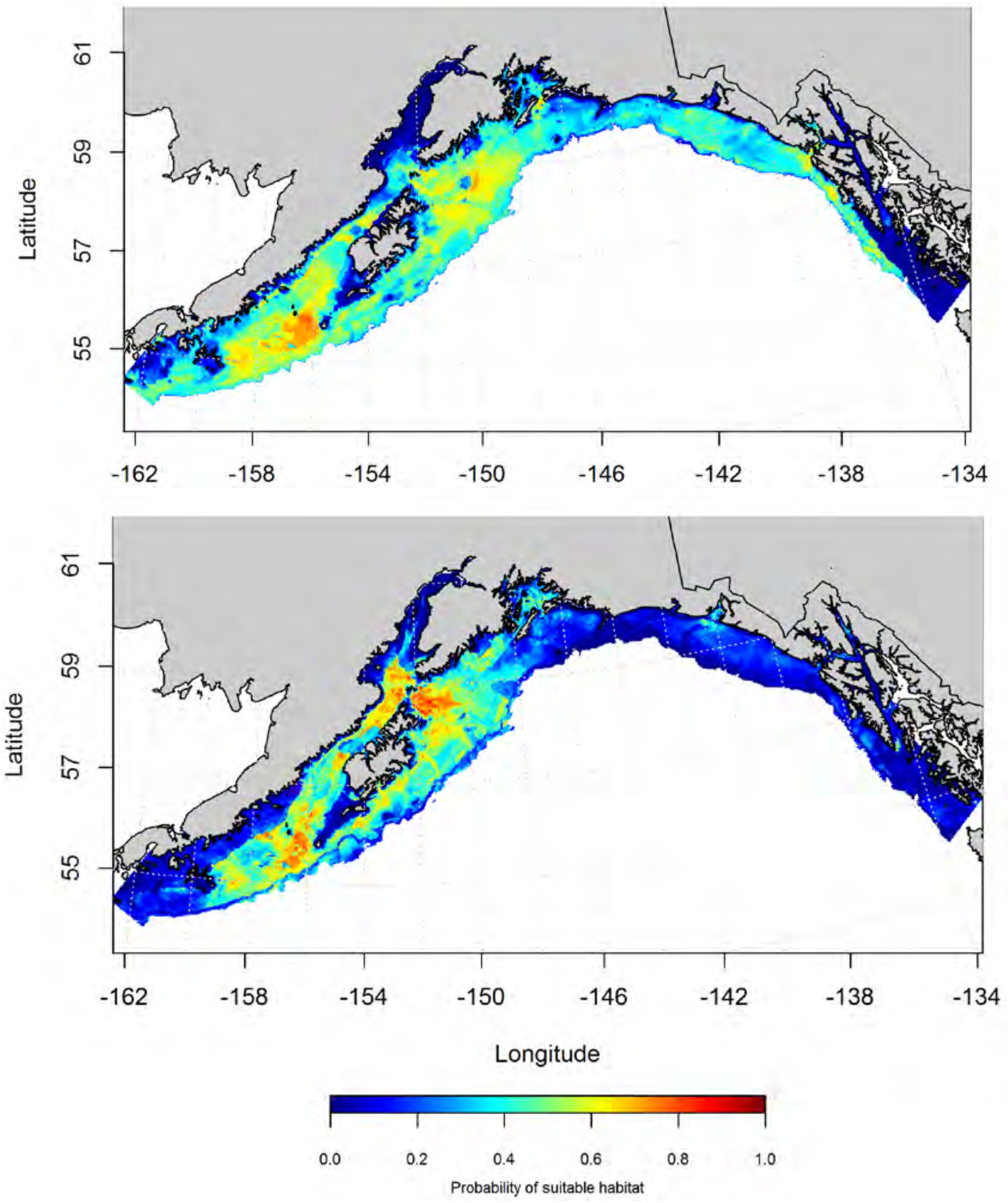


Figure 36. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of *M. pacificus* eggs from maximum entropy modeling of the Gulf of Alaska.

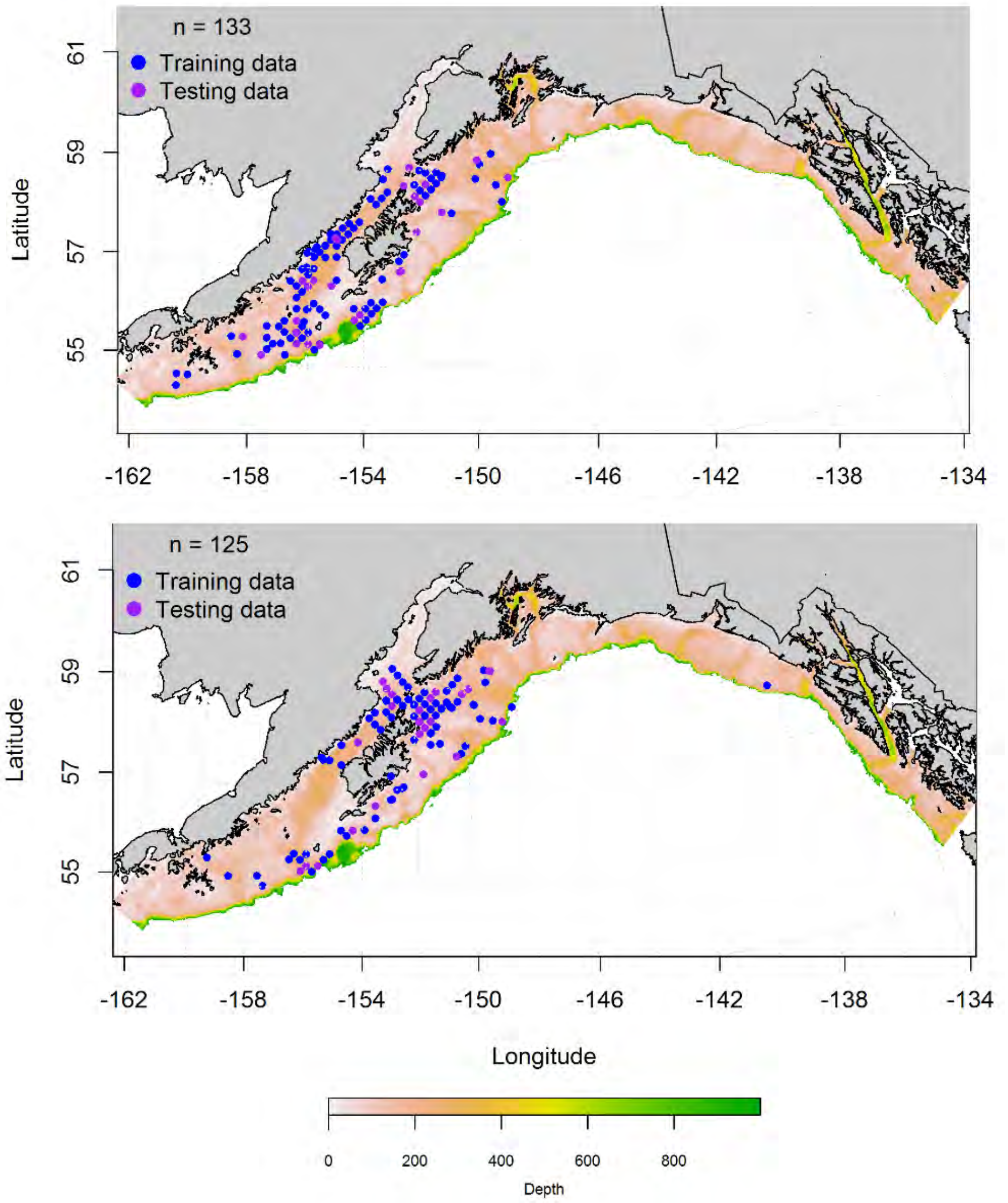


Figure 37. -- Spring and summer observations (top and bottom panel, respectively) of larval *M. pacificus* from the Gulf of Alaska.

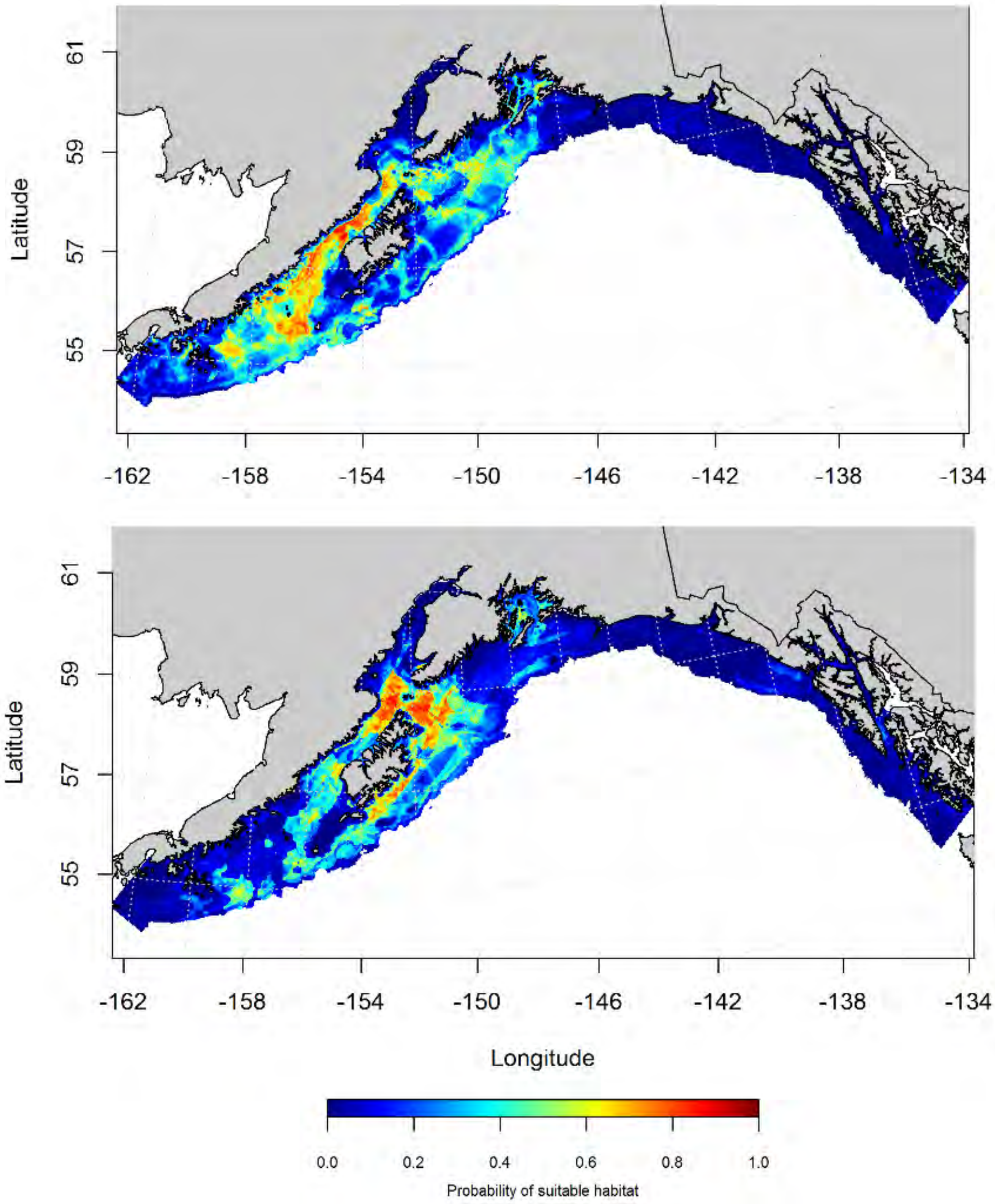


Figure 38. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *M. pacificus* from maximum entropy modeling of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *M. pacificus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile Dover sole are broadly distributed across much of the shelf in the Gulf of Alaska (Figure 39).

The best-fitting GAM indicated that longitude and latitude, depth, and slope were the most important variables predicting the distribution of juvenile Dover sole. The model explained 28% of the variability of the CPUE in the training data, and 26% of the variability in the test data. Juvenile Dover sole were predicted to occur at low abundances across much of the shelf in the eastern GOA, particularly in the deeper valleys and gullies (Figure 40).

Summer bottom trawl survey data also indicate adult Dover sole occur across much of the shelf in the GOA (Figure 39). The best-fitting GAM indicated that depth, latitude and longitude, and ocean color were the most important variables predicting the distribution of adult Dover sole. The model explained 44% of the variability in CPUE for the training data and 43% of testing data. Adult Dover sole were predicted to occur at low abundances throughout much of the shelf in the GOA (Figure 41).

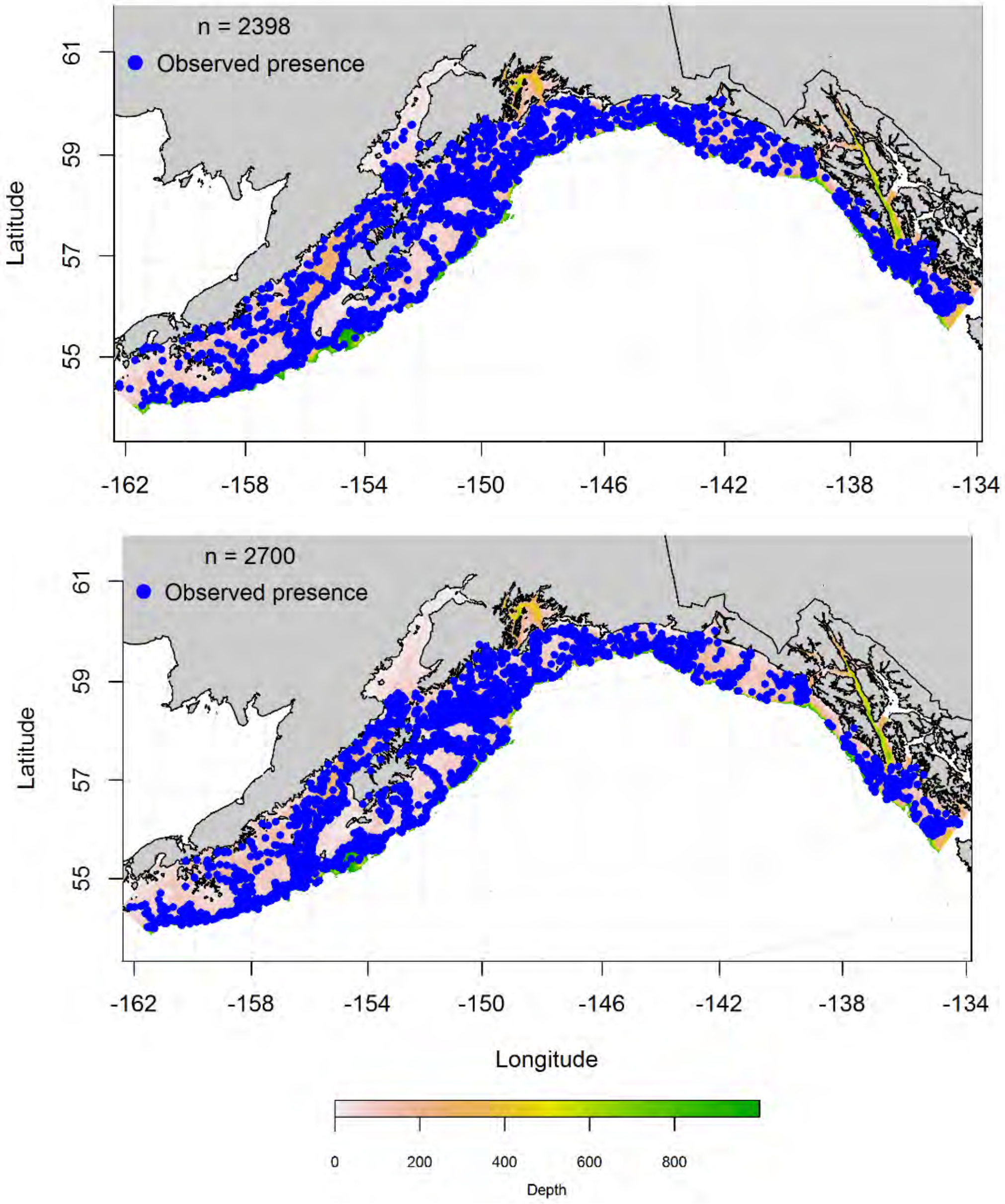


Figure 39. -- Locations of catches of juvenile and adult *M. pacificus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

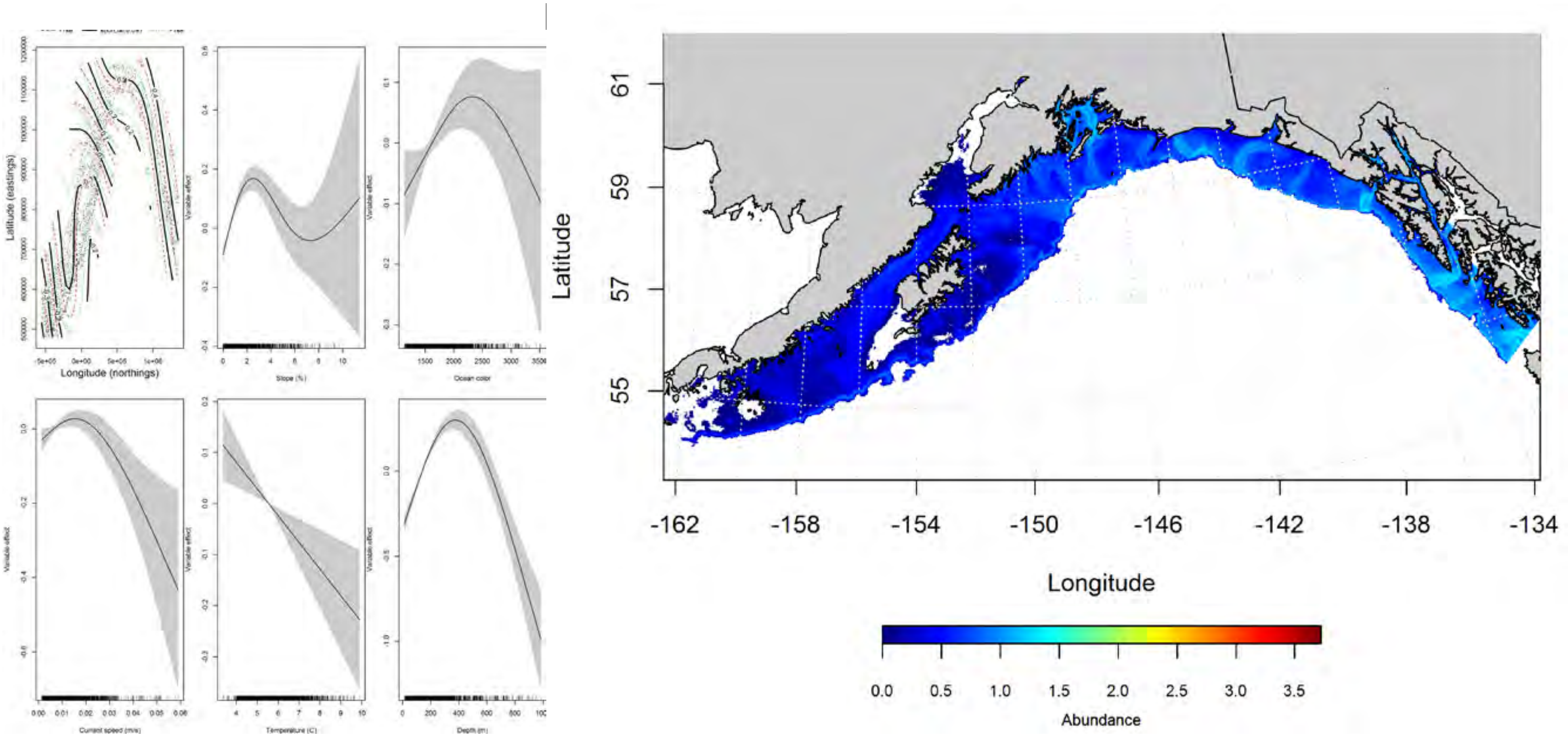


Figure 40. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of juvenile *M. pacificus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted juvenile *M. pacificus* abundance (right panel).

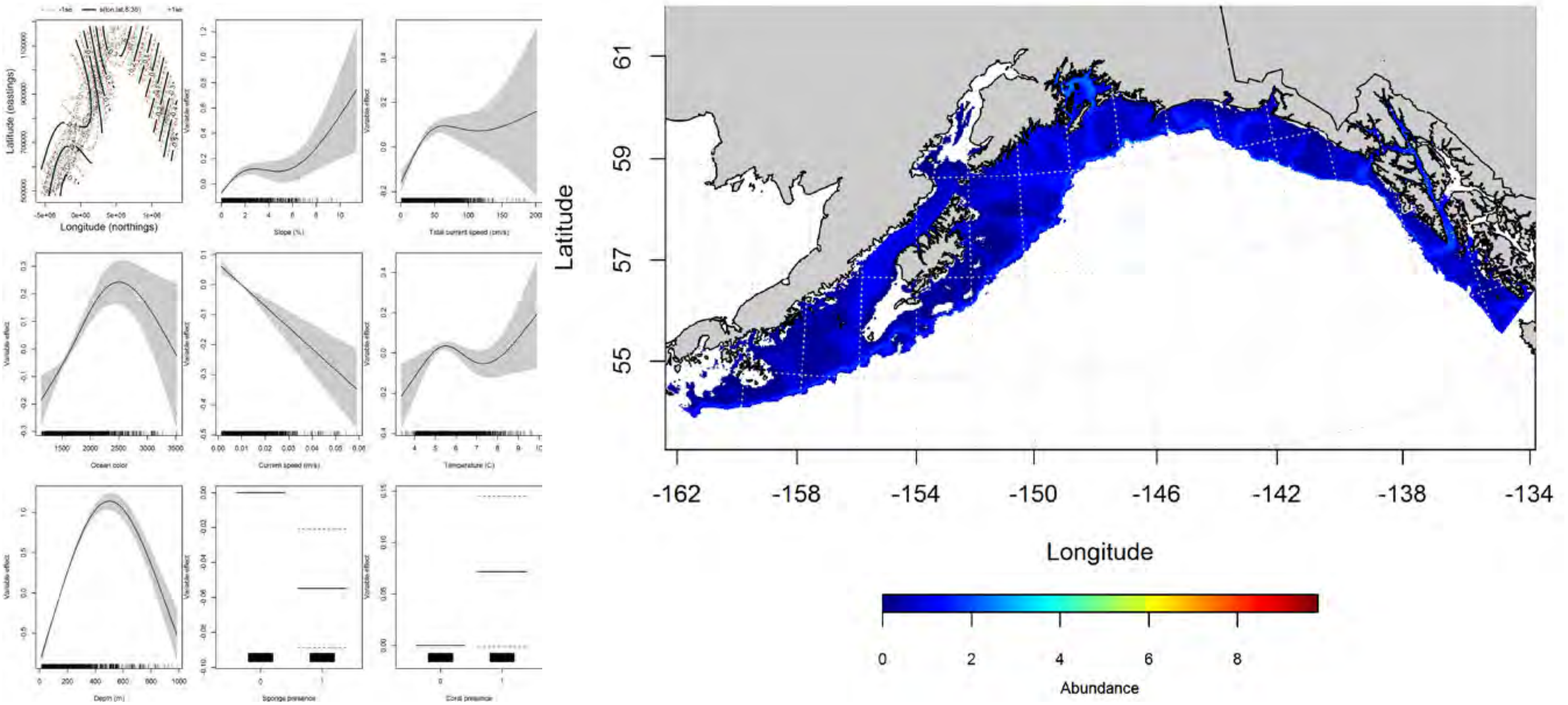


Figure 41. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *M. pacificus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *M. pacificus* abundance (right panel).

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Seasonal distribution of commercial fisheries catches of adult *M. pacificus* in the Gulf of Alaska -- Commercial catch data indicate Dover sole largely occur in the western GOA around Kodiak Island, particularly in the deeper channels and depressions. In the fall, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of Dover sole (relative importance = 31.9 and 25.4 respectively). The AUC for the training data 0.90, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The percent of observations correctly classified for the training data was 83%, and it was 80% for the test data. In the fall, the habitat with the highest predicted suitability for Dover sole occurred around Kodiak Island, particularly in the deeper channels and depressions such as Shelikof and Shumagin Gullies (Figure 42).

In the winter, *MaxEnt* modeling determined that ocean color and bottom temperature were the most important variables determining the distribution of Dover sole (relative importance = 31.1 and 21.8 respectively). The AUC was 0.96 for the training data, indicating an excellent model fit. The AUC for the test data was 0.88, indicating a good model fit. The percent of observations correctly classified was 91% and 88% respectively, for the training and test data. In the winter, the habitat with the highest predicted suitability for Dover sole occurred along the shelf break east of Kodiak Island, practically along the offshore edge of Albatross and Portlock Banks (Figure 43).

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of Dover sole (relative importance = 62.5 and 19.6 respectively). The AUC was 0.91 for the training data, indicating an excellent model fit. It was 0.84 for the test data, indicating a good model fit. During the spring, high suitability habitat for Dover sole were predicted to be more dispersed and occur at deeper depths than was observed during either the fall or the winter. High suitability habits were predicted to occur in deeper portions of the shelf, including the shelf break and depressions such as Shumagin and Shelikof Gullies along the Alaska Peninsula and off Cape Ommaney and Prince of Wales Island off southeast Alaska (Figure 44).

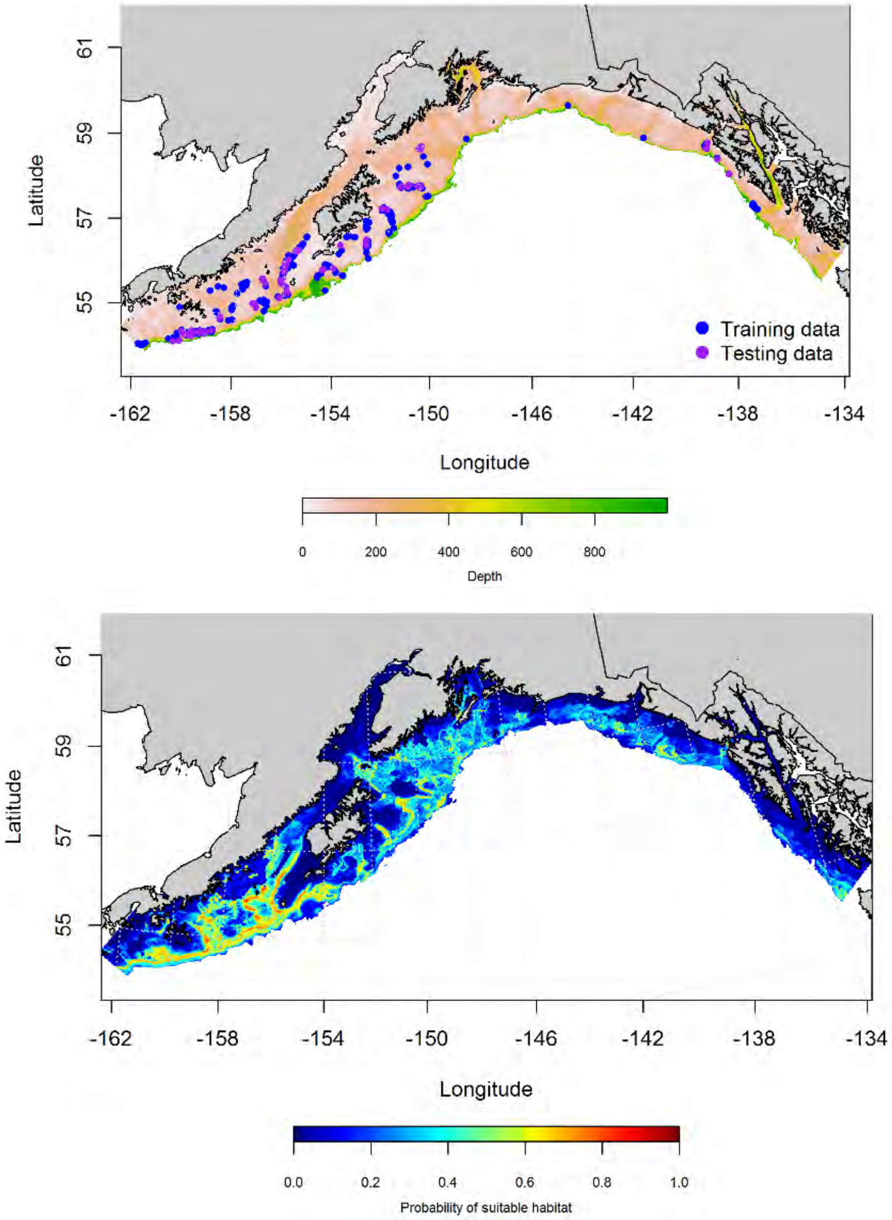
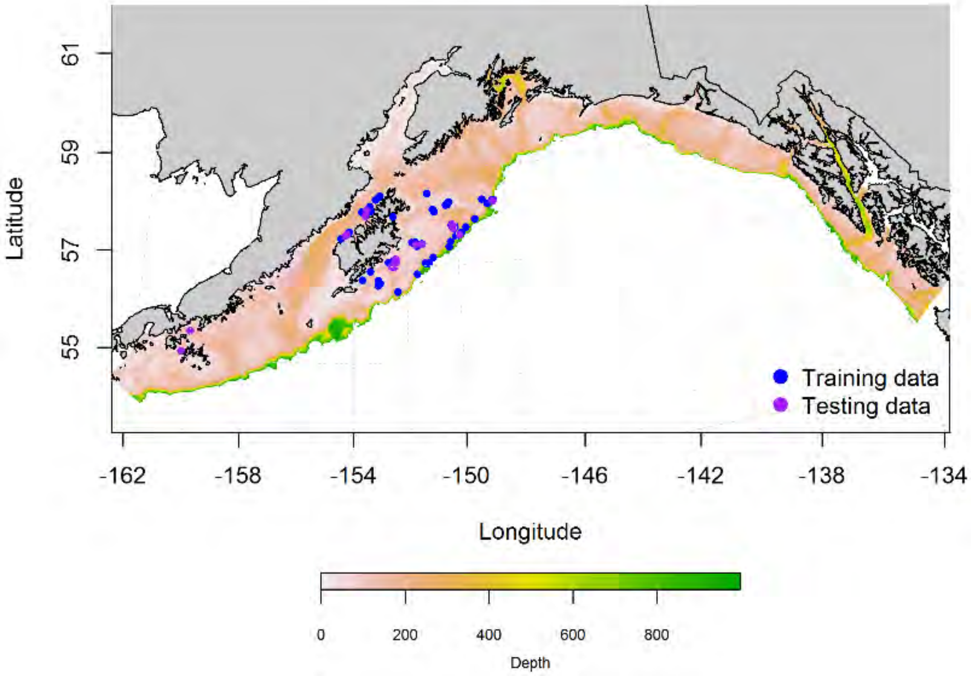


Figure 42. -- Locations of fall (September-November) commercial fisheries catches of *M. pacificus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *M. pacificus* commercial catches (bottom panel) and the purple points were used to test the model.



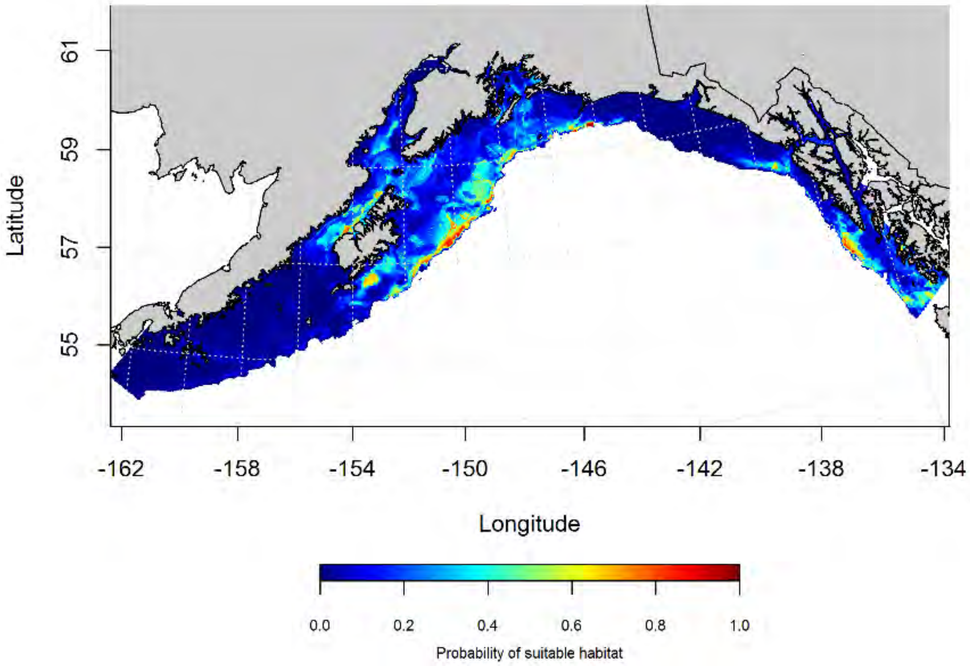


Figure 43. -- Locations of winter (December-February) commercial fisheries catches of *M. pacificus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *M. pacificus* commercial catches (bottom panel) and the purple points were used to test the model.

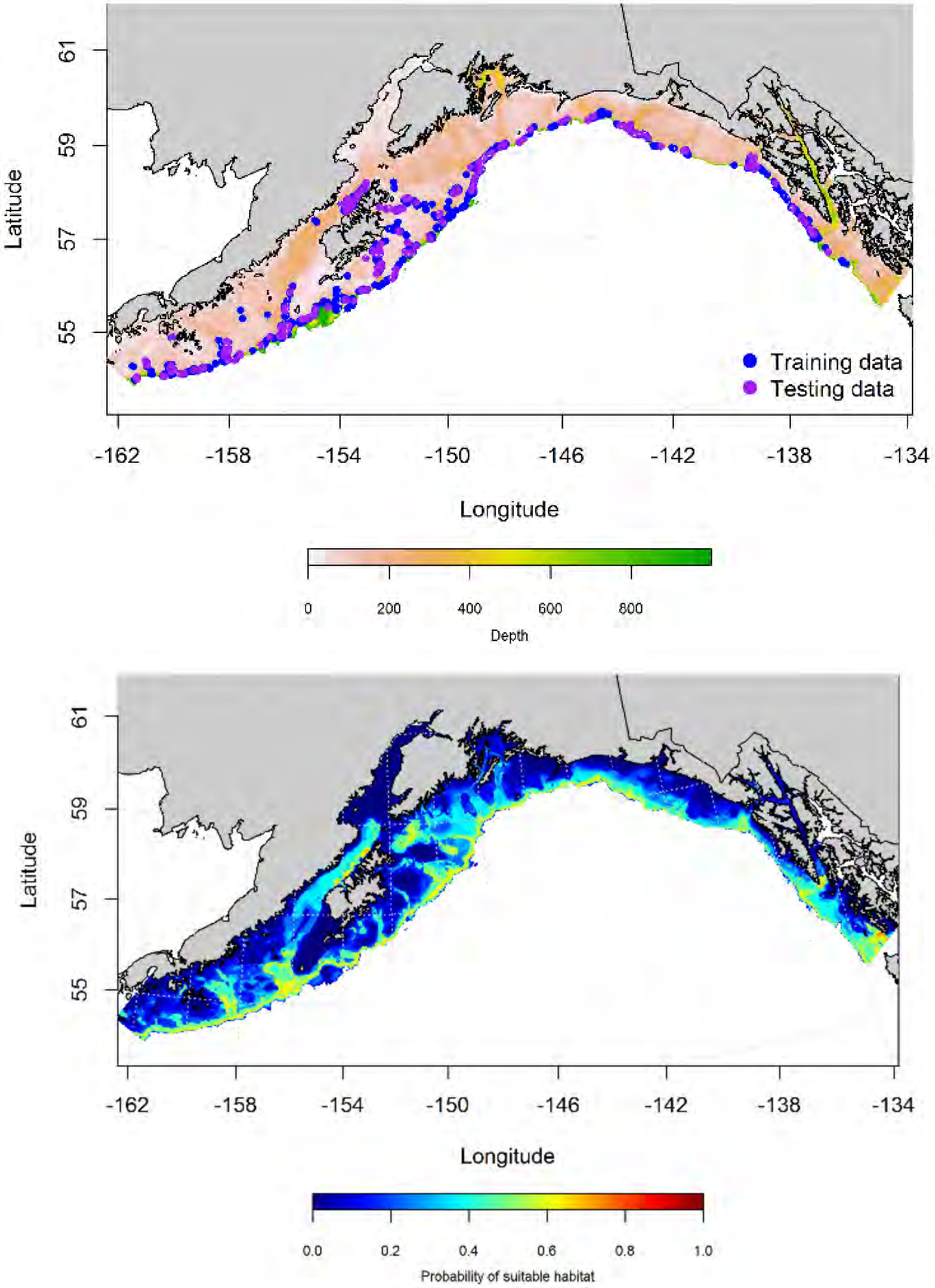


Figure 44. -- Locations of spring (March-May) commercial fisheries catches of *M. pacificus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *M. pacificus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *M. pacificus* Essential Fish Habitat Maps and Conclusions -- Dover sole essential fish habitat predicted by modeling is extensively distributed across much of the shelf in the Gulf of Alaska. EFH for Dover sole eggs, during the spring was predicted to include most of the shelf in the Gulf of Alaska. During the summer, EFH for Dover sole eggs, was predicted to be more restricted and occur largely in the western gulf (Figure 45).

EFH for larval Dover sole, during the spring was predicted to include the inner and middle-shelf in the western gulf. During the summer EFH for larval Dover sole was predicted to largely occur along the middle-shelf east of Kodiak Island (Figure 46). EFH for early juvenile Dover sole could not be predicted.

Summer EFH for juvenile and adult Dover sole, based on trawl survey observations, was predicted to include much of deeper portion of the middle- and outer-shelf, such as valleys and channels and along the shelf break (Figure 47). EFH was also predicted to occur in Prince William Sound; however, these predictions were not supported by any observations.

During the fall EFH for Dover sole, based on commercial fisheries data, was predicted to include much of the shelf, particularly the deeper depressions on the middle-shelf and the shelf break (Figure 48). During the winter, EFH for Dover sole was predicted to largely occur along the shelf break east of Kodiak Island. Spring EFH was predicted to be similar the summer EFH and to include the deeper portions of the middle- and outer-shelf, including the shelf break.

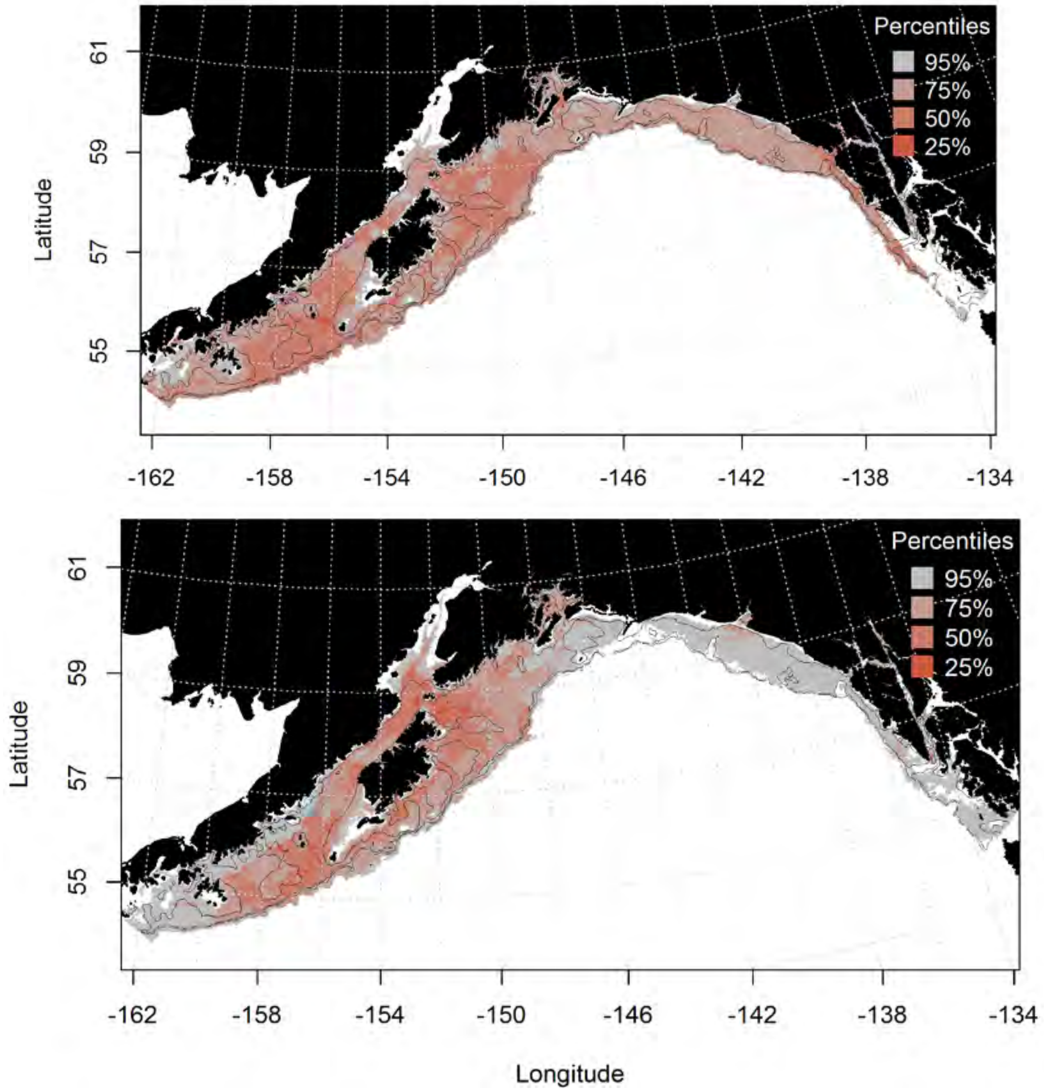


Figure 45. -- Spring, and summer essential fish habitat predicted for *M. pacificus* eggs (top and bottom panel, respectively) from the EcoFOCI database.

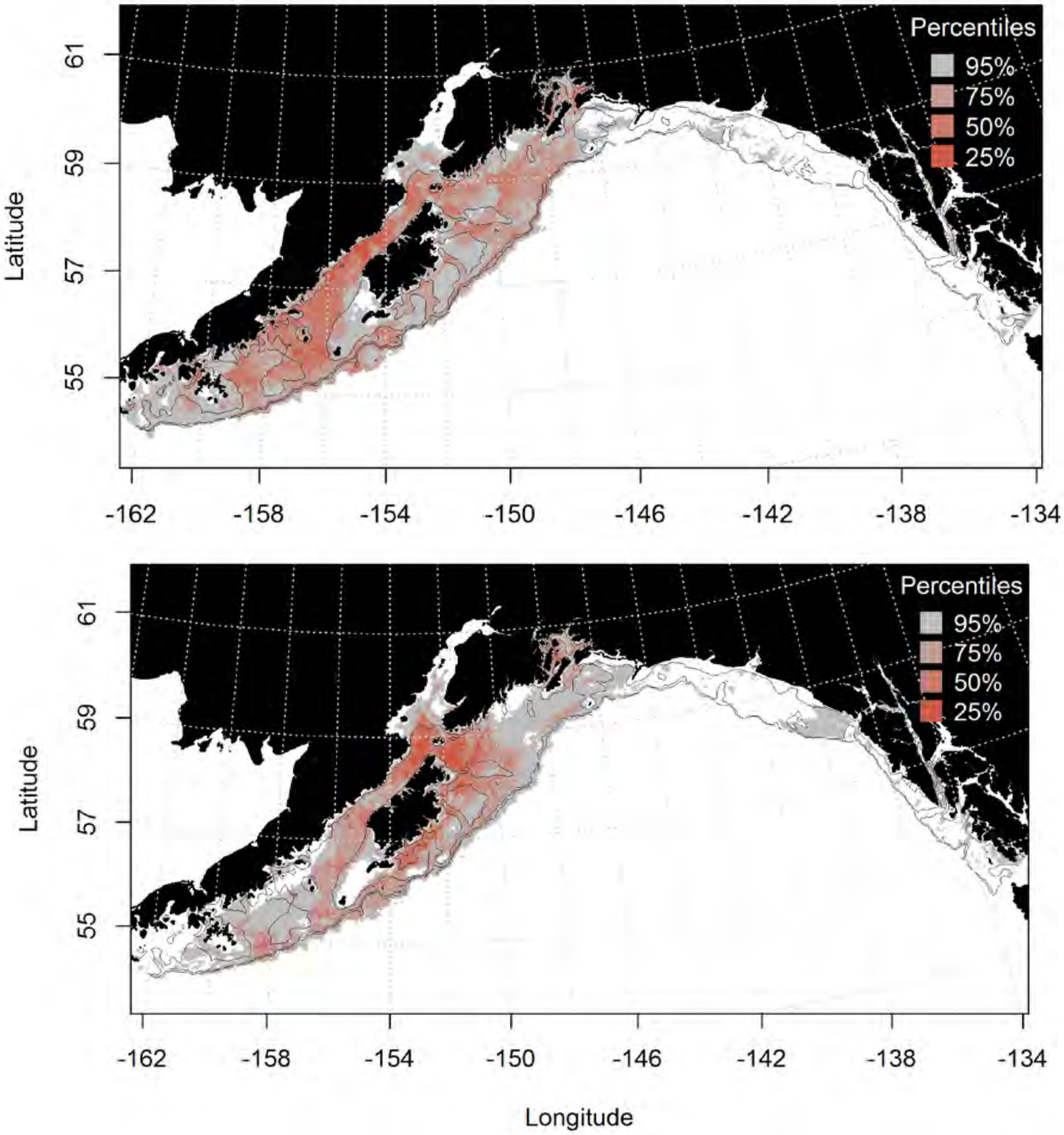


Figure 46. -- Spring, and summer essential fish habitat predicted for larval *M. pacificus* (top and bottom panel, respectively) from the EcoFOCI database.

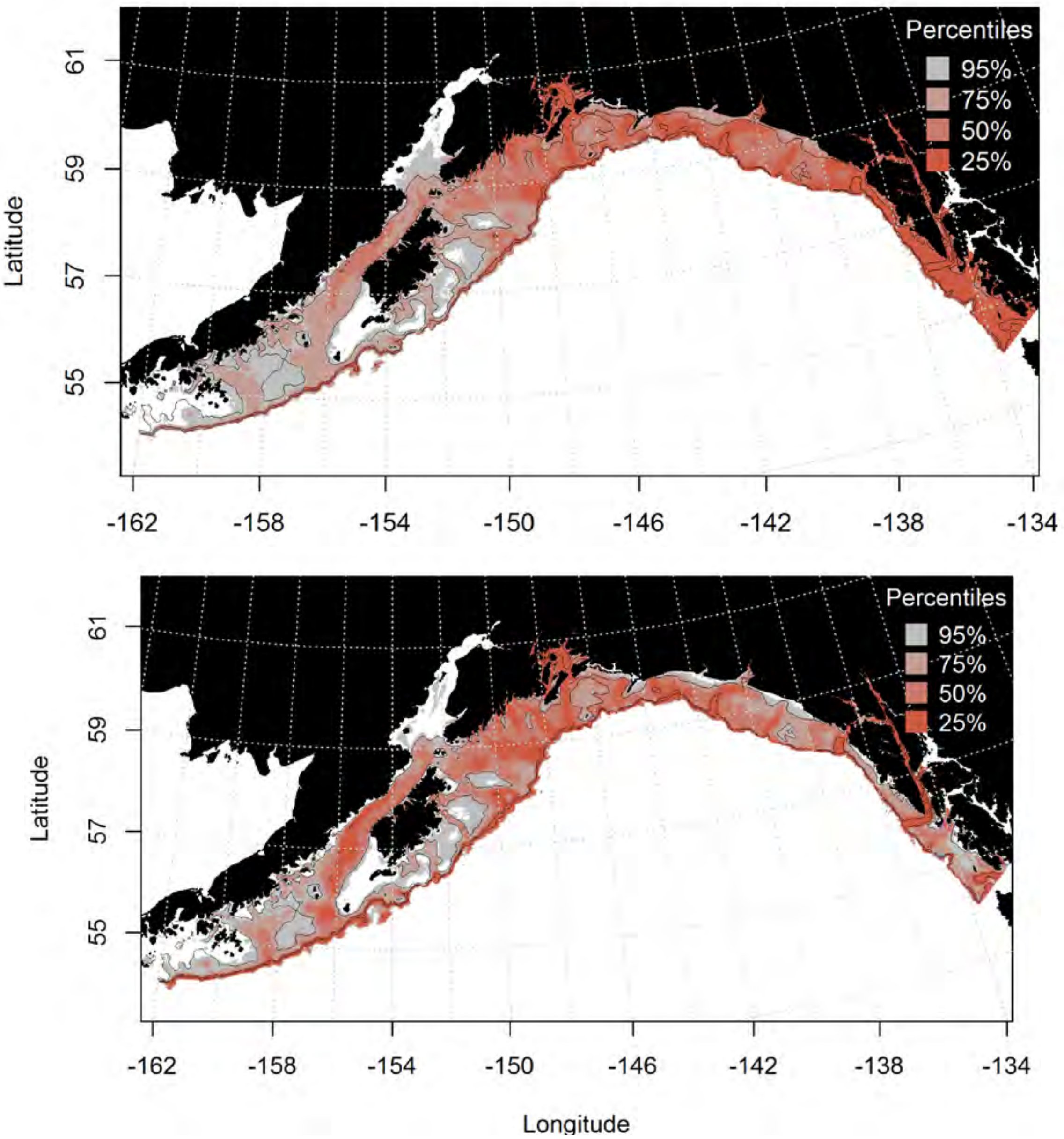


Figure 47. -- Predicted summer essential fish habitat for *M. pacificus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

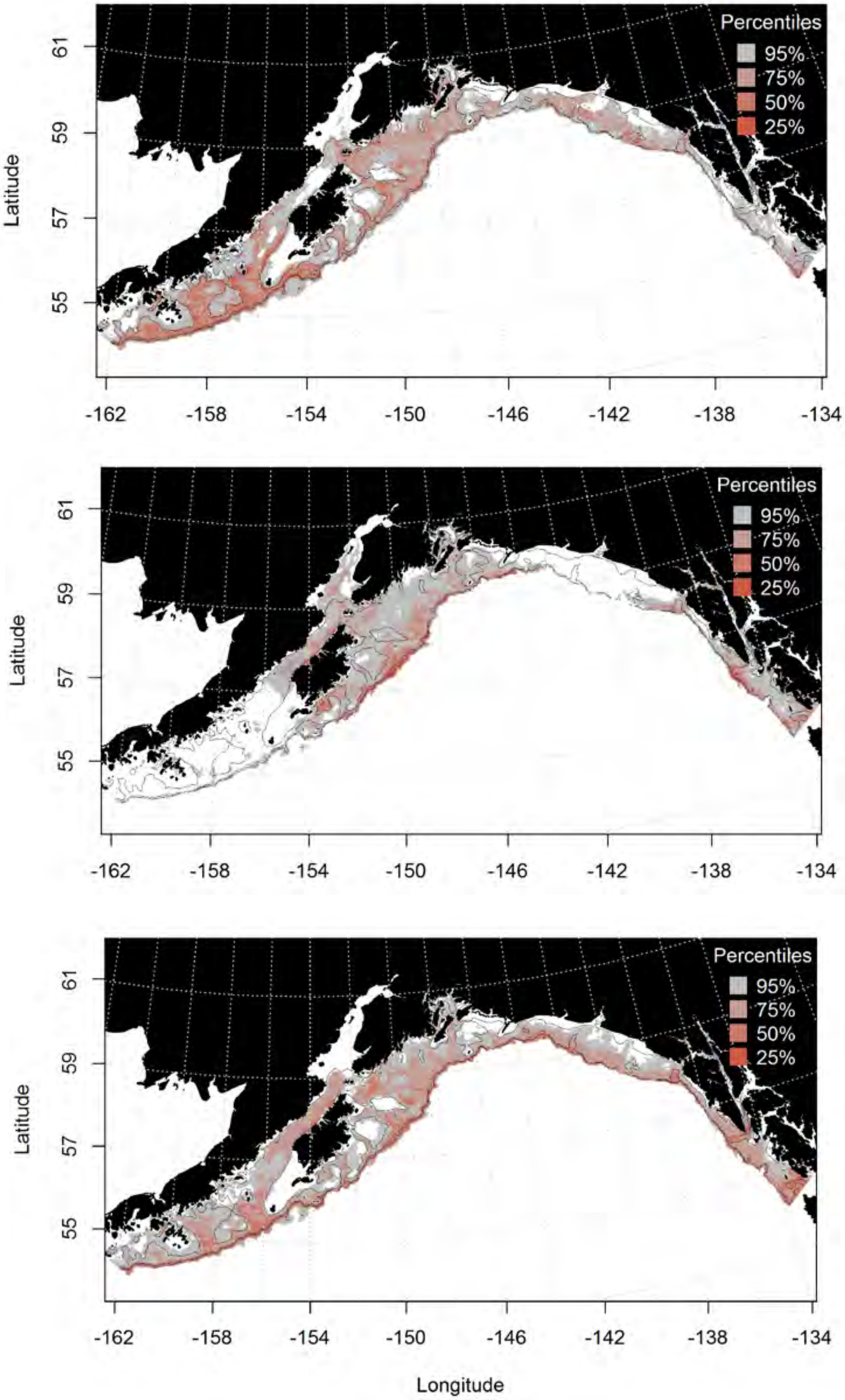


Figure 48. -- Essential fish habitat predicted for *M. pacificus* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

flathead sole (*Hippoglossoides elassodon*)

Flathead sole primarily occur in bays around Kodiak Island and the Alaska Peninsula, at depths less than 200 m (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *H. elassodon* in the Gulf of Alaska -- Throughout much of their early life history flathead sole appear to largely occur in the western Gulf of Alaska. Flathead sole eggs were observed throughout the year (Figure 5.1). During both the fall and the winter, a single egg was observed along the inner-shelf in the western gulf (Figure 5.1). During the spring, flathead sole eggs were much more abundant. The best-fitting *MaxEnt* model indicated that surface temperature and depth (relative importance 29.0 and 22.3 respectively) were the most important variables predicting habitat suitability. The AUC for the training data was 0.89, indicating a good model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of the observations correctly classified in the training data was 89% and 81% for the test data. Flathead sole eggs were predicted to occur across much of the shelf west of Kodiak Island, particularly along Shelikof Strait and Shelikof Gully (Figure 5.2). During the summer flathead sole eggs were also abundant. The best-fitting *MaxEnt* model indicated that surface temperature and surface speed (relative importance 50.4 and 18.3 respectively) were the most important variables predicting habitat suitability. The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.82, indicating a good model fit. The percent of the observations correctly classified in the training data was 87% and 82% for the test data. During the summer, flathead sole eggs were predicted to occur around Kodiak Island, Shelikof Strait and Marmot Gully and inshore waters to the east (Figure 5.2).

Larval flat head sole were abundant during both the spring and the summer, and observed over much of the western shelf (Figure 5.3). During the spring, the best-fitting *MaxEnt* model indicated that surface temperature and depth (relative importance 27.5 and 18.0 respectively) were the most important variables habitat suitable. The AUC was 0.91, indicating an excellent model fit for the training data. The AUC was 0.81 for the testing data, indicating a good model fit for the test data. The percent of the observations correctly classified in the training data was 82% and 81% for the test data. During the spring, flathead sole larval habitat was predicted to include much of the inner- and middle-shelf west of Kodiak Island, particularly from Shelikof Gully to Shumagin Gully (Figure 5.4). During the summer, larval flathead sole were abundant across much of the western GOA. The most important variable predicting larval habitat suitability were surface temperature and depth (62.2 and 17.2, respectively). The AUC was 0.88 for the training data, indicating a good model fit. The AUC for the testing data was 0.77, indicating a fair model fit. The percent of the observations correctly classified in the training data was 80% and 77% for the test data. During the summer, flathead sole larval habitat included much of the inner and middle-shelf around Kodiak Island, particularly Shelikof Strait and Shelikof Gully to the west, and Marmot Gully and inshore waters to the east (Figure 5.4).

Observations of early juvenile flathead sole only occurred during the summer. There were nine observations, and they occurred on the middle-shelf around Kodiak Island and the Alaska Peninsula (Figure 5.5)

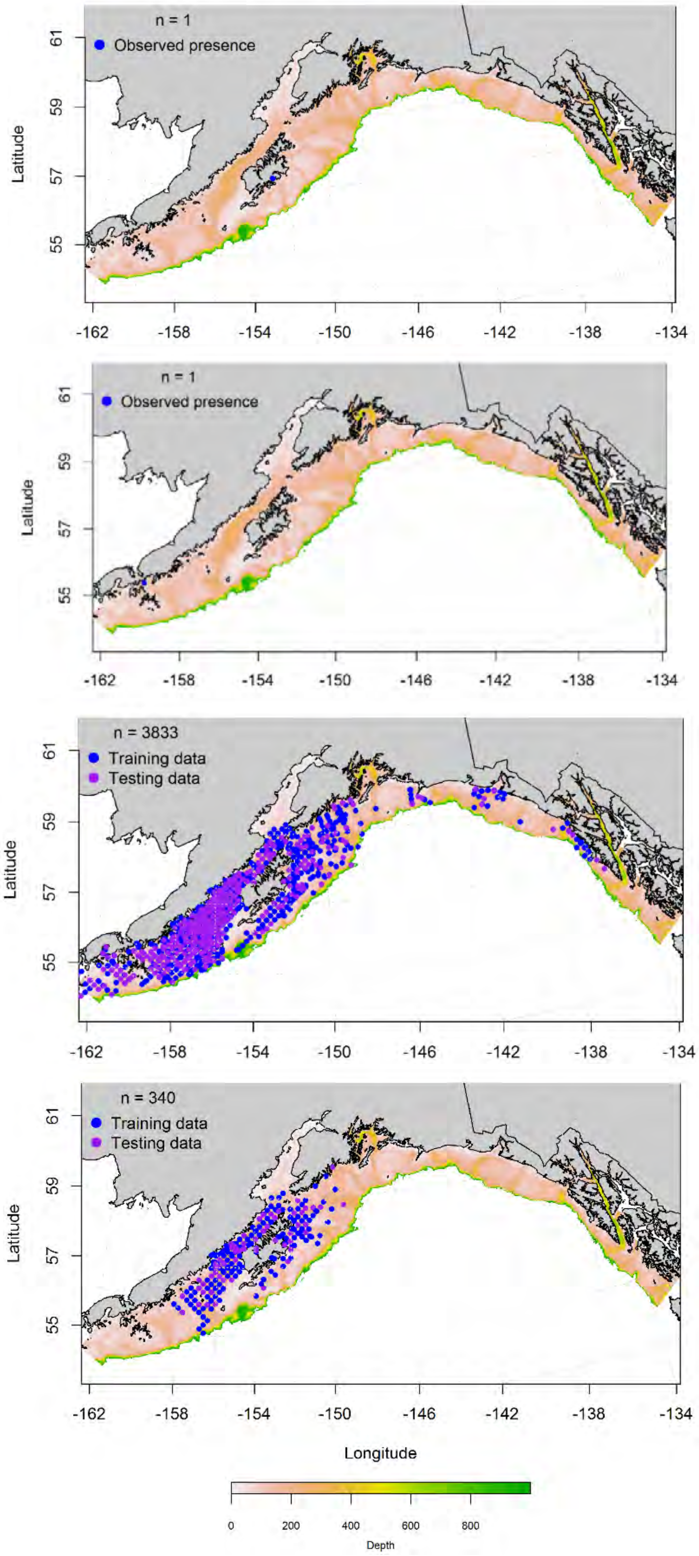


Figure 49. -- Fall, winter, spring, and summer (top, second, third, and bottom panel, respectively) observations of *H. elassodon* eggs from the Gulf of Alaska.

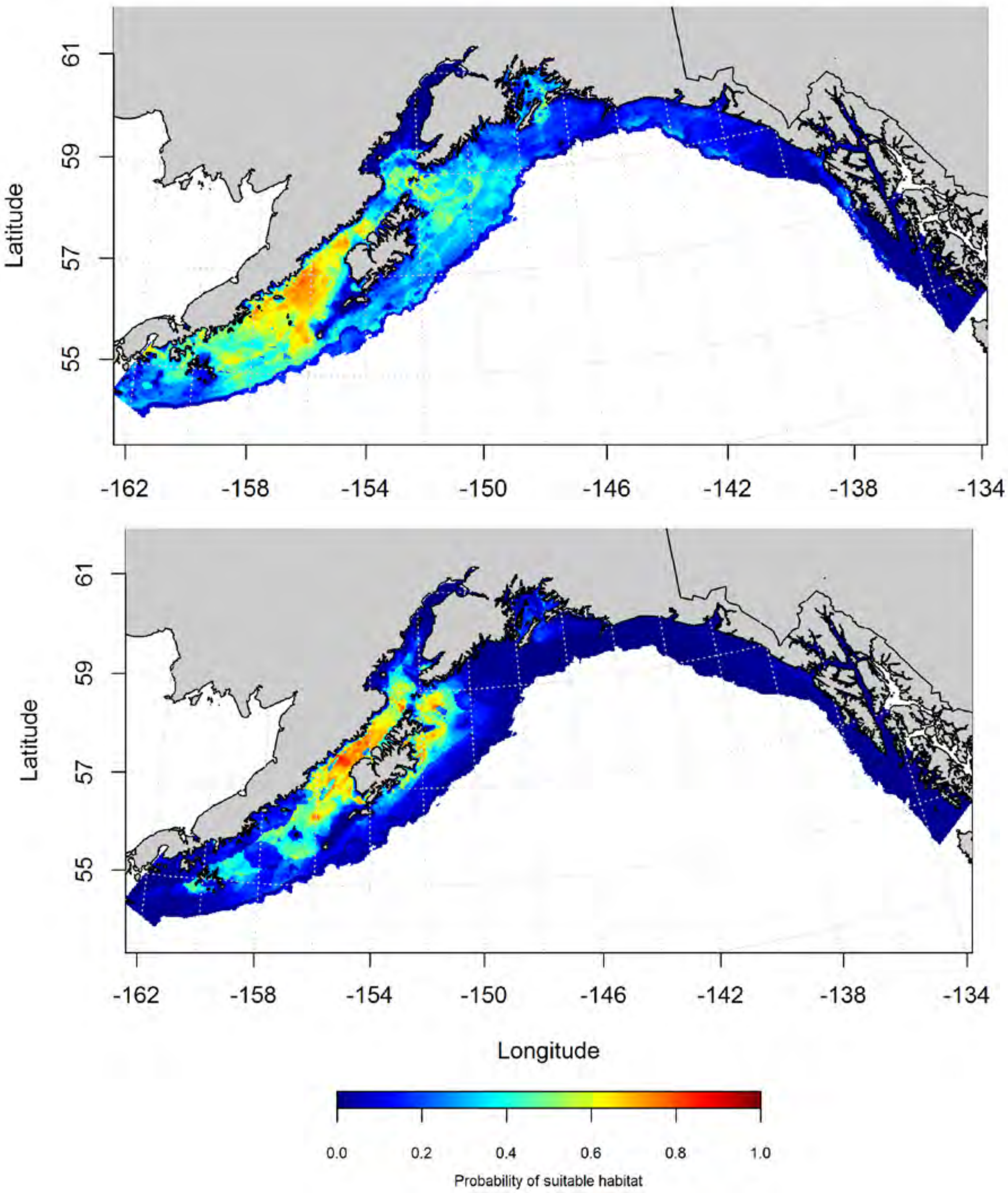


Figure 50. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of *H. elassodon* eggs from maximum entropy modeling of the Gulf of Alaska.

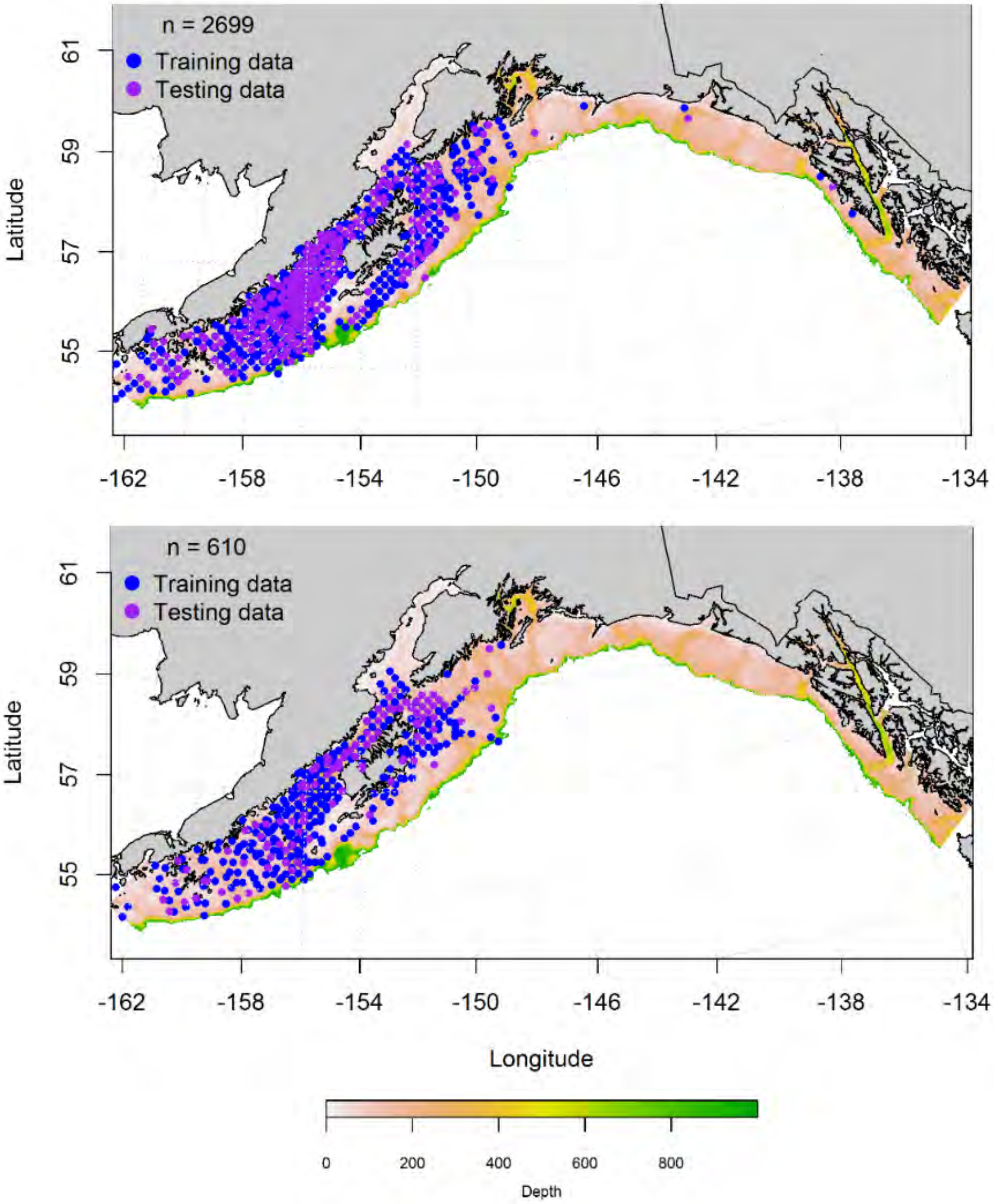


Figure 51. -- Spring and summer observations (top and bottom panel, respectively) of larval *H. elassodon* from the Gulf of Alaska.

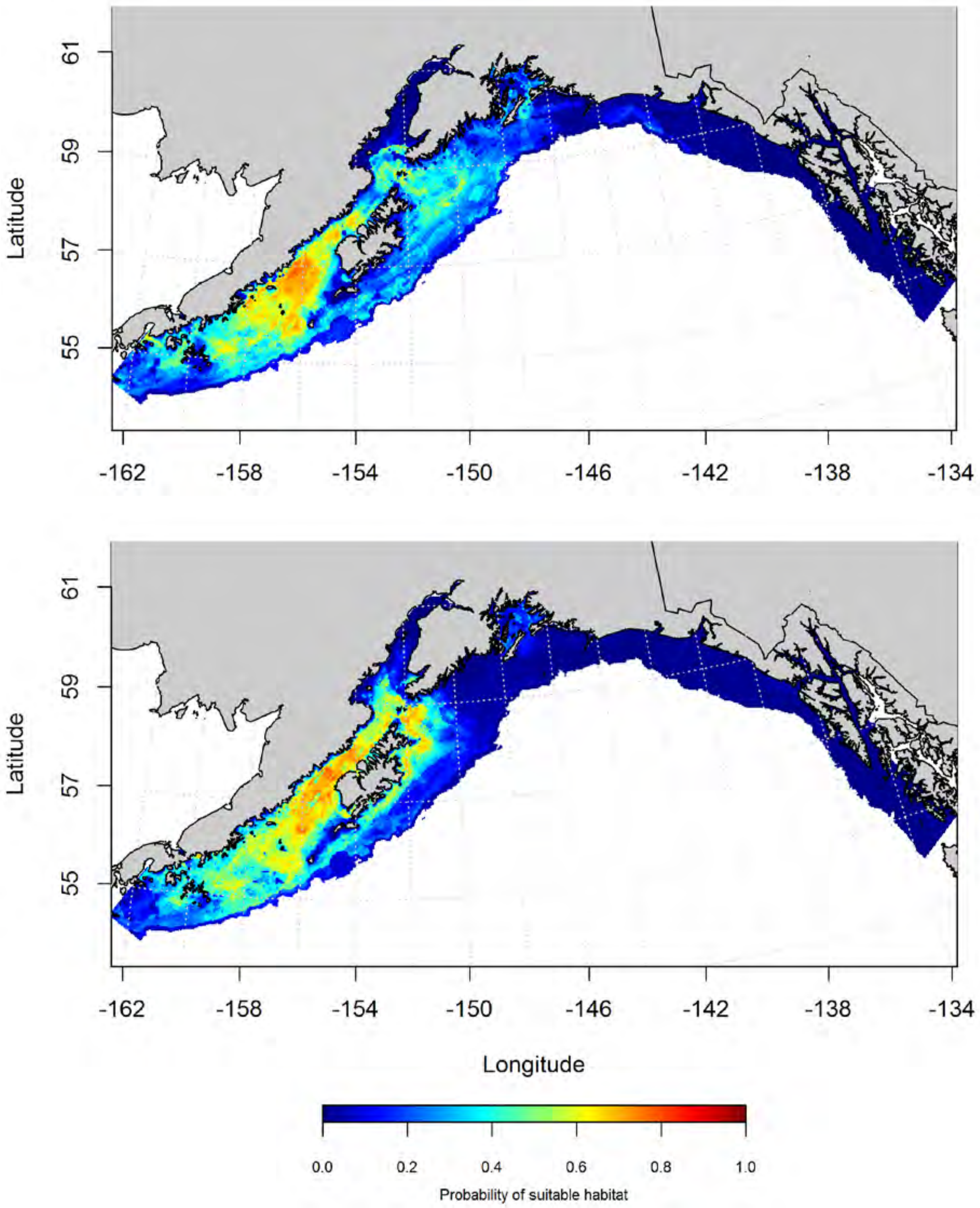


Figure 52. -- Predicted probability of suitable habitat for spring and summer observations (top, middle, and bottom panel, respectively of larval *H. elassodon* from maximum entropy modeling of the Gulf of Alaska.

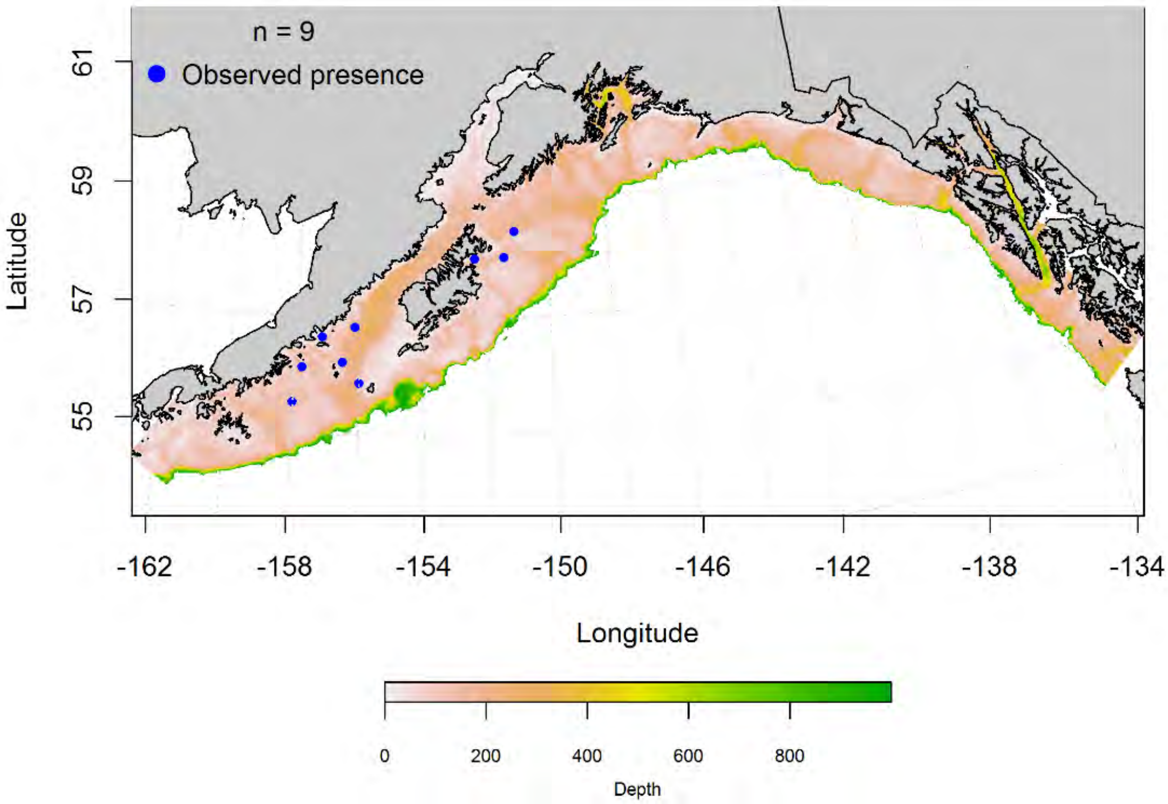
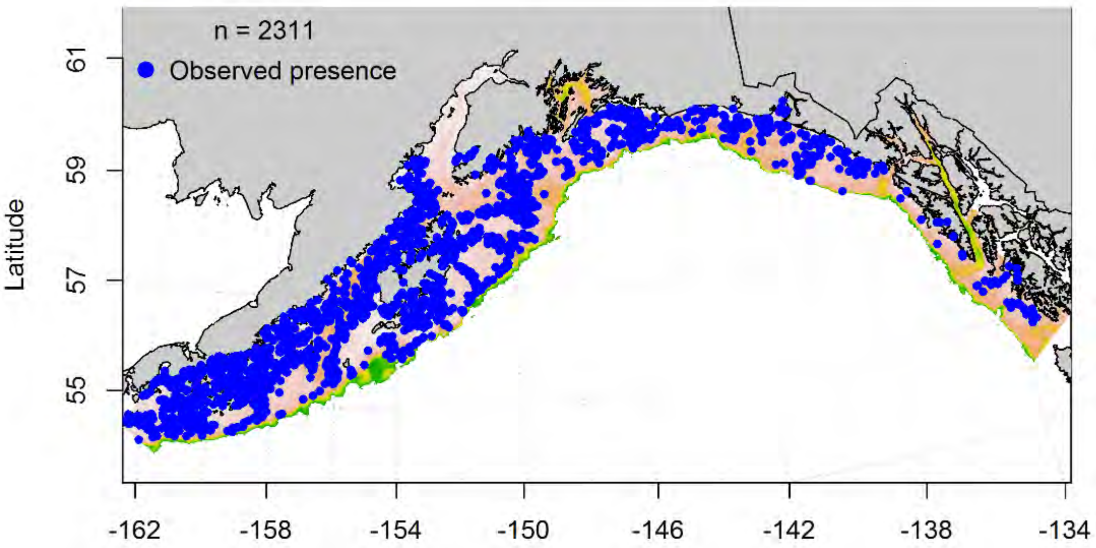


Figure 53. -- Summer catches (top and bottom, respectively) of early juvenile *H. elassodon* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *H. elassodon* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile flathead sole occur across much of the inner and middle-shelf in the Gulf of Alaska (Figure 5.6). The best-fitting GAM indicated that longitude and latitude, tidal currents and depth were the most important variables predicting the distribution of juvenile flathead sole. The model explained 36% of the variability in CPUE for both the training and the test data. Juvenile flathead sole were predicted to occur at low abundances on inner-shelf along the Alaska Peninsula, particularly around the Shumagin Islands (Figure 55).

Summer bottom trawl survey data indicate adult flathead sole occur throughout much of the inner and middle-shelf of the GOA (Figure 54).

The best-fitting GAM indicated that latitude and longitude, sponge presence and depth were the most important predictors of adult flathead sole distribution. The model explained 43% of the variability in CPUE of both the training and testing data. Adult flathead were predicted to occur at low abundances on the inner-shelf along the Alaska Peninsula (Figure 56).



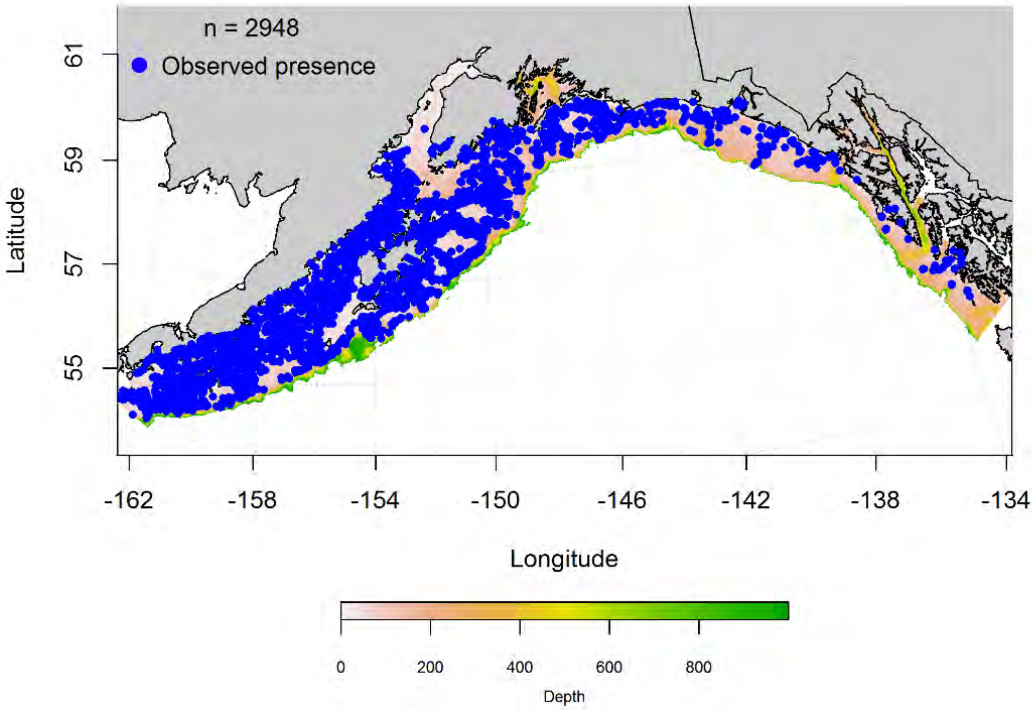


Figure 54. -- Locations of catches of juvenile and adult *H. elassodon* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

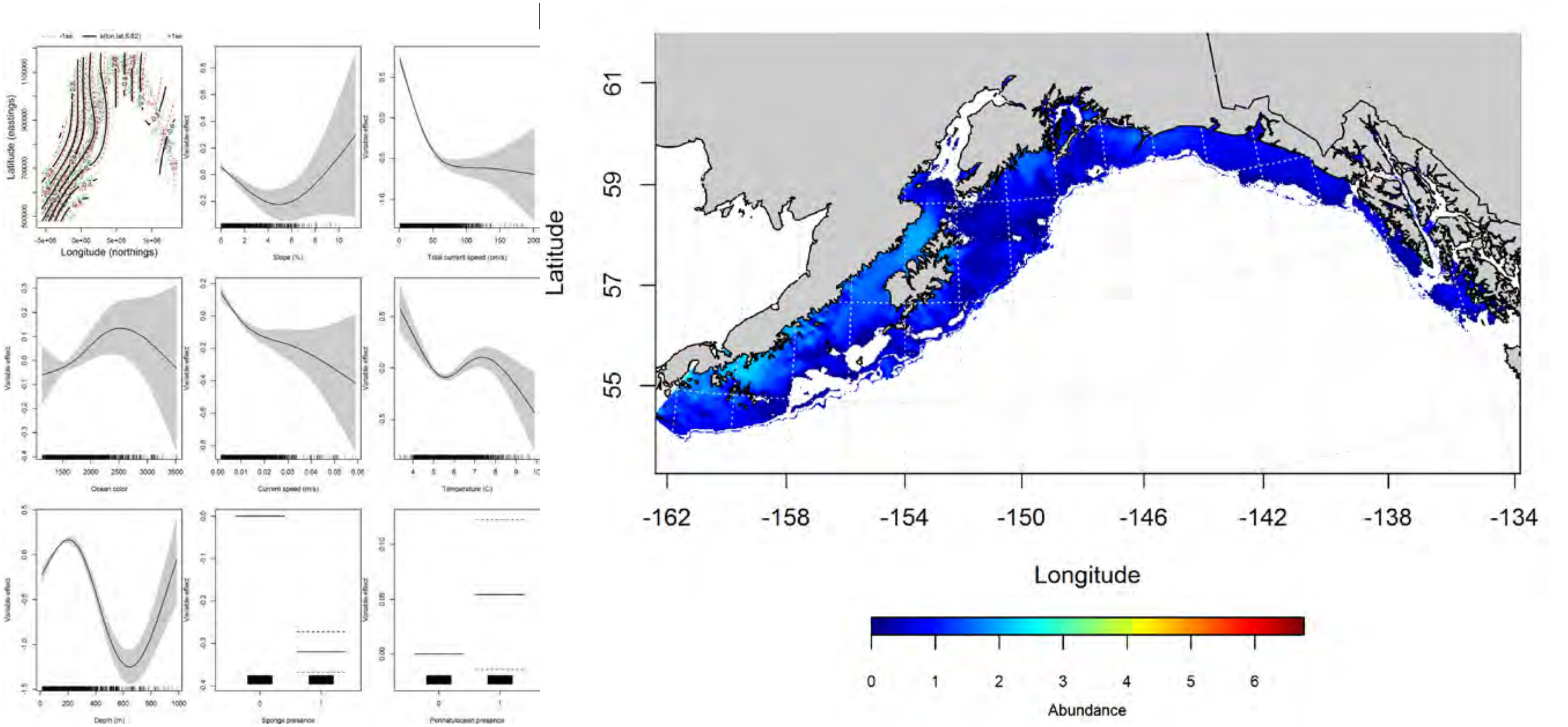


Figure 55. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of juvenile *H. elassodon* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted juvenile *H. elassodon* abundance (right panel).

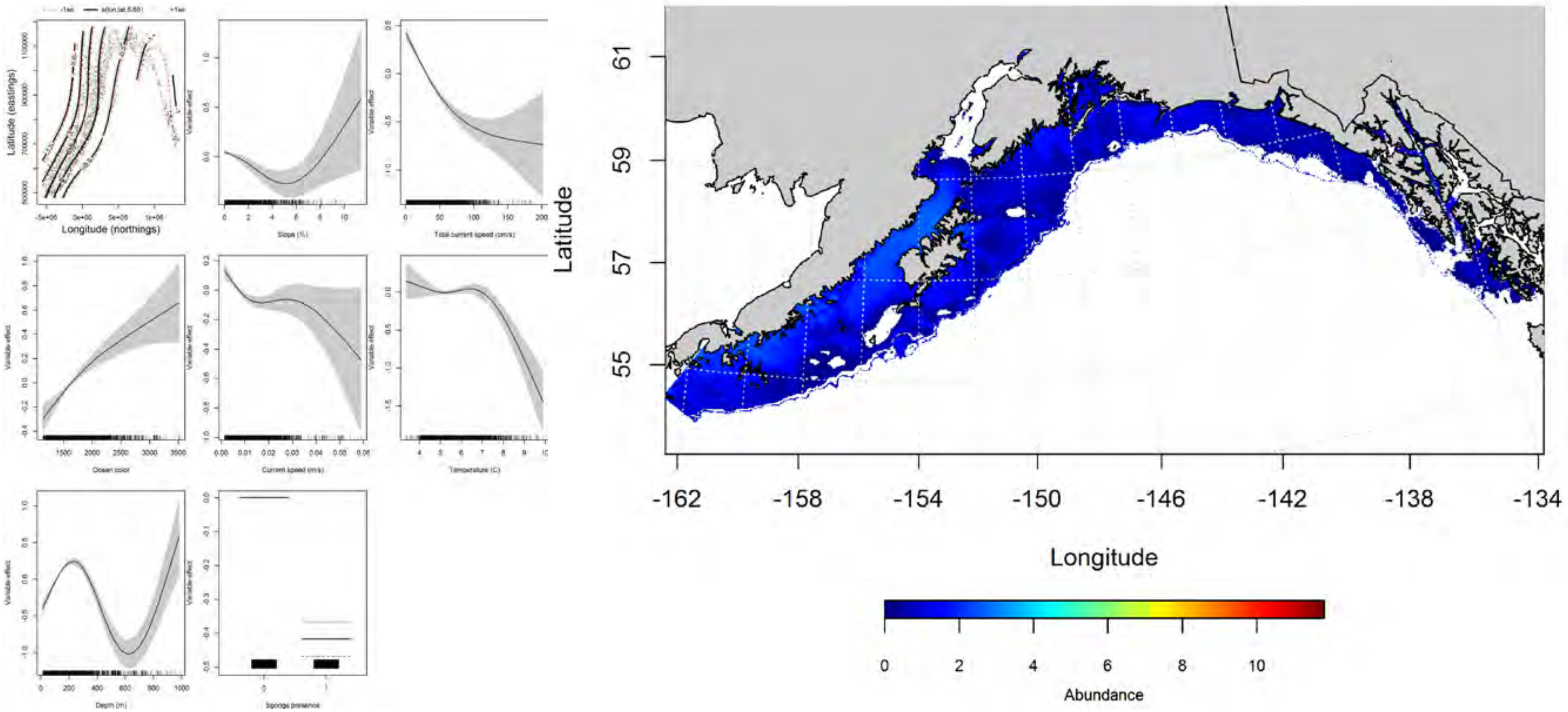


Figure 56. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *H. elassodon* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *H. elassodon* abundance (right panel)

Seasonal distribution of commercial fisheries catches of adult *H. elassodon* in the Gulf of Alaska -- Commercial catch data indicate flathead sole largely occur on the inner and middle-shelf around Kodiak Island. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of flathead sole (relative importance = 38.8 and 18.3 respectively). The AUC of the best fitting fall model was 0.89 for the training data indicating a good model fit; however, the AUC for the test data was 0.77, indicating only a fair model fit. The percent of observations correctly classified for the training data was 82%, and it was 77% for the test data. In the fall, the habitat with the highest predicted suitability for flathead sole occurred along in the deeper gullies around Kodiak Island, particularly Shumagin and Shelikof gullies to the west, and off Albatross and Portlock Banks to the east (Figure 57).

In the winter, depth and current speed were the most important variables predicting the distribution of flathead sole (relative importance = 32.8 and 26.3 respectively). The AUC of the fall model training data was 0.90, representing an excellent model fit. The AUC for the test data was 0. 77, representing only a fair model fit, due to some model over fitting. The percent of observations correctly classified for the training data was 82%, and it was 77% for the test data. During the winter, the predicted distribution of flathead sole shifted slightly eastward to include much of the middle-shelf offshore of Kodiak Island and west of the Kenai Peninsula (Figure 58).

In the spring, depth and tidal currents were the most important variables predicting the distribution of flathead sole (relative importance = 45.8 and 29.6 respectively). The AUC of the training data was 0.88, and it was 0.84 for the test data, both of which indicated good model fits.

In both cased, the models correctly classified ≥82% of the observations correctly. During the spring, flathead sole catches were predicted to occur across much of the deeper portions of the middle-shelf around Kodiak Island, including Shumagin and Shelikof Gullies to the west, and Shelikof Strait and Marmot Gully to the east (Figure 59).

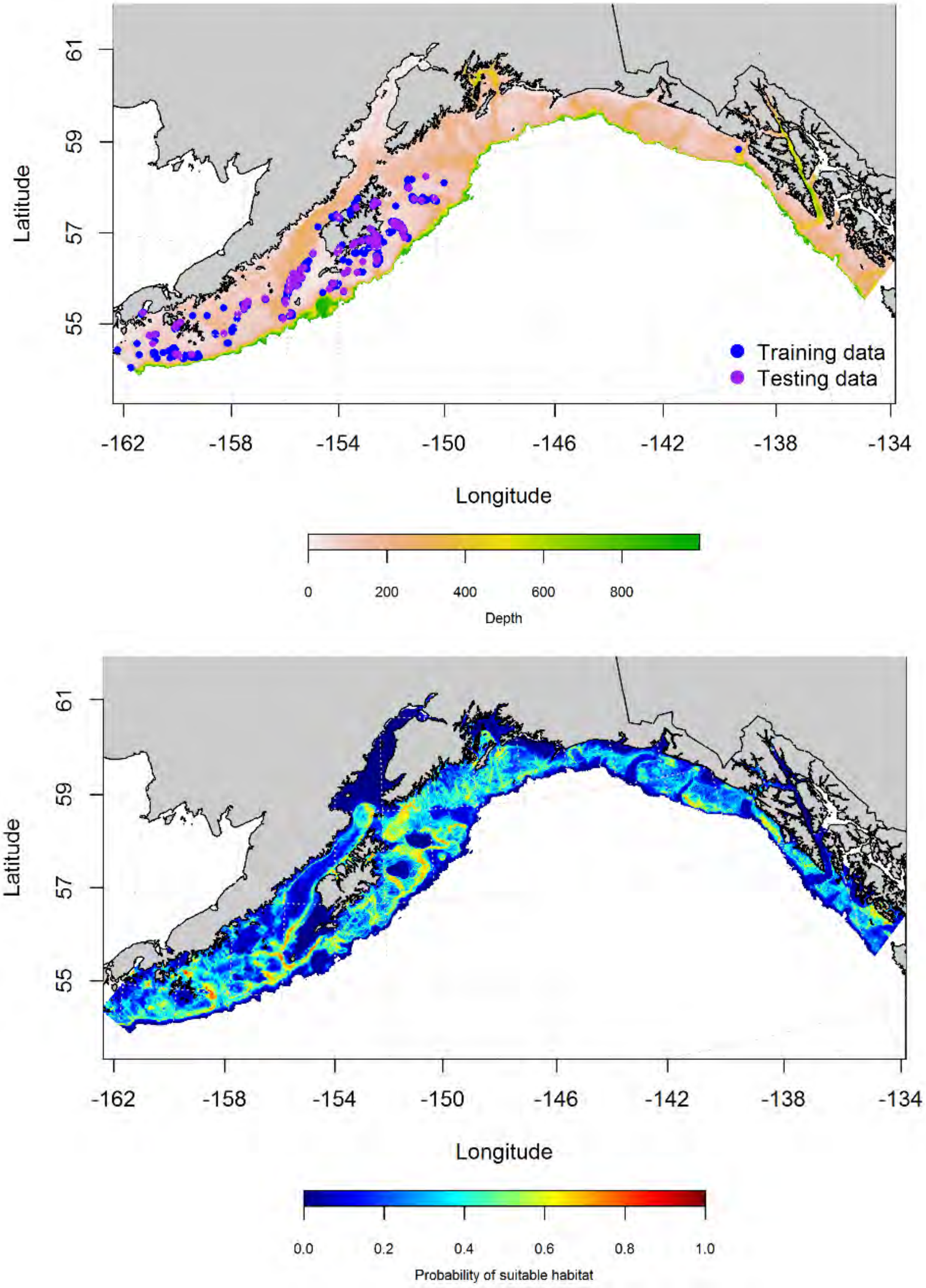


Figure 57. -- Locations of fall (September-November) commercial fisheries catches of *H. elassodon* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *H. elassodon* commercial catches (bottom panel) and the purple points were used to test the model.

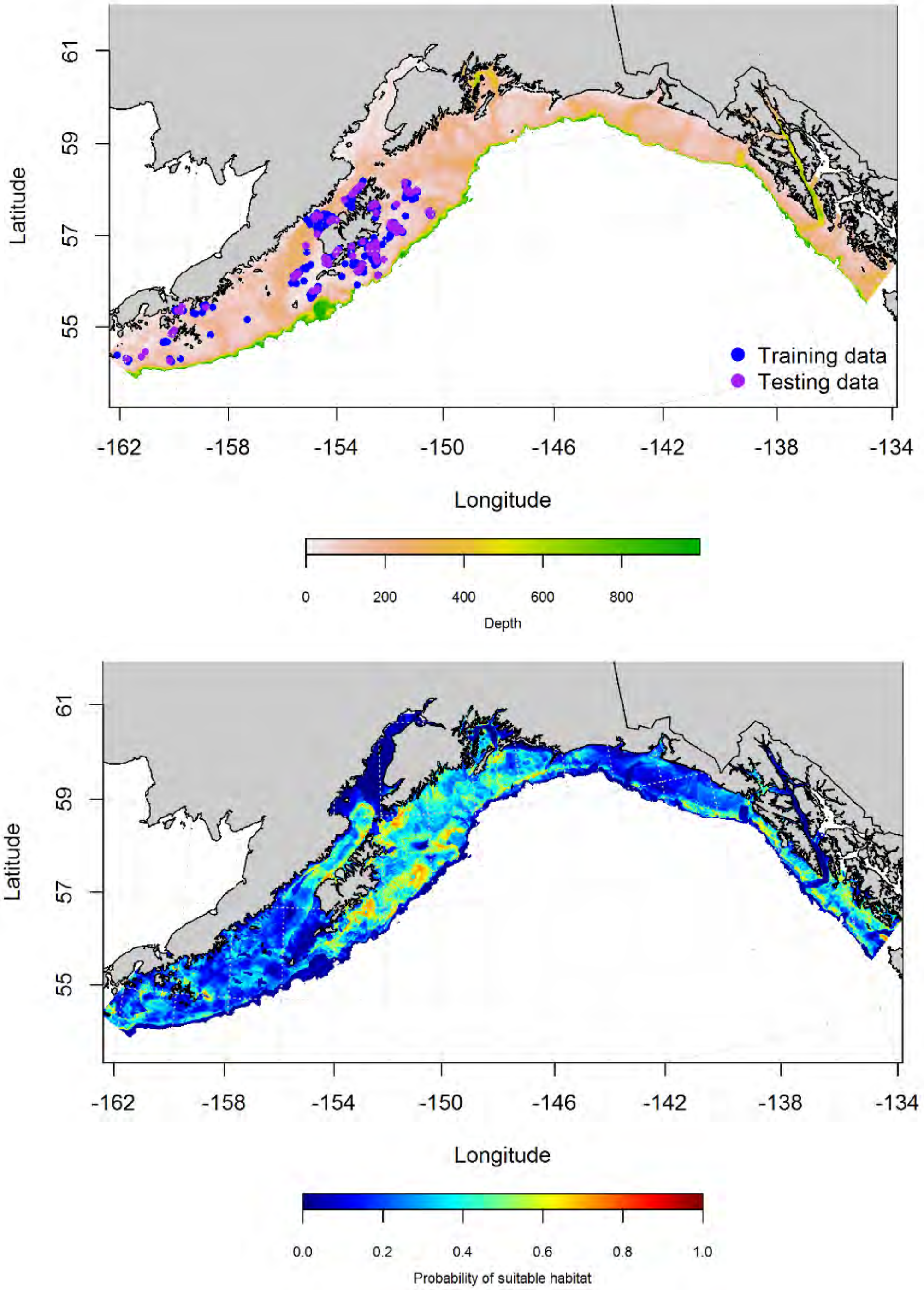


Figure 58. -- Locations of winter (December-February) commercial fisheries catches of *H. elassodon* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *H. elassodon* commercial catches (bottom panel) and the purple points were used to test the model.

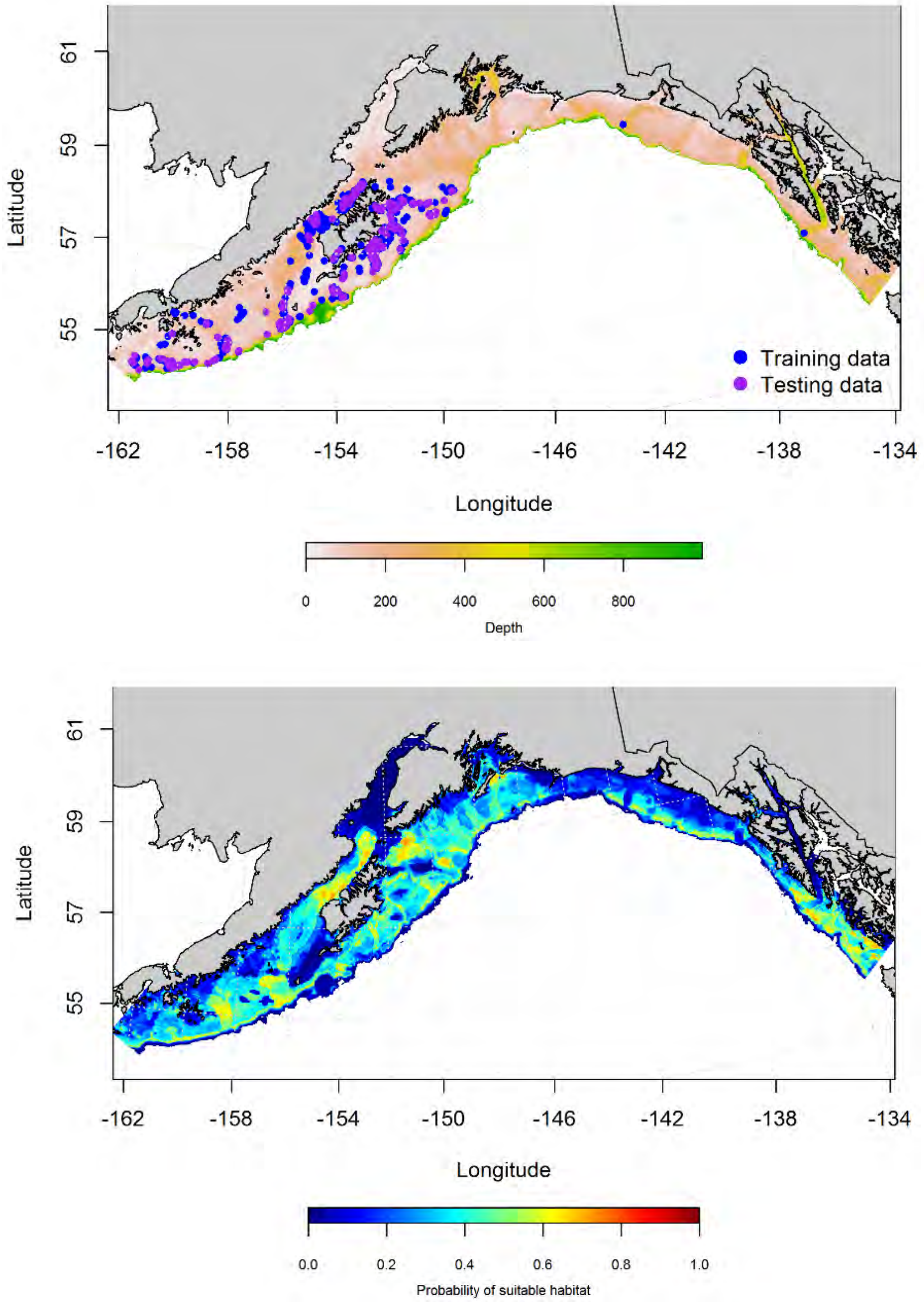


Figure 59. -- Locations of spring (March-May) commercial fisheries catches of *H. elassodon* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *H. elassodon* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *H. elassodon* Essential Fish Habitat Maps and Conclusions --

Essential fish habitat for flathead sole predicted by modeling is extensively distributed across the inner and middle-shelf in the western Gulf of Alaska. EFH for flathead sole eggs during the spring, was predicted to include much of the shelf in the western gulf (Figure 60). EFH for flathead sole eggs, during the summer was predicted to be more restricted and to include much of the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula.

EFH for larval flathead sole, during the spring and summer, was predicted include much of the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula (Figure 61). EFH for early juvenile flathead sole could not be predicted.

Summer EFH for juvenile and adult flathead sole, based on trawl survey observations, was predicted to include much of the inner-shelf along the Alaska Peninsula and Kodiak Island, and to a lesser extent the inner-shelf as far east as Cross Sound (Figure 62).

Fall and winter EFH of flathead sole, based on commercial catch data, and included much of the deeper portions of the middle-shelf, such as gullies and valleys, across the GOA. Spring EFH for flathead sole was predicted to be more restricted, and occur along the middle and outer-shelf in the northern gulf, particularly around Kodiak Island and the Kenai Peninsula (Figure 63).

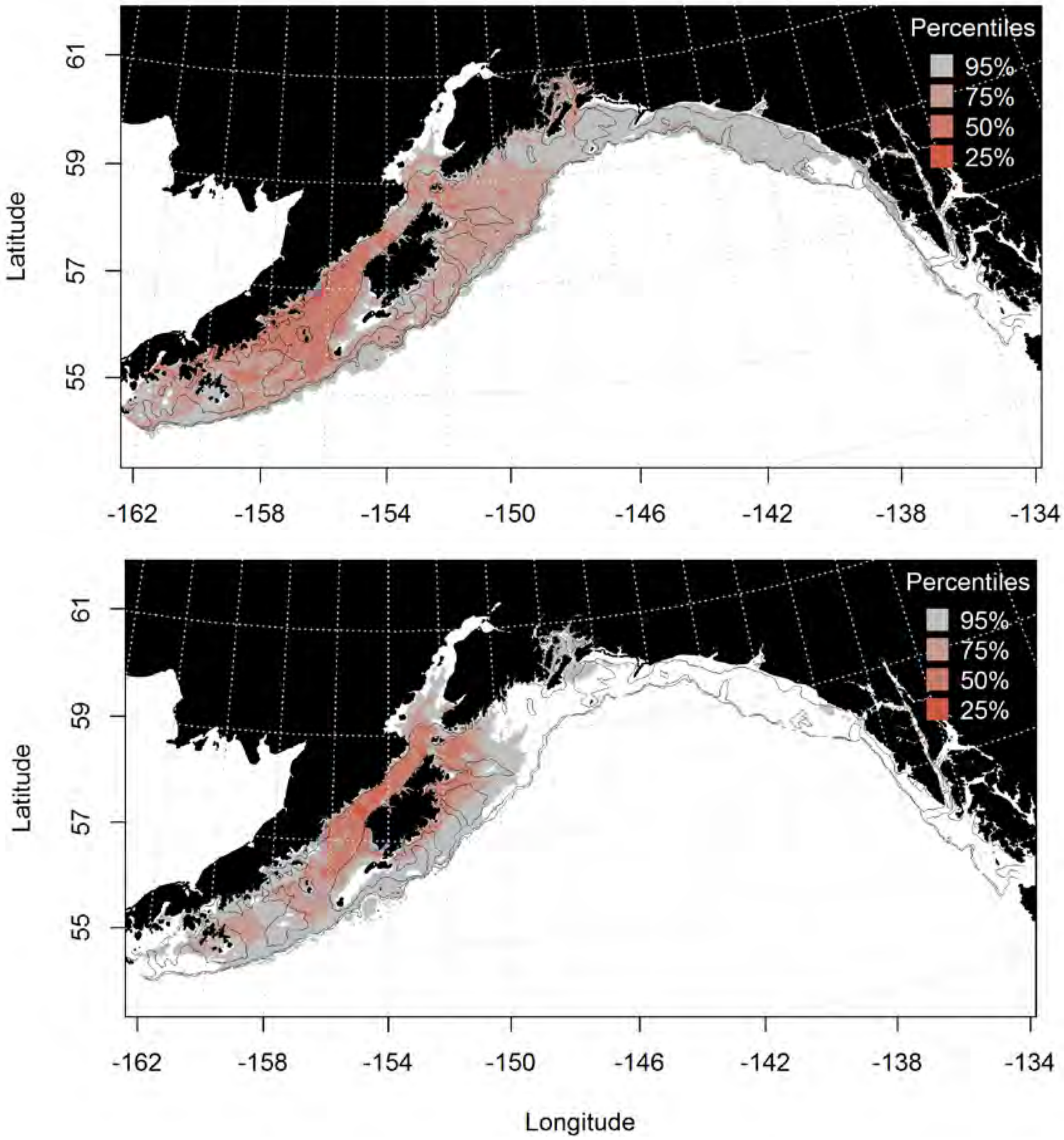


Figure 60. -- Spring and summer essential fish habitat predicted for *H. elassodon* eggs (top and bottom panel, respectively) from the EcoFOCI database.

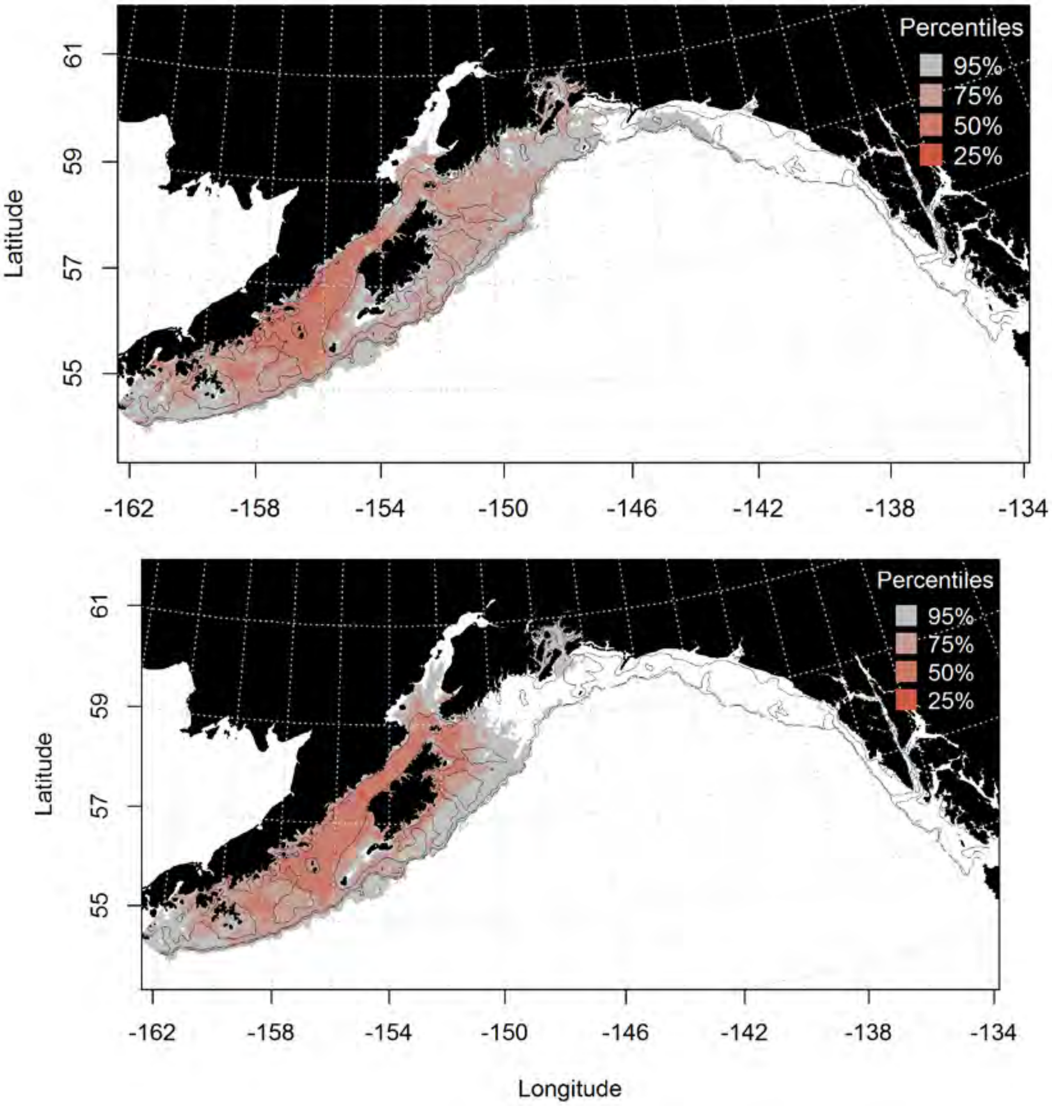


Figure 61. -- Spring and summer essential fish habitat predicted for larval *H. elassodon* (top and bottom panel, respectively) from the EcoFOCI database.

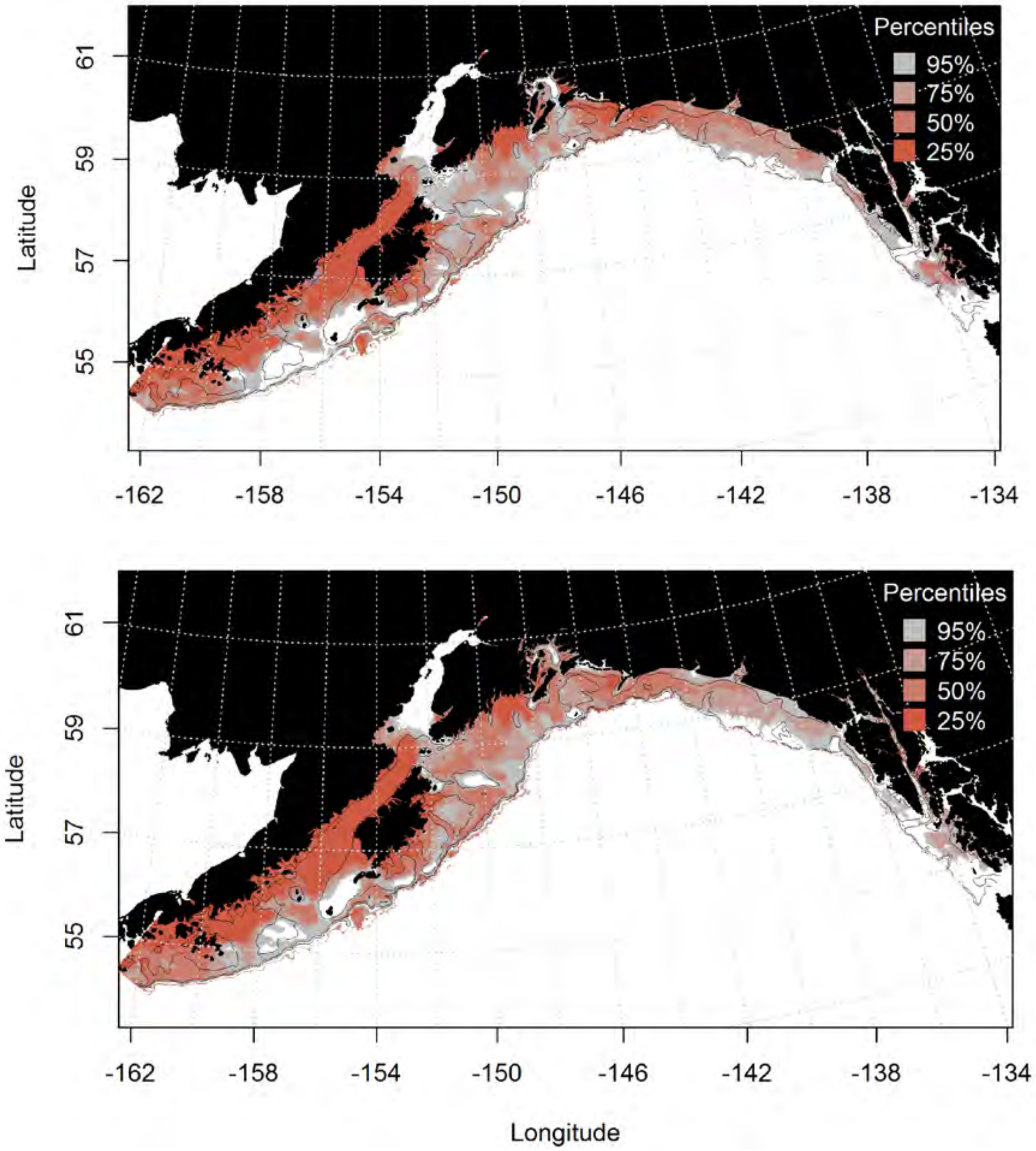


Figure 62. -- Predicted essential fish habitat for *H. elassodon* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

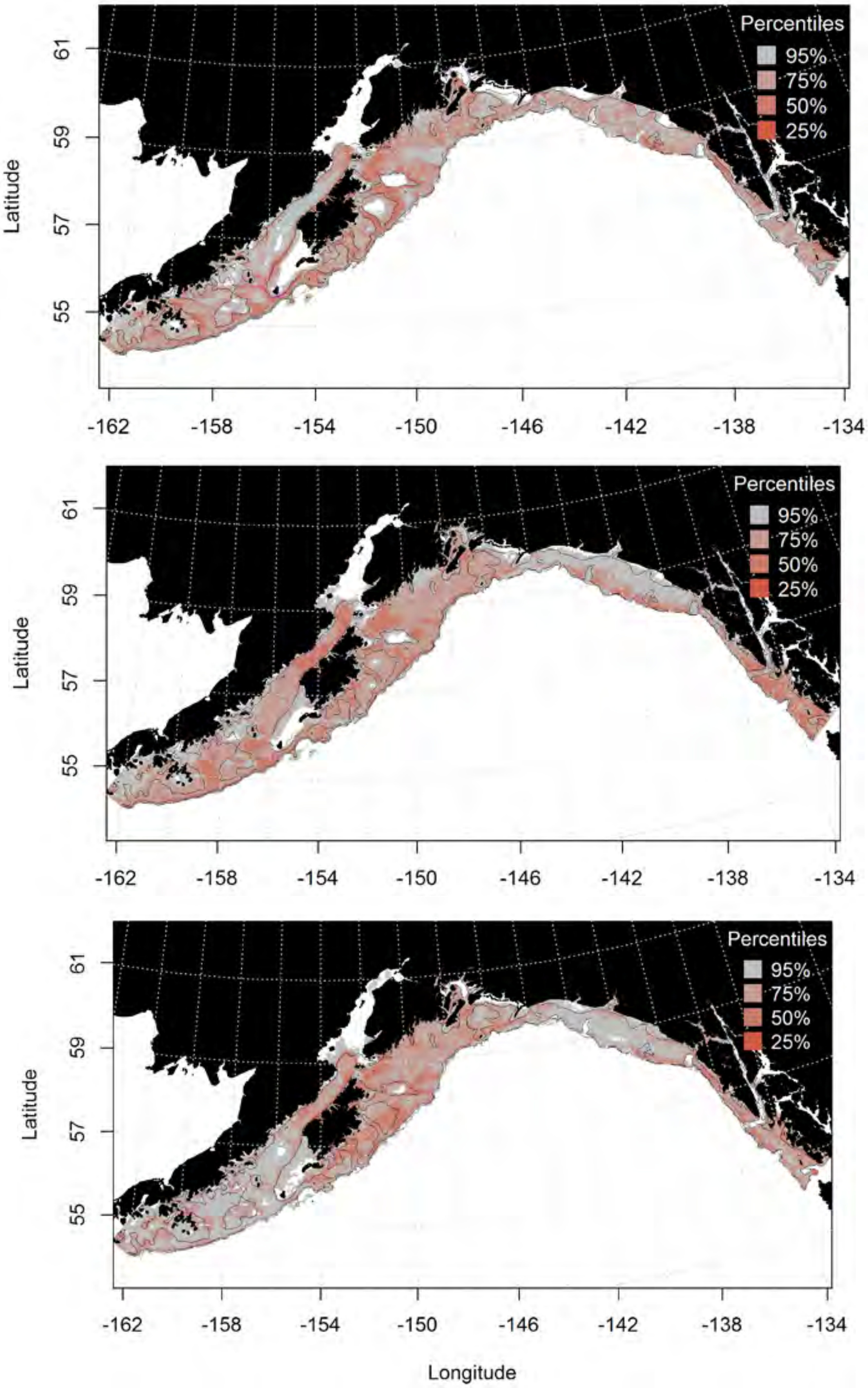


Figure 63. -- Essential fish habitat predicted for *H. elassodon* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

yellowfin sole (*Limanda aspera*)

Yellowfin sole are locally abundant in the bays around Kodiak Island and the Alaska Peninsula, but have a limited distribution in the remainder of the Gulf of Alaska. They almost exclusively occur at less than 100 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *L. aspera* in the Gulf of Alaska -- Throughout much of their early life history yellowfin sole appear to largely occur in nearshore waters around Kodiak Island and the Alaska Peninsula. Yellowfin sole eggs were observed during the spring and summer (Figure 64). During the spring, only 15 eggs were observed. They occurred primarily in nearshore waters around Kodiak Island and in Shelikof Strait. There was insufficient data to model the distribution of yellowfin sole eggs in the spring. During the summer, yellowfin sole eggs were more abundant.

The best-fitting *MaxEnt* model indicated that surface temperature and ocean color (relative importance 37.9 and 17.3 respectively) were the most important variables predicting habitat suitable. The AUC for the training data was 0.96, indicating an excellent model fit. The AUC for the testing data was 0.91, indicating an excellent model fit. The percent of the observations correctly classified in the training data was 91% and 83% for the test data. Yellowfin sole eggs were predicted to largely occur in the bays and nearshore waters around Kodiak Island and to a lesser extent the Alaska Peninsula. (Figure 65).

Larval yellowfin sole were observed during the spring and summer. During the spring, only two larval yellowfin sole observed, both occurred in the vicinity of Kodiak Island. In the summer, larval yellowfin sole were more abundant, occurring primarily in inshore waters around Kodiak Island and the Alaska Peninsula (Figure 66). There was insufficient data to predict larval yellowfin sole habitats.

No observations of early juvenile yellowfin sole occurred in the EcoFOCI database.

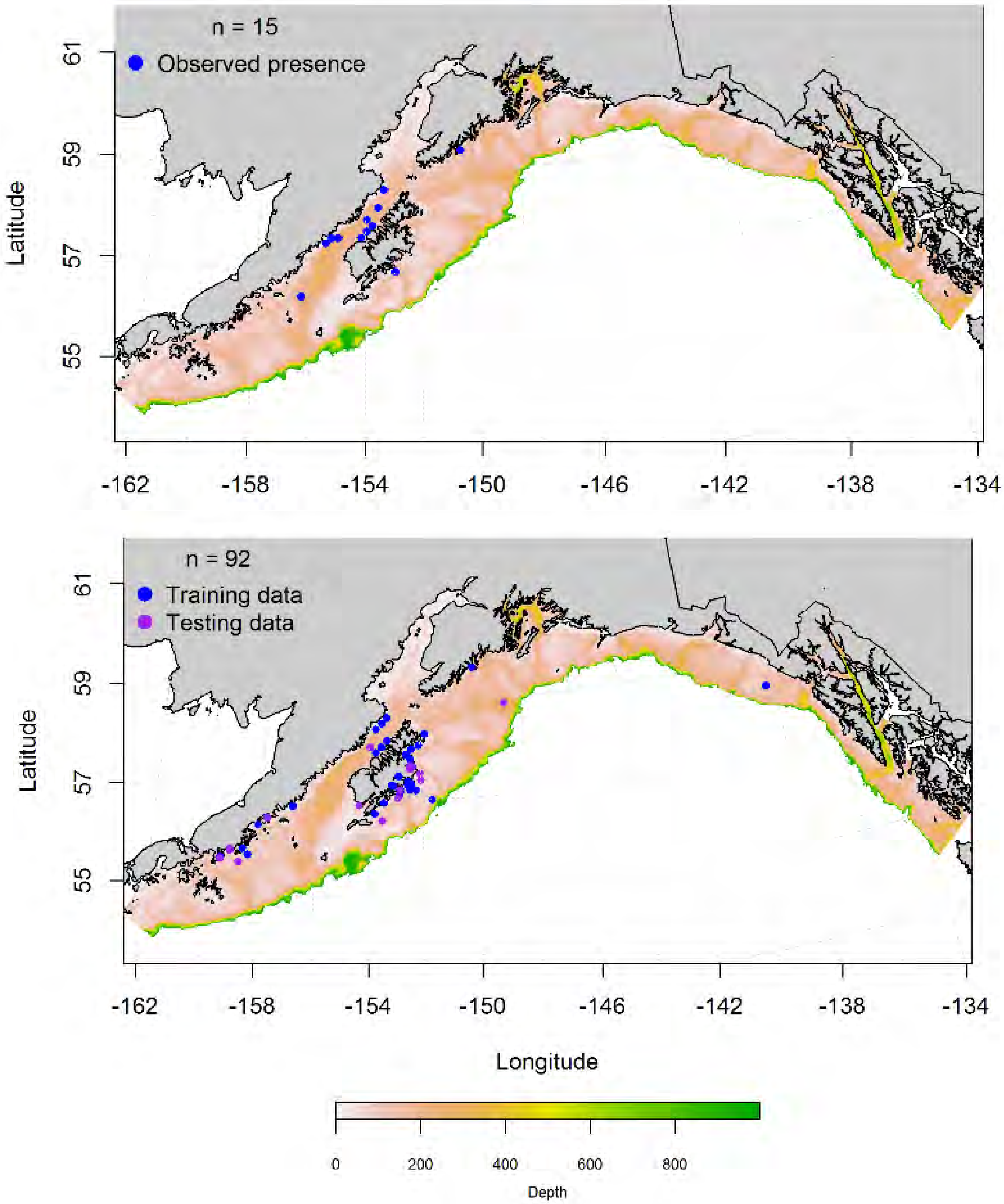


Figure 64. -- Spring and summer (top and bottom panel, respectively) observations of *L. aspera* eggs from the Gulf of Alaska.

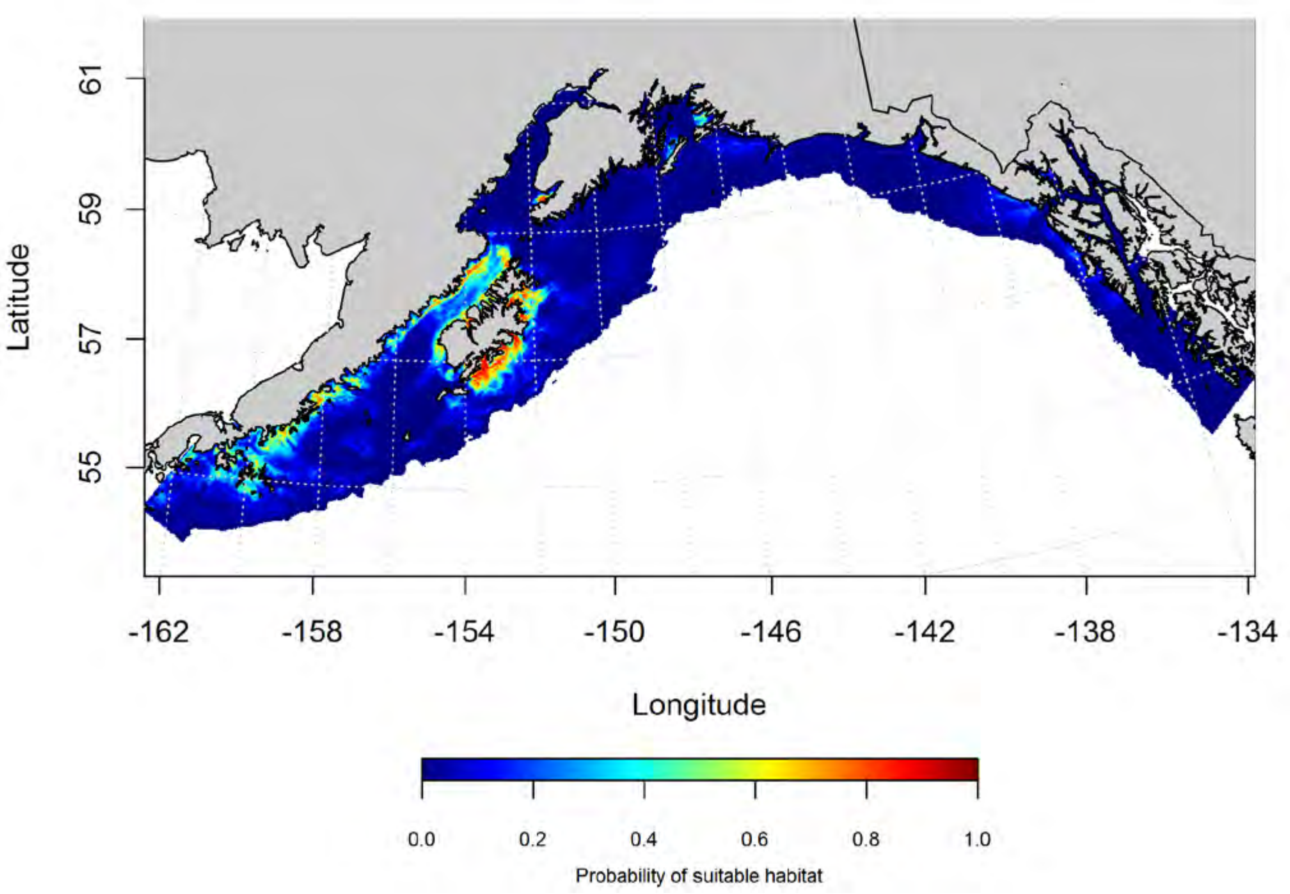


Figure 65. -- Predicted probability of suitable habitat for summer observations of *L. aspera* eggs from maximum entropy modeling of the Gulf of Alaska.

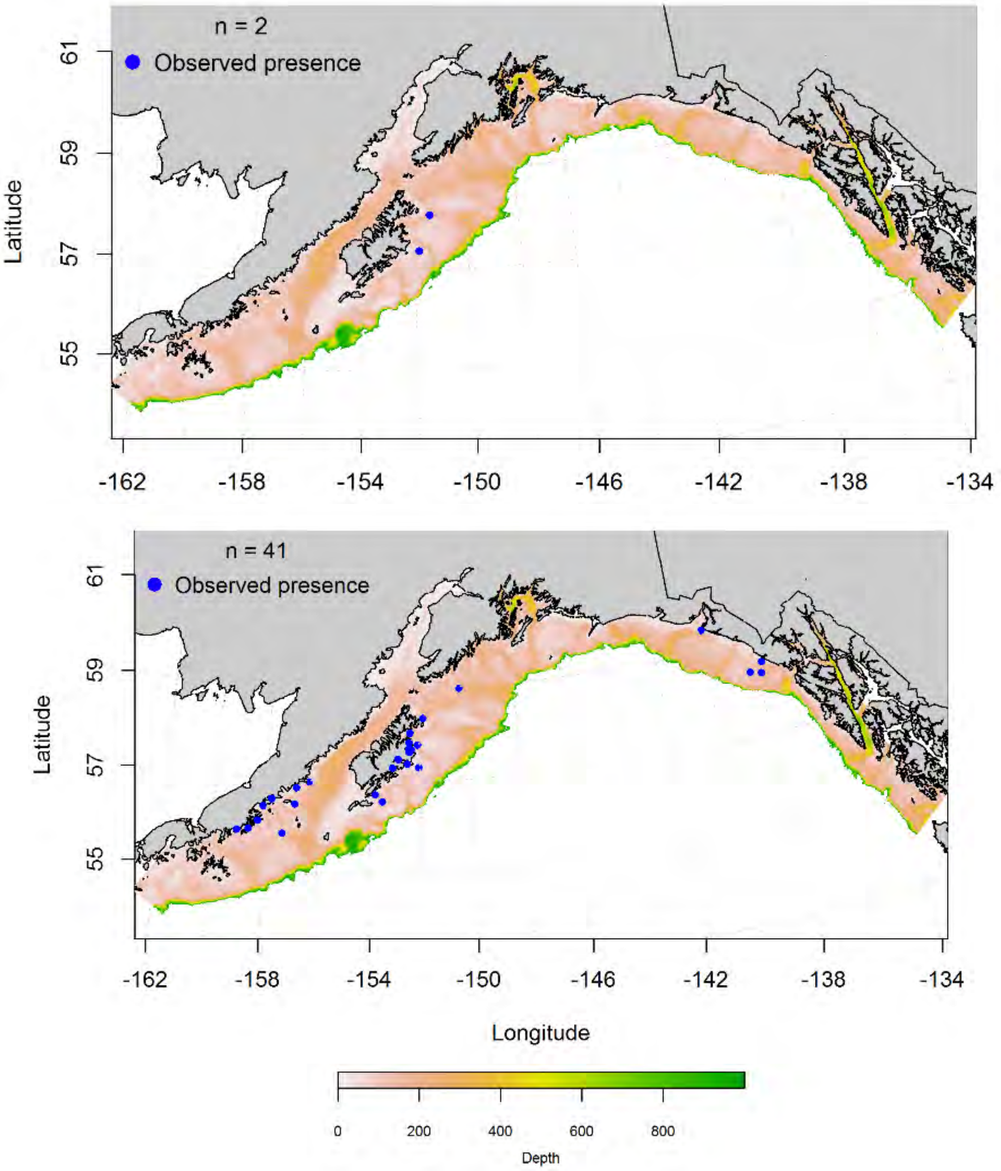


Figure 66. -- Spring and summer observations (top, middle, and bottom panel, respectively) of larval *L. aspera* from the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *L. aspera* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile yellowfin sole predominantly occur in nearshore waters around Kodiak Island and the Alaska Peninsula (Figure 67).

The best-fitting *MaxEnt* model indicated that depth and tidal currents were the most important variables (relative importance = 80.5 and 10.6 respectively) predicting the distribution of juvenile flathead sole. The AUC for the training data was 0.96, representing an excellent model fit. The AUC for the test data was 0.88, representing a good model fit. The percent of observations correctly classified for the training data was 91%, and it was 88% for the test data. The predicted distribution of juvenile yellowfin sole included most of the inshore waters in the western and central GOA, with predicted localized areas of high probability around the Shumagin Islands, Alaska Peninsula, western Kodiak Island, and Kamishak Bay, and Cape St. Elias (Figure 68).

Summer bottom trawl survey data indicate that adult yellowfin sole also predominantly occur in nearshore waters around Kodiak Island and the Alaska Peninsula (Figure 67).

The variables determined to be the best predictors of the occurrence of adult yellowfin sole were latitude and longitude, tidal current, and current speed. The AUC for both the training and test data was 0.98, indicating an excellent model fit, while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.08. The percent of observations correctly classified was 93% for the training data set, and 81% for the test data set. The most important variables predicting the abundance of juvenile yellowfin sole were latitude and latitude and depth. The best-fitting GAM explained 29% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult yellowfin sole were predicted to occur along much of the inner-shelf in the western GOA. Predicted areas of high abundance; however were, much more localized, an included Sandman Reefs, on the Alaska Peninsula, and the eastern side of Kodiak Island in the vicinity of Chiniak (Figure 69). High abundances were also predicted in Cook Inlet; however, these predictions were not supported by any observations.

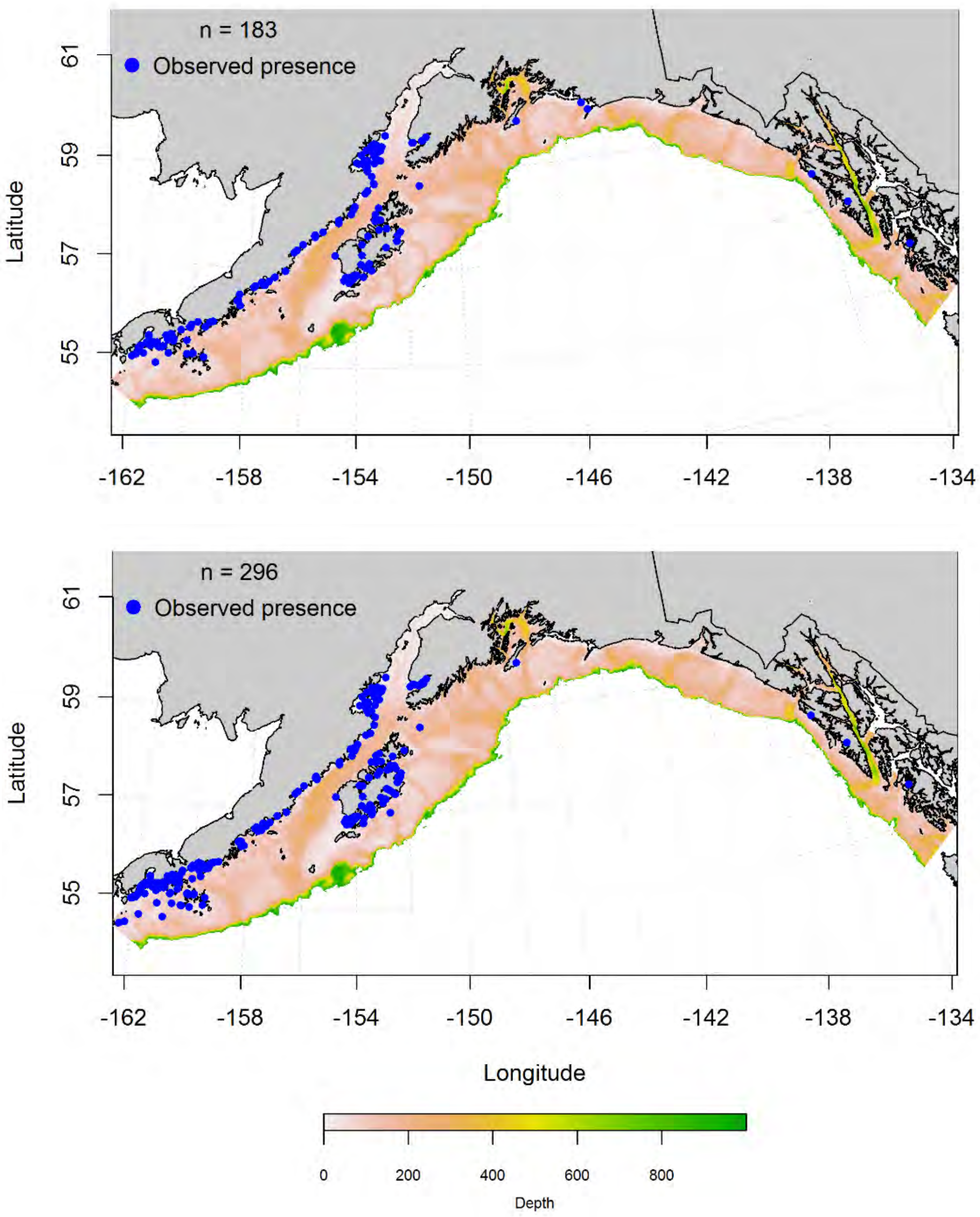


Figure 67. -- Locations of catches of juvenile and adult *L. aspera* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

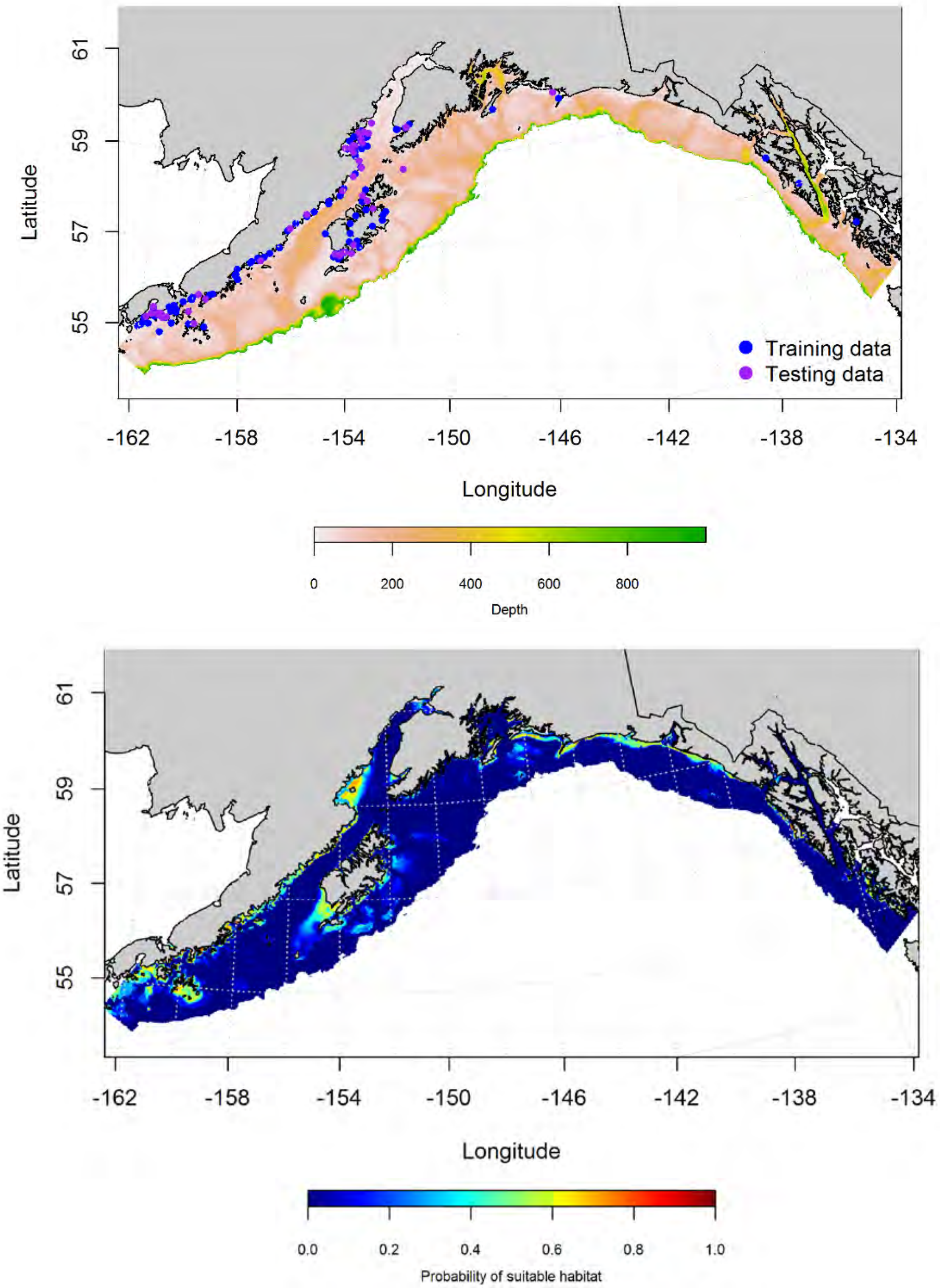


Figure 68. -- Locations of trawl survey catches of juvenile *L. aspera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *L. aspera* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

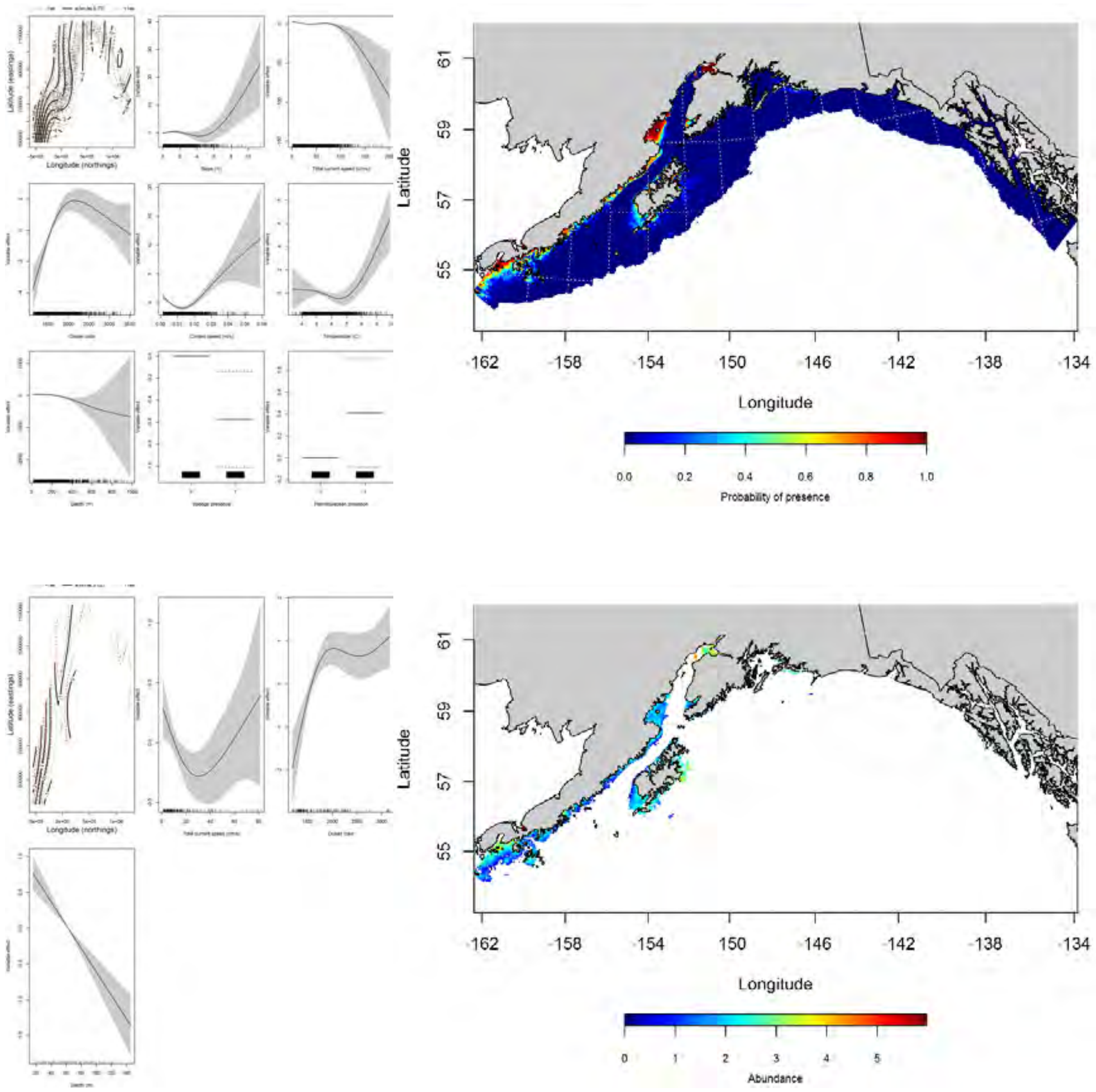
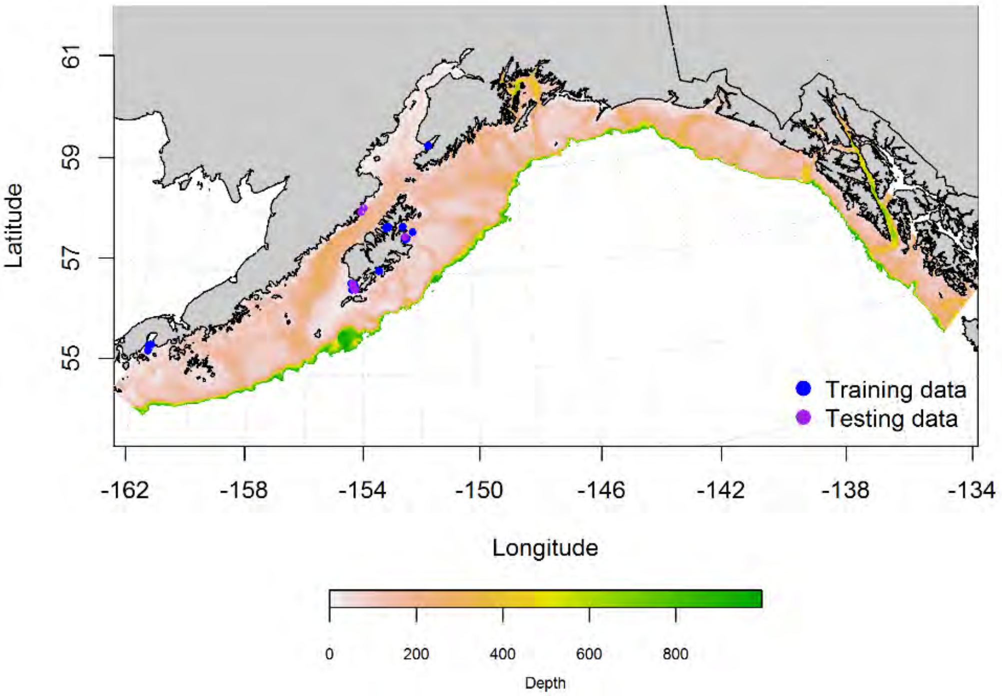


Figure 69. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *L. aspera* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *L. aspera* in the Gulf of Alaska -- Commercial catch data indicate yellowfin sole largely occur in inshore waters around Kodiak Island. Commercial catch data were only available during the winter. *MaxEnt* modeling determined that current speed and depth were the most important variables predicting the distribution of yellowfin sole (relative importance = 39.2 and 34.1 respectively). The AUC of the best fitting fall model was 0.96 for the training data indicating a good model fit; however, the AUC for the test data was 0.75, indicating only a fair model fit. The percent of observations correctly classified for the training data was 96%, and it was 75% for the test data. In the winter, high suitability yellowfin sole habitat was predicted to occur in nearshore waters around Kodiak Island, as well as in the vicinity of Cordova, in the central gulf (Figure 70).



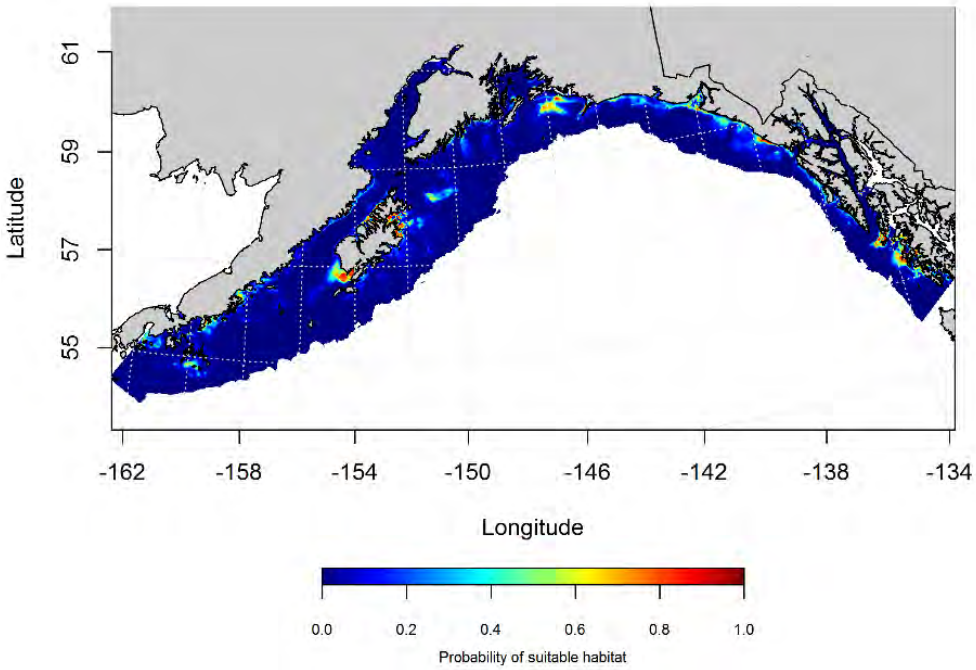


Figure 70. -- Locations of winter (December-February) commercial fisheries catches of *L. aspera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *L. aspera* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *L. aspera* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for yellowfin sole was predicted to occur in inshore waters in western Gulf of Alaska. EFH for yellowfin sole eggs in the summer, was predicted to occur in nearshore waters and bays around Kodiak Island and the Alaska Peninsula (Figure 71). EFH for the remaining early life history stages of yellowfin sole could not be predicted.

Summer EFH for juvenile yellowfin sole, based on trawl survey observations, were predicted to include inshore waters along the Alaska Peninsula and Kodiak Island, and to a lesser extent, inshore waters in the eastern gulf (Figure 72). EFH for adult yellowfin sole was predicted to be more restricted, and to largely occur in inshore waters along the Alaska Peninsula and Kodiak

Island, as well as in nearshore waters off Cordova. EFH was also predicted in Cook Inlet; however, these predictions were not supported by any observations

Winter EFH of yellowfin sole, based on commercial catch data, was predicted to be largely occur in inshore waters around Kodiak Island and off Cordova (Figure 73).

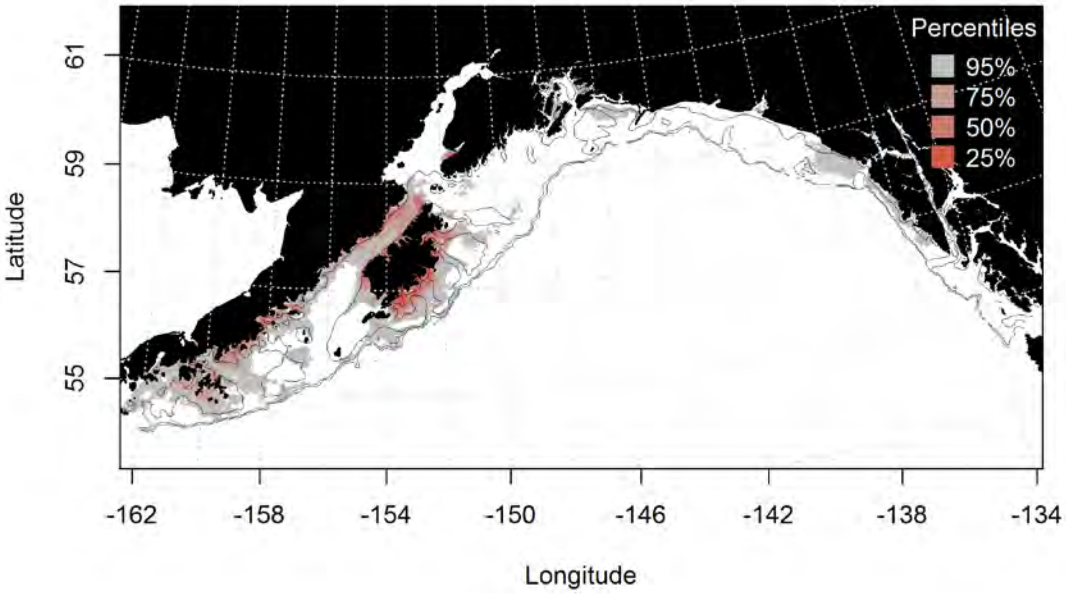


Figure 71. -- Predicted summer essential fish habitat for *L. aspera* eggs from the EcoFOCI database.

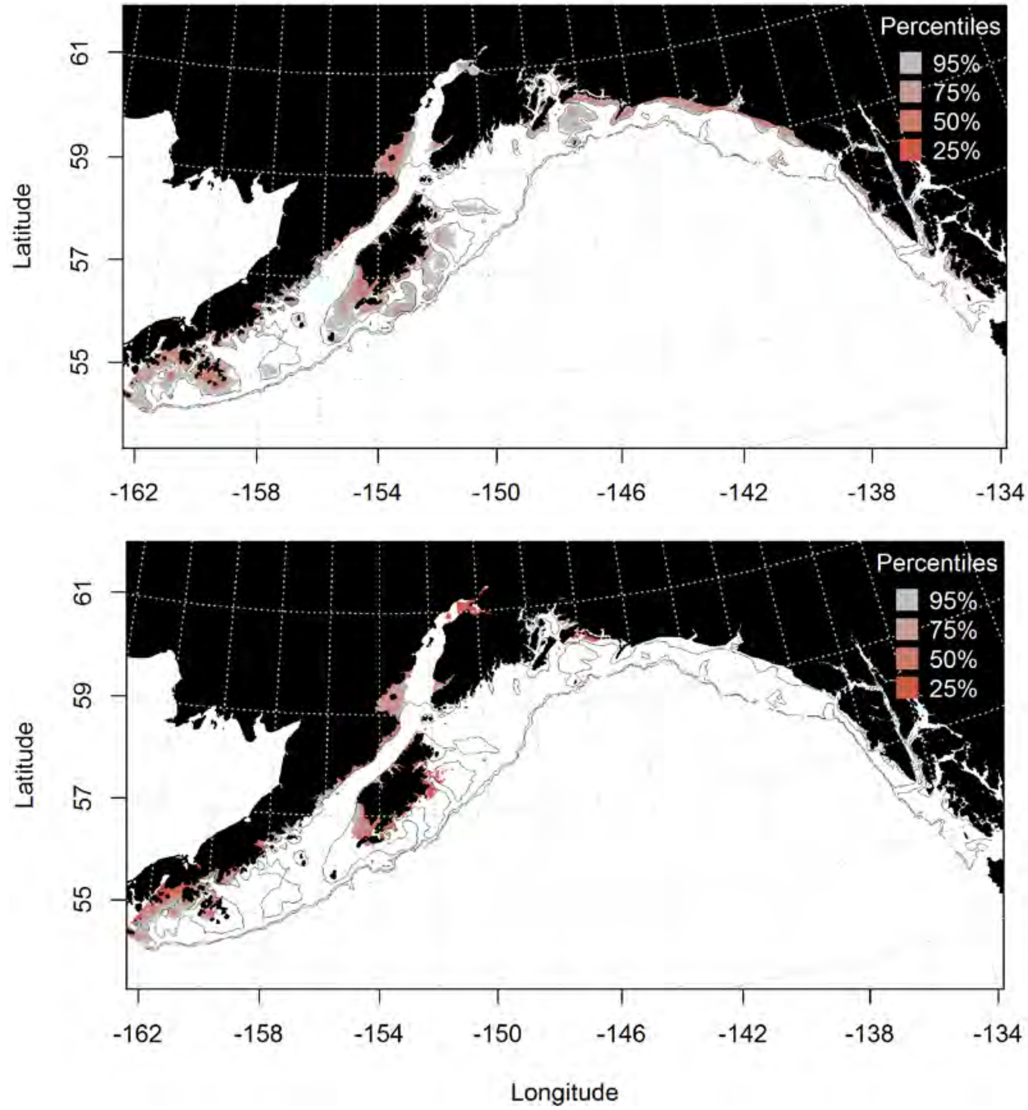


Figure 72. -- Predicted summer essential fish habitat for *L. aspera* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

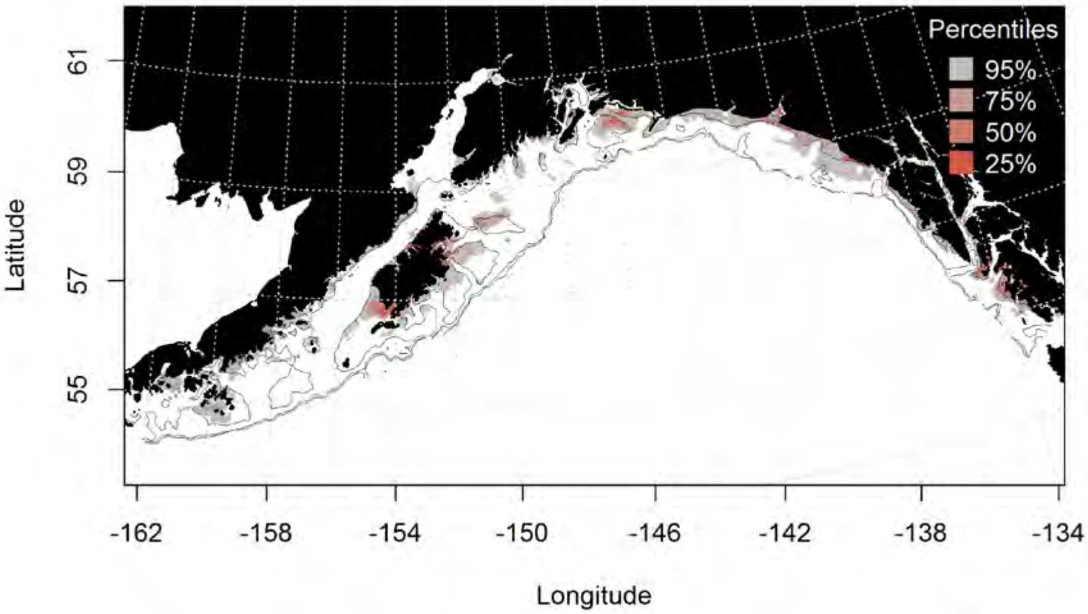


Figure 73. -- Essential fish habitat predicted for *L. aspera* during winter from commercial catches.

northern rock sole (*Lepidopsetta polyxystra*)

Northern rock sole occur along the Alaska Peninsula and Kodiak Island, and they are largely confined to depths less than 100 m (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *L. polyxystra* in the Gulf of Alaska -- Throughout much of their early life history of northern rock sole appear to largely occur around Kodiak Island and the Alaska Peninsula. No observations of northern rock sole eggs were located in the EcoFOCI database.

Larval northern rock sole were observed throughout the year in the GOA (Figure 74). During the fall and winter, a total of three larval northern rock sole were observed in vicinity of Kodiak

Island and the Alaska Peninsula. There was insufficient data to model the distribution of these larval northern rock sole. In the spring, larval northern rock sole were abundant.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables (relative importance = 38.5 and 14.8 respectively) predicting the distribution of larval northern rock sole. The AUC for the training data was 0.91, representing an excellent model fit. The AUC for the test data was 0.80, representing a good model fit. The percent of observations correctly classified for the training data was 83%, and it was 80% for the test data. In the spring, larval northern rock sole were predicted to occur across much of inner- and middle-shelf west of Kodiak Island and along the Alaska Peninsula, particular in Shelikof Gully (Figure 75). In the summer, larval northern rock sole were also abundant. The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables (relative importance = 65.0 and 10.9 respectively) predicting the distribution of larval northern rock sole. The AUC for the training data was 0.93, representing an excellent model fit. The AUC for the test data was 0.80, representing a good model fit. The percent of observations correctly classified for the training data was 84%, and it was 80% for the test data. The summer EFH for larval northern rock sole was predicted to be much the same as that during the spring, with the addition of some inshore waters and bays on the east side of Kodiak Island.

Only a single observation of early juvenile stage northern rock sole occurred in the EcoFOCI database, it was located in inshore waters on the east side of Kodiak Island (Figure 76).

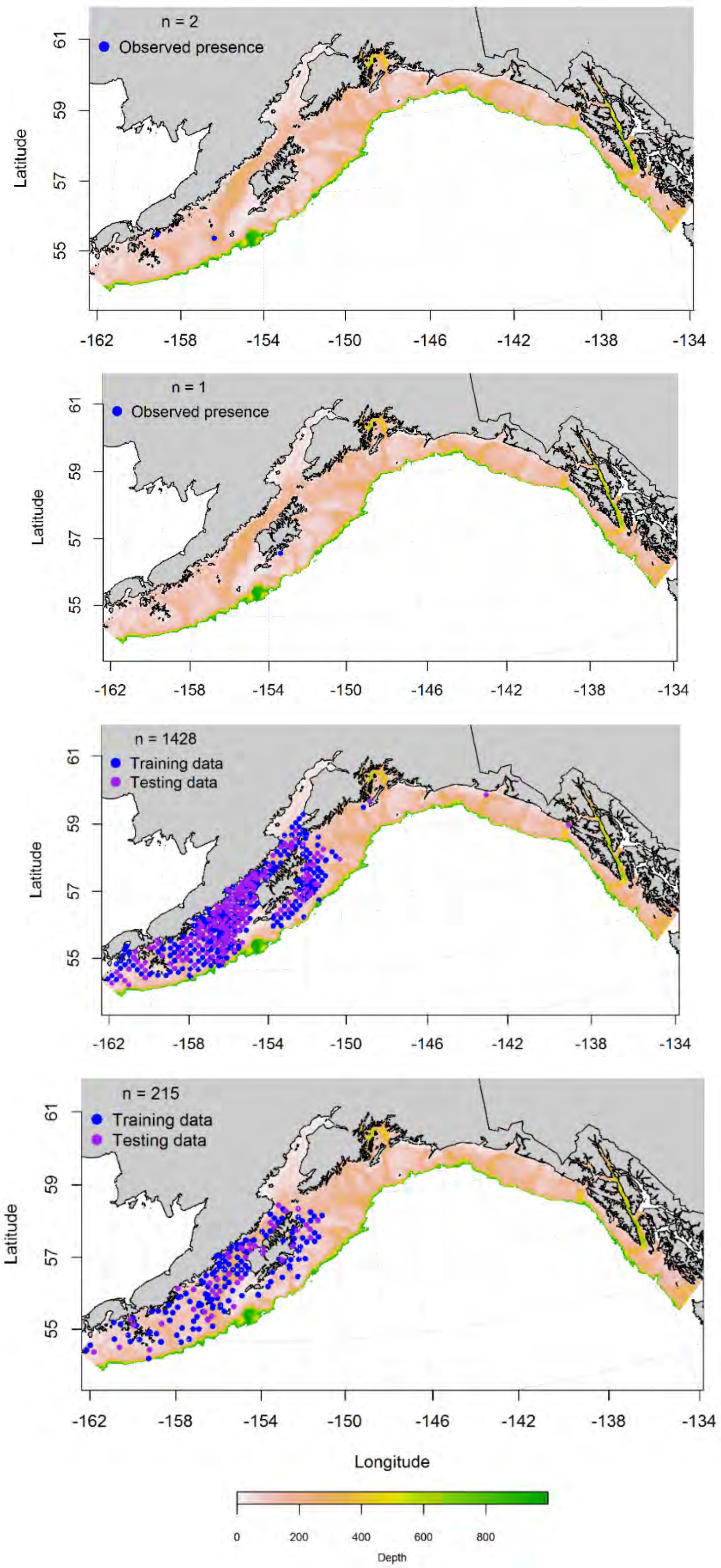


Figure 74. -- Fall, winter, spring and summer observations (top, second, third, and bottom panels, respectively) of larval *L. polyxystra* from the Gulf of Alaska.

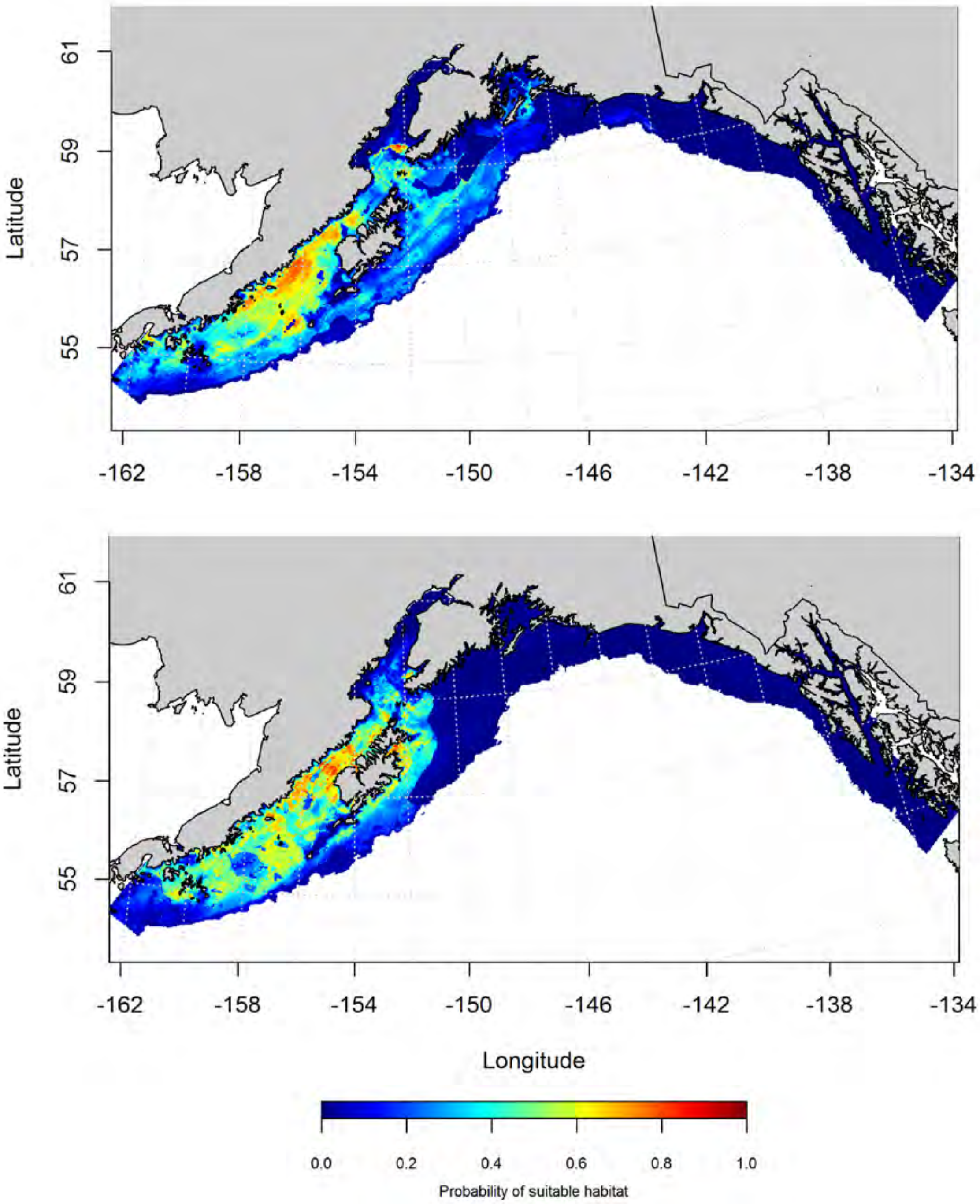


Figure 75. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *L. polyxystra*, from maximum entropy modeling of the Gulf of Alaska.

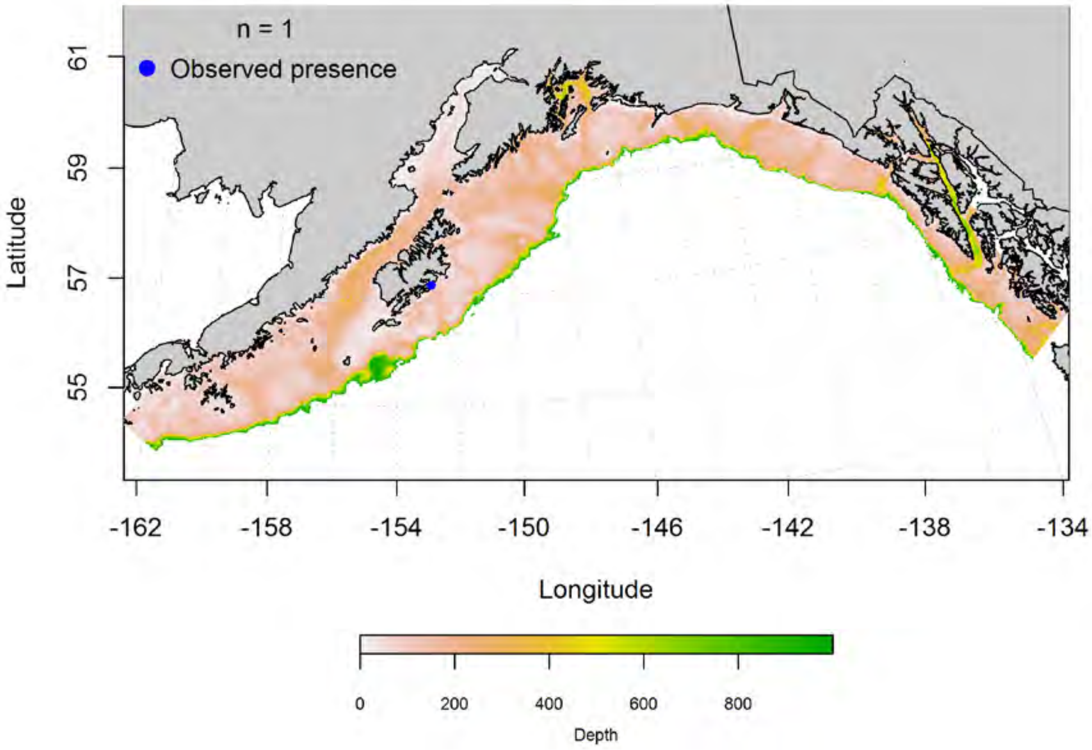


Figure 76. -- Summer catches of early juvenile *L. polyxystra* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *L. polyxystra* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile northern rock sole predominantly occur on the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula (Figure 77).

The variables determined to be the best predictors of the occurrence of juvenile northern rock sole were depth, latitude and longitude, and current speed. The AUC for the training was 0.95, indicating an excellent model fit; while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.32. The percent of observations correctly classified was 87% for the training data set, and 94% for the test data set. The most important variables predicting the abundance of juvenile northern rock sole were latitude and latitude and depth. The best-fitting GAM explained 19% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile northern rock sole were predicted to occur across much of the inner-shelf around Kodiak Island and the Alaska Peninsula. Predicted areas of high abundance included waters around the Shumagin Islands, Albatross and Chirikof Banks off Kodiak Island, and the entrance to Cook Inlet (Figure 78).

The variables determined to be the best predictors of the occurrence of adult northern rock sole were depth, latitude and longitude, and temperature. The AUC for both the training and test data was 0.95, indicating an excellent model fit, while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.33. The percent of observations correctly classified was 89% for the training data set, and 94% for the test data set. The most important variables predicting the abundance of juvenile northern rock sole were depth, latitude and latitude and temperature. The best-fitting GAM explained 24% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult northern rock sole were predicted to occur in similar habitats as juveniles, primarily around the Shumigan Islands on the Alaska Peninsula, and on Albatross and Chirikof Banks off Kodiak Island (Figure 79). High abundances were also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

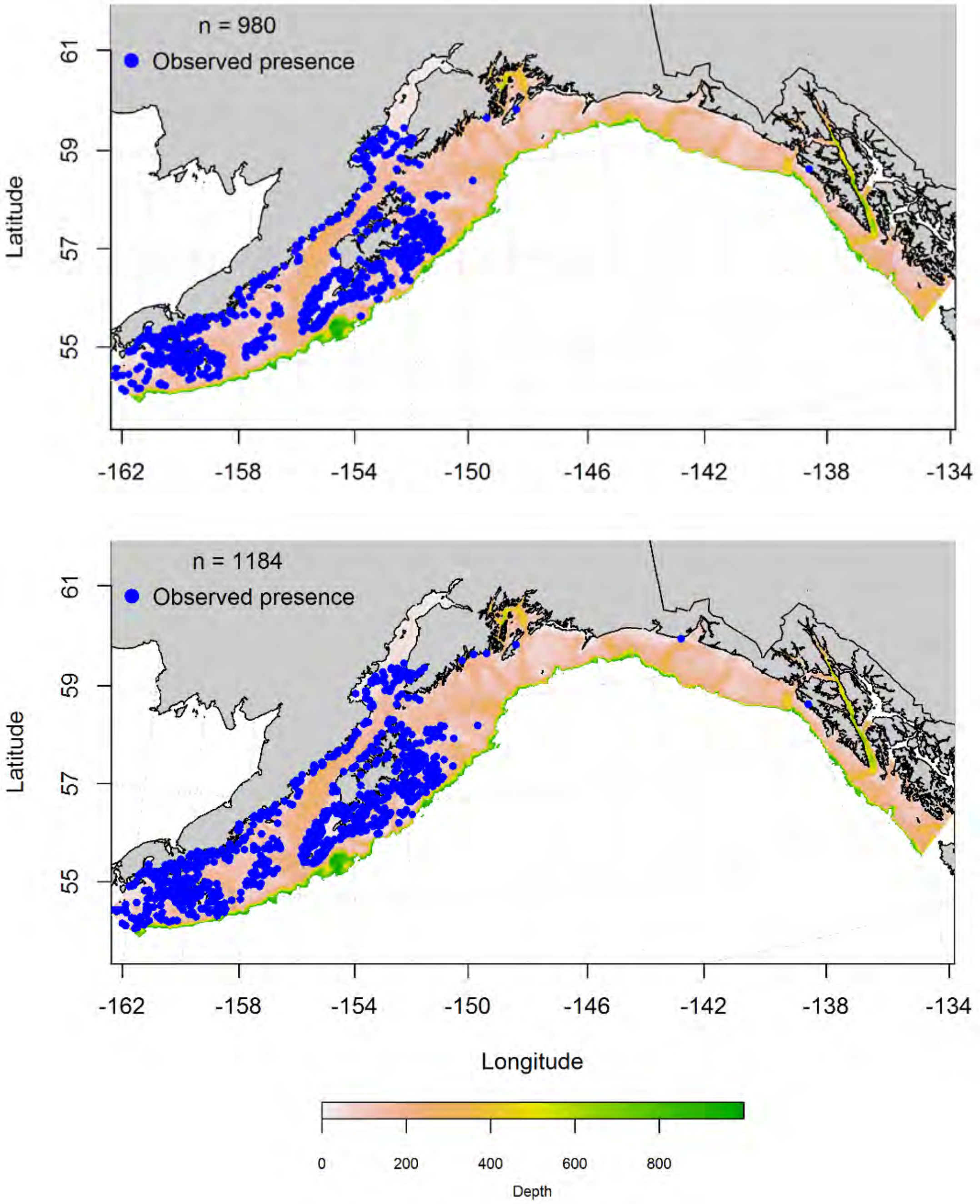


Figure 77. -- Locations of catches of juvenile and adult *L. polyxystra* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

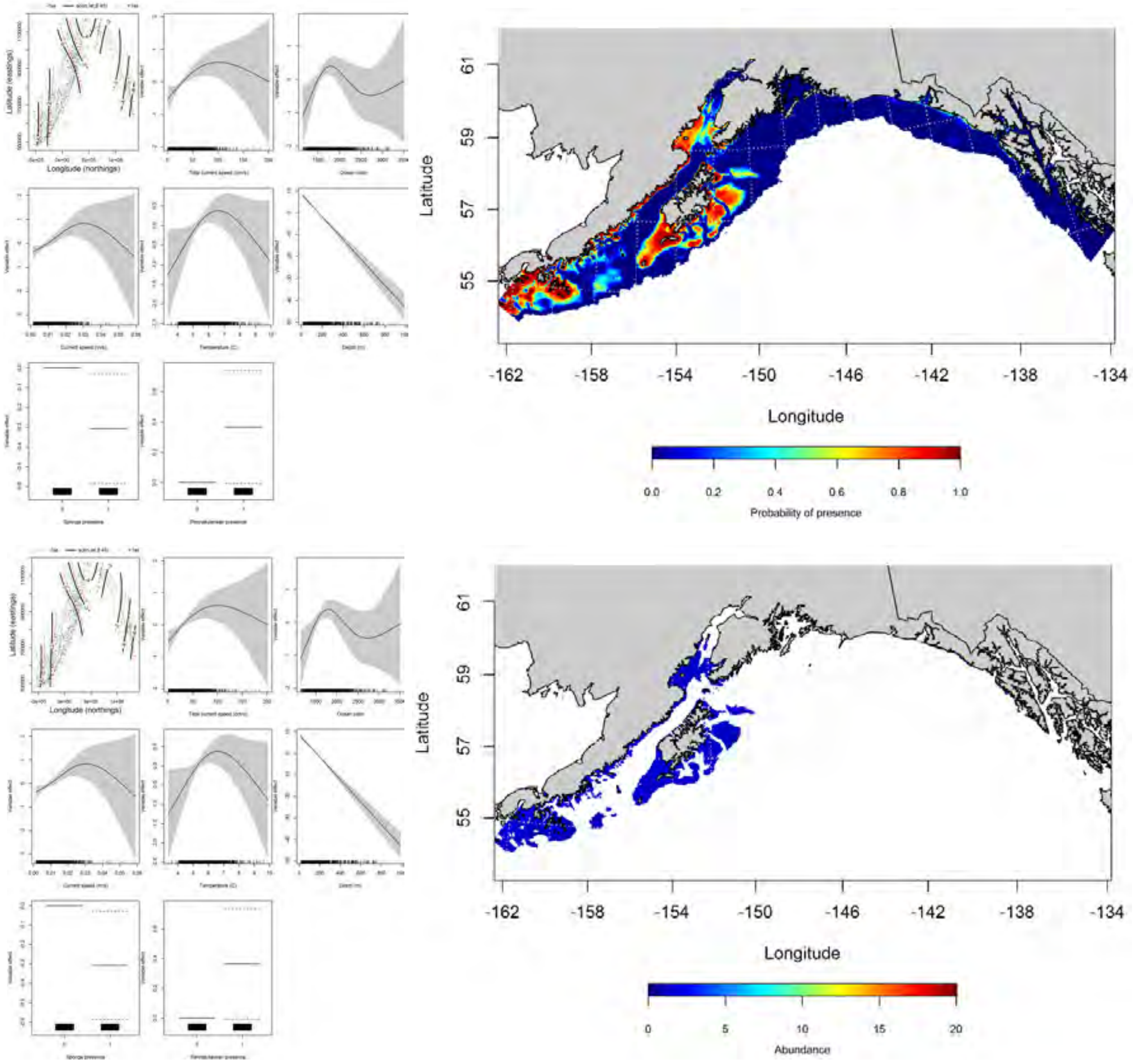


Figure 78. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *L. polyxystra* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

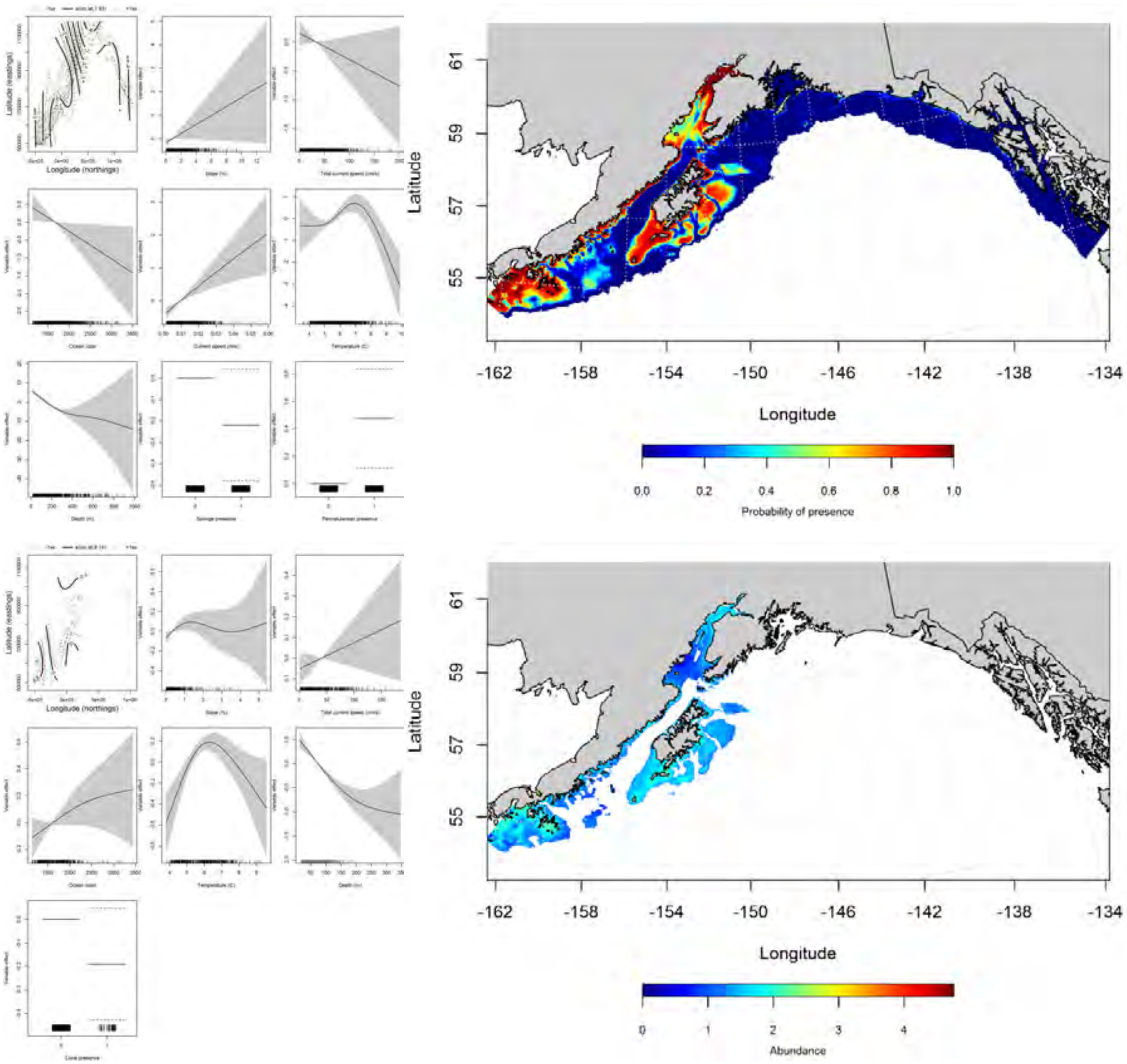


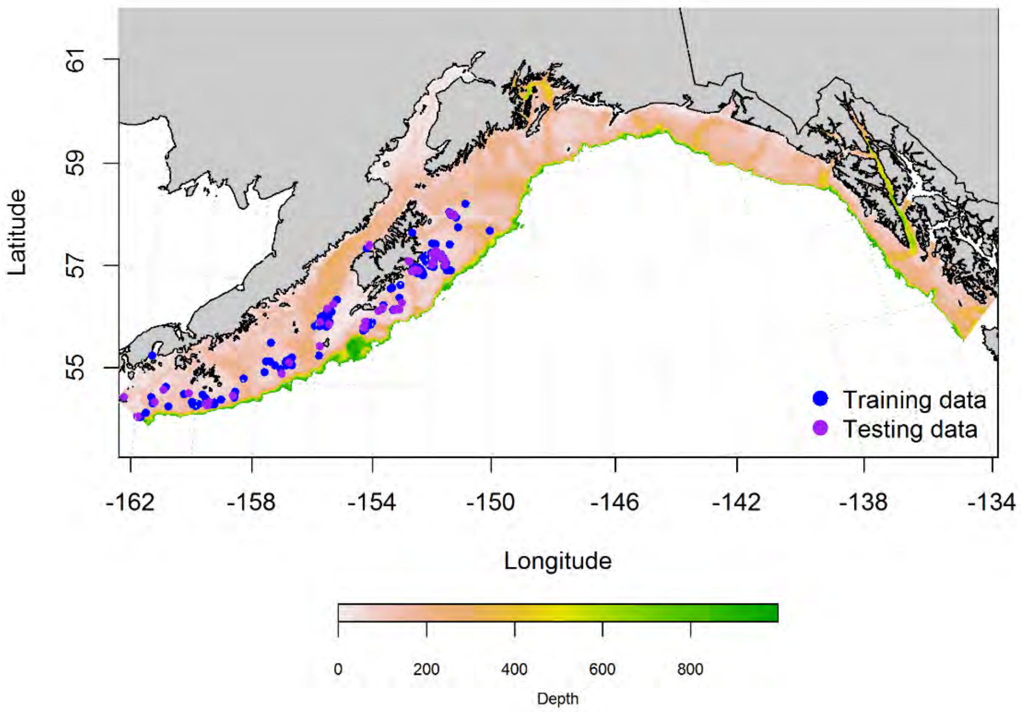
Figure 79. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *L. polyxystra* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *L. polyxystra* in the Gulf of Alaska -- Observations of northern and southern rock sole (*Lepidopsetta bilineata)* in commercial fisheries catches are difficult for observers to consistently separate by species. Consequently analysis of these species was conducted at the genus level, *Lepidopsetta* spp. The catch of *Lepidopsetta spp.* from commercial fisheries data indicate they largely occur on the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula.

During the fall, *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of rock sole (relative importance = 38.5 and 34.8 respectively). The AUC of the best fitting fall model was 0.94 for the training data indicating an excellent model fit. The AUC for the test data was 0.79, indicating a fair model fit. The percent of observations correctly classified for the training data was 86%, and it was 79% for the test data. In the fall, *Lepidopsetta* spp. habitat was predicted to occur on Albatross and Chirikof Banks off Kodiak Island, and Wessels Reef in the central gulf (Figure 80).

During the winter, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of rock sole (relative importance = 45.7 and 29.1 respectively). The AUC of the best fitting fall model was 0.96 for the training data indicating a good model fit; however, the AUC for the test data was 0.86, indicating a fair model fit. The percent of observations correctly classified for the training data was 89%, and it was 86% for the test data. In the winter, *Lepidopsetta* spp. habitat was predicted to occur around Kodiak Island, on Albatross and Portlock Banks, as well as off the Kenai Peninsula and the entrance to Cook Inlet (Figure 81).

During the spring, *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of rock sole (relative importance = 31.1 and 27.5 respectively). The AUC of the best fitting fall model was 0.93 for the training data indicating a good model fit; however, the AUC for the test data was 0.81, indicating a good model fit. The percent of observations correctly classified for the training data was 85%, and it was 81% for the test data. In the spring, *Lepidopsetta* spp. habitat was predicted to occur around Kodiak Island, particularly Albatross Bank, as well as localized abundance at the entrance of Cook Inlet and entrance of Prince William Sound (Wessels Reef) (Figure 82).



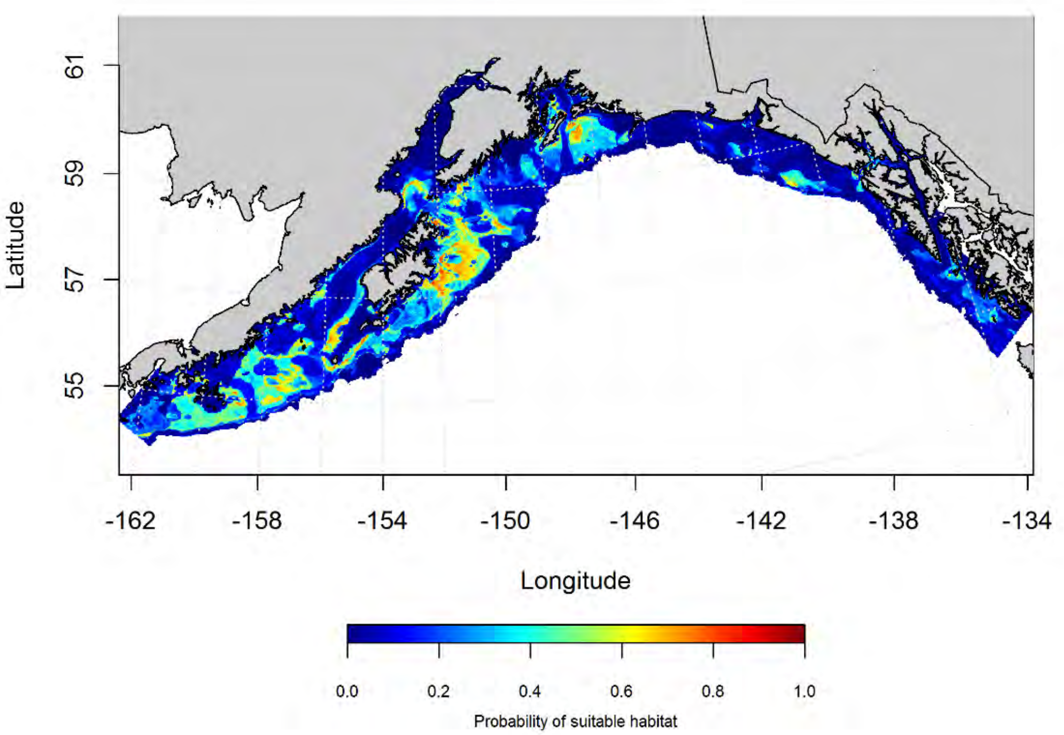


Figure 80. -- Locations of fall (September-November) commercial fisheries catches of *Lepidopsetta spp.* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *Lepidopsetta spp.* commercial catches (bottom panel) and the purple points were used to test the model.

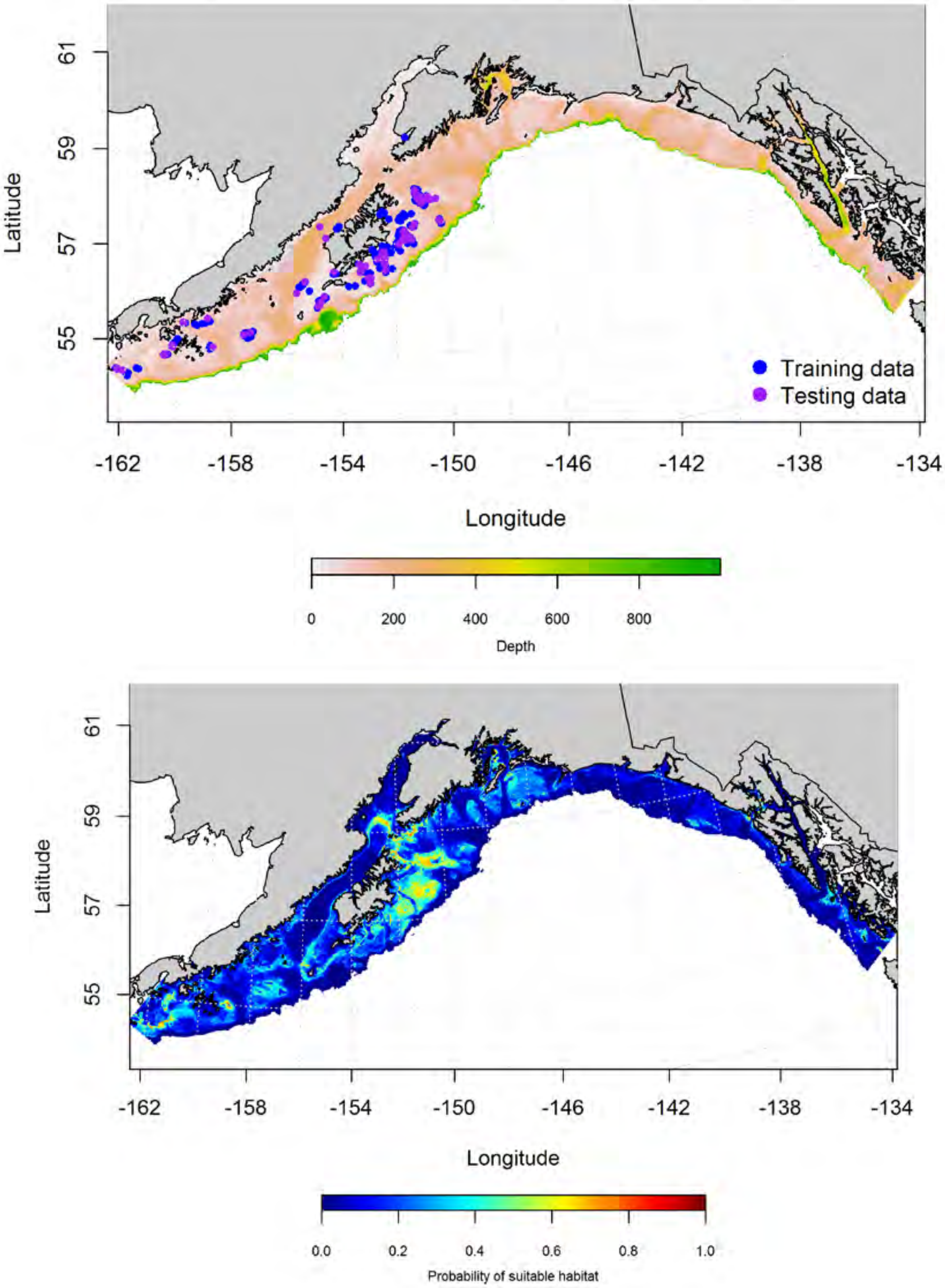


Figure 81. -- Locations of winter (December-February) commercial fisheries catches of *Lepidopsetta spp.* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *Lepidopsetta spp.* commercial catches (bottom panel) and the purple points were used to test the model.

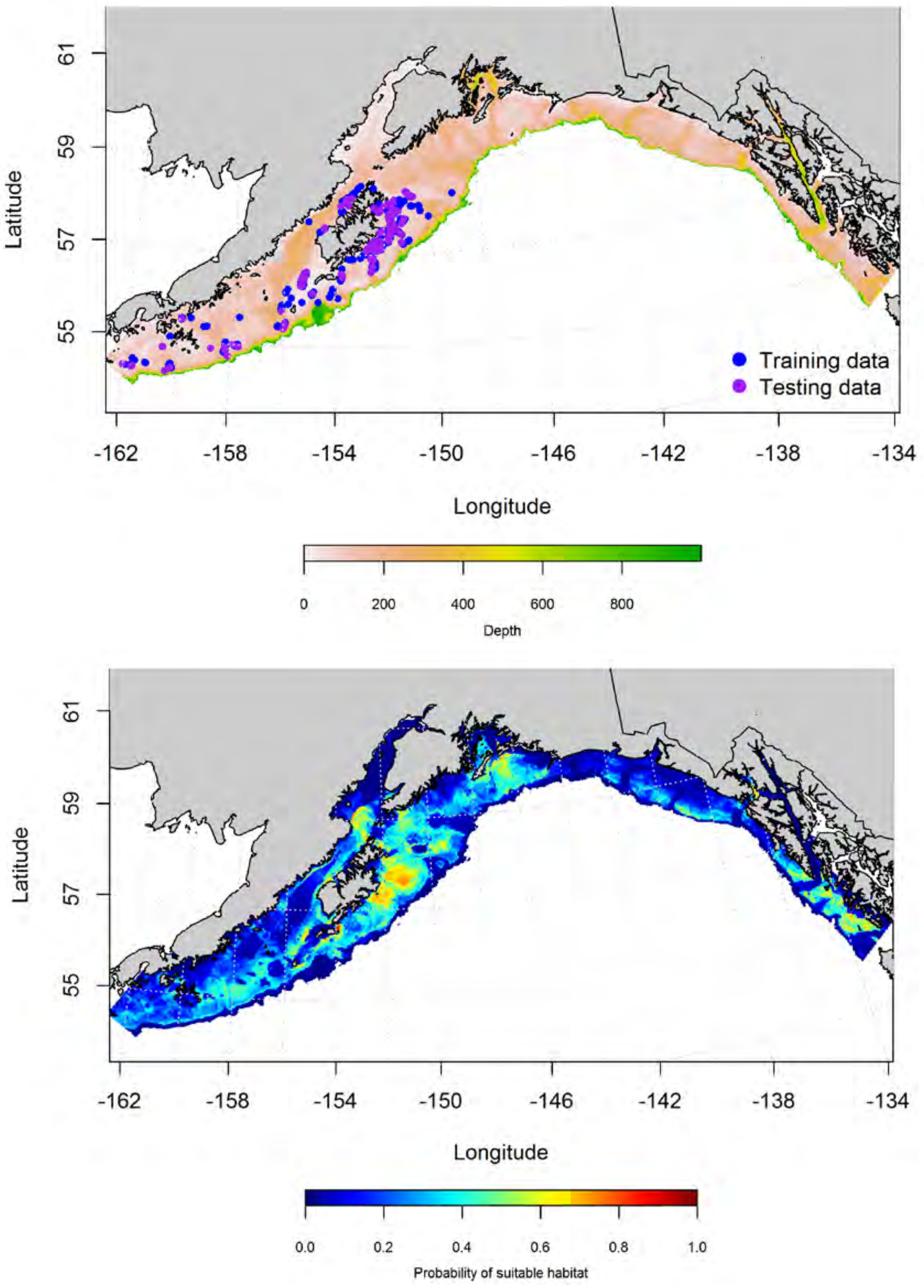


Figure 82. -- Locations of spring (March-May) commercial fisheries catches of *Lepidopsetta spp.* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *Lepidopsetta spp.* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *L. polyxystra* Essential Fish Habitat Maps and Conclusions --

Essential fish habitat for northern rock sole was predicted to largely occur to the shallow portions of the inner- and middle-shelf off Kodiak Island and the Alaska Peninsula. EFH for northern rock sole eggs and juvenile stages could not be predicted. Spring and summer EFH for larval northern rock sole was predicted to occur over much of the inner-and middle-shelf off Kodiak Island and the Alaska Peninsula (Figure 83).

Summer EFH for juvenile and adult northern rock sole, based on trawl survey observations, were predicted be very similar. They include much of the shallower portions of the inner-shelf along the Alaska Peninsula and Kodiak Island as well as portions of Cook Inlet (Figure 84).

Observations of rock sole in commercial fisheries data included both northern and southern rock sole, consequently EFH predictions based on these data were developed at the genus level, *Lepidopsetta spp.* During the fall EFH for *Lepidopsetta spp.* was predicted to include much of the shallower portions of the middle-shelf in the western gulf along the Alaska Peninsula to Prince William Sound, including Semidi Bank, Albatross and Portlock Banks off Kodiak Island, and Wessels Reef off Prince William Sound (Figure 85). Winter EFH for *Lepidopsetta spp.*, was more restricted, and was predicted to largely occur on Albatross and Portlock Banks, and off the Kenai Peninsula to the east. During the spring, EFH for *Lepidopsetta spp.*, was predicted to occur over much of the middle-shelf, particularly between Kodiak Island and Wessels Reefs.

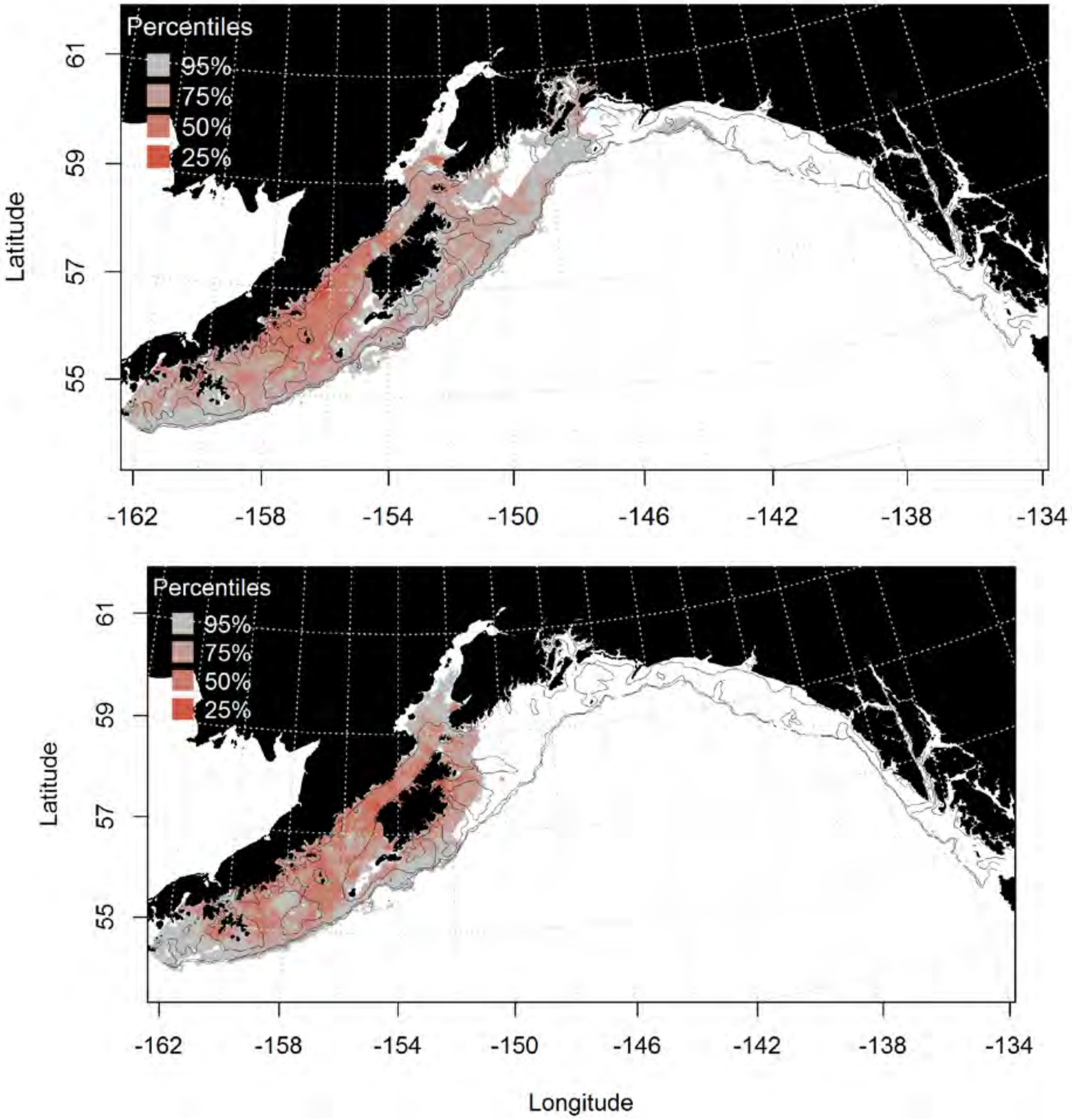


Figure 83. -- Spring and summer essential fish habitat predicted for larval *L. polyxystra* (top and bottom panel, respectively) from EcoFOCI database.

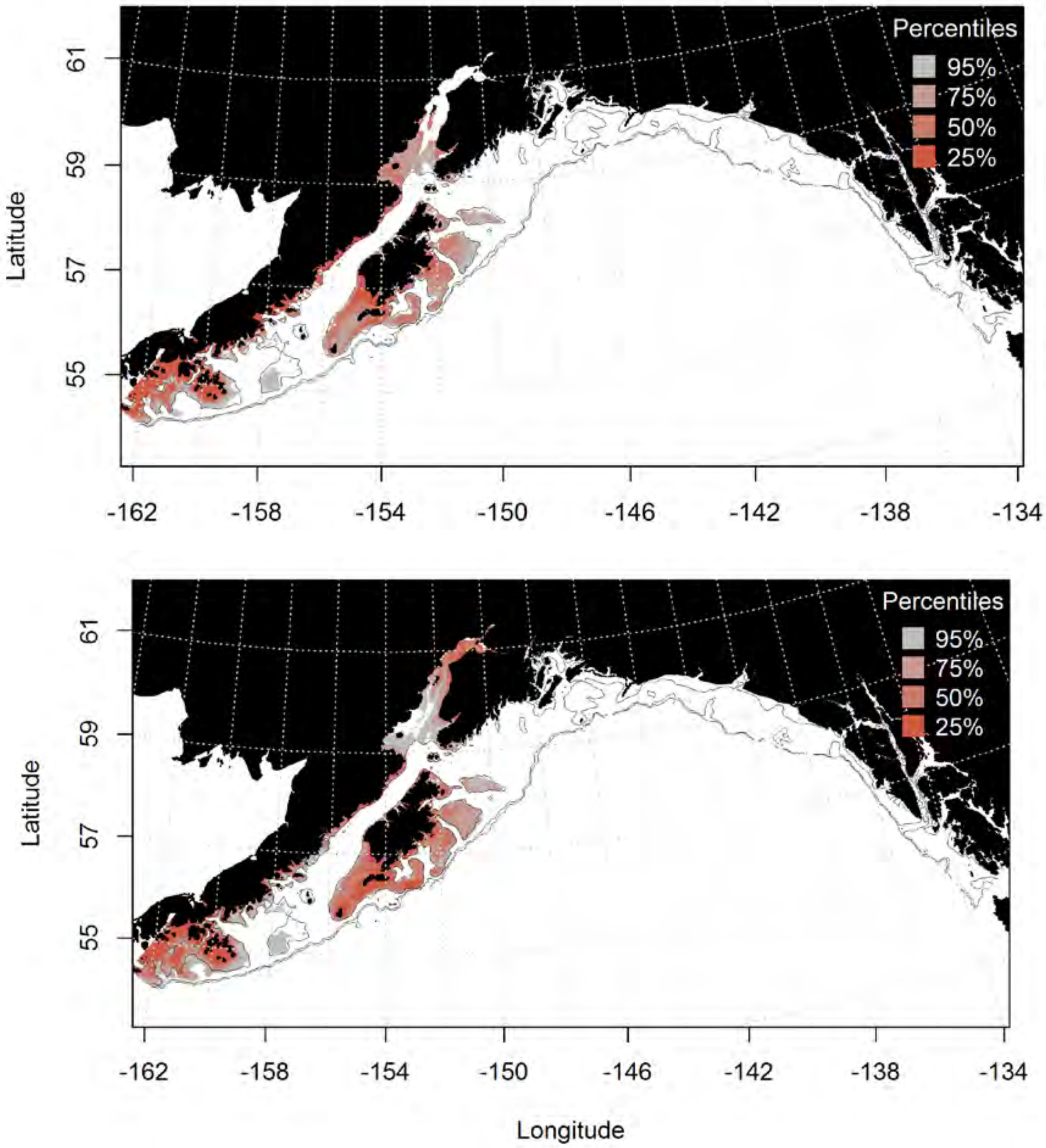


Figure 84. -- Predicted summer essential fish habitat for *L. polyxystra* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

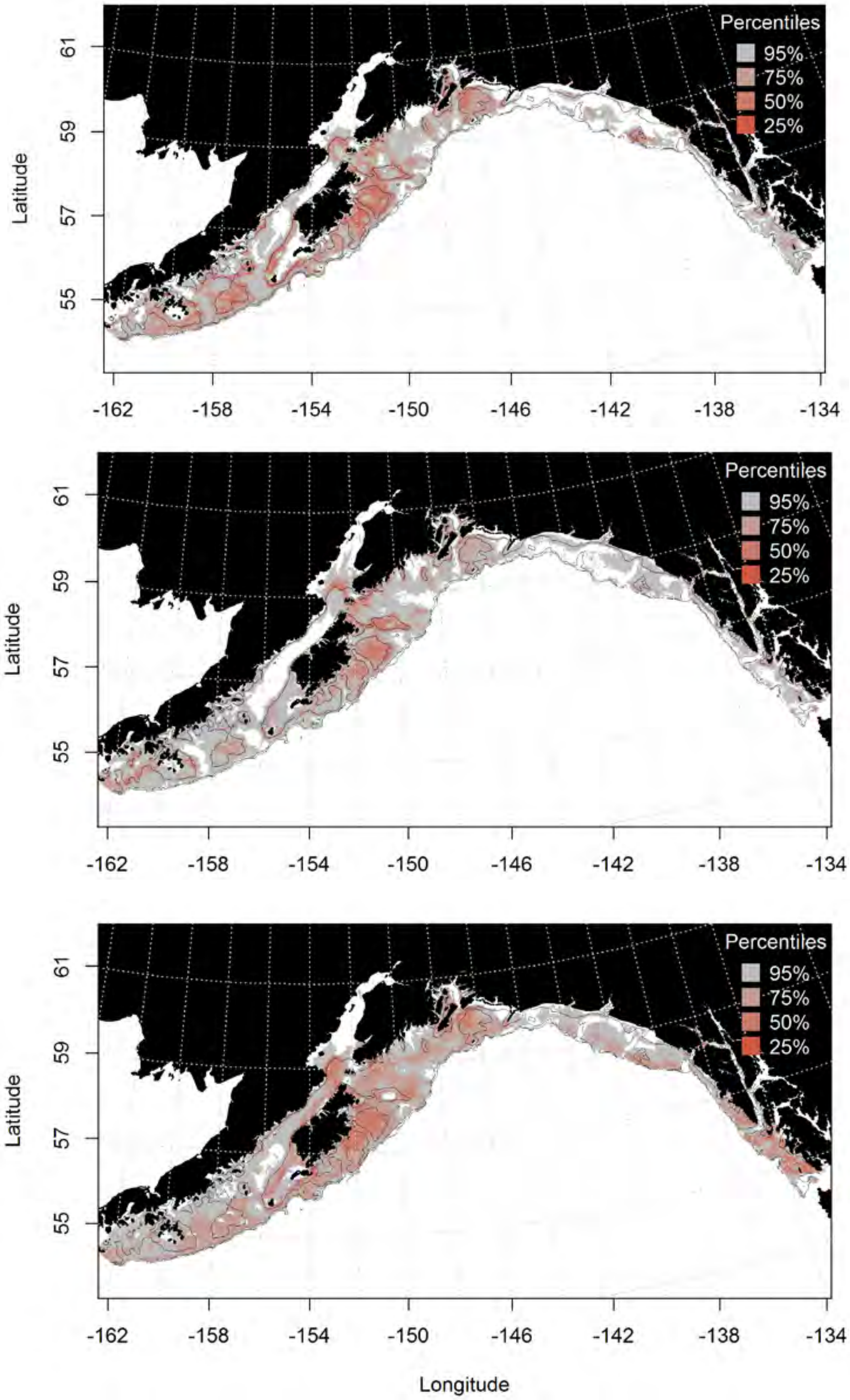


Figure 85. -- Essential fish habitat predicted for *Lepidopsetta spp.* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

southern rock sole (*Lepidopsetta bilineata*)

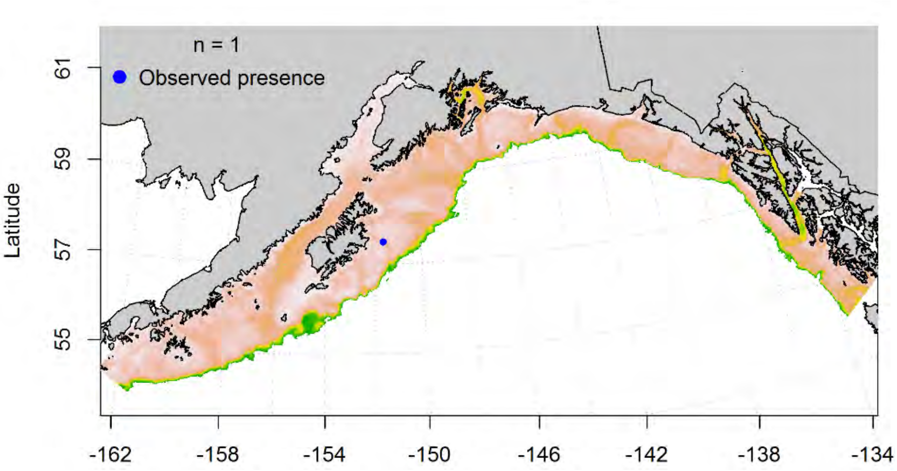
Southern rock sole primarily occurred in nearshore waters along the Alaska Peninsula and Kodiak Island, at depth less than 100 m (von Szalay et al. 2010).

**Seasonal distribution of early life history stages of *L. bilineata* in the Gulf of Alaska -- ** Throughout much of their early life history of southern rock sole appear to occur around Kodiak Island and the Alaska Peninsula. No observations of southern rock sole eggs or early juvenile occured in the EcoFOCI database.

Larval southern rock sole were observed during the fall, spring and summer. During the fall, a single larval southern rock sole were observed east of Kodiak Island in the vicinity of Chiniak Gully (Figure 86). In the spring, larval southern rock sole were much more abundant.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables (relative importance = 31.9 and 24.8 respectively) predicting the distribution of larval southern rock sole. The AUC for the training data was 0.88, representing a good model fit. The AUC for the test data was 0.76 representing a fair model fit. The percent of observations correctly classified for the training data was 80%, and it was 76% for the test data. In the spring, larval southern rock sole were predicted to occur across much of inner- and middle-shelf around the Alaska Peninsula and Kodiak Island, particularly between Shelikof Gully and the Shumagin Islands (Figure 87). In the summer, larval southern rock sole were also abundant. The best-fitting

MaxEnt model indicated that surface temperature and depth were the most important variables (relative importance = 54.2 and 22.5 respectively) predicting the distribution of larval southern rock sole. The AUC for the training data was 0.90, representing an excellent model fit. The AUC for the test data was 0.76 representing a fair model fit. The percent of observations correctly classified for the training data was 81%, and it was 76% for the test data. In the summer, they were predicted to be occur along much of the inner- and middle-shelf along the Alaska Peninsula, particularly in Shelikof Strait and among the bays and banks located on the east side of Kodiak Island.



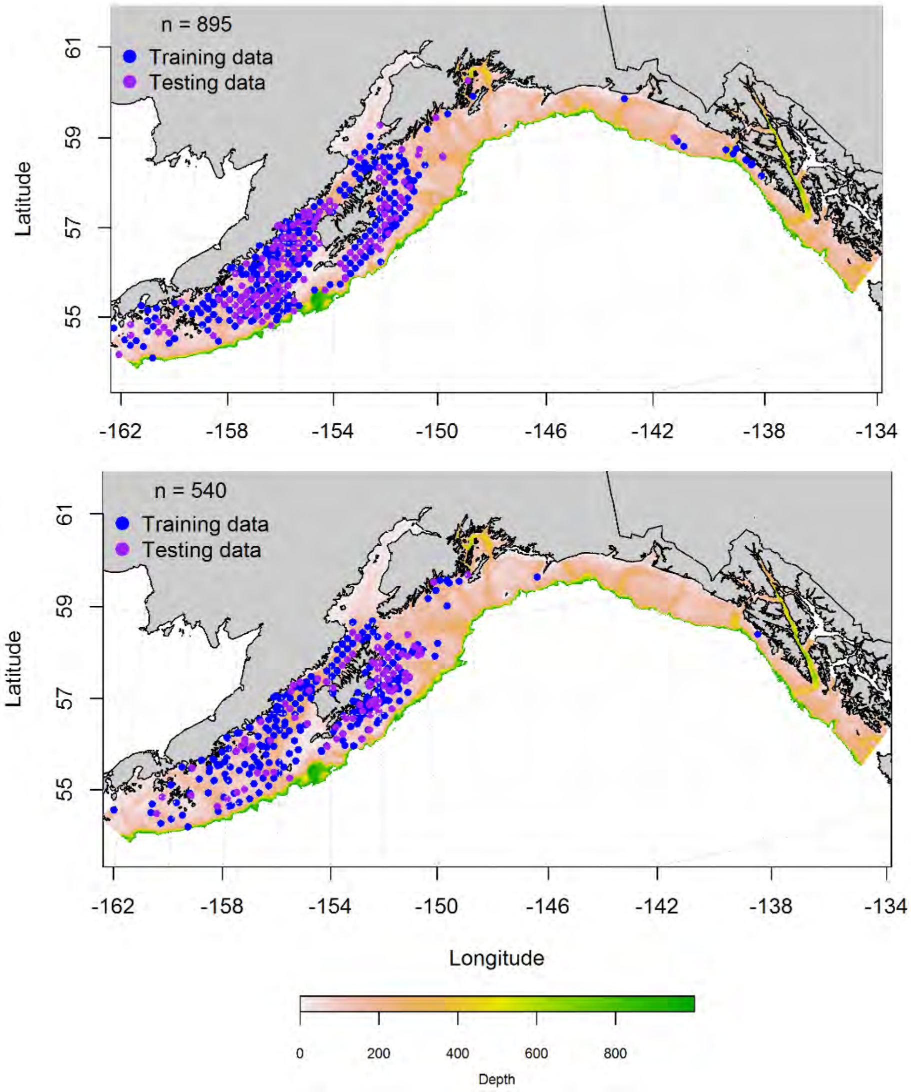


Figure 86. -- Fall, spring, and summer observations (top, middle, and bottom panels, respectively) of larval *L. bilineata* from the Gulf of Alaska.

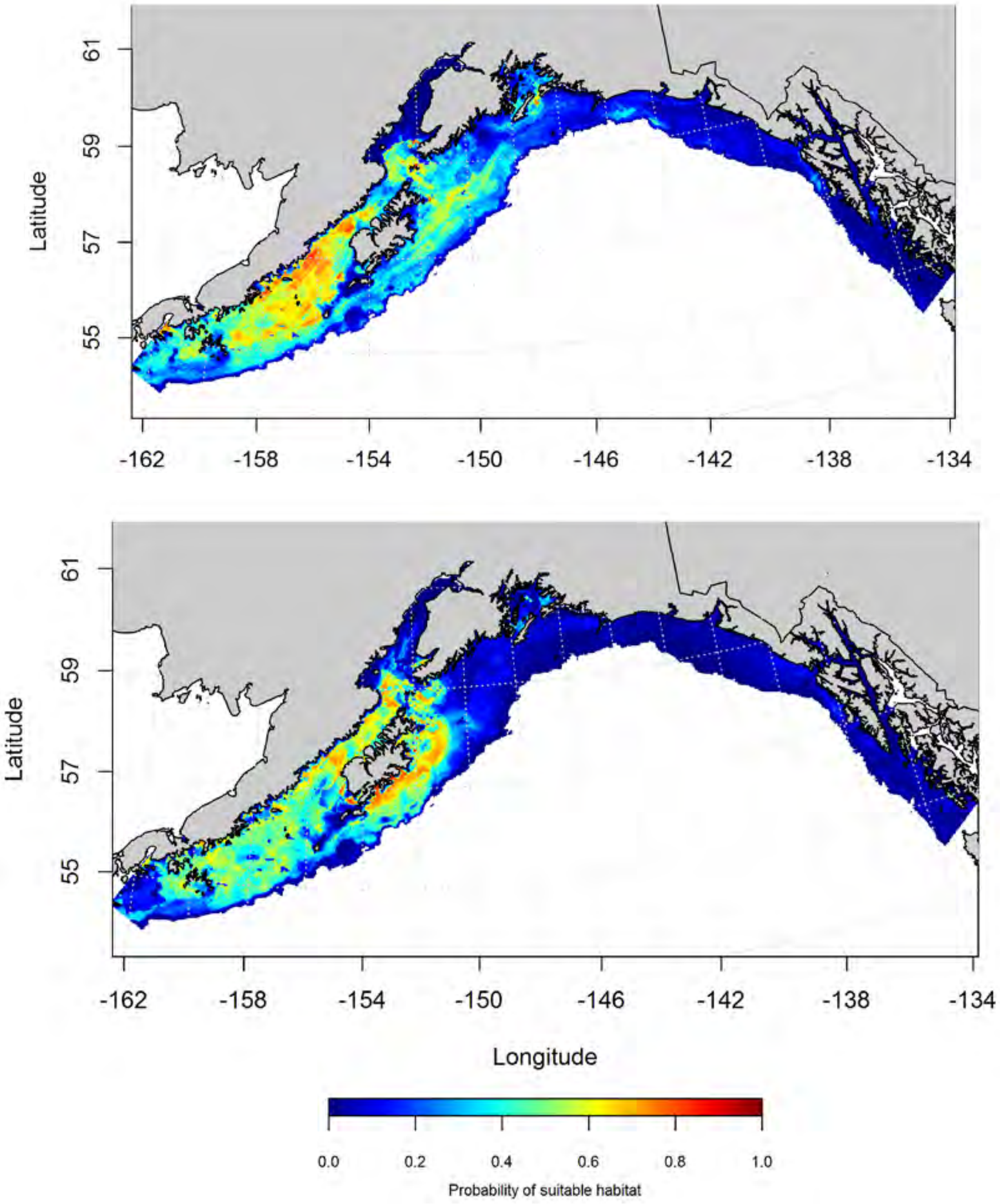


Figure 87. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *L. bilineata* from maximum entropy modeling of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *L. bilineata* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile southern rock sole predominantly occur on the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula. Smaller more isolated pockets also occurring off Prince William Sound and southeast Alaska (Figure 88).

The variables determined to be the best predictors of the occurrence of juvenile south rock sole were depth, latitude and longitude, and temperature. The AUC for both the training and test data was 0.94, indicating an excellent model fit. The optimum threshold was 0.35. The percent of observations correctly classified was 89% for the training data set, and 94% for the test data set. The most important variables predicting the abundance of juvenile southern rock sole were depth, latitude and latitude, and tidal current. The best-fitting GAM explained 25% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile southern rock sole were predicted to occur in much of the shallower areas around Kodiak Island and the Alaska Peninsula, and to a lesser extent off southeast Alaska. Predicted areas of high abundance also included waters around the Shumagin Islands, Albatross and Chirikof Banks off Kodiak, and inshore waters off southeast Alaska (Figure 89).

Summer bottom trawl survey data also indicated adult southern rocksole occur across much of the inner- and middle-shelf around Kodiak Island and the Alaska Peninsula. A smaller isolated pockets also occur off Prince William Sound and southeast Alaska (Figure 90). The best-fitting GAM indicated that depth, latitude and longitude, and temperature were the most important variables predicting the distribution of adult Dover sole. The model explained 52% of the variability in CPUE for the training data and 55% of testing data. Adult southern rock sole were predicted to occur in much same areas as juveniles of the species, primarily around the Shumigan

Islands on the Alaska Peninsula, Albatross and Chirikof Banks off Kodiak Island, the head of Cook Inlet, and Chatham Strait in southeast Alaska.

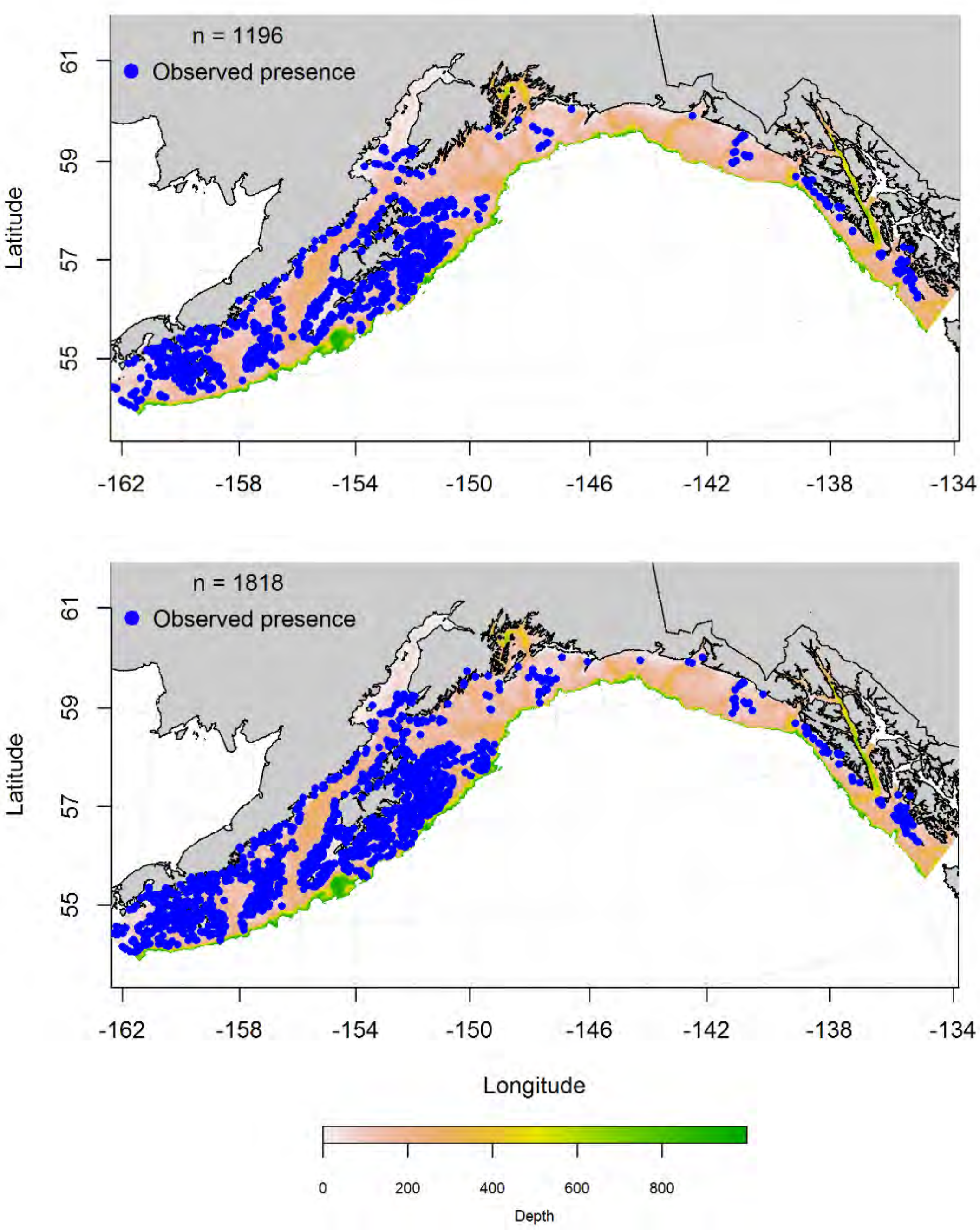


Figure 88. -- Locations of catches of juvenile and adult *L. bilineata* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

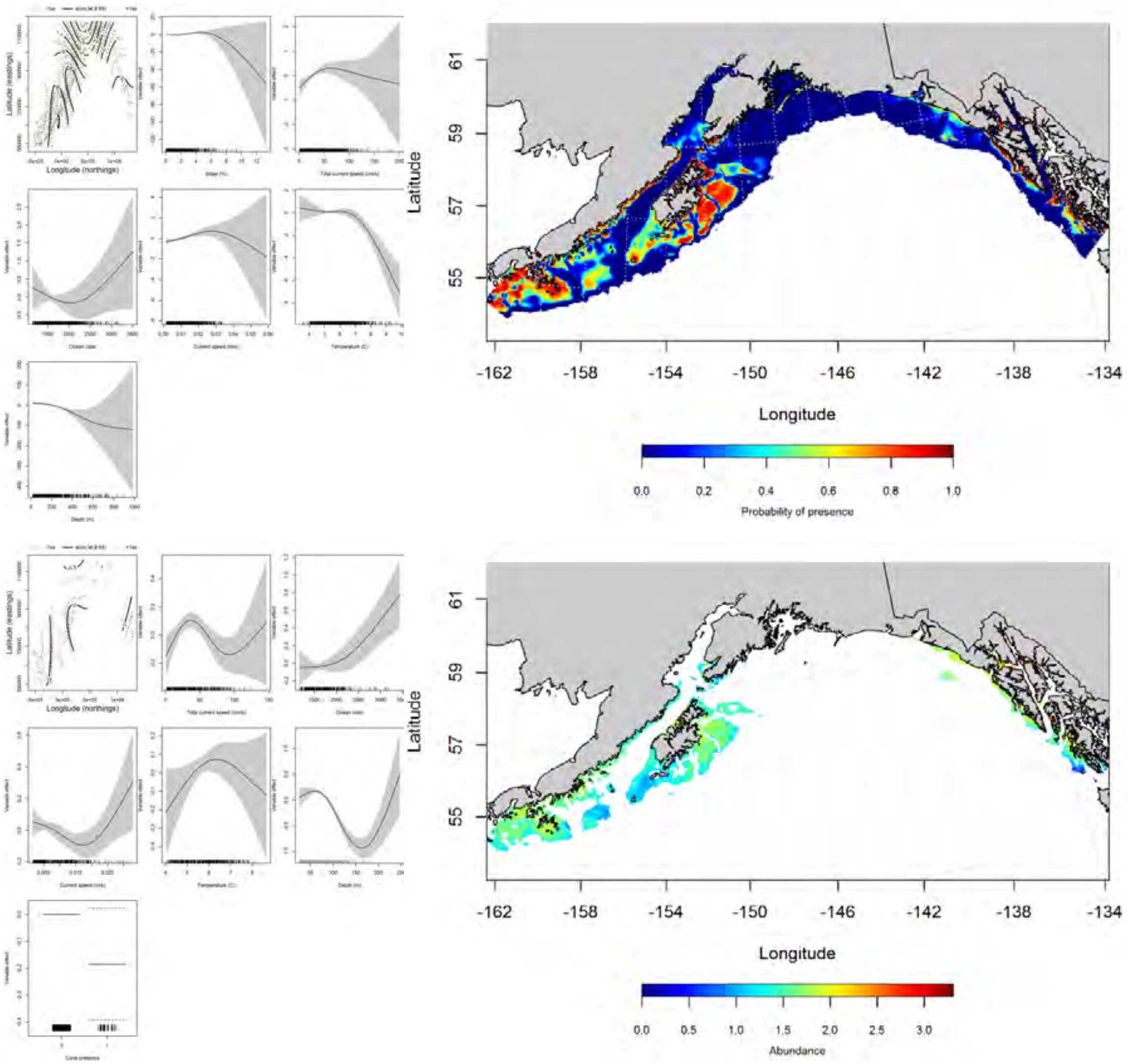


Figure 89. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *L. bilineata* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

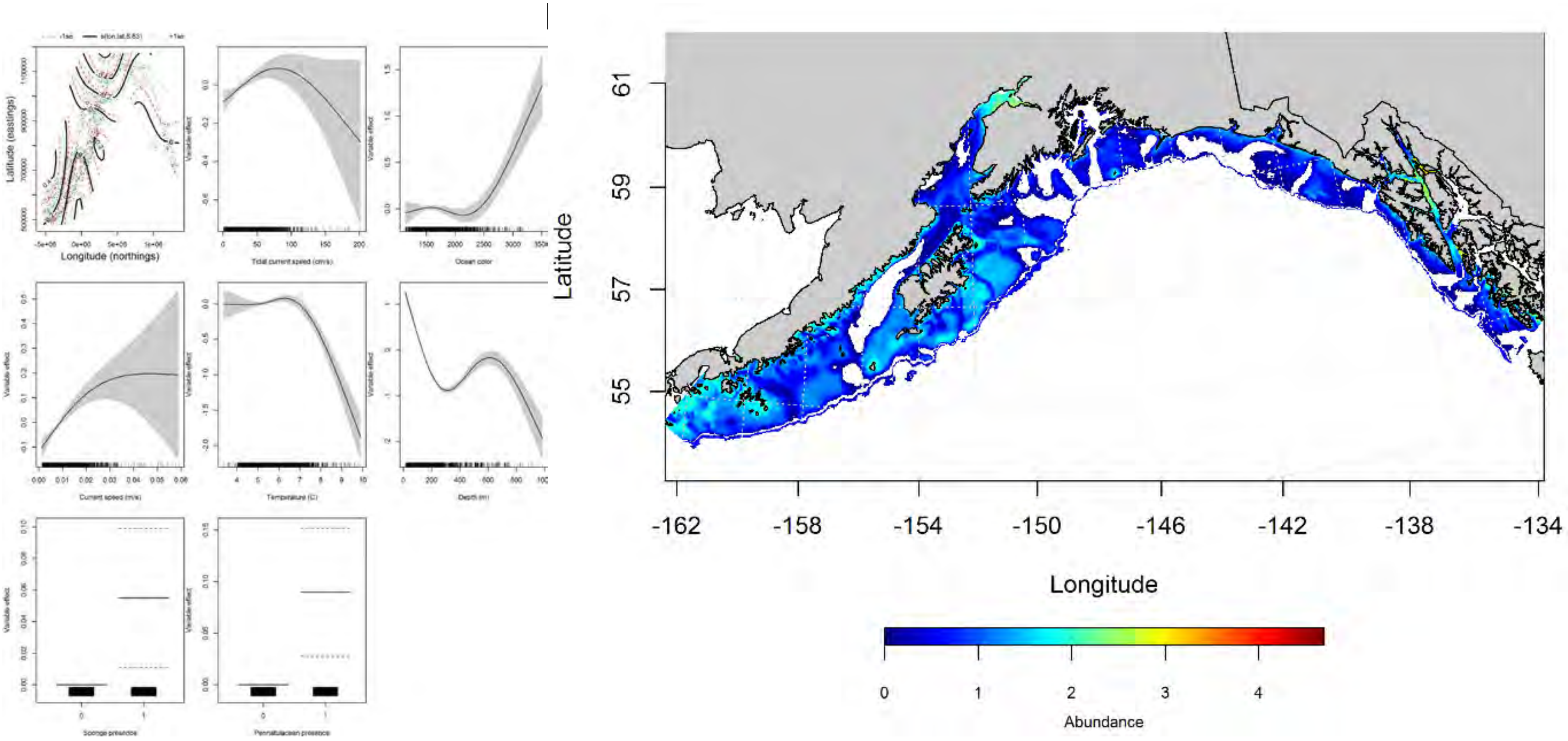


Figure 90. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *L. bilineata* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *L. bilineata* abundance (right panel)

Seasonal distribution of commercial fisheries catches of adult *L. bilineata* in the Gulf of Alaska -- Northern and southern rock sole (*Lepidopsetta bilineata)* in commercial fisheries catches are difficult for observers to consistently separate by species. Consequently analysis of these species was conducted at the genus level, *Lepidopsetta* spp. Please see the analysis of commercial catch data discussed under norther rock sole above of this report for additional details.

Gulf of Alaska *L. bilineata* Essential Fish Habitat Maps and Conclusions -- Southern rock sole essential fish habitat predicted by modeling was predicted to occur over large portions of the inner- and middle-shelf off Kodiak Island and the Alaska Peninsula. EFH for southern rock sole eggs and juvenile stages could not be predicted. EFH for spring and summer EFH for larval southern rock sole, occurred across much of the inner-and middle-shelf off Kodiak Island and the Alaska Peninsula (Figure 91).

Summer EFH for juvenile southern rock sole, based on trawl survey observations, was predicted to be centered around the Shumagin Islands on Alaska Peninsula as well as on Albatross Bank, off Kodiak Island (Figure 92). High probability summer EFH habitat was also predicted to occur in nearshore waters off southeast Alaska. Summer EFH for adult southern rock sole was predicted to be more extensive than that of juvenile southern rock sole. It included much of the shallower portions of the inner- and middle shelf, particularly around the Shumigan Islands, Albatross and Chirikof Banks off Kodiak Island, as well as the nearshore waters in southeast Alaska.

Observations of rock sole in commercial fisheries data included both northern and southern rock sole, consequently EFH predictions based on these data were developed at the genus level, *Lepidopsetta spp.* See the northern rock sole section for an analysis of these data.

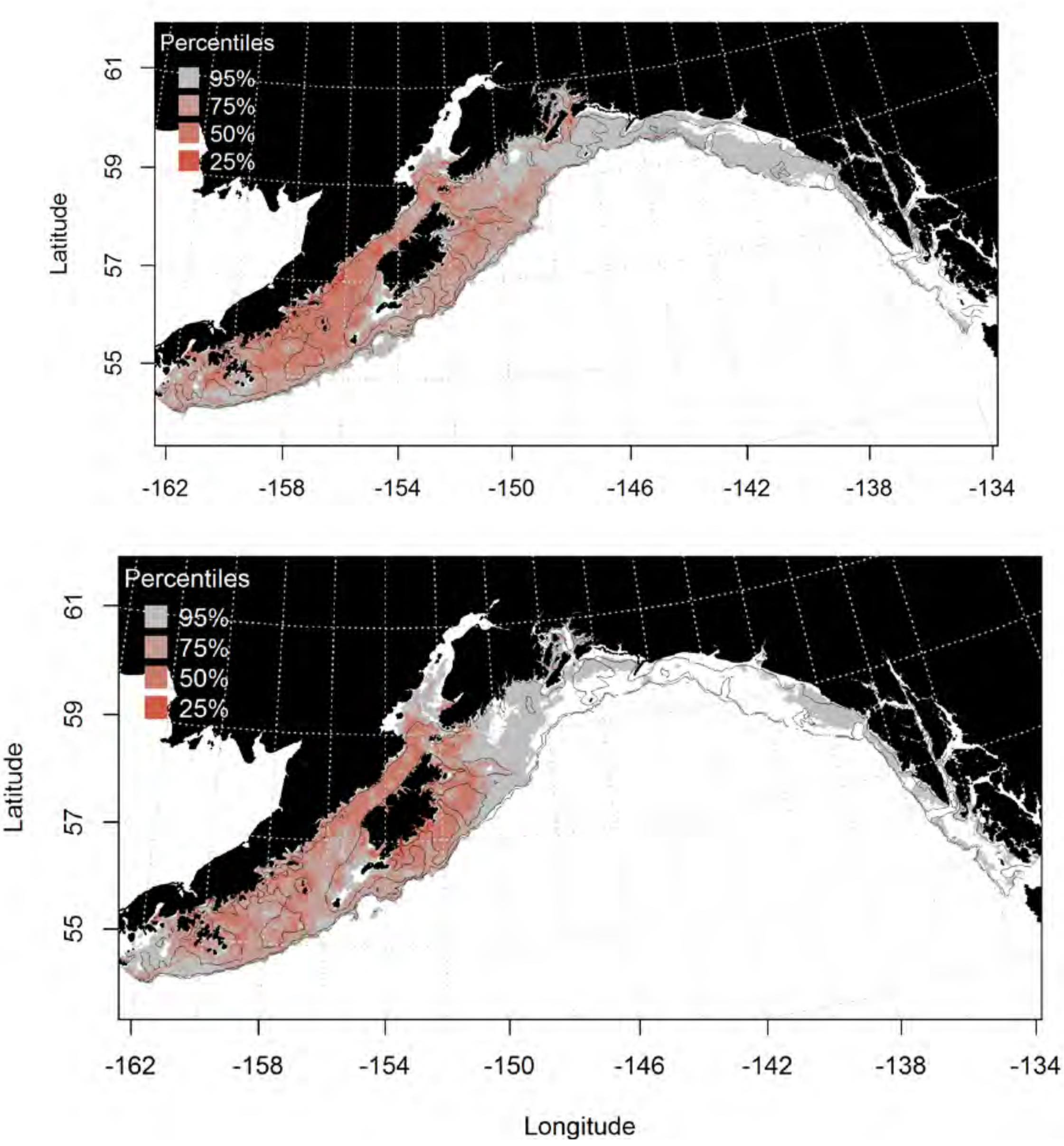


Figure 91. -- Spring and summer essential fish habitat predicted for larval *L. bilineata* (top and bottom panel, respectively) from EcoFOCI database.

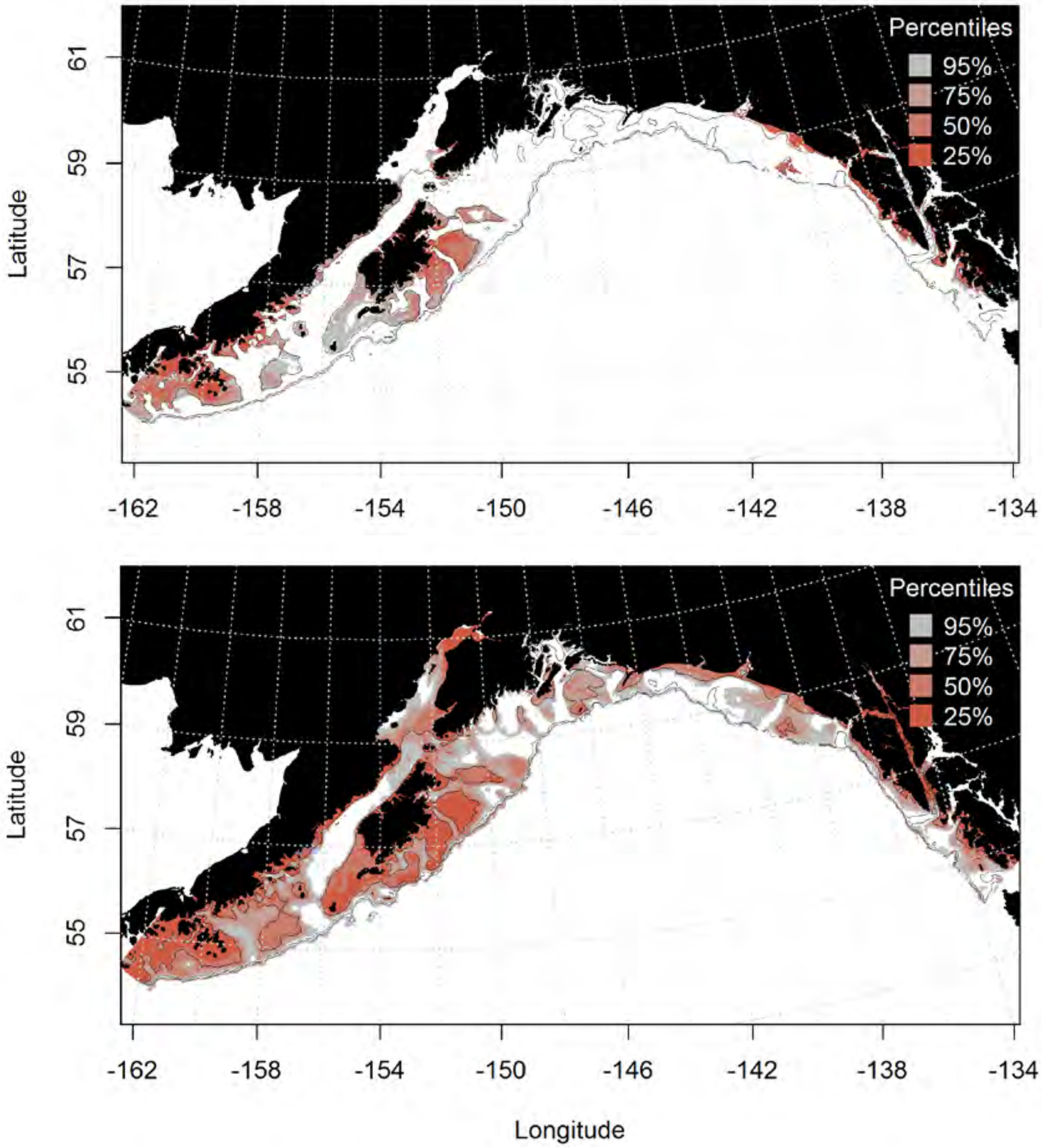


Figure 92. -- Predicted summer essential fish habitat for *L. bilineata* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

Alaska plaice (*Pleuronectes quadrituberculatus*)

Alaska plaice largely occur in the western Gulf of Alaska, typically on soft bottoms in less than 150 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *P. quadrituberculatus* in the Gulf of Alaska -- Throughout much of their early life history Alaska plaice were predicted to be largely occur on the inner-shelf along the Alaska Peninsula. Alaska plaice eggs were observed during the spring and the summer. During the spring, Alaska plaice eggs were abundant along the Alaska Peninsula. The best-fitting *MaxEnt* model indicated that surface temperature and depth (relative importance 48.0 and 29.1, respectively) the most important variables predicting habitat suitability. The AUC for the training data was 0.96, and 0.90 for the testing data, indicating an excellent model fit for both. The percent of correctly classified observations was 89% for the training data and 90% for the test data. In the spring, Alaska plaice eggs were predicted along inner-shelf off the Alaska Peninsula, including Shelikof Strait and Shelikof Gully (Figure 93).

During the summer, only 12 Alaska plaice eggs were observed. Most occurred around Kodiak Island, ranging in distribution from Shelikof Strait to the outer shelf break (Figure 94)

Alaska plaice larvae were observed during the spring and the summer. During the spring, Alaska plaice larvae occurred along much of the inner-shelf along the Alaska Peninsula. The best-fitting *MaxEnt* model indicated that surface temperature and current direction (relative importance 28.5 and 16.9 respectively) were the most important variables predicting habitat suitability. The AUC for the training data was 0.95, indicating an excellent model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of correctly classified observations was 89% for the training data and 81% for the test data. Juvenile Alaska plaice habit was predicted to occur on the inner-shelf along the Alaska Peninsula, including Shelikof Strait and Shelikof Gully (Figure 95).

During the summer, the best-fitting *MaxEnt* model indicated that surface temperature and depth (relative importance 46.4 and 18.0 respectively) the most important variables predicting habitat suitability. The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the testing data was 0.75, indicating a fair model fit. The percent of correctly classified observations was 93% for the training data and 75% for the test data. Summer juvenile Alaska plaice habitat was predicted to occur along Shelikof Strait off the Alaska Peninsula, and among the bays and nearshore waters around Kodiak Island (Figure 96).

No observations of early juvenile Alaska plaice were located in the EcoFOCI database.

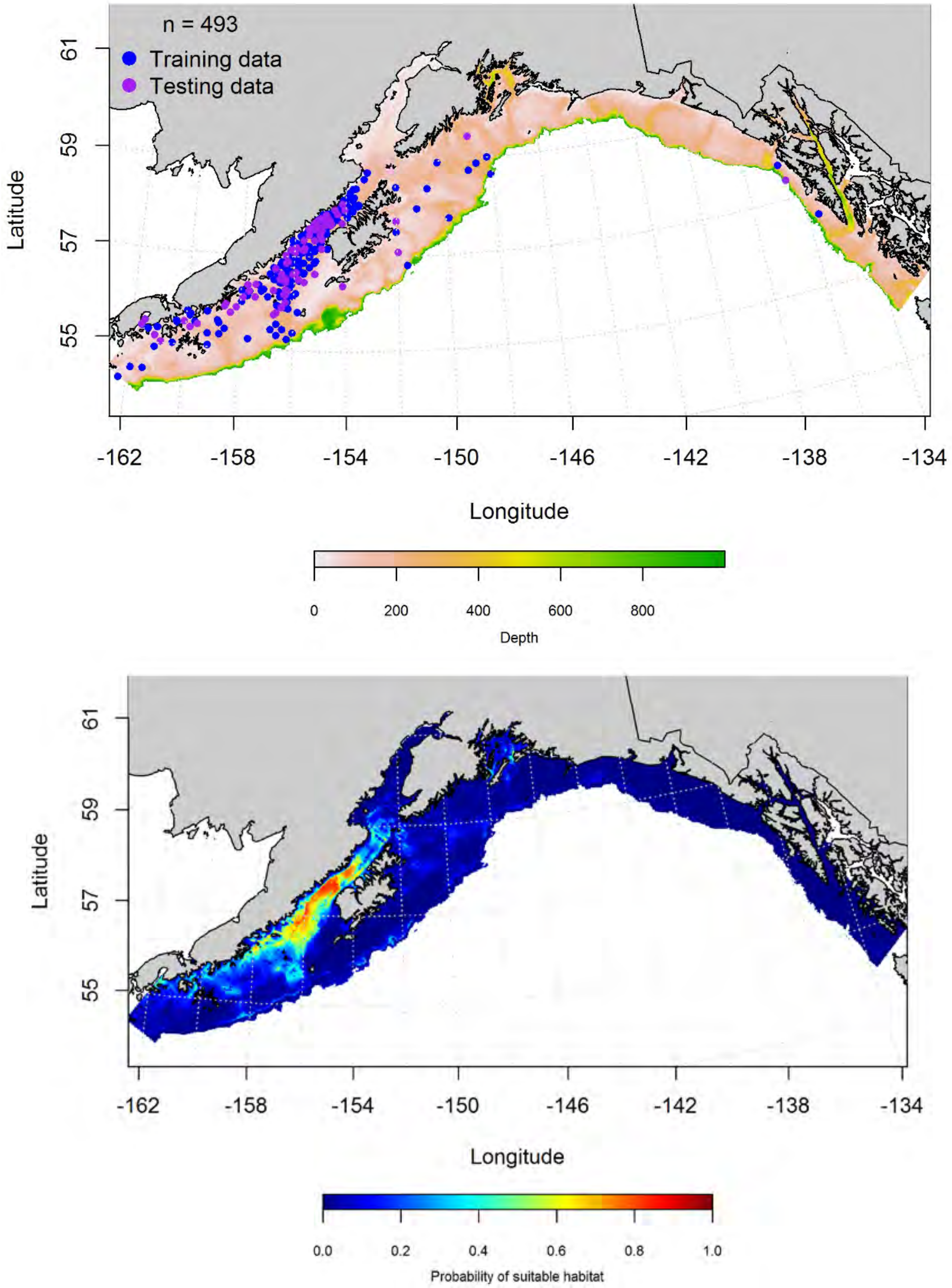


Figure 93. -- Predicted probability of spring observations (top and bottom panel, respectively) distribution of *P. quadrituberculatus* eggs from maximum entropy modeling of the Gulf of Alaska

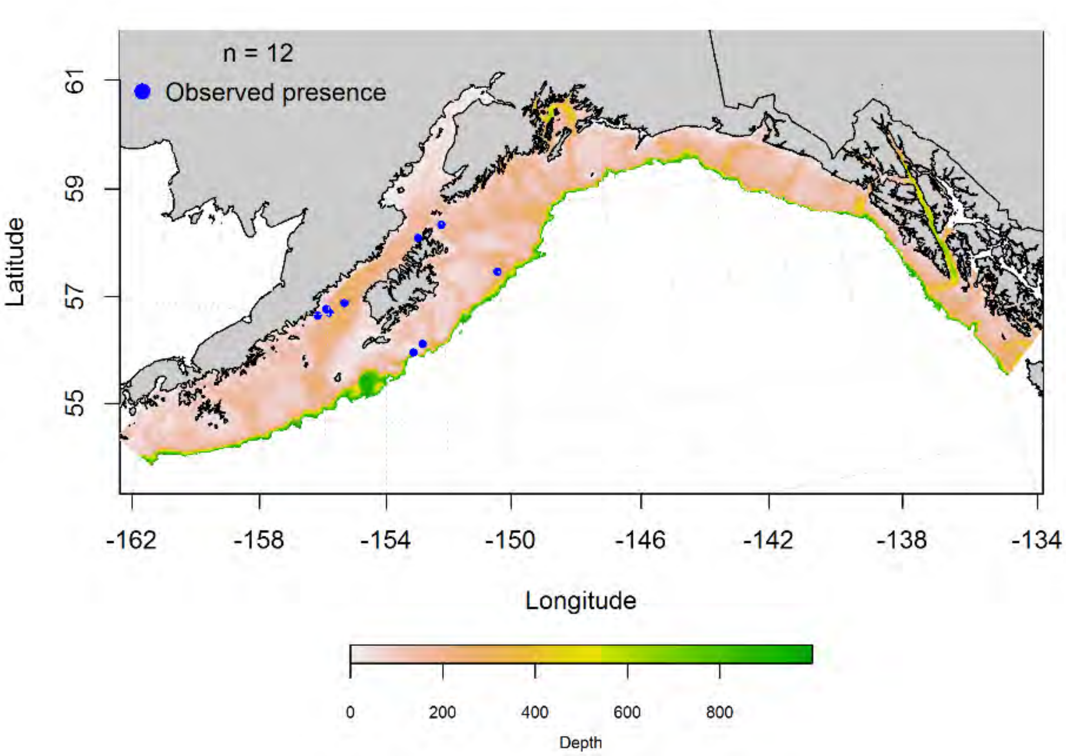
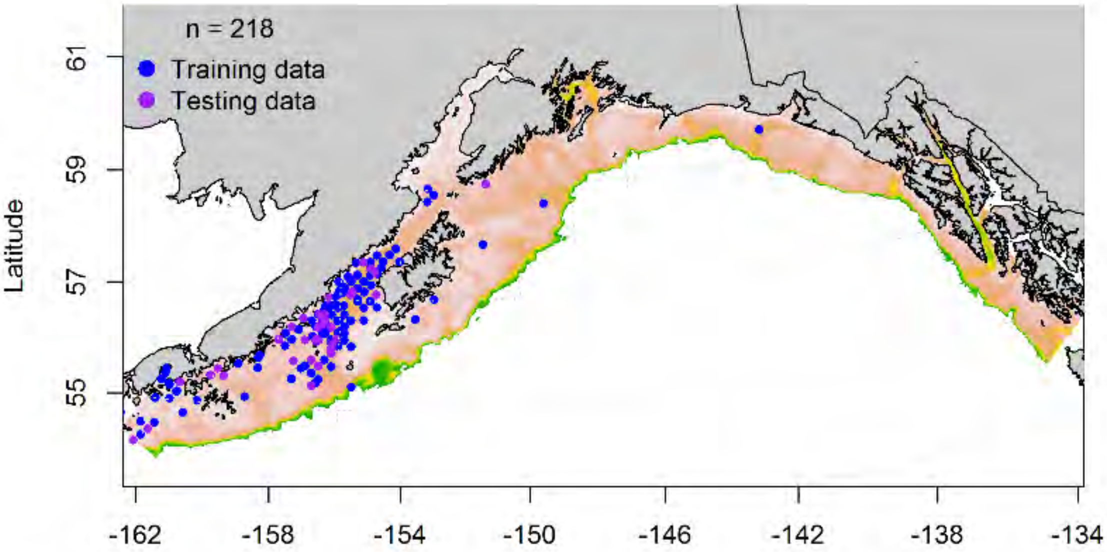


Figure 94. -- Summer (top and bottom panel, respectively) observations of *P. quadrituberculatus* eggs from the Gulf of Alaska.



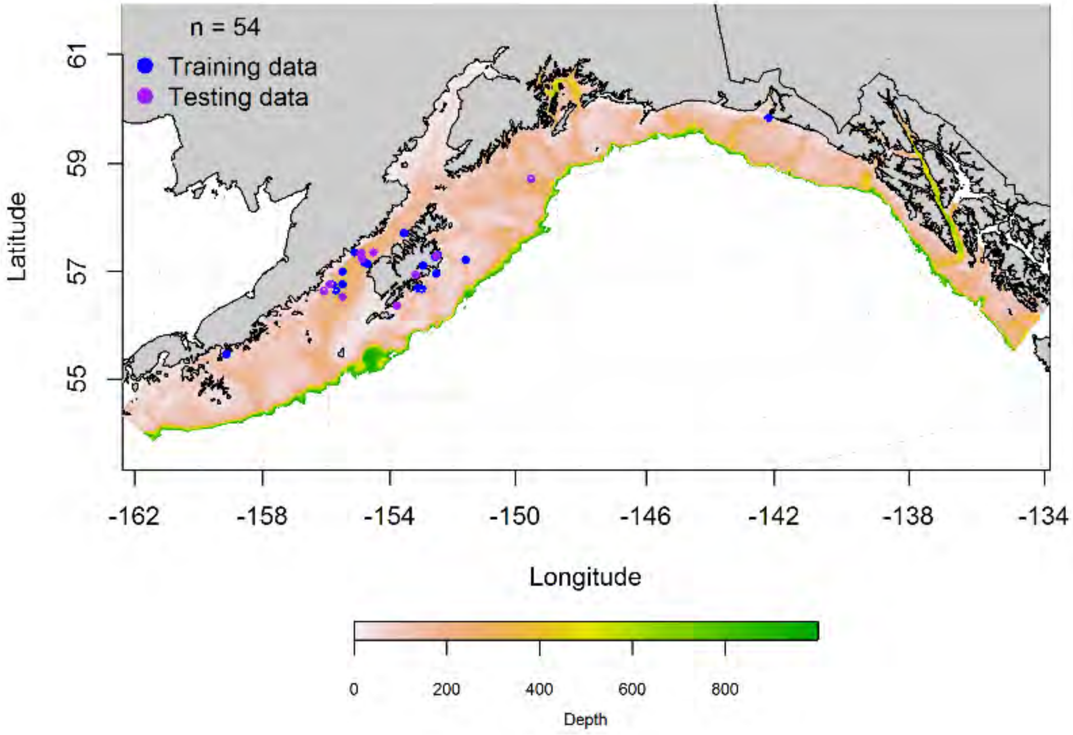
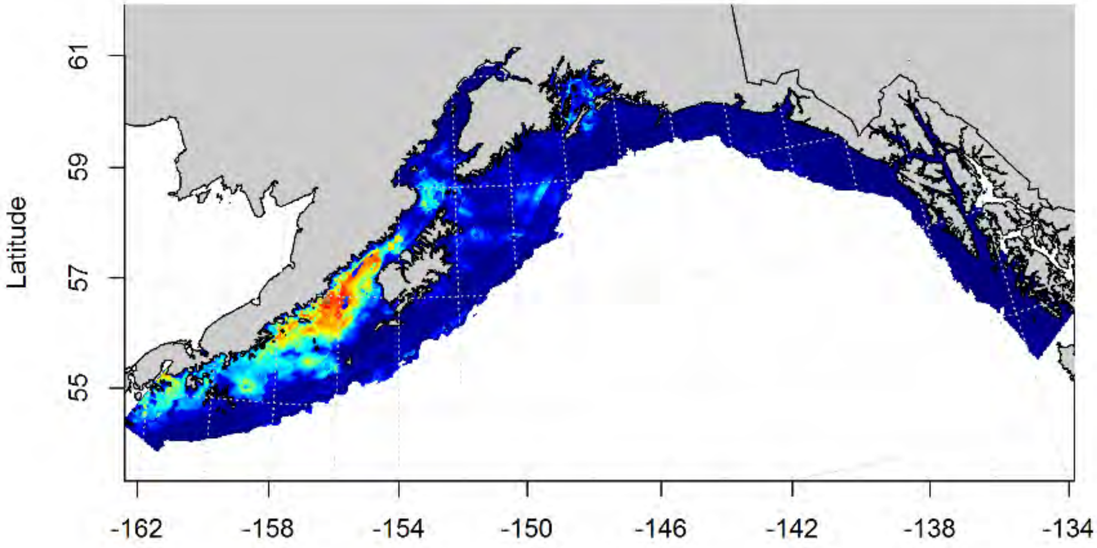


Figure 95. -- Spring and summer observations (top and bottom panel, respectively) of larval *P. quadrituberculatus* from the Gulf of Alaska.



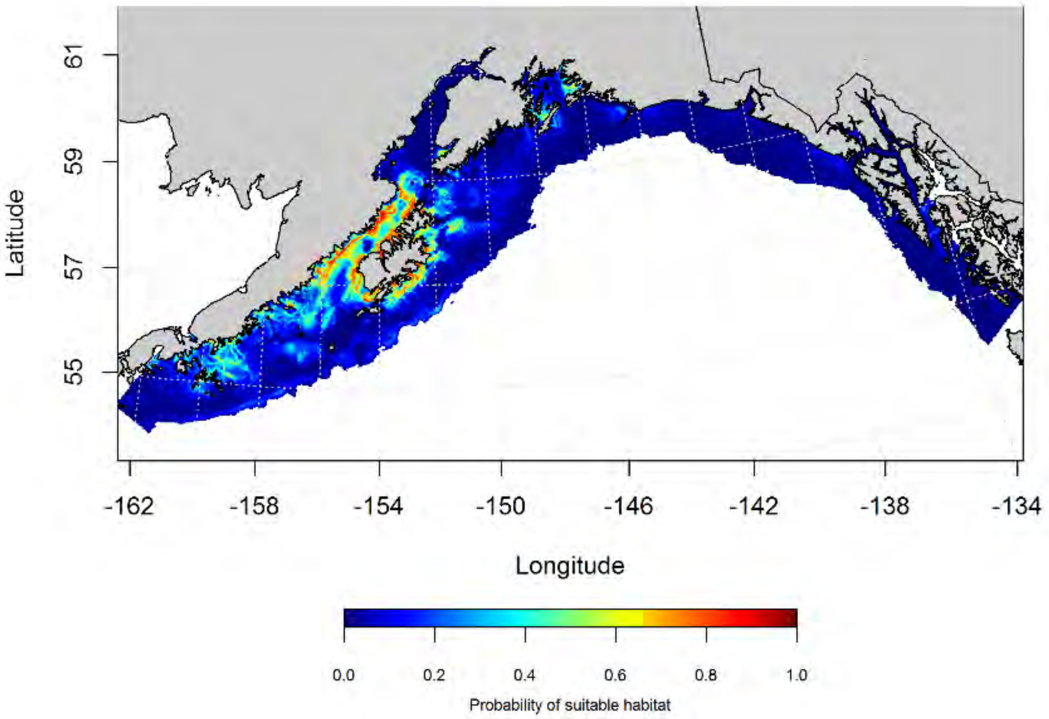


Figure 96. -- Predicted probability of spring and summer observations (top and bottom panel, respectively) distribution of larval *P. quadrituberculatus* from maximum entropy modeling of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *P. quadrituberculatus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile Alaska plaice largely occur on the inner-shelf in the western Gulf of Alaska. No juvenile Alaska place were observed during the summer bottom trawl survey; however, a number of adults were observed (Figure 97).

The variables determined to be the best predictors of the occurrence of adult Alaska plaice were latitude and longitude, tidal currents, and ocean color. The AUC for the training was 0.96, indicating an excellent model fit; while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was only 0.07. The percent of observations correctly classified was 89% for the training data set, and 77% for the test data set. The most important variables predicting the abundance of adult Alaska plaice were latitude and latitude and depth. The best-fitting GAM explained 16% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult Alaska plaice were predicted to occur in nearshore waters along the Alaska Peninsula and in Cook Inlet. Predicted areas of high abundance occurred on the Sandman Reefs and Shumagin Islands (Figure 98). High suitability habitats were also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

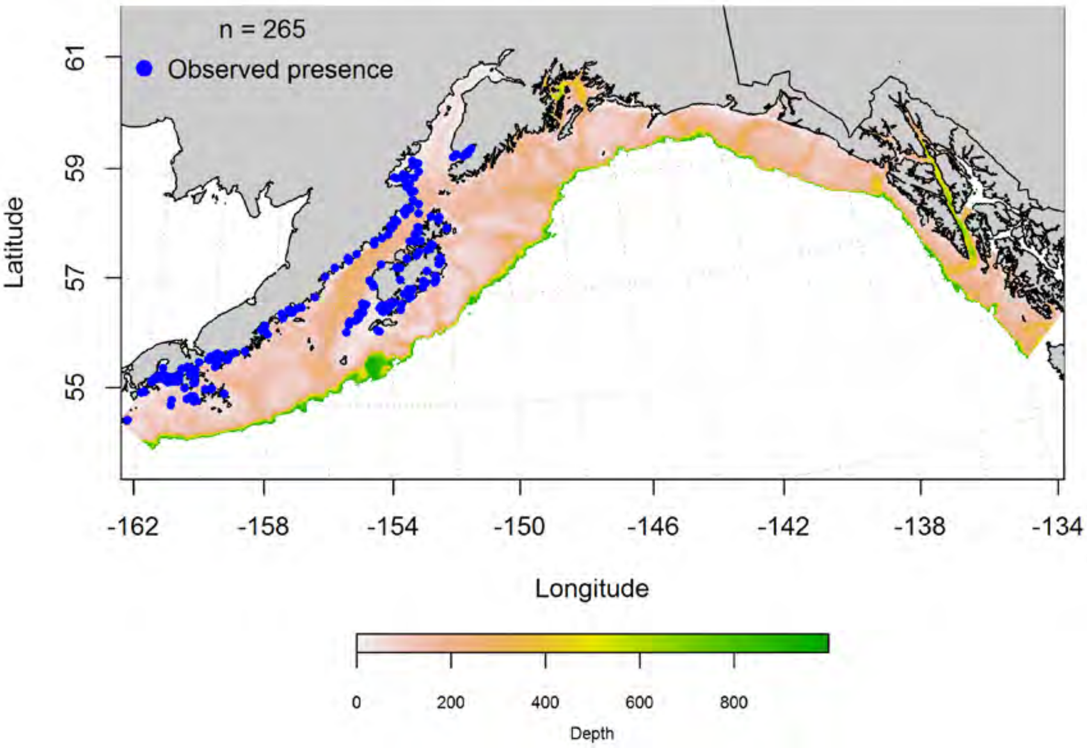


Figure 97. -- Locations of catches adult *P. quadrituberculatus* from summer bottom trawl surveys of the Gulf of Alaska.

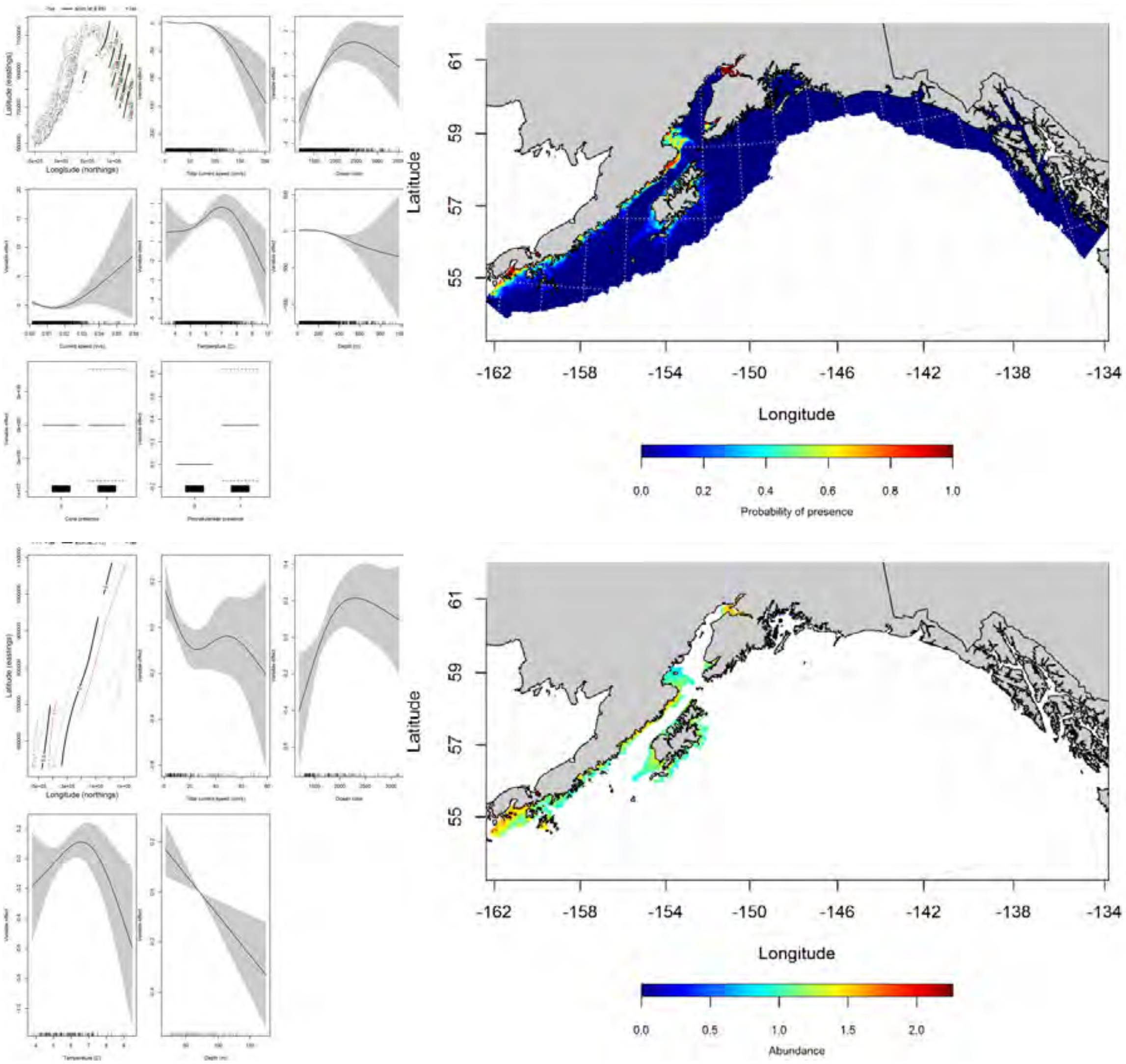


Figure 98. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *P. quadrituberculatus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *P. quadrituberculatus* in the Gulf of Alaska -- There were no observations of adult Alaska plaice from commercial fisheries data.

Gulf of Alaska *P. quadrituberculatus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Alaska plaice predicted was predicted to largely occur on the inner-and middle-shelf in the western Gulf of Alaska. EFH for Alaska plaice eggs, during the spring was predicted to include the inner and middle-shelf along the Alaska Peninsula, including Shelikof Strait (Figure 99). EFH for larval Alaska plaice, during the spring was predicted to include the inner and middle-shelf west of Kodiak Island, along the Alaska Peninsula.

During the summer, EFH for larval Alaska plaice was predicted to occur along the inner-shelf and bays on Kodiak Island and the Alaska Peninsula (Figure 100). EFH for early juvenile Alaska plaice could not be predicted.

Summer EFH for juvenile Alaska place could not be predicted. Summer EFH for adult Alaska place, based on prediction from trawl survey observations, was largely restricted to nearshore waters and bays along the Alaska Peninsula and Kodiak Island (Figure 101). EFH was also was also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

EFH for Alaska place, based on commercial fisheries data, could not be predicted.

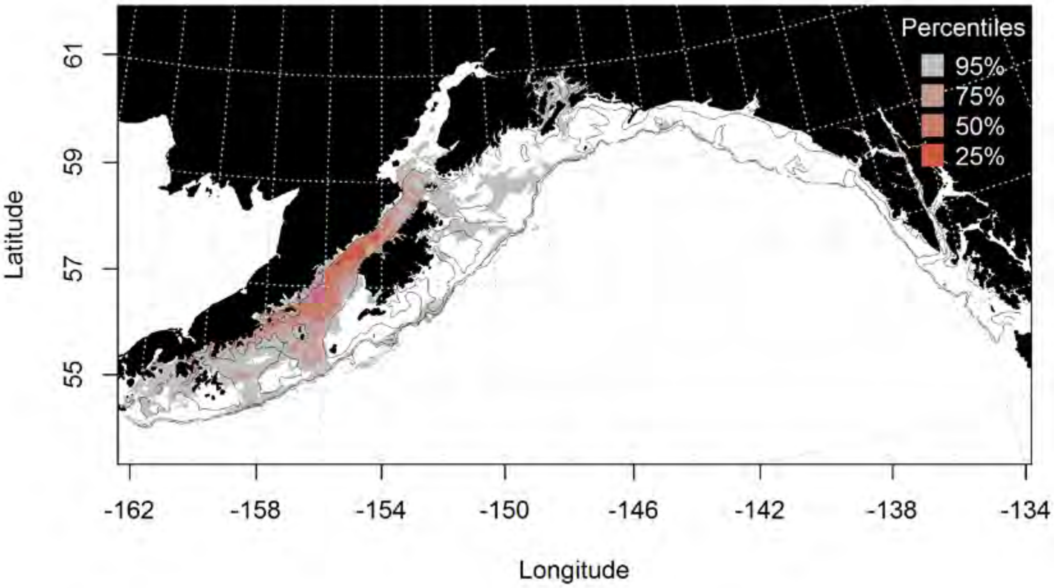


Figure 99. -- Spring essential fish habitat predicted for *P. quadrituberculatus* eggs from the EcoFOCI database.

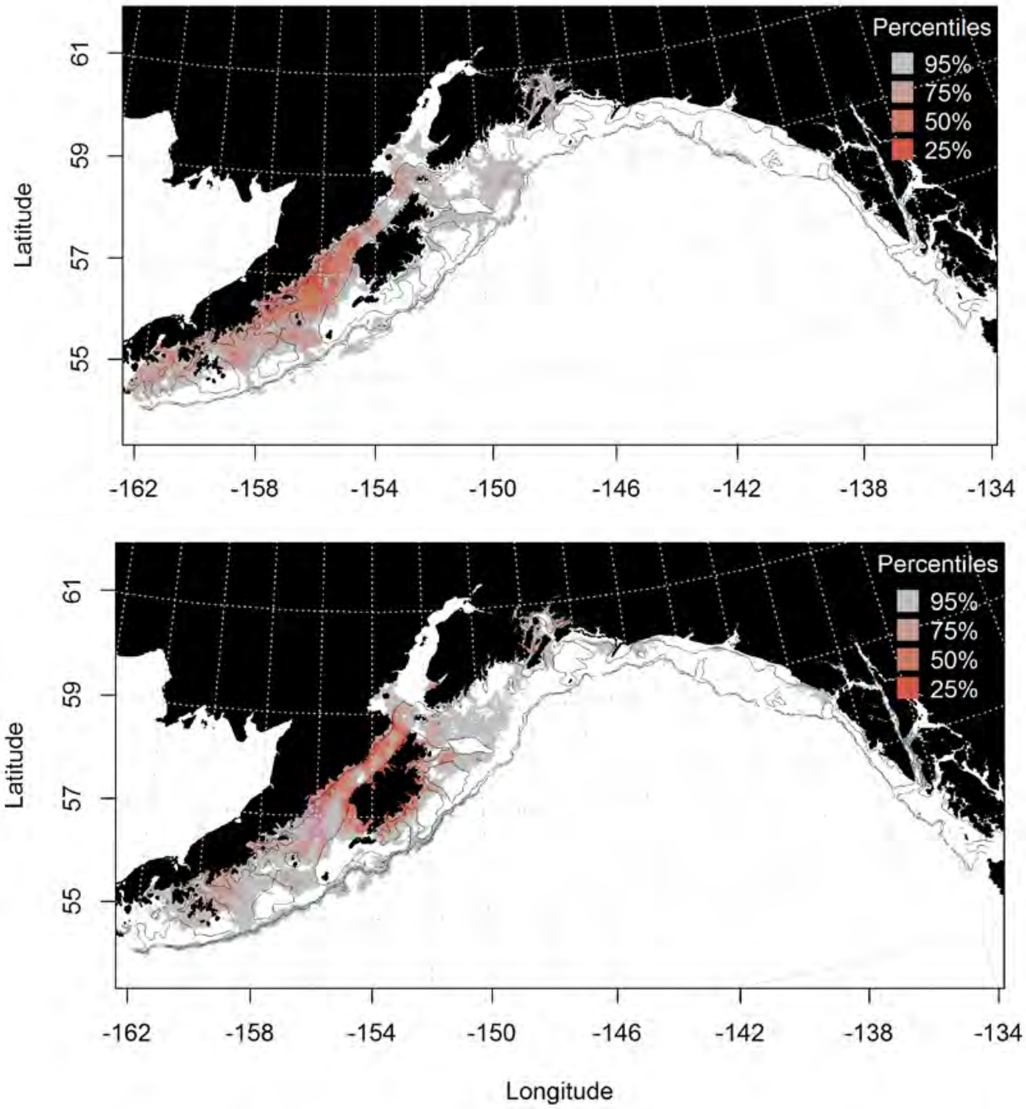


Figure 100. -- Spring, and summer essential fish habitat predicted for larval *P. quadrituberculatus* (top and bottom panel, respectively) from the EcoFOCI database.

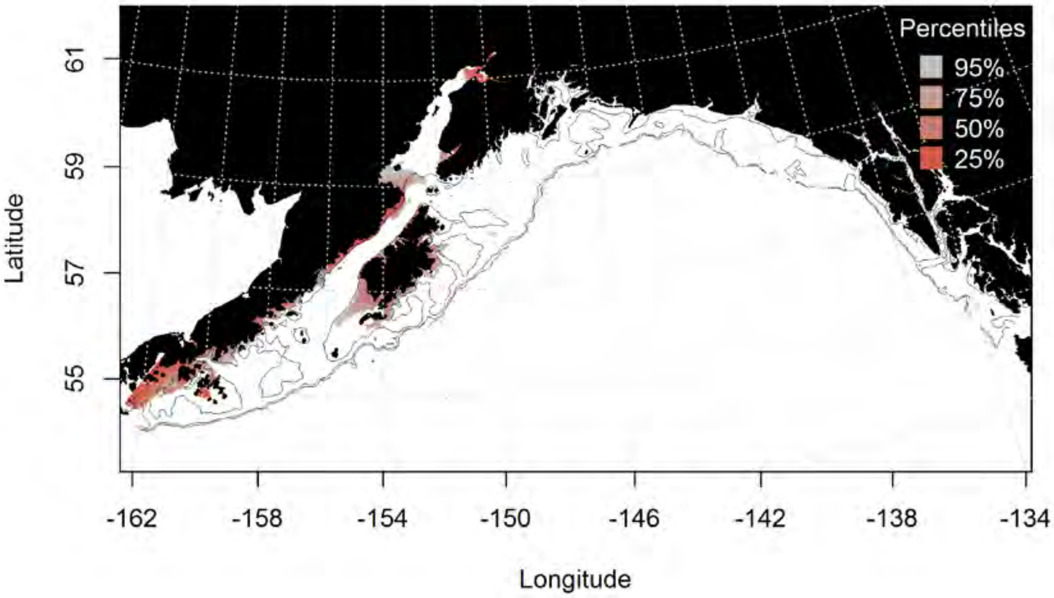


Figure 101. -- Predicted summer essential fish habitat for adult *P. quadrituberculatus* from summer bottom trawl surveys.

Greenland turbot (*Reinhardtius hippoglossoides*)

Greenland turbot occur thought much of the Gulf of Alaska, and are typically found in soft bottom habitats at depth between 50-650 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *R. hippoglossoides* in the Gulf of Alaska -- Throughout much of their early life history Greenland turbot are largely occur in the western Gulf of Alaska.

Greenland turbot eggs were observed in the GOA during the fall, winter, spring, and summer. In the fall, there were only a single observation of Greenland turbot egg that occurred in nearshore waters off Kodiak Island (Figure 102). In the winter, there was also only a single observation of a Greenland turbot egg that occurred in in the vicinity of Sand Point. During the spring, Greenland turbot eggs were much more abundant.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables predicting habitat suitable (relative importance 29.0 and 22.3 respectively). The AUC was 0.89 for the training data, indicating a good model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of the observations correctly classified in both the training and testing data was 81%. During the spring, Greenland turbot larval habitat was predicted to include much of the inner- and middle-shelf in the western GOA, with the highest suitability habitats occurring along Shelikof Strait and Shelikof Gully as well as the Alaska Peninsula (Figure 103). During the summer, Greenland turbot eggs were also abundant. The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables predicting habitat suitable (relative importance 50.4 and 18.3 respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.82, indicating a good model fit. The percent of the observations correctly classified in the training data was 87% and 82% for the test data. During the summer, Greenland turbot egg habitat was predicted to include much of the inner- and middle-shelf around Kodiak Island, with the highest suitability habitats occurring along Shelikof Strait and Marmot Gully and inshore waters to the east of the island.

Larval Greenland turbot were observed during the spring and the summer (Figure 104). Larval Greenland turbot were very abundant during the spring.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables predicting habitat suitable (relative importance 26.7 and 18.2 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.80, indicating the good model fit. The percent of the observations correctly classified in the training data was 82% and 80% for the test data. During the spring, Greenland turbot larval habitat was predicted to include much of the inner- and middle-shelf in the western GOA, with the highest suitability habitats occurring along Shelikof Gully and the Alaska Peninsula (Figure 105). During the summer, larval Greenland turbot were also abundant across much of the inner- and middle-shelf in the western GOA. The most important variable predicting larval habitat suitability were surface temperature and depth (62.2 and 17.2, respectively). The AUC was 0.88 for the training data, indicating a good model fit. The AUC for the testing data was 0.77, indicating the fair model fit. The percent of the observations correctly classified in the training data was 80% and 77% for the test data. Greenland turbot larval habitat during the summer was more extensive than what was predicted for the spring. It included much of the inner- and middle-shelf in the western gulf, particularly Shelikof Strait and Shelikof Gully to the west and Marmot Gully and nearshore waters off Kodiak Island to the east.

Early juvenile Greenland turbot were observed only during the summer. Nine individuals were observed, they all occurred along the inner- and middle-shelf in the western gulf (Figure 106).

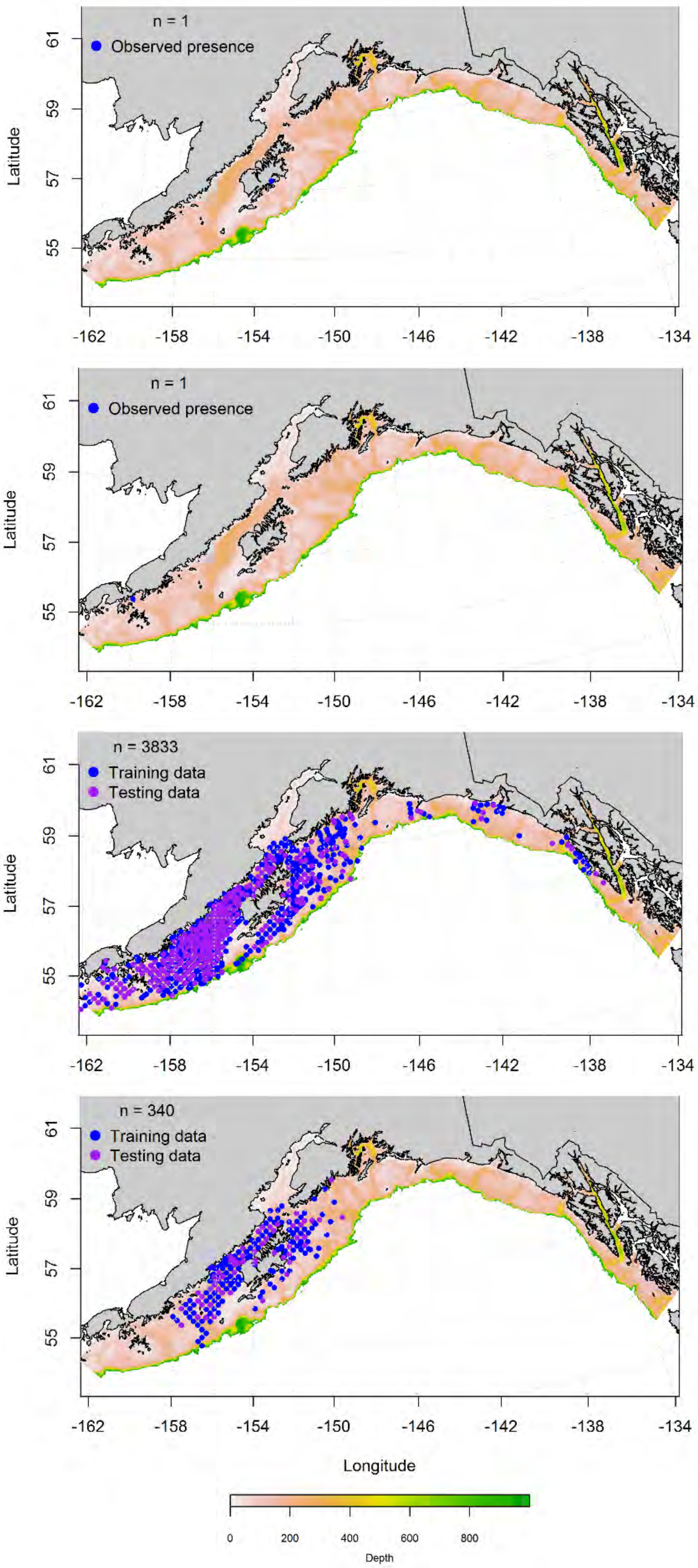


Figure 102. -- Fall, winter, spring, and summer (top, second, third, and bottom panel, respectively) observations of *R. hippoglossoides* eggs from the Gulf of Alaska.

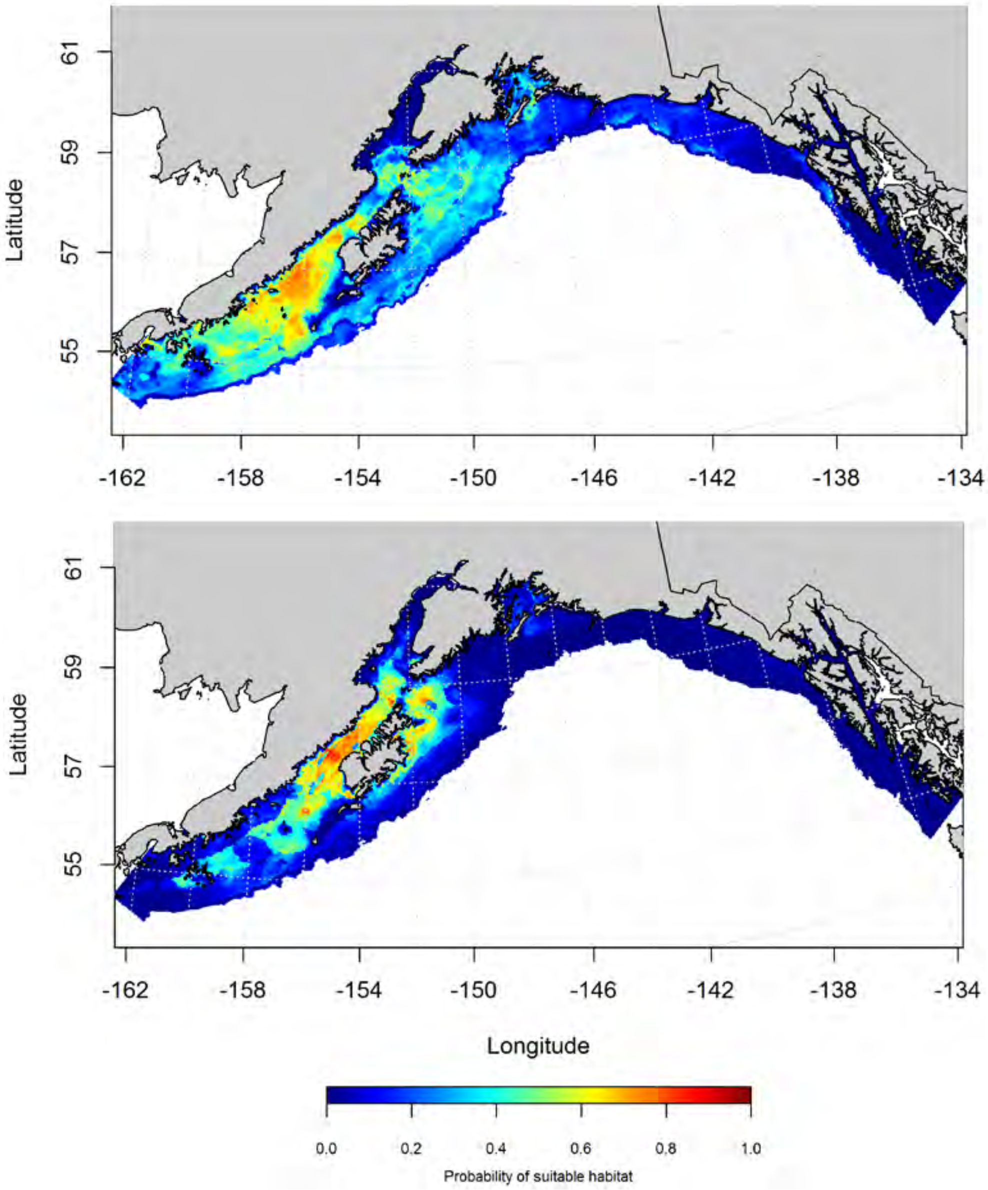


Figure 103. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of *R. hippoglossoides* eggs from maximum entropy modeling of the Gulf of Alaska.

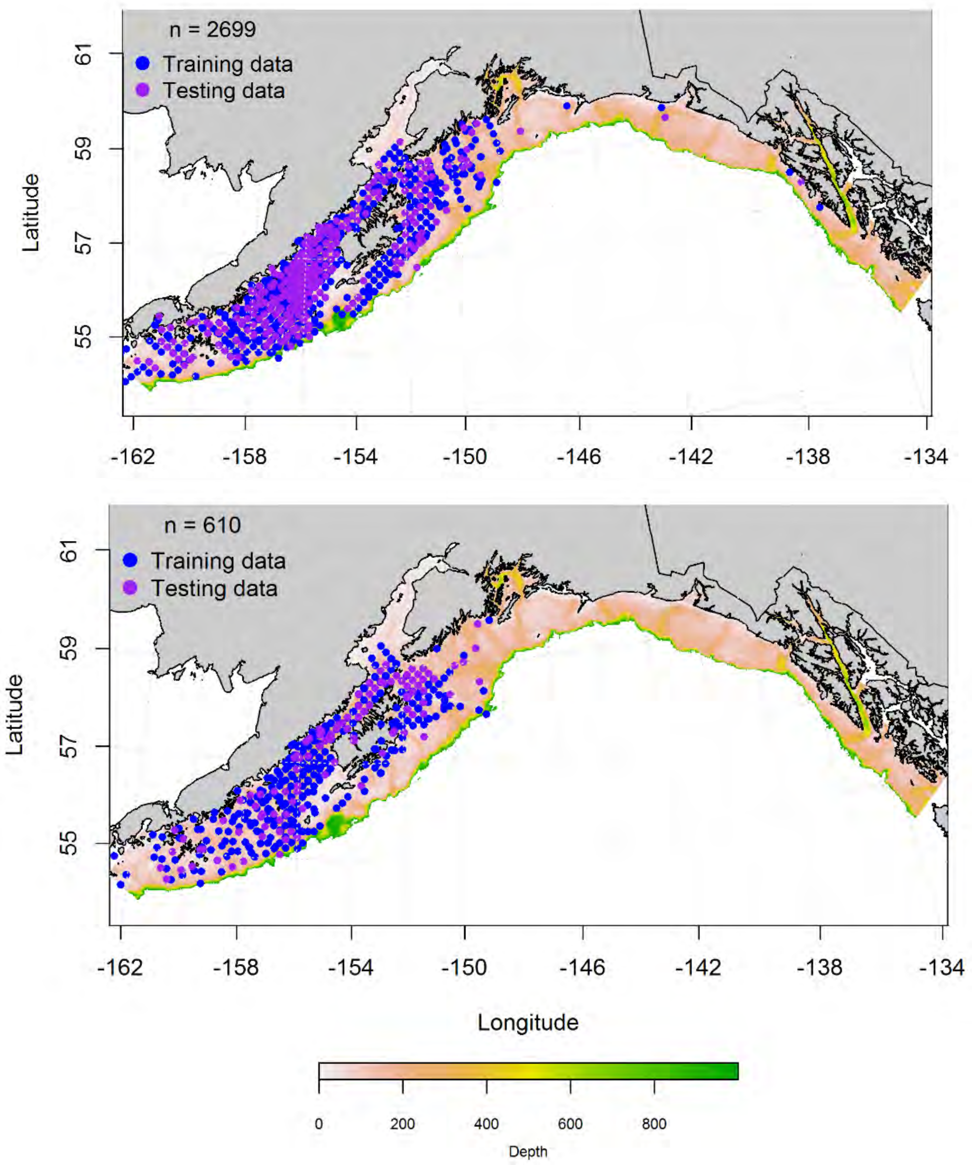


Figure 104. -- Spring and summer observations (top and bottom panel, respectively) of larval *R. hippoglossoides* from the Gulf of Alaska.

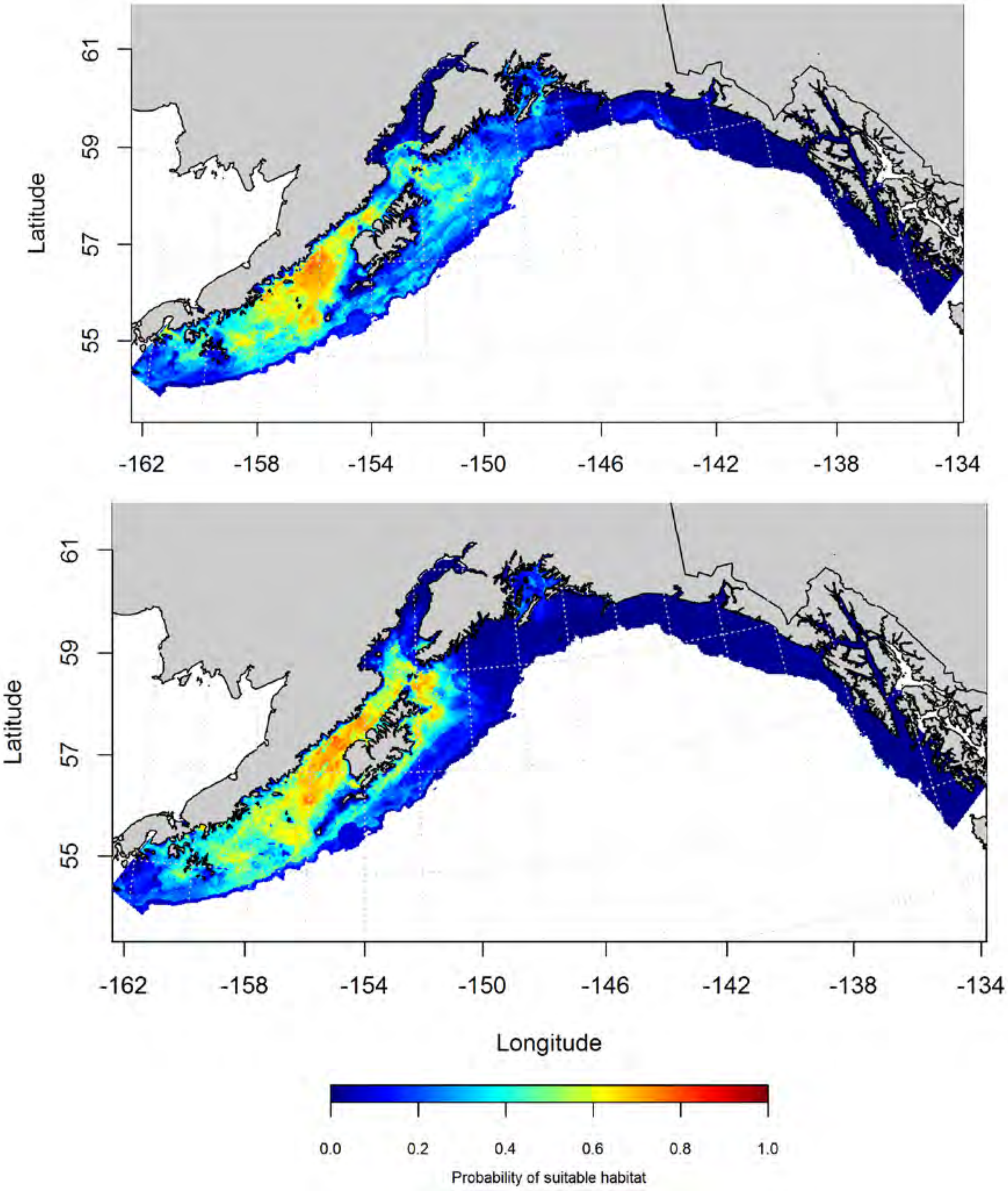


Figure 105. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *R. hippoglossoides* from maximum entropy modeling of the Gulf of Alaska.

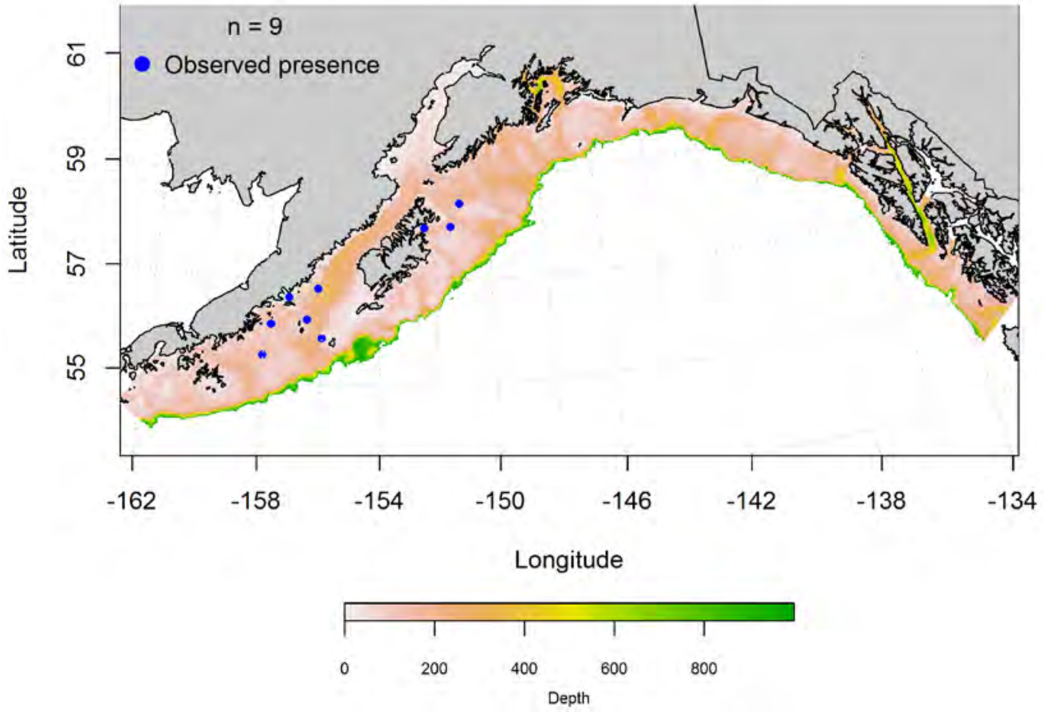


Figure 106. -- Summer catches of early juvenile *R. hippoglossoides* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *R. hippoglossoides* from bottom trawl surveys of the Gulf of Alaska -- No observations of juvenile or adult Greenland turbot occurred during NOAA summer trawl surveys in the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *R. hippoglossoides* in the Gulf of Alaska -- Commercial catch data indicate Greenland turbot largely occur along the shelf break in the Gulf of Alaska. Most observations occurred during the spring (Figure 107). The best fitting *MaxEnt* model indicated that depth and tidal current were the most important variables predicting the distribution of Greenland turbot (relative importance = 38.1 and 29.9 respectively). The AUC for the training data 0.94, indicating an excellent model fit. The AUC for the test data was 0.80, indicating a good model fit. The percent of observations correctly classified for the training data was 90%, and it was 80% for the test data. In the spring, high suitability habitats were predicted to occur along the shelf break, across much of the Gulf of Alaska. Habitat suitability was predicted to particularly high between Cape St. Elias and Pamplona Spur, in the central GOA.

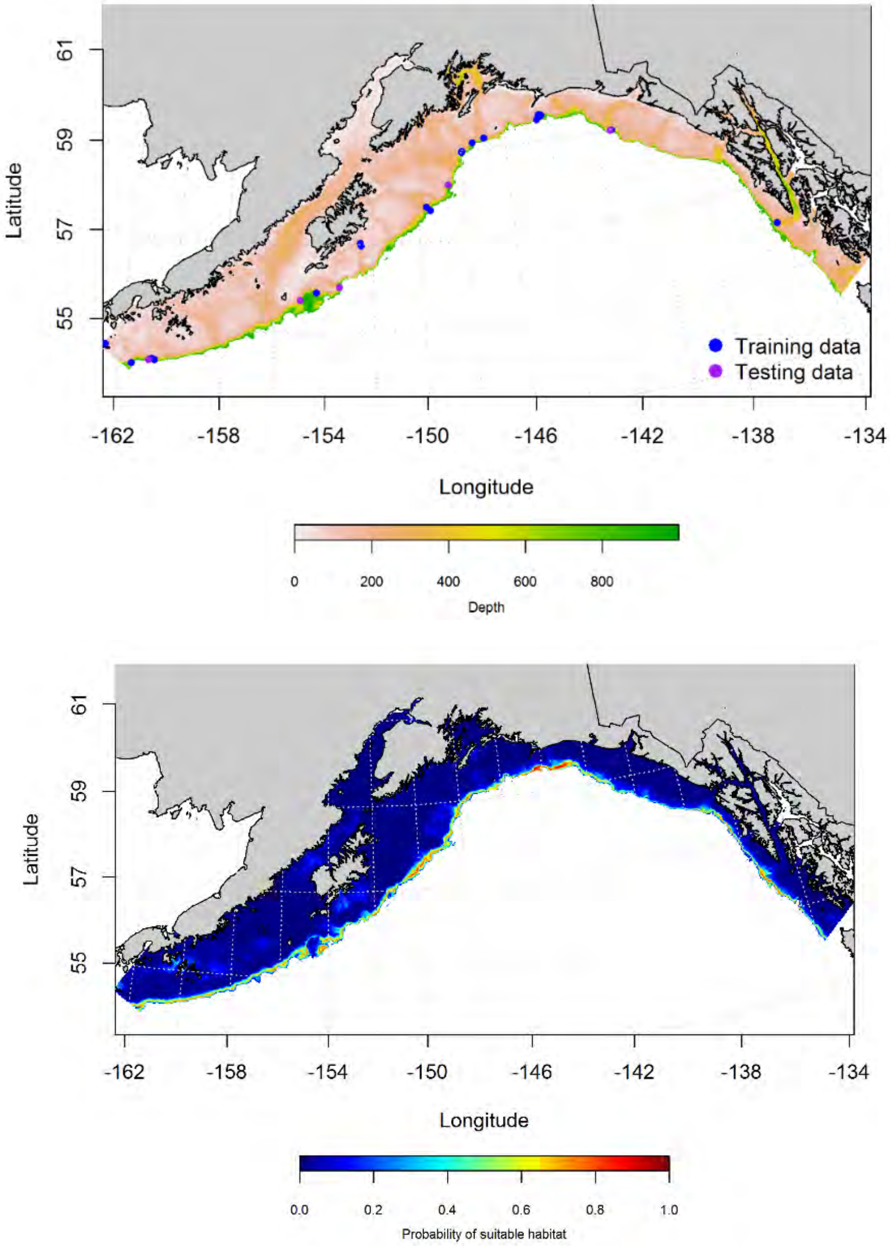


Figure 107. -- Locations of spring (March-May) commercial fisheries catches of *R. hippoglossoides* (top panel). Blue points were used to train the maximum entropy model

predicting the probability of the spring distribution of *R. hippoglossoides* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *R. hippoglossoides* Essential Fish Habitat Maps and Conclusions -- Greenland turbot essential fish habitat predicted by modeling is extensively distributed across much of the inner- and middle-shelf shelf in the western Gulf of Alaska. During the spring, EFH for Greenland turbot eggs was predicted to occur over much of the inner- and middle-shelf shelf in the western Gulf of Alaska (Figure 108). In the summer, EFH for Greenland turbot eggs was more restricted, and centered on the inner- and middle-shelf off Kodiak Island. High probability habits were predicted to occur in Shelikof Strait and Shelikof Gully, as well as in Marmot Gully and inshore waters to the east of the island.

During the spring, EFH for larval Greenland turbot was predicted to include much of the shelf in the western gulf, particularly in Shelikof Strait and Shelikof Gully (Figure 109). In the summer, EFH for Greenland turbot eggs was more restricted, and centered on the inner- and middle-shelf off Kodiak Island. High probability habits were predicted to occur in Shelikof Strait and Shelikof Gully, as well as in Marmot Gully and inshore waters to the east of the island.

Summer EFH habitats for juvenile and adult Greenland turbot, based on summer trawl survey data, could not be predicted.

During the spring, EFH of Greenland turbot, based on commercial fisheries data, were predicted to occur along the shelf break across much of the Gulf of Alaska (Figure 110).

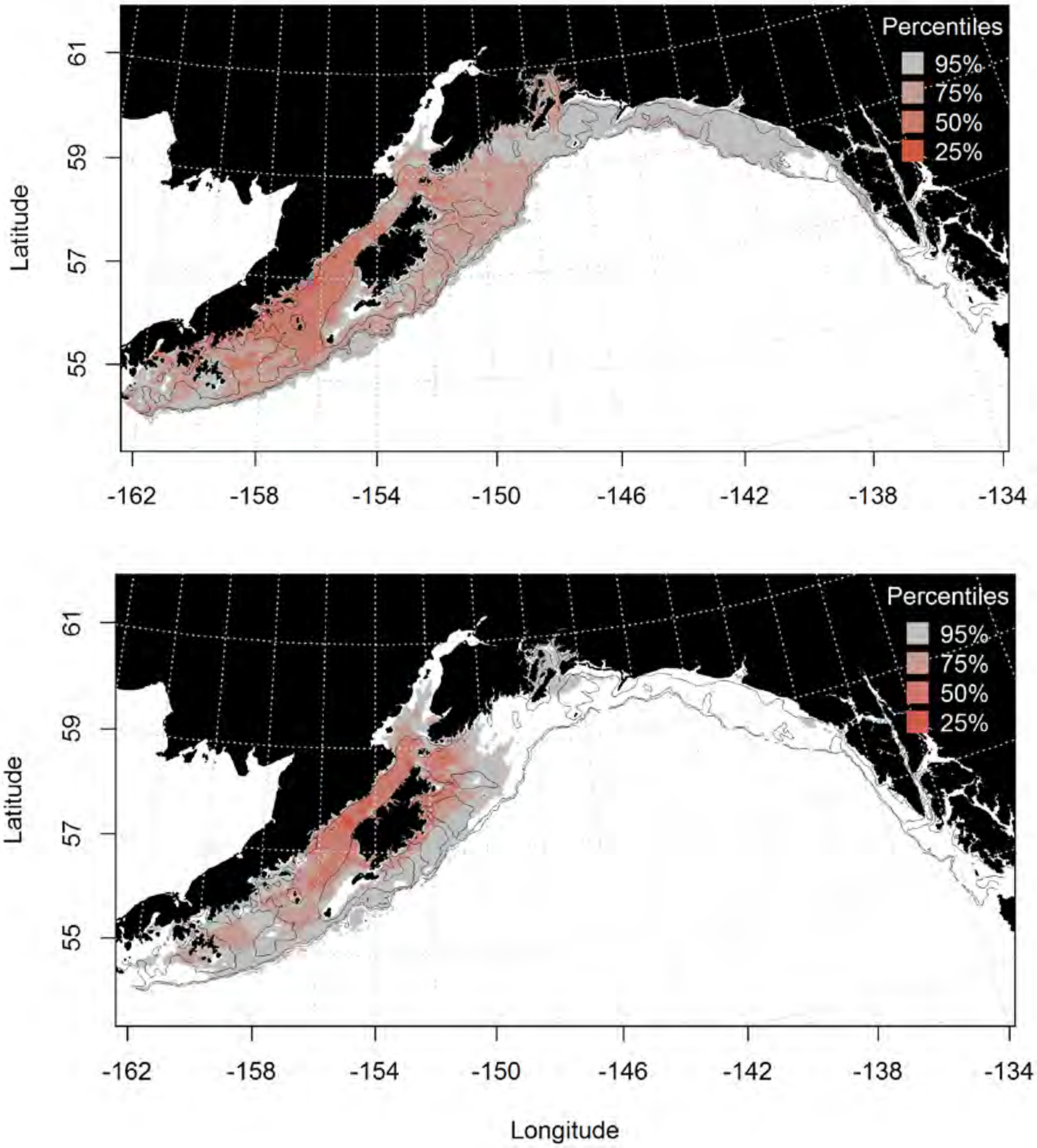


Figure 108. -- Spring, and summer essential fish habitat predicted for *R. hippoglossoides* eggs (top and bottom panel, respectively) from the EcoFOCI database.

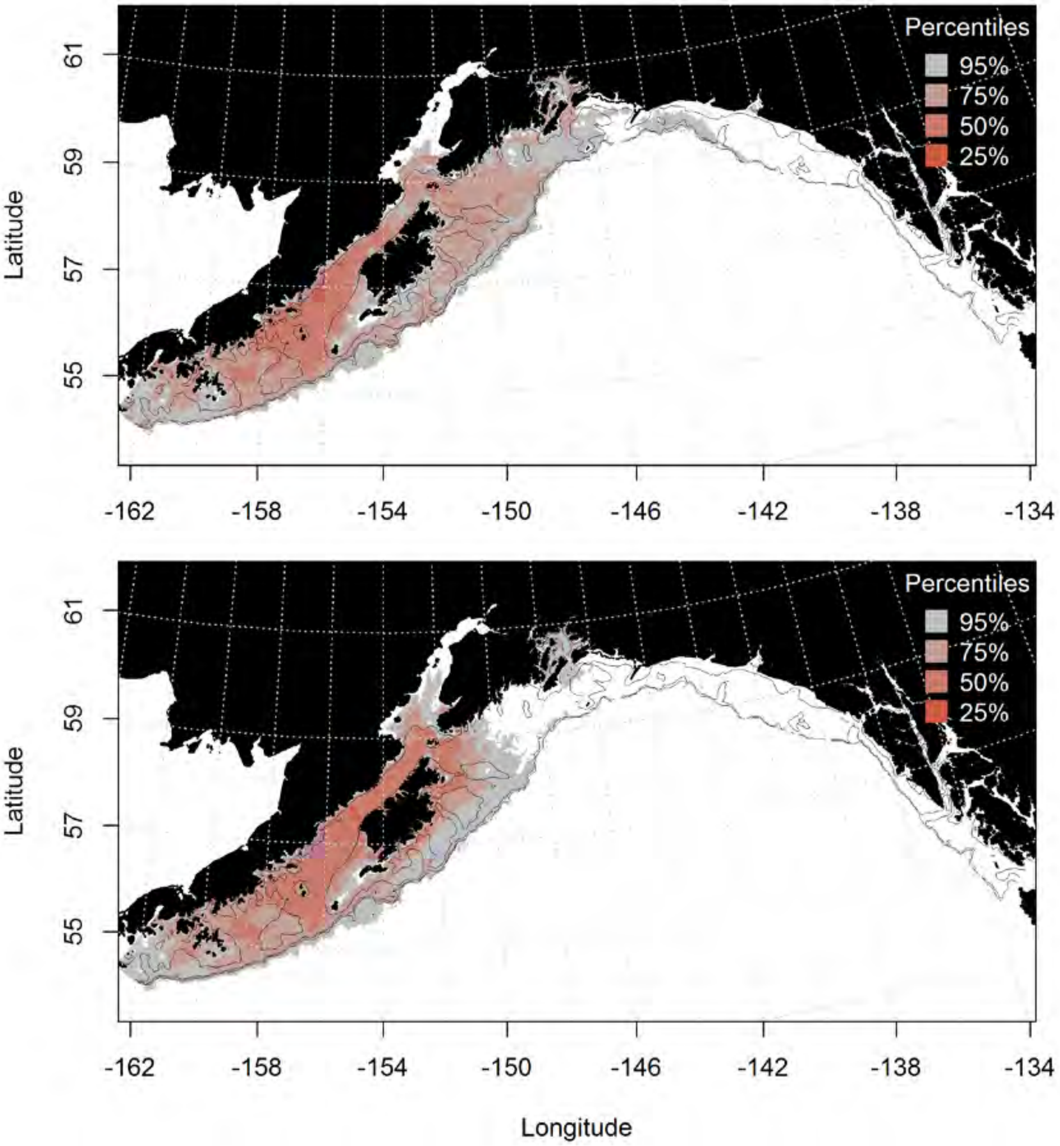


Figure 109. -- Spring, and summer essential fish habitat predicted for larval *R. hippoglossoides* (top and bottom panel, respectively) from the EcoFOCI database.

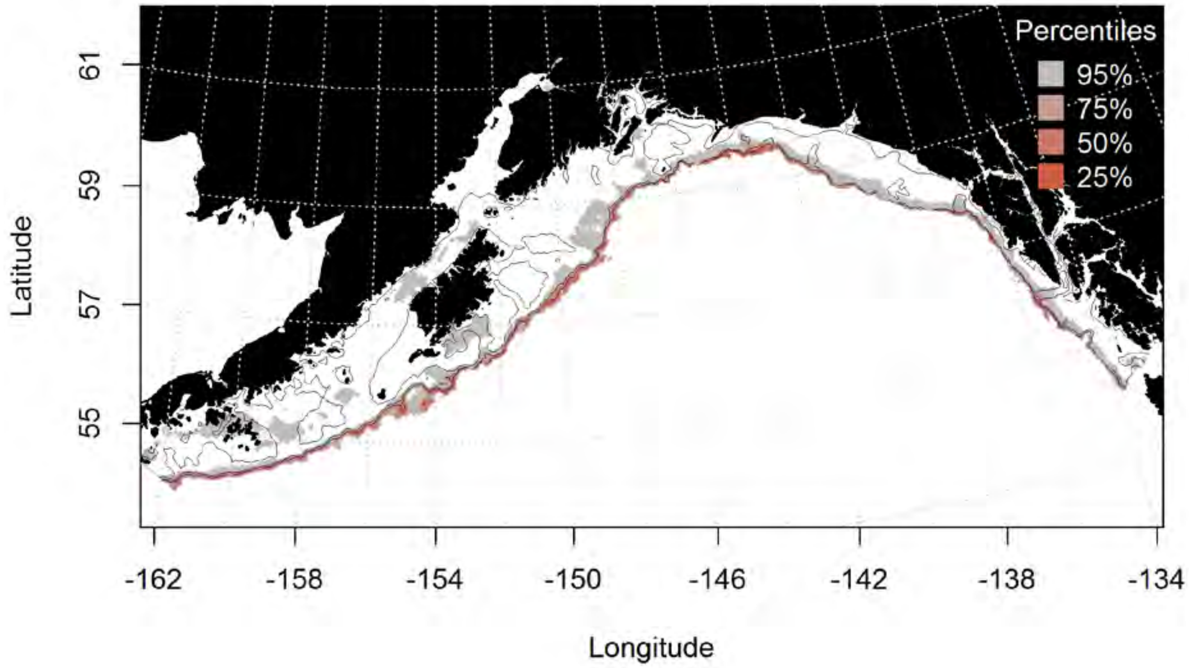


Figure 110. -- Essential fish habitat predicted for *R. hippoglossoides* during spring from commercial catches.

Roundfish

walleye pollock (*Gadus chalcogramma*)

Walleye pollock are one of the most abundant fishes caught in the AFSC bottom trawl surveys, and they are much of the Gulf of Alaska. They are most abundant at depths less than 200 m, but are occur down to 500 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *G. chalcogrammus* in the Gulf of Alaska -- Throughout much of their early life history walleye pollock were predicted to occur in the western Gulf of Alaska. Walleye pollock eggs were observed in the GOA throughout the entire year (Figure 111). In the fall, there were only eight observations of walleye pollock eggs, the majority of which occurred in nearshore waters around Kodiak Island. There, were; however, not enough observations to model the distribution of walleye pollock eggs during the fall. In the winter, there were only three observations of walleye pollock eggs. They occurred in nearshore waters around Kodiak Island and the Alaska Peninsula. There were; however, not enough observations to model the distribution of walleye pollock eggs during the winter. During the spring, walleye pollock eggs were very abundant. Most were observed along the around Kodiak Island and the Alaska Peninsula; however, a large numbers were also observed off southeast Alaska and in the vicinity of Yakutat Valley.

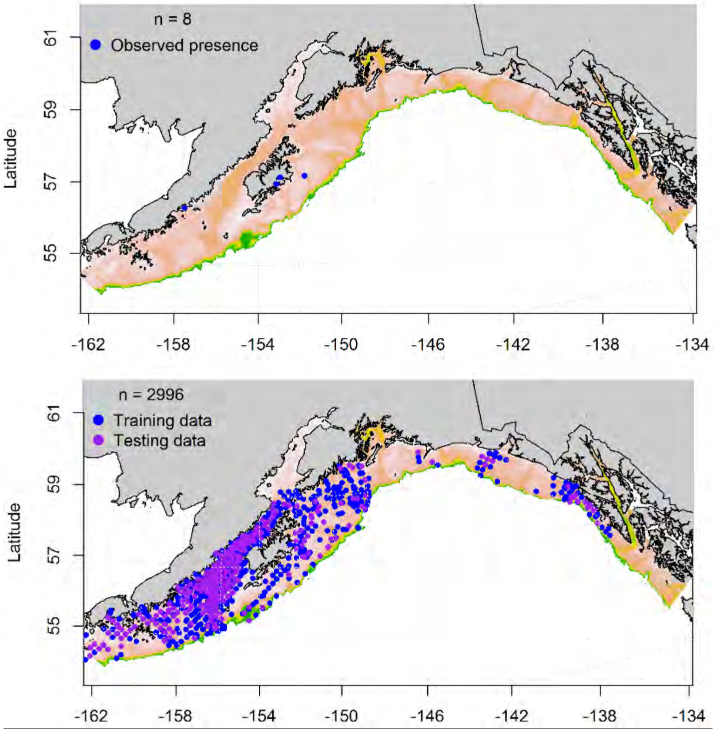
The best-fitting *MaxEnt* model indicated that surface temperature and depth (relative importance 36.2 and 29.0 respectively) were the most important variables predicting the distribution of walleye pollock eggs. The AUC for the training data was 0.91, indicating an excellent model fit. The AUC for the testing data was 0.82, indicating a poor model fit. The percent of the observations correctly classified in both the training and testing data was 82%. Walleye pollock eggs were predicted to be occur around Kodiak Island, particularly in Shelikof Strait and Shelikof Gully (Figure 112). During the summer walleye pollock eggs were also abundant around Kodiak Island. The best-fitting *MaxEnt* model indicated that surface temperature and ocean color (relative importance 44.6 and 16.4 respectively) were the most important variables predicting habitat suitable. The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of the observations correctly classified in the training data was 93% and 81% for the test data. Walleye pollock eggs were predicted to occur in Shelikof Strait and in several bays on the east side of Kodiak Island.

Larval walleye pollock were observed during the winter, spring, and the summer (Figure 113). A single walleye pollock larva was observed in the winter, in the vicinity of Sand Point. Larval walleye pollock were much more abundant during the spring.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables predicting habitat suitable (relative importance 35.6 and 24.3 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.84, indicating the good model fit. The percent of the observations correctly classified in the training data was 83% and 84% for the test data. During the spring, walleye pollock larval habitat was predicted to include much of the western GOA, with the highest suitability habitats occurring along Shelikof Strait and Shelikof Gully (Figure 114). During the summer, larval walleye pollock were also abundant across much of the western GOA. The most important variable predicting larval habitat suitability were surface temperature and depth (50.5 and 20.3, respectively). The AUC was 0.89 for the training data, indicating a good model fit. The AUC for the testing data was 0.78, indicating the fair model fit. The percent of the observations correctly classified in the training data was 80% and 78% for the test data. During the summer, walleye pollock larval habitat was predicted to include much of the western GOA, from Semidi Bank west along the Alaska Peninsula to the Sandman reefs.

Early juvenile walleye pollock were observed during the spring and the summer (Figure 115). During the summer, early juvenile walleye pollock were much more abundant.

The most important variable predicting early juvenile habitat suitability were surface temperature and ocean color (53.3 and 30.8, respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.82, indicating the good model fit. The percent of the observations correctly classified in the training data was 87% and 82% for the test data. During the summer, walleye pollock larval habitat was predicted to include much of the shelf west of the Semidi Islands to the Sandman Reefs (Figure 116).



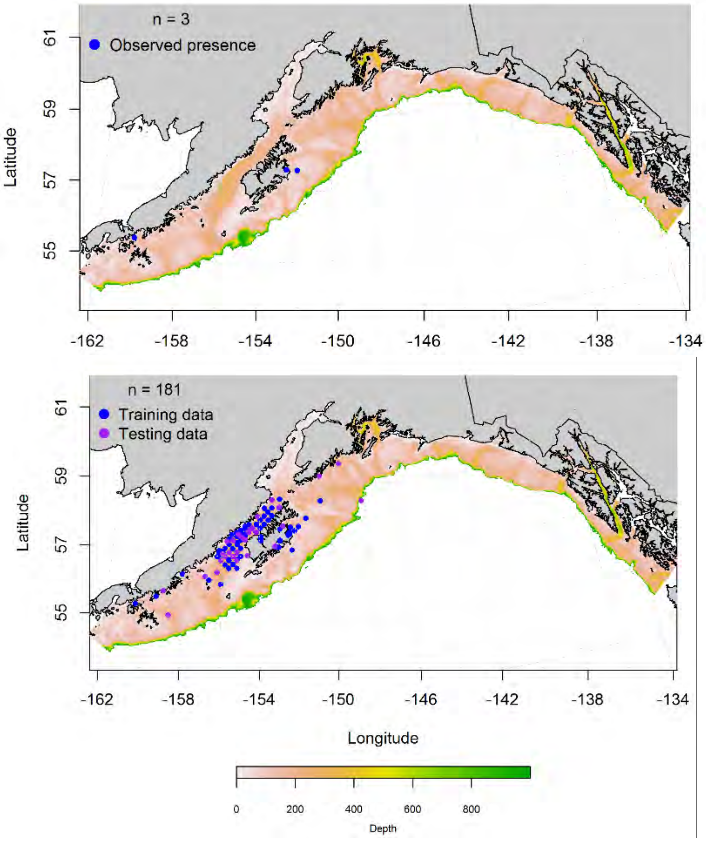


Figure 111. -- Fall, winter, spring and summer (top, second, third, and bottom panel, respectively) observations of *G. chalcogrammus* eggs from the Gulf of Alaska.

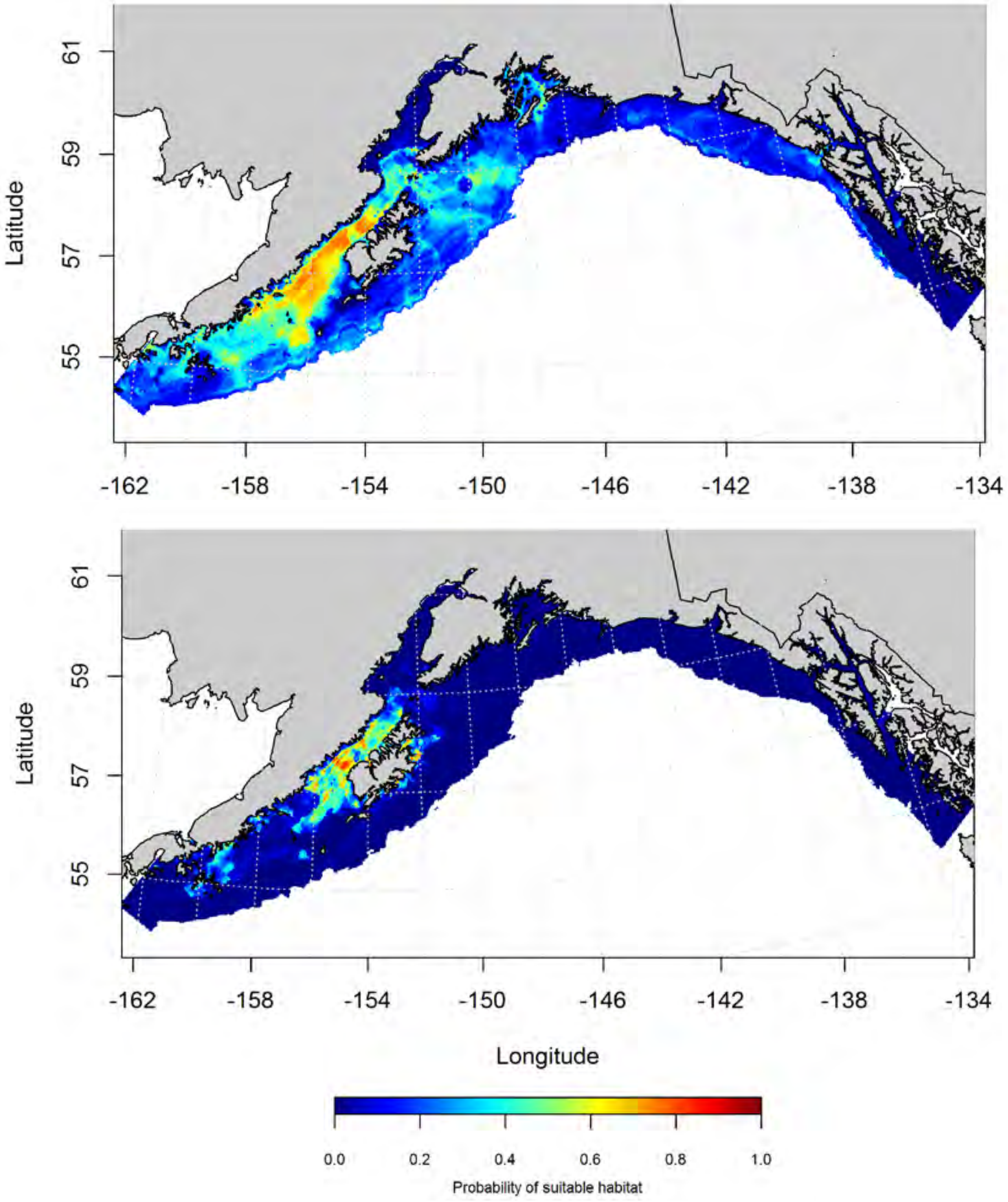


Figure 112. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of *G. chalcogrammus eggs* from maximum entropy modeling of the Gulf of Alaska.

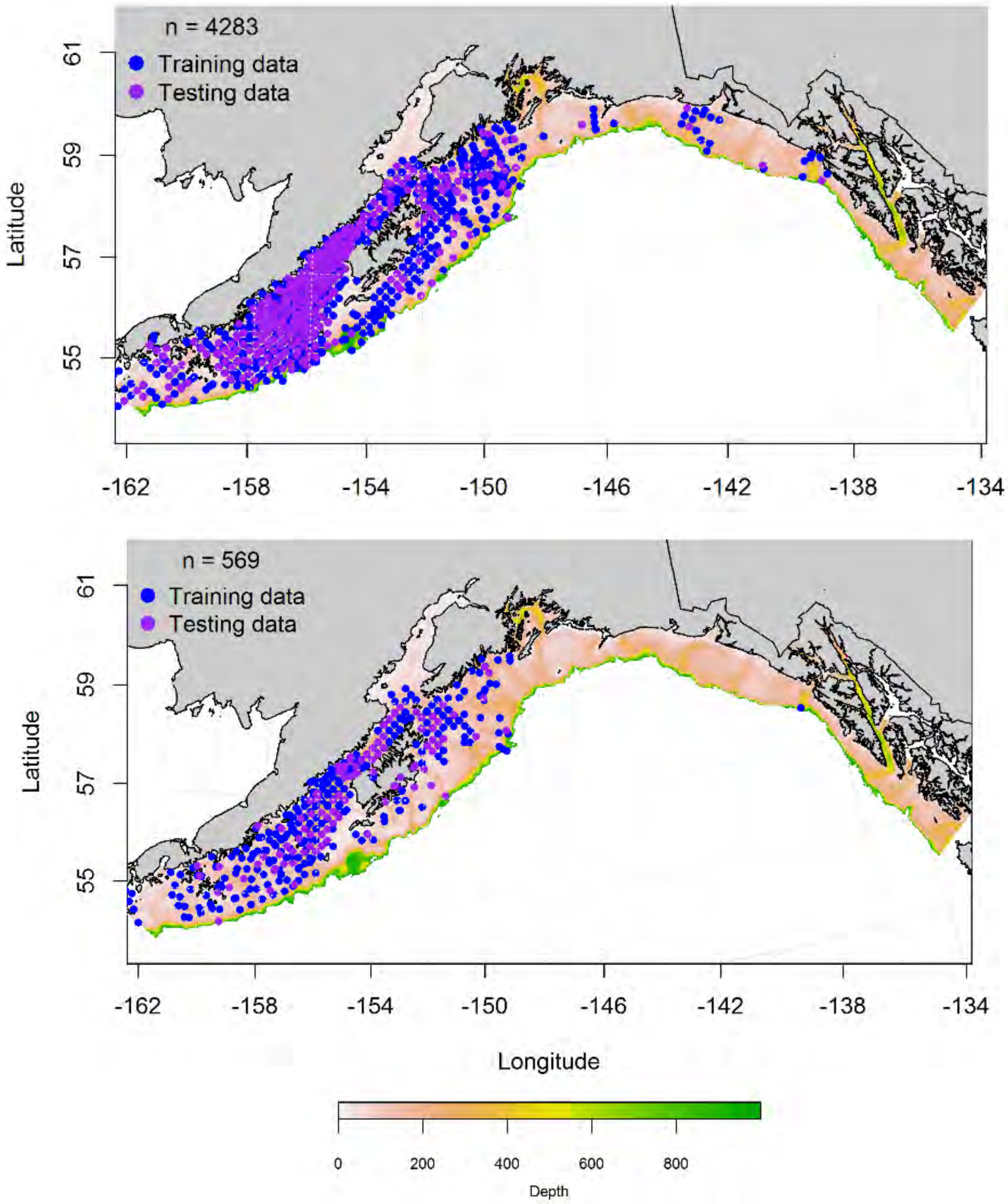


Figure 113. -- Spring and summer observations (top and bottom panel, respectively) of larval *G. chalcogrammus* from the Gulf of Alaska.

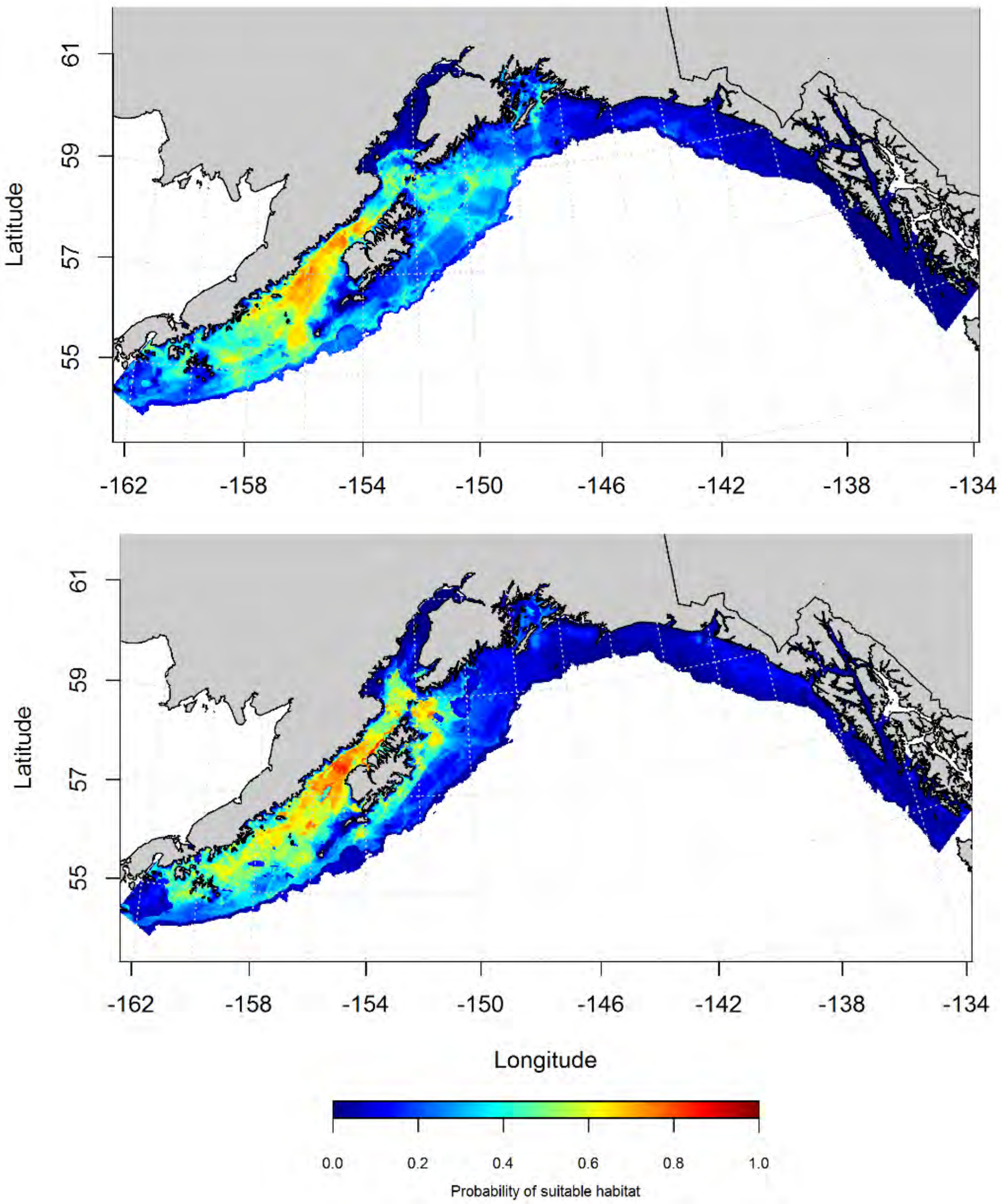


Figure 114. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *G. chalcogrammus* from maximum entropy modeling of the Gulf of Alaska.

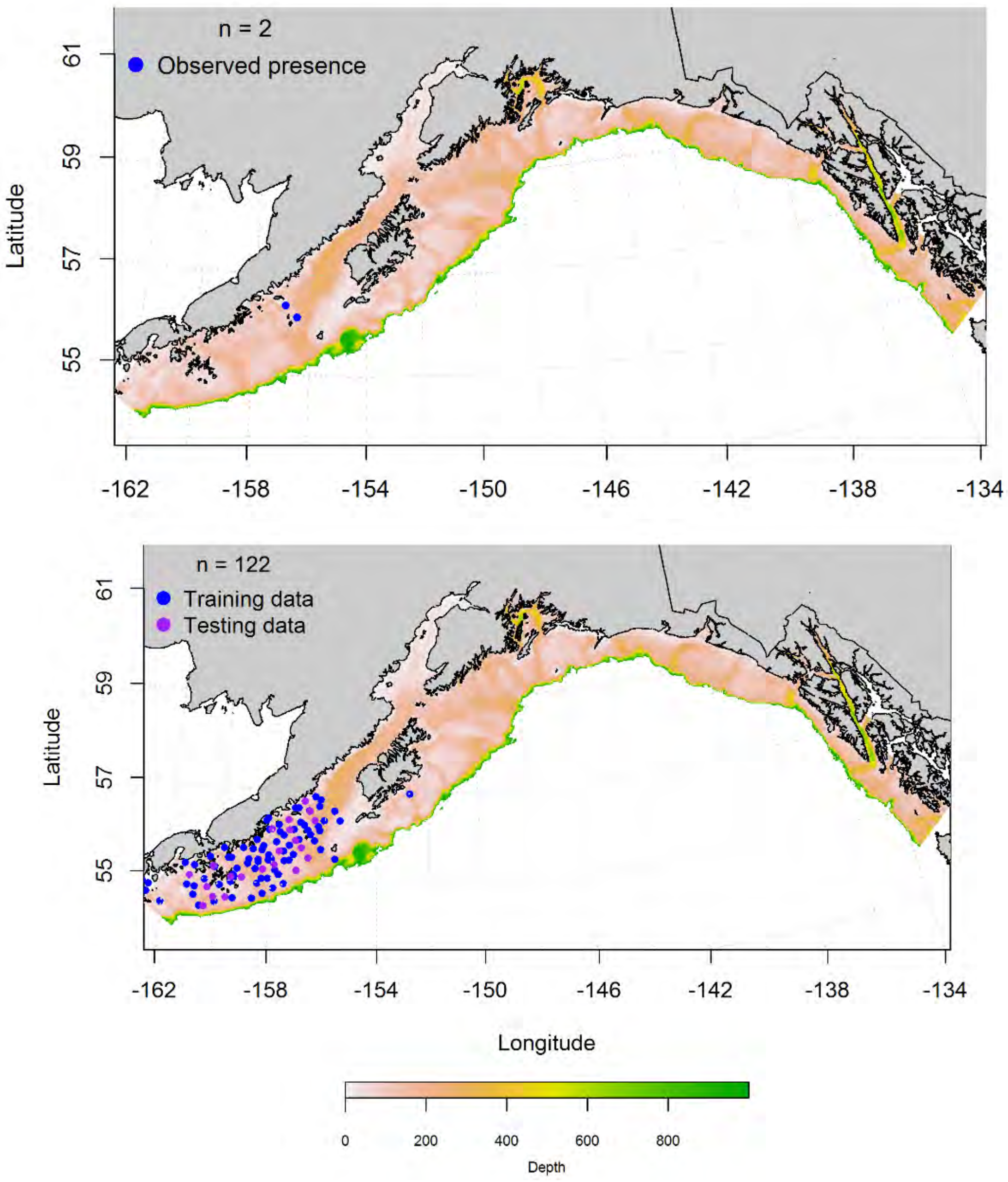


Figure 115. -- Spring and summer catches (top and bottom, respectively) of early juvenile *G. chalcogrammus* in the Gulf of Alaska.

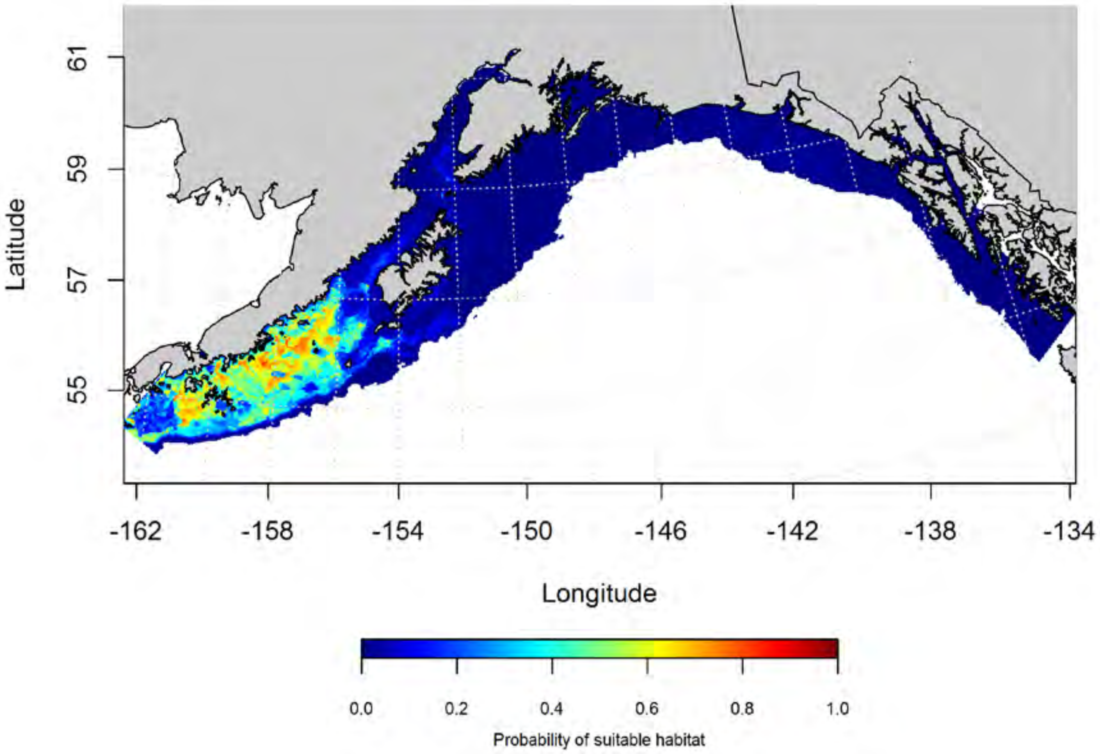


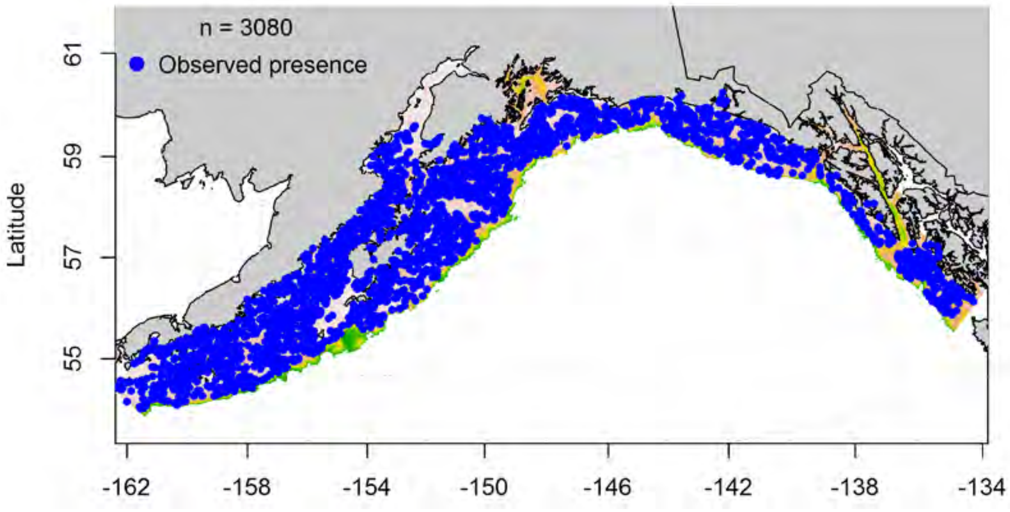
Figure 116. -- Predicted probability of suitable habitat for summer observations of early juvenile *G. chalcogrammus* from maximum entropy modeling of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *G. chalcogrammus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile walleye pollock are broadly distributed across much of the shelf in the Gulf of Alaska (Figure 117).

The best-fitting GAM indicated that longitude and latitude, depth, and tidal current were the most important variables predicting the distribution of juvenile walleye pollock. The model explained 16% of the variability of the CPUE in the training data, and 15% of the variability in the test data. Juvenile walleye pollock were predicted to occur across much of the inner- and middle-shelf throughout the GOA. High suitability habitat was predicted to occur along the Alaska Peninsula including Shelikof Strait, eastern Prince William Sound, and inside waters in southern Alaska. (Figure 118). High suitability habitats were also identified in upper Cook Inlet, in the vicinity of Anchorage; however, these predictions were not supported by any observations.

Summer bottom trawl survey data also indicate adult walleye pollock occur throughout much of the shelf in the GOA (Figure 117).

The best-fitting GAM indicated that depth, latitude and longitude, and tidal currents were the most important variables predicting the distribution of adult walleye pollock. The model explained 25% of the variability in CPUE for the training data and 23% of testing data. Adult walleye pollock were predicted to largely occur in Shelikof Strait and to a lesser extent in the deeper channels and depressions along much of the rest of the shelf (Figure 119).



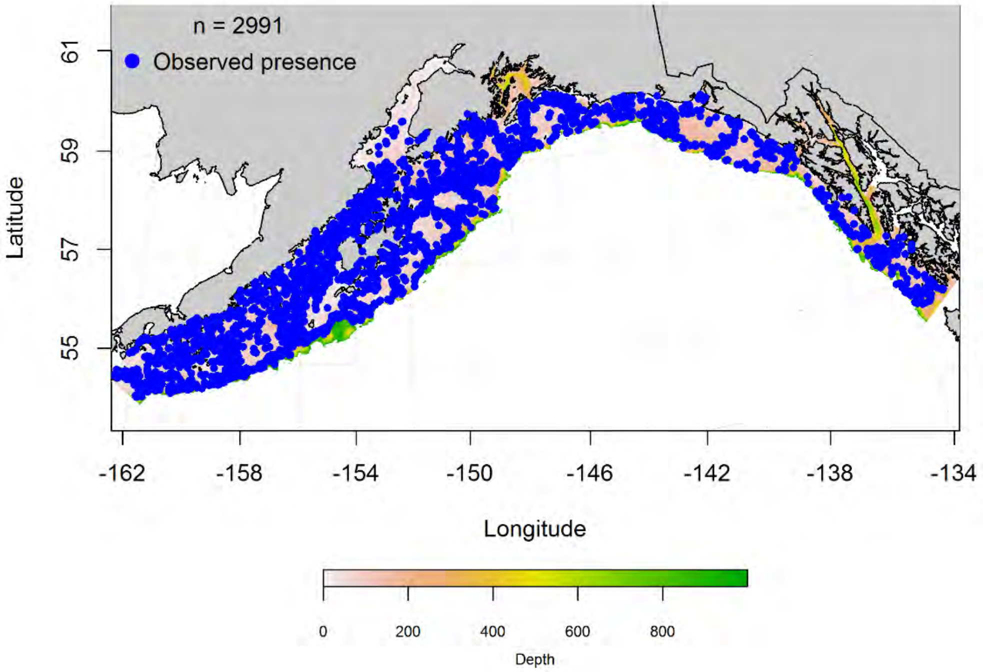


Figure 117. -- Locations of catches of juvenile and adult *G. chalcogrammus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

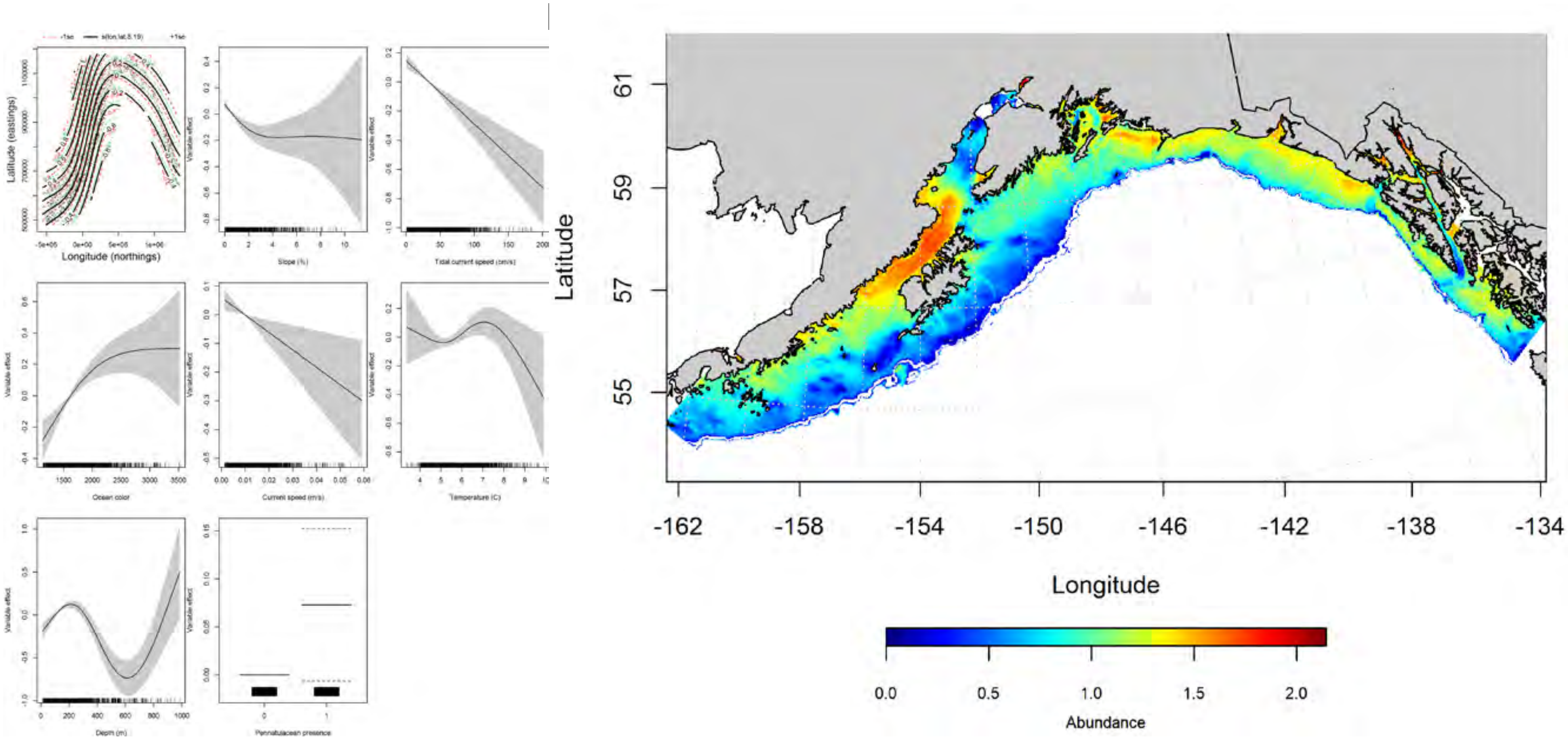


Figure 118. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of juvenile *G. chalcogrammus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted juvenile *G. chalcogrammus* abundance (right panel).

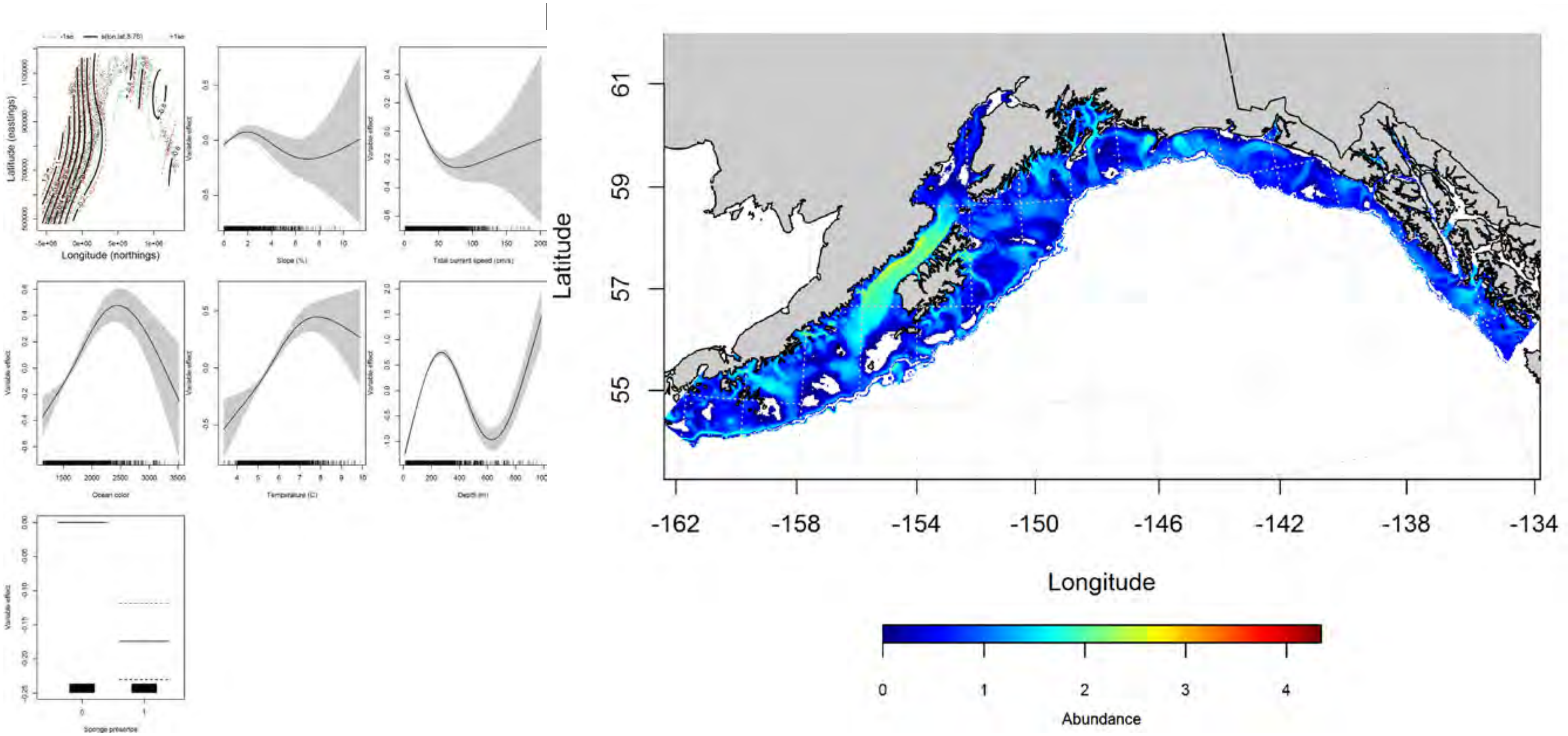


Figure 119. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *G. chalcogrammus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *G. chalcogrammus* abundance (right panel)

Seasonal distribution of commercial fisheries catches of adult *G. chalcogrammus* in the Gulf of Alaska -- Commercial catch data indicate walleye pollock largely occur in the western GOA around Kodiak Island, particularly in the deeper channels and depressions. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of walleye pollock (relative importance = 35.7 and 24.7 respectively). The AUC for the training data 0.90, indicating an excellent model fit. The AUC for the test data was 0.76, indicating a fair model fit. The percent of observations correctly classified for the training data was 81%, and it was 76% for the test data. In the fall, the habitat with the highest predicted suitability for walleye pollock was widely distributed across the GOA, particularly in the deeper channels and depressions such as Shumagin Gully on the Alaska Peninsula, the edge of Albatross Bank and Marmot Gully off Kodiak Island, and off Chichagof Island in southeast Alaska (Figure 120).

In the winter, *MaxEnt* modeling determined that ocean color and current speed were the most important variables determining the distribution of walleye pollock (relative importance = 31.2 and 29.3 respectively). The AUC was 0.87 for the training data, indicating a good model fit. The AUC for the test data was 0.80, indicating a good model fit. The percent of observations correctly classified was 80% and 80% respectively, for the training and test data. In the winter, the habitat with the highest predicted suitability for walleye pollock occurred much of the shelf in the GOA, practically between Cape St. Elias and Kodiak Island, and to a lesser extent off southeast Alaska (Figure 121).

There were no observations of walleye pollock from commercial fisheries data in during the spring.

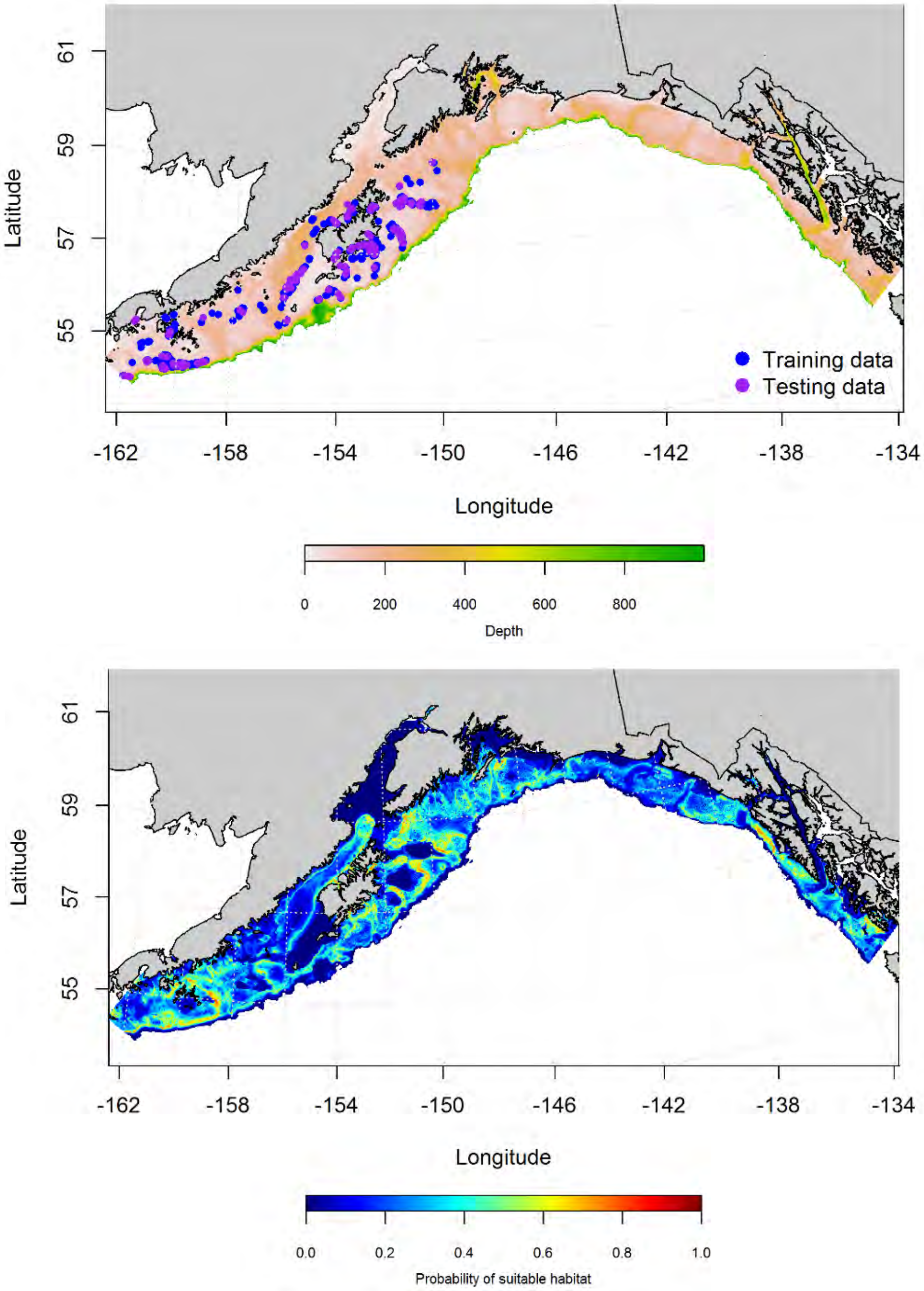


Figure 120. -- Locations of fall (September-November) commercial fisheries catches of *G. chalcogrammus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *G. chalcogrammus* commercial catches (bottom panel) and the purple points were used to test the model.

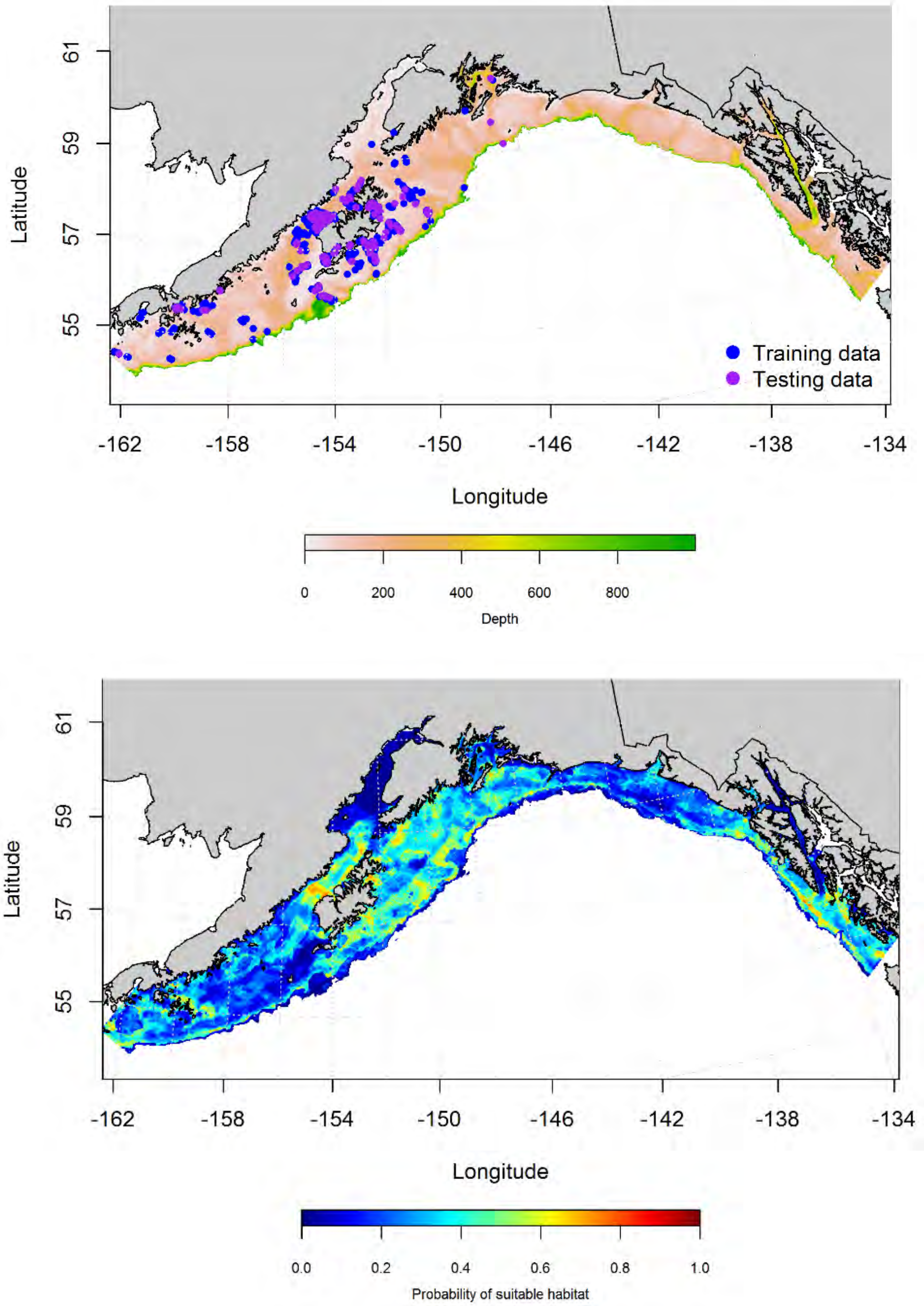


Figure 121. -- Locations of winter (December-February) commercial fisheries catches of *G. chalcogrammus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *G. chalcogrammus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *G. chalcogrammus* Essential Fish Habitat Maps and Conclusions -- Walleye pollock essential fish habitat predicted by modeling is extensively distributed across much of the shelf in the Gulf of Alaska. EFH for walleye pollock eggs in the spring occurred across much of the inner- and middle-shelf in the western GOA, particularly in Shelikof Strait and Shelikof Gully and along the Alaska Peninsula (Figure 122). In the summer, EFH for walleye pollock eggs was more restricted and it largely occurred in Shelikof Strait and Shelikof Gully.

EFH for larval walleye pollock, during the spring was predicted to include much of the shelf west of Prince William Sound, particularly in Shelikof Strait and Shelikof Gully (Figure 123). During the summer, EFH for larval walleye pollock was predicted to be slightly more restricted than the predicted spring EFH, including much of the inner -- and middle-shelf west of the Kenai Peninsula out along the Alaska Peninsula.

Early juvenile EFH could only be predicted during the summer. It included much of the shelf west of Chirikof Island and out along the Alaska Peninsula (Figure 124).

Summer EFH for juvenile walleye pollock, based on trawl survey observations, was predicted to occur across most of the inner- and middle-shelf throughout the GOA. EFH was identified in upper Cook Inlet and Prince William Sound; however, these predictions were not supported by any observations. EFH for adult walleye pollock was predicted to include much of the same habitat as the juveniles; however, for higher suitability habitats for the adults tended to occur at slightly deeper depths, such as in valleys and channels or along the shelf break (Figure 125). EFH was identified in Prince William Sound; however, these predictions were not supported by any observations.

Spring and summer EFH for walleye pollock, based on commercial fisheries data, was predicted to include much of the continental shelf throughout the GOA, and in particular deeper depressions on the middle-shelf and the shelf break (Figure 126). During the winter, EFH for walleye pollock was predicted to be more restricted in extent, and to largely occur along the shelf break east of Kodiak Island. During the spring, EFH for walleye pollock was predicted to include the deeper portion of the middle and outer-shelf, such as valleys and channels, and along the shelf break.

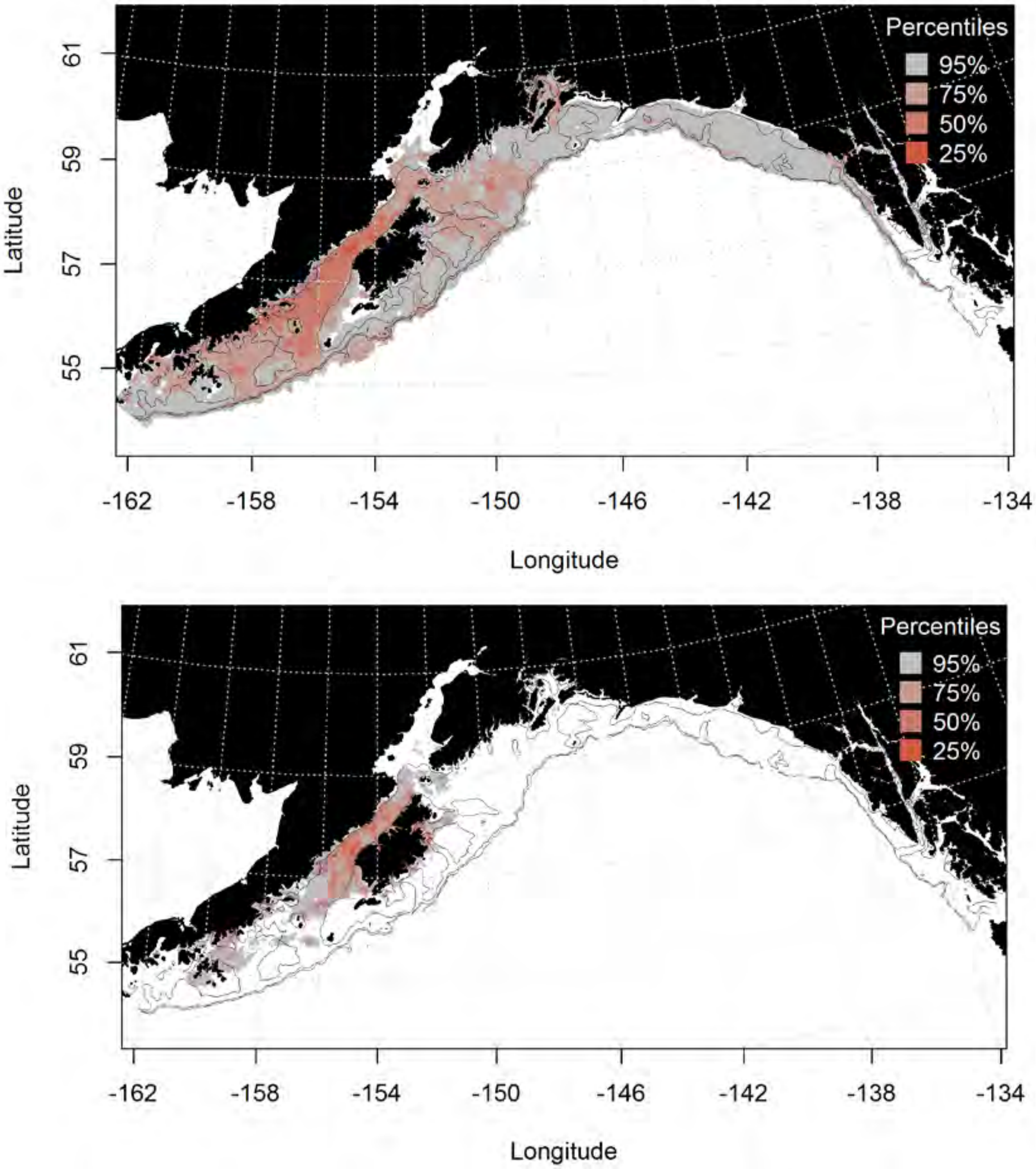


Figure 122. -- Spring and summer essential fish habitat predicted for *G. chalcogrammus* eggs (top and bottom panel, respectively) from the EcoFOCI database.

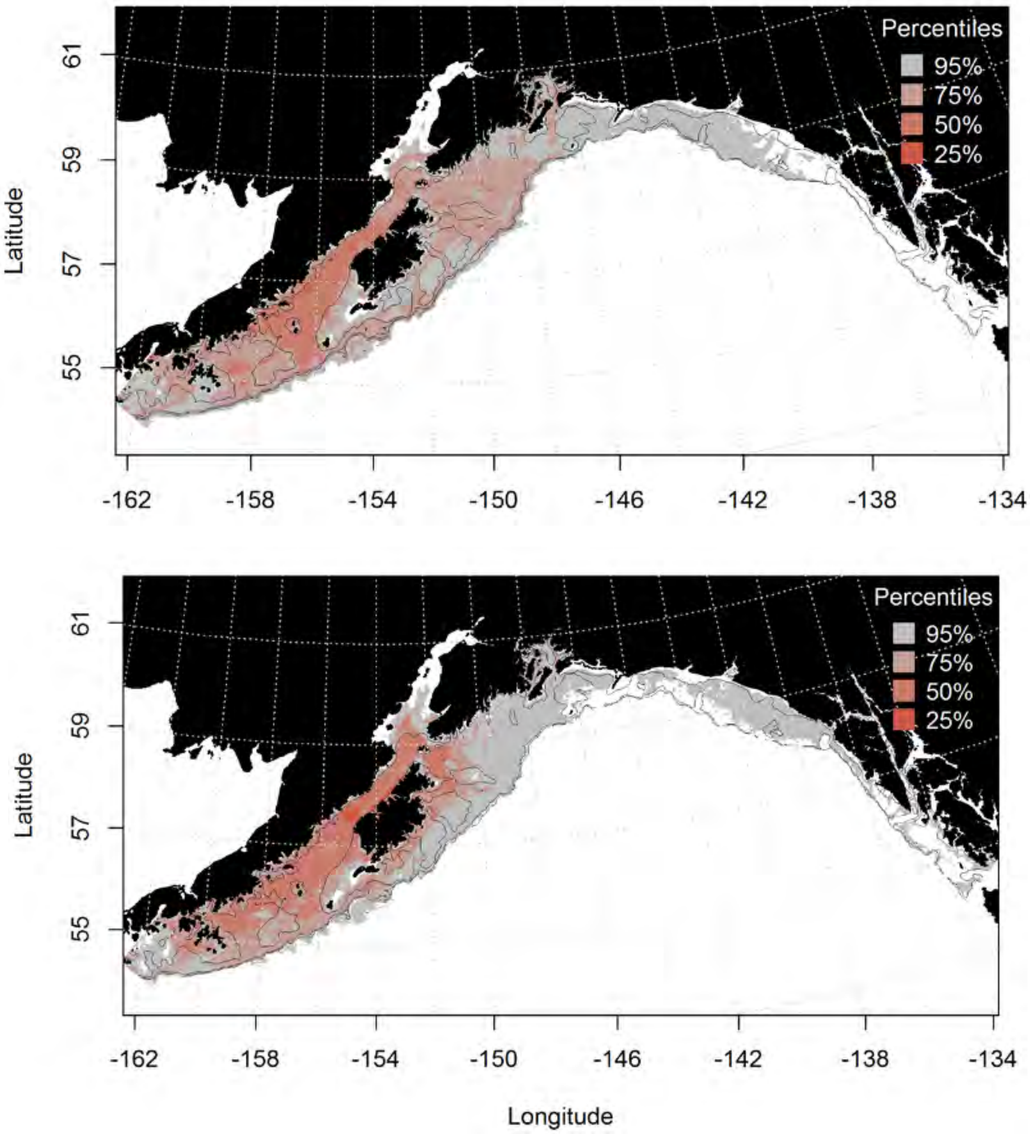


Figure 123. -- Spring and summer essential fish habitat predicted for larval *G. chalcogrammus* (top and bottom panel, respectively) from the EcoFOCI database.

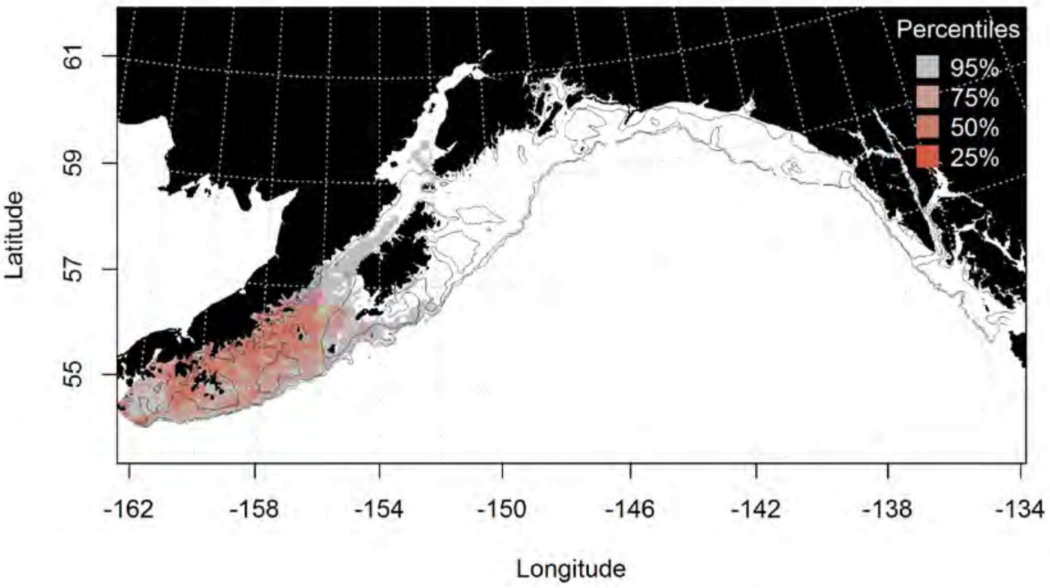
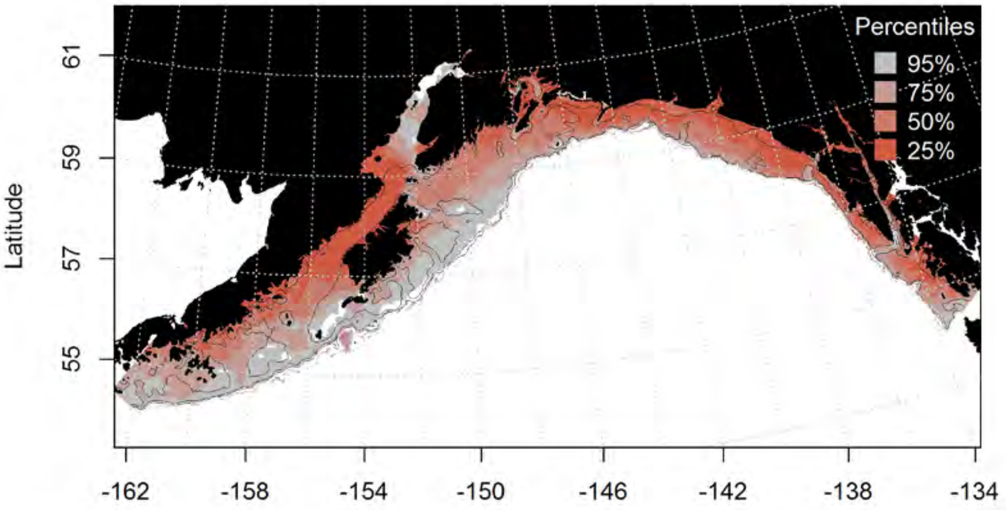


Figure 124. -- Summer essential fish habitat predicted for early juvenile *G. chalcogrammus* from the EcoFOCI database.



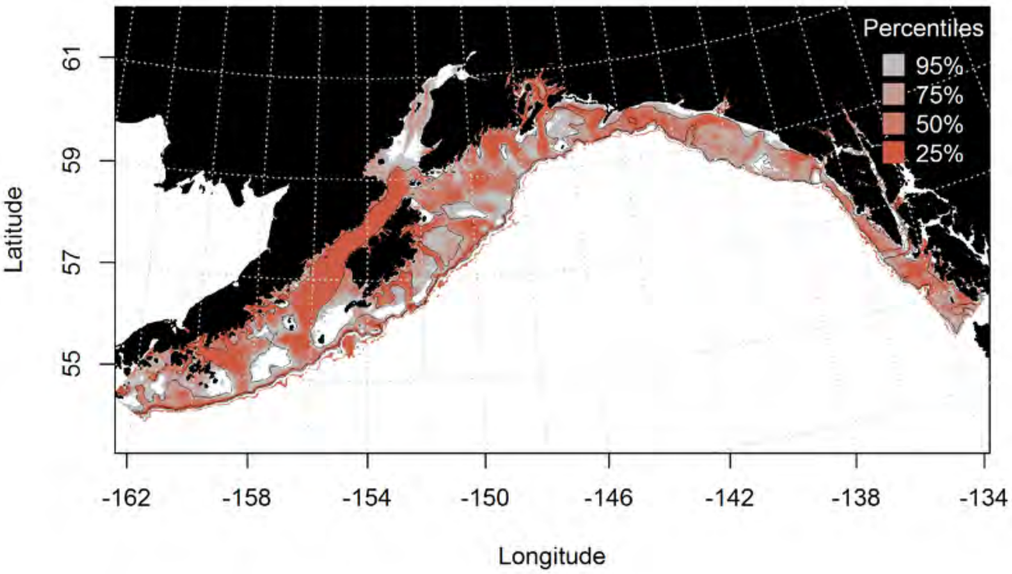


Figure 125. -- Predicted summer essential fish habitat for *G. chalcogrammus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

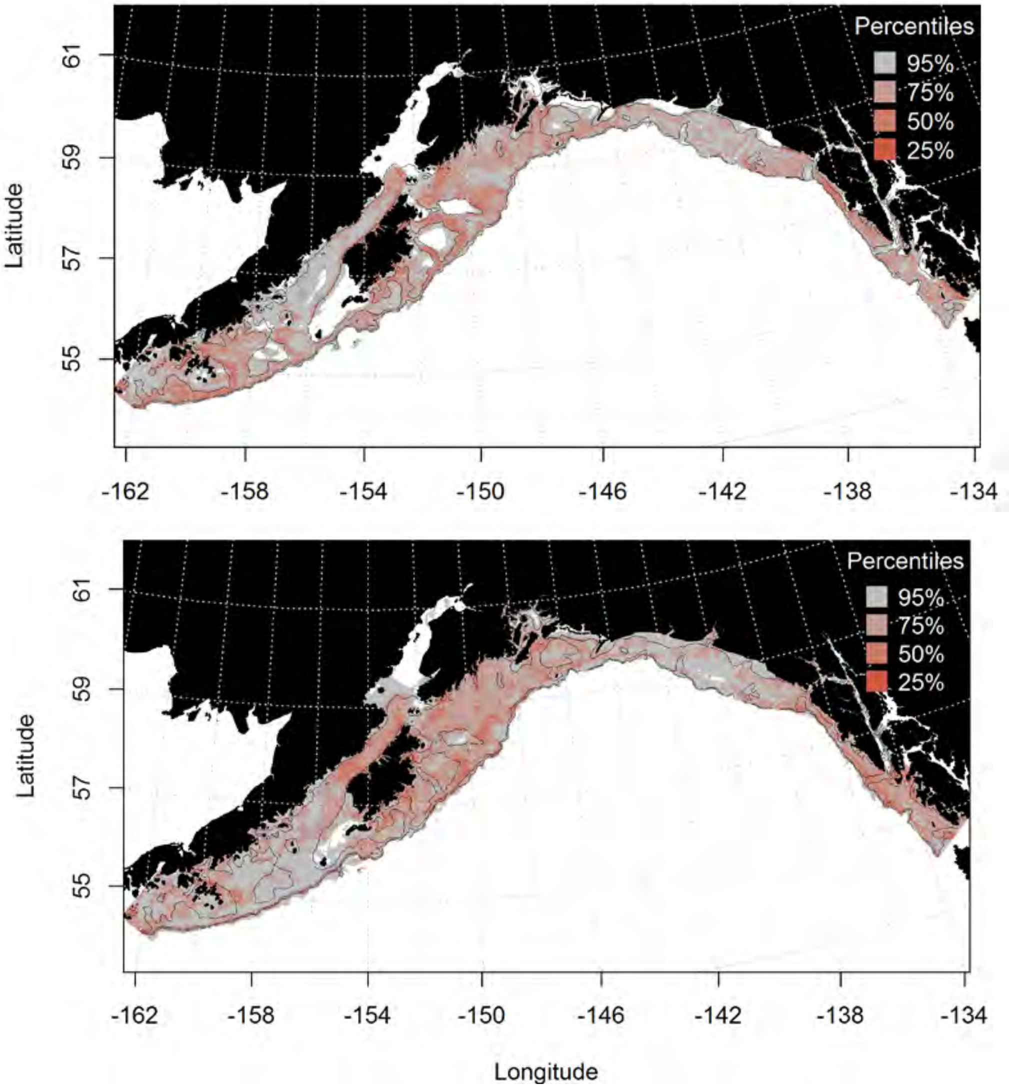


Figure 126. -- Essential fish habitat predicted for *G. chalcogrammus* during fall (top panel) and winter (bottom panel) from commercial catches.

Pacific cod (*Gadus macrocephalus*)

Pacific cod are one of most abundant species caught in the AFSH bottom trawl surveys. A majority of them occur in the central and western Gulf of Alaska, typically at less than 100 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *G. macrocephalus* in the Gulf of Alaska -- Throughout much of their early life history Pacific cod largely occur in the western Gulf of Alaska.

Pacific cod eggs were observed in the GOA during the spring and summer. In the spring, there were only nine observations of Pacific cod eggs, the majority of which occurred in on the inner- and middle-shelf in the western gulf (Figure 127). In the summer, only two Pacific cod eggs were observed, both occurred on Portlock Bank. There was insufficient data to predict the distribution of Pacific cods eggs either during the spring or summer.

Larval Pacific cod were observed during the spring and the summer (Figure 128). Larval Pacific cod were very abundant during the spring.

The best-fitting *MaxEnt* model indicated that surface temperature and depth were the most important variables predicting habitat suitable (relative importance 26.7 and 18.2 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.80, indicating the good model fit. The percent of the observations correctly classified in the training data was 82% and 80% for the test data. During the spring, Pacific cod larval habitat was predicted to include much of the inner- and middle-shelf in the western GOA, with the highest suitability habitats occurring along Shelikof Gully and the Alaska Peninsula (Figure 129).

During the summer, larval Pacific cod were also abundant across much of the inner- and middle-shelf in the western GOA. The most important variable predicting larval habitat suitability were surface temperature and surface speed (59.7 and 13.9, respectively). The AUC was 0.91 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.75, indicating the fair model fit. The percent of the observations correctly classified in the training data was 82% and 75% for the test data. Pacific cod larval habitat during the summer was more restricted, and largely occur in the inner- and middle-shelf along the Alaska Peninsula, including Shelikof Strait (Figure 129).

Early juvenile Pacific cod were observed only during the summer. The most important variable predicting early juvenile habitat suitability were surface temperature and ocean color (71.1 and 11.8, respectively). The AUC was 0.92 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.76, indicating the fair model fit. The percent of the observations correctly classified in the training data was 85% and 76% for the test data. During the summer, Pacific cod larval habitat was predicted to include much of the shelf from Shelikof Gully west along the Alaska Peninsula (Figure 130).

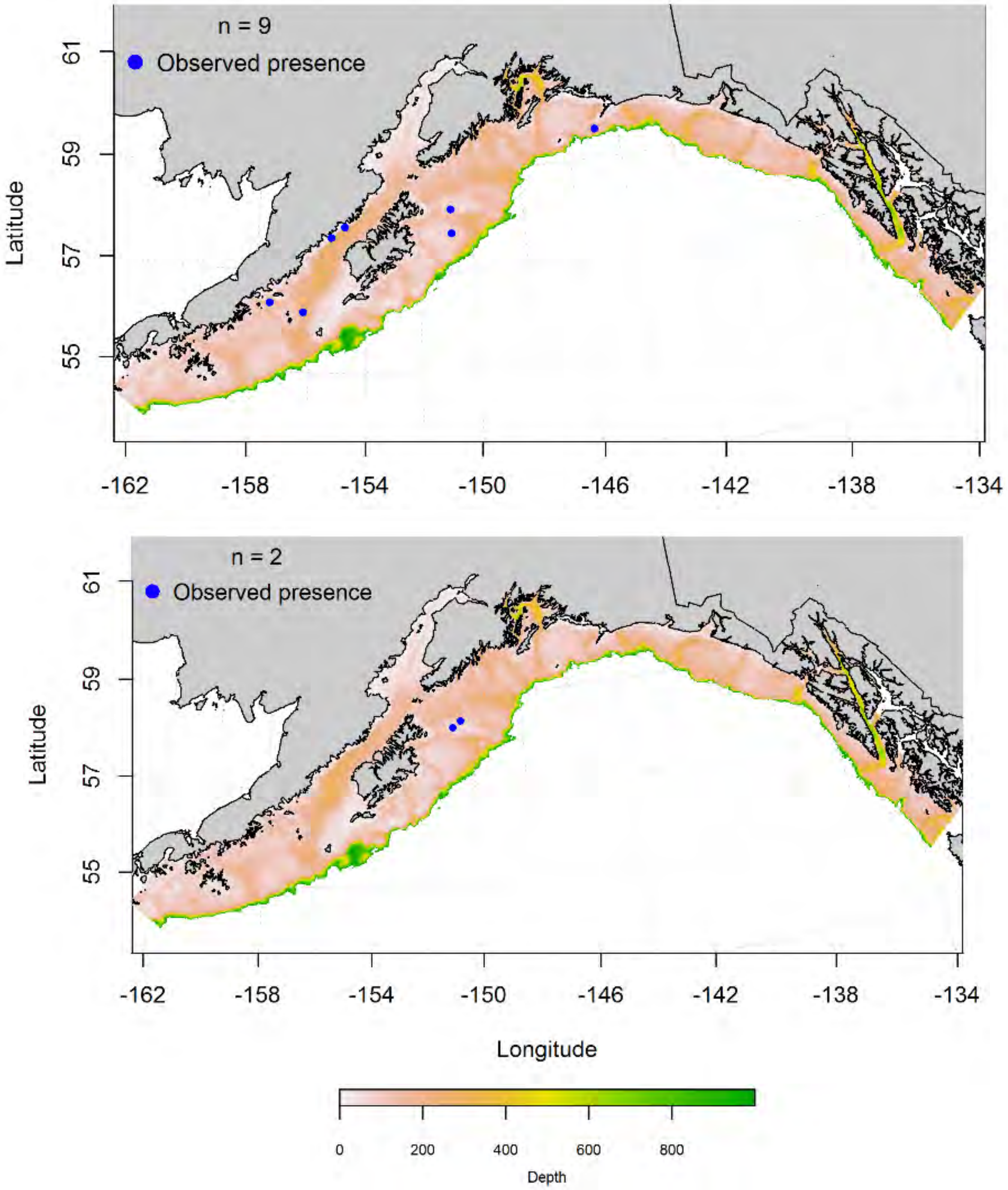


Figure 127. -- Spring and summer (top and bottom panel, respectively) observations of *G. macrocephalus* eggs from the Gulf of Alaska.

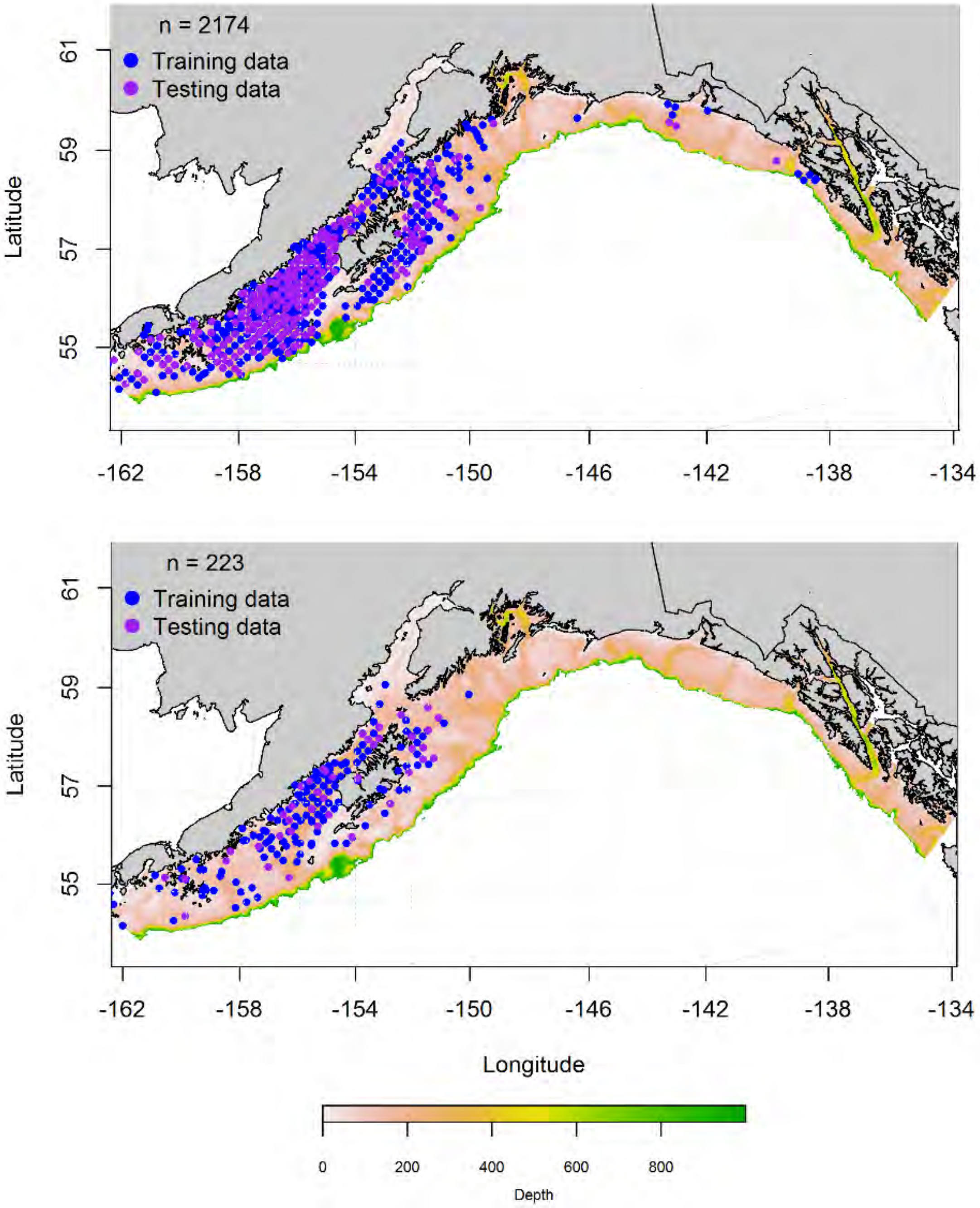


Figure 128. -- Spring and summer observations (top and bottom panel, respectively) of larval *G. macrocephalus* from the Gulf of Alaska.

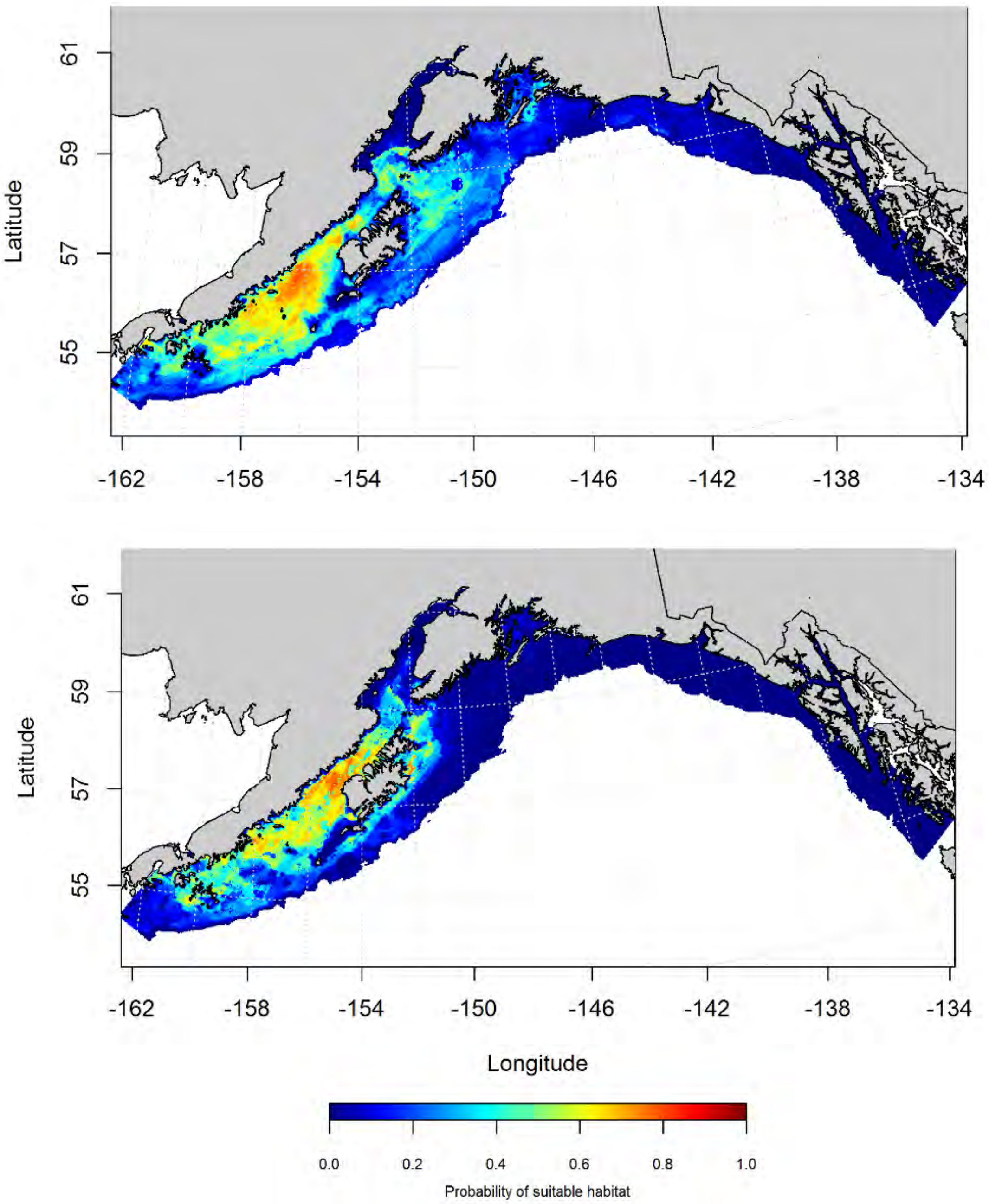


Figure 129. -- Predicted probability of suitable habitat for spring and summer observations (top and bottom panel, respectively) of larval *G. macrocephalus* from maximum entropy modeling of the Gulf of Alaska.

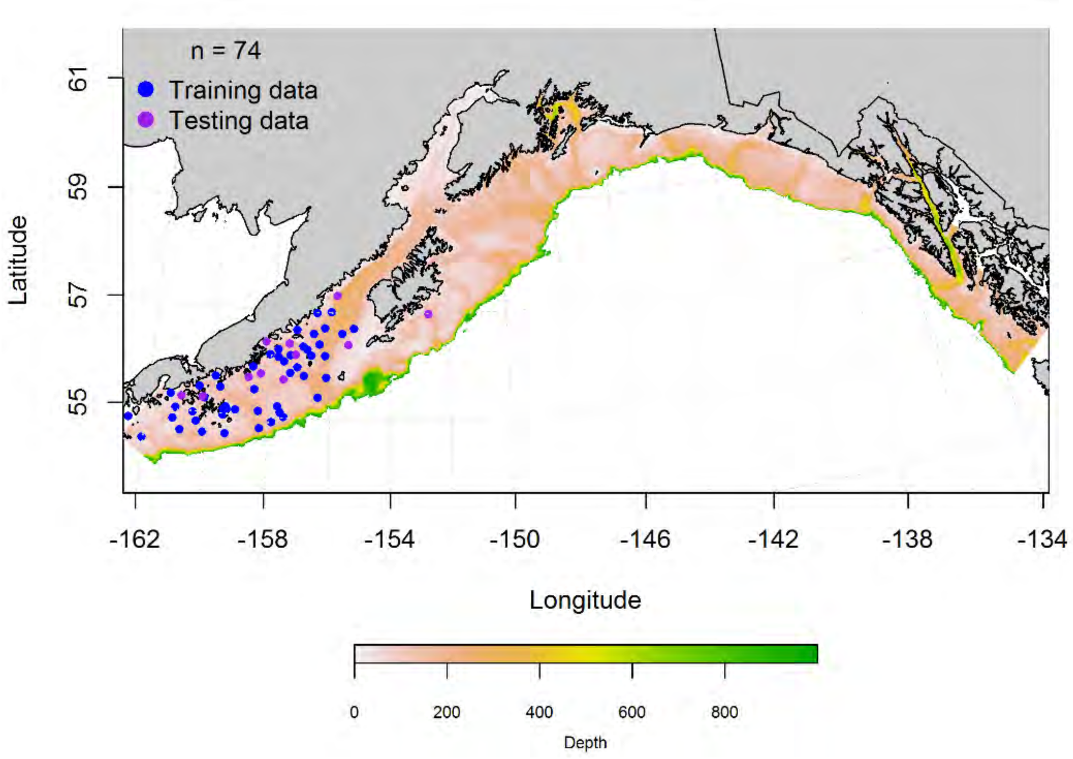
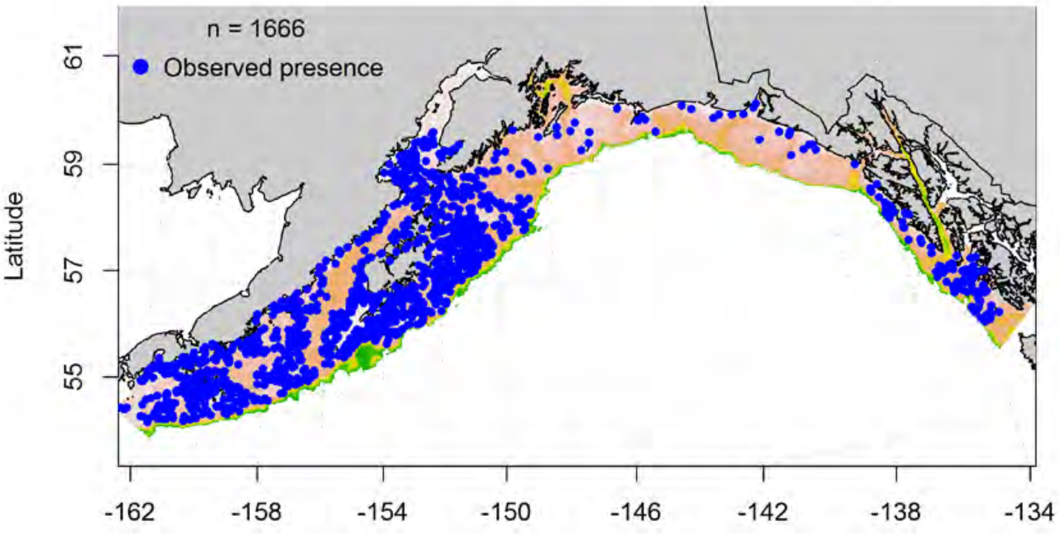


Figure 130. -- Summer catches of early juvenile *G. macrocephalus* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *G. macrocephalus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile Pacific cod occur across much of the shelf in the GOA (Figure 131).

The best-fitting GAM indicated that depth, longitude and latitude, and sponge presence were the most important variables predicting the distribution of juvenile Pacific cod. The model explained 24% of the variability of the CPUE in the training data, and 27% of the variability in the test data. Juvenile Pacific cod were predicted to occur in shallower portions of inner- and middle-shelf throughout much of the western GOA. In particular, high abundance were predicted to occur at the head of Cook Inlet; however, these predictions were not supported by any observations (Figure 132).

Summer bottom trawl survey data also indicate adult Pacific cod occur throughout much of the shelf in the GOA (Figure 131). The best-fitting GAM indicated that latitude and longitude, depth and tidal currents were the most important variables predicting the distribution of adult Pacific cod. The model explained 21% of the variability in CPUE for the training data and testing data. Adult Pacific cod were predicted to occur at low abundances across most of the shelf in the Gulf of Alaska (Figure 133).



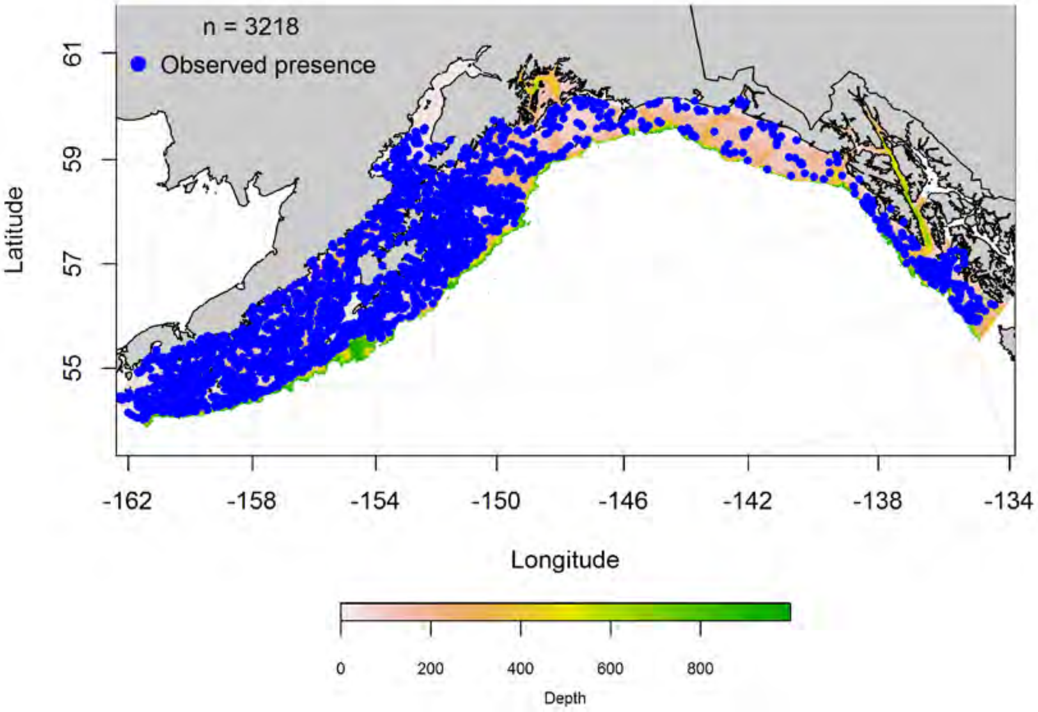


Figure 131. -- Locations of catches of juvenile and adult *G. macrocephalus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

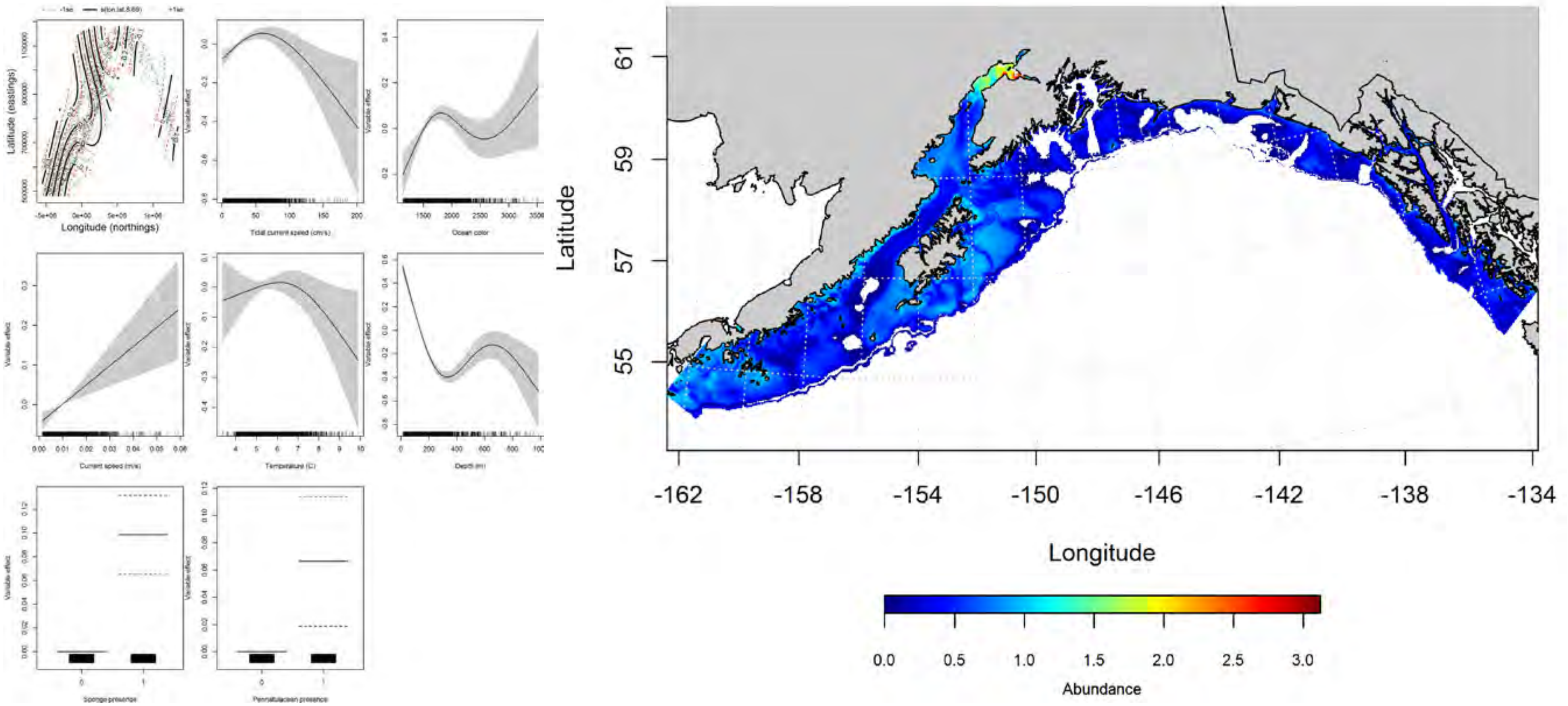


Figure 132. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of juvenile *G. macrocephalus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted juvenile *G. macrocephalus* abundance (right panel).

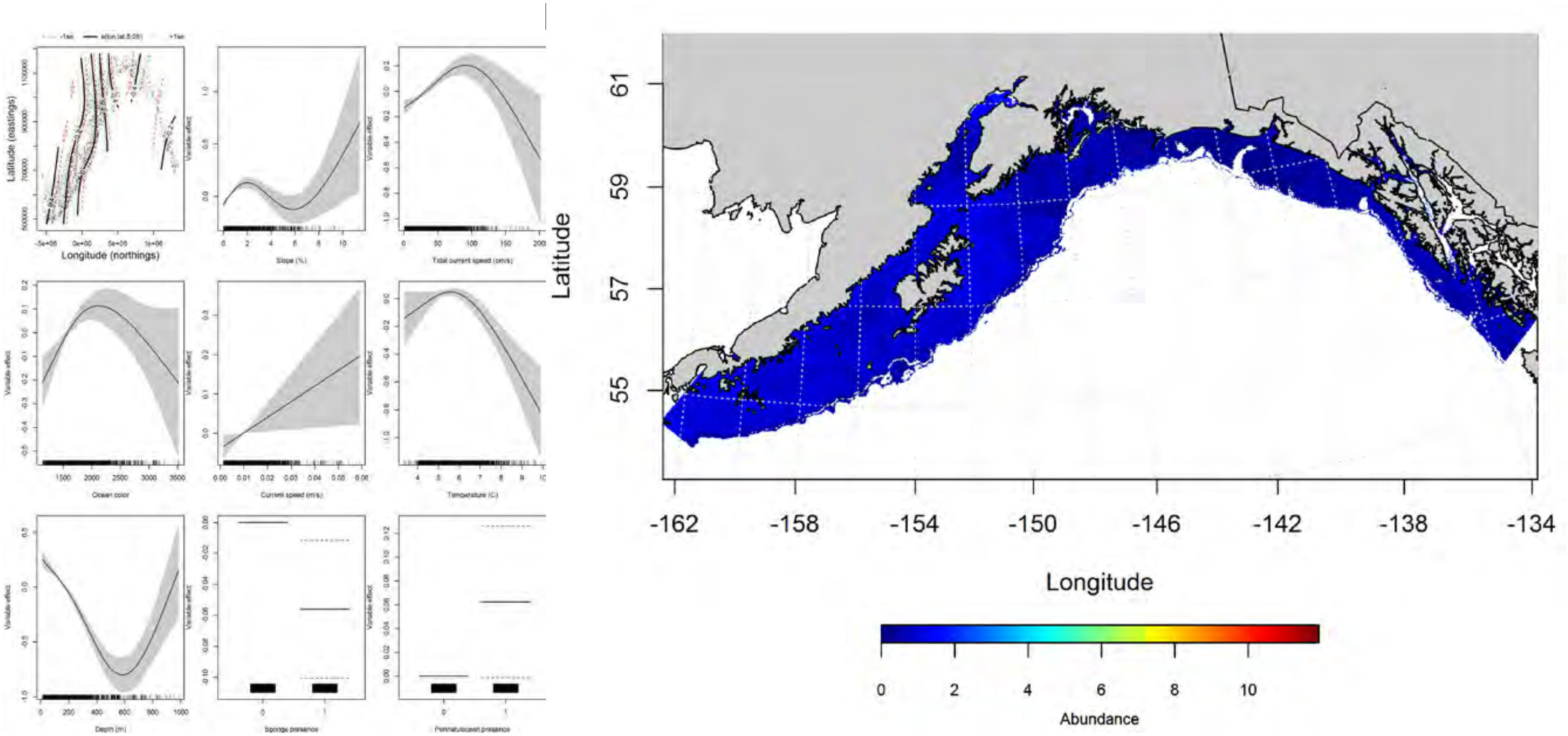


Figure 133. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *G. macrocephalus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *G. macrocephalus* abundance (right panel)

Possibly replot scaling issue

Seasonal distribution of commercial fisheries catches of adult *G. macrocephalus* in the Gulf of Alaska -- Commercial catch data indicate that Pacific cod largely occur in the western GOA. In the winter, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of Pacific cod (relative importance = 50.5 and 16.3 respectively). The AUC for the training data 0.88, indicating an excellent model fit. The AUC for the test data was 0.79, indicating a fair model fit. The percent of observations correctly classified for the training data was 80%, and it was 79% for the test data. In the winter, the habitat for Pacific cod was predicted to widely distributed across much of the western GOA, particularly on shallow portions of the middle-shelf including Albatross and Portlock Banks off Kodiak Island (Figure 134).

In the spring, *MaxEnt* modeling determined that tidal current and depth were the most important variables determining the distribution of Pacific cod (relative importance = 34.3 and 26.3 respectively). The AUC was 0.86 for the training data, indicating a good model fit. The AUC for the test data was 0.76, indicating a fair model fit. The percent of observations correctly classified was 79% and 76% respectively, for the training and test data. In the spring, the habitat with the highest predicted suitability for Pacific cod included much of the middle- and outer-shelf in the GOA, practically Shumagin and Shelikof Gullies on the Alaska Peninsula, Marmot Gully off the Kenai Peninsula, and off southeast Alaska (Figure 135).

There were no observations of Pacific cod from commercial fisheries data in during the fall or summer.

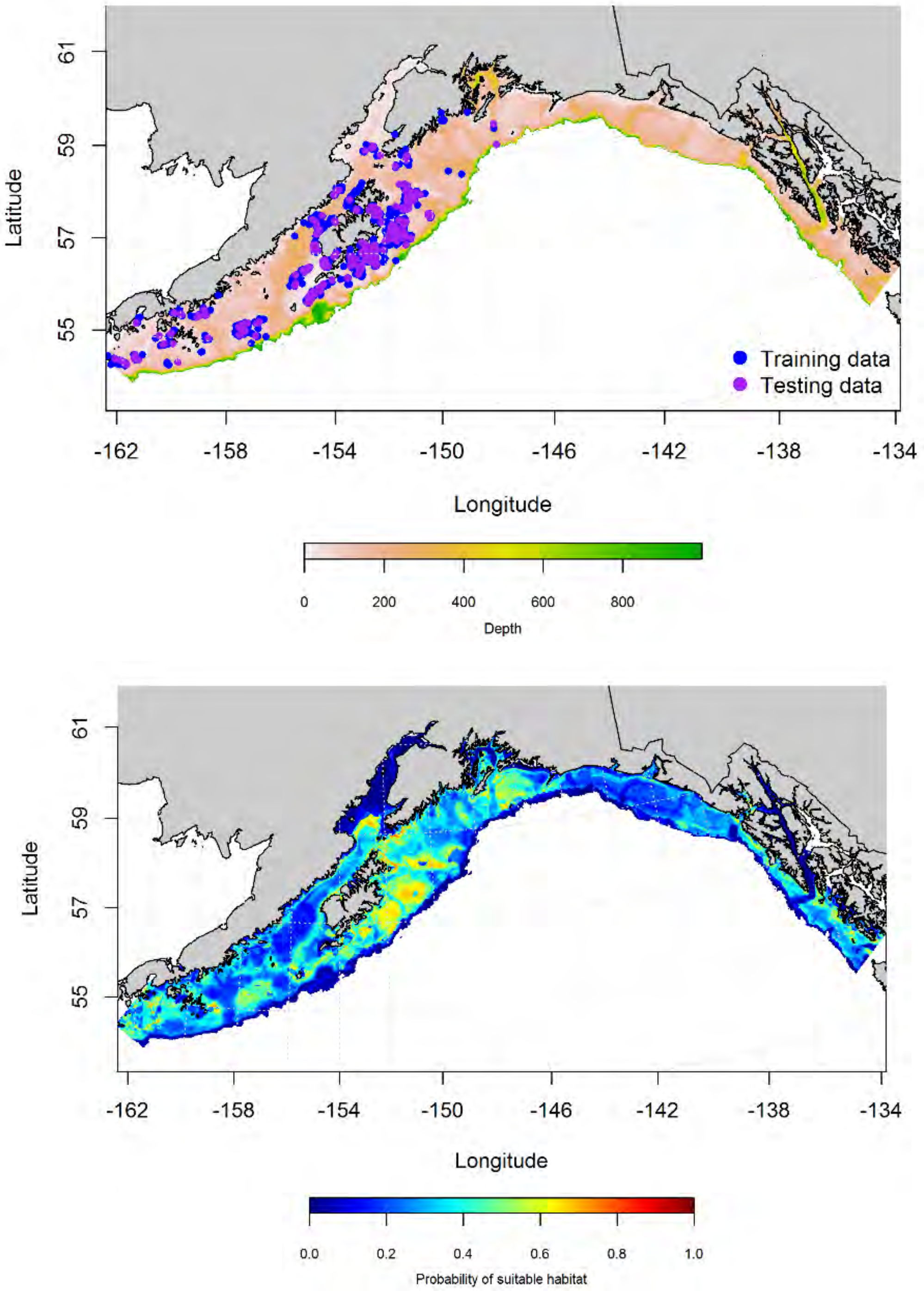


Figure 134. -- Locations of winter (December-February) commercial fisheries catches of *G. macrocephalus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *G. macrocephalus* commercial catches (bottom panel) and the purple points were used to test the model.

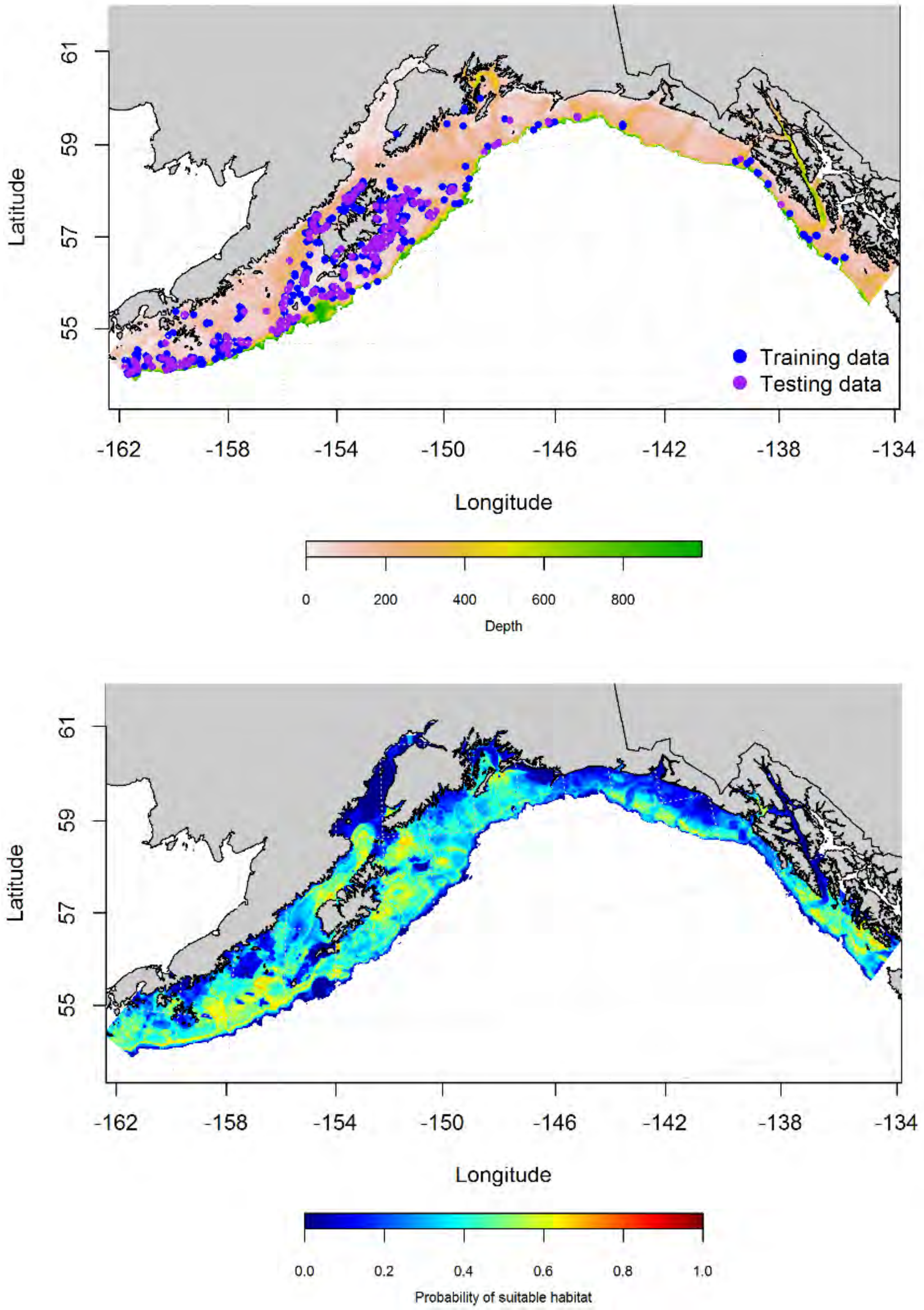


Figure 135. -- Locations of spring (March-May) commercial fisheries catches of *G. macrocephalus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *G. macrocephalus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *G. macrocephalus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Pacific cod was predicted to be extensively distributed across much of the shelf in the Gulf of Alaska. There were no observations of Pacific cod eggs in the EcoFOCI database.

During the spring, EFH for larval Pacific cod was predicted to include much of the shelf in the western gulf, particularly in Shelikof Strait and Shelikof Gully (Figure 136). During the summer, EFH for larval Pacific cod was predicted to be more limited. It included much of the inner- and middle-shelf west of the Kenai Peninsula out along the Alaska Peninsula.

Summer EFH for juvenile Pacific cod, based on trawl survey observations, was predicted to occur across most of the inner- and middle-shelf throughout the GOA (Figure 137). EFH for juvenile Pacific cod was also identified in upper Cook Inlet; however, these predictions were not supported by any observations. EFH for adult Pacific cod was predicted to include much of the same habitat as the juveniles; adult EFH tended to occur at slightly deeper depths, such as in valleys and channels or along the shelf break. EFH was identified in upper Cook Inlet; however, these predictions were not supported by any observations.

No observations of adult Pacific cod were available during the fall. Winter EFH for adult Pacific cod, based on commercial fisheries data, was predicted to include much of the continental shelf throughout the GOA, and in particular shallower portions of inner and middle-shelf (Figure 138). During the spring, EFH for adult Pacific cod was predicted to be much more extensive and included much of the middle- and outer-shelf.

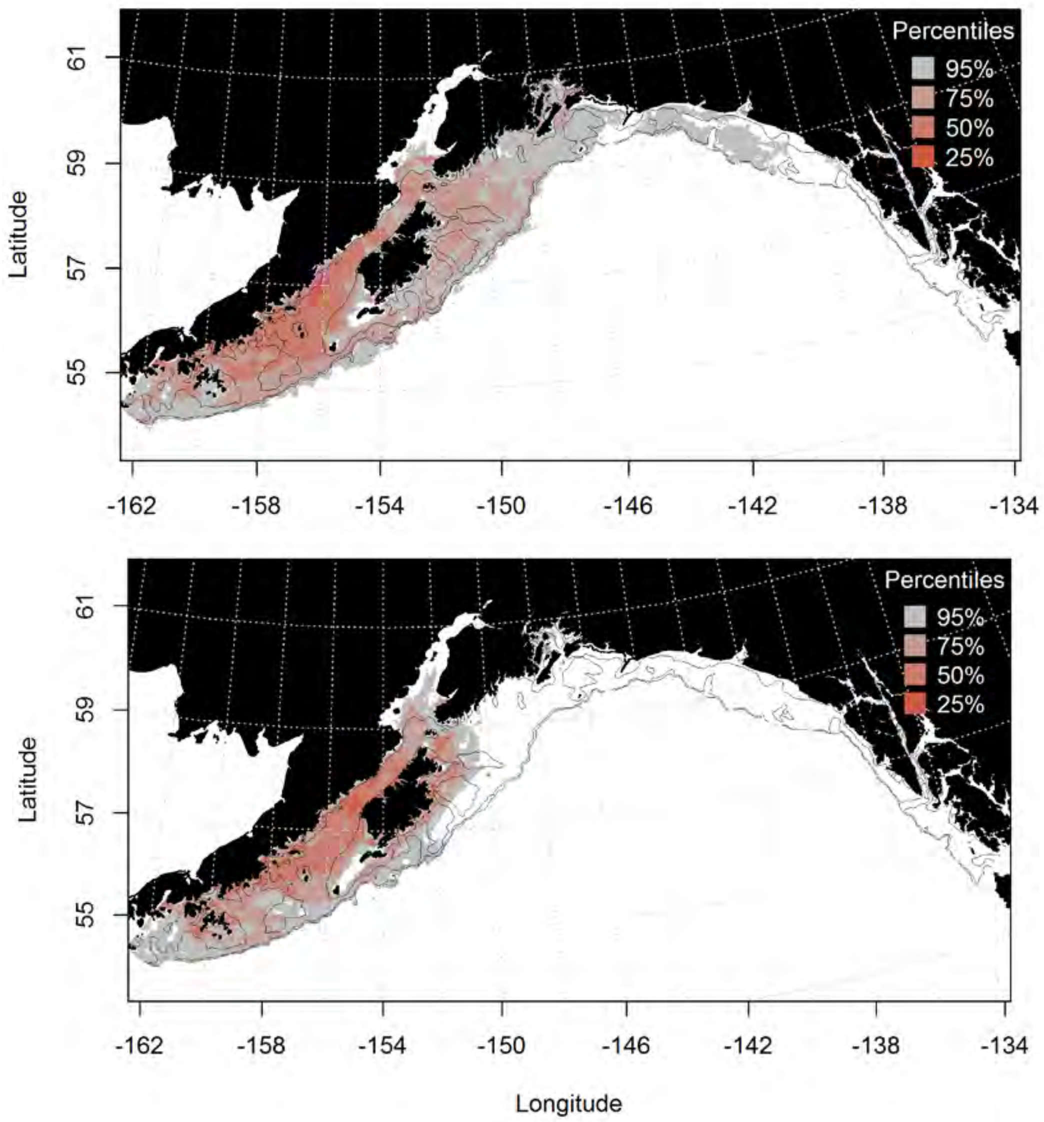


Figure 136. -- Spring and summer essential fish habitat predicted for larval *G. macrocephalus* (top and bottom panel, respectively) from the EcoFOCI database.

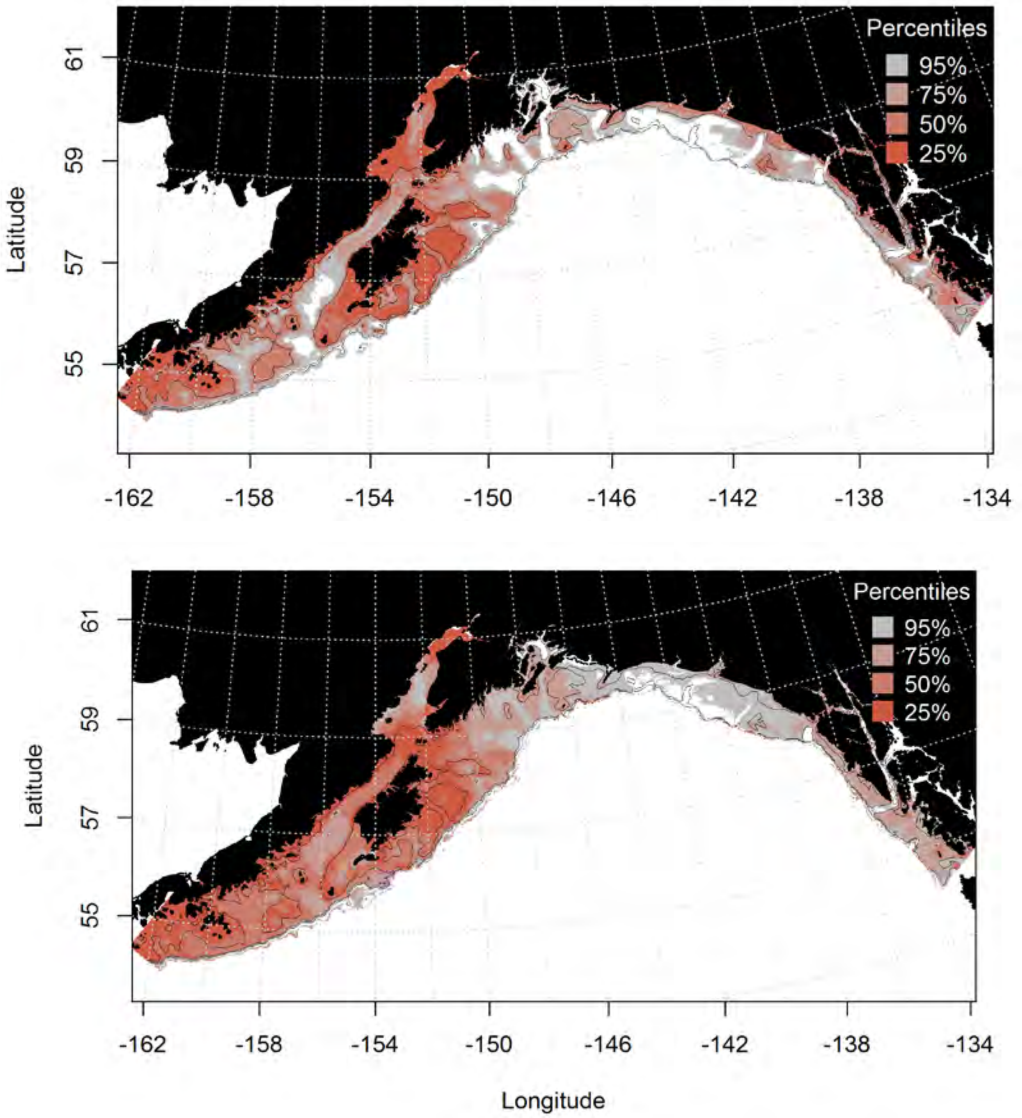


Figure 137. -- Predicted summer essential fish habitat for *G. macrocephalus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

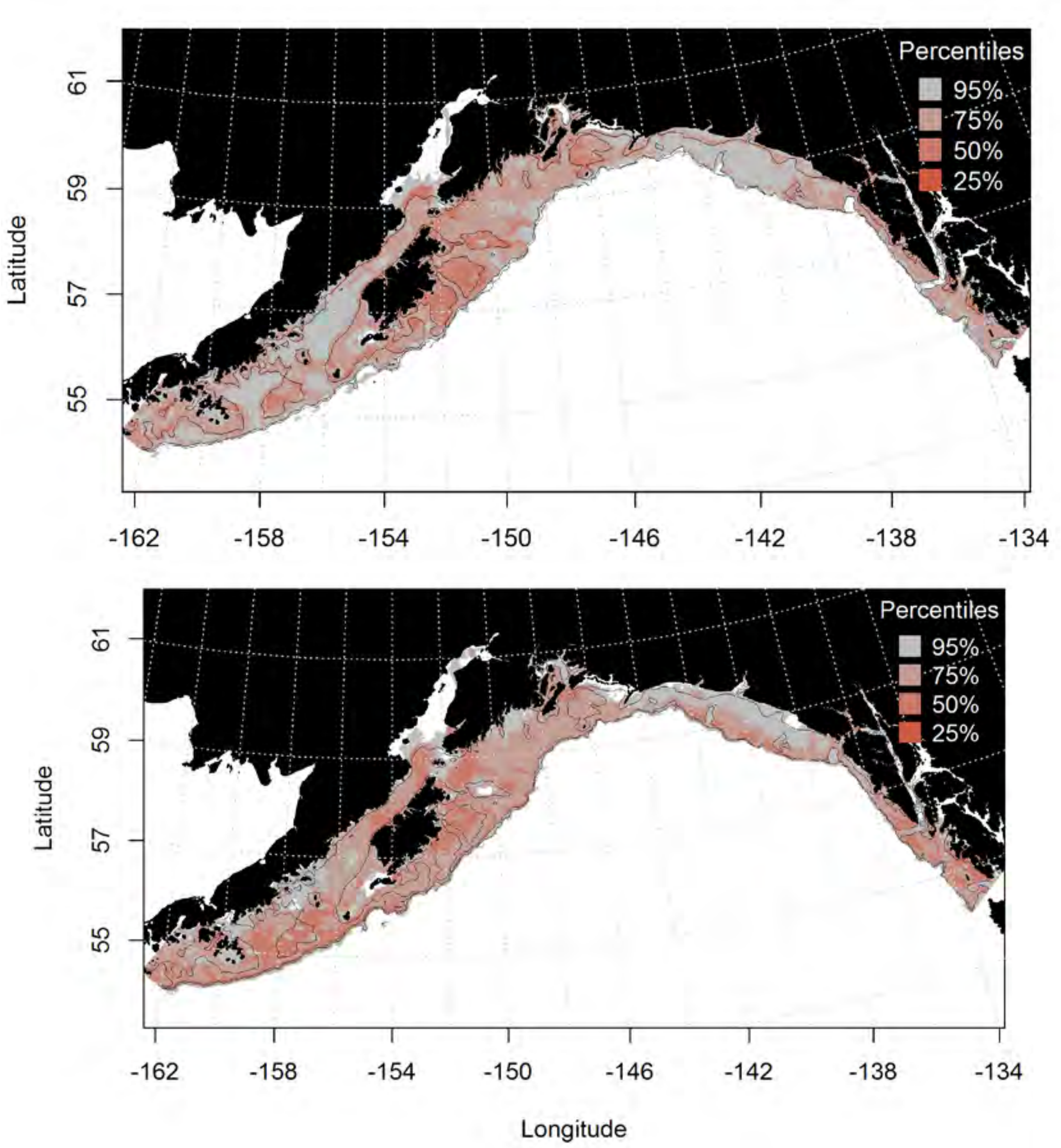


Figure 138. -- Essential fish habitat predicted for *G. macrocephalus* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

sablefish (*Anoplopoma fimbria*)

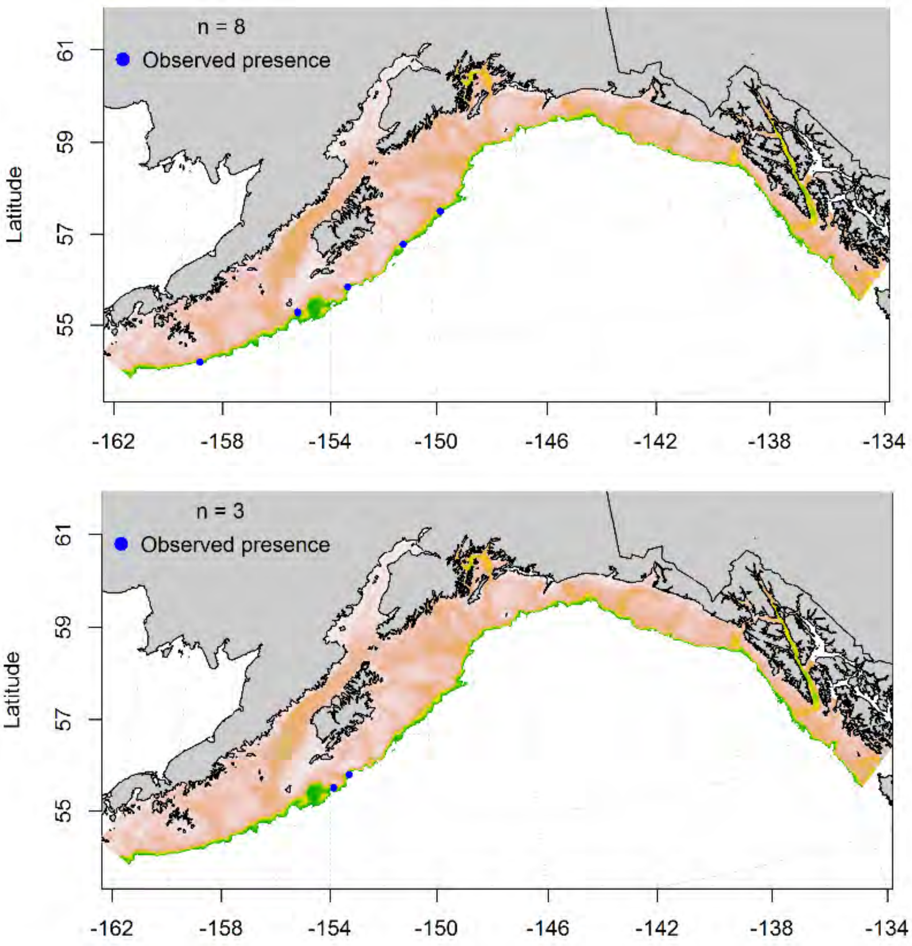
Sablefish were abundant throughout the Gulf of Alaska. They most abundant along the continental slope in waters deeper than 200 m (von Szalay et al. 2010).

**Seasonal distribution of early life history stages of *A. fimbria* in the Gulf of Alaska -- ** Throughout much of their early life history sablefish occur across much of the Gulf of Alaska. Sablefish eggs were observed in the GOA during the winter, spring and summer. In the winter, there were only eight observations of sablefish eggs, all of which occurred along the shelf break in the western gulf (Figure 139). In the spring, there was only a single observation of sablefish eggs which occurred on the inner-shelf in the vicinity of Kodiak Island. No observations of sablefish eggs during the summer in the EcoFOCI database.

Larval sablefish were observed during the spring and the summer (Figure 140). Larval sablefish were abundant during the spring.

The best-fitting *MaxEnt* model indicated that depth and surface temperature were the most important variables predicting habitat suitable (relative importance 37.3 and 26.1 respectively). The AUC was 0.86 for the training data, indicating a good model fit. The AUC for the testing data was 0.67, indicating the poor model fit. The percent of the observations correctly classified in the training data was 77% and 67% for the test data. During the spring, larval sablefish habitat was predicted to occur in deeper portion of the middle- and outer-shelf in the western gulf. They high suitability habitat was predicted to occur around Shumagin and Shelikof Gully to the west of Kodiak Island; as well as in Marmot Gully east of Kodiak Island (Figure 141). During the summer, larval sablefish largely occur in the western portion of the GOA. The most important variable predicting larval habitat suitability were depth and surface temperature (31.5 and 18.1, respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.85, indicating a good model fit. The percent of the observations correctly classified in the training data was 82% and 85% for the test data. During the summer, sablefish larval habitat was predicted to occur in the deeper portions of the middle- and outer-shelf, particularly around Shumagin and Shelikof Gully off of Kodiak Island, in Amatuli Trough off the Kenai Peninsula, and off southeast Alaska.

Early juvenile sablefish were observed during the spring and the summer (Figure 142). There were no observations of early juvenile sable fish during the winter. A single early juvenile sablefish was during the spring off the eastern tip of Kodiak Island. During the summer, a single early juvenile sable fish was observed west of Kodiak Island, in Shelikof Gully.



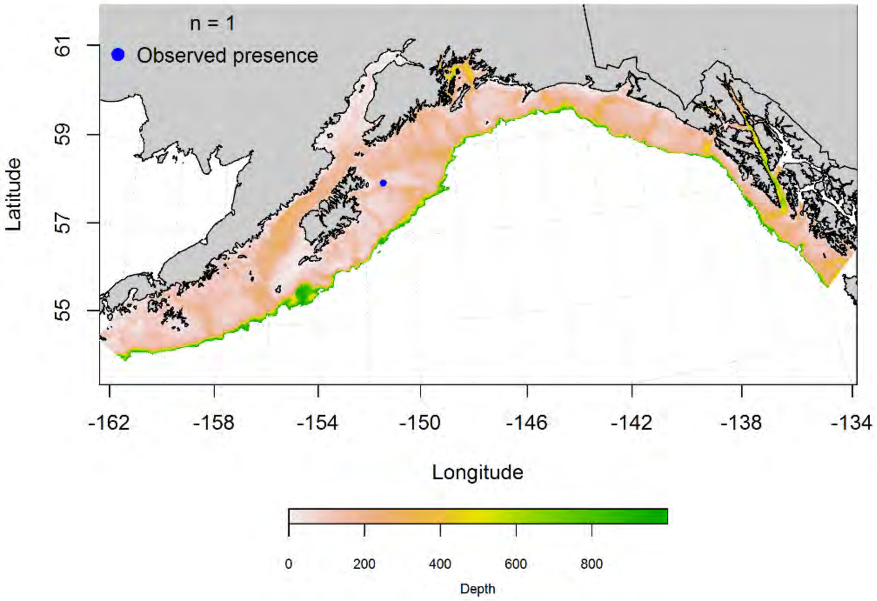


Figure 139. -- Winter, spring, and summer (top, middle, and bottom panel, respectively) observations of *A. fimbria* eggs from the Gulf of Alaska.

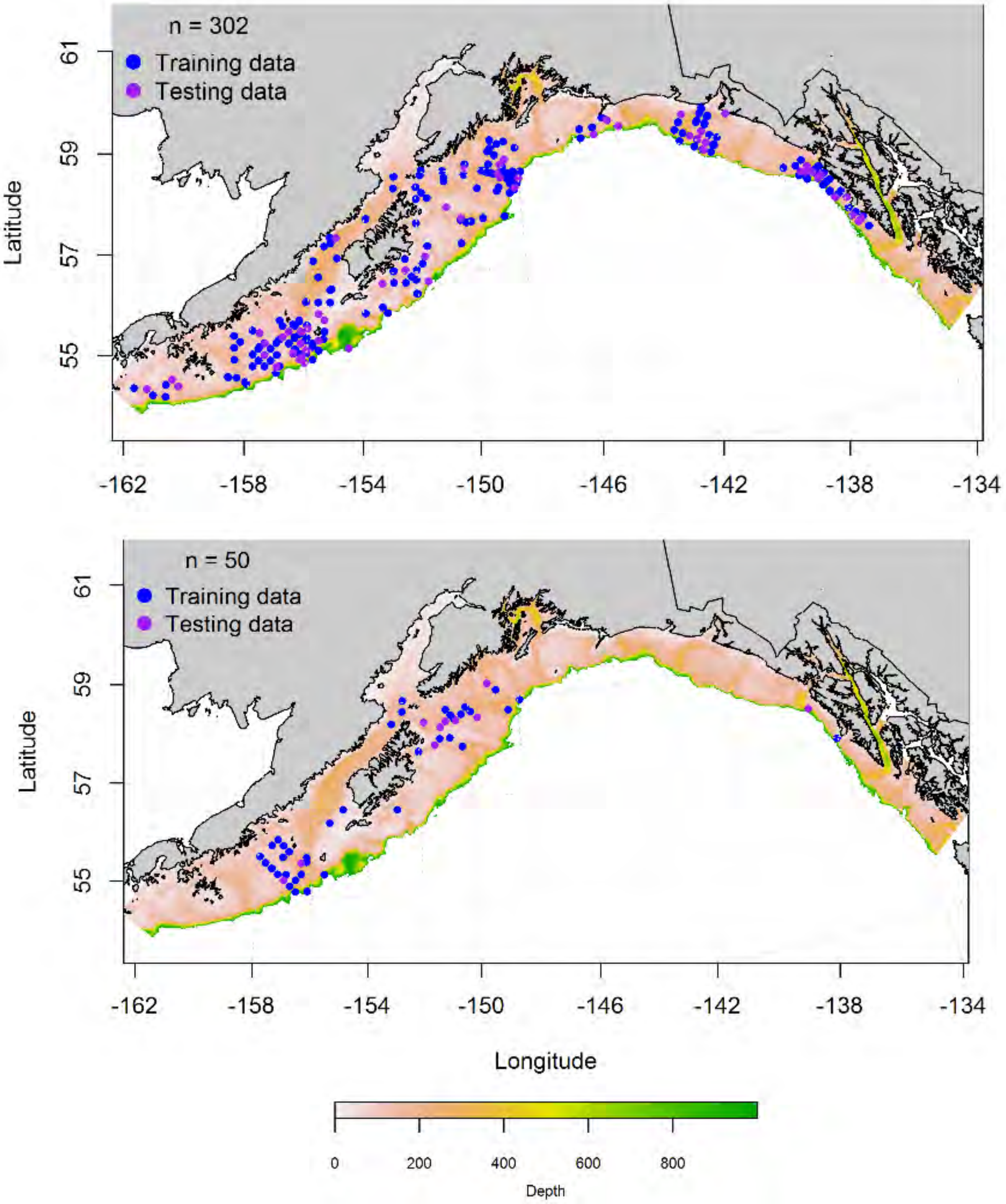


Figure 140. -- Spring and summer observations (top and bottom panel, respectively) of larval *A. fimbria* from the Gulf of Alaska.

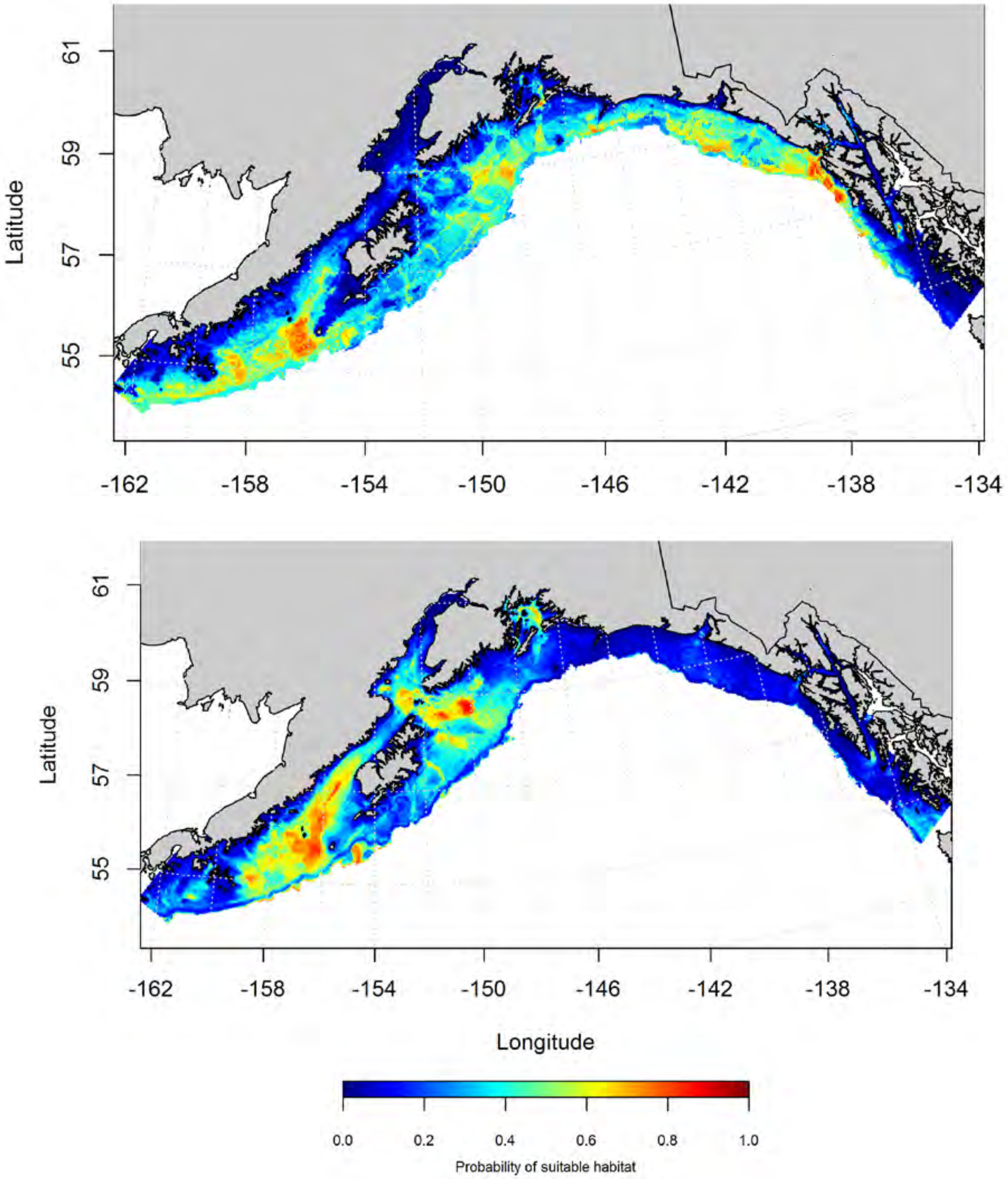


Figure 141. -- Predicted probability of spring and summer observations (top and bottom panel, respectively) distribution of larval *A. fimbria* from maximum entropy modeling of the Gulf of Alaska.

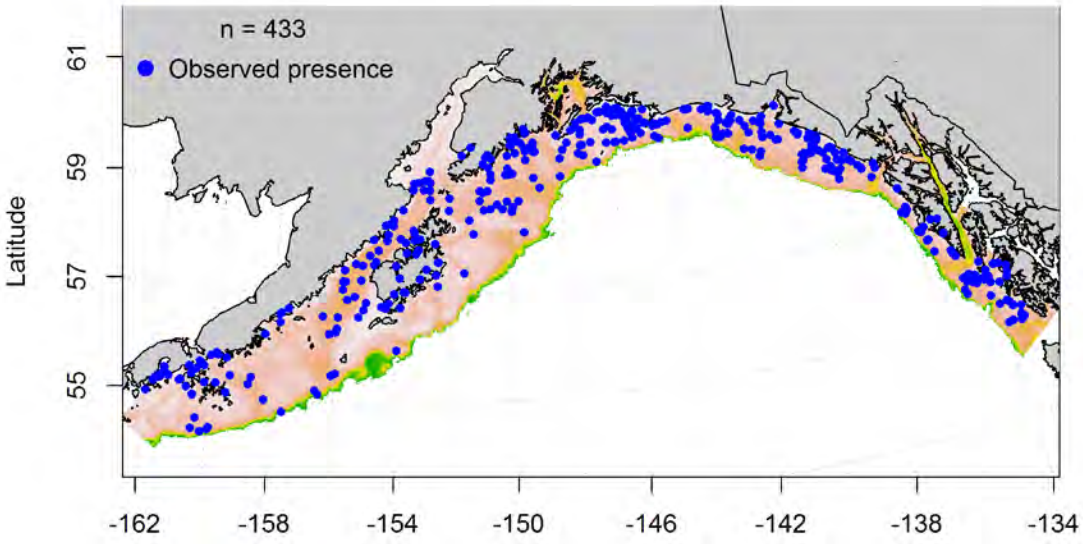
MISSING EARLY JUVENILE SABLEFISH OCCURRENCE FIGURE

Figure 142. -- Occurrences of early juvenile sablefish in FOCI ichthyoplankton surveys of the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *A. fimbria* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile sablefish are broadly distributed across much of the shelf in the GOA (Figure 143).

The variables determined to be the best predictors of the occurrence of juvenile sablefish were latitude and longitude, current speed and tidal current. The AUC for the training was 0.86, indicating a good model fit; while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was only 0.08. The percent of observations correctly classified was 78% for the training data set, and 81% for the test data set. The most important variables predicting the abundance of juvenile sablefish were tidal current, pennatulacean present, and depth. The best-fitting GAM explained 0% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile sablefish were predicted to occur along the inner- and middle-shelf in the central and eastern gulf, as well as on the inner-shelf in the western gulf. Juvenile sablefish were predicted to be abundant on the inner-shelf in the central and eastern gulf, as well as the inner-shelf in the western gulf (Figure 144). In addition, juvenile sablefish were also predicted to be abundant at the head of Cook Inlet, in Prince William Sound, and off southeast Alaska; however, these predictions were not supported by any observations.

Summer bottom trawl survey data also indicate adult sablefish occur throughout much of the shelf in the GOA (Figure 145). The best-fitting GAM indicated that depth, latitude and longitude, and current speed were the most important variables predicting the distribution of adult sablefish. The model explained 53% of the variability in CPUE for the training data and 50% of testing data. Adult sablefish were predicted to be abundant along the shelf break throughout much of the Gulf of Alaska. In addition, high abundances were also predicted to occur in Chatham Strait, in Prince William Sound, and at the head of Cook Inlet; however, these predictions were not supported by any observations.



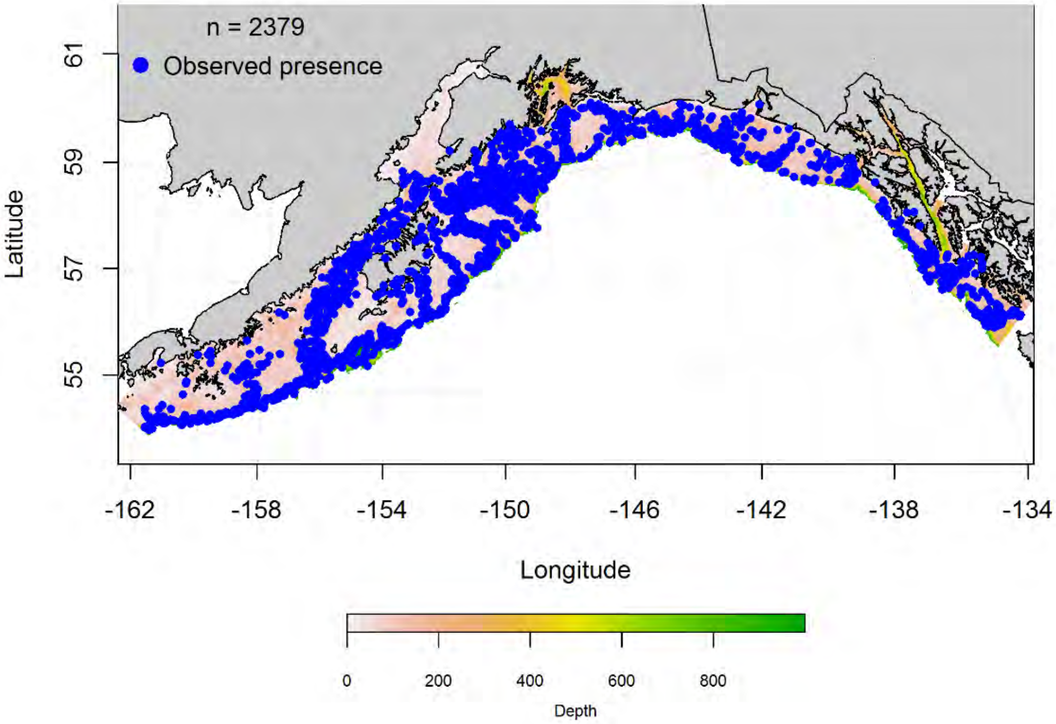


Figure 143. -- Locations of catches of juvenile and adult *A. fimbria* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska

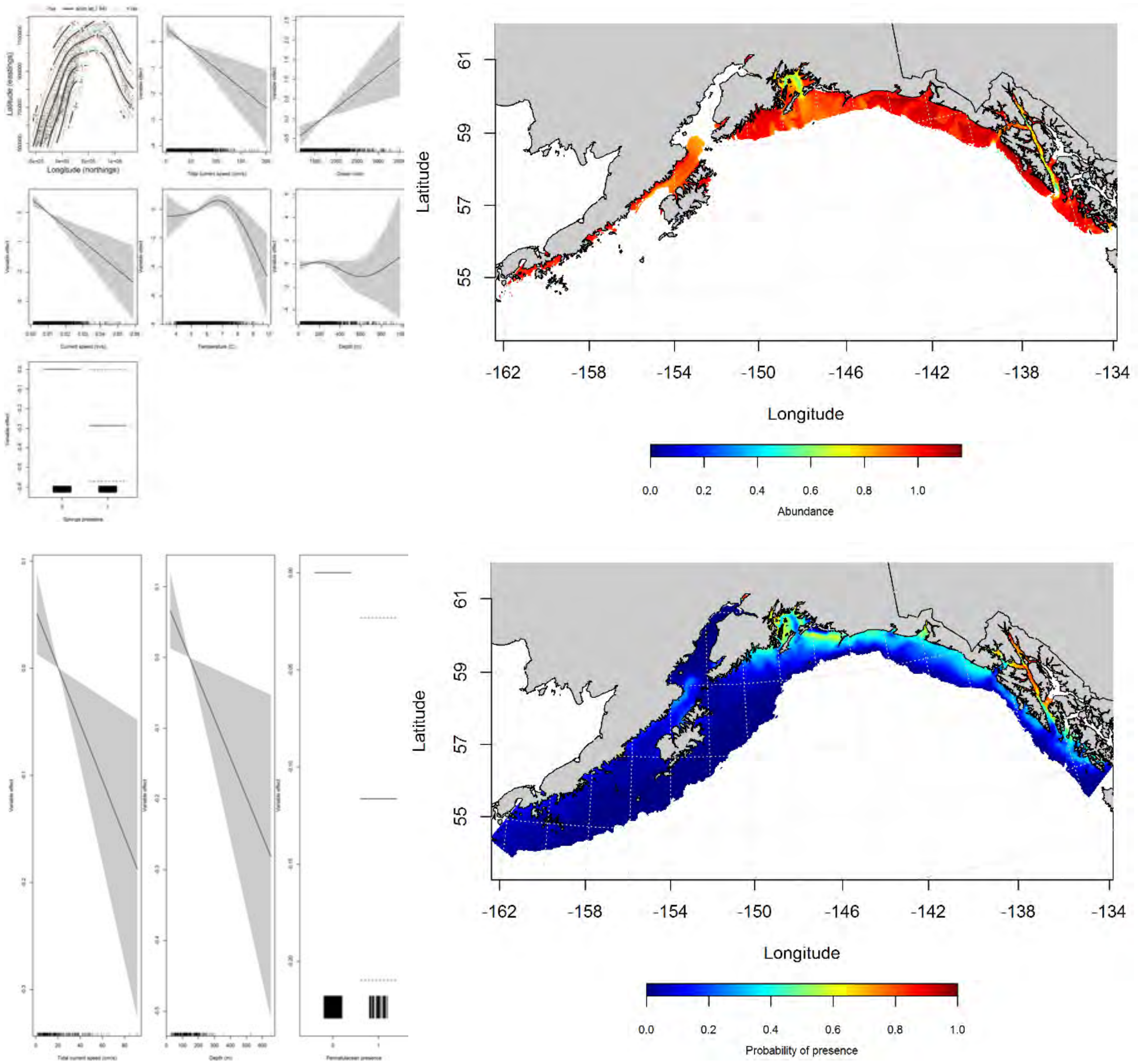


Figure 144. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *A. fimbria* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

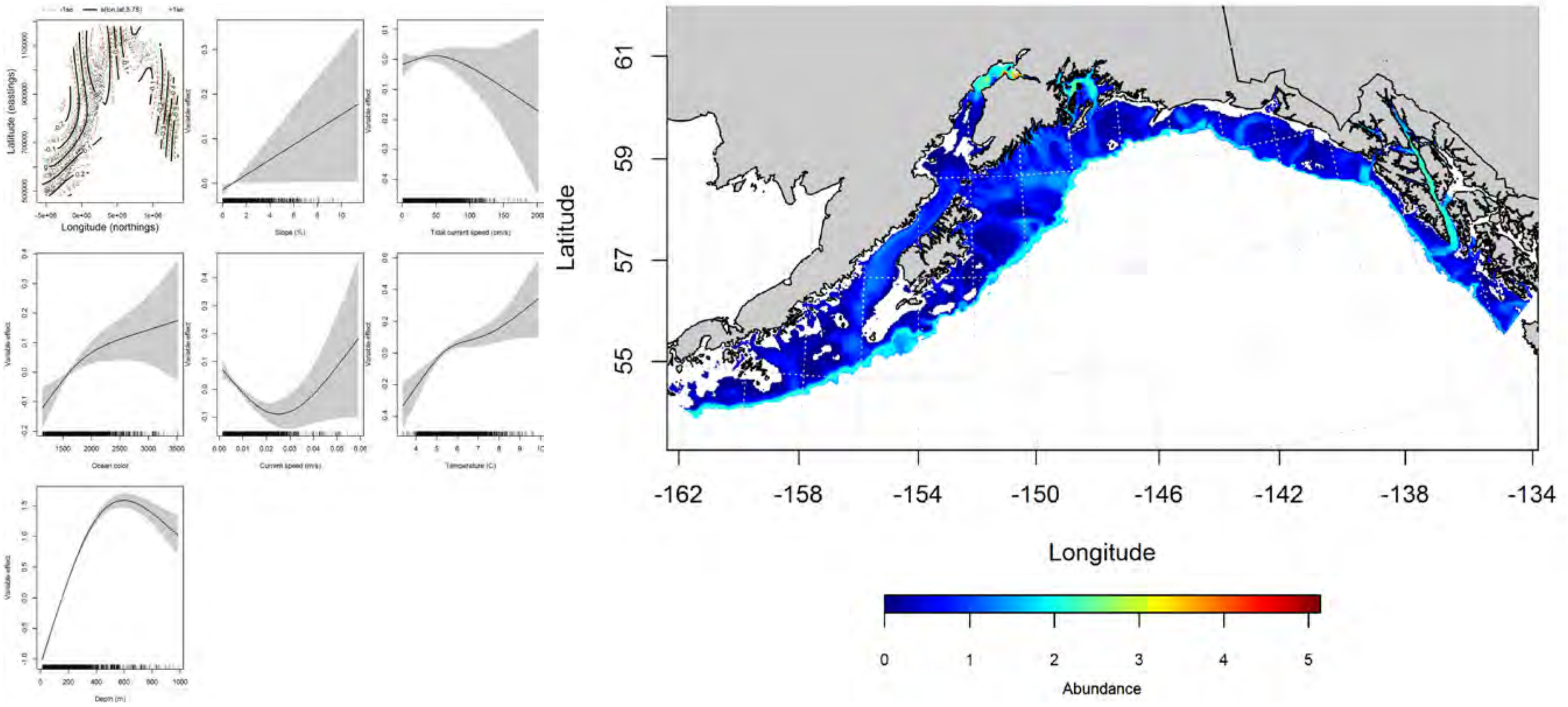


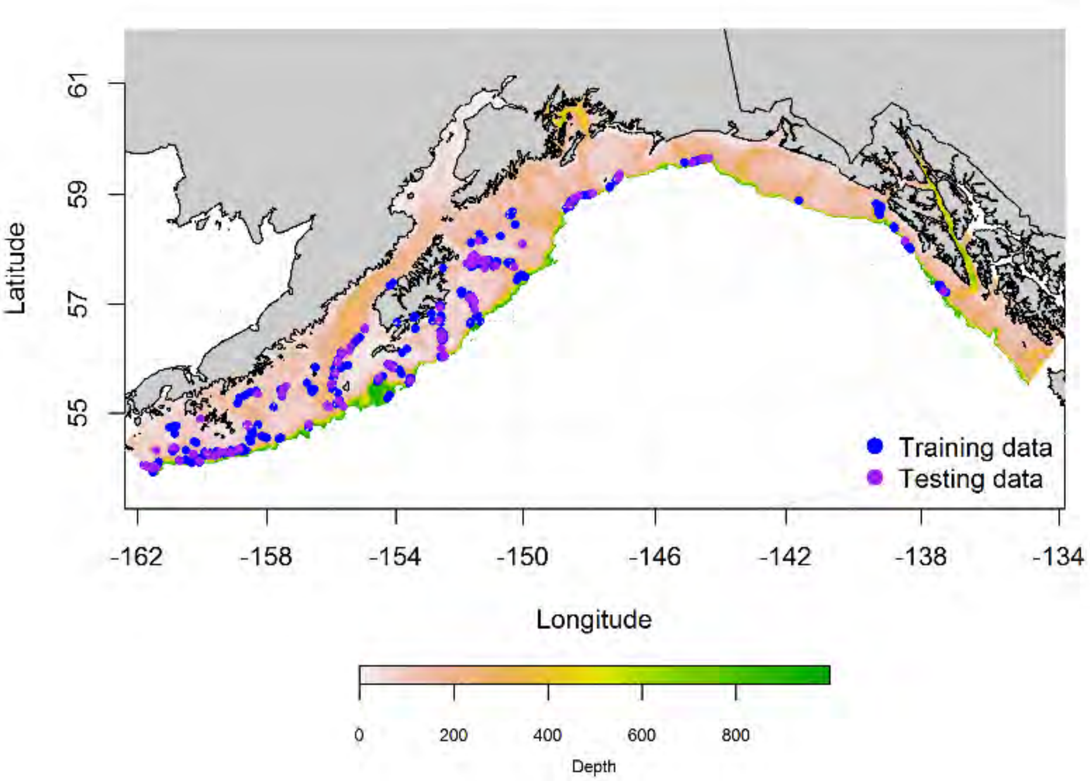
Figure 145. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *A. fimbria* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *A. fimbria* abundance (right panel)

Seasonal distribution of commercial fisheries catches of adult *A. fimbria* in the Gulf of Alaska -- Commercial catch data indicate sablefish largely occur in deeper portions of the western GOA. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of sablefish (relative importance = 32.2 and 22.1 respectively). The AUC for the training data 0.88, indicating a good model fit. The AUC for the test data was 0.77, indicating a fair model fit. The percent of observations correctly classified for the training data was 80%, and it was 77% for the test data. In the fall, high suitability habitat for adult sablefish was predicted to include most of the deeper portions of the middle- and outer-shelf, particularly in the Shumagin and Shelikof Gullies and the edge of Albatross Bank and Marmot Gully off Kodiak Island (Figure 146).

In the winter, *MaxEnt* modeling determined that current speed and tidal current were the most important variables predicting the distribution of sablefish (relative importance = 28.6 and 21.4 respectively). The AUC was 0.95 for the training data, indicating an excellent model fit. The AUC for the test data was 0.77, indicating a fair model fit. The percent of observations correctly classified was 86% and 77% respectively, for the training and test data. In the winter, the adult sablefish habitat was predicted to occur along the shelf break between Cape St. Elias and Kodiak Island (Figure 147). Localized areas of high suitability habit were also predicted in Barnabus Gully, off Kodiak Island and along the shelf break off Cape Ommaney.

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of sablefish (relative importance = 72.8 and 15.9 respectively). The AUC was 0.96 for the training data, indicating an excellent model fit. The

AUC for the test data was 0.90, indicating an excellent model fit. The percent of observations correctly classified was 90% for both the training and testing data. In the spring, high suitability for adult sablefish was predicted to occur along shelf break and deeper portions of middle-shelf (Figure 148).



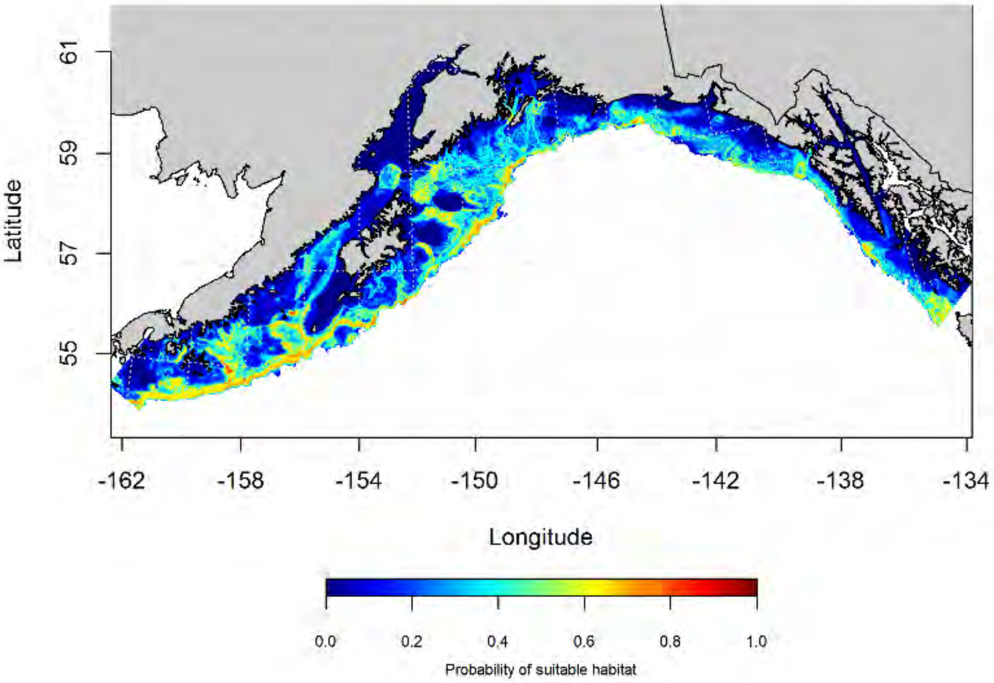
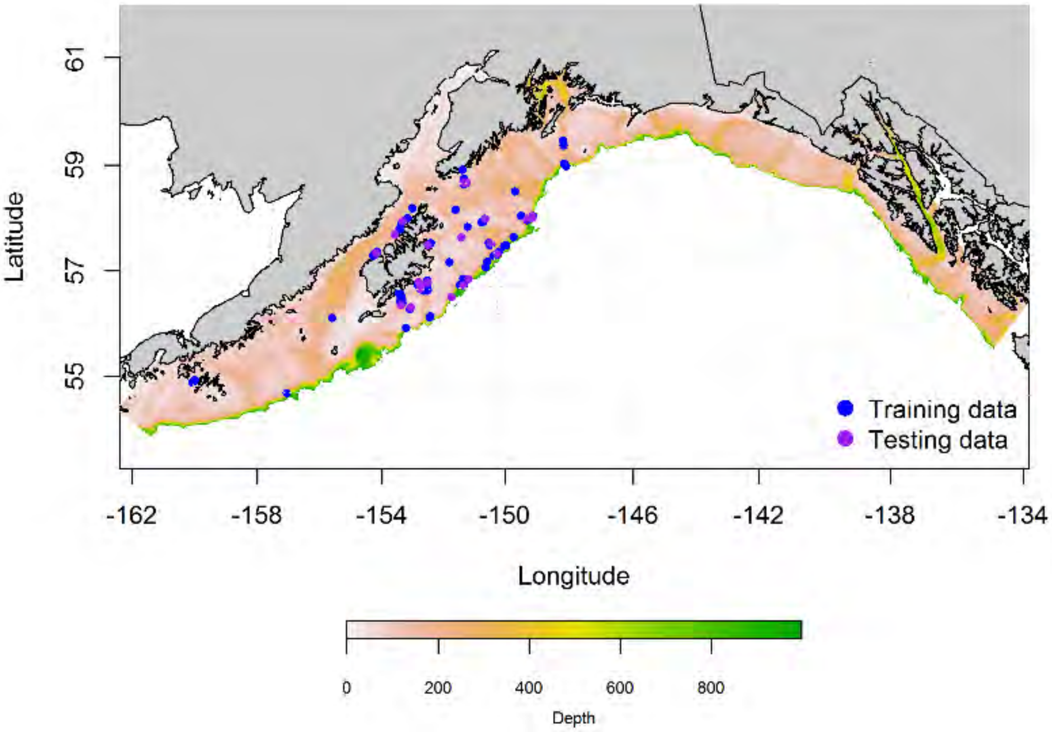


Figure 146. -- Locations of fall (September-November) commercial fisheries catches of *A. fimbria*(top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *A. fimbria* commercial catches (bottom panel) and the purple points were used to test the model.



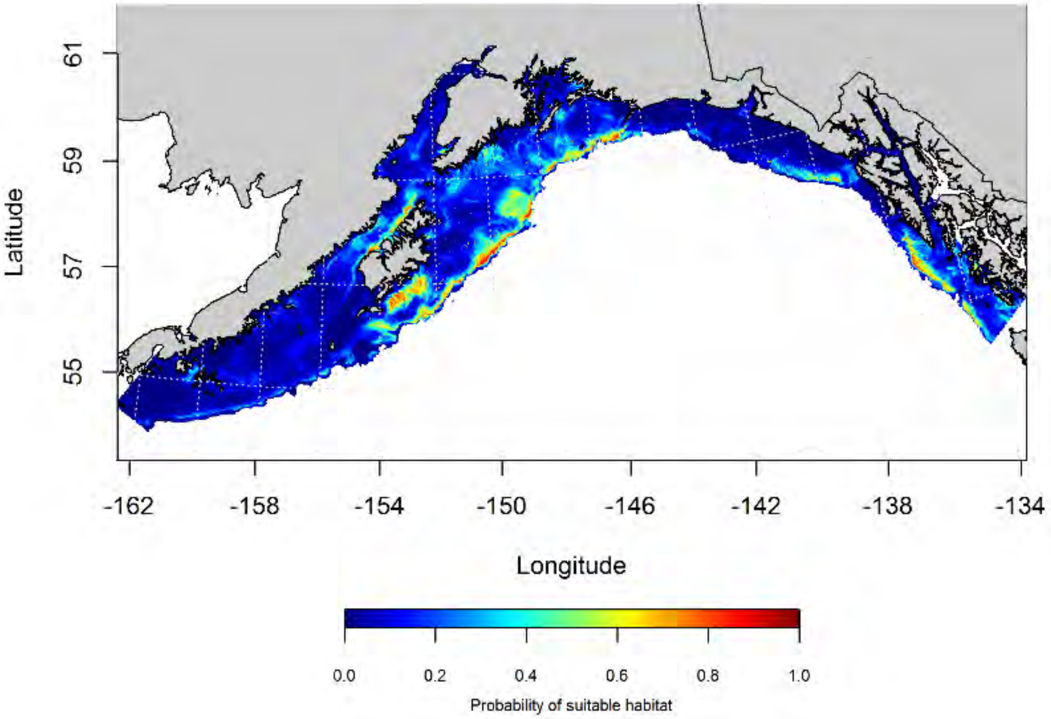


Figure 147. -- Locations of winter (December-February) commercial fisheries catches of *A. fimbria* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *A. fimbria* commercial catches (bottom panel) and the purple points were used to test the model.

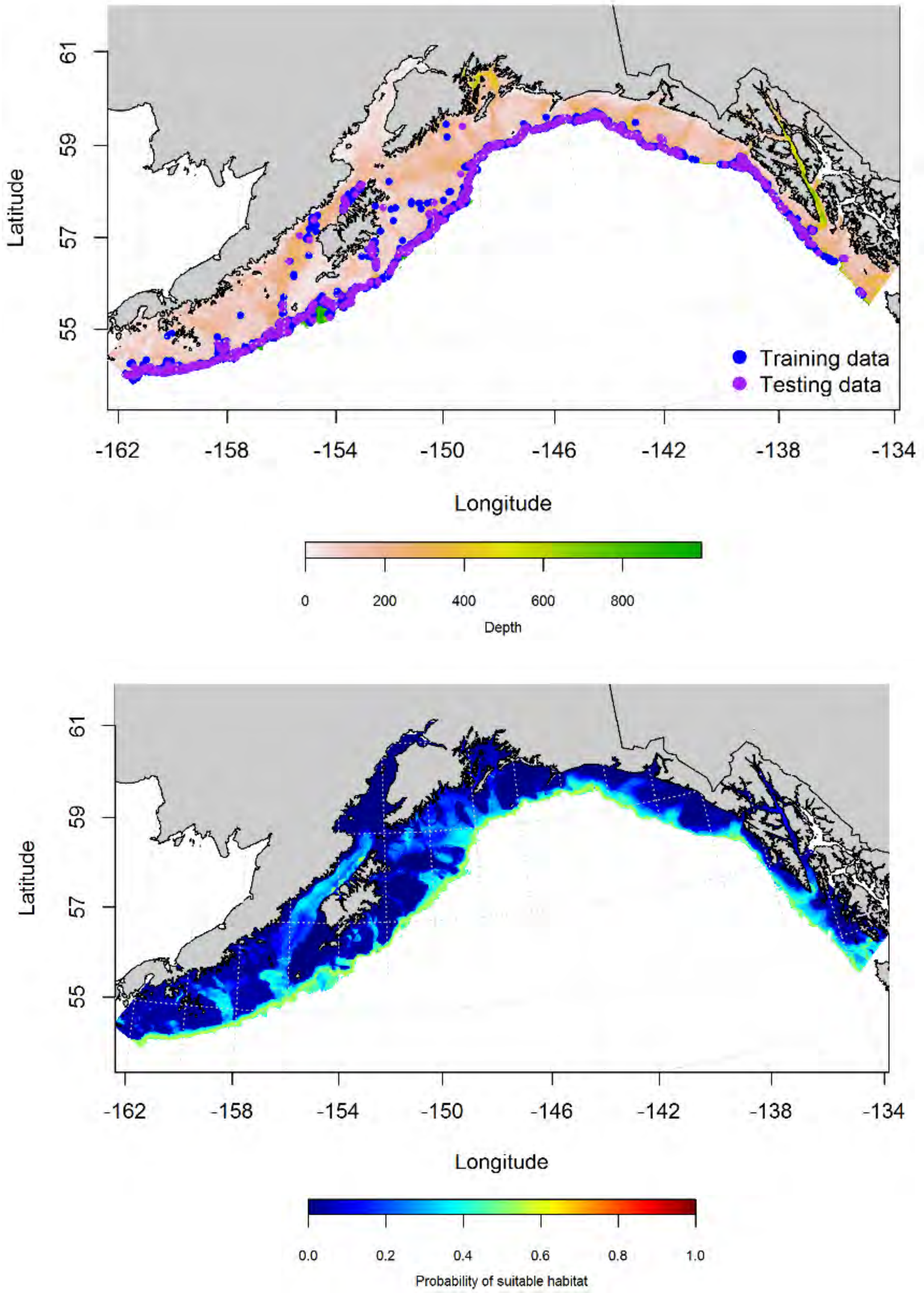


Figure 148. -- Locations of spring (March-May) commercial fisheries catches of *A. fimbria* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *A. fimbria* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *A. fimbria* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for most of the early life history stages of sablefish was predicted to occur across much of Gulf of Alaska. EFH for sablefish eggs and early juveniles could not be predicted.

Spring EFH for larval sablefish, was predicted to include much of the middle- and outer-shelf except off southeast Alaska (Figure 149). Summer EFH for juvenile sablefish was predicted to largely occur in the western gulf. EFH for early juvenile sablefish could not be predicted.

Summer EFH for juvenile sablefish, based on trawl survey observations, was predicted to include much of the inner- and middle-shelf in the eastern GOA (Figure 150). EFH for juvenile sablefish was also predicted to occur at the head of Cook Inlet; however, these predictions were not supported by any observations. EFH for adult sablefish, was more predicted to be extensive than the juvenile habits. It was predicted to include much of the deeper portions of the middle- and outer-shelf across the Gulf of Alaska. EFH for adult sablefish was also predicted to occur at the head of Cook Inlet, in Prince William Sound, and in some of the inside waters in southeast Alaska; however, these predictions were not supported by any observations.

Fall EFH for adult sablefish, based on commercial fisheries data, and was predicted to include much of the deeper portion of the middle- and outer-shelf continental shelf in the GOA (Figure 151). During the winter, EFH for sablefish was predicted to largely occur along the shelf break, and to a lesser extent on the deeper portions of the middle-shelf in the central gulf (Figure 13.12). During the spring, EFH for adult sablefish was predicted to mainly occur along the shelf break, and to a lesser extent the deeper portion of the middle-shelf.

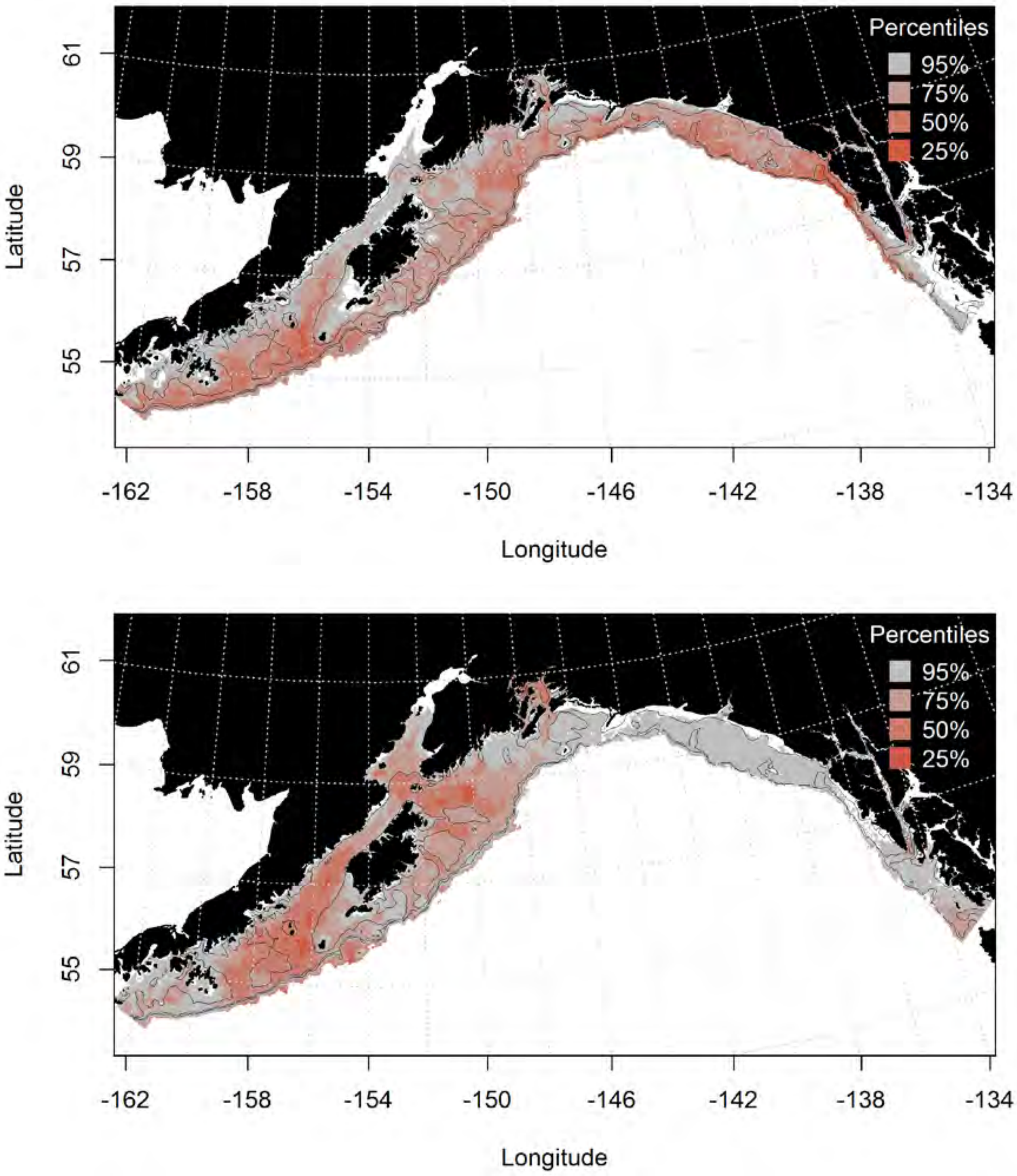


Figure 149. -- Spring and summer (top and bottom panel, respectively) essential fish habitat predicted for larval *A. fimbria* from the EcoFOCI database.

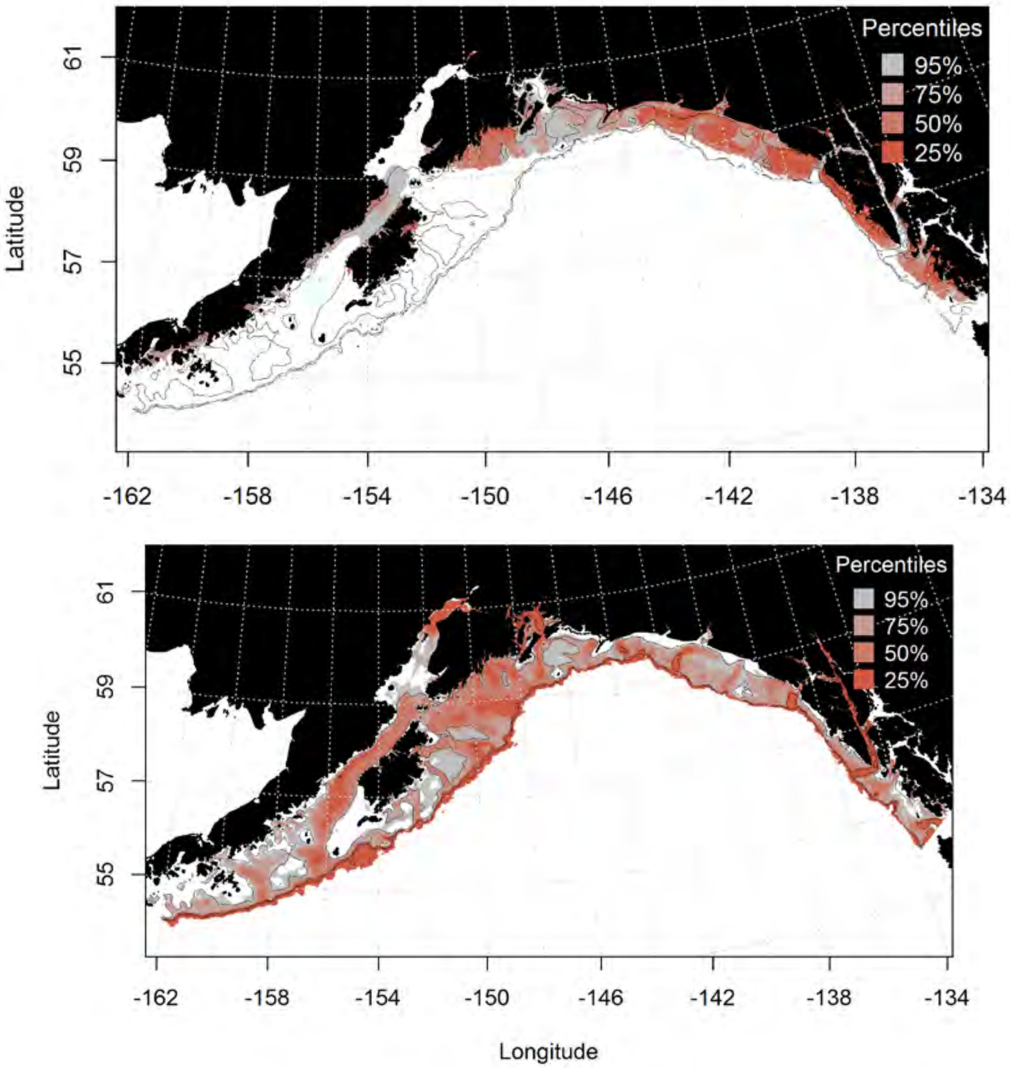


Figure 150. -- Predicted summer essential fish habitat for *A. fimbria* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

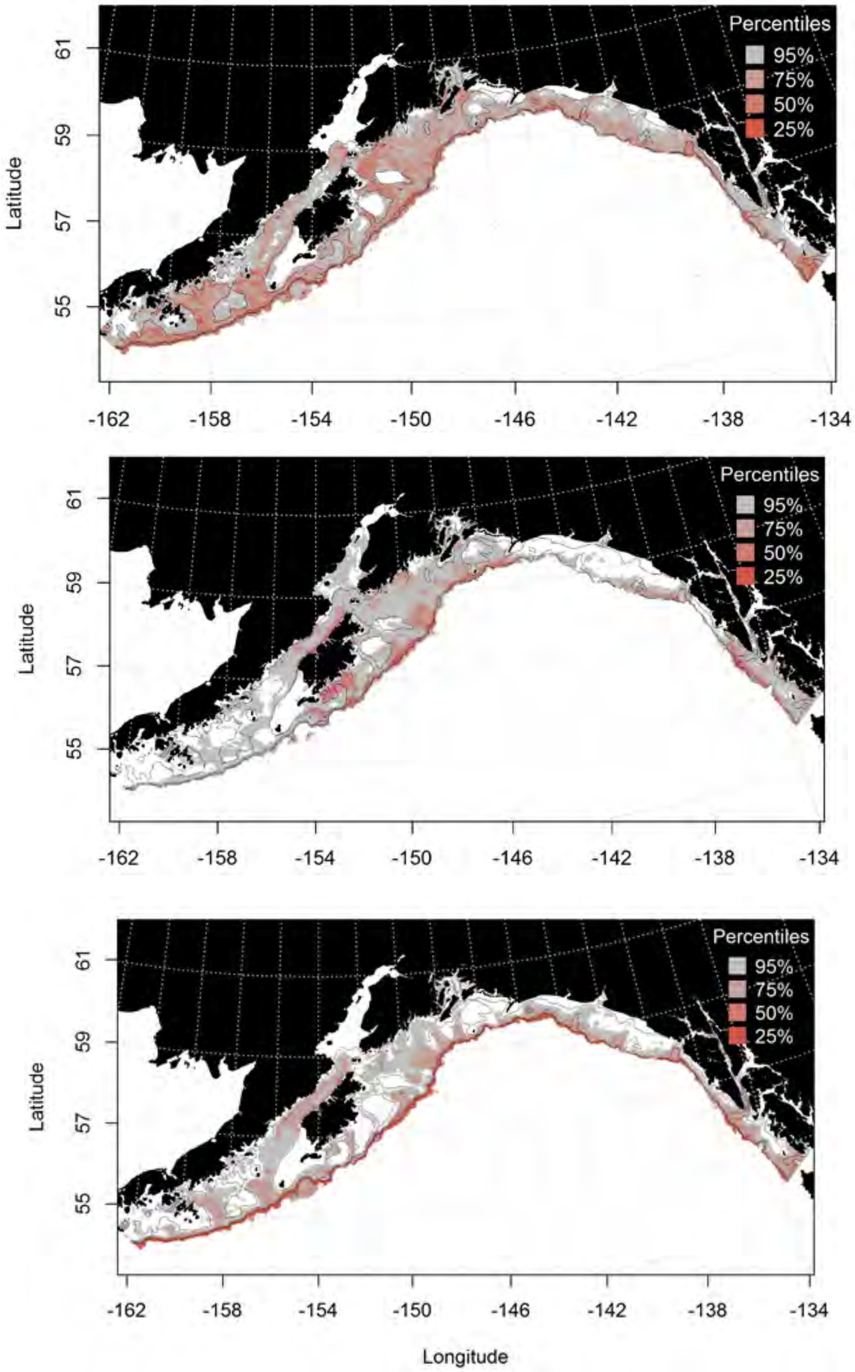


Figure 151. -- Essential fish habitat predicted for *A. fimbria* during fall (top panel), winter (middle panel) and fall (bottom panel) from commercial catches.

Atka mackerel (*Pleurogrammus monopterygius*)

Atka mackerel were abundant in the Gulf of Alaska, in the area west of the Shumagin islands. Most occurred in less than 100 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *P. monopterygius* in the Gulf of Alaska -- Throughout much of their early life history Atka mackerel largely occured in the western portion of the Gulf of Alaska. There were no observations of Atka mackerel eggs in the EcoFOCI database.

Larval Atka mackerel were observed during the winter and spring (Figure 152). During the winter nine larval Atka mackerel observed on the middle-shelf off Kodiak Island. During the spring, six larval Atka mackerel were observed. Most occurred on the middle-shelf off of Kodiak Island. There were insufficient data to model the distribution of larval Atka mackerel.

A single early juvenile Atka mackerel was observed during the spring, it occurred along the shelf break in the vicinity of Yakutat Valley (Figure 153).

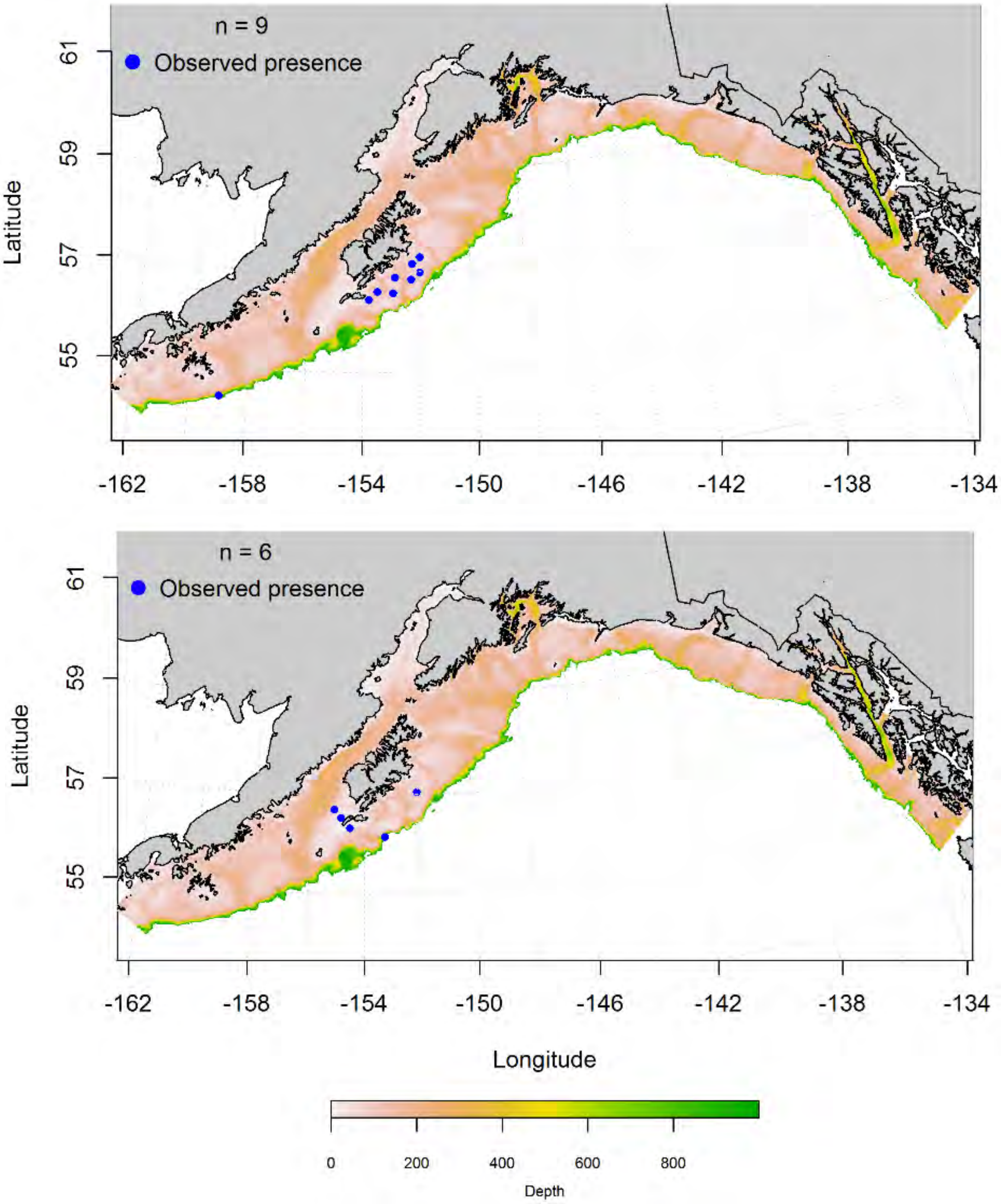


Figure 152. -- Winter and spring observations (top and bottom panel, respectively) of larval *P. monopterygius* from the Gulf of Alaska.

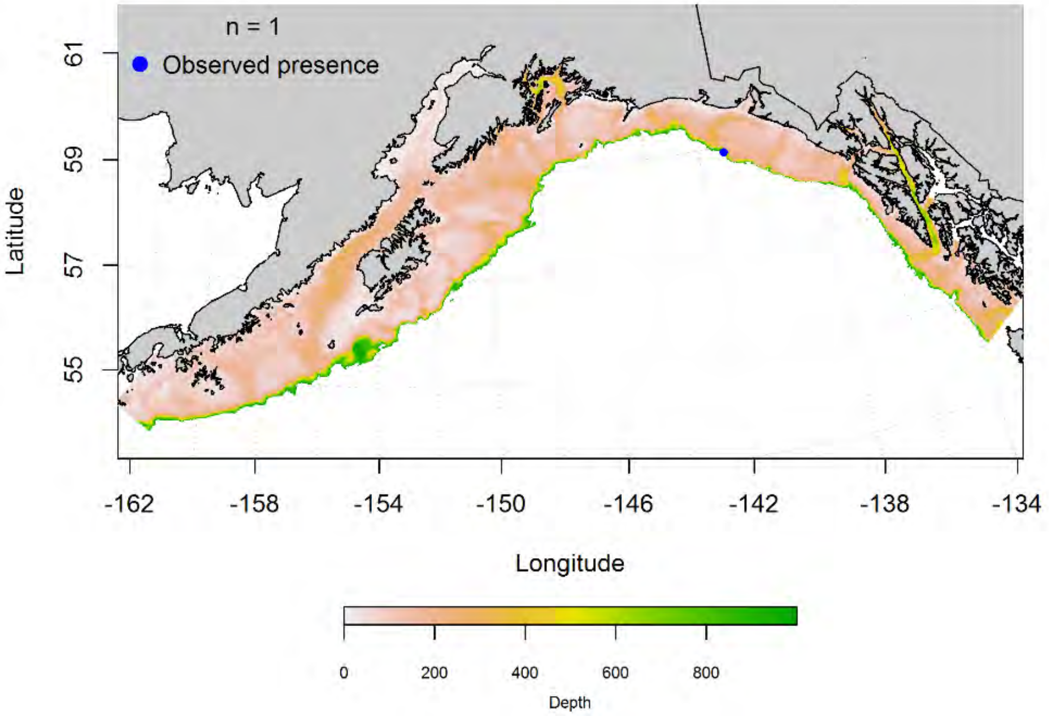
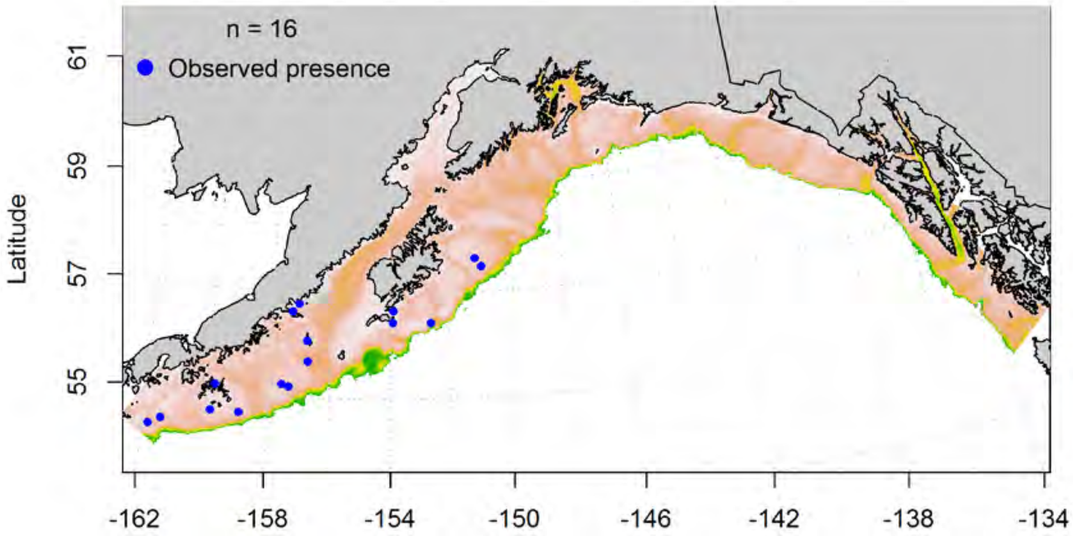


Figure 153. -- Spring catch (top and bottom, respectively) of early juvenile *P. monopterygius* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *P. monopterygius* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate Atka mackerel largely occur in the western portions of the Gulf of Alaska (Figure 154). Sixteen juvenile Atka mackerel were observed during the summer bottom trawl survey, most occurred along the middle-shelf west of Kodiak Island. Adult Atka mackerel were more abundant and they also largely occured in the western GOA.

The variables determined to be the best predictors of the occurrence of adult Atka mackerel were latitude and longitude, tidal currents and depth. The AUC for both the training and test data was 0.86, indicating a good model fit. The AUC for both the training and test data was 0.83, indicating a good model fit. The optimum threshold was only 0.08. The percent of observations correctly classified was 79% for the training data set, and 81% for the test data set. The most important variables predicting the abundance of adult Atka mackerel were coral presence, depth, and temperature. The best-fitting GAM explained 13% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult Atka mackerel were predicted to occur along the outer-shelf west of Chirikof Island. They were predicted to be most abundant along the middle-and outer-shelf west of Chirikof Island (Figure 155).



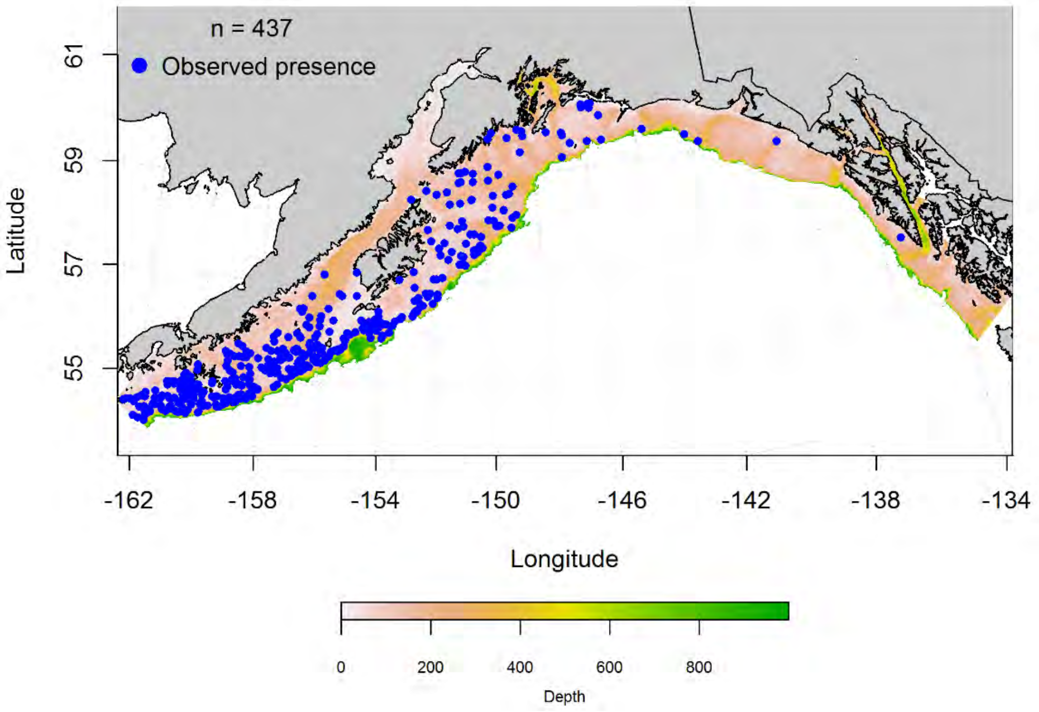


Figure 154. -- Locations of catches of juvenile and adult *P. monopterygius* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

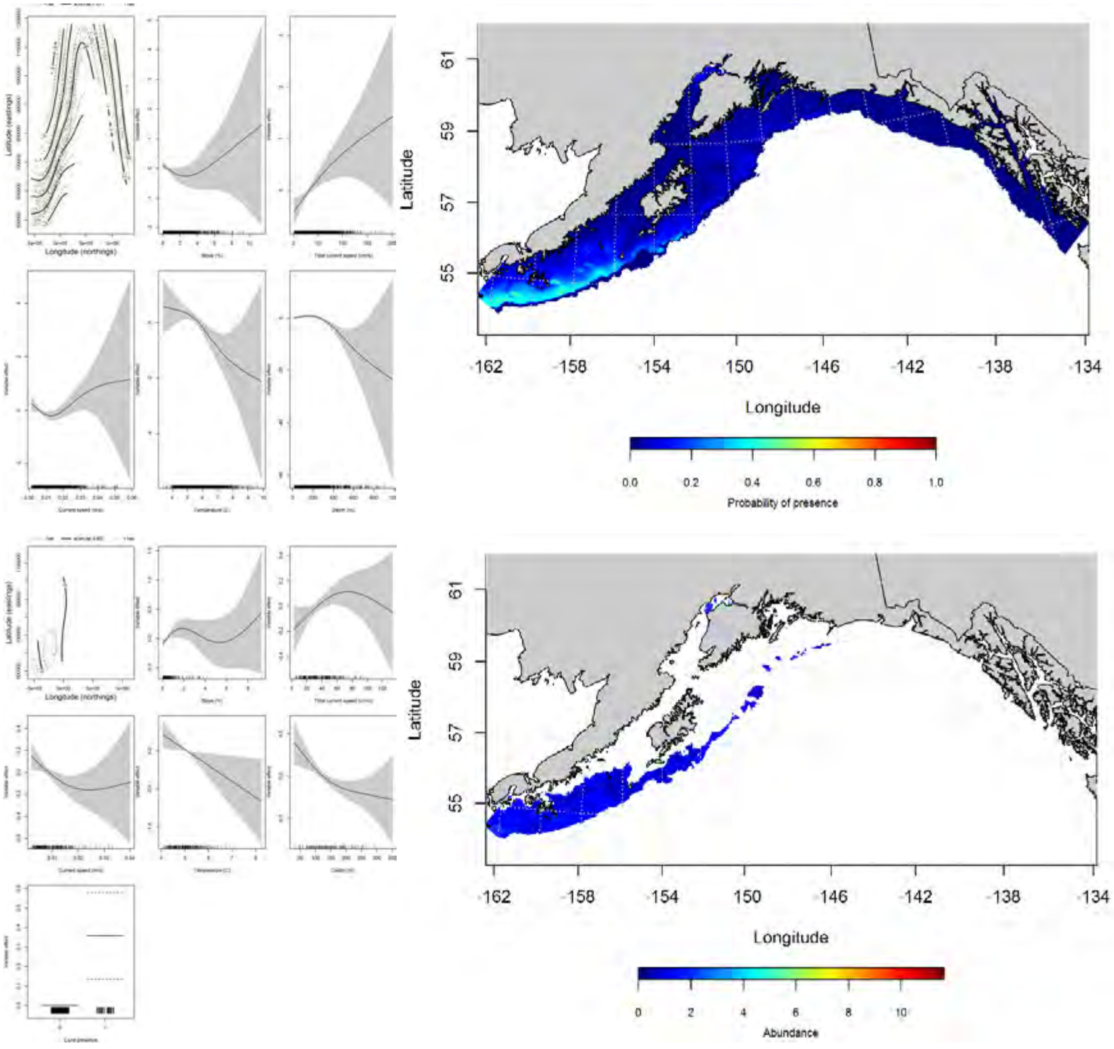
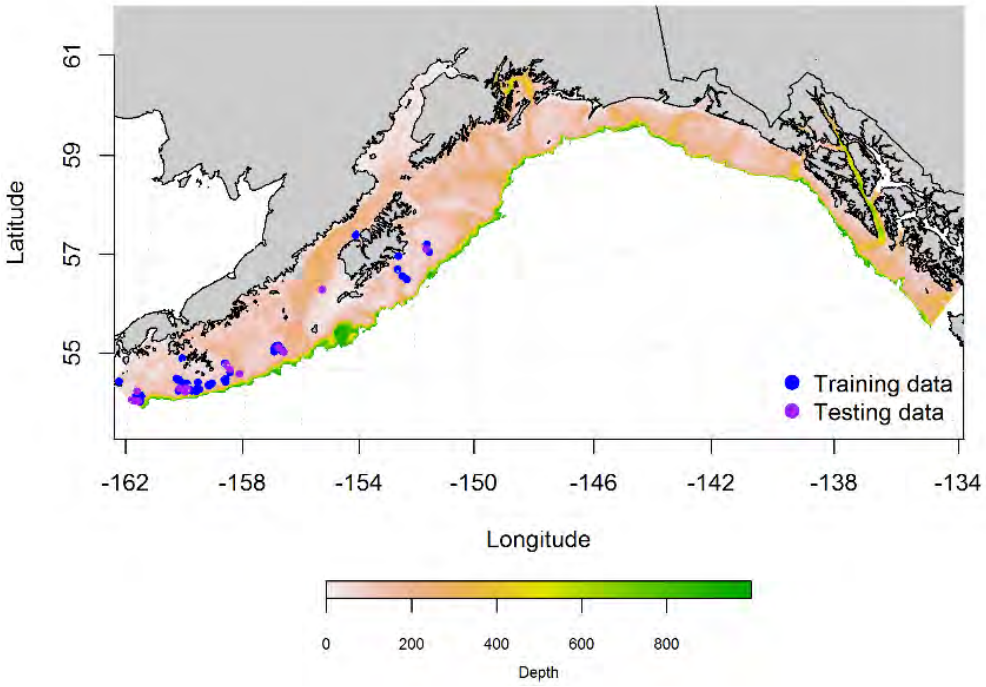


Figure 155. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *P. monopterygius* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *P. monopterygius* in the Gulf of Alaska -- Commercial catch data indicate that Atka mackerel largely occur in the western GOA. In the fall, *MaxEnt* modeling determined that ocean color, bottom temperature, and current speed were the most important variables predicting the distribution of adult Atka mackerel (relative importance = 32.1 and 25.6 respectively). The AUC for the training data 0.94, indicating an excellent model fit. The AUC for the test data was 0.85, indicating a good model fit. The percent of observations correctly classified for the training data was 88%, and it was 85% for the test data. In the fall, Atka mackerel were predicted to occur on the middle- and outer-shelf between the Semidi Islands and Davidson Bank (Figure 156).

In the winter, Atka mackerel habit included large portions of the central and western GOA. *MaxEnt* modeling determined that depth and ocean color were the most important variables determining the distribution of Atka mackerel (relative importance = 45.2 and 25.0 respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The percent of observations correctly classified was 87% and 83% respectively, for the training and test data. In the winter, Atka mackerel were predicted to occur in the shallower portions of the middle-shelf in the central and western gulf. High suitability habits were predicted to occur on Davidson Bank on the Alaska Peninsula, on Albatross and Portlock Banks off the Kodiak Island, and on Wessels Reef in the central gulf (Figure 157).

In the spring, Atka mackerel habit largely occurred west of Chirikof Island. *MaxEnt* modeling determined ocean color and tidal current were the most important variables determining the distribution of Atka mackerel (relative importance = 31.5 and 24.0 respectively). The AUC was 0.97 for the training data, indicating an excellent model fit. The AUC for the test data was 0.87, indicating a good model fit. The percent of observations correctly classified was 92% and 87% respectively, for the training and test data. In the spring, Atka mackerel were predicted to occur on the deeper portions of the middle-shelf in the western gulf, including Shelikof and Shumagin Gullies (Figure 158).



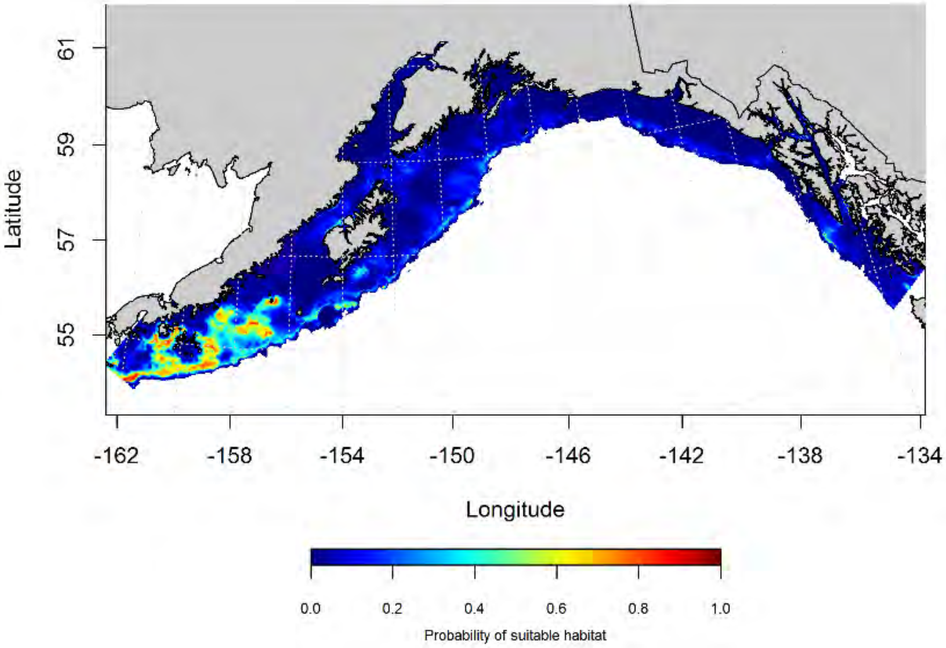


Figure 156. -- Locations of fall (September-November) commercial fisheries catches of *P. monopterygius* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *P. monopterygius* commercial catches (bottom panel) and the purple points were used to test the model.

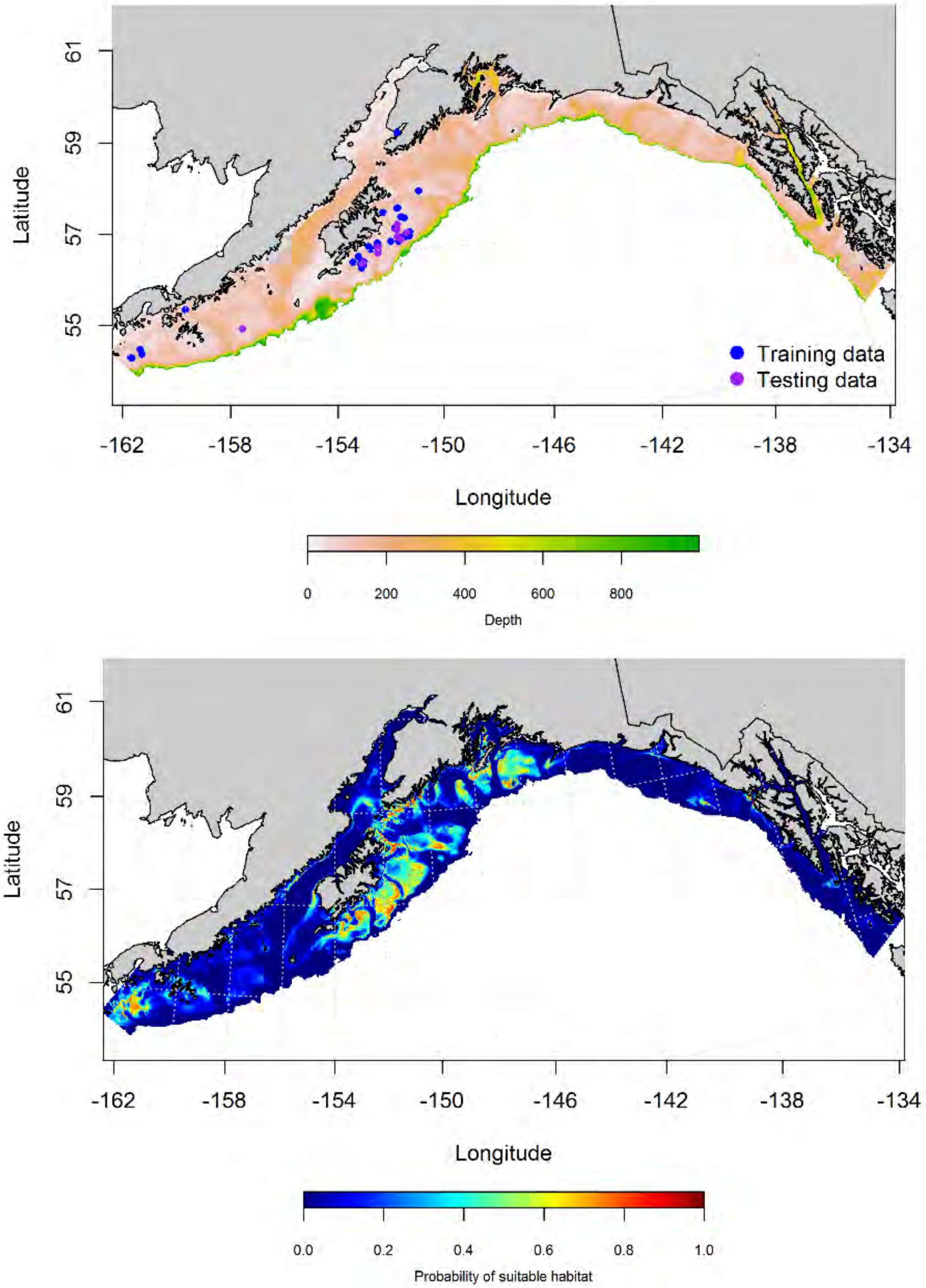


Figure 157. -- Locations of winter (December-February) commercial fisheries catches of *P. monopterygius* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *P. monopterygius* commercial catches (bottom panel) and the purple points were used to test the model.

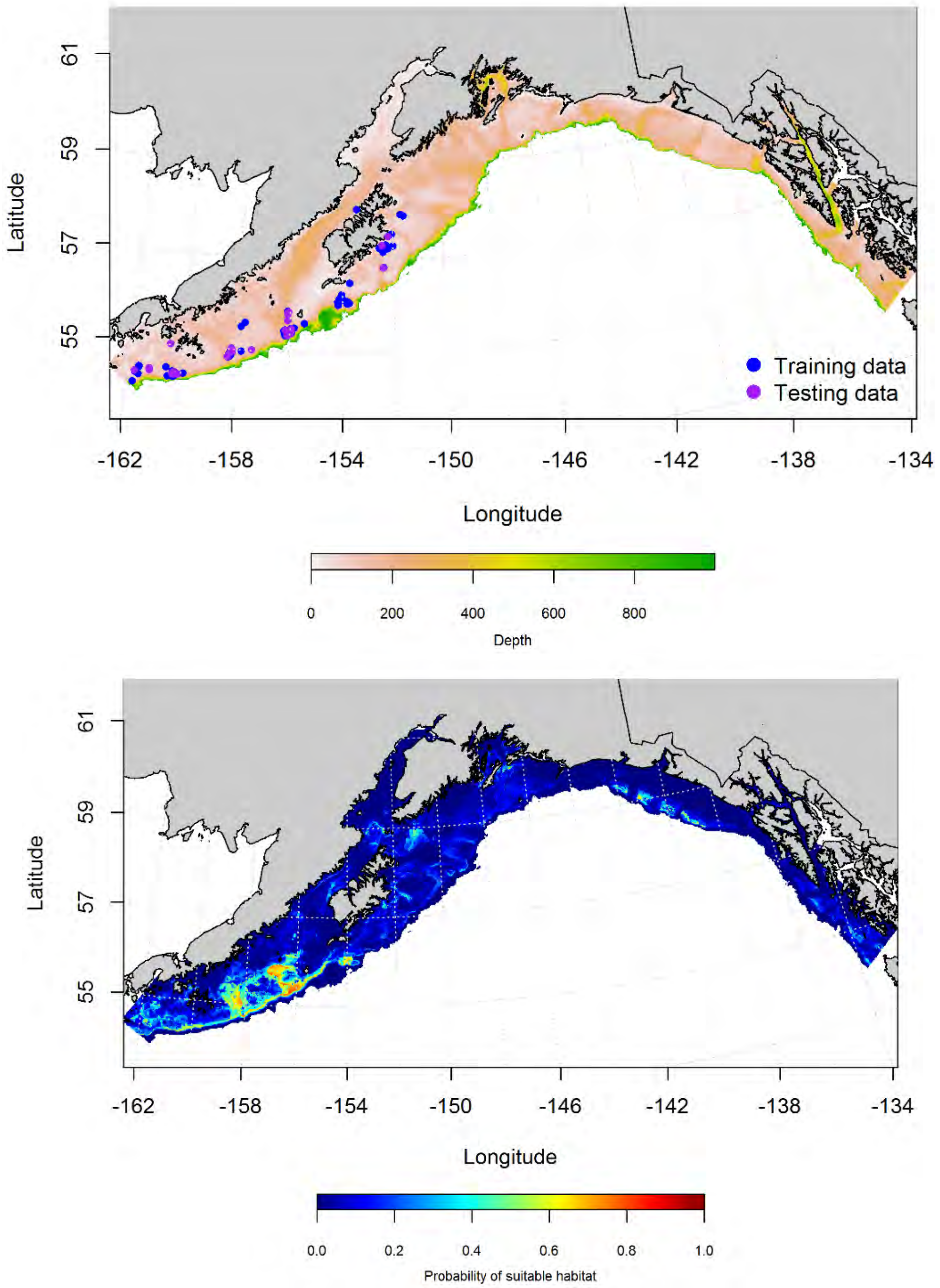


Figure 158. -- Locations of spring (March-May) commercial fisheries catches of *P. monopterygius* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *P. monopterygius* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *P. monopterygius* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Atka mackerel was predicted to occur in the western Gulf of Alaska. There was an insufficient data to model EFH for any of the early life history stages of Atka mackerel, based on observations in the EcoFOCI database.

There was insufficient data to model EFH for juvenile Atka mackerel, based on observations from the summer trawl survey. Summer EFH for adult Atka mackerel, based on summer trawl survey data, occured along the shelf break off Kodiak Island, and middle- and outer-shelf west of Chirikof Island (Figure 159). EFH for adult Atka mackerel was also predicted to occur in Cook Inlet; however, his was not supported by any observations.

Fall EFH for adult Atka mackerel, based on commercial fisheries data, and was predicted occur on the middle- and outer-shelf, from the Semidi Islands to Davidson Bank (Figure 14.8). During the winter, EFH for Atka mackerel was predicted to occur on the middle- and outer portions of the central and western GOA, particularly around Davidson Bank; on Albatross and Portlock Banks, and around Wessels Reef (Figure 160). During the spring, EFH for adult Atka mackerel was predicted to occur along the deeper portion of the middle-and outer-shelf, west of Chirikof Island.

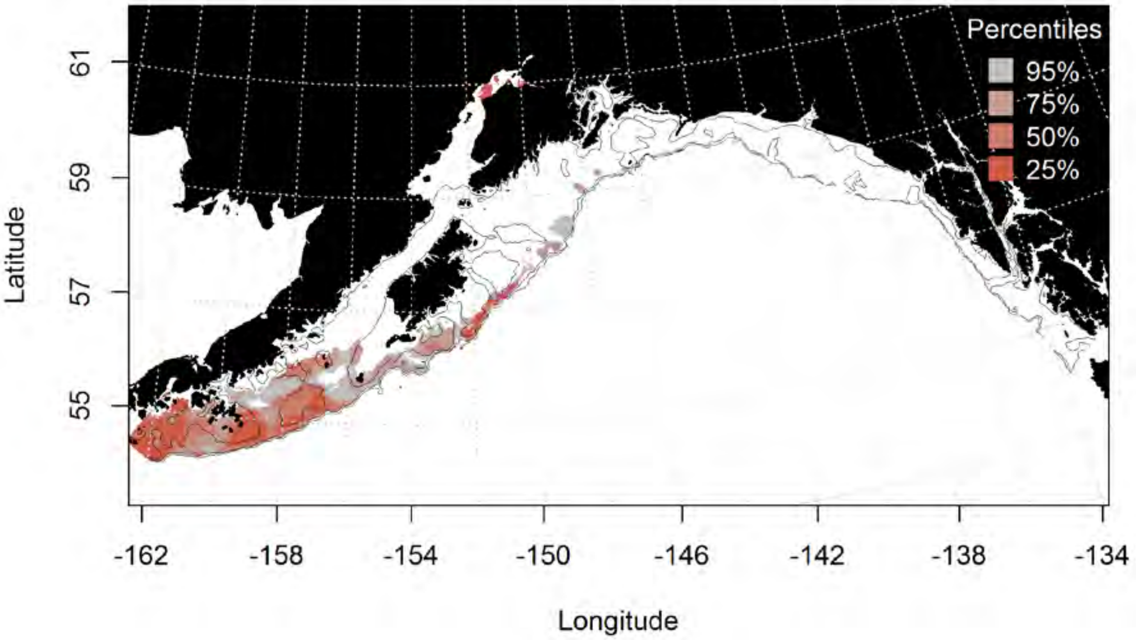


Figure 159. -- Predicted summer essential fish habitat for *P. monopterygius* adults from summer bottom trawl surveys.

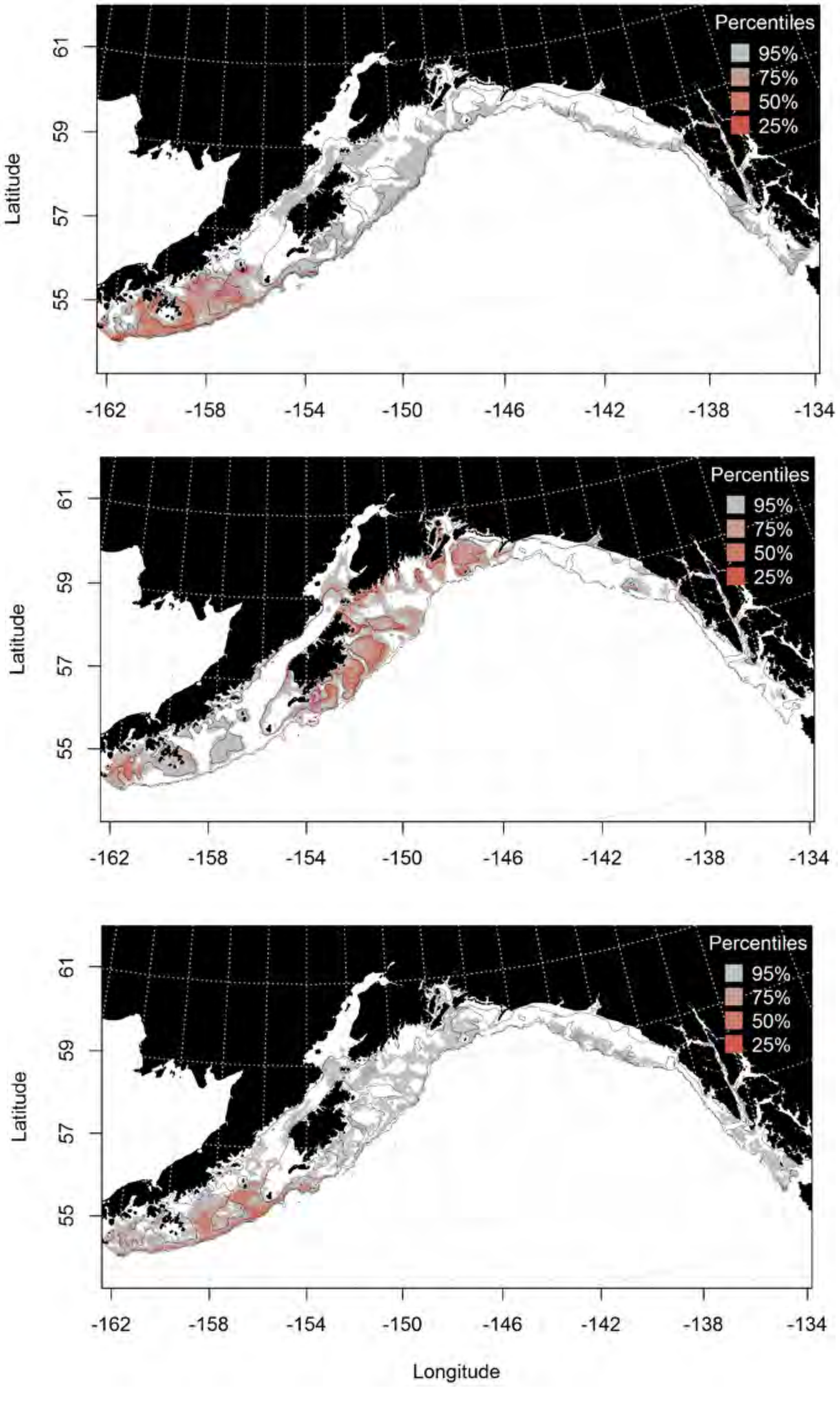


Figure 160. -- Essential fish habitat predicted for *P. monopterygius* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

yellow irish lord (*Hemilepidotus jordani*)

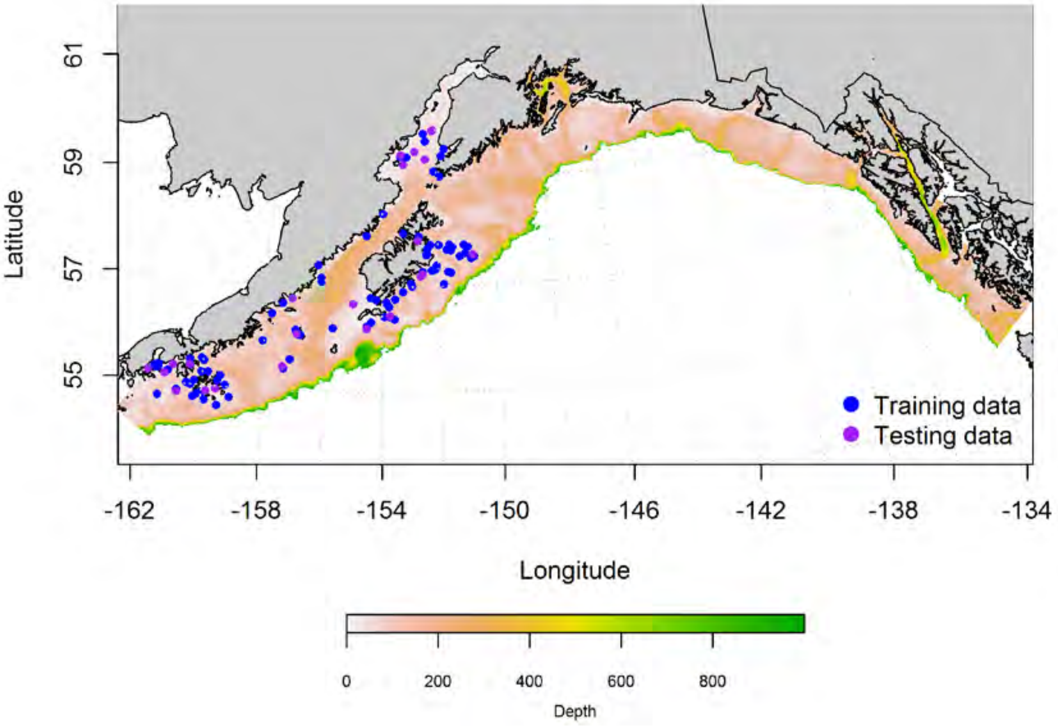
Yellow irish lords occur throughout the Gulf of Alaska. They are usually found on soft bottoms, from subtidal depths to 110 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *H. jordani* in the Gulf of Alaska -- There were no observations of any early life history stage of yellow Irish lords in the EcoFOCI database.

Spring and summer distribution of juvenile and adult *H. jordani* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile yellow Irish lord largely occur in the western Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and ocean color the most important variables predicting habitat suitability (relative importance 86.8 and 4.2 respectively). The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.68, indicating a poor model fit. The percent of correctly classified observations was 89% for the training data and 68% for the test data. Summer juvenile yellow Irish lord habitat was predicted to occur across much of the shallower portions of the inner- and middle-shelf throughout the GOA (Figure 161). High suitability habits were predicted to occur around the Shumagin Island and in nearshore waters along the Alaska Peninsula, on Albatross and Portlock Banks, in Cook Inlet.

Adult yellow Irish lord also largely occur in the western gulf (Figure 162).

The variables determined to be the best predictors of the occurrence of adult yellow Irish lord were latitude and longitude, depth, and current speed. The AUC for the training was 0.88, indicating a good model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.16. The percent of observations correctly classified was 80% for the training data set, and 91% for the test data set. The most important variables predicting the abundance of juvenile yellow Irish lord were longitude and latitude, depth, and ocean color. The best-fitting GAM explained 4% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult yellow Irish lord were predicted to occur along much of the shallower portion of the inner- and middle-shelf in the western gulf. Yellow Irish lord were predicted to be abundant in the Shumagin Islands and Sandman Reefs, on Albatross Bank, and in nearshore waters along the Alaska Peninsula (Figure 163).



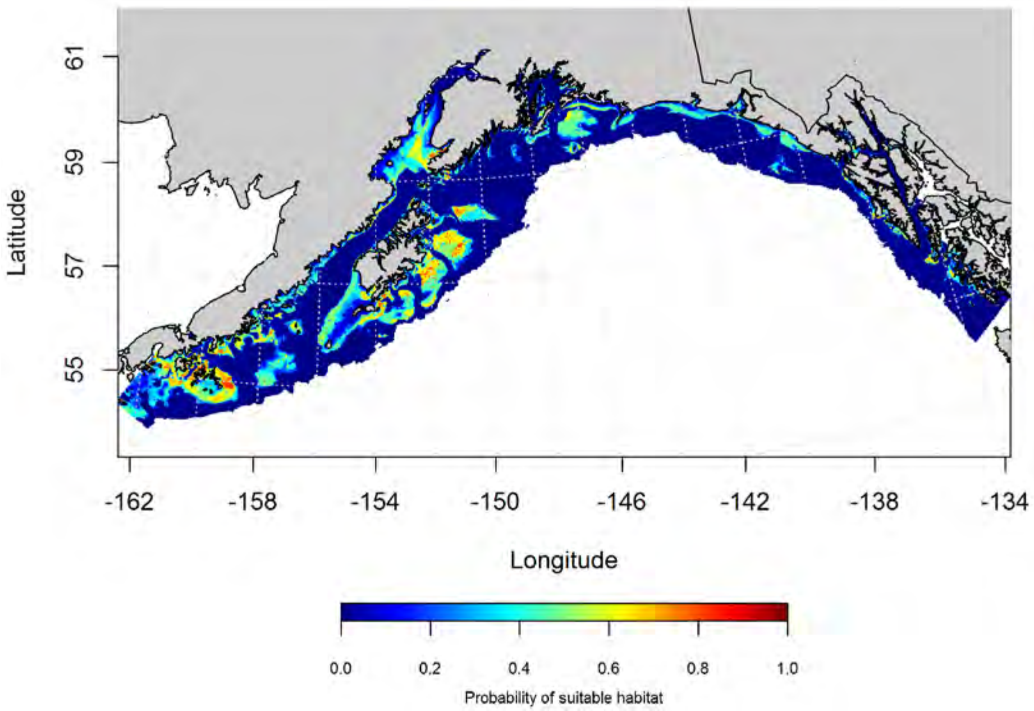


Figure 161. --Locations of trawl survey catches of juvenile *H. jordani* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *H. jordani* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

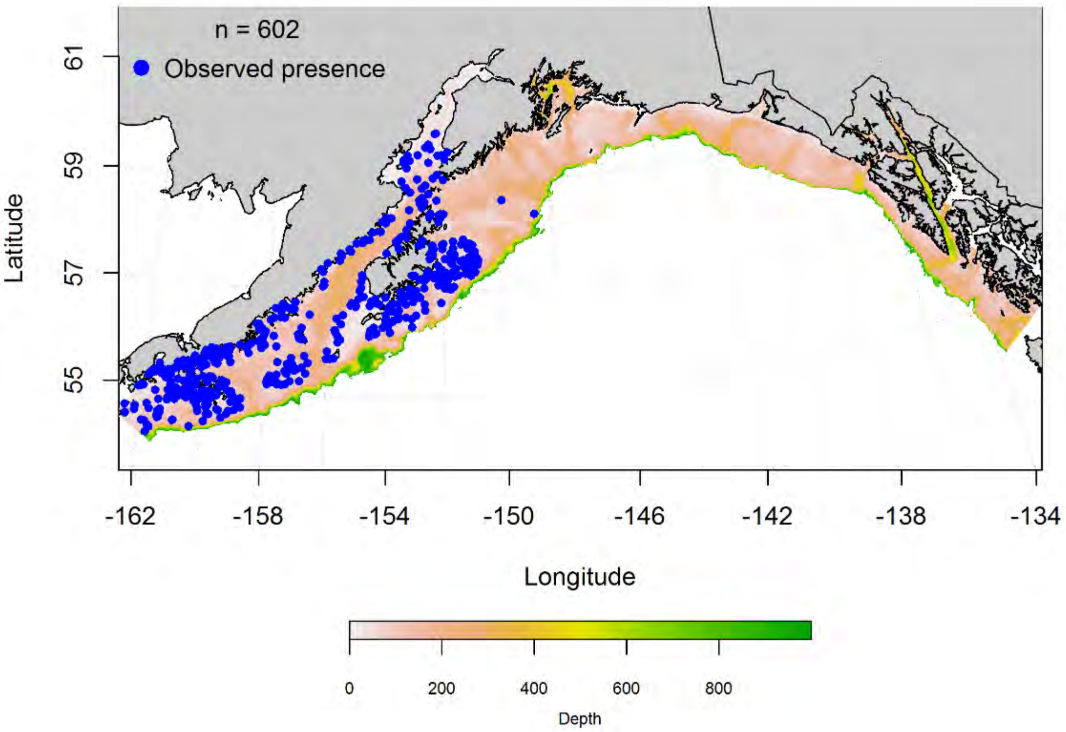


Figure 162. -- Locations of catches of adult *H. jordani* from summer bottom trawl surveys of the Gulf of Alaska.

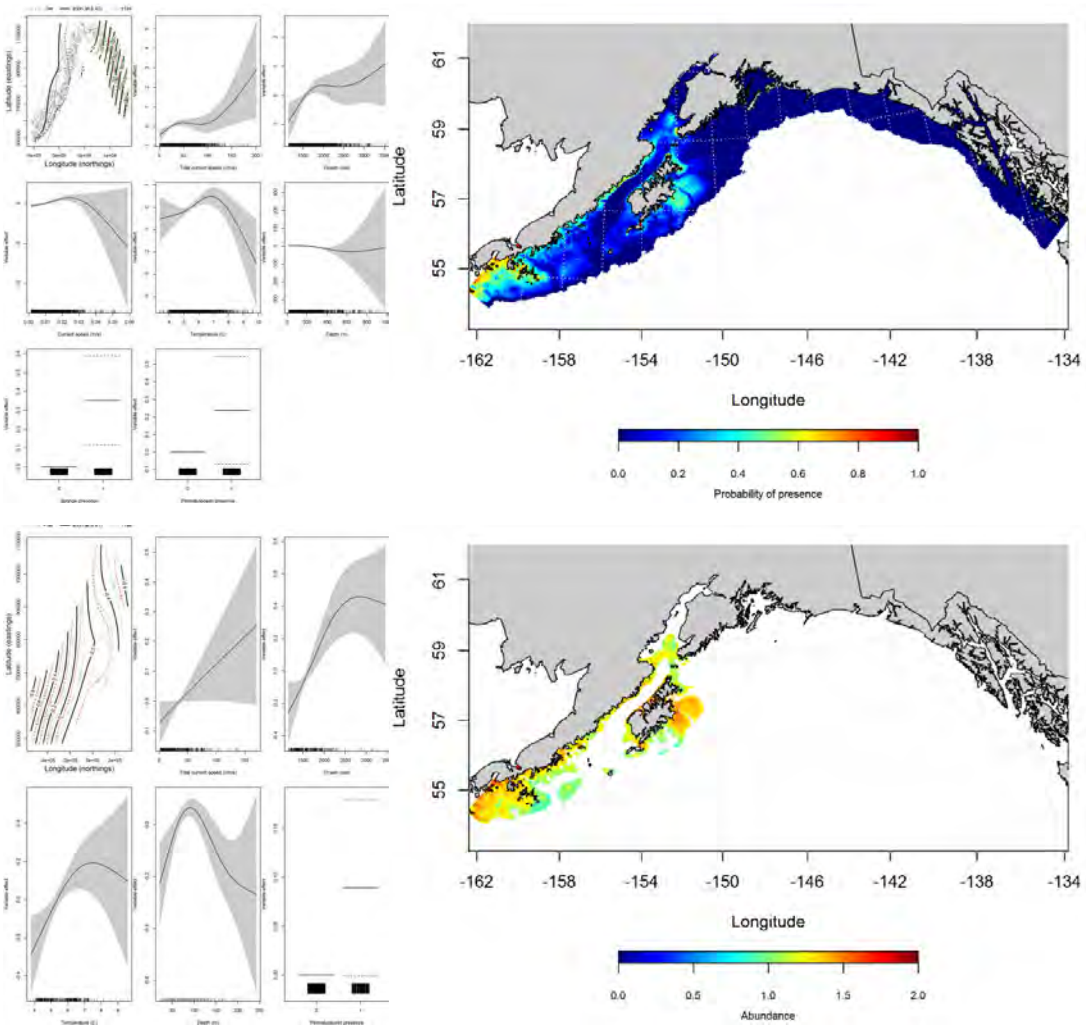


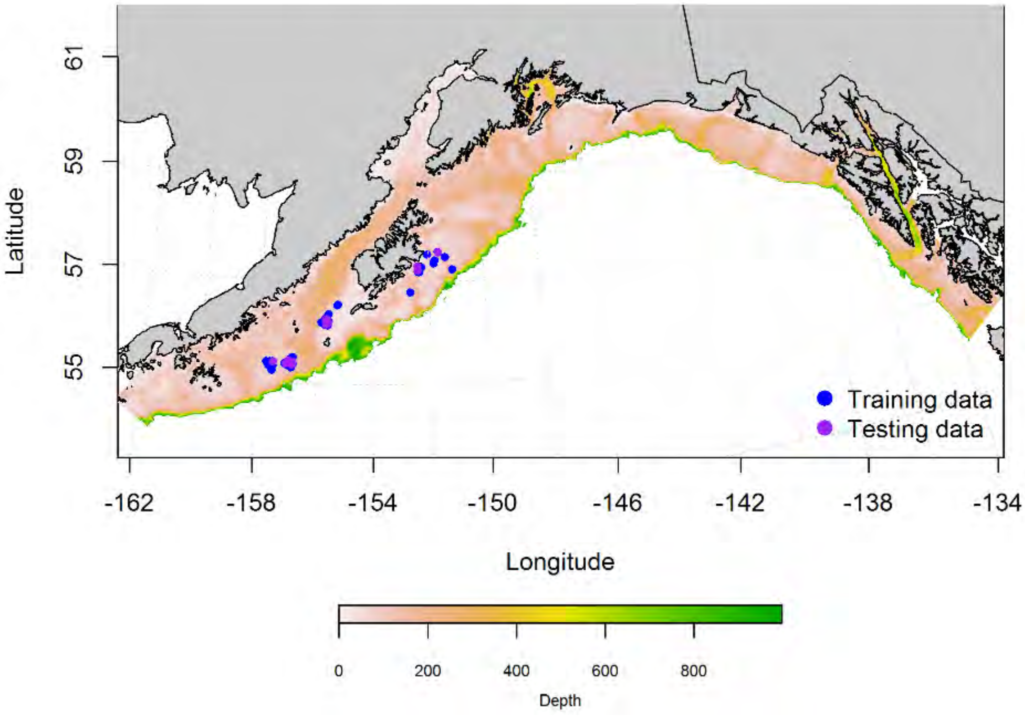
Figure 163. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *H. jordani* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *H. jordani* in the Gulf of Alaska -- Commercial catch data indicated that yellow Irish lord largely occur in deeper portions of the western GOA, particularly around Kodiak Island. In the fall, *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of yellow Irish lord (relative importance = 52.3 and 23.6 respectively). The AUC for the training data 0.96, indicating an excellent model fit. The AUC for the test data was 0.79, indicating a fair model fit. The percent of observations correctly classified for the training data was 93%, and it was 79% for the test data. In the fall, adult yellow Irish lord were predicted to occur in the shallower portion of the middle-shelf in the central and western gulf, particularly on Semidi, Chirikof, and Albatross Banks in the western gulf and on Wessels Reef in the central gulf (Figure 164).

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of yellow Irish lord (relative importance = 55.2 and 18.8 respectively). The AUC was 0.84 for the training data, indicating a good model fit. The AUC for the test data was 0.74, indicating a fair model fit. The percent of observations correctly classified was 75% and 74% respectively, for the training and test data. In the winter, adult yellow Irish lord habitat was predicted to occur on the shallower portion of the inner- and middle-shelf, west of Cross Sound. The highest suitability habits were predicted in the Shumagin Islands, and on Semidi and Chirikof Banks (Figure 165).

In the spring, *MaxEnt* modeling determined that depth and ocean color were the most important variables determining the distribution of yellow Irish lord (relative importance = 36.6 and 29.1

respectively). The AUC was 0.95 for the training data, indicating an excellent model fit. The AUC for the test data was 0.88, indicating a good model fit. The percent of observations correctly classified was 82% for the training and 88% for the testing data. In the spring, adult yellow Irish lord were predicted to occur on Albatross Bank. High suitability habitats were also predicted to occur on Wessels Reefs in the central gulf and Chichagof Island in southeast Alaska; whoever, these predictions were not supported by any observations (Figure 166).



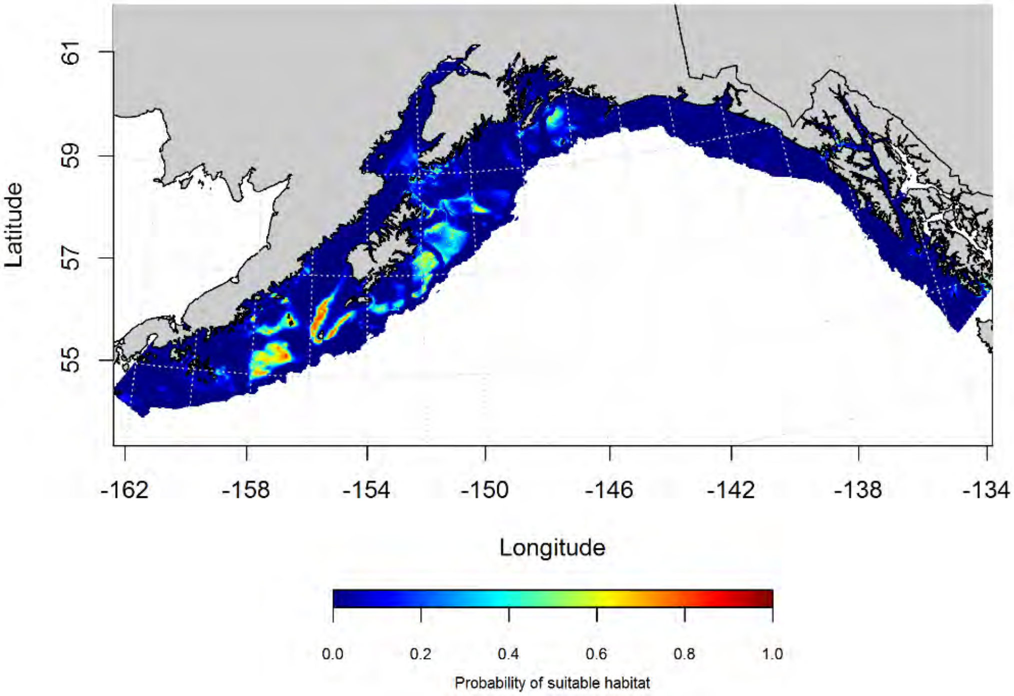


Figure 164. -- Locations of fall (September-November) commercial fisheries catches of *H. jordani* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *H. jordani* commercial catches (bottom panel) and the purple points were used to test the model.

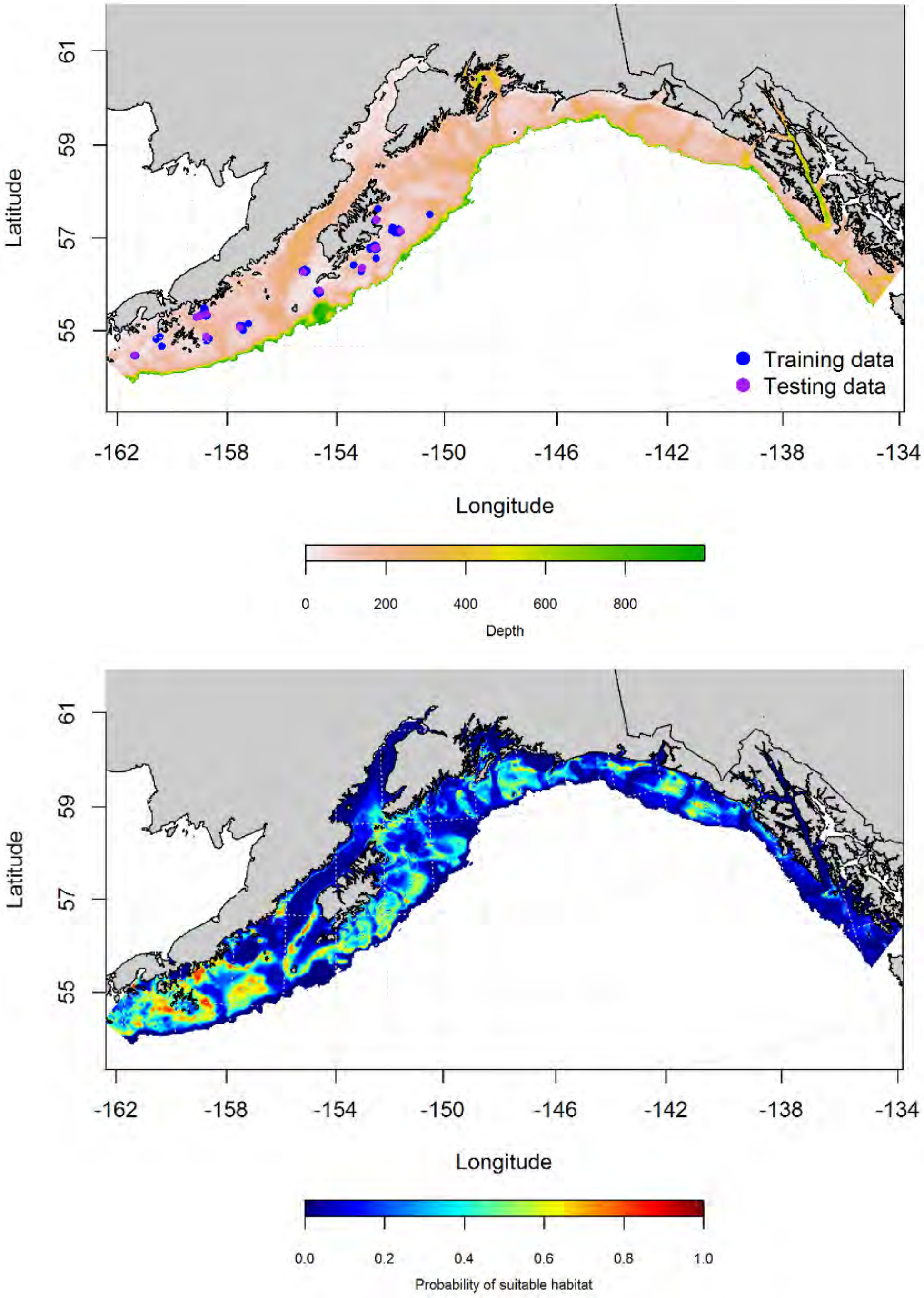


Figure 165. -- Locations of winter (December-February) commercial fisheries catches of *H. jordani* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *H. jordani* commercial catches (bottom panel) and the purple points were used to test the model.

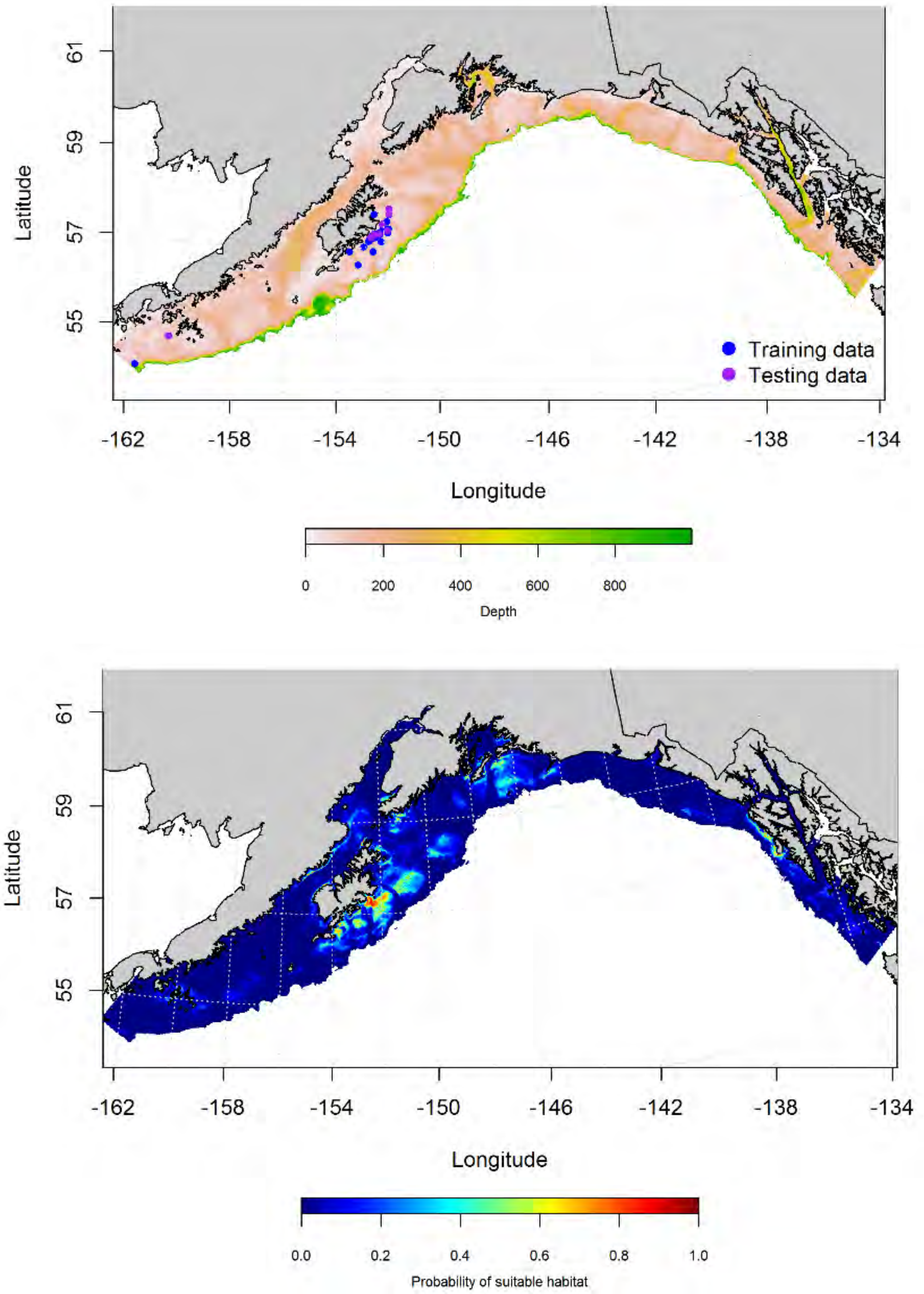


Figure 166. -- Locations of spring (March-May) commercial fisheries catches of *H. jordani* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *H. jordani* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *H. jordani* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for yellow Irish lord was predicted to occur across much of the shallower portions of the central and western Gulf of Alaska. There were no observations of any early life history stage of yellow Irish lord in the EcoFOCI database.

Summer EFH for juvenile yellow Irish lord, based on trawl survey observations, was predicted to include much of the shallower portions of the inner- and middle-shelf in the western GOA. These included the area around the Shumagin Islands, Albatross and Portlock Bank off Kodiak Island, the Cook Inlet and Wessels Reef in the central gulf (Figure 167). EFH for adult yellow Irish lord was more restricted, and it was predicted to include areas in the Shumagin Islands, Albatross Bank, and nearshore waters along Kodiak Island and the Alaska Peninsula.

Fall EFH for adult yellow Irish lord, based on commercial fisheries data, was predicted to include Semidi, Chirikof, Albatross, and Portlock Banks in the western gulf and Wessels Reef in the central gulf (Figure 168). During the winter, EFH for yellow Irish lord was predicted to include most of the shallower portions of the inner- and middle-shelf west of Cross Sound. During the spring, EFH for adult yellow Irish lord was predicted to occur on Albatross Bank. EFH habitats were also predicted on Wessels Reefs in the central gulf and Chichagof Island in southeast Alaska; however, these predictions were not supported by any observations.

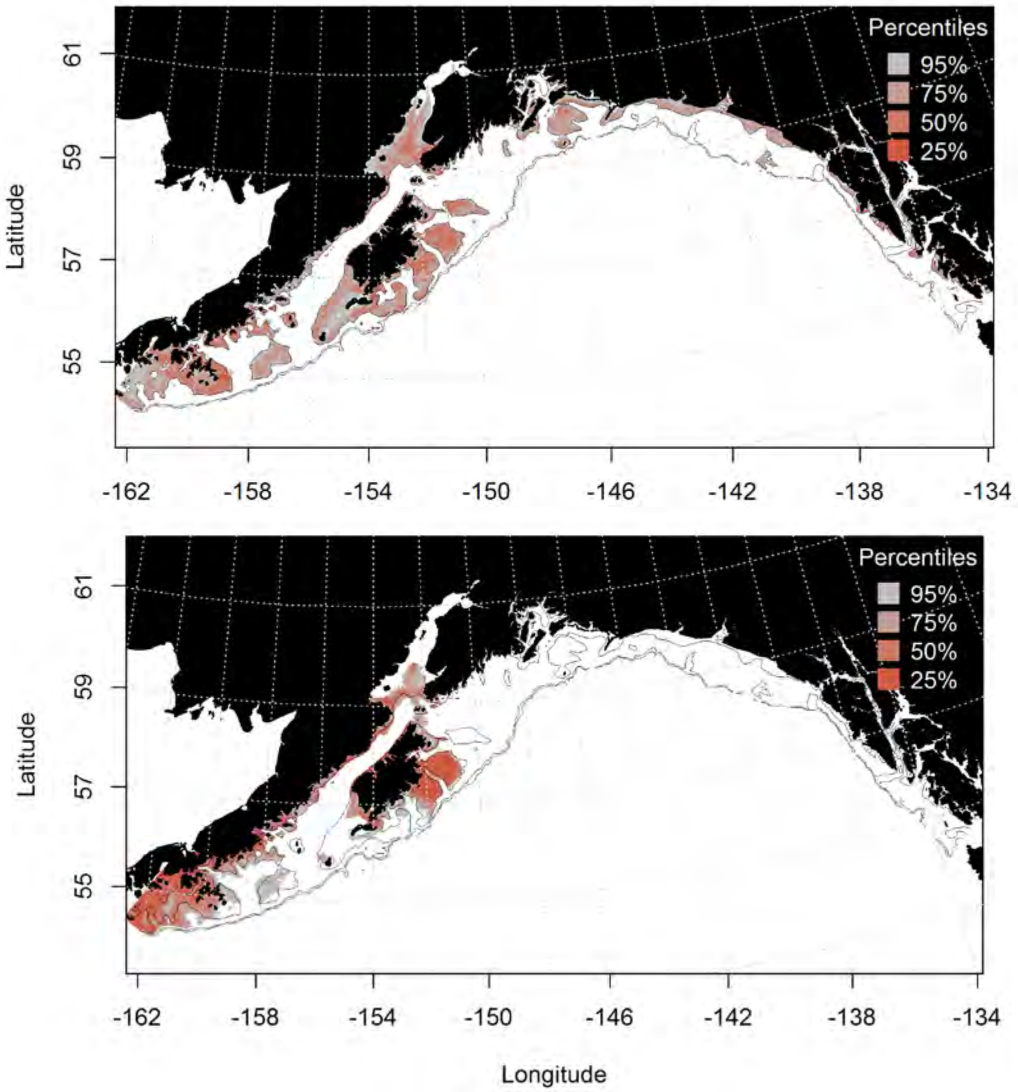


Figure 167. -- Predicted summer essential fish habitat for *H. jordani* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

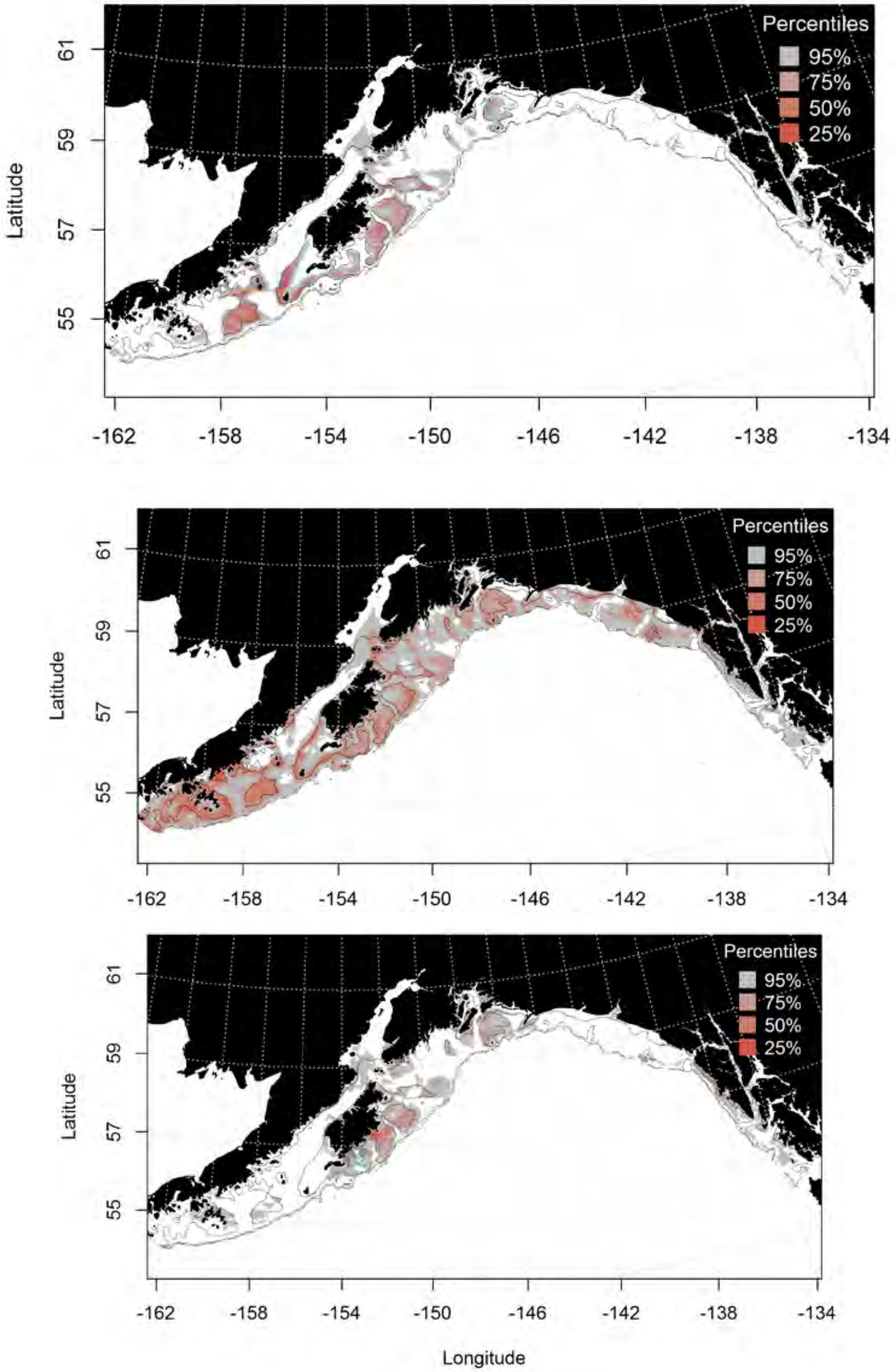


Figure 168. -- Essential fish habitat predicted for *H. jordani* during fall (top panel), winter (middle panel) and fall (bottom panel) from commercial catches.

gr**eat sculpin (*Myoxocephalus polyacanthocephalus*)**

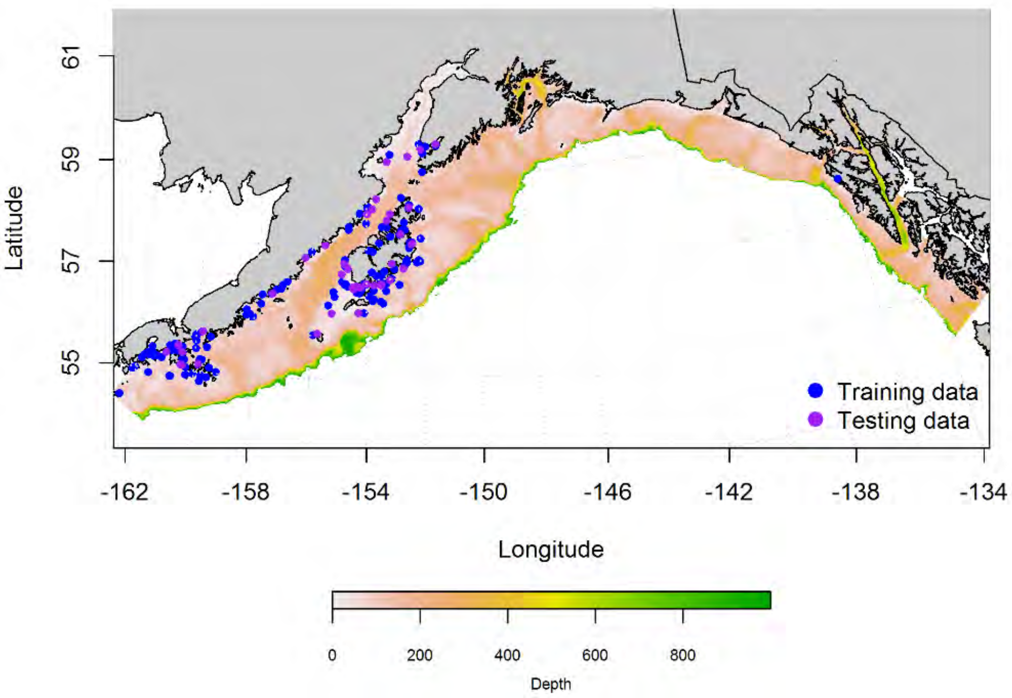
Great sculpin occur throughout the Gulf of Alaska, typically on sand or mud bottoms in the intertidal zone down to 200 m depth (Mecklenburg et al. 2002)

Seasonal distribution of early life history stages of *M. polyacanthocephalus* in the Gulf of Alaska -- No observations of great sculpin occurred in the EcoFOCI database.

Spring and summer distribution of juvenile and adult *M. polyacanthocephalus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile great sculpin largely occur in nearshore waters around Kodiak Island and the Alaska Peninsula.

The best-fitting *MaxEnt* model indicated that depth and tidal current the most important variables predicting habitat suitability for juvenile great sculpin (relative importance 63.9 and 15.4 respectively). The AUC for the training data was 0.90, indicating an excellent model fit. The AUC for the testing data was 0.79, indicating a fair model fit. The percent of correctly classified observations was 85% for the training data and 79% for the test data. Summer juvenile great sculpin habitat was predicted to occur across much of the shallower portions of the inner- and middle-shelf (Figure 169). High suitability habits were predicted to occur around the Shumagin Islands, as well as on Albatross Banks and nearshore water around Kodiak Island. High suitability habitats were also predicted in nearshore waters in the eastern gulf; however, these were supported by only a single observations.

Catches of adult great sculpin had roughly the same distribution as juveniles. The best-fitting *MaxEnt* model indicated that depth and tidal currents the most important variables predicting habitat suitability (relative importance 63.3 and 16.0 respectively). The AUC for the training data was 0.90, indicating an excellent model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of correctly classified observations was 82% for the training data and 81% for the test data. Summer habitat for adult great sculpin habitat was similar to that of the juveniles; however, it extended to slightly deeper depths (Figure 170). High suitability habits were predicted to occur in the Shumagin Islands, on Albatross Banks and nearshore water around Kodiak Island. High suitability habitats were also predicted in nearshore waters in the eastern gulf; however, these predictions were not supported by any observations.



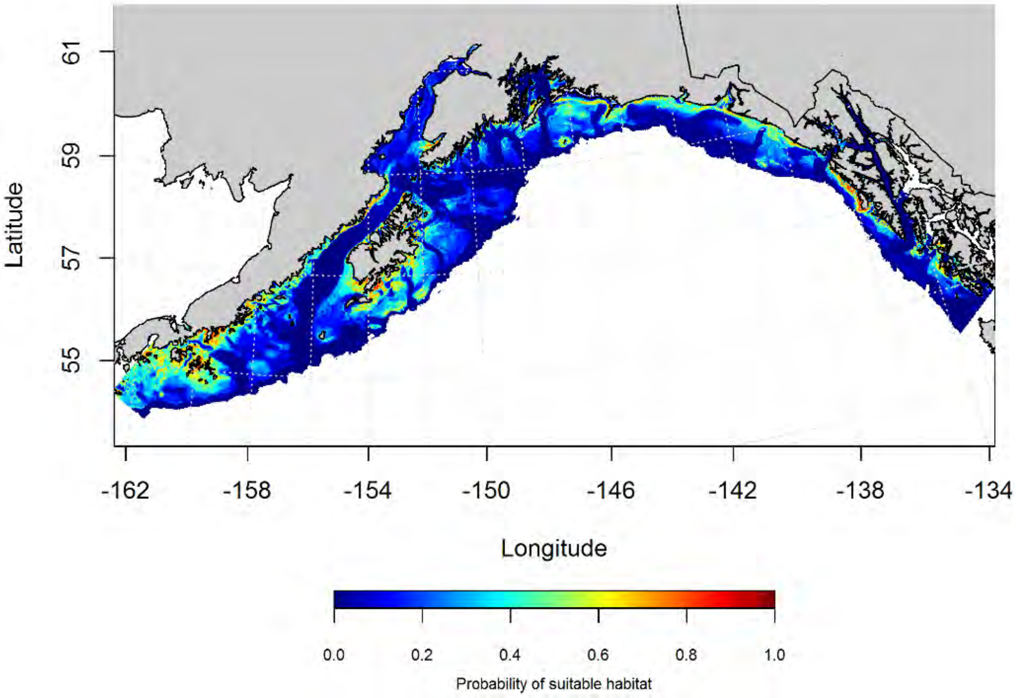
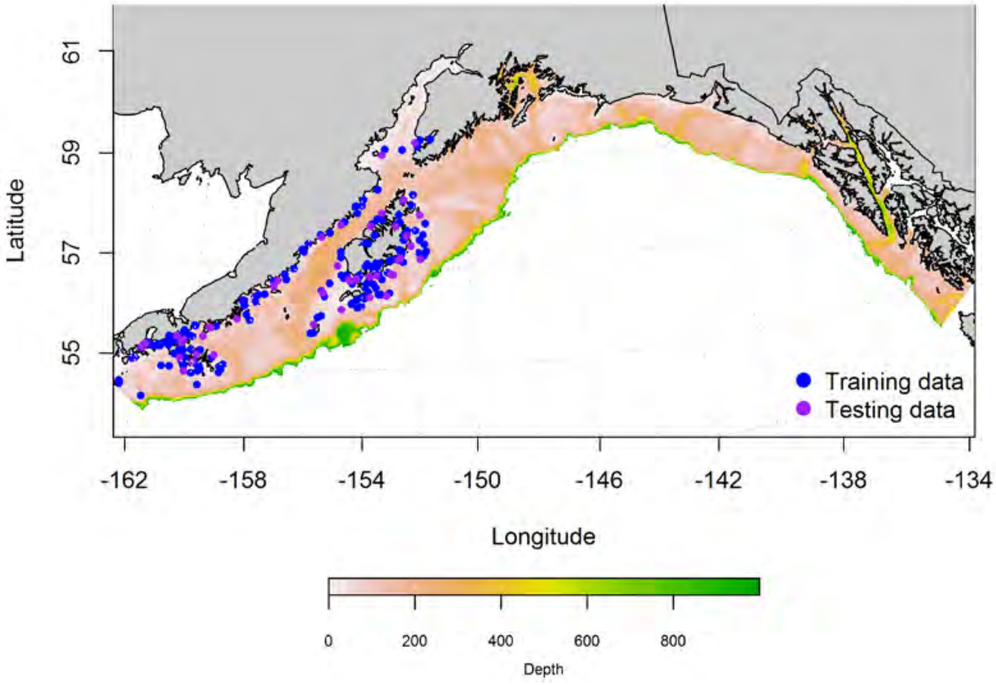


Figure 169. -- Locations of catches of juvenile *M. polyacanthocephalus* during the AFSC summer bottom trawl survey (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *M. polyacanthocephalus* (bottom panel) and the purple points were used to test the model.



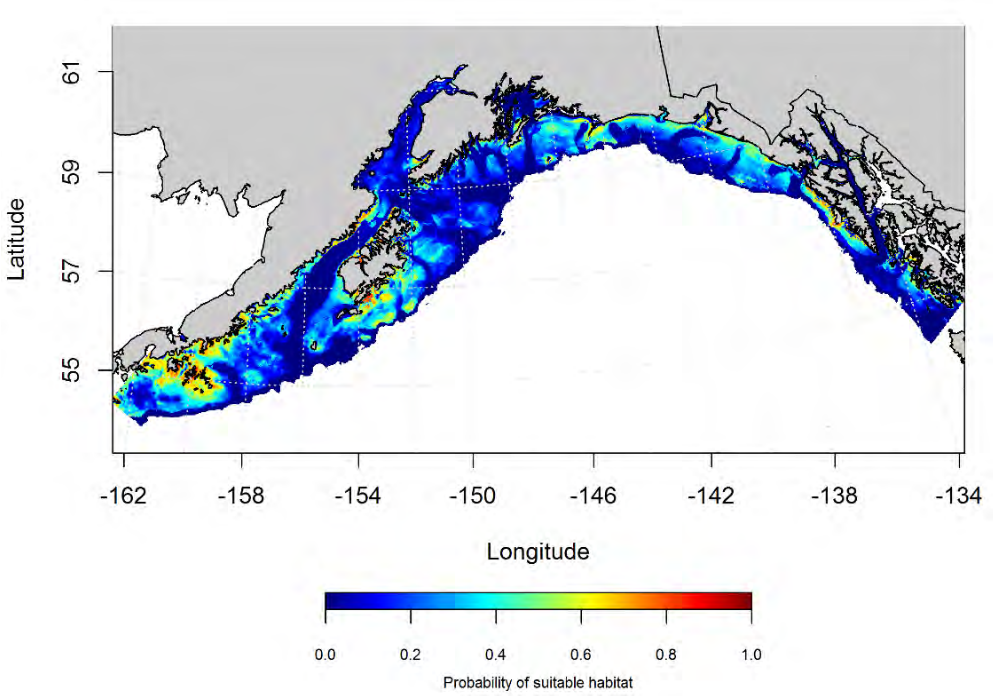


Figure 170. -- Locations of catches of adult *M. polyacanthocephalus* during the AFSC summer bottom trawl survey (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *M. polyacanthocephalus* (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *M. polyacanthocephalus* in the Gulf of Alaska -- No observations of adult great sculpins were reported in the commercial catch data.

Gulf of Alaska *M. polyacanthocephalus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for great sculpin predicted was predicted to occur across much of the inner-shelf in the Gulf of Alaska. EFH could not be predicted for any early life history stages of great sculpin.

Summer EFH for juvenile great sculpin, based on trawl survey observations, was predicted to include much of the inner- and middle-shelf, including around the Shumagin Islands, around Kodiak Island; as well as inshore waters along much of the central and eastern gulf (Figure 171). EFH for adult great sculpin, was predicted to be much similar to that of the juveniles; however, it also slightly deeper areas as well. High suitability habits were also predicted at the head of Cook Inlet, in Prince William Sound, and in southeast Alaska; however, these predictions were not supported by any observations.

EFH for adult great sculpin, could not be predicted based on commercial catch data.

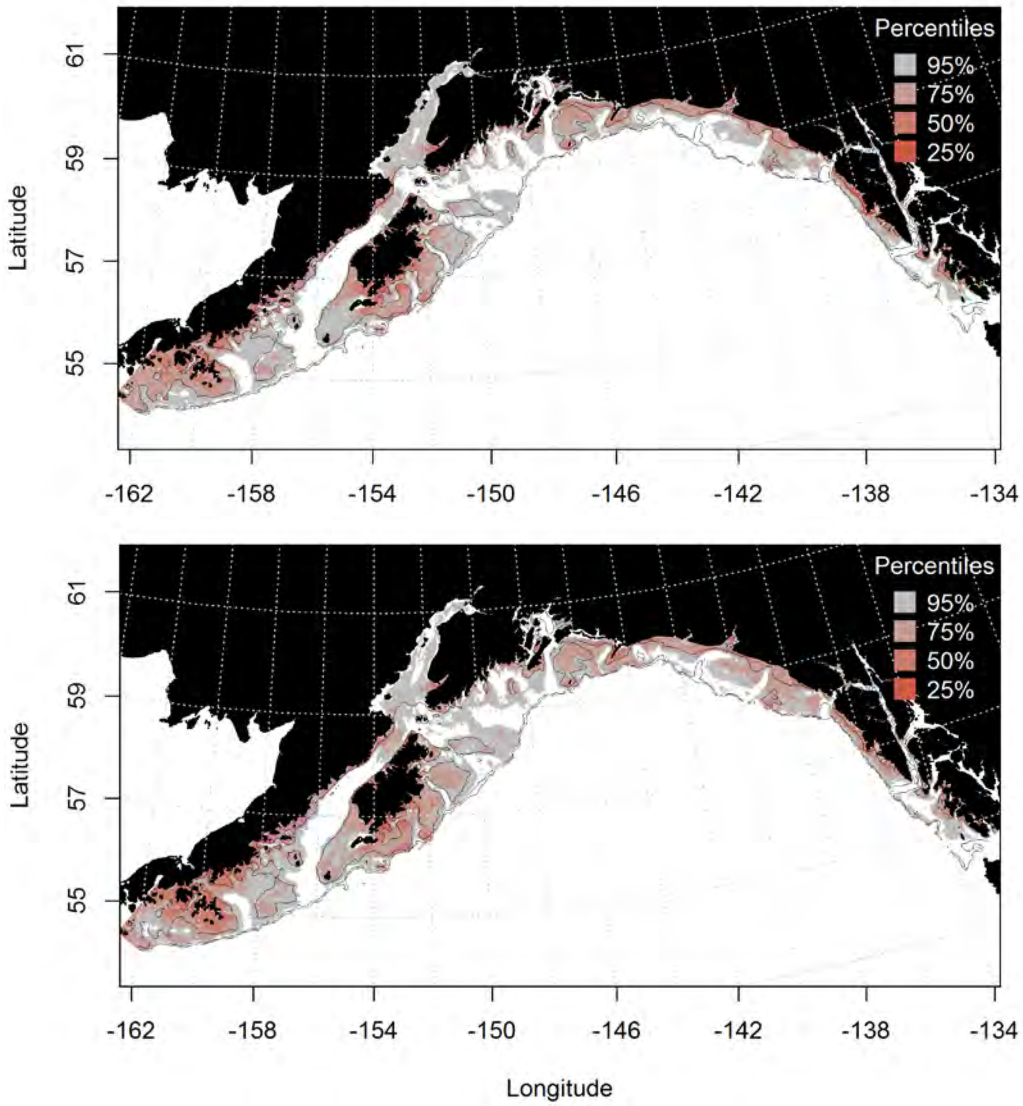


Figure 171. -- Predicted summer essential fish habitat for *M. polyacanthocephalus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

bigmouth sculpin (*Hemitripterus bolini*)

Bigmouth sculpin occur throughout the Gulf of Alaska, between 25-925 m depth; but they are most common 100-300 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *H. bolini* in the Gulf of Alaska -- The early life history stages of bigmouth sculpin were not able to be consistently distinguished from those of other species within the family. As a result the observations were analyzed together at the family level, Hemitripteridae. There were no observations of Hemitripteridae eggs in the EcoFOCI database.

Larval Hemitripteridae were observed during the winter, spring and the summer. Only eight larval Hemitripteridae were observed during the winter. Most occurred on the inner-shelf on the south side of Kodiak Island (Figure 172).

Larval Hemitripteridae were observed during the spring and the summer. During the spring, they were abundant across much of the inner- and middle-shelf west of the Kenai Peninsula. The most important variable predicting larval habitat suitability were surface temperature and ocean color (31.4 and 24.6, respectively). The AUC was 0.92 for the training data, indicating an excellent model fit. The AUC for the testing data was 0.79, indicating a fair model fit. The percent of the observations correctly classified in the training data was 84% and 79% for the test data. During the spring Hemitripteridae larval habitat was predicted to occur on the inner- and middle-shelf along the Alaska Peninsula west of Kodiak Island. During the summer, only four larval Hemitripteridae were observed. They were widely dispersed across the inner- and middle-shelf west of Kodiak Island (Figure 173).

Early juvenile Hemitripteridae were observed during the spring and summer. During the spring, only seventeen early juveniles were observed. They were widely dispersed across much of the central and western gulf, west of Yakutat. During the summer, only four early juvenile Hemitripteridae were observed. They were widely dispersed across the inner- and middle-shelf around Kodiak Island and along the Alaska Peninsula (Figure 174).

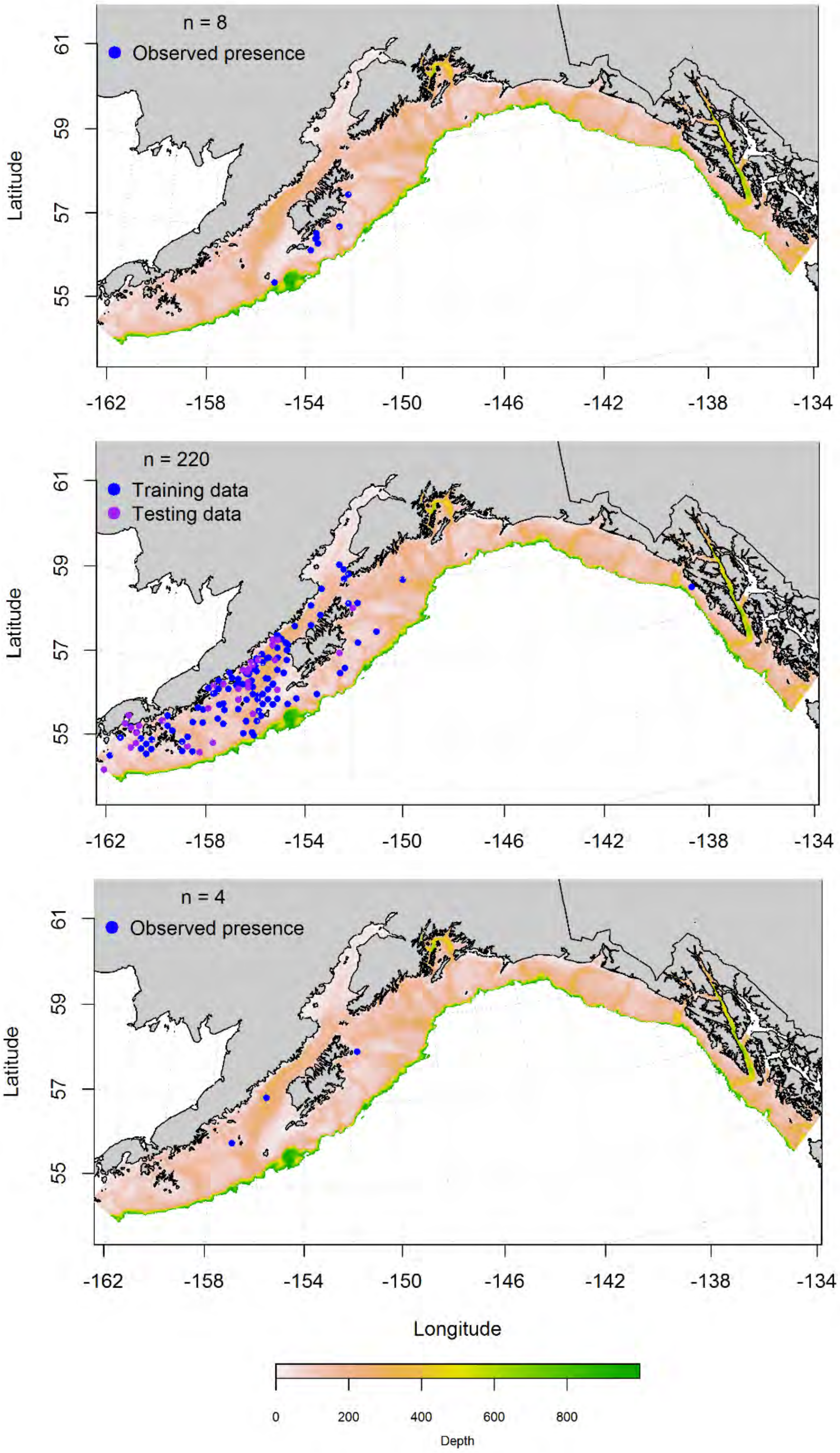


Figure 172. -- Winter, spring, and summer observations (top, middle, and bottom panel, respectively) of larval *H. bolini* from the Gulf of Alaska.

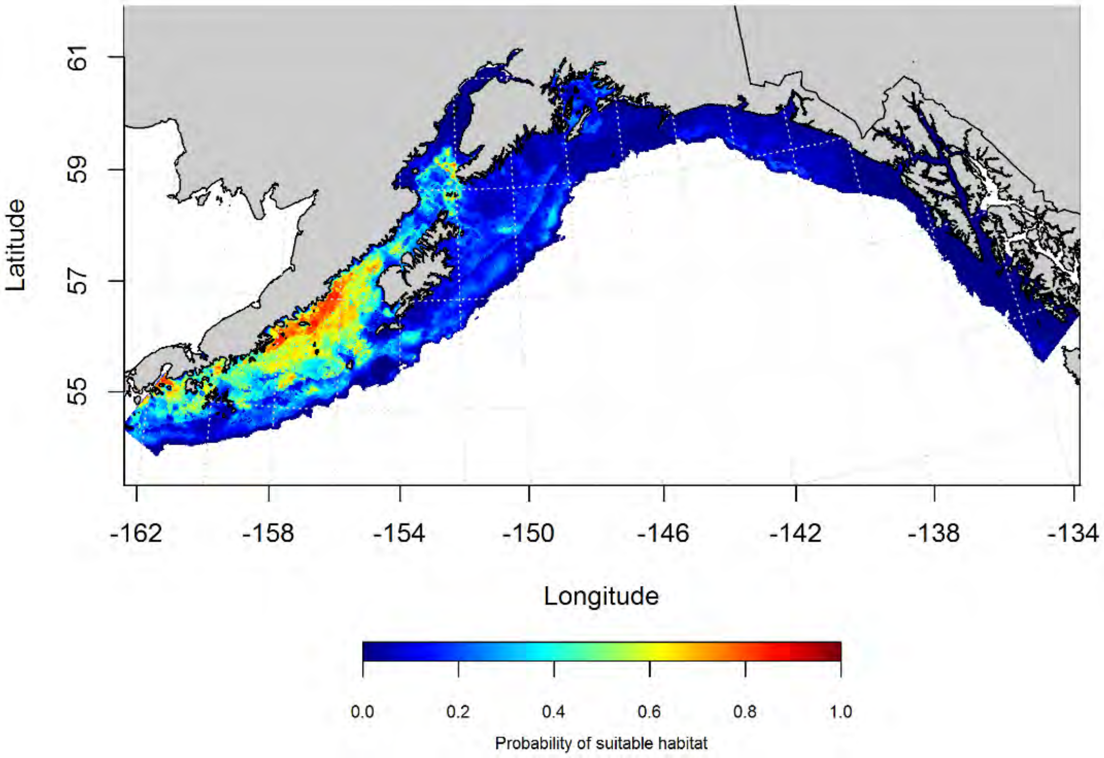


Figure 173. -- Predicted probability of suitable habitat for spring of larval *H. bolini* from maximum entropy modeling of the Gulf of Alaska.

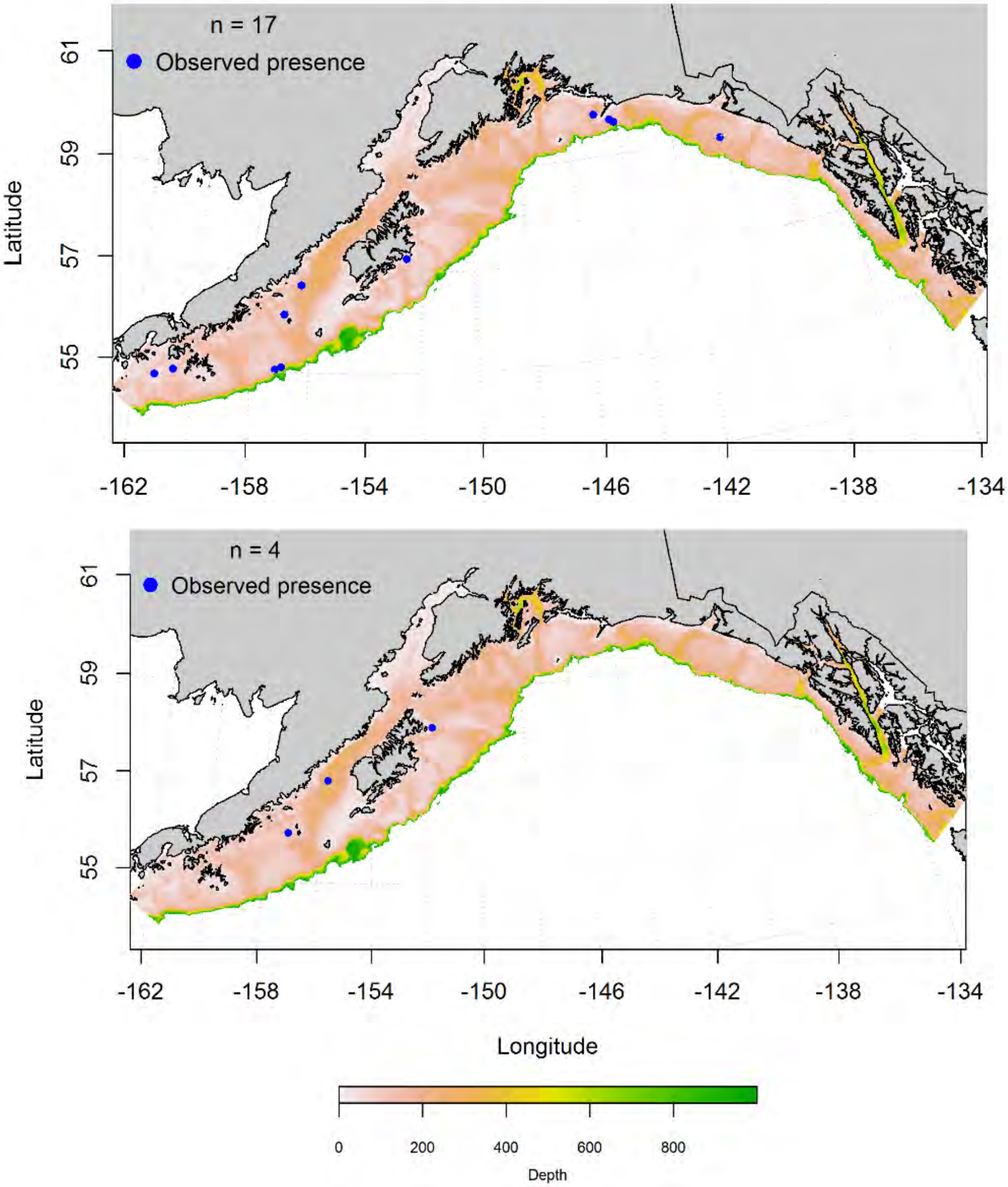


Figure 174. -- Spring and summer catches (top and bottom, respectively) of early juvenile *H. bolini* in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *H. bolini* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile bigmouth sculpin largely occur in the western Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability for juvenile bigmouth sculpin (relative importance 34.1 and 27.1 respectively). The AUC for the training data was 0.83, indicating a good model fit. The AUC for the testing data was 0.66, indicating a poor model fit. The percent of correctly classified observations was 78% for the training data and 66% for the test data. Summer juvenile bigmouth sculpin habitat was predicted to occur in the western gulf, along the inner- and middle-shelf. High suitability habits was predicted around the Shumagin Islands and western Alaska Peninsula, as well as around Kodiak Island (Figure 175). High suitability habitats were also predicted to occur off southeast Alaska; however, these predictions were not supported by any observations.

Adult bigmouth sculpin also largely occur in the western GOA (Figure 176). The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 55.7 and 16.3 respectively). The AUC for the training data was 0.83, indicating an excellent model fit. The AUC for the testing data was 0.74, indicating a good model fit. The percent of correctly classified observations was 76% for the training data and 74% for the test data. Summer habitat for adult bigmouth sculpin was predicted to include much of the deeper portions of the middle-shelf in the central and western gulf. High suitability habits were predicted in the Shumagin and Shelikof Gullies along the Alaska Peninsula; and in Marmot Gully and Amatuli Trough east of Kodiak Island. High suitability habitats were also predicted to occur in the eastern gulf; however, these predictions were only supported by a three observations.

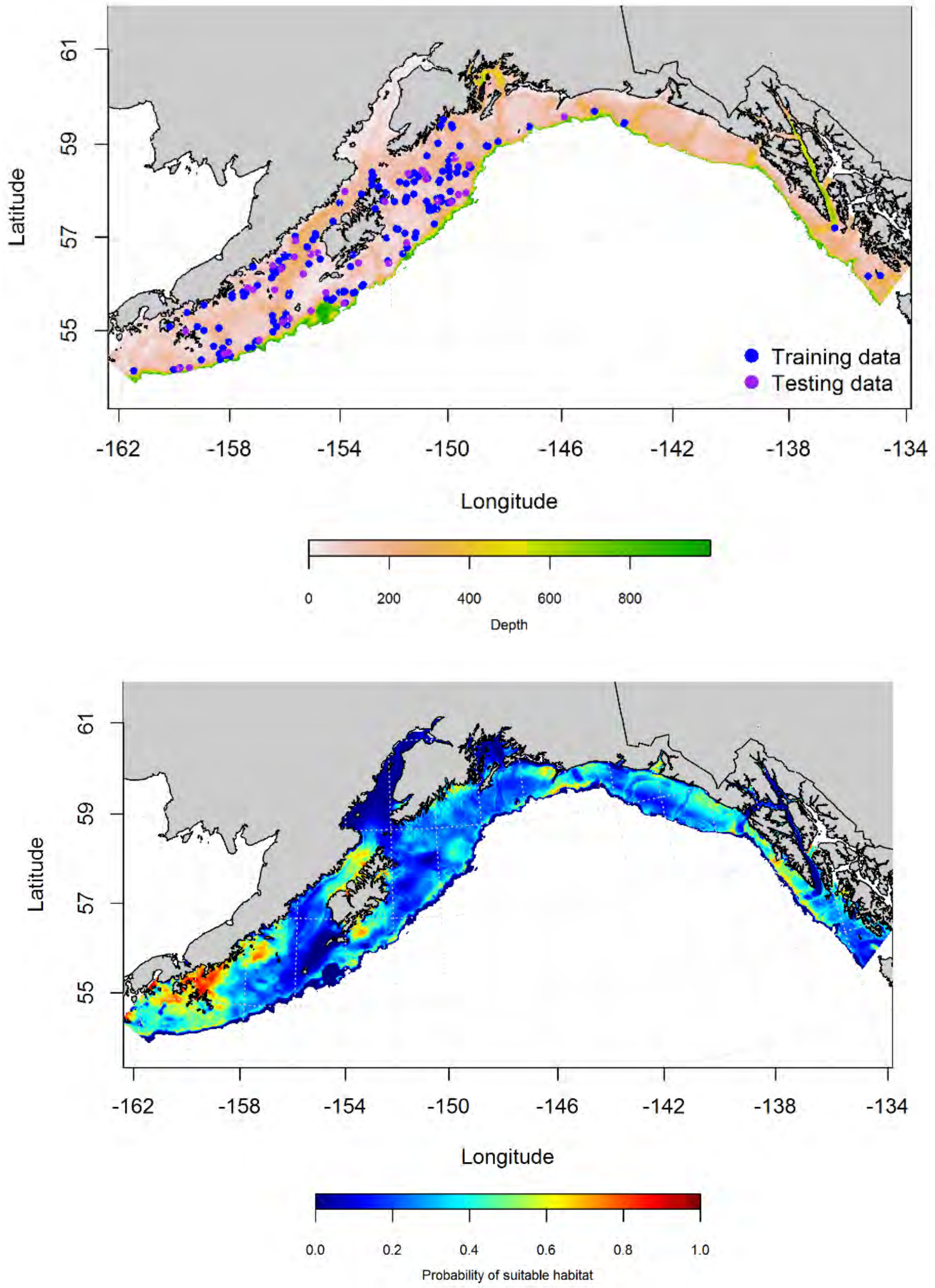


Figure 175. -- Locations of trawl survey catches of juvenile *H. bolini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *H. bolini* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

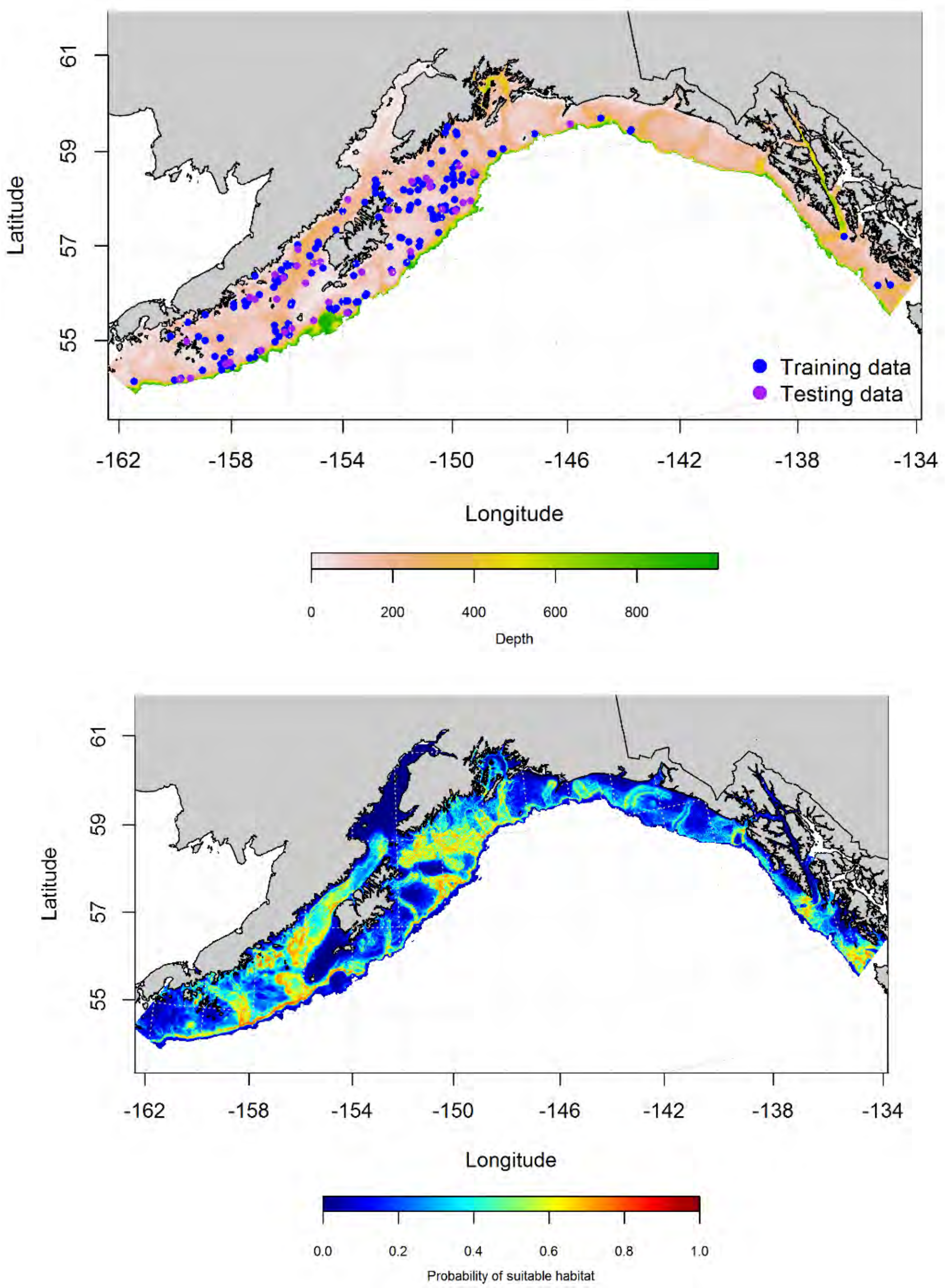


Figure 176. -- Locations of trawl survey catches of adult *H. bolini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *H. bolini* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *H. bolini* in the Gulf of Alaska -- Commercial catch data indicate bigmouth sculpin largely occur in the western GOA around Kodiak Island and the Alaska Peninsula. There were no observations of bigmouth sculpin from commercial catch data during the fall.

In the winter, *MaxEnt* modeling determined that ocean color and depth were the most important variables predicting the distribution of bigmouth sculpin (relative importance = 27.2 and 26.9 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the test data was 0.89, indicating a good model fit. The percent of observations correctly classified was 83% and 89% respectively, for the training and test data. In the winter, adult bigmouth sculpin were predicted to occur on the middle-shelf in the central and western gulf. Particularly on the Sandman Reefs; on Barnabus Gully and the deeper portions of Albatross and Portlock Bank; and around Wessels Reef (Figure 177).

In the spring, *MaxEnt* modeling determined that current speed and depth were the most important variables determining the distribution of bigmouth sculpin (relative importance = 34.1 and 20.9; Figure 178). The AUC was 0.79 for the training data, indicating a fair model fit. The AUC for the test data was 0.67, indicating a poor model fit. The percent of observations correctly classified was 71% for the training data and 67% testing data. In the spring, adult bigmouth sculpin were predicted to occur on the middle- and outer-shelf. High suitability habits were predicted just inshore of the shelf break along the Alaska Peninsula west of Kodiak Island as well as off Amatuli Trough. High suitability habitats were also predicted to occur along the outer-shelf off southeast Alaska and the Yakutat Valley; however, these predictions were not supported by any observations.

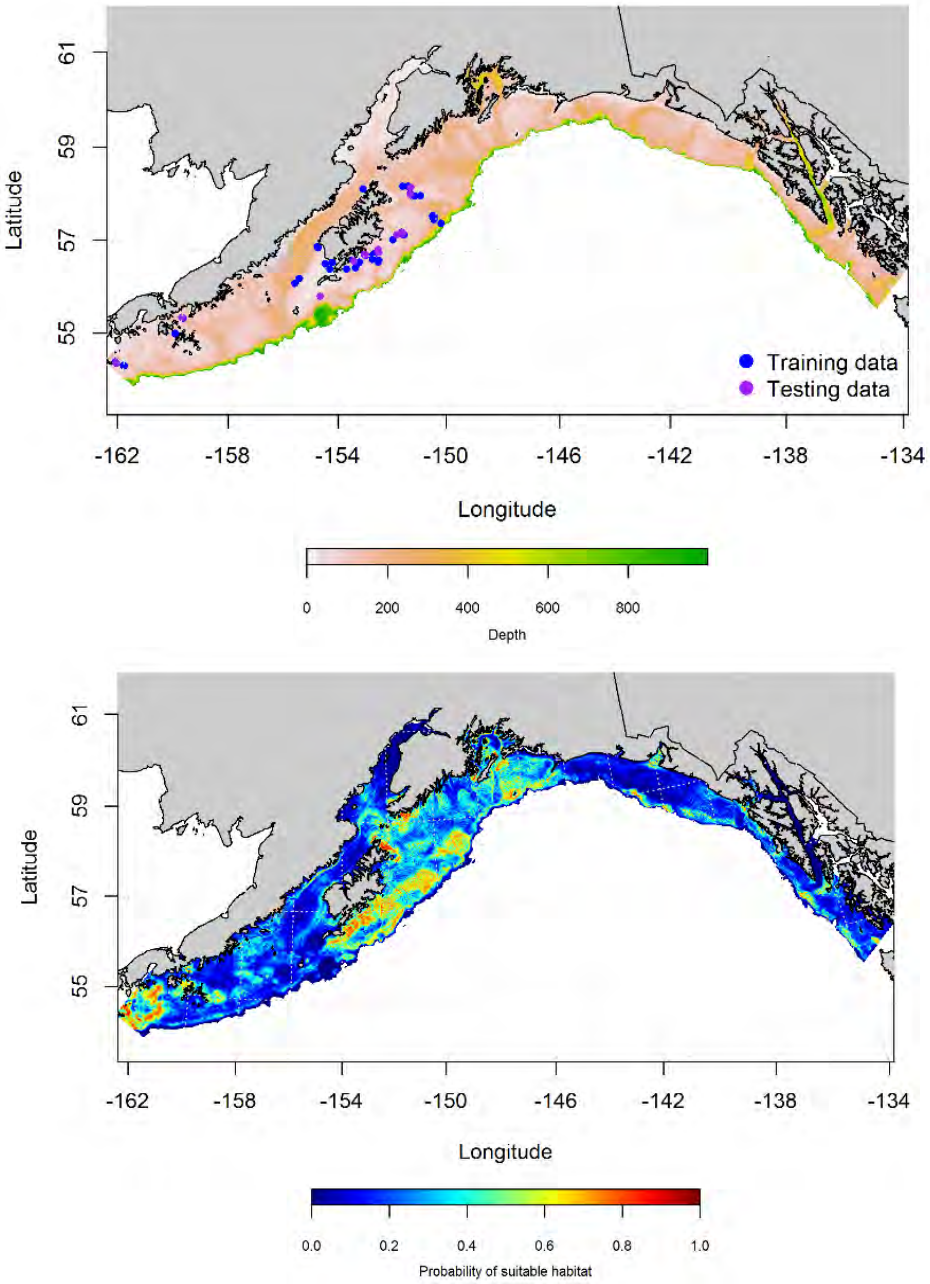


Figure 177. -- Locations of winter (December-February) commercial fisheries catches of *H. bolini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *H. bolini* commercial catches (bottom panel) and the purple points were used to test the model.

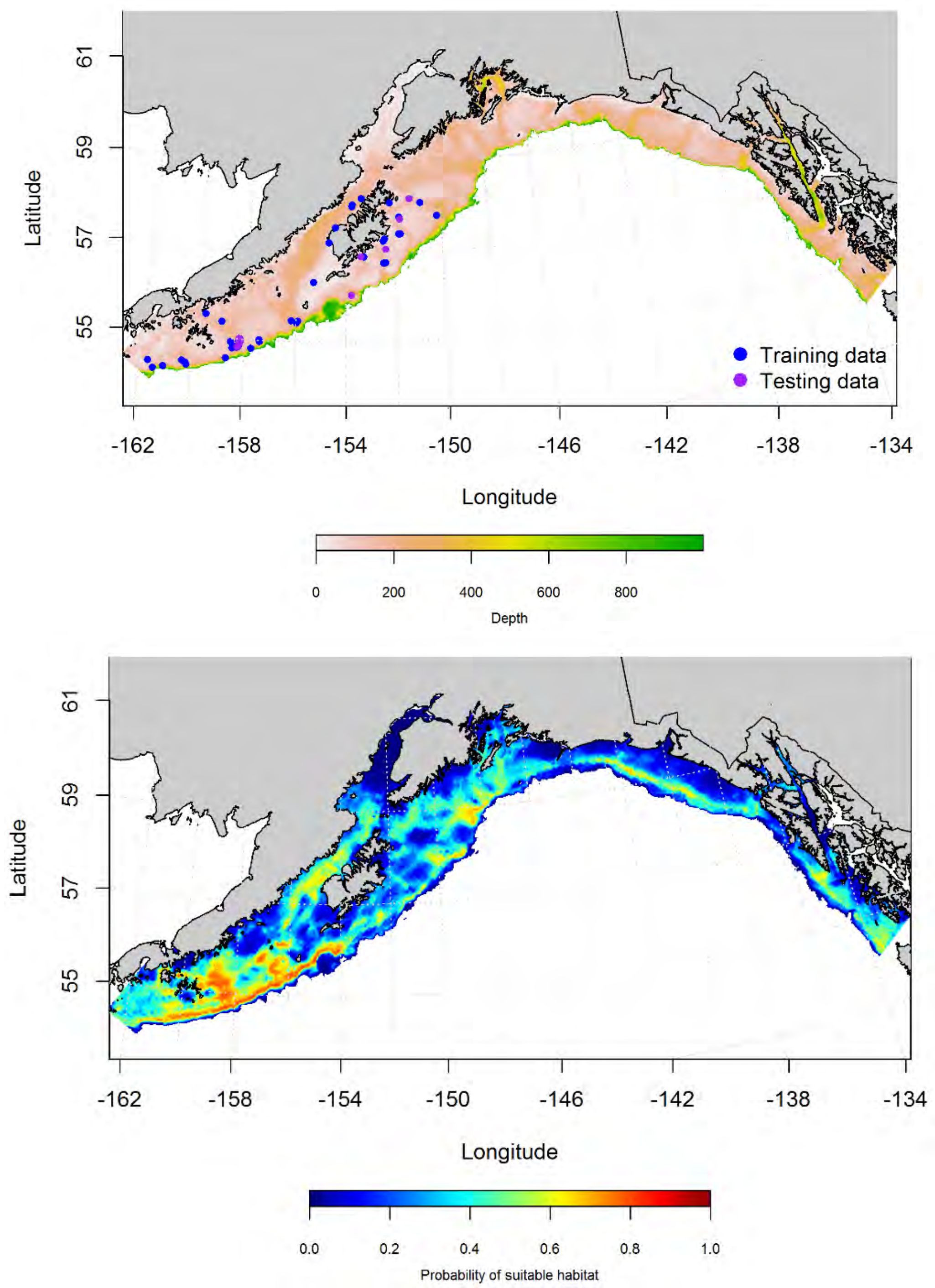


Figure 178. -- Locations of spring (March-May) commercial fisheries catches of *H. bolini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *H. bolini* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *H. bolini* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for bigmouth sculpin was predicted to occur across much of the Gulf of Alaska. No EFH could be predicted for Hemitripteridae eggs or early juvenile stages. Spring EFH for larval Hemitripteridae was predicted to occur along the inner- and middle shelf along the Alaska Peninsula (Figure 179).

Spring EFH for juvenile bigmouth sculpin, based on trawl survey observations, and was predicted to include much of the inner- and middle-shelf around the Shumagin Islands and Alaska Peninsula, around Kodiak Island, and much of the central and eastern gulf (Figure 17.9). EFH for adult bigmouth sculpin, was also predicted to include much of the deeper portions of the middle- and outer-shelf (Figure 180).

Winter EFH for adult bigmouth sculpin, based on commercial catch data, was predicted to have a patchy distribution across much of the middle-shelf. Higher probability EFH habits were predicted to occur around the Sandman Reefs, as well as on Albatross and Porrtlock Banks (Figure 17.10). Spring EFH for adult bigmouth sculpin was predicted to be much more abundant, and include much of the deeper portions of the middle-and outer-shelf (Figure 181).

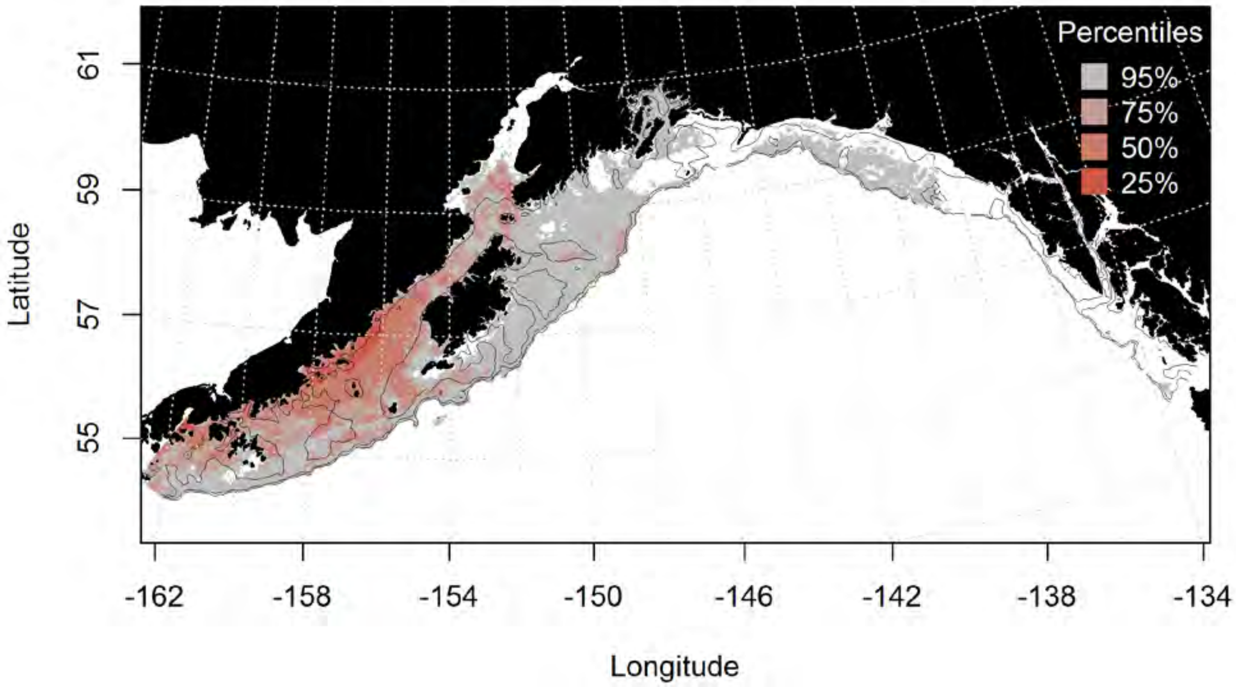


Figure 179. -- Spring essential fish habitat predicted for larval Hemitripteridae from the EcoFOCI database.

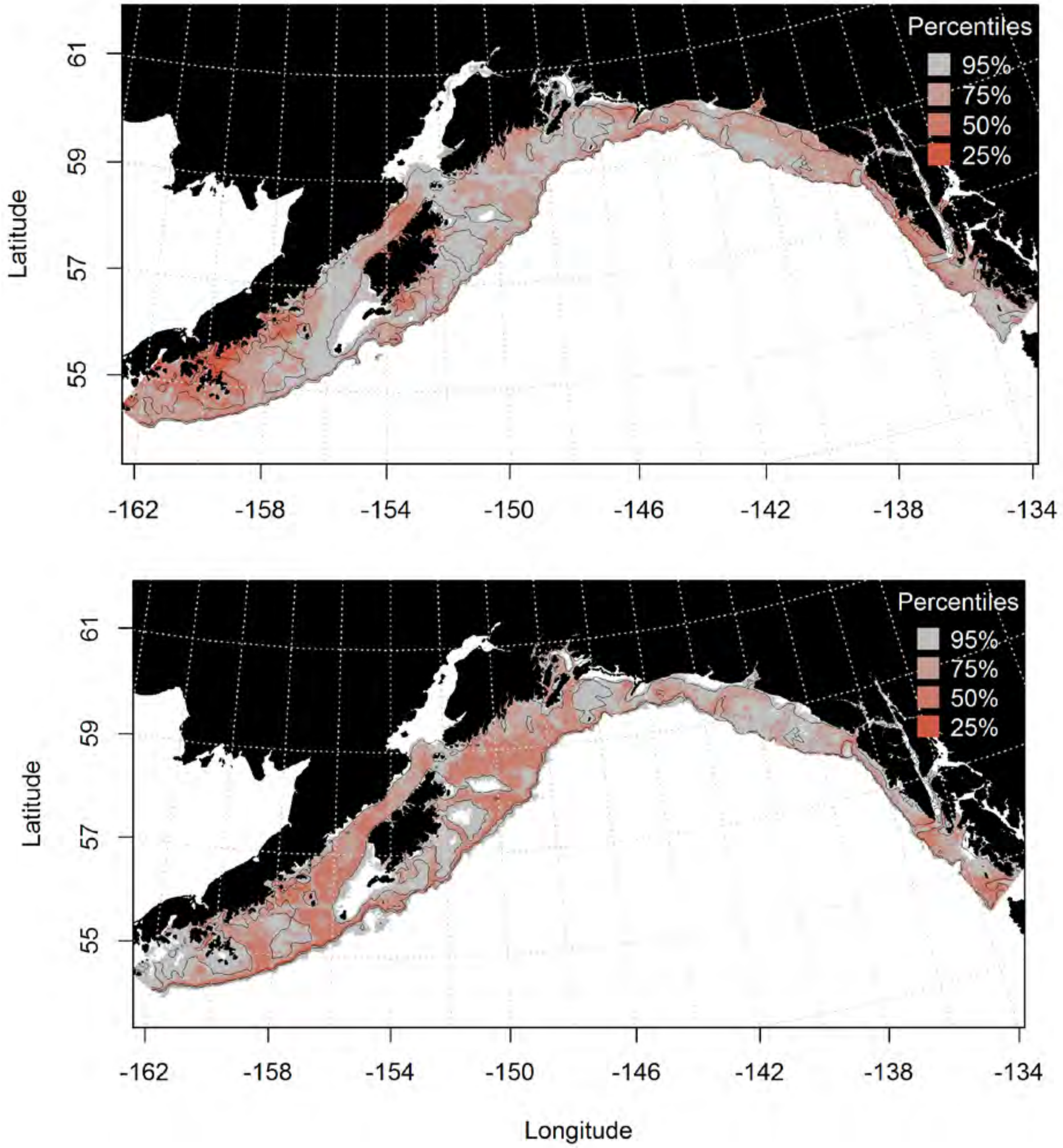


Figure 180. -- Predicted summer essential fish habitat for *H. bolini* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

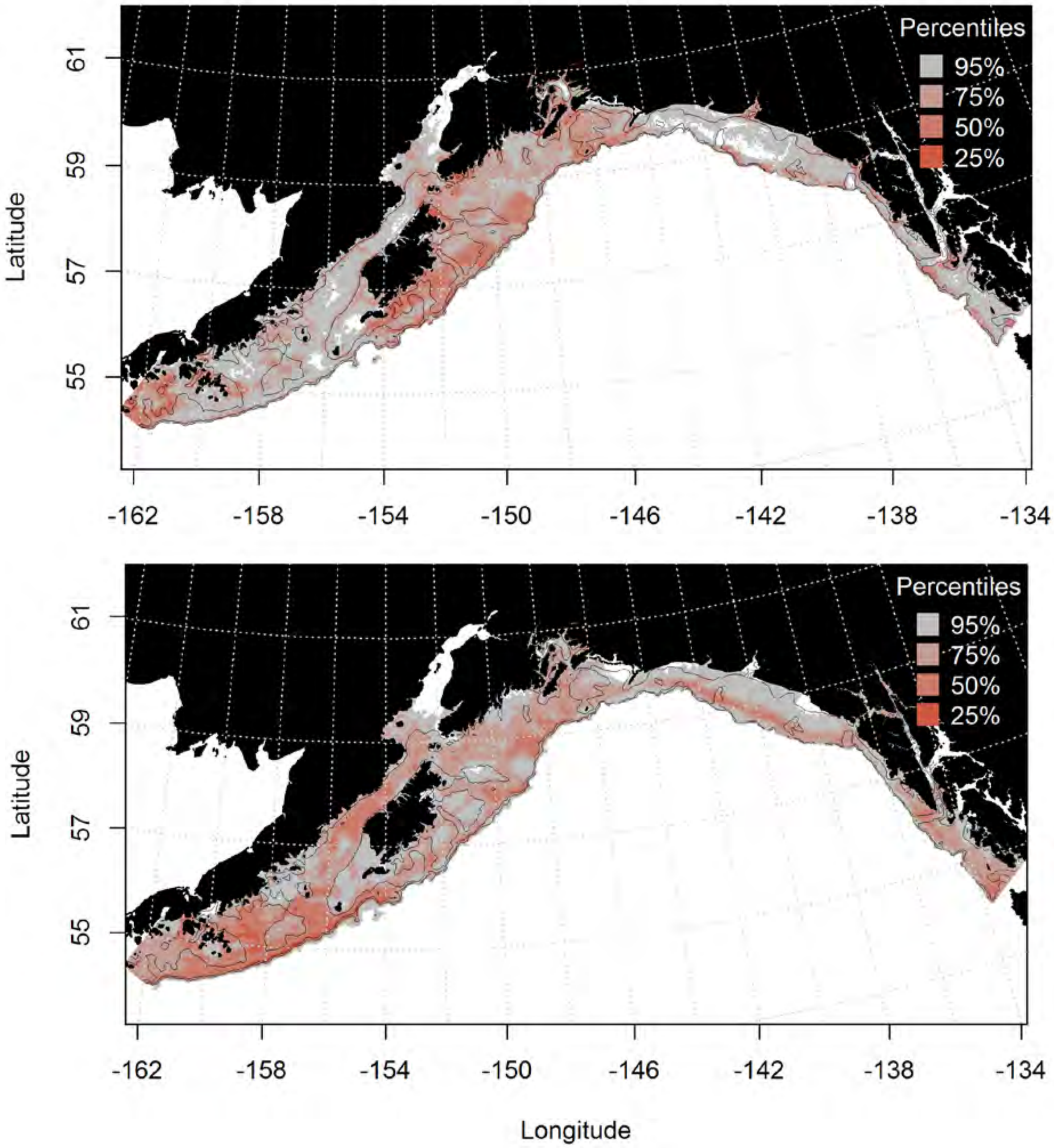


Figure 181. -- Essential fish habitat predicted for *H. bolini* during winter (top panel) and spring (bottom panel) from commercial catches.

Rockfishes

shortspine thornyhead (*Sebastolobus alascanus*)

Shortspine thornyhead are one of the most abundant rockfish in the Gulf of Alaska. They are generally most abundant on the continental slope at between 301-700 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastolobus* spp. the Gulf of Alaska -- Observations of shortspine and longspine thornyhead (*Sebastolobus altivelis)* early life history stages were difficult to consistently separate by species. Consequently analysis of these the early life history stages of these species was conducted at the genus level, *Sebastolobus* spp.

Observations of early life history stages of *Sebastolobus* spp. were limited, and they did not show any consistent patterns in their distribution. *Sebastolobus* spp. eggs were observed during the spring and summer. In the spring, there were thirty-one observations of eggs, which were wildly distributed across much of the shelf (Figure 182). In the summer there were fifteen observations of eggs, a majority of which occurred off southeast Alaska. There was insufficient data to model the distribution of *Sebastolobus* spp. eggs.

Larval *Sebastolobus* spp. were observed during the spring and the summer (Figure 183). Only four larvae were observed during the spring. All of them occurred on the middle-shelf in the vicinity of Kodiak Island. In the summer, there were twenty-six observations of larval *Sebastolobus* spp. Most of these larvae occurred along the outer-shelf in the vicinity of Albatross and Portlock Banks. There was insufficient data to model the distribution of *Sebastolobus* spp. larvae.

There were no observations of early juvenile *Sebastolobus* spp. in the EcoFOCI database.

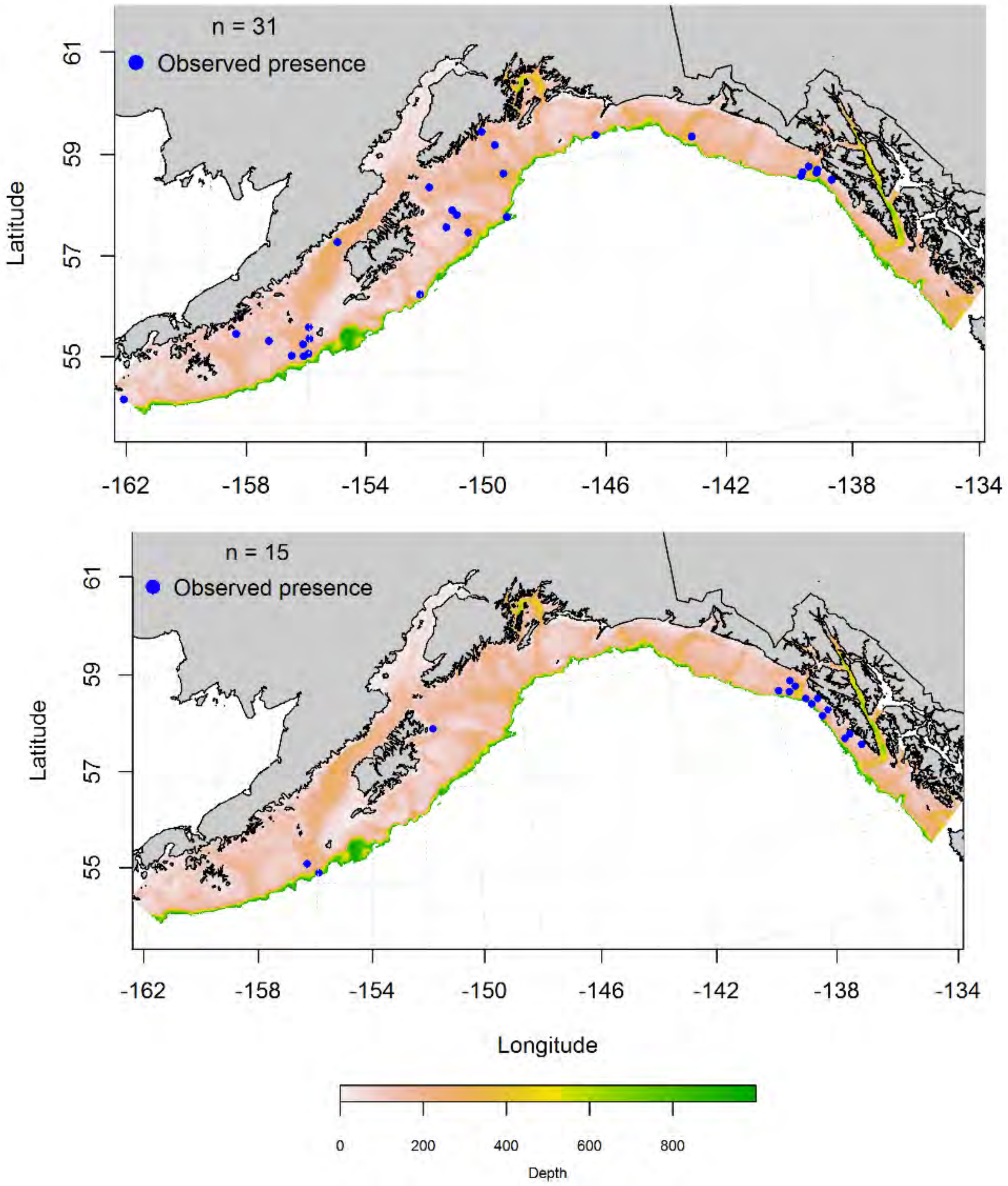


Figure 182. -- Spring and summer (top and bottom panel, respectively) observations of *Sebastolobus* spp. eggs from the Gulf of Alaska.

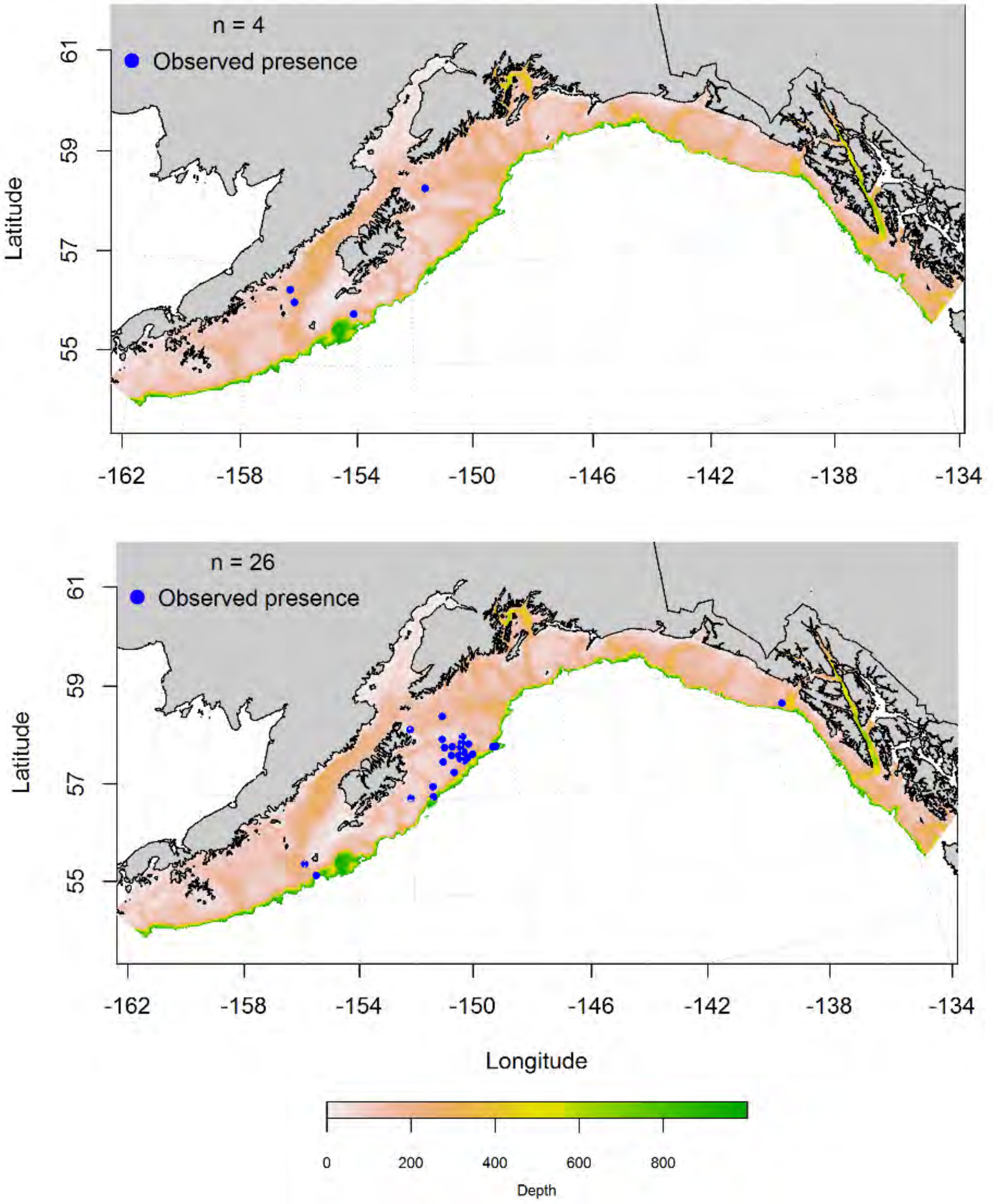


Figure 183. -- Spring and summer observations (top and bottom panel, respectively) of larval *Sebastolobus* spp. from the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *S. alascanus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile shortspine thornyhead largely occur in deeper portions of the middle- and outer-shelf (Figure 184). The variables determined to be the best predictors of the occurrence of juvenile shortspine thornyhead were depth, latitude and longitude, and tidal current.

The AUC for the training was 0.98, indicating an excellent model fit; while the AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.25. The percent of observations correctly classified was 94% for both the training test data. The most important variables predicting the abundance of juvenile shortspine thornyhead were depth, latitude and latitude, and slope. The best-fitting GAM explained 40% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile shortspine thornyhead were predicted to occur in deeper portions of the middle- and outer-shelf (Figure 185). Juvenile shortspine thornyhead were predicted to be most abundant along the shelf break. High abundance of juvenile shortspine thornyhead were also predicted to occur in Prince William Sound; however, these predictions were not supported by any observations.

Adult shortspine thornyhead were also predicted to occur in deeper portions of the middle- and outer-shelf. The variables determined to be the best predictors of habit for adult shortspine thornyhead were depth, latitude and longitude, and ocean color. The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.25. The percent of observations correctly classified was 93% for the training data set, and 94% for the test data set. The most important variables predicting the abundance of juvenile shortspine thornyhead were depth, latitude and latitude and slope. The best-fitting GAM explained 52% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult shortspine thornyhead were predicted to occur at low abundances over much of the deeper portions of the middle- and outer-shelf (Figure 186). They were also predicted to occur in Prince William Sound and Chatham Strait in southeast Alaska; however, these predictions were not supported by any observations.

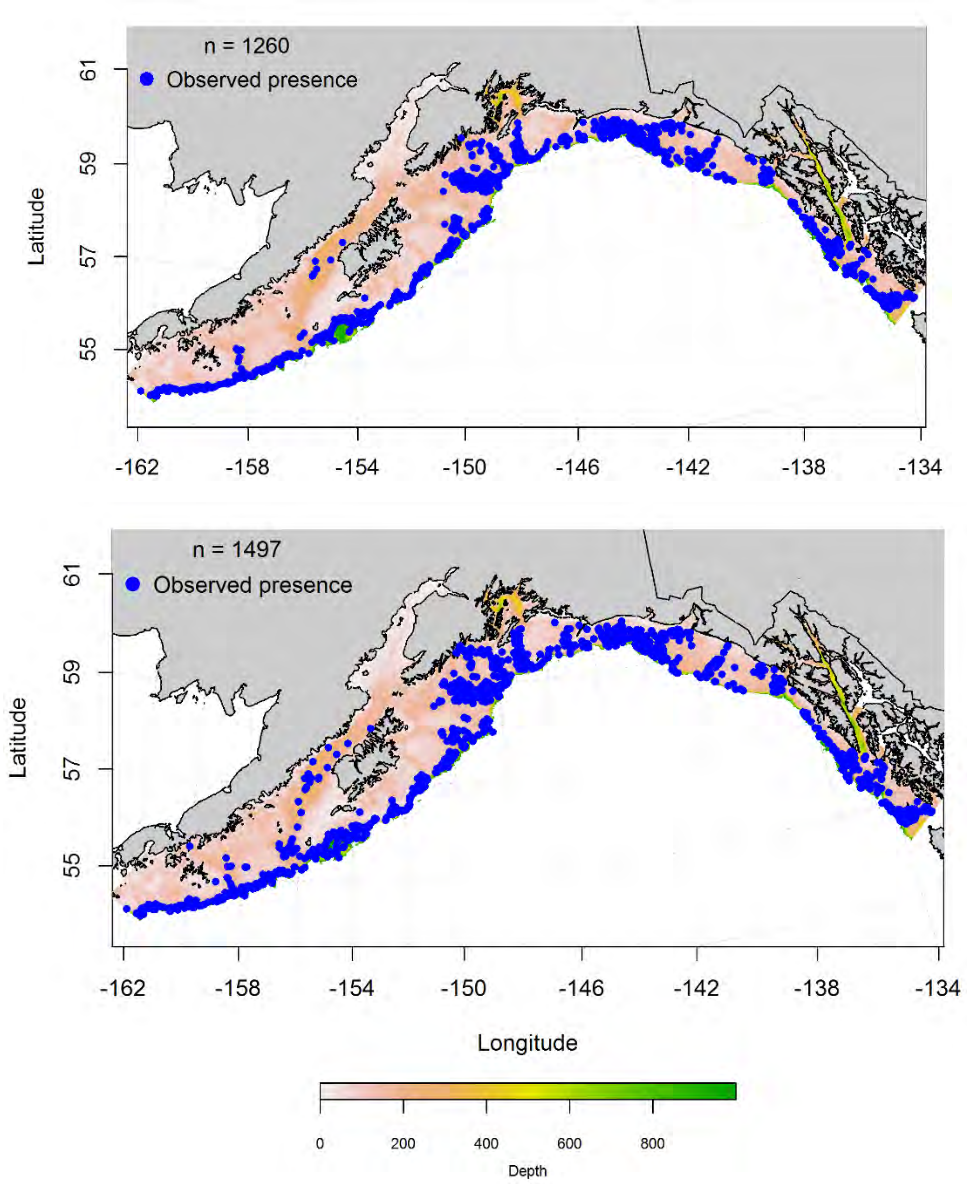


Figure 184. -- Locations of catches of juvenile and adult *S. alascanus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

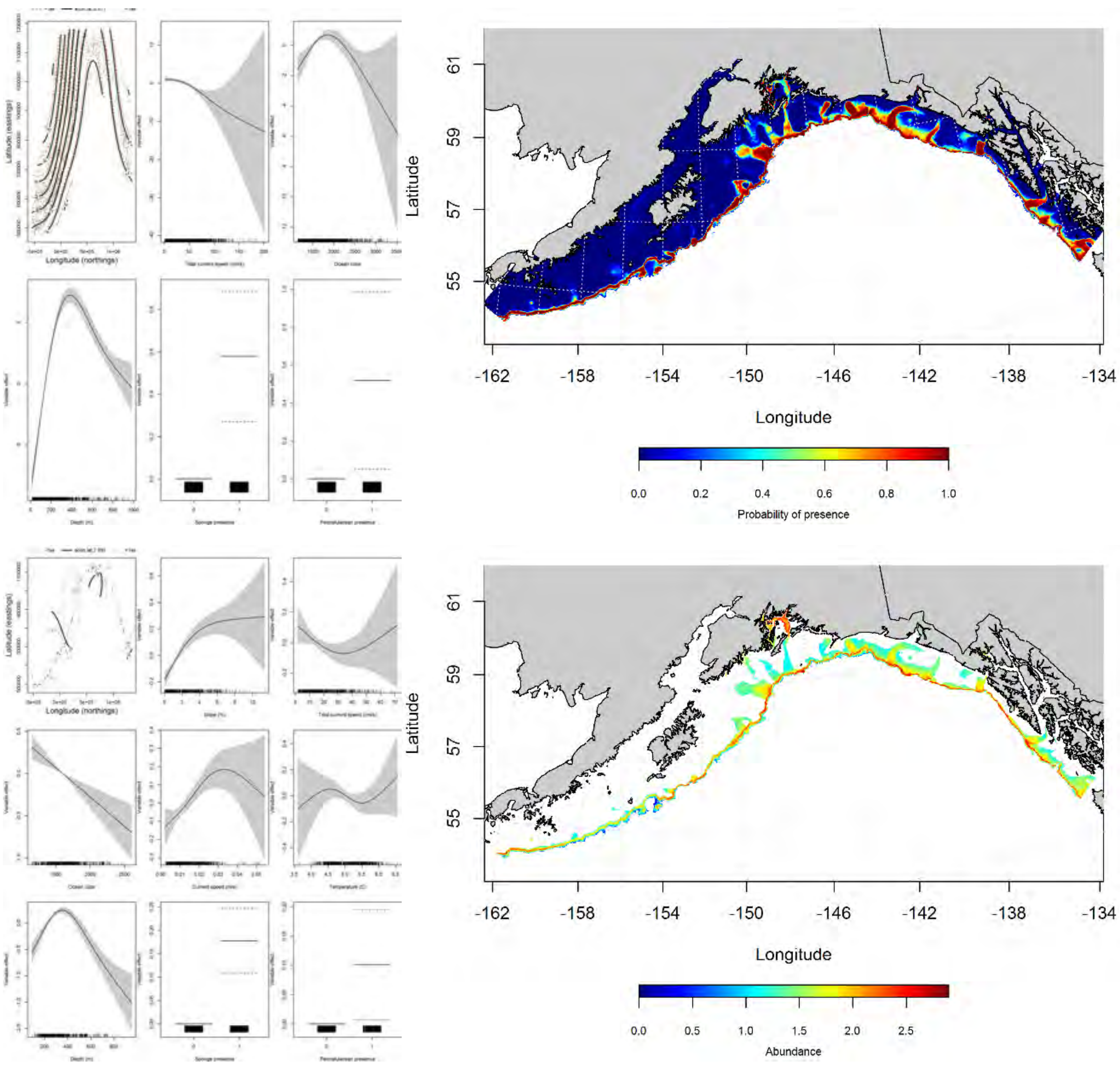


Figure 185. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *S. alascanus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

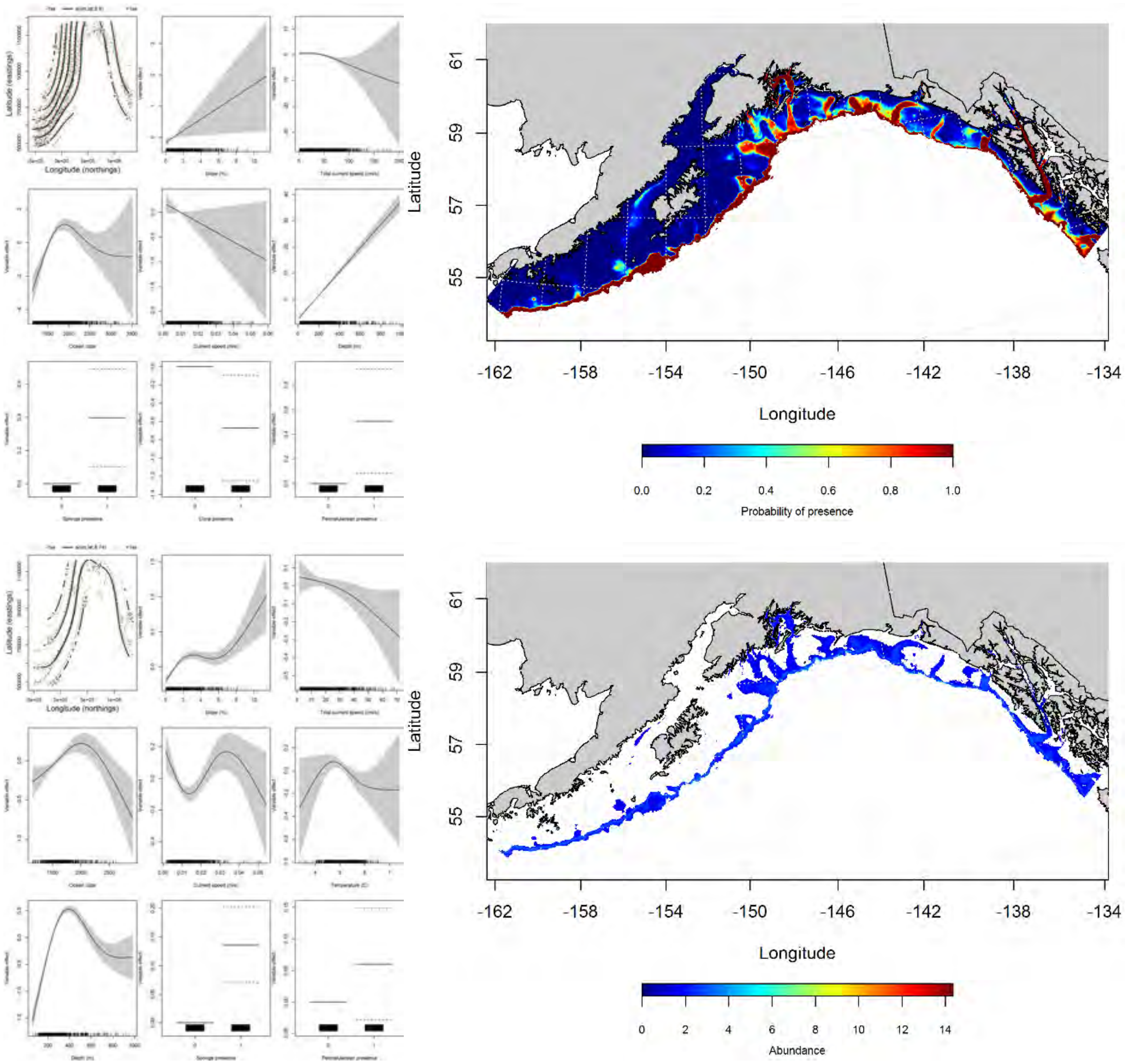


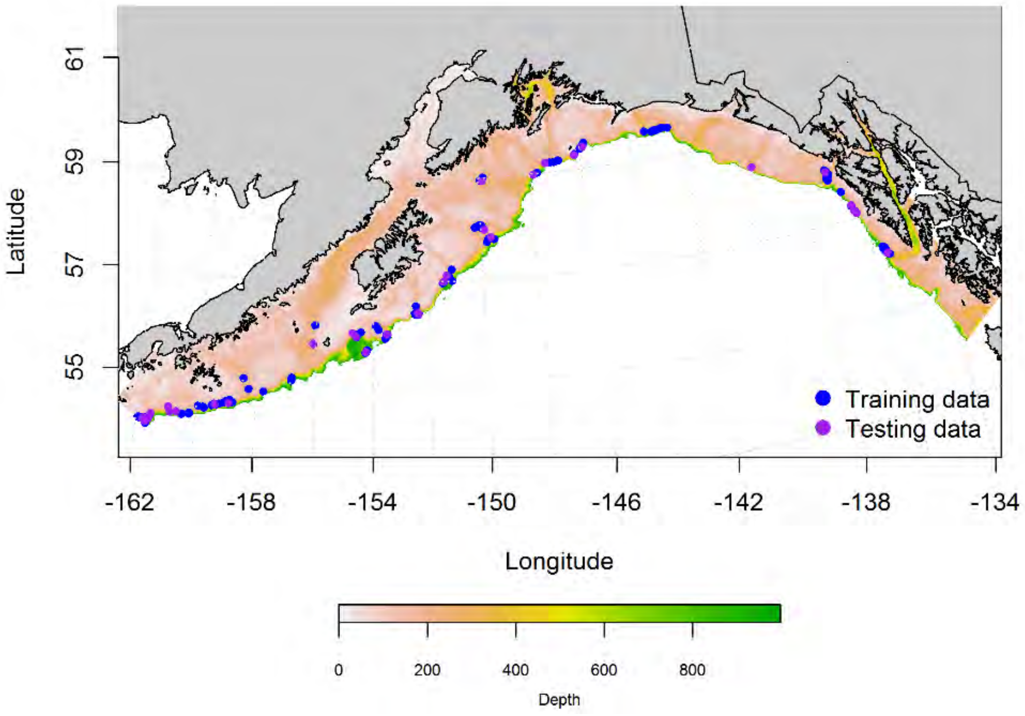
Figure 186. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. alascanus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. alascanus* in the Gulf of Alaska -- Commercial catch data indicate shortspine thornyhead largely occur along the shelf break in the Gulf of Alaska.

In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of shortspine thornyhead (relative importance = 48.9 and 26.9 respectively). The AUC was 0.97 for the training data, indicating an excellent model fit. The AUC for the test data was 0.91, indicating an excellent model fit. The percent of observations correctly classified was 92% and 91% respectively, for the training and test data. In the fall, adult shortspine thornyhead were predicted to occur along the shelf break throughout much of the GOA (Figure 187).

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of shortspine thornyhead (relative importance = 38.6 and 37.6 respectively). The AUC was 1.00 for the training data, indicating an excellent model fit. The AUC for the test data was 0.92, indicating an excellent model fit. The percent of observations correctly classified was 96% and 92% respectively, for the training and test data. In the winter, adult shortspine thornyhead habitat was predicted to largely occur along the shelf break between Cape St. Elias and Kodiak Island, as well as along the shelf break off Cape Ommaney in southeast Alaska (Figure 188). High suitability habitat was also predicted in Prince William Sound; however, these predictions were not supported by any observations.

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of shortspine thornyhead (relative importance = 87.8 and 7.2 respectively). The AUC was 0.97 for the training data, indicating a fair model fit. The AUC for the test data was 0.92, indicating an excellent model fit. The percent of observations correctly classified was 93% for the training data and 92% testing data. In the spring, adult shortspine thornyhead habitat was predicted to occur along the shelf break throughout much of the GOA (Figure 189).



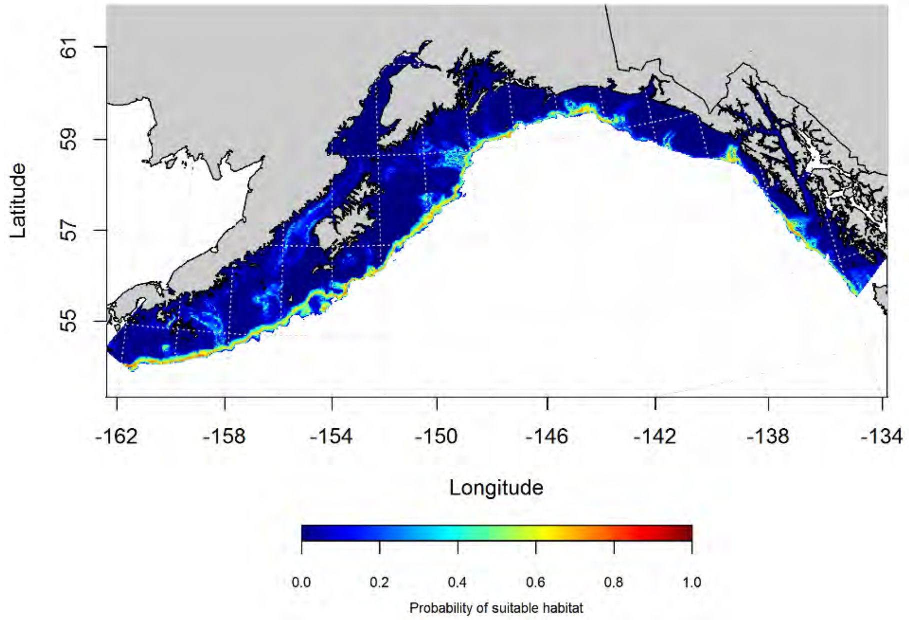
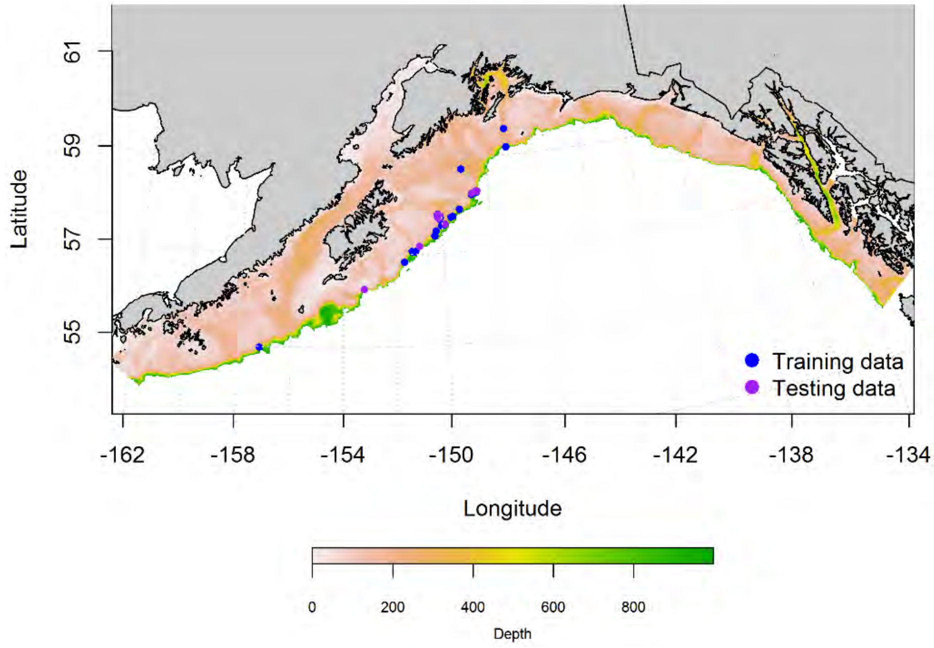


Figure 187. -- Locations of fall (September-November) commercial fisheries catches of *S. alascanus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *S. alascanus* commercial catches (bottom panel) and the purple points were used to test the model.



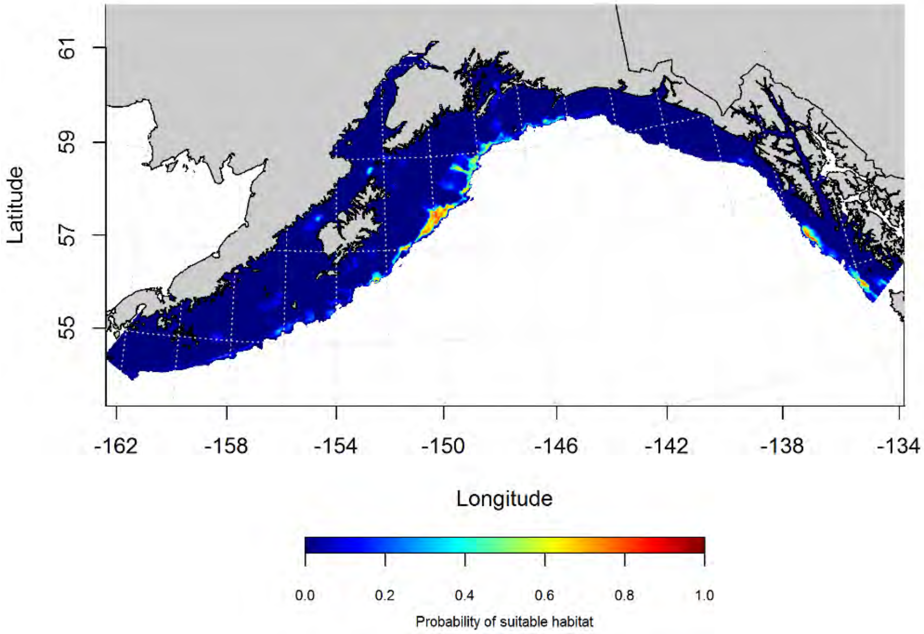
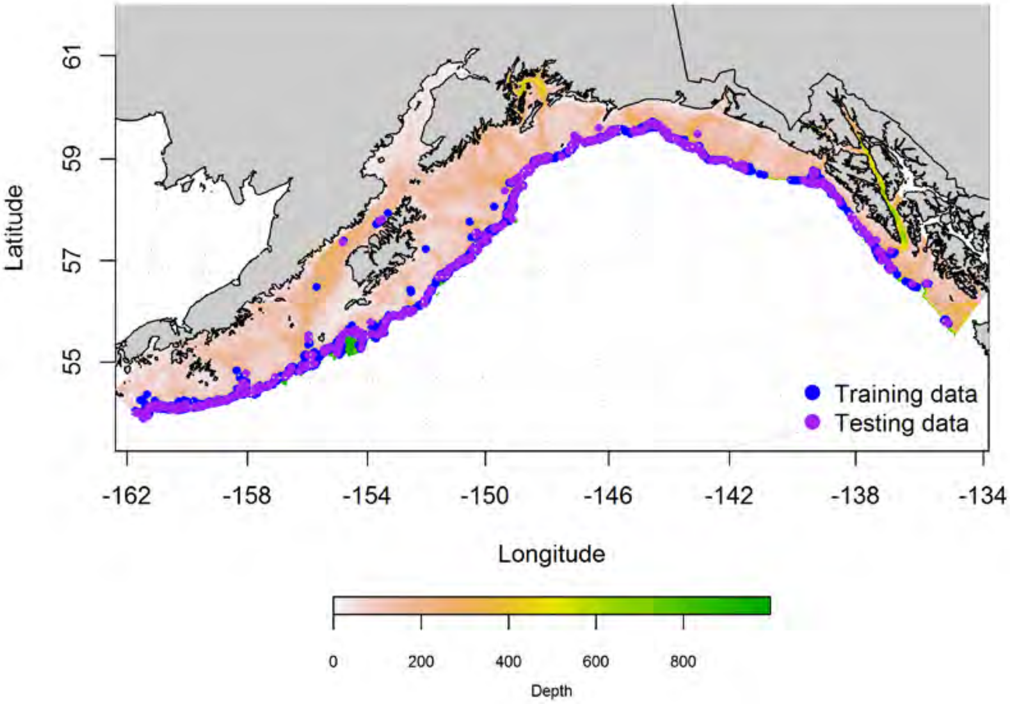


Figure 188. -- Locations of winter (December-February) commercial fisheries catches of *S. alascanus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *S. alascanus* commercial catches (bottom panel) and the purple points were used to test the model.



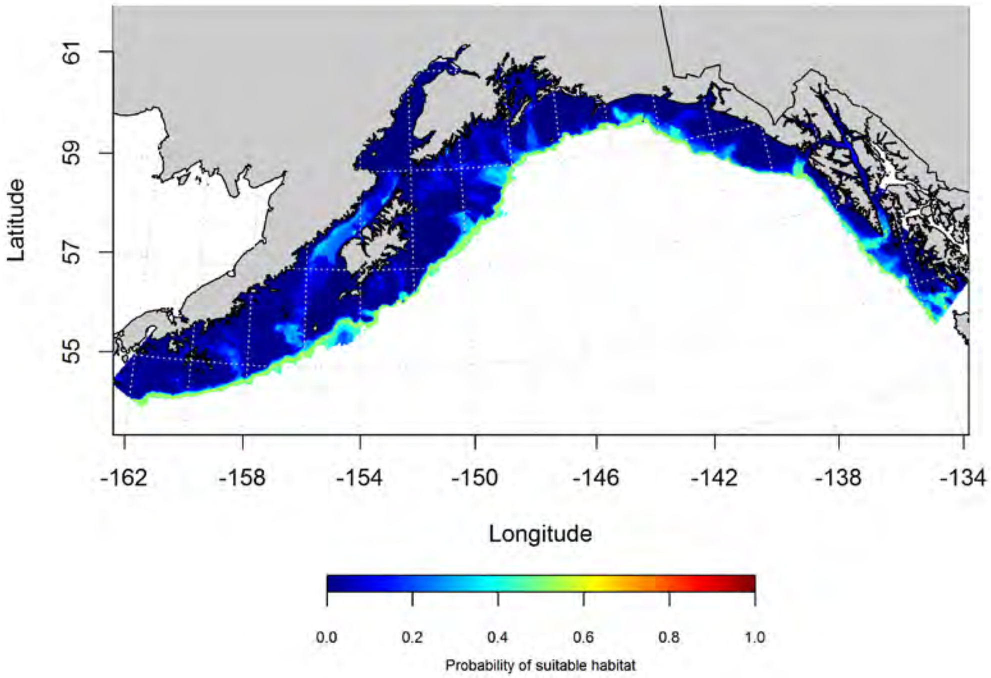


Figure 189. -- Locations of spring (March-May) commercial fisheries catches of *S. alascanus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. alascanus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. alascanus* Essential Fish Habitat Maps and Conclusions --

Essential fish habitat for Shortspine thornyhead was predicted to occur in deeper portions of the middle- and outer-shelf. No EFH could be predicted for any of the early life history stages of shortspine thornyhead.

Summer EFH for juvenile shortspine thornyhead, based on trawl survey observations, was predicted to include deeper portions of middle-and outer-shelf (Figure 190). EFH for juvenile shortspine thornyhead were also predicted to occur in Prince William Sound; however, these predictions were not supported by any observations. Summer EFH for adult shortspine thornyhead, based on trawl survey observations, was predicted to include the deeper portions of middle- and outer-shelf. EFH for adult shortspine thornyhead were also predicted to occur in Prince William Sound; however, these predictions were not supported by any observations.

Fall and spring EFH for shortspine thornyhead, based on commercial catch data, also included the deeper portions of the middle-shelf, and shelf break across the GOA. During the spring EFH for shortspine thornyhead was predicted to be more restricted, and to largely occur along the shelf break between Cape St. Elias and Kodiak Island (Figure 191).

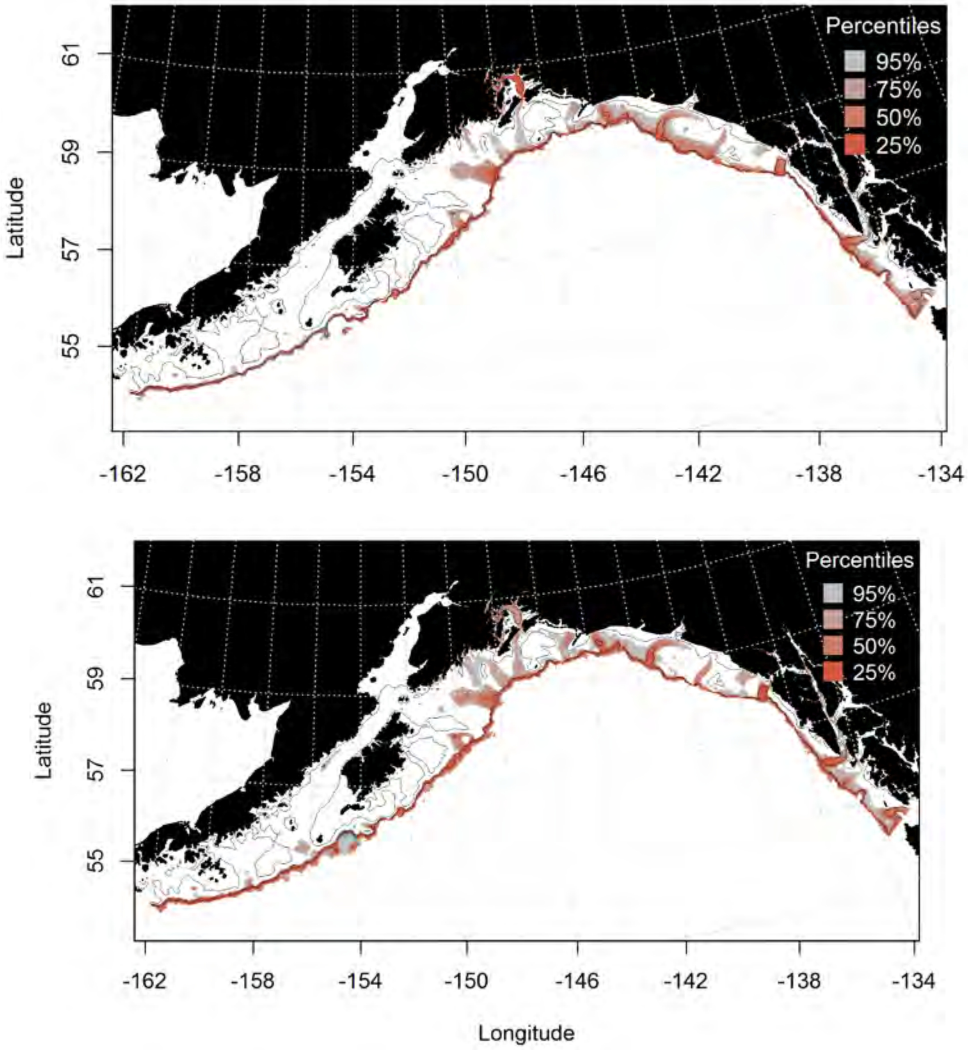


Figure 190. -- Predicted summer essential fish habitat for *S. alascanus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

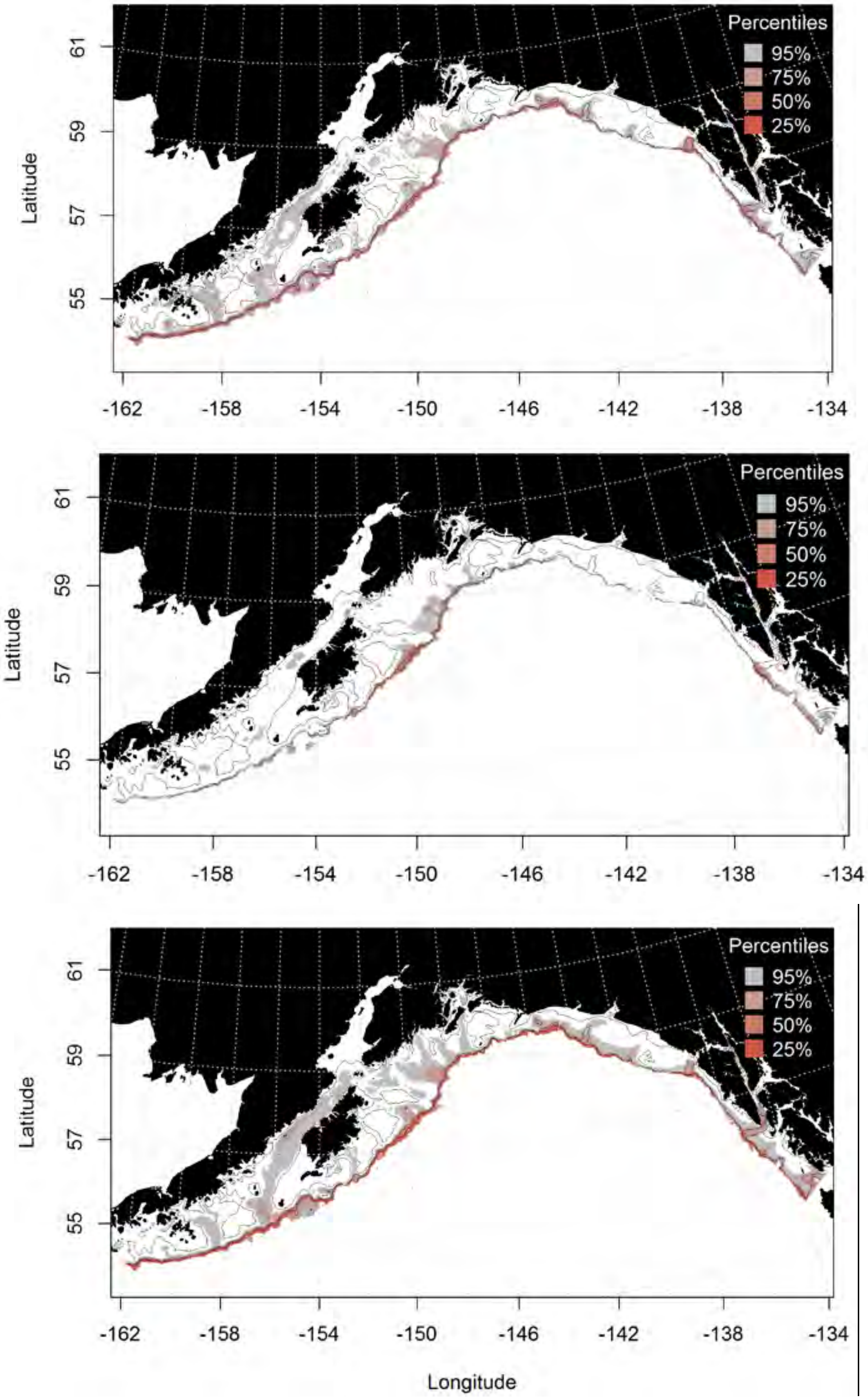


Figure 191. -- Essential fish habitat predicted for *S. alascanus* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

longspine thornyhead (*Sebastolobus altivelis*)

The distribution of longspine thornyhead in the Gulf of Alaska is poorly understood, and they typically occur on the continental shelf and slope at depth of 201-1,756 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastolobus* spp. in the Gulf of Alaska -- Observations of longspine and shortspine thornyhead (*Sebastolobus alascanus*) early life history stages were difficult to consistently separate by species. Consequently analysis of these the early life history stages of these species was conducted at the genus level, *Sebastolobus* spp. Please refer to section 18.1 of this report for an analysis of information early life history of *Sebastolobus* spp.

Spring and summer distribution of juvenile and adult *S. altivelis* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate longspine thornyhead largely occurs along the shelf beak throughout much of the Gulf of Alaska. Juvenile and adult longspine thornyhead were difficult to consistently separate and therefore they were aggregated together during the analysis of trawl survey data. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability for longspine thornyhead (relative importance 85.4 and 11.2 respectively). The AUC for the training data was 1.00, indicating an excellent model fit. The AUC for the testing data was 0.96, indicating an excellent model fit. The percent of correctly classified observations was 97% for the training data and 96% for the test data. During the summer longspine thornyhead were predicted to have a patchy distribution along the shelf break, with the highest suitably habits predominantly occurring in the western gulf (Figure 192).

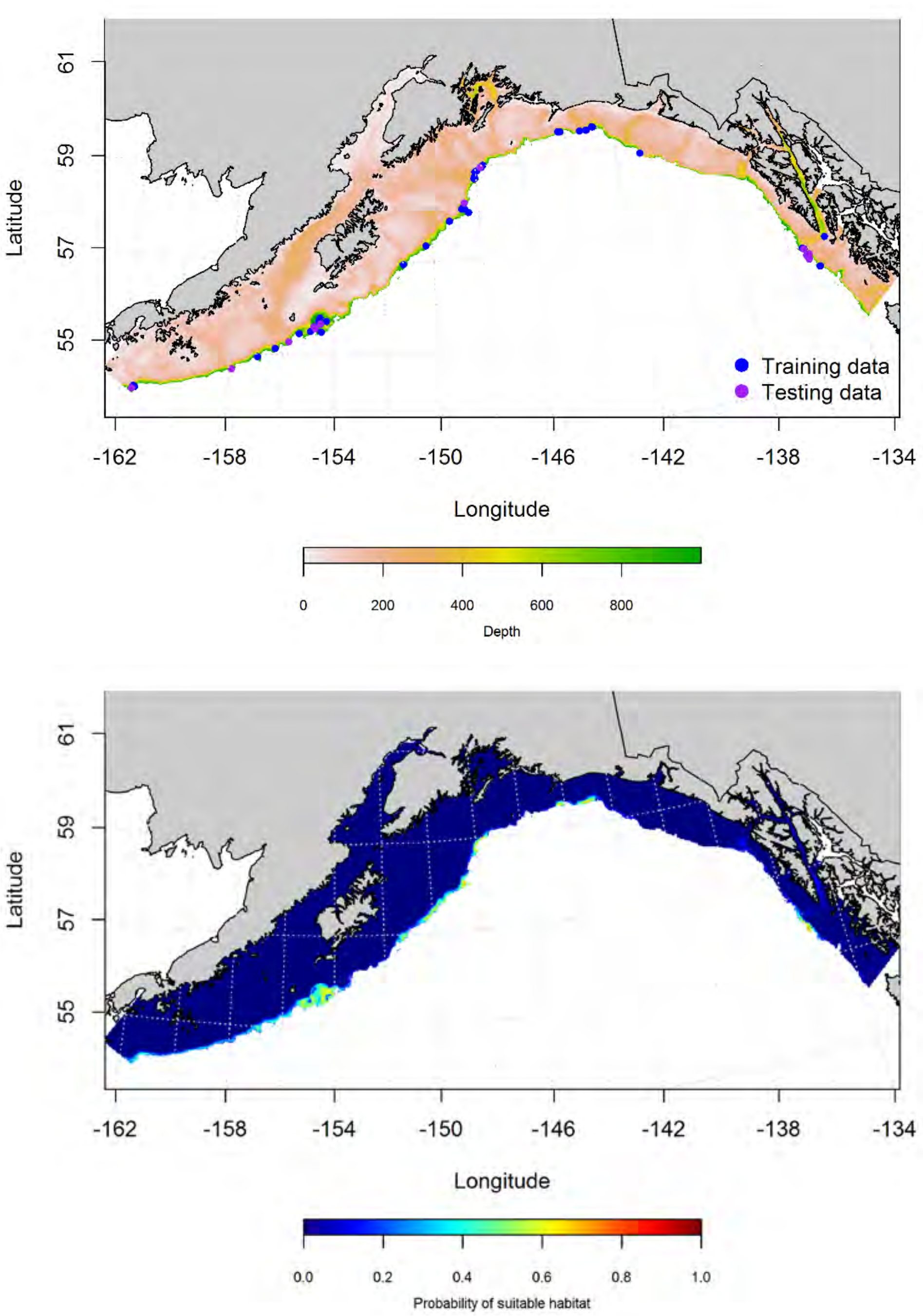


Figure 192. -- Locations of trawl survey catches of all life stages combined for *S. altivelis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of

the distribution of all life stages combined for *S. altivelis* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. altivelis* in the Gulf of Alaska -- Commercial catch data were available only during the spring. *MaxEnt* modeling determined that depth and slope were the most important variables predicting the distribution of longspine thornyhead (relative importance = 77.8 and 8.0 respectively). The AUC for the training data 0.97, indicating an excellent model fit. The AUC for the test data was 0.82, indicating a good model fit. The percent of observations correctly classified for the training data was 93%, and it was 82% for the test data. In the spring, longspine thornyhead were predicted to occur along the shelf break, particularly between Cape St. Elias and Kodiak Island (Figure 193).

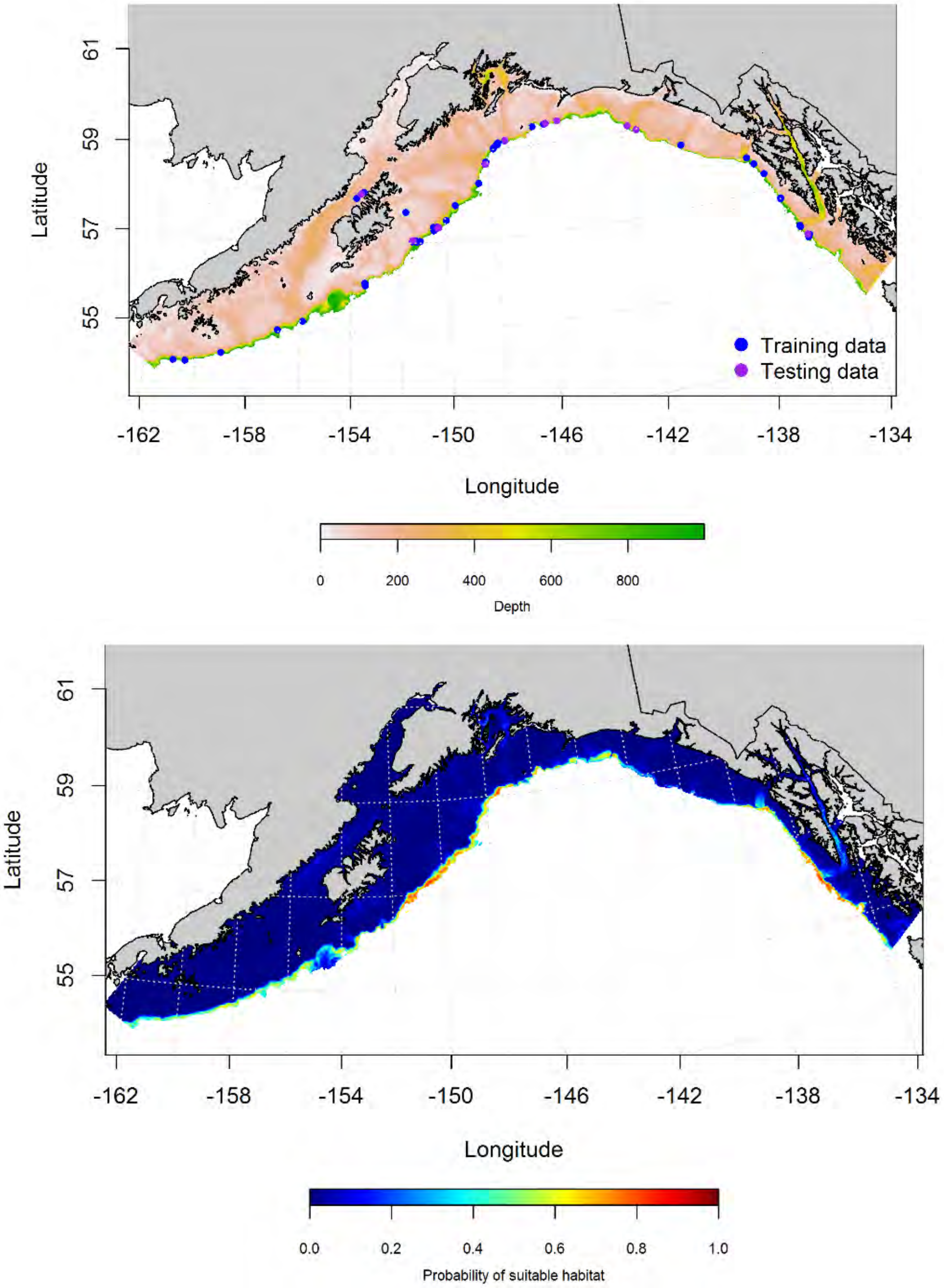


Figure 193. -- Locations of spring (March-May) commercial fisheries catches of *S. altivelis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. altivelis* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. altivelis* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for longspine thornyhead was predicted to occur along the shelf break throughout the Gulf of Alaska. No EFH could be predicted for early life history stages of longspine thornyhead. Summer EFH for longspine thornyhead, based on trawl survey observations was predicted to occur in a patchy distribution along shelf break across much of the GOA (Figure 194).

Spring EFH for longspine thornyhead, based on commercial catch data, was predicted to occur along the shelf break throughout much of the GOA (Figure 195).

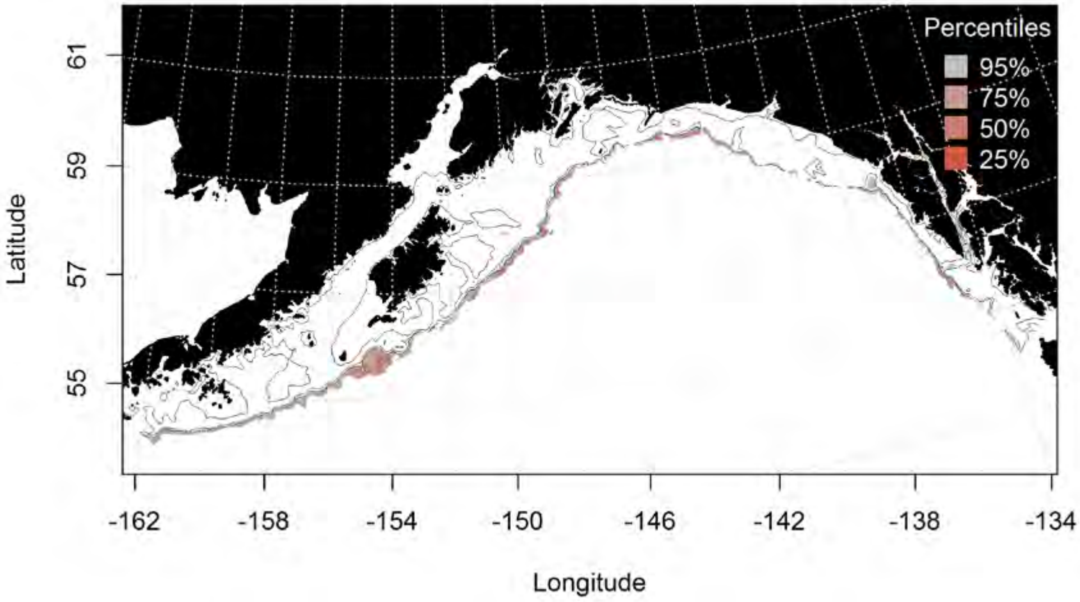


Figure 194. -- Predicted summer essential fish habitat for *S. altivelis* all life stages combined from summer bottom trawl surveys.

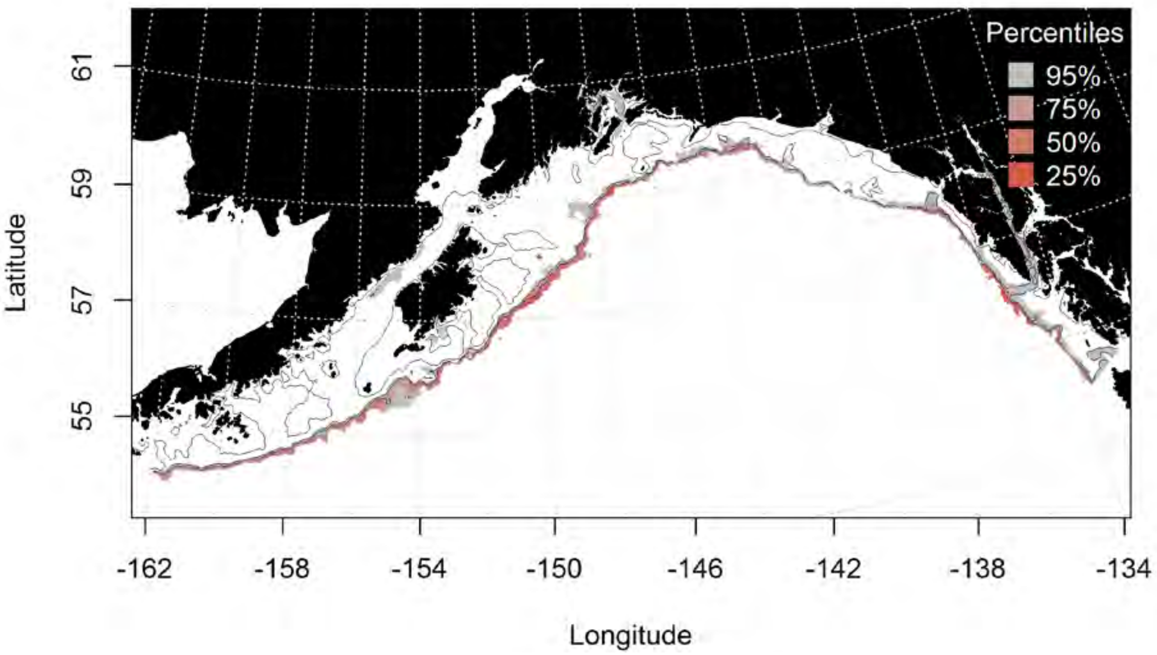


Figure 195. -- Essential fish habitat predicted for *S. altivelis* during spring from commercial catches.

Rougheye rockfish (*Sebastes aleutianus*)

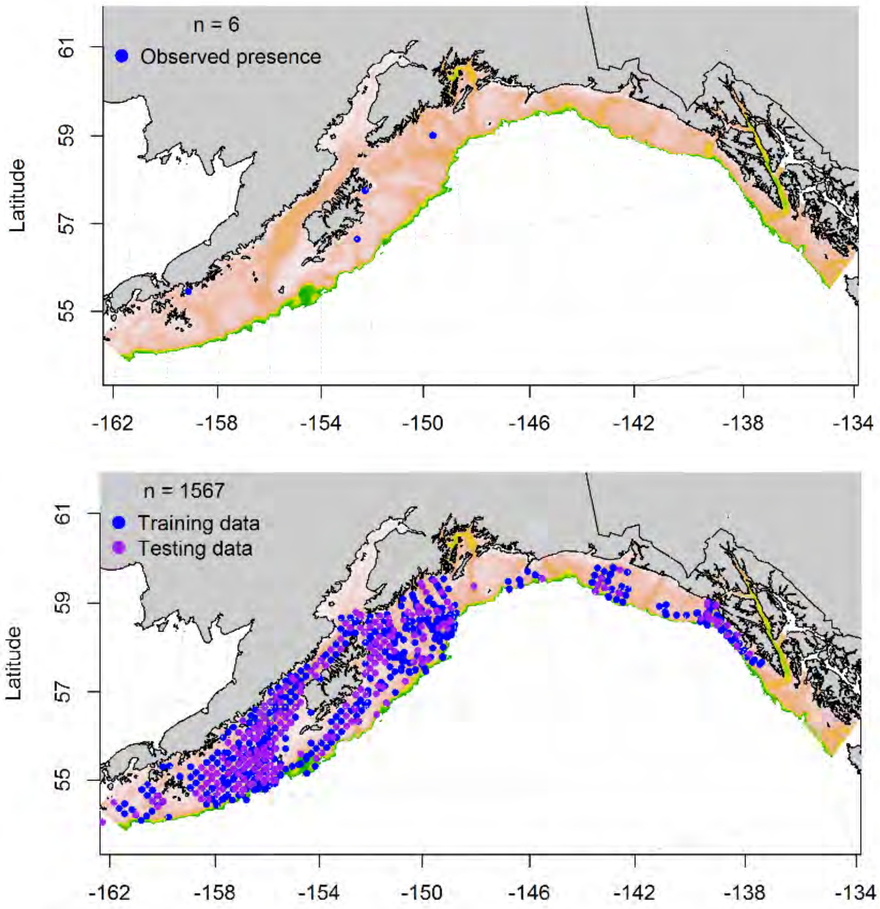
Rougheye rockfish occur throughout the Gulf of Alaska, primarily on the upper continental slope and in the deeper gullies between 201-500 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *S. aleutianus* in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp. There were no observation of Sebastes eggs in the EcoFOCI database.

Larval *Sebastes* spp. were observed during the fall, spring, and the summer (Figure 196). During the winter, six *Sebastes* spp. larvae. They distributed across much of the inner- and middle-shelf in the western gulf. In the spring, larval Sebastes spp. were abundant and they were observed across much of the shelf.

The best-fitting *MaxEnt* model indicated that depth and surface temperature were the most important variables predicting habitat suitable (relative importance 42.0 and 16.5 respectively). The AUC was 0.83 for the training data, indicating a good model fit. The AUC for the testing data was 0.71, indicating a fair model fit. The percent of the observations correctly classified in the training data was 73% and 71% for the test data. During the spring, *Sebastes* spp. larval were predicted to occur across much of the western GOA, with the highest suitability habitats occurring in Shelikof Strait, in Shelikof Gully, and Amatuil Trough (Figure 197). An isolated area of high probability habitat was also predicted to occur between Montague and Hinchinbrook Island in Prince William Sound; however, these predictions were not supported by any observations. During the summer, larval *Sebastes* spp. were also abundant. The most important variable predicting larval habitat suitability were depth surface temperature (36.2 and 26.6, respectively). The AUC was 0.79 for the training data, indicating a fair model fit. The AUC for the testing data was 0.68, indicating a poor model fit. The percent of the observations correctly classified in the training data was 72% and 68% for the test data. During the summer, *Sebastes* spp. larval habitat were predicted to include much of the western GOA, particularly around Kodiak Island. A smaller isolated area of high suitability habitat was also predicted on the outer-shelf south of Cape Ommaney.

Early juvenile *Sebastes* spp. were only observed during the summer (OR SPRING?). Eighteen larvae were observed, they largely occurred along the middle- and outer-shelf in the western gulf (Figure 198). There was insufficient data to predict the distribution of early juvenile *Sebastes* spp.



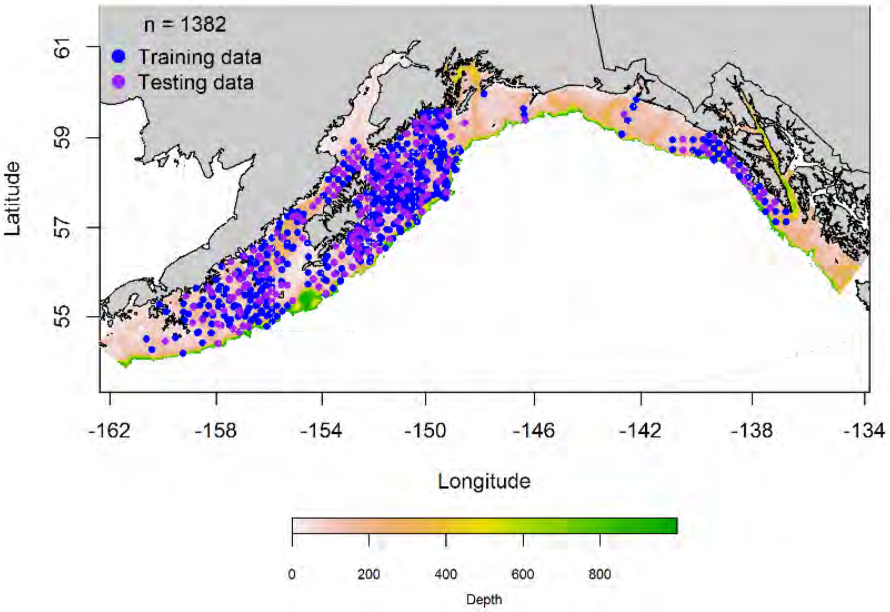
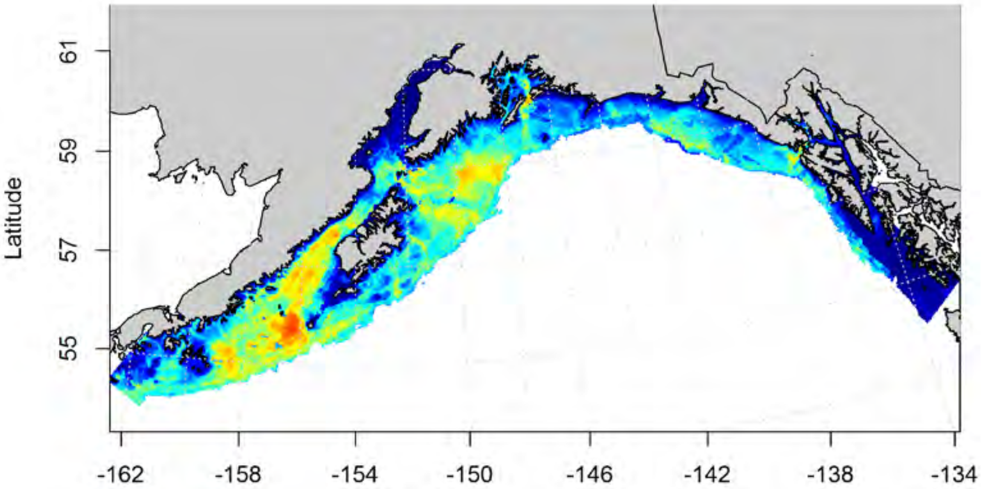


Figure 196. -- Fall, spring, and summer observations (top, middle, and bottom panel, respectively) of larval *Sebastes* spp. from the Gulf of Alaska.



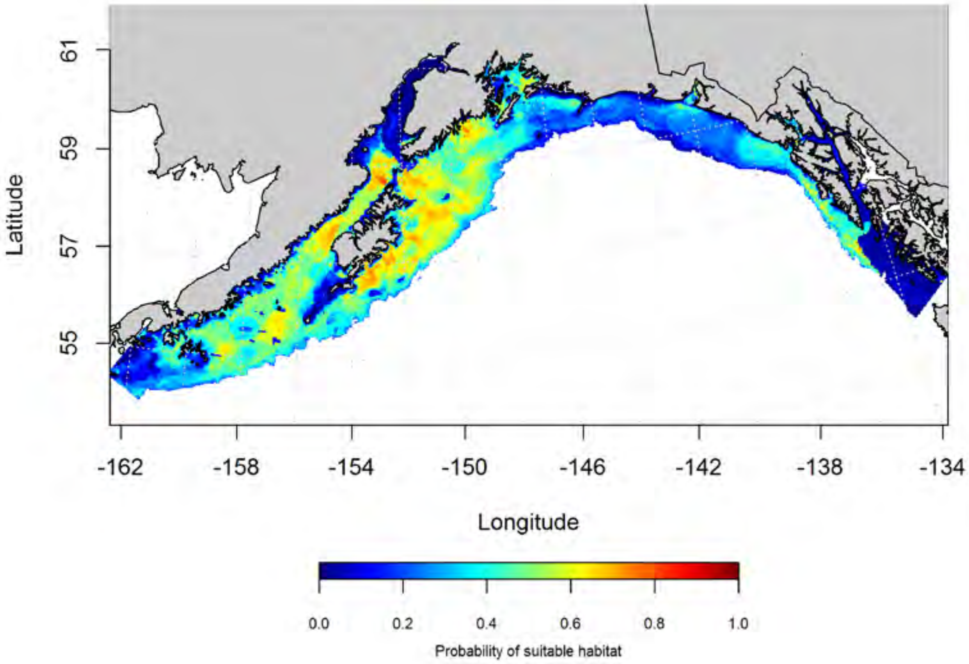


Figure 197. -- Predicted probability of spring and summer observations (top and bottom panel, respectively) distribution of larval *Sebastes* spp. from maximum entropy modeling of the Gulf of Alaska.

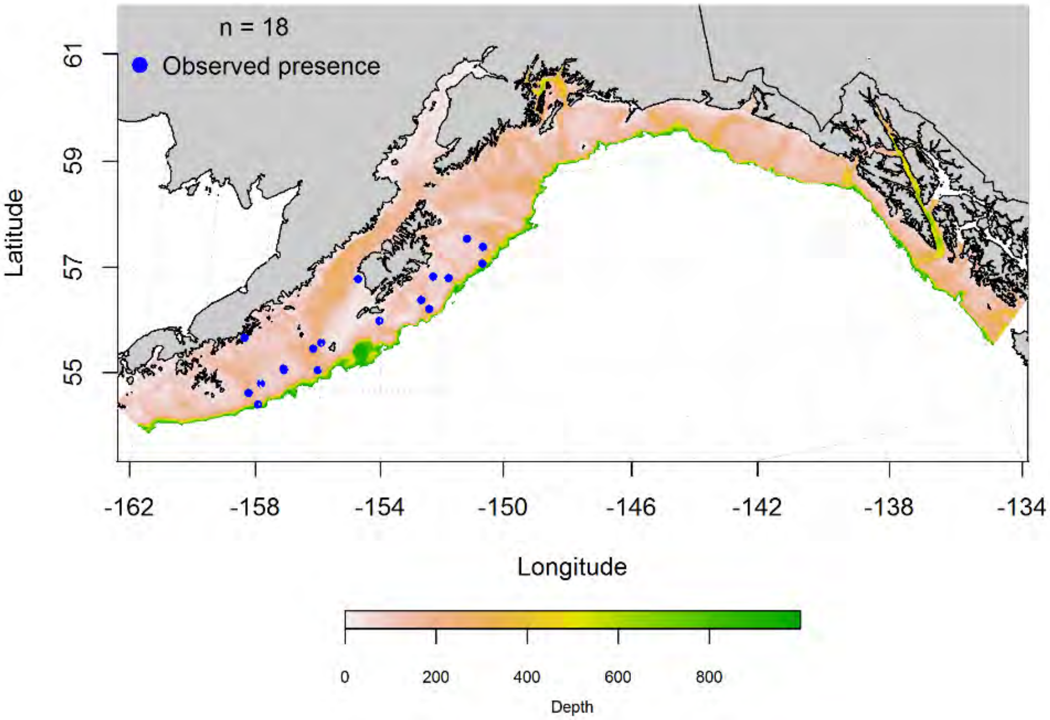


Figure 198. -- Spring catches of early juvenile *Sebastes* spp. in the Gulf of Alaska.

Spring and summer distribution of juvenile and adult *S. aleutianus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile rougheye rockfish occur across much of the shelf in the Gulf of Alaska (Figure 199).

The variables determined to be the best predictors of the occurrence of juvenile rougheye rockfish were depth, latitude and longitude, and tidal current. The AUC for the training was 0.92, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.24. The percent of observations correctly classified was 84% for the training data set, and 93% for the test data set. The most important variables predicting the abundance of juvenile rougheye rockfish were latitude and longitude, tidal current, and depth. The best-fitting GAM explained 22% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile rougheye rockfish were predicted to occur along much of the deeper portions of the middle-shelf in the central and eastern gulf, as well in Shelikof Strait in the western gulf. Predicted areas of high juvenile rougheye rockfish abundance included the deeper portions of the outer-shelf in the central and eastern gulf, particular from the Kenai Peninsula to southeast Alaska (Figure 200). High abundances of juvenile rougheye rockfish were also predicted in Prince William Sound and inside waters in southeast Alaska; however, these predictions were not supported by any observations.

Summer bottom trawl survey data indicated that adult rougheye rockfish also occurred across much of shelf, but at slightly deeper depths than the juveniles. The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 80.7 and 14.2 respectively). The AUC for the training data was 0.95, indicating an excellent model fit. The AUC for the testing data was 0.83, indicating a good model fit. The percent of correctly classified observations was 86% for the training data and 83% for the test data. Summer adult rougheye rockfish habitat was predicted to occur in most of the deeper valleys and troughs in the eastern and central gulf, as well as along the shelf break and Shelikof Strait in the western gulf (Figure 201).

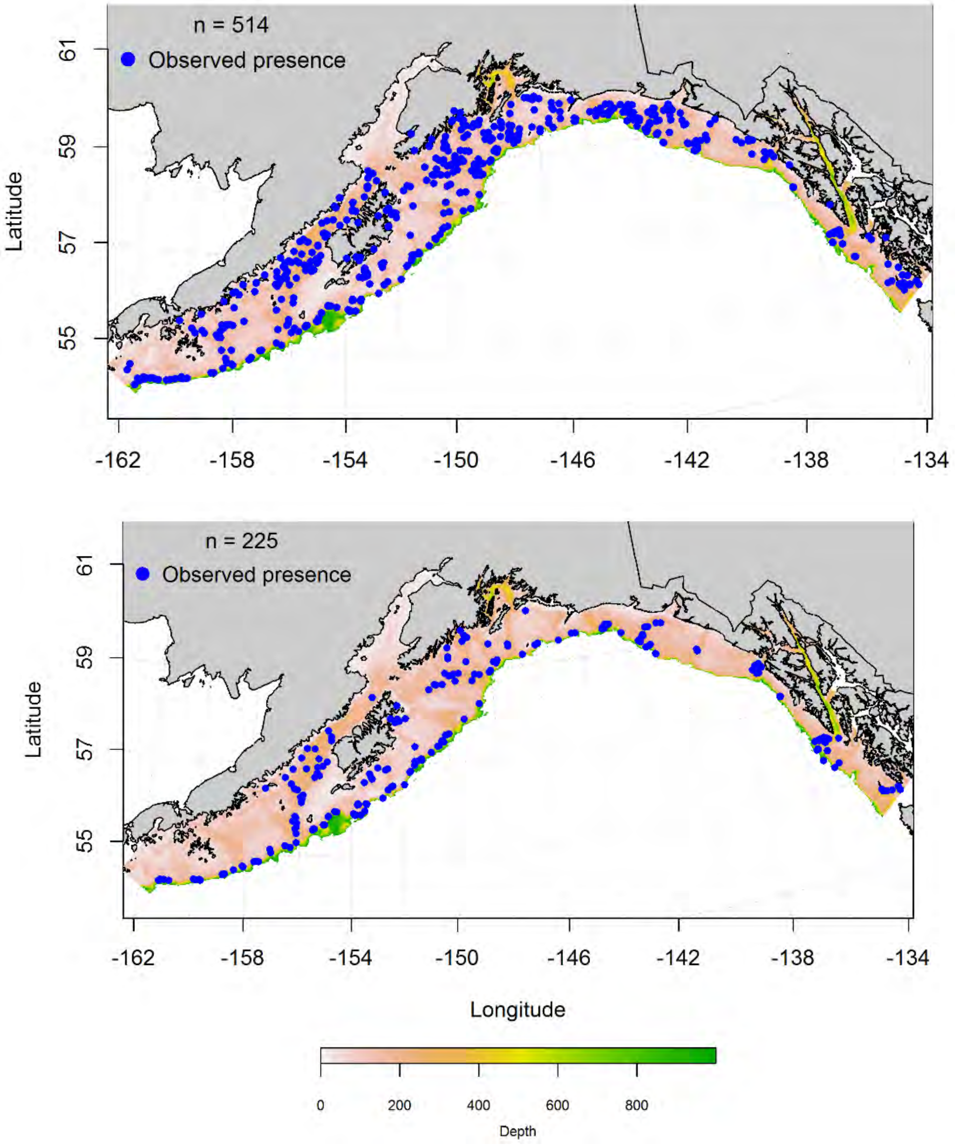


Figure 199. -- Locations of catches of juvenile and adult *S. aleutianus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

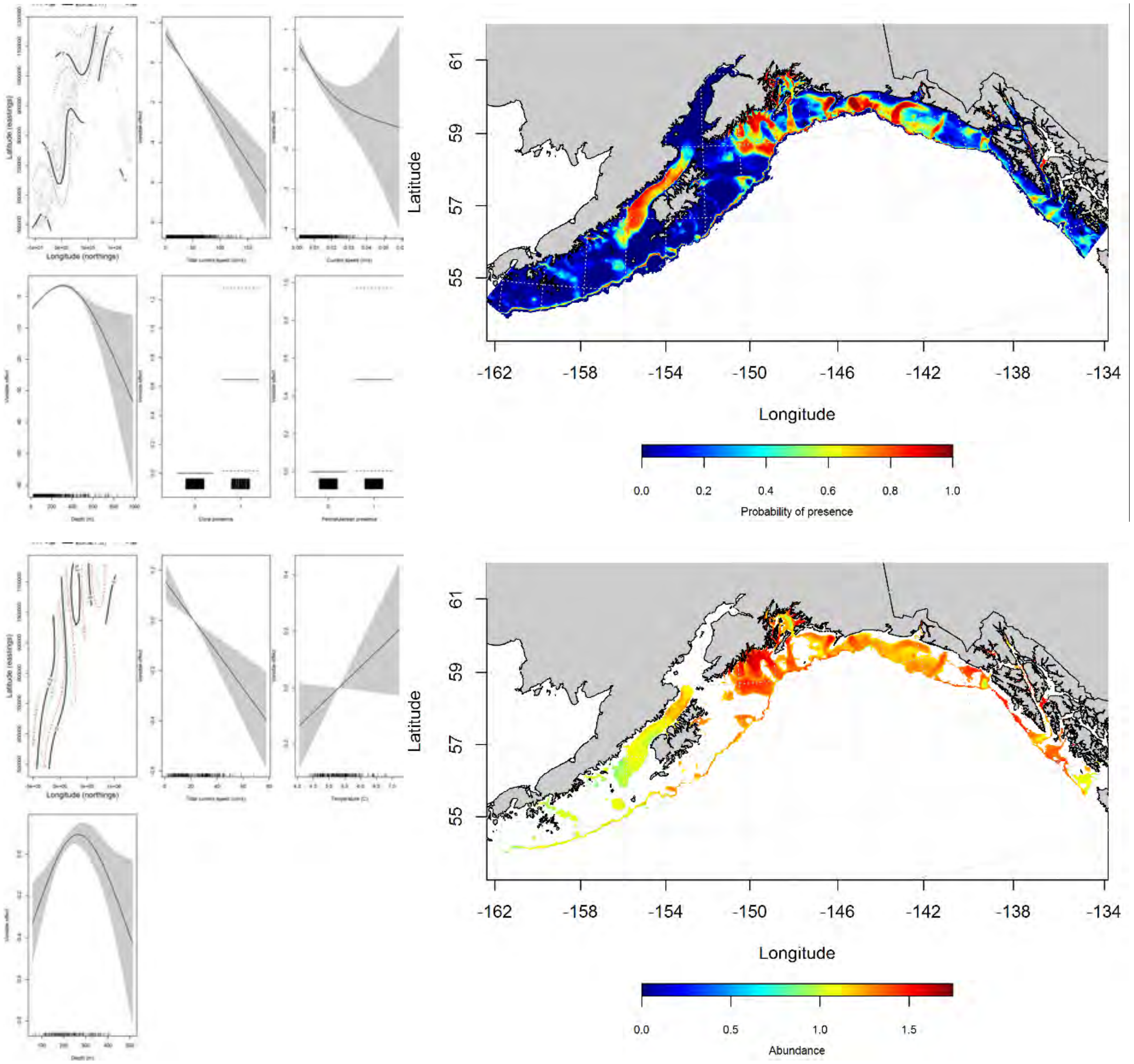


Figure 200. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *S. alascanus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

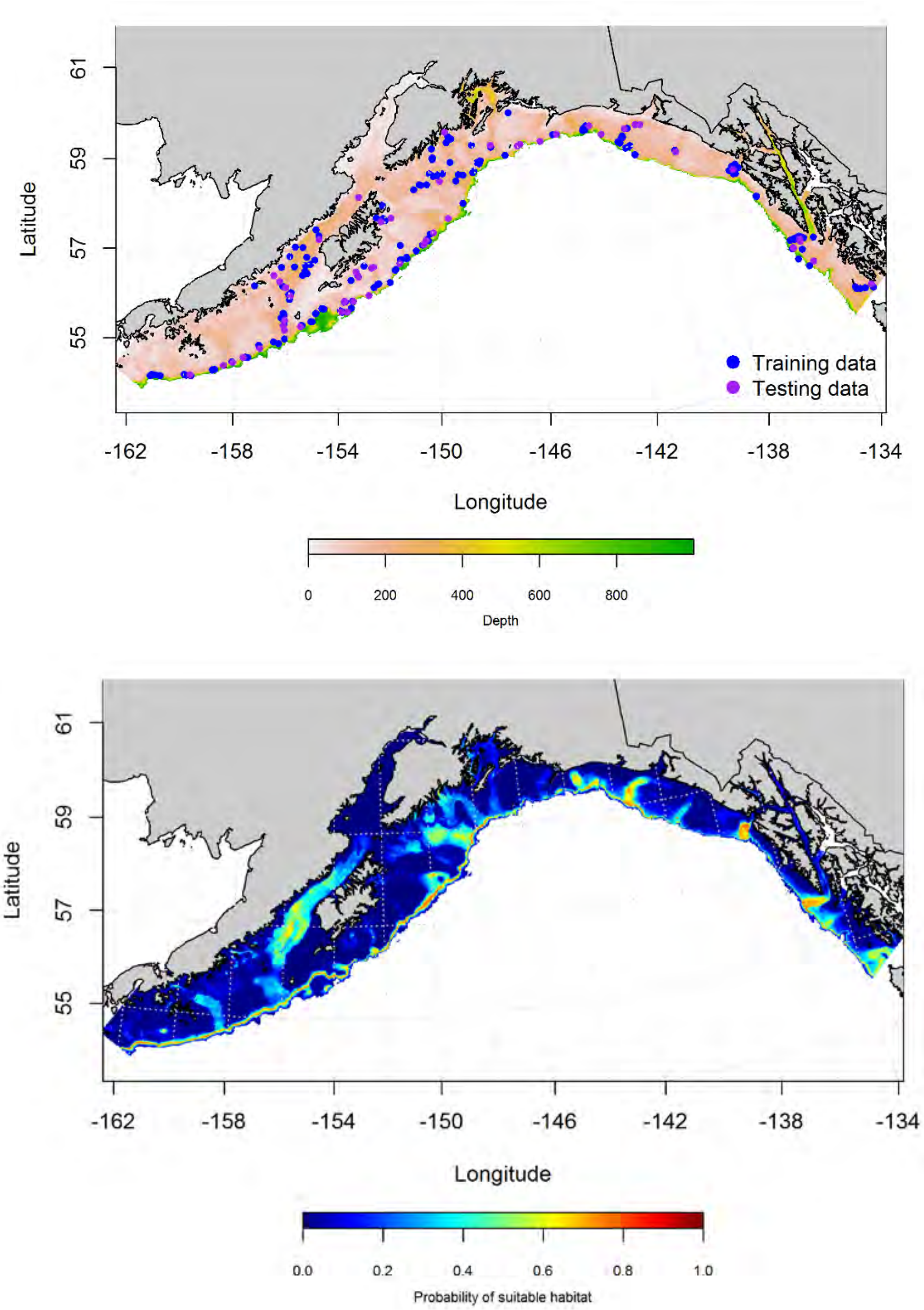


Figure 201. -- Locations of trawl survey catches of adult *S. aleutianus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. aleutianus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. aleutianus* in the Gulf of Alaska -- There were no observations of rougheye rockfish from commercial fisheries data.

Gulf of Alaska *S. aleutianus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for rougheye rockfish was predicted to occur in the deeper portions of the shelf in the eastern and central Gulf of Alaska. Because the early life history stages of most rockfish, including rougheye rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp. There were not a sufficient number of observations in the EcoFOCI database to be able to model the distribution of EFH for rockfish eggs.

EFH for larval rockfish, during the spring and summer was predicted to include much of the shelf in the GOA, except off southeast Alaska (Figure 202). There were not a sufficient number of observations in the EcoFOCI database to be able to model the distribution of EFH for early juvenile rockfish.

Summer EFH for juvenile rougheye rockfish, based on trawl survey observations, was predicted to include much of the deeper portions of middle-and outer-shelf in the eastern and central GOA (Figure 203). EFH for juvenile rougheye rockfish was also predicted to occur in Prince William Sound and inside waters in southeast Alaska; however, these predictions were not supported by any observations. EFH for adult rougheye rockfish, was more predicted to include much of the deeper portions of the outer-shelf in the eastern and central GOA, as well as the shelf break and Shelikof Strait in the western GOA.

There were not sufficient observations from commercial fisheries data to be able to model the distribution of EFH for rougheye rockfish.

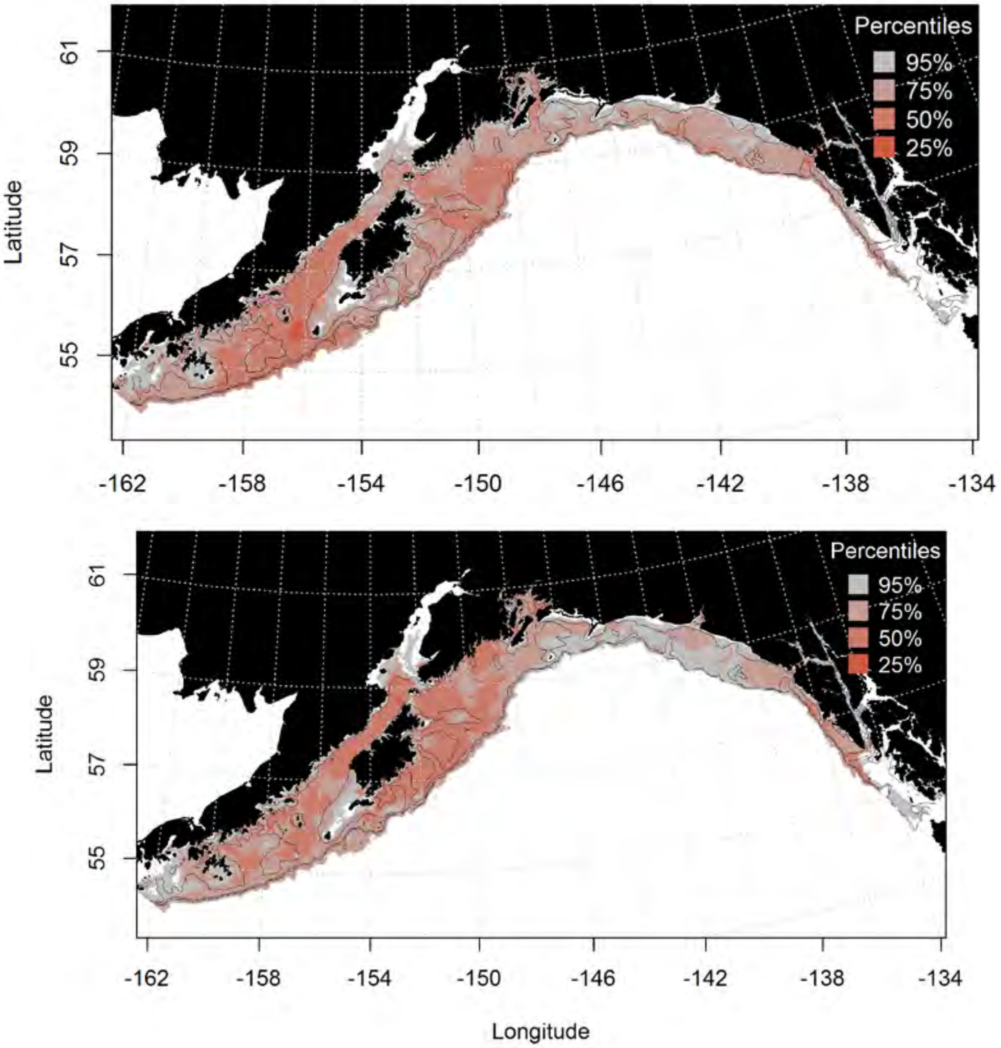


Figure 202. -- Spring and summer essential fish habitat predicted for larval *Sebastes* spp. (top and bottom panel, respectively) from the EcoFOCI database.

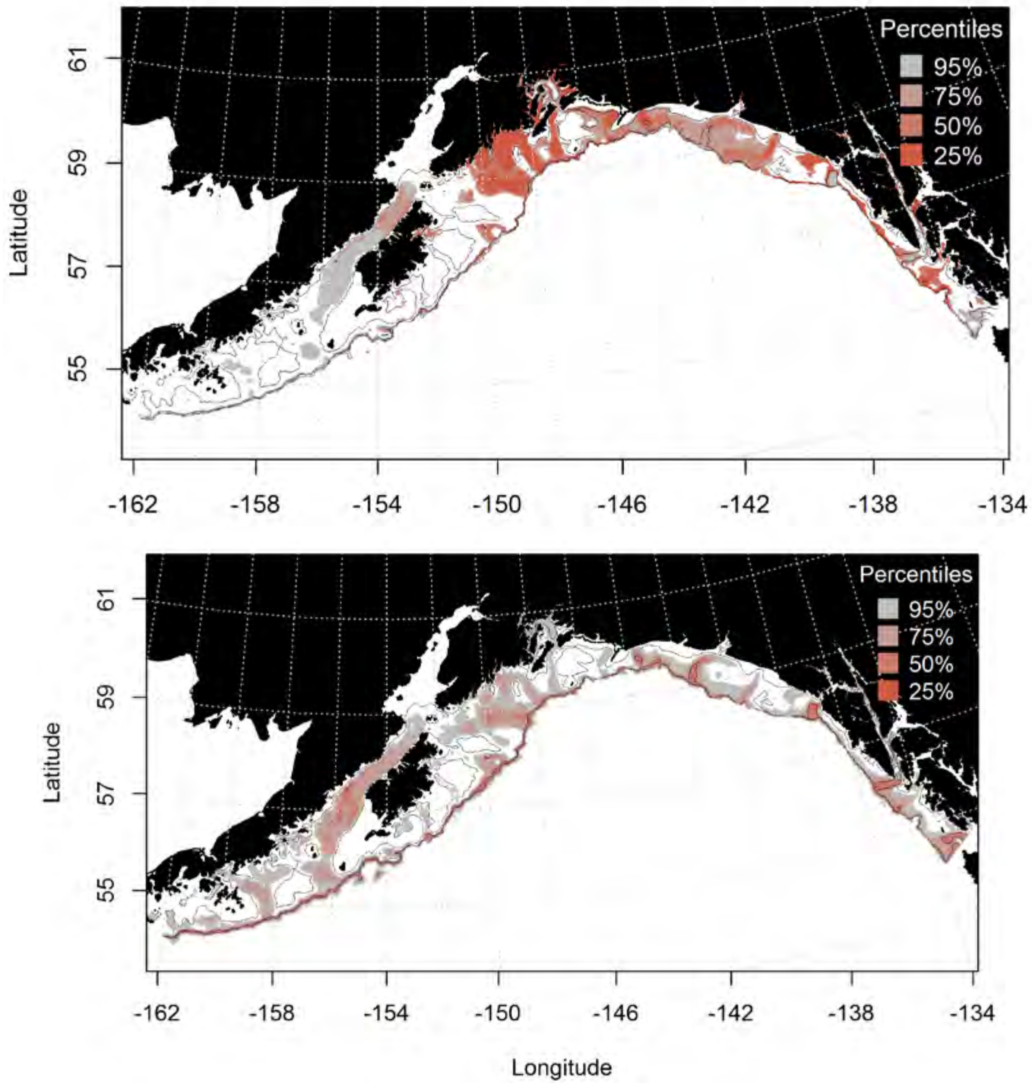


Figure 203. -- Predicted summer essential fish habitat for *S. aleutianus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

There were no observations of rougheye rockfish from commercial fisheries data in during the fall or summer.

Pacific ocean perch (*Sebastes alutus*)

Pacific ocean perch are one of the most abundant rockfish species in the Gulf of Alaska. They occur throughout much of the GOA, at between 101-300 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes spp.* in the Gulf of Alaska –

THIS SECTION IS WRONG SINCE POP LARVAE CAN BE DISTINGUISHED FROM OTHER SEBASTES LARVAE

The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp. Please see section 20.1 of this report for an analysis of these data.

Spring and summer distribution of juvenile and adult *S. alutus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile Pacific ocean perch occur over much of the shelf in the Gulf of Alaska (Figure 204).

The variables determined to be the best predictors of the occurrence of juvenile Pacific ocean perch were depth, latitude and longitude, and tidal current. The AUC for the training was 0.92, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.24. The percent of observations correctly classified was 84% for the training data set, and 93% for the test data set. The most important variables predicting the abundance of juvenile Pacific ocean perch were latitude and longitude, tidal current, and depth. The best-fitting GAM explained 22% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile Pacific ocean perch were predicted to occur along much of the deeper portions of the middle-shelf in the central and eastern gulf, as well in Shelikof Strait in the western gulf. Juvenile Pacific ocean perch were predicted to be abundant on outer-shelf in the central and eastern gulf, particular between the Kenai Peninsula and southeast Alaska (Figure 205). Juvenile Pacific ocean perch were also predicted to be abundant in Prince William Sound and inside waters in southeast Alaska; however, these predictions were not supported by any observations.

Summer bottom trawl survey data indicate adult Pacific ocean perch had roughly the same distribution as juveniles, but they occurred at deeper depths. The best-fitting *MaxEnt* model indicated that depth and latitude and longitude the most important variables predicting habitat suitability (relative importance 80.4 and 6.7 respectively). The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.91, indicating an excellent model fit. The percent of correctly classified observations was 87% for the training data and 91% for the test data. Summer habitat for adult Pacific ocean perch habitat was predicted to occur in most of the deeper portions of the middle- and outer-shelf (Figure 206).

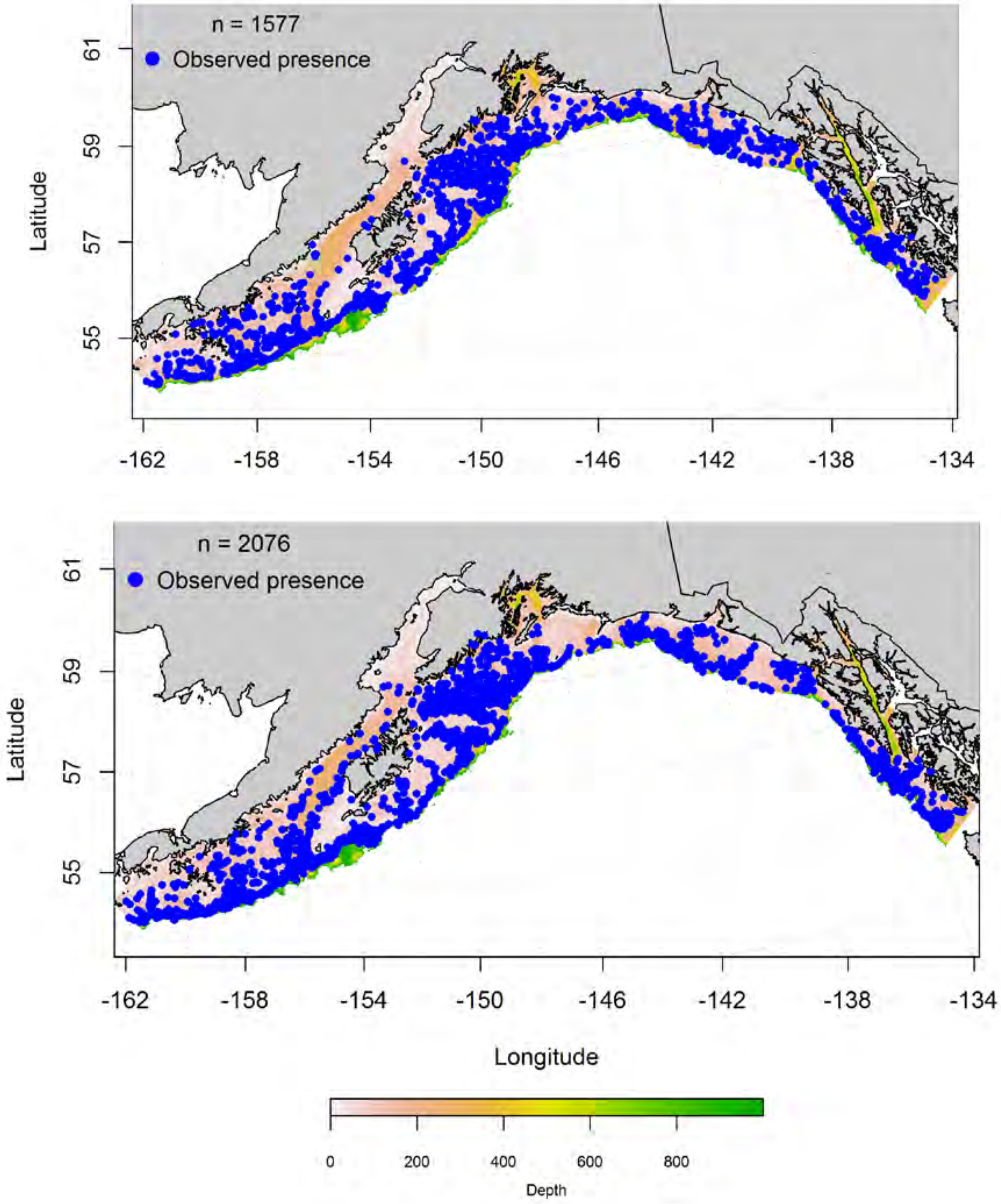


Figure 204. -- Locations of catches of juvenile and adult *S. alutus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

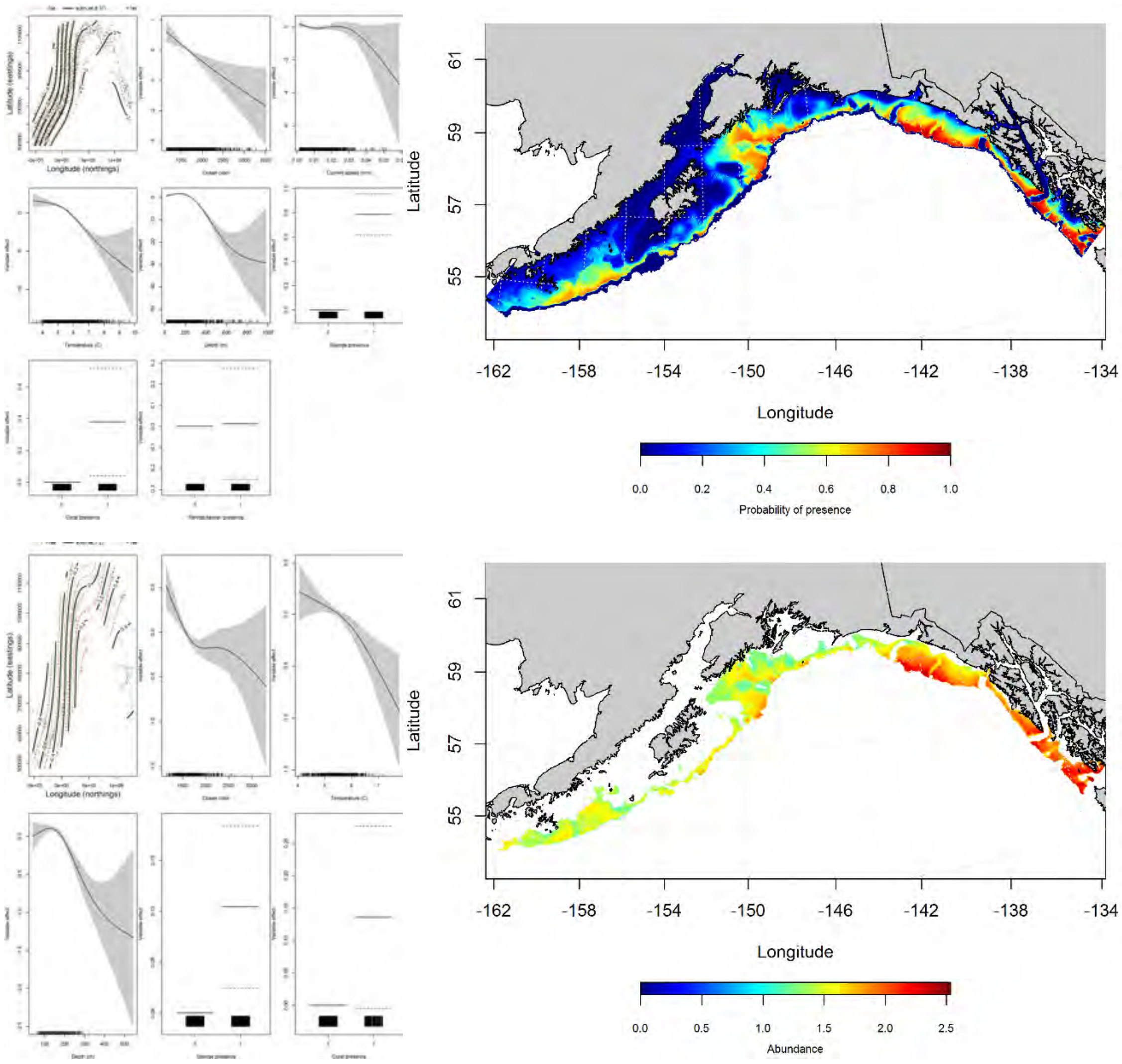


Figure 205. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *S. alutus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

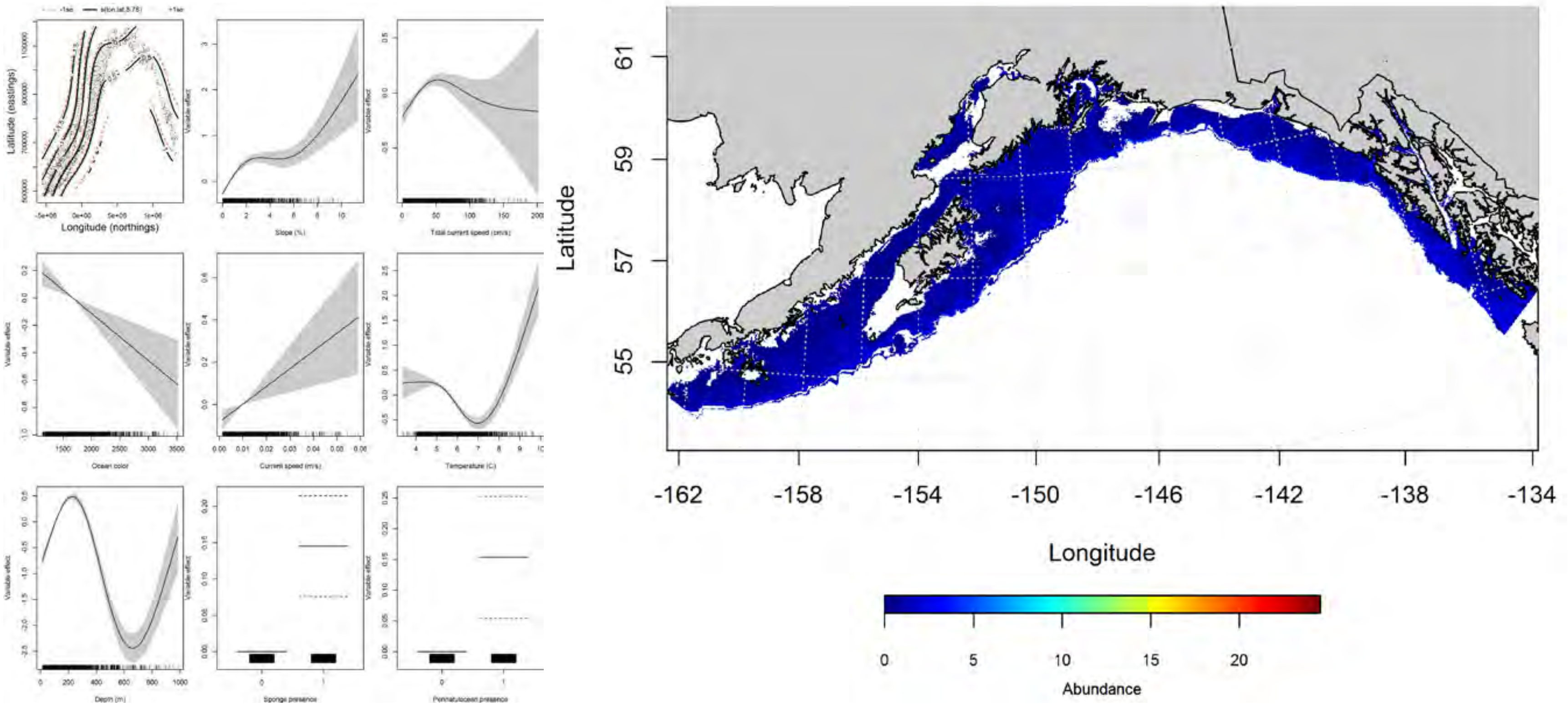


Figure 206. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables on abundance (kg·ha^{-1}) of adult *S. alutus* from summer bottom trawl surveys of the Gulf of Alaska slope and shelf (left panel) alongside GAM-predicted adult *S. alutus* abundance (right panel)

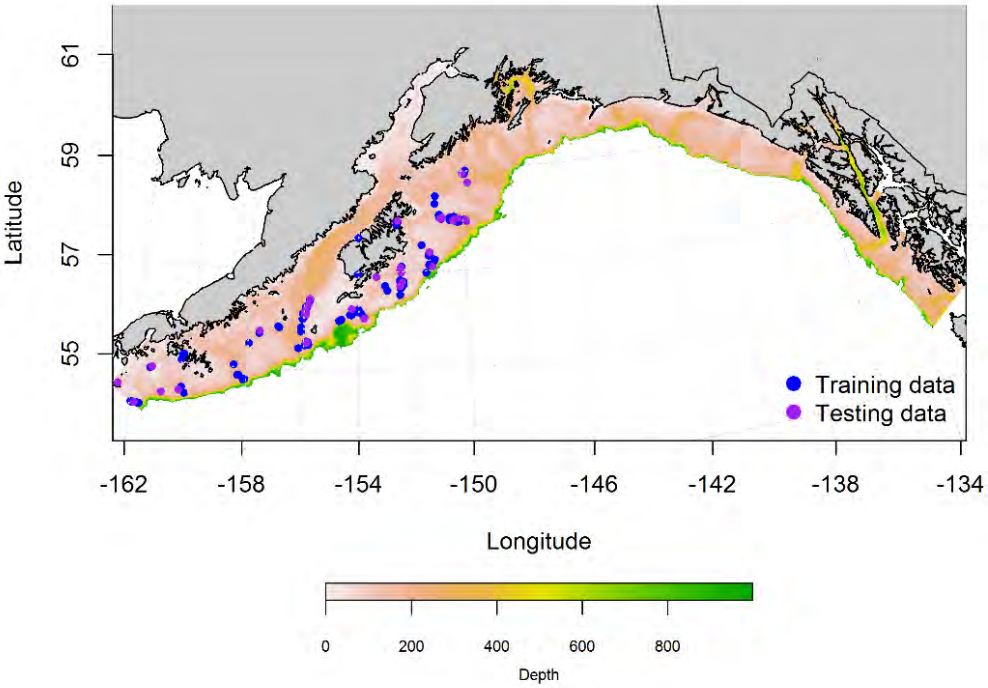
Replot scaling issue

Seasonal distribution of commercial fisheries catches of adult *S. alutus* in the Gulf of Alaska -- Commercial catch data indicate Pacific ocean perch largely occur in the deeper portions of the western GOA. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of Pacific ocean perch (relative importance = 31.9 and 19.4 respectively). The AUC for the training data 0.92, indicating an excellent model fit. The AUC for the test data was 0.75, indicating a fair model fit. The percent of observations correctly classified for the training data was 86%, and it was 75% for the test data. In the fall, adult Pacific ocean perch were predicted to occur in the deeper portion of middle- and outer-shelf in the western and central gulf, particularly in the Shumagin and Shelikof Gullies on the Alaska Peninsula, and along the edge of Albatross and Portlock Banks off Kodiak Island (Figure 207).

In the winter, *MaxEnt* modeling determined that ocean color and bottom temperature were the most important variables predicting the distribution of Pacific ocean perch (relative importance = 36.3 and 19.3 respectively). The AUC was 0.97 for the training data, indicating an excellent model fit. The AUC for the test data was 0.88, indicating a good model fit. The percent of observations correctly classified was 91% and 88% respectively, for the training and test data. In the winter, adult Pacific ocean perch habitat was predicted to occur on Albatross Bank (Figure 208). High suitability habit was also predicted to occur off the Kenai Peninsula; however, these predictions were not supported by any observations.

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of Pacific ocean perch (relative importance =

42.8 and 18.3 respectively). The AUC was 0.95 for the training data, indicating an excellent model fit. The AUC for the test data was 0.88, indicating a good model fit. The percent of observations correctly classified was 90% for both the training and testing data. In the spring, adult Pacific ocean perch were predicted to occur in the deeper portions of middle-and outer-shelf across the western and central Gulf of Alaska (Figure 209). Localized areas of high suitability habit were also predicted off Prince of Wales Island; however, these predictions were not supported by any observations



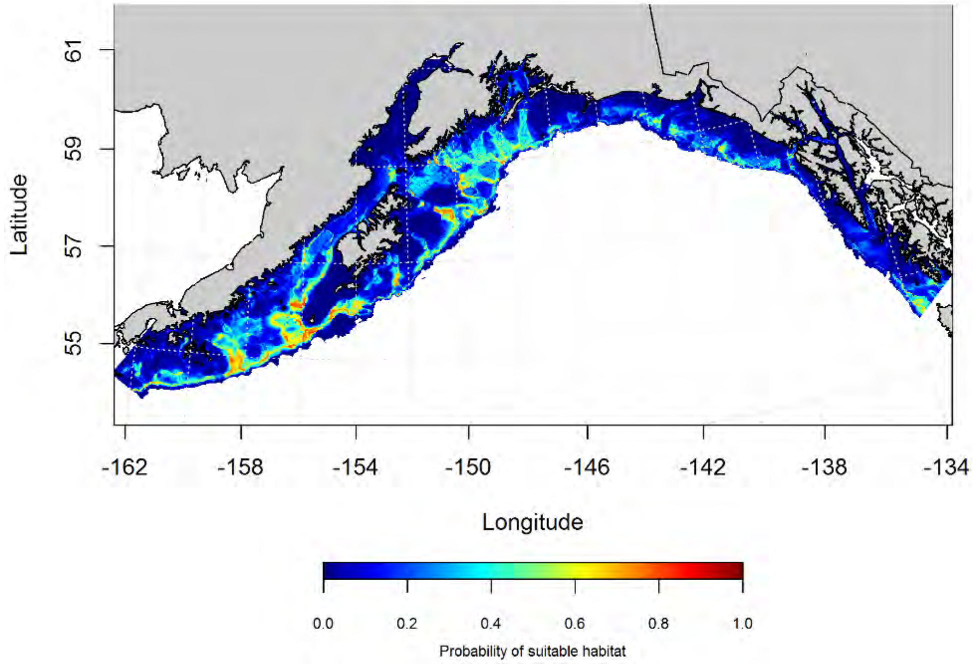
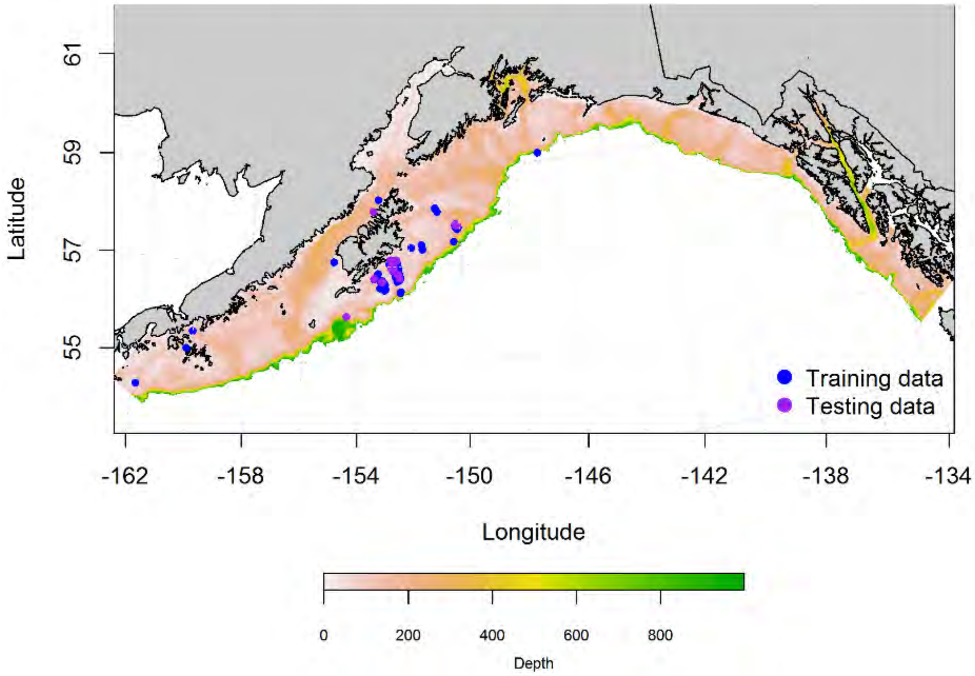


Figure 207. -- Locations of fall (September-November) commercial fisheries catches of *S. alutus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *S. alutus* commercial catches (bottom panel) and the purple points were used to test the model.



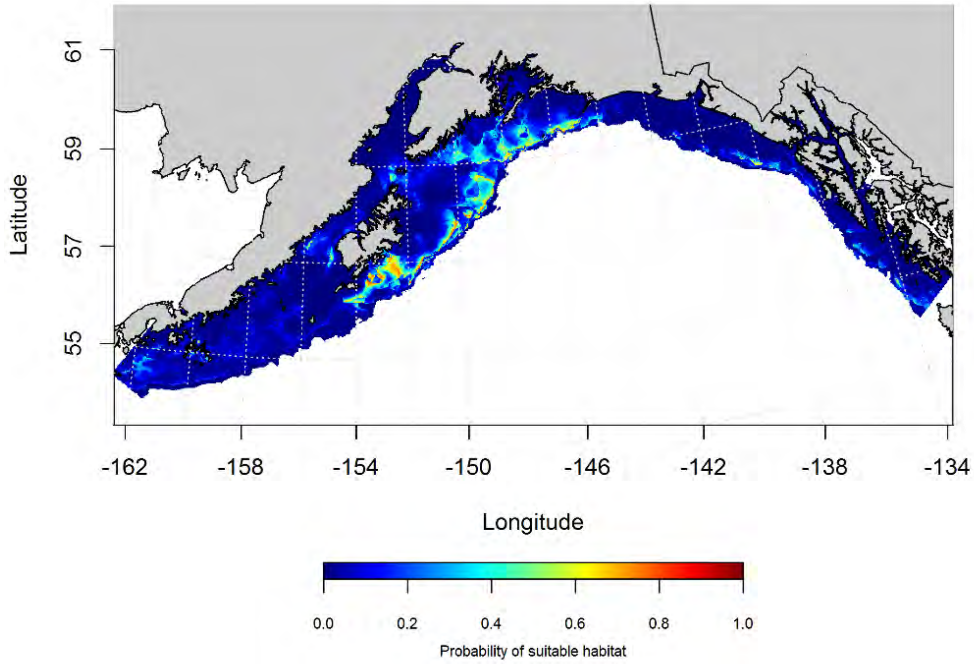
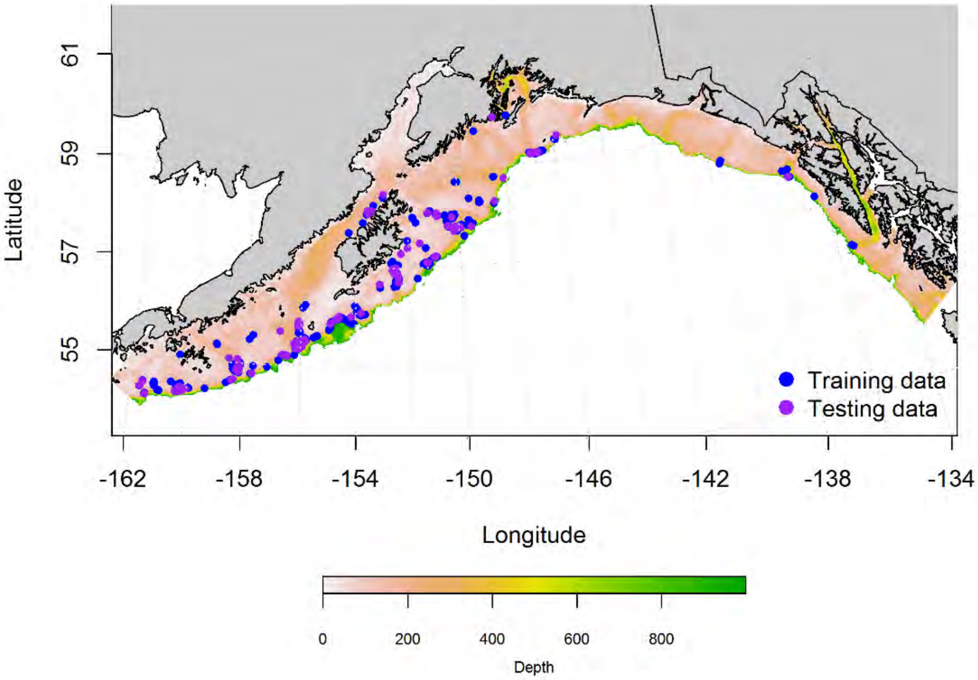


Figure 208. -- Locations of winter (December-February) commercial fisheries catches of *S. alutus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *S. alutus* commercial catches (bottom panel) and the purple points were used to test the model.



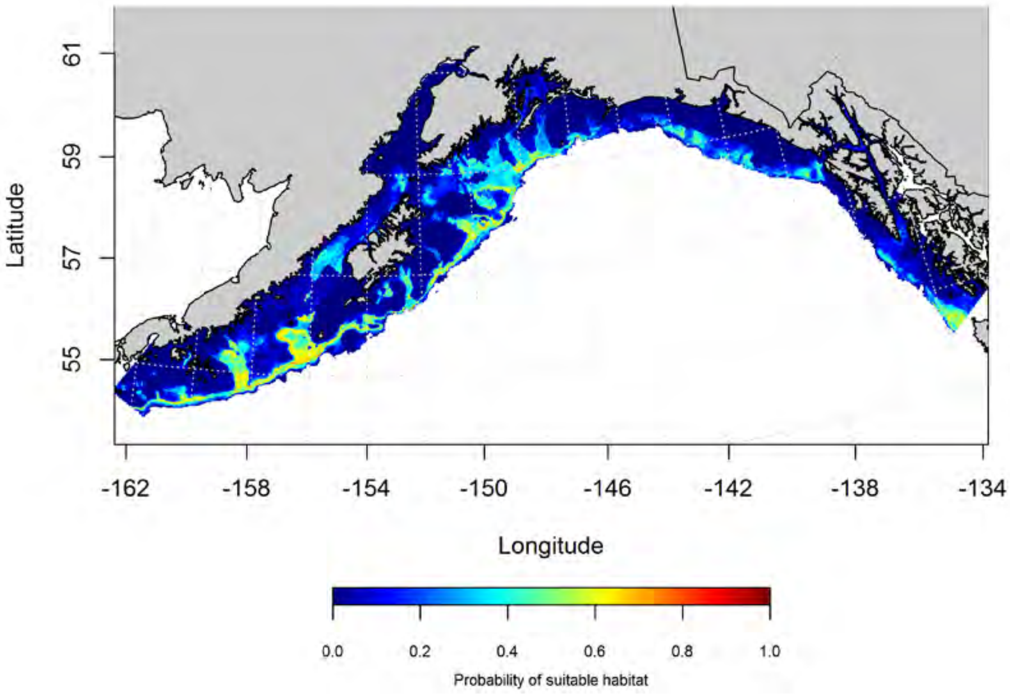
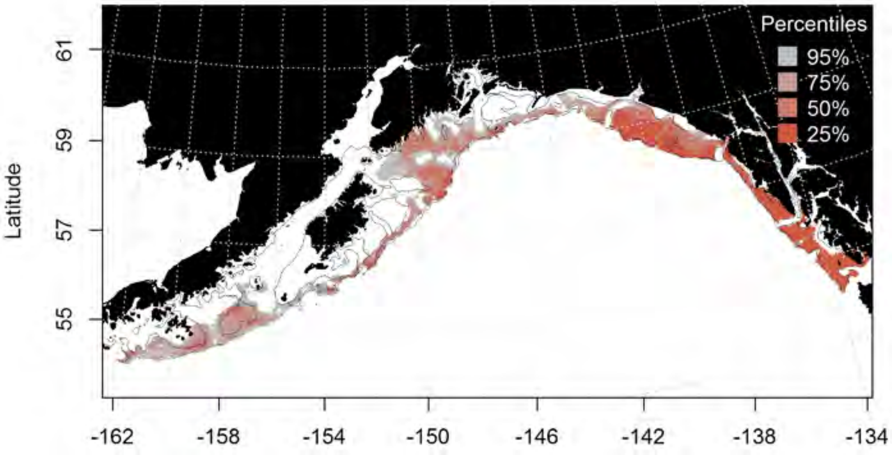


Figure 209. -- Locations of spring (March-May) commercial fisheries catches of *S. alutus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. alutus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. alutus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Pacific ocean perch was predicted to occur in the deeper portions of the shelf in the eastern and central GOA. Because the early life history stages of most rockfish, including Pacific ocean perch, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp. Please see section 20.4 of this report for analysis of EFH for the early life history stages of rockfish. WRONG FOR LARVAE BUT PROBABLY RIGHT FOR EGGS

Summer EFH for juvenile Pacific ocean perch, based on trawl survey observations, was predicted to occur along the middle-and outer-shelf in the eastern and central GOA, and as well as along the shelf break in the western gulf (Figure 210). EFH for adult Pacific ocean perch, was more predicted to be more extensive and to include much of the middle- and outer-shelf throughout the GOA. A localized areas of high suitability habit was also predicted in Cook Inlet; however, these predictions were not supported by any observations.

Fall EFH for adult Pacific ocean perch, based on commercial fisheries data, and was predicted to include much of the deeper portion of the middle- and outer-shelf continental shelf in the western GOA (Figure 211). During the winter, EFH for Pacific ocean perch was predicted to be more restricted, and to largely occur along the shelf break, and to a lesser extent deeper portion of the middle-shelf in the western gulf. During the spring, EFH for adult Pacific ocean perch was predicted to mainly occur along the shelf break, and to a lesser extent deeper portions of the middle-shelf between Cape St. Elias and Kodiak Island.



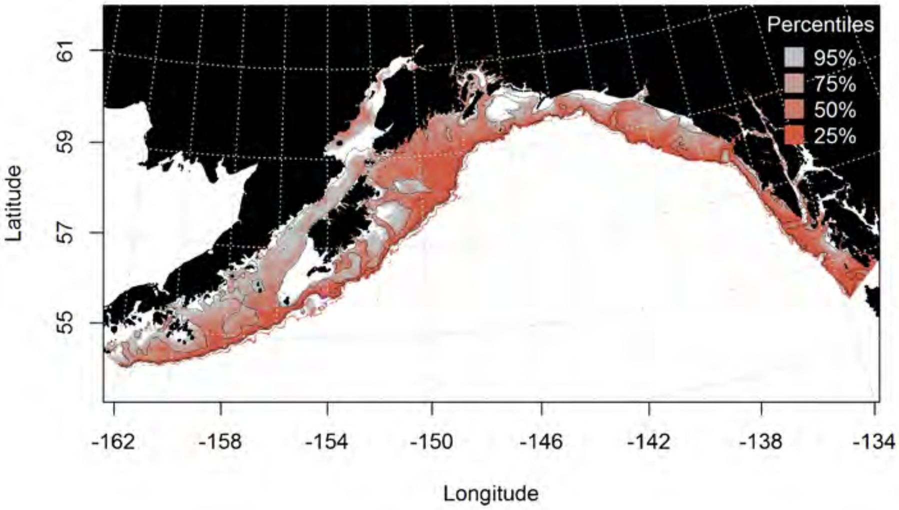
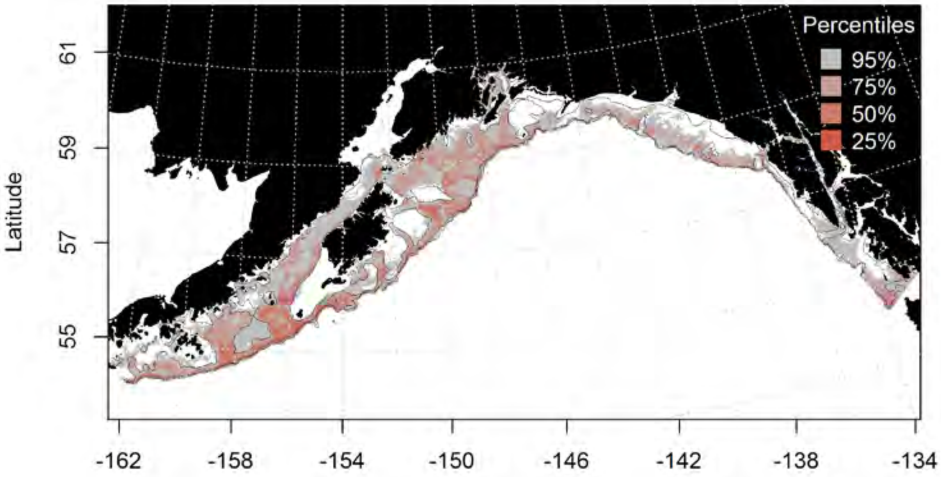


Figure 210. -- Predicted summer essential fish habitat for *S. alutus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.



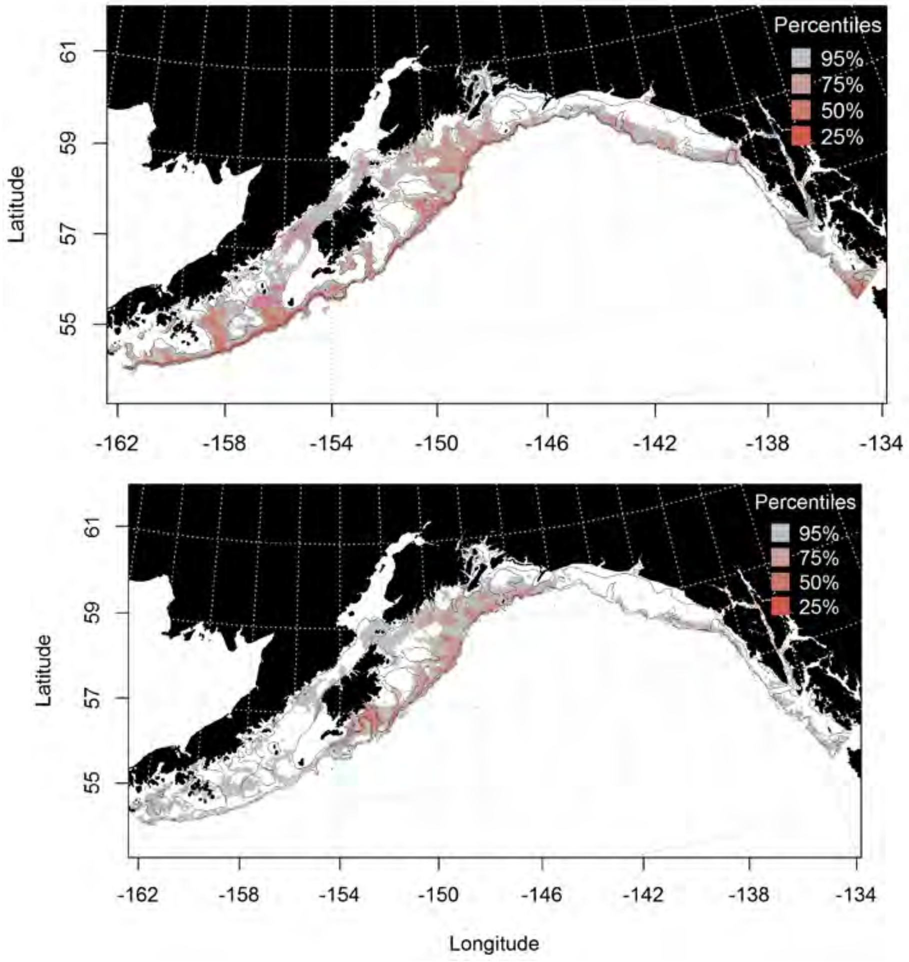


Figure 211. -- Essential fish habitat predicted for *S. alutus* during fall (top panel), winter (middle panel), and spring (bottom panel) from commercial catches.

redbanded rockfish (*Sebastes babcocki*)

Redbanded rockfish occur in relatively modest numbers in the Gulf of Alaska, with a majority of individuals occurring off southeast Alaska at from 201 to 300 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently an analysis of the early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. babcocki* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile redbanded rockfish occur in the deeper portions of the middle- and outer-shelf in the Gulf of Alaska (Figure 212).

The variables determined to be the best predictors of the occurrence of juvenile redbanded rockfish were latitude and longitude, depth, and sponge presence. The AUC for the training was 0.95, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.13. The percent of observations correctly classified was 88% for the training data set, and 89% for the test data set. The most important variables predicting the abundance of juvenile redbanded rockfish were latitude and longitude, slope, and tidal current. The best-fitting GAM explained 32% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile redbanded rockfish were predicted to occur along the deeper portions of the outer-shelf. Juvenile redbanded rockfish were predicted to be abundant on the outer-shelf off southeast Alaska, and to a lesser extent along the shelf break in the central and western GOA (Figure 213).

Summer bottom trawl survey data indicate adult Redbanded rockfish also occur in deeper porting of the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 80.4 and 6.7 respectively). The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.91, indicating an excellent model fit. The percent of correctly classified observations was 87% for the training data and 91% for the test data. Summer habitat for adult Redbanded rockfish habitat was predicted to occur in most of the deeper portions of the middle- and outer-shelf (Figure 214).

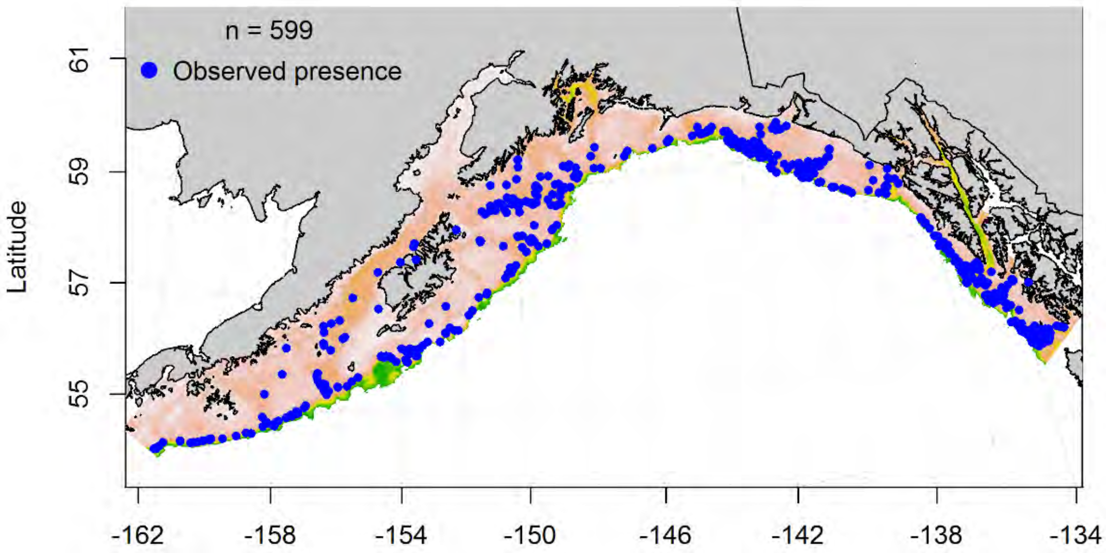


Figure 212. -- Locations of catches of juvenile *S. babcocki* from summer bottom trawl surveys of the Gulf of Alaska.

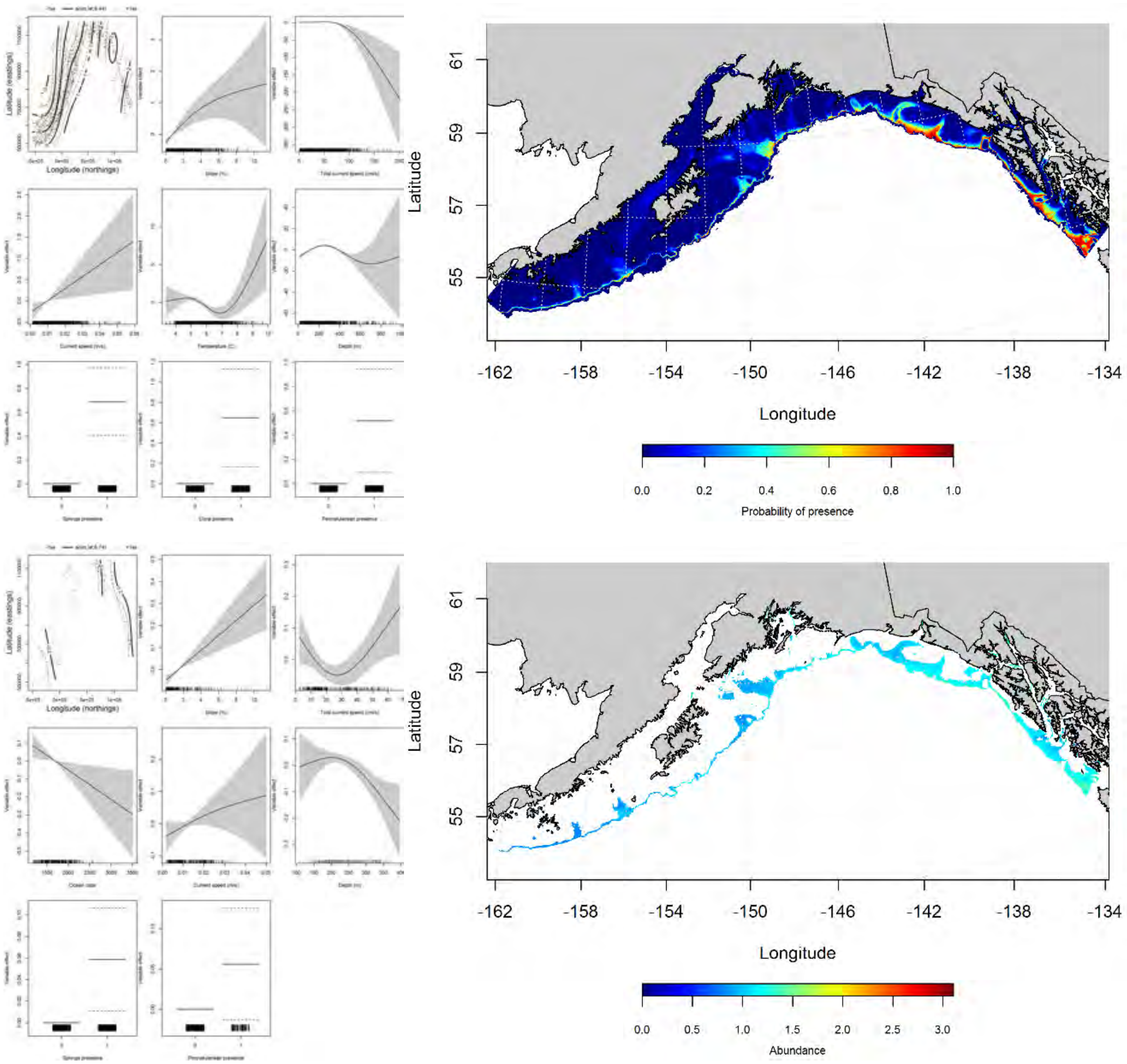


Figure 213. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *S. babcocki* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

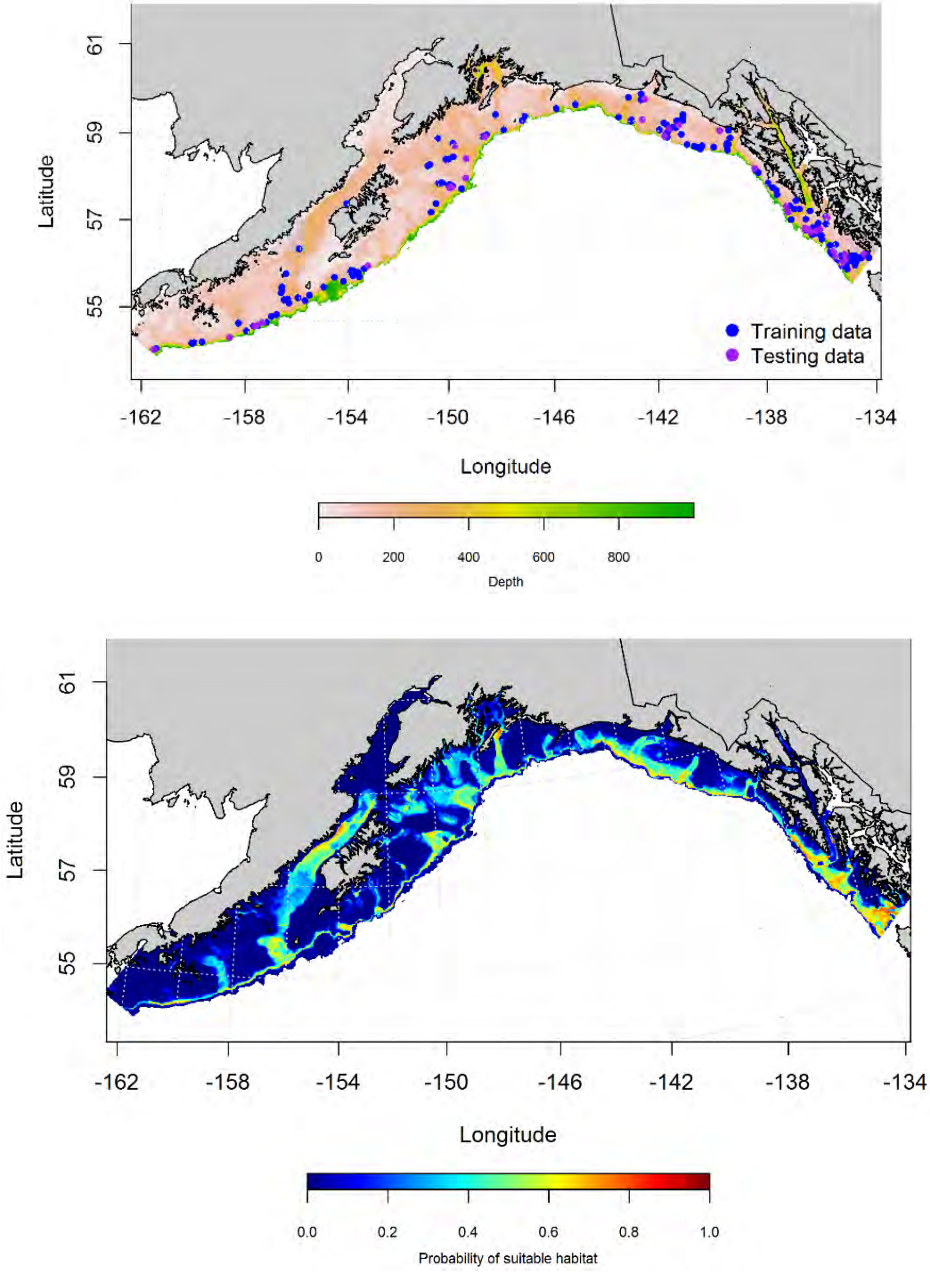
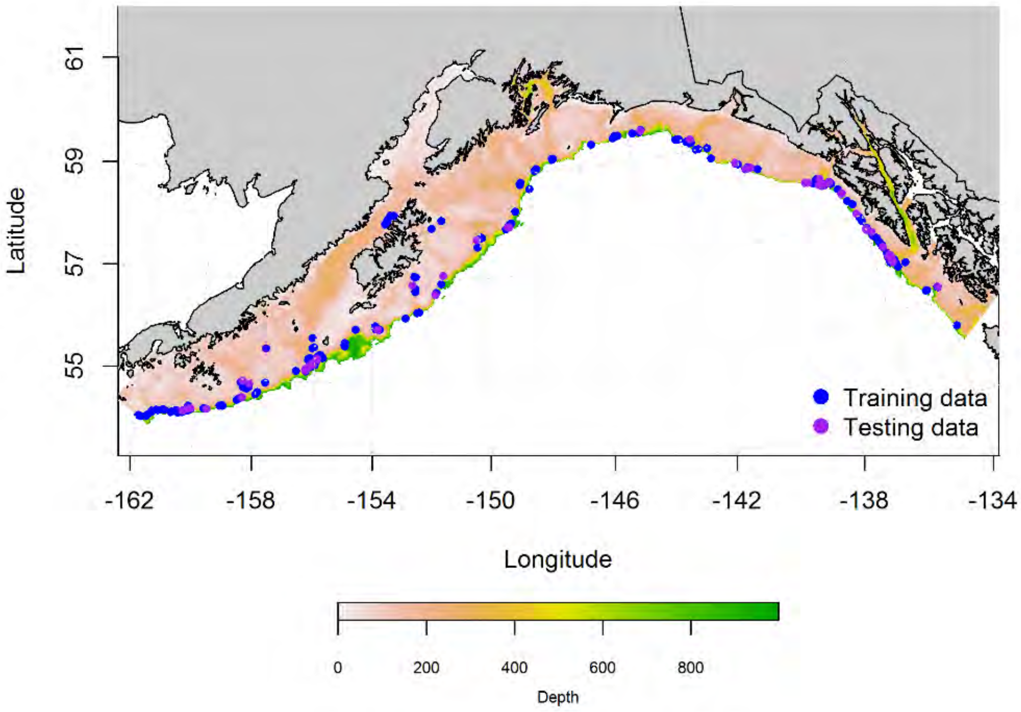


Figure 214. -- Locations of trawl survey catches of adult *S. babcocki* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. babcocki* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. babcocki* in the Gulf of Alaska -- Commercial catch data of redbanded rockfish were available only during the spring, they indicate that redbanded rockfish largely occur in the deeper portions of the shelf. *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of redbanded rockfish (relative importance = 54.3 and 17.6 respectively). The AUC was 0.96 for the training data, indicating an excellent model fit. The AUC for the test data was 0.92, indicating a good model fit. The percent of observations correctly classified was 89% for the training and 92% testing data. In the spring, adult redbanded rockfish were predicted to occur along the shelf break and deeper portions of outer-shelf (Figure 215).



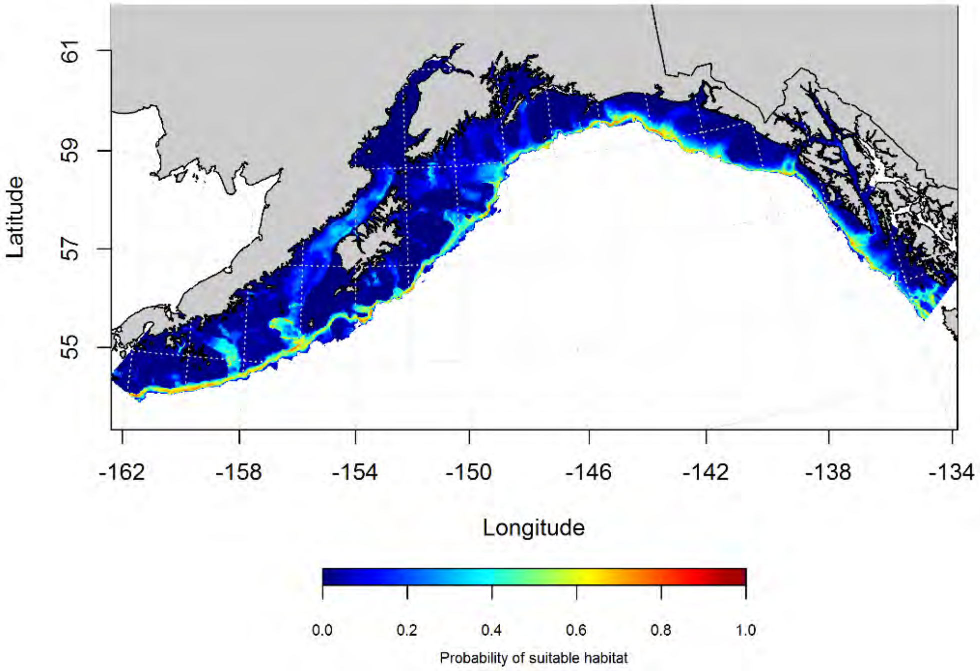


Figure 215. -- Locations of spring (March-May) commercial fisheries catches of *S. babcocki* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. babcocki* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. babcocki* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for redbanded rockfish was predicted to occur in the deeper portions of the shelf in the eastern and central GOA. Because the early life history stages of most rockfish, including redbanded rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp. Please see section 20.4 of this report for analysis of EFH for the early life history stages of rockfish.

Summer EFH for juvenile redbanded rockfish, based on trawl survey observations, was predicted to occur in the deeper portions of middle-and outer-shelf in the eastern GOA (Figure 22.5). EFH for adult redbanded rockfish, more extensive than that of the juveniles, and it was predicted to include much of the middle- and outer-shelf (Figure 216).

During the spring, EFH for adult redbanded rockfish was predicted to mainly occur along the deeper portions of the outer-shelf (Figure 217).

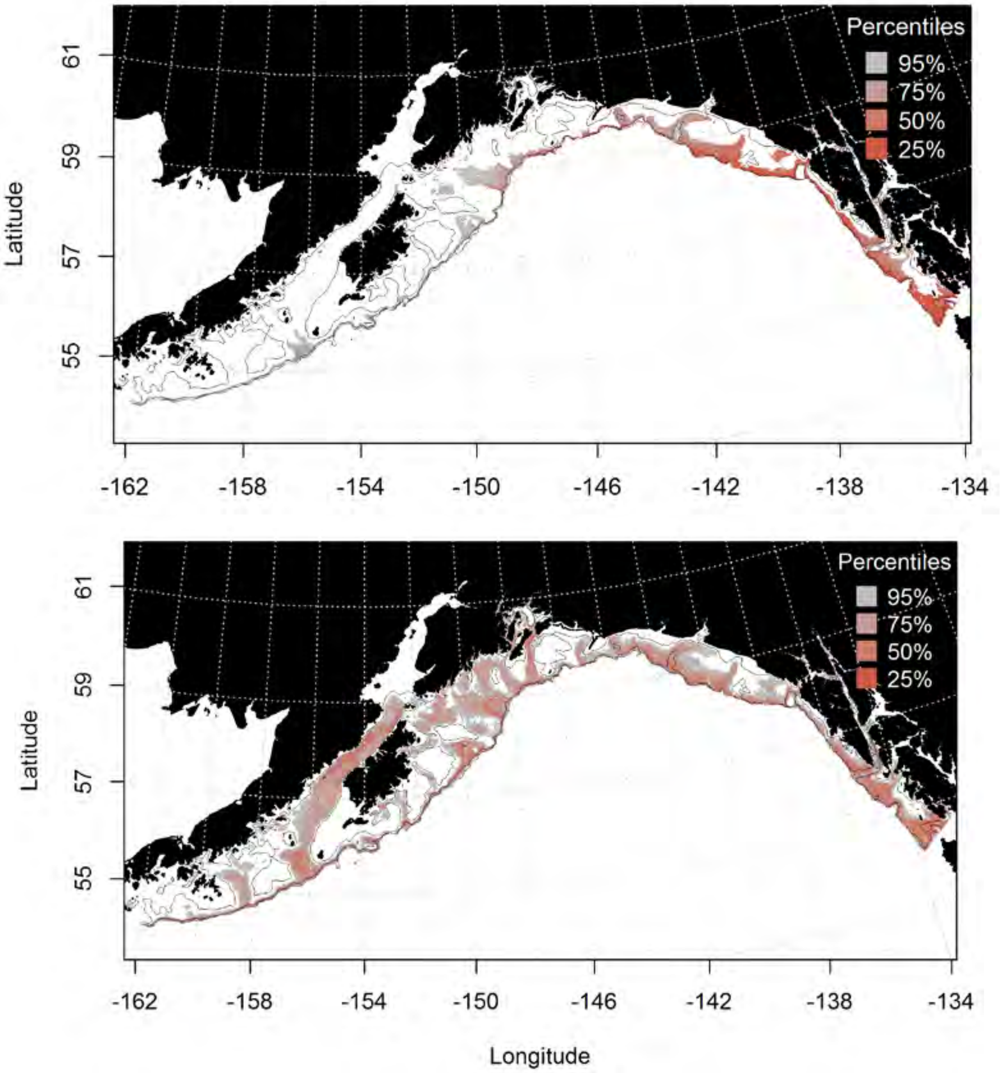


Figure 216. -- Predicted summer essential fish habitat for *S. babcocki* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

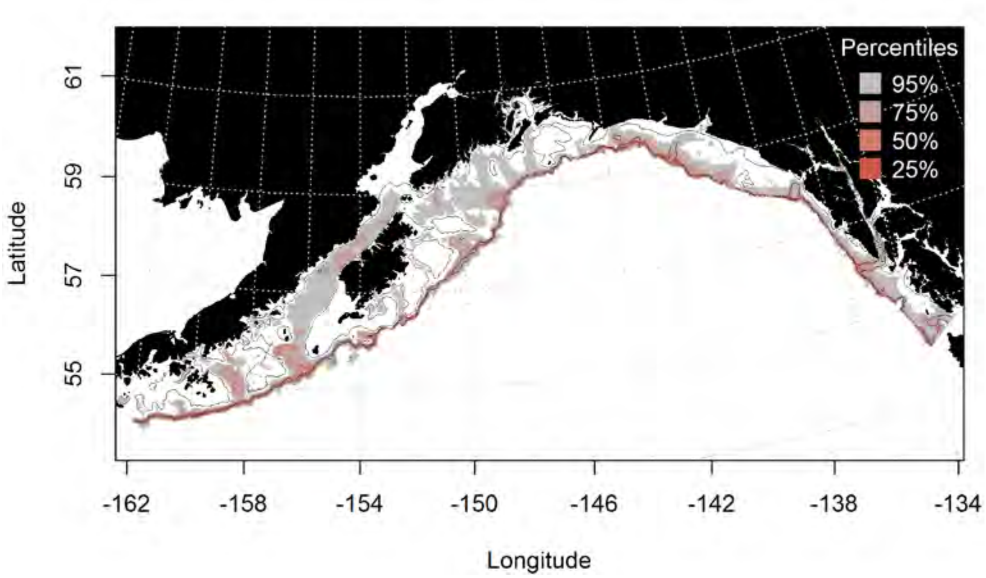


Figure 217. -- Essential fish habitat predicted for *S. babcocki* during spring from commercial catches.

shortraker rockfish (*Sebastes borealis*)

Shortraker rockfish occur throughout the Gulf of Alaska, although they are considerably more densely populated in the central and eastern gulf. They are found almost exclusively on the continental slope between 200 to 700 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes spp.* in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. borealis* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile shortraker rockfish largely occur along the shelf break and in the deeper portions of the outer-shelf in the Gulf of Alaska (Figure 218).

The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 68.6 and 16.8 respectively). The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the testing data was 0.92, indicating an excellent model fit. The percent of correctly classified observations was 94% for the training data and 92% for the test data. Summer habitat for juvenile shortraker rockfish habitat was predicted to largely occur along the shelf break in the central and western gulf (Figure 219).

Summer bottom trawl survey data indicate that adult shortraker rockfish also occur in the deeper portions of the outer-shelf (Figure 220). The variables determined to be the best predictors of the occurrence of adult shortraker rockfish were depth, latitude and longitude, and slope. The AUC for the training data was 0.97, indicating an excellent model fit. The AUC for the testing data was 0.83, indicating a good model fit. The optimum threshold was 0.12. The percent of observations correctly classified was 92% for the training data set, and 88% for the test data set. The most important variables predicting the abundance of adult shortraker rockfish were depth and current speed. The best-fitting GAM explained 17% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult shortraker rockfish were predicted to occur along the shelf break and deeper portions of the outer-shelf in the eastern gulf, including Yakutat Valley and Spencer Gully. High abundances were also predicted in Cook Inlet and Prince William Sound; however, these predictions were not supported by any observations.

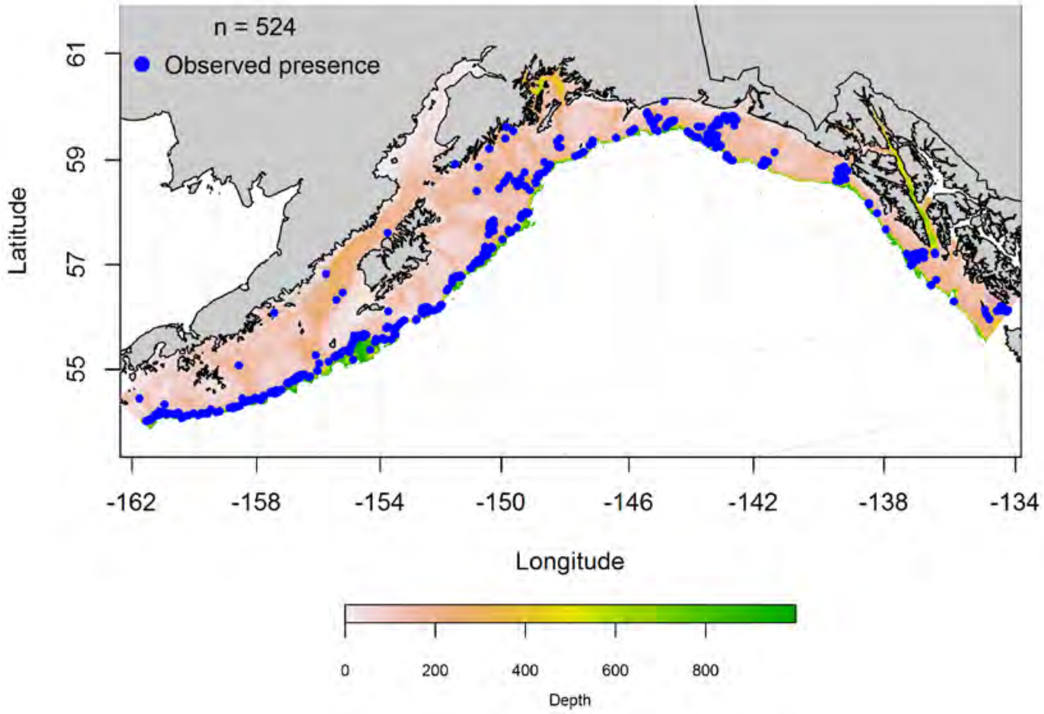
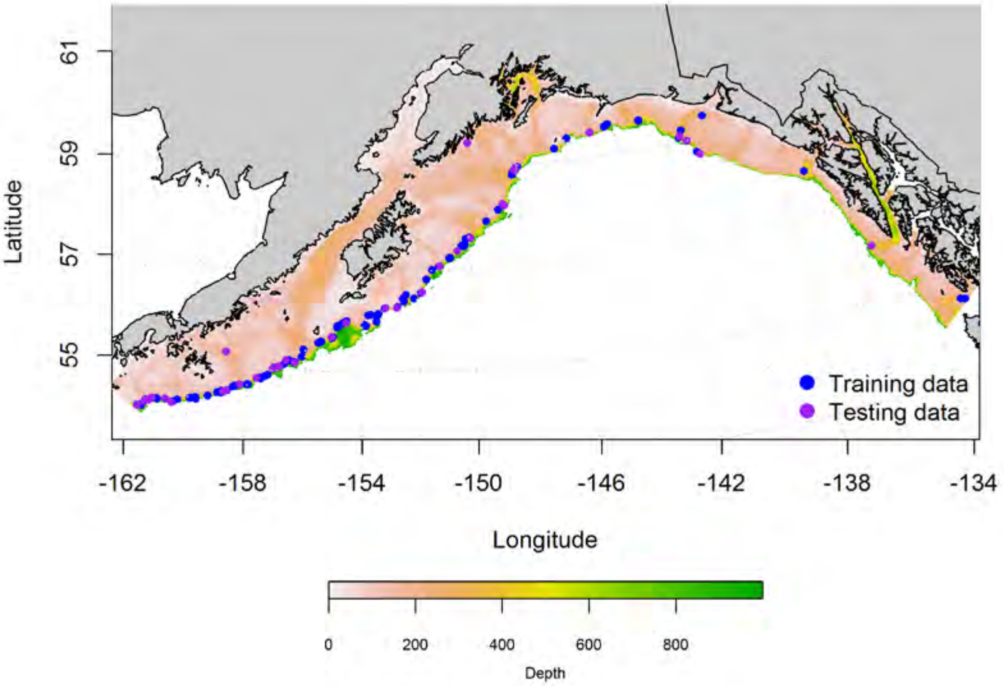


Figure 218. -- Locations of catches of adult *S. borealis* from summer bottom trawl surveys of the Gulf of Alaska.



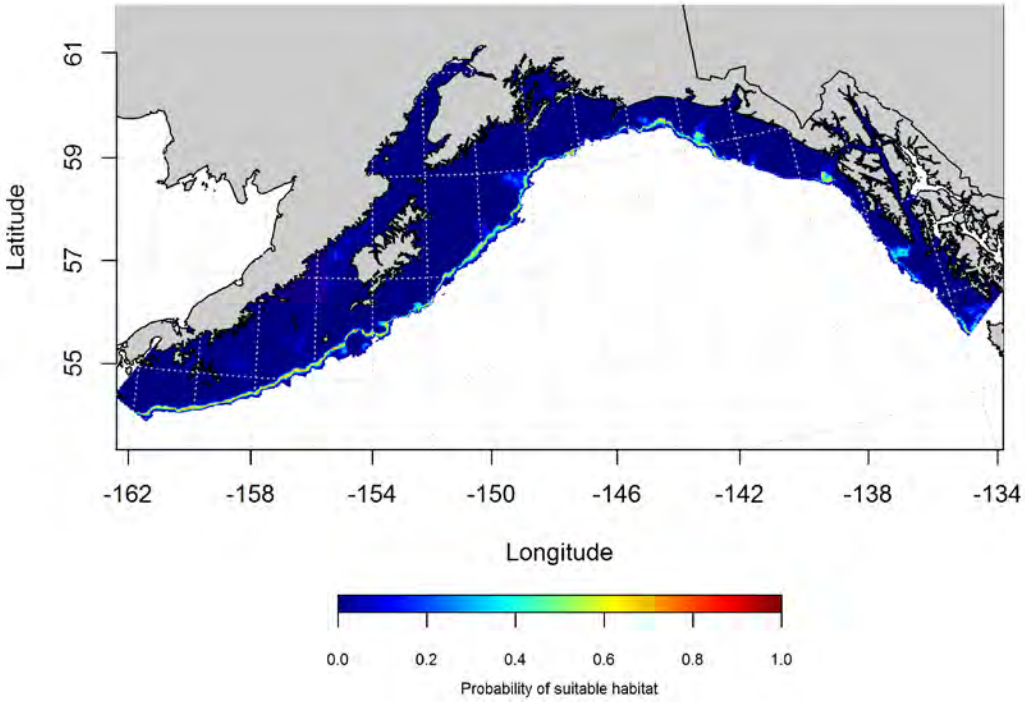


Figure 219. -- Locations of trawl survey catches of juvenile *S. borealis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. borealis* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

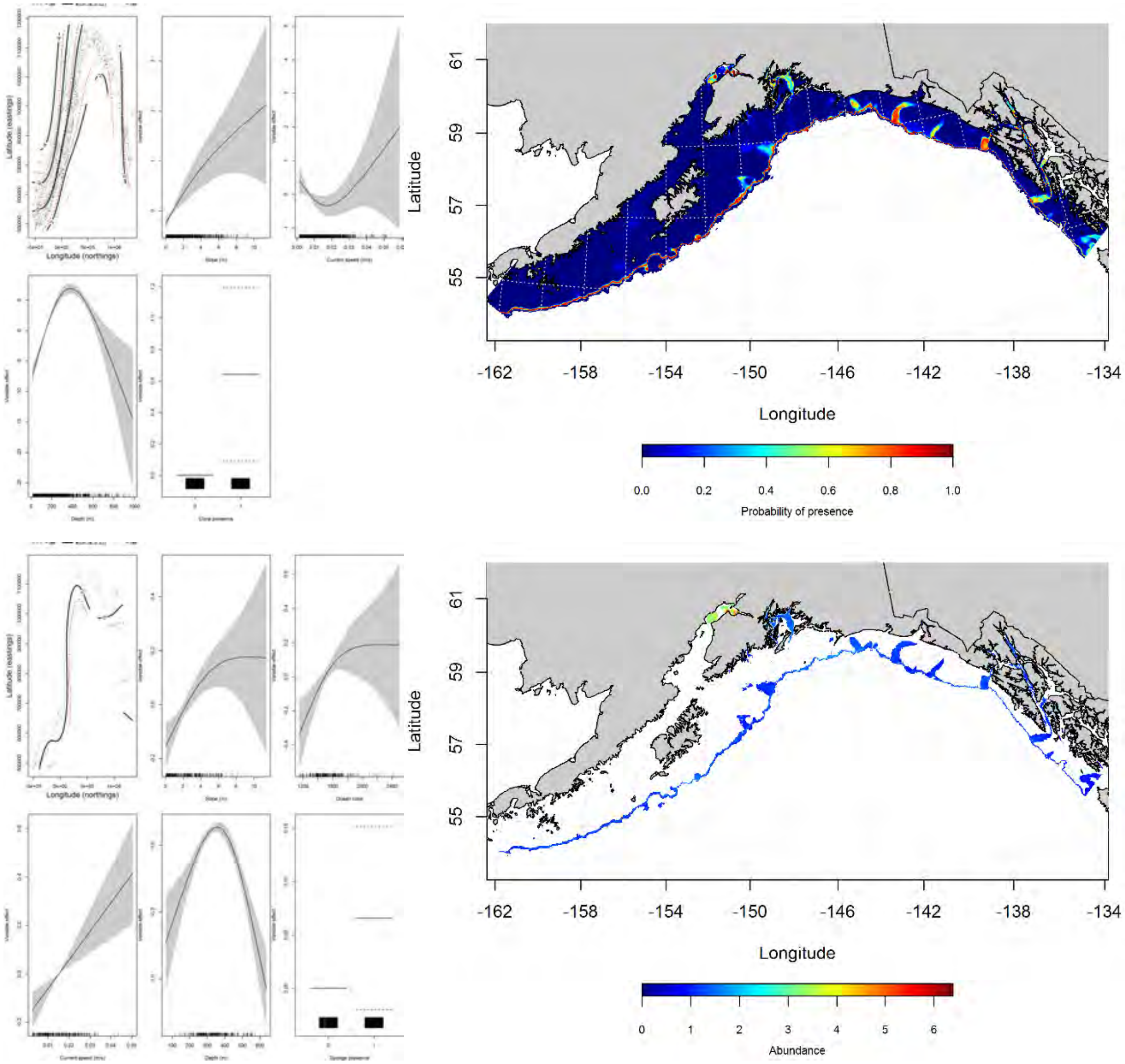


Figure 220. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. borealis* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. borealis* in the Gulf of Alaska -- Commercial catch data indicate shortraker rockfish largely occurs in the deeper portions of the western GOA, around Kodiak Island. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of shortraker rockfish (relative importance = 45.0 and 26.7 respectively). The AUC for the training data 0.96, indicating an excellent model fit. The AUC for the test data was 0.94, indicating an excellent model fit. The percent of observations correctly classified for the training data was 90%, and it was 94% for the test data. In the fall, adult shortraker rockfish were predicted to occur along the shelf break in the central and western GOA (Figure 221).

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of shortraker rockfish (relative importance = 43.9 and 25.3 respectively). The AUC was 0.86 for the training data, indicating a good model fit. The AUC for the test data was 0.75, indicating a fair model fit. The percent of observations correctly classified was 78% and 75% respectively, for the training and test data. In the winter, the adult shortraker rockfish habitat were predicted to occur along the shelf break, particularly between Cape St. Elias and Kodiak Island (Figure 222). Localized areas of high suitability habit were also predicted off Cape Ommaney and in Prince William Sound; however, these predictions were not supported by any observations.

In the spring, *MaxEnt* modeling determined that depth and current speed were the most important variables determining the distribution of shortraker rockfish (relative importance = 83.6 and 8.4 respectively). The AUC was 0.96 for the training data, indicating an excellent model fit. The AUC for the test data was 0.90, indicating an excellent model fit. The percent of observations correctly classified was 90% for both the training and testing data. In the spring, adult shortraker rockfish were predicted to largely occur along the shelf break (Figure 223).

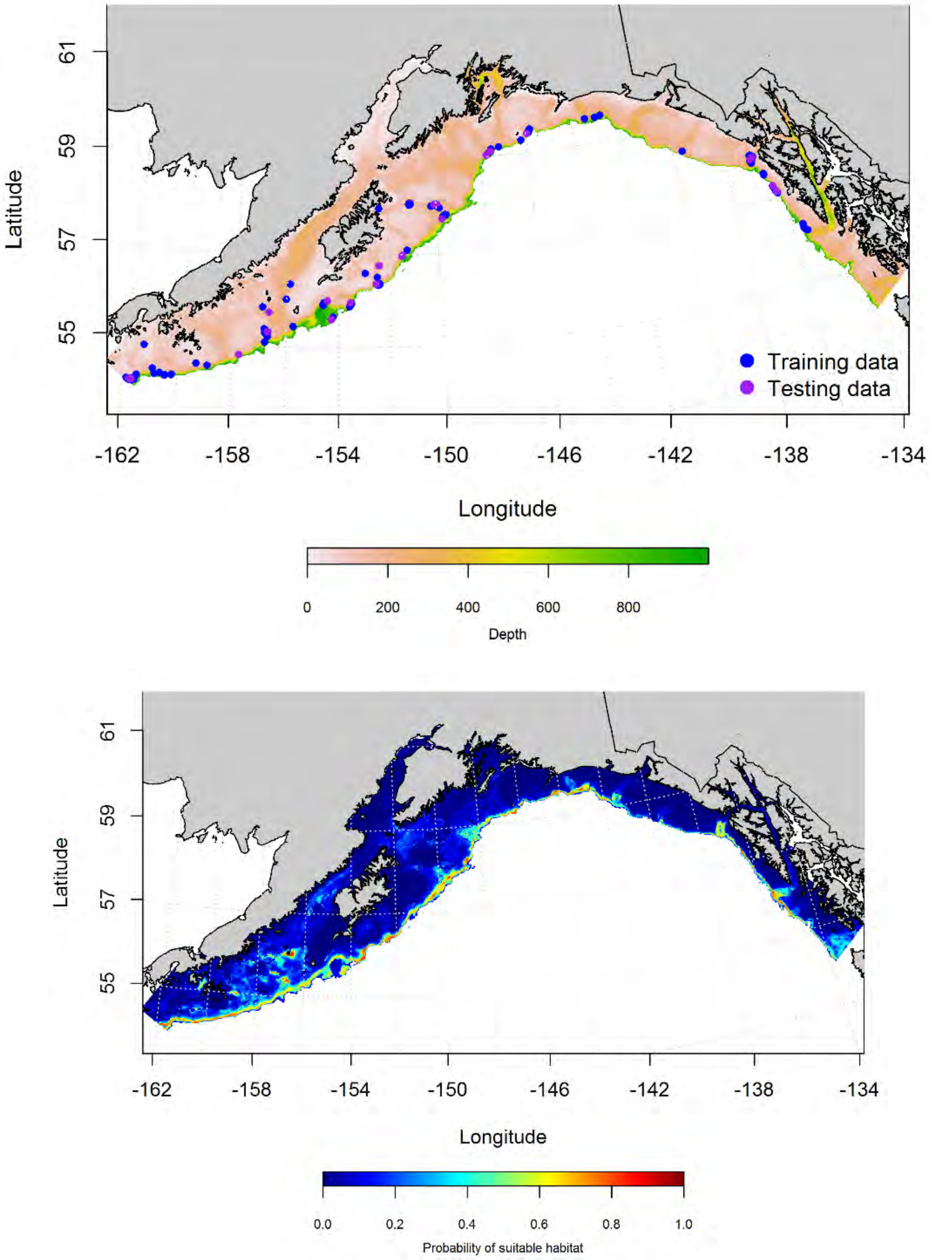


Figure 221. -- Locations of fall (September-November) commercial fisheries catches of *S. borealis* (top panel). Blue points were used to train the maximum entropy model predicting the

probability of the fall distribution of *S. borealis* commercial catches (bottom panel) and the purple points were used to test the model.

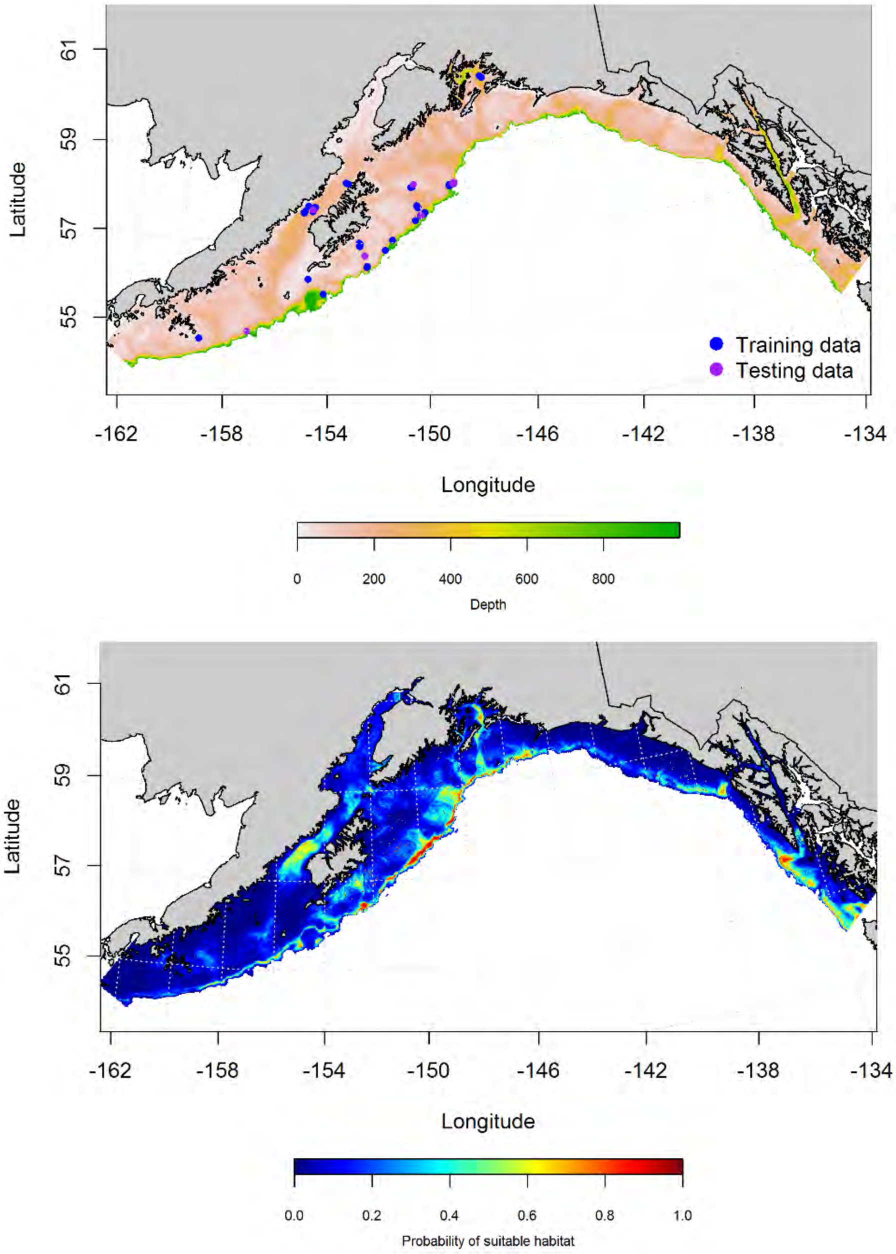


Figure 222. -- Locations of winter (December-February) commercial fisheries catches of *S. borealis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *S. borealis* commercial catches (bottom panel) and the purple points were used to test the model.

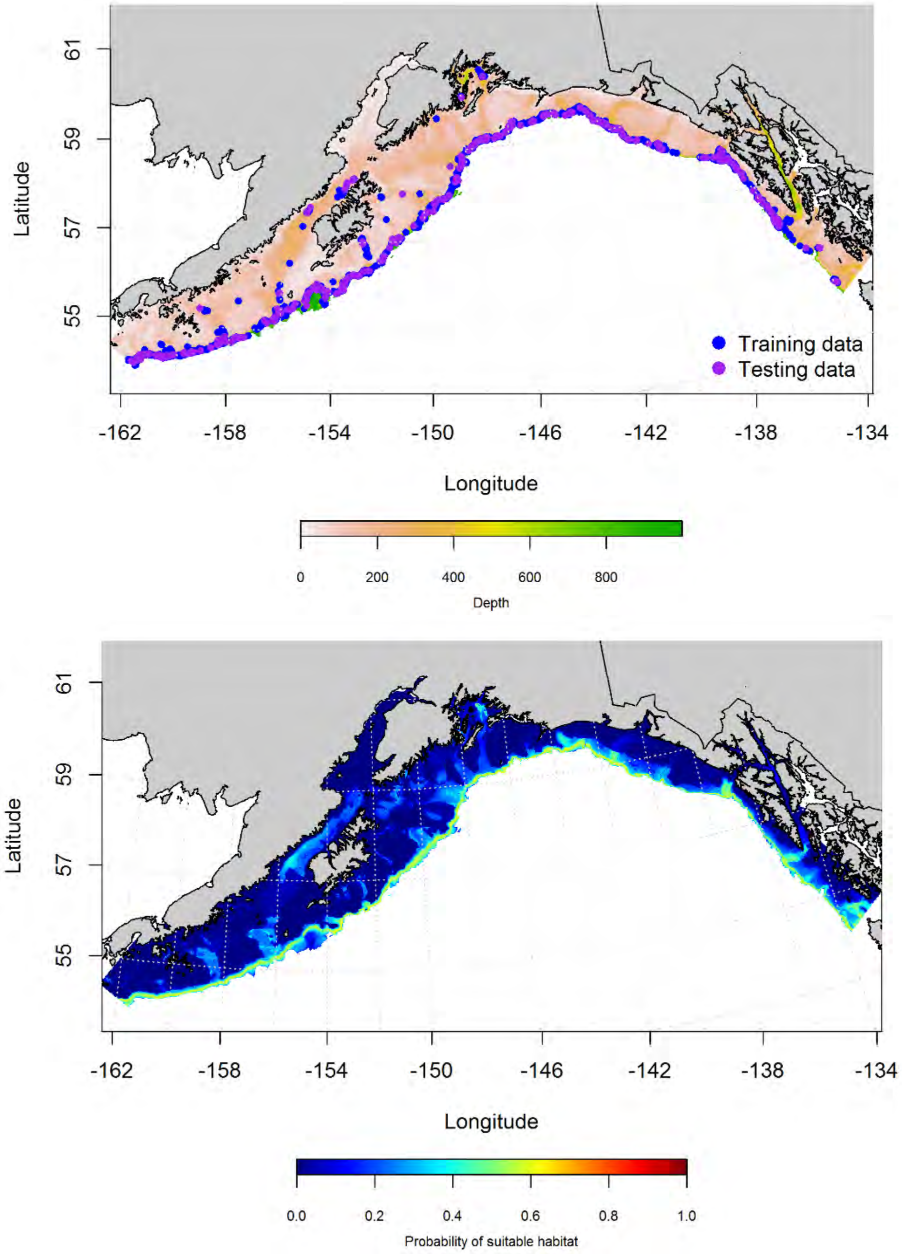


Figure 223. -- Locations of spring (March-May) commercial fisheries catches of *S. borealis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. borealis* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. borealis* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for shortraker rockfish was predicted to occur in the deeper portions of the shelf in the eastern and central gulf. Because the early life history stages of most rockfish, including shortraker rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile shortraker rockfish, based on trawl survey observations, was predicted to occur the deeper portions of outer-shelf, including Yakutat Valley, Spencer Gully, and off Cape Ommaney (Figure 224). EFH for adult shortraker rockfish, was predicted to be more extensive and to include most of the shelf break and deeper portions of the outer-shelf throughout the GOA. EFH for adult shortraker rockfish was also predicted to occur in portions of Prince William Sound and Cook Inlet; however, these predictions were not supported by any observations.

During the fall and spring, EFH for adult shortraker rockfish was predicted to occur along the deeper portion of the outer-shelf (Figure 225). During the winter, EFH for adult shortraker rockfish was predicted to be more extensive, and to include deeper portion of the middle- and outer-shelf throughout the GOA. During the winter EFH for adult shortraker rockfish was also predicted to occur in portions of Prince William Sound; however, these predictions were not supported by any observations.

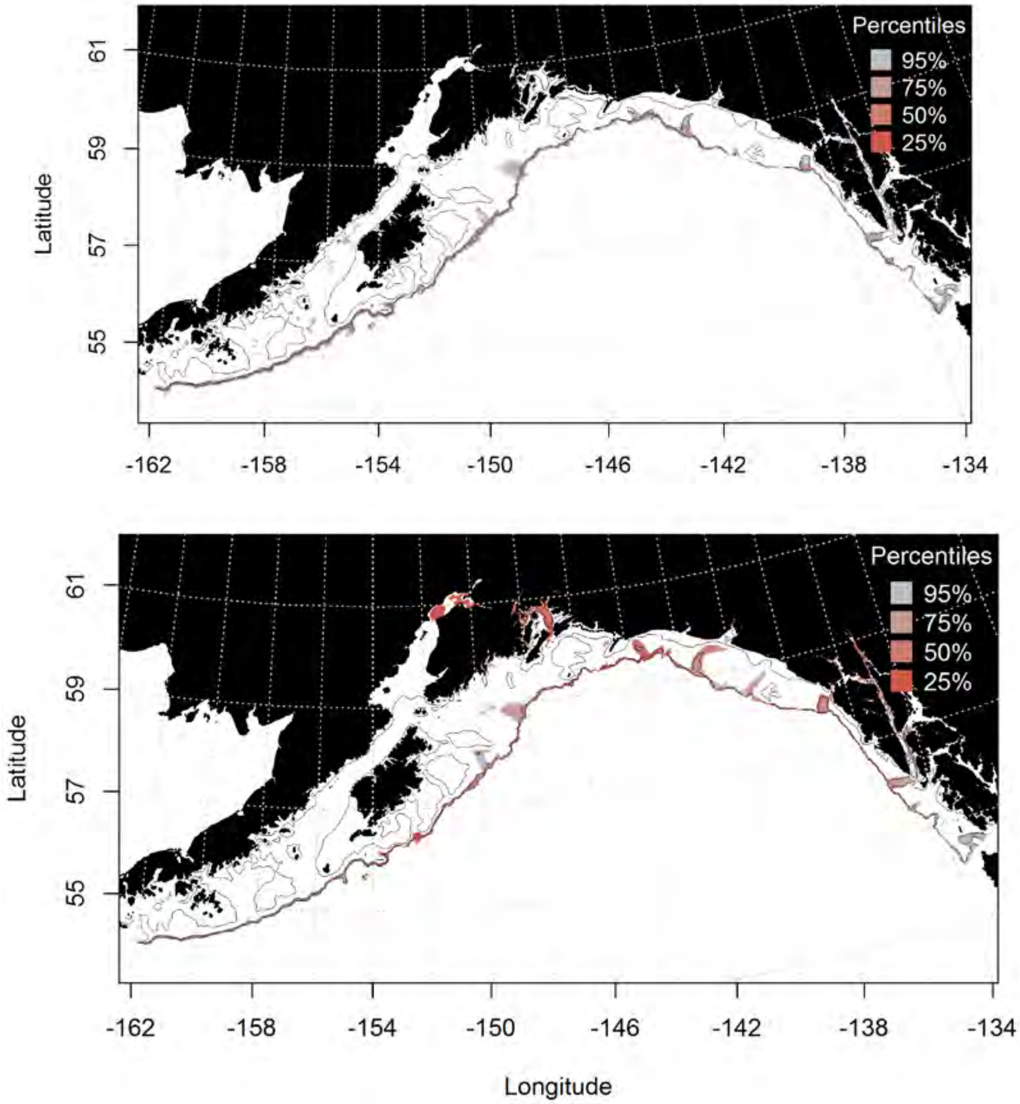


Figure 224. -- Predicted summer essential fish habitat for *S. borealis* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

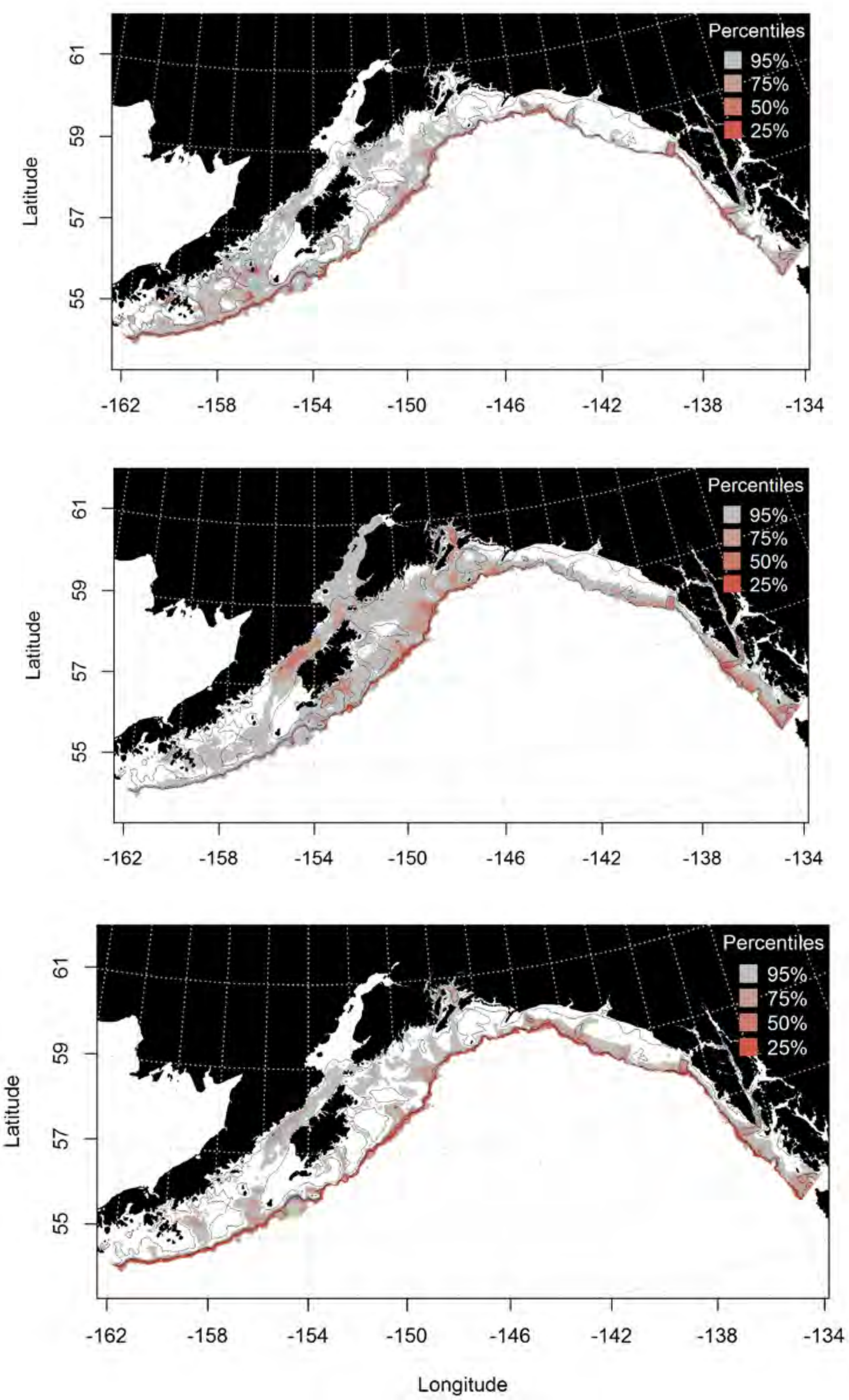


Figure 225. -- Essential fish habitat predicted for *S. borealis* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

silvergray rockfish (*Sebastes brevispinis*)

Silvergray rockfish were rarely observed outside the eastern Gulf of Alaska, and they are typically caught between 101 to 300 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. brevispinis* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile silvergray rockfish largely occur along the deeper portions of the outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 43.8 and 23.9 respectively). The AUC for the training data was 0.88, indicating a good model fit. The AUC for the testing data was 0.71, indicating a fair model fit. The percent of correctly classified observations was 79% for the training data and 71% for the test data. Summer habitat for juvenile silvergray rockfish habitat was predicted to occur across large portions of the centrals and eastern gulf, particularly off southeast Alaska (Figure 226).

Summer bottom trawl survey data indicate adult silvergray rockfish also occur in deeper portions of the outer-shelf (Figure 227).

The variables determined to be the best predictors of the occurrence of adult silvergray rockfish were latitude and longitude, depth, and temperature. The AUC for the training data was 0.96, indicating an excellent model fit. The AUC for the testing data was 0.83, indicating a good model fit. The optimum threshold was only 0.05. The percent of observations correctly classified was 88% for the training data set, and 83% for the test data set. The most important variables predicting the abundance of adult silvergray rockfish were latitude and longitude and depth. The best-fitting GAM explained 21% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult silvergray rockfish were predicted to occur along most of the outer- and middle-shelf in the eastern gulf, particularly off of Prince of Wales Island (Figure 228). Abundances of adult silvergery rockfish were predicted to be highest off southeast Alaska, particularly south of Cape Ommaney. Lower abundances were also predicted to occur between Spencer Gully and Yakutat Valley.

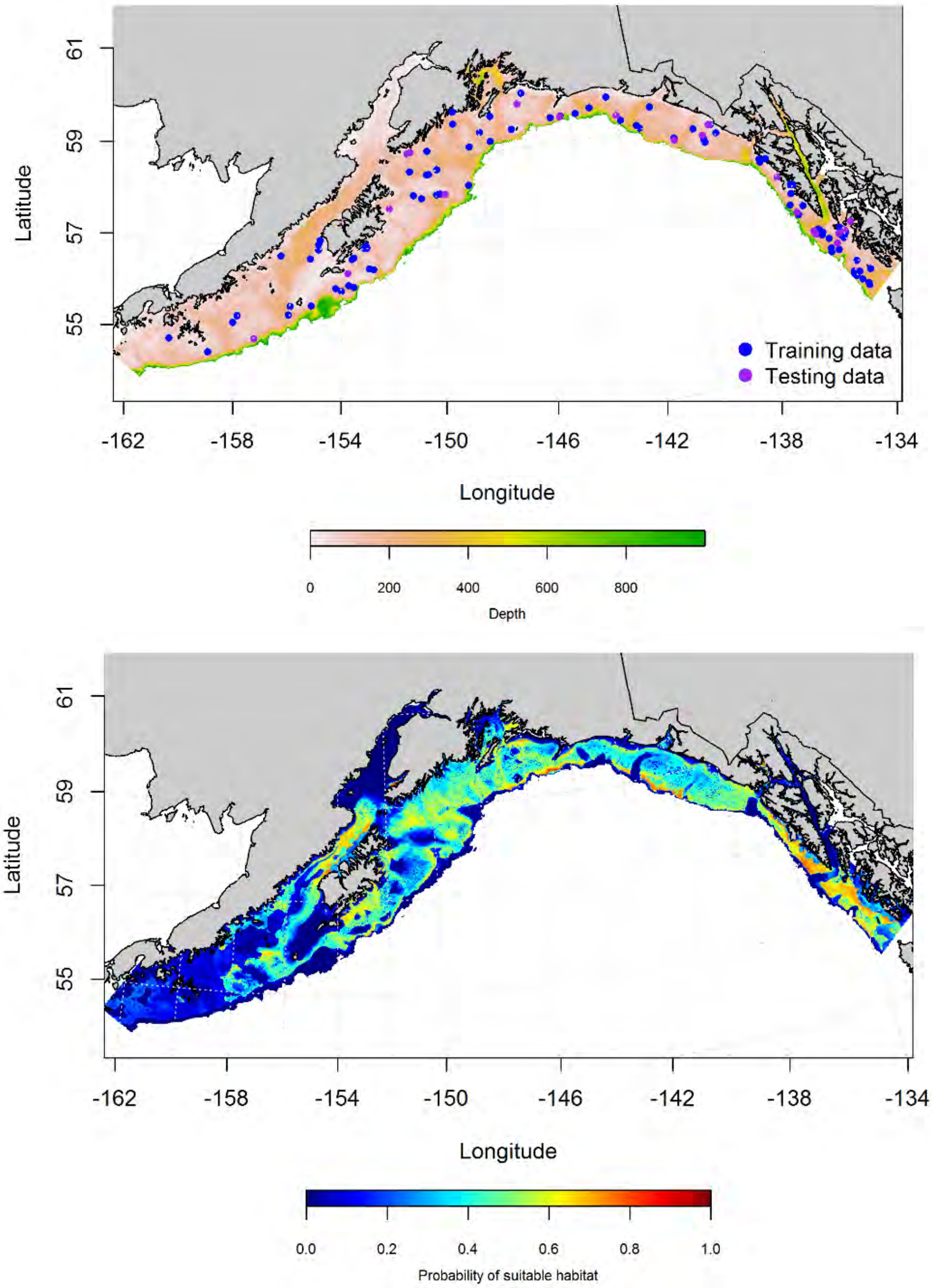


Figure 226. -- Locations of trawl survey catches of juvenile *S. brevispinis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. brevispinis* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

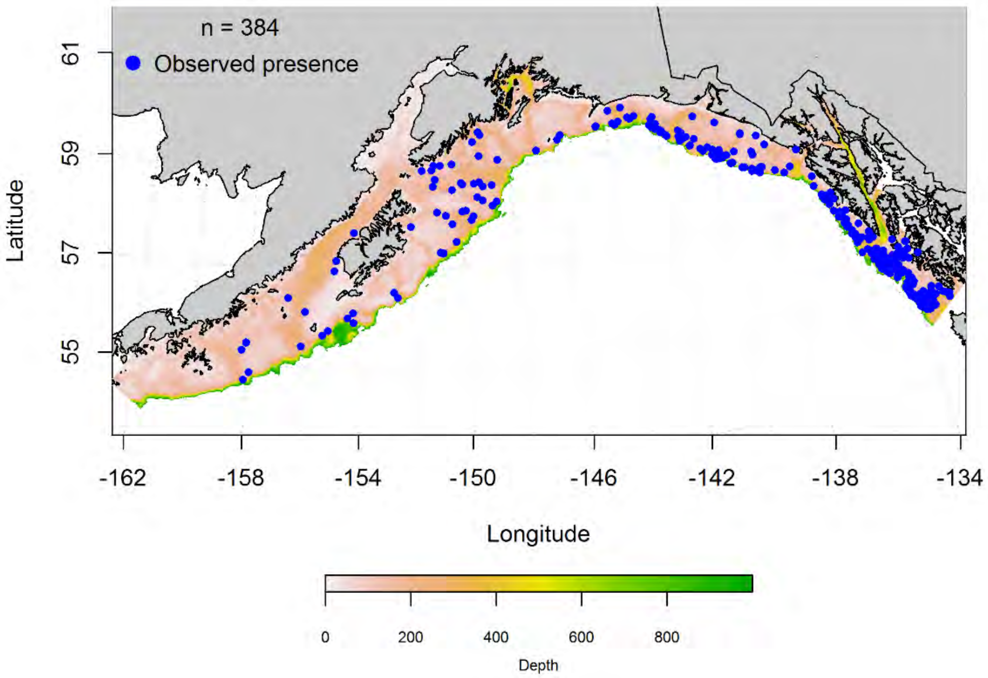


Figure 227. -- Locations of catches of adult *S. brevispinis* from summer bottom trawl surveys of the Gulf of Alaska.

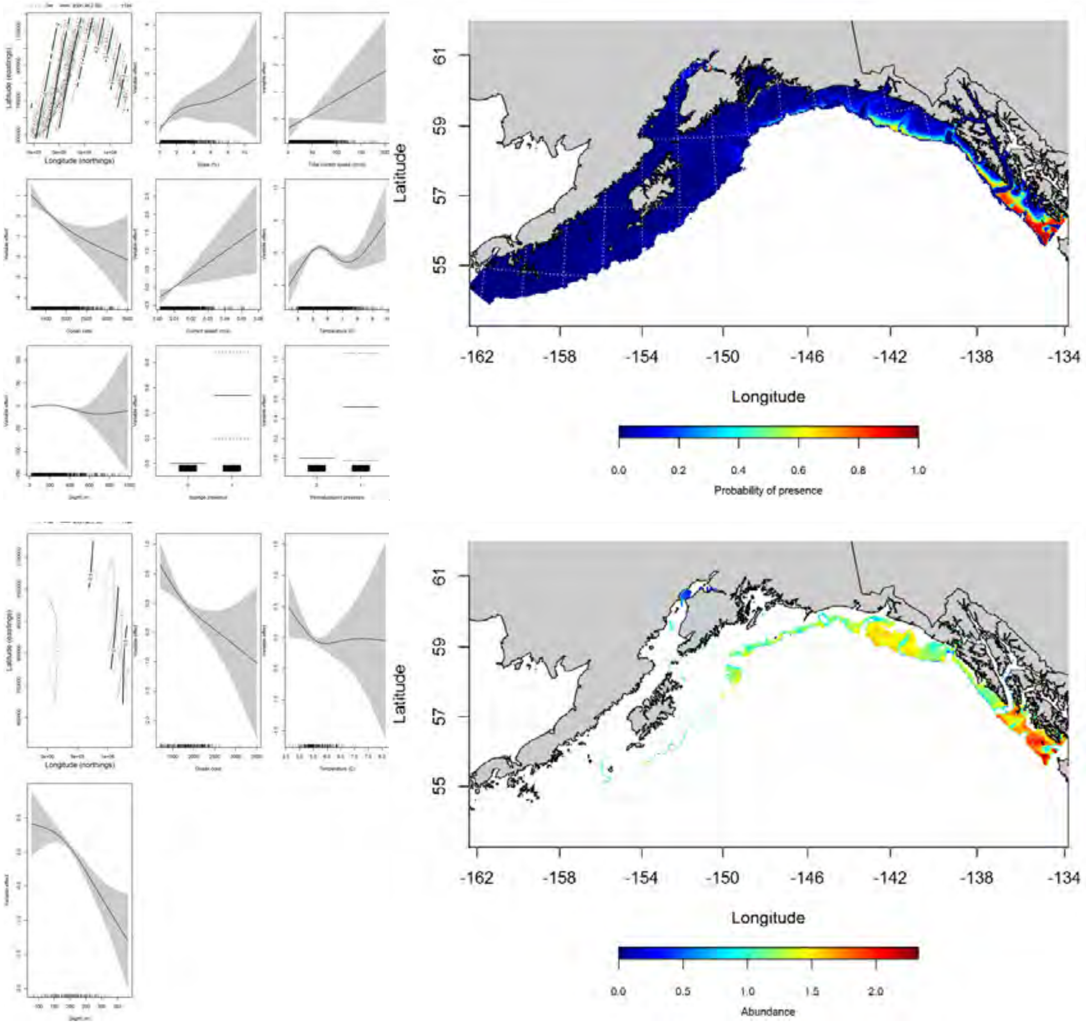


Figure 228. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. brevispinis* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. brevispinis* in the Gulf of Alaska -- There were no observations of juvenile or adult silvergray rockfish from commercial fisheries data.

Gulf of Alaska *S. brevispinis* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for silvergray rockfish was predicted to predominantly occur off southeast Alaska. Because the early life history stages of most rockfish, including silvergray rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile silvergray rockfish, based on trawl survey observations, was predicted to include most of the shelf, east of Kodiak Island (Figure 229). EFH for adult silvergray rockfish, was predicted to largely occur on the middle- and outer-shelf in the eastern gulf, from Yakutat Valley south to Dixon Entrance.

EFH for silvergray rockfish based on observations from commercial catches could not predicted.

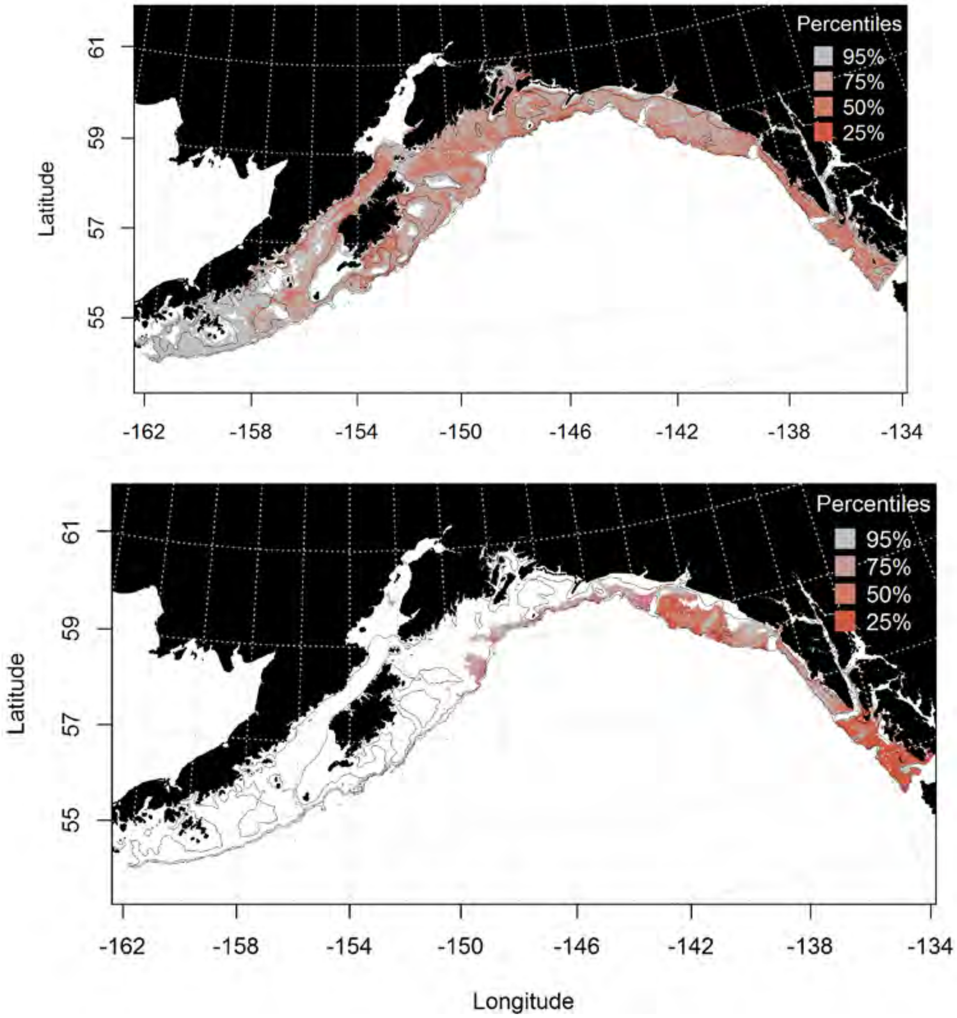


Figure 229. -- Predicted summer essential fish habitat for *S. brevispinis* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

dark rockfish (*Sebastes ciliatus*)

Dark rockfish are rarely caught in Gulf of Alaska, and a majority fish that are captured occur around the Shumagin Island and Alaska Peninsula (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. ciliatus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile dark rockfish largely occur along the middle- and outer-shelf in the western Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 43.8 and 23.9 respectively). The AUC for the training data was 0.88, indicating a good model fit. The AUC for the testing data was 0.71, indicating a fair model fit. The percent of correctly classified observations was 79% for the training data and 71% for the test data. Summer habitat for juvenile dark rockfish habitat was predicted to occur across much of the middle- and outer-shelf in the western gulf, particularly around the Shumagin Islands and Semidi Bank (Figure 230).

Summer bottom trawl survey data indicate adult dark rockfish largely occur in deeper portions of the middle- and outer-shelf in the western Gulf of Alaska. Only 29 adult dark rockfish were observed, with most occurring along the outer-shelf between Kodiak and the Shumagin Islands (Figure 231). There were not a sufficient number of observations to model adult dark rockfish distributions.

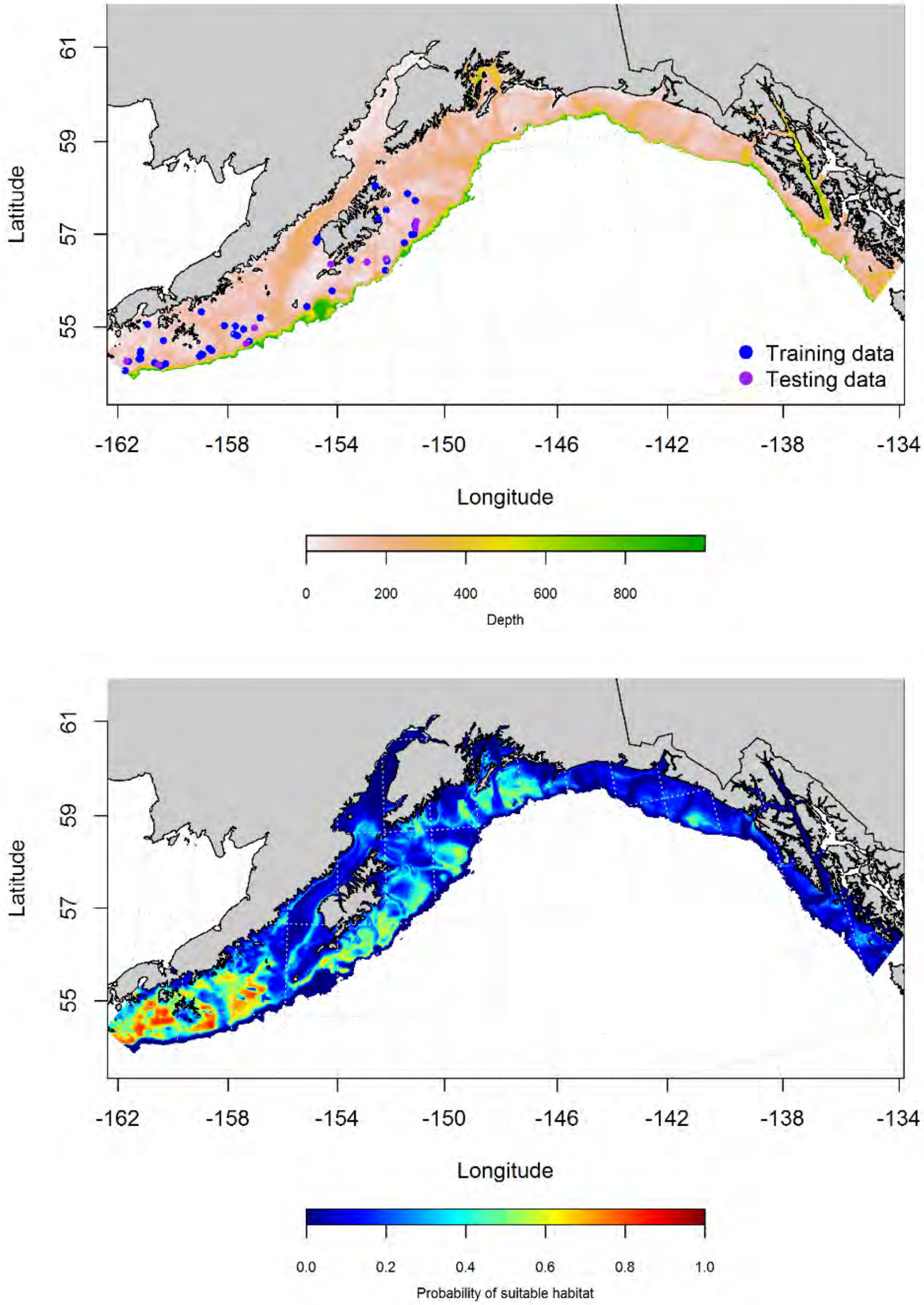


Figure 230. -- Locations of trawl survey catches of juvenile *S. ciliatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. ciliatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

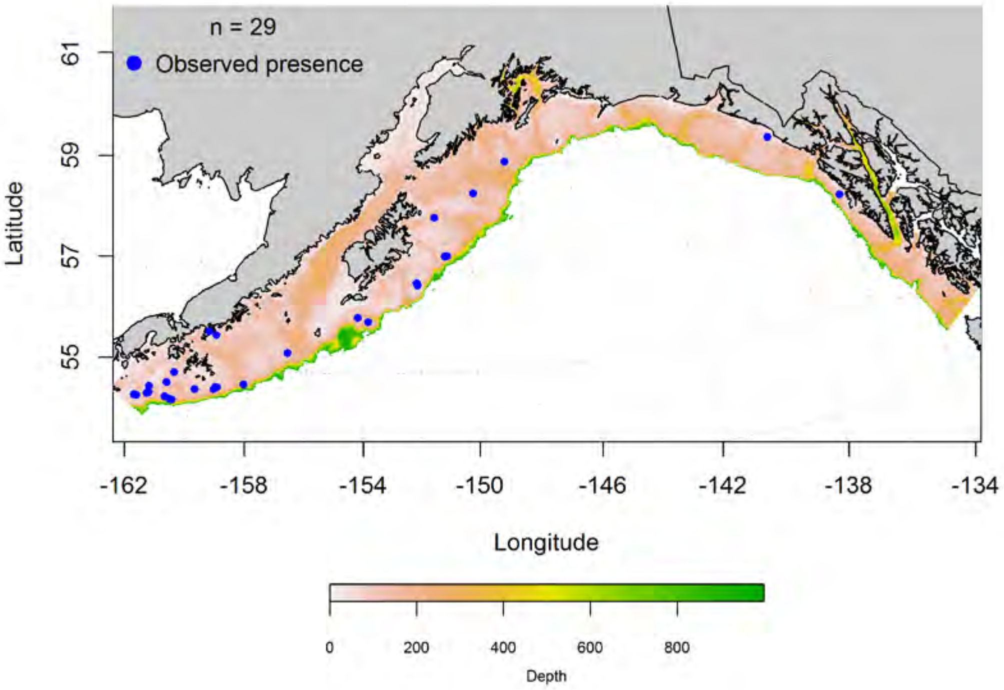


Figure 231. -- Locations of catches of adult *S. ciliatus* from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. ciliatus* in the Gulf of Alaska -- There were no observations of juvenile or adult dark rockfish from commercial fisheries data.

Gulf of Alaska *S. ciliatus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for dark rockfish was predicted to occur off southeast Alaska. Because the early life history stages of most rockfish, including dark rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp. Please see section 20.4 of this report for analysis of EFH for the early life history stages of rockfish.

Summer EFH for juvenile dark rockfish, based on trawl survey observations, was predicted occur on the middle- and outer-shelf in the western gulf, particularly around the Shumagin Islands and on Semidi Bank (Figure 232). EFH for adult dark rockfish could not predicted based on summer trawl survey observations.

EFH for dark rockfish based on observations from commercial catches could not predicted.

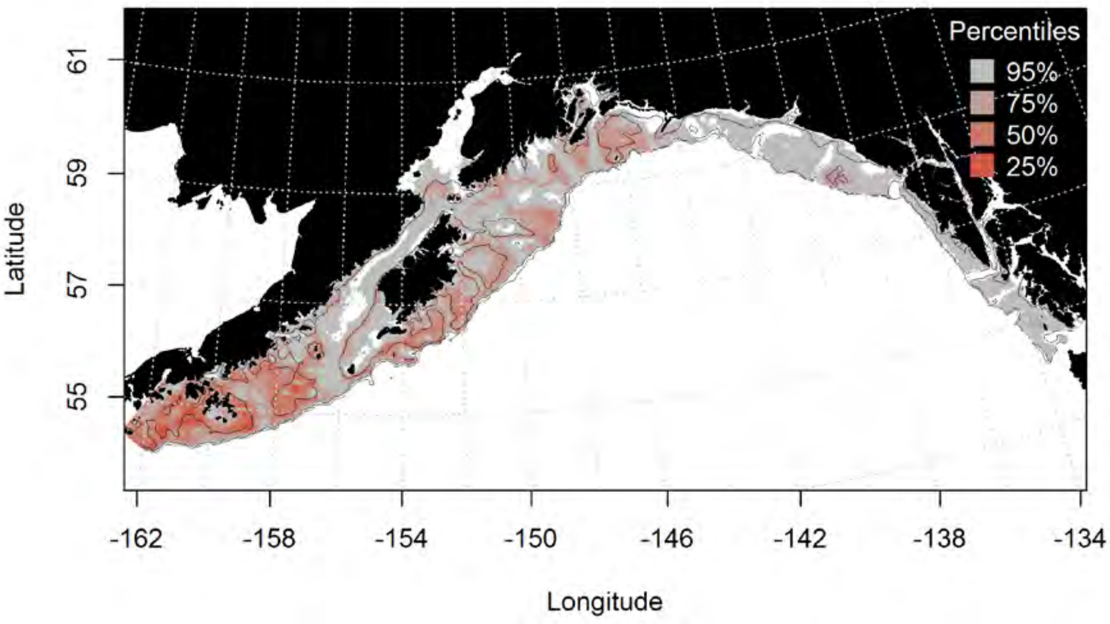


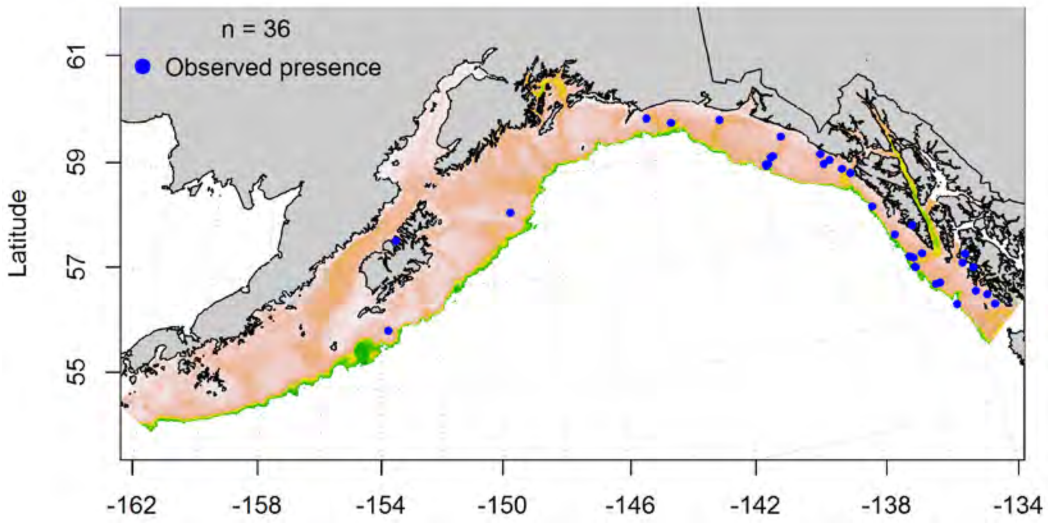
Figure 232. -- Predicted summer essential fish habitat for *S. ciliatus* juveniles from summer bottom trawl surveys.

darkblotched rockfish (*Sebastes crameri*)

Darkblotched rockfish occur throughout much of the the Gulf of Alaska, but most observations are from southeast Alaska. They occur over soft bottoms, and are typically found at 100 to 400 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. crameri* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile darkblotched rockfish largely occur in the eastern gulf off southeast Alaska (Figure 233). Only thirty-six juvenile darkblotched rockfish were observed. Most were observed south of Yakutat, and they were observed across much of the shelf. There were eighteen observations of adult darkblotched rockfish, most occurred along the outer-shelf and shelf break off southeast Alaska. There were not a sufficient number of observations to model juvenile or adult darkblotched rockfish distributions.



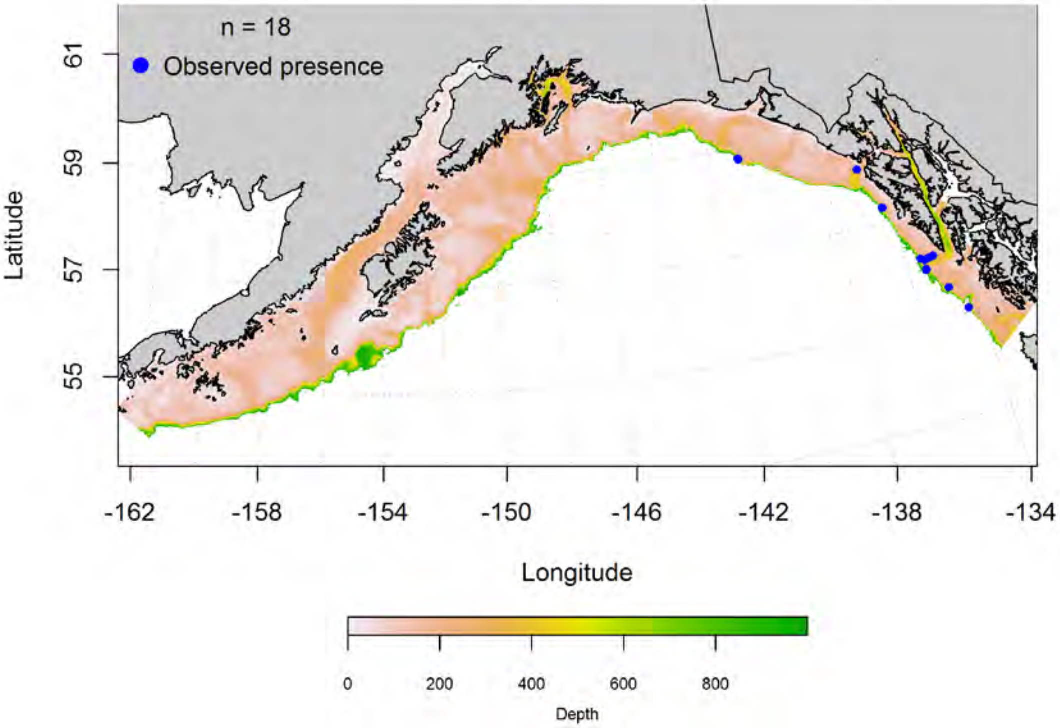


Figure 233. -- Locations of catches of juvenile and adult *S. crameri* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. ciliatus* in the Gulf of Alaska -- There were no observations of juvenile or adult darkblotched rockfish from commercial fisheries data.

Gulf of Alaska *S. ciliatus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for darkblotched rockfish could not be predicted.

splitnose rockfish (*Sebastes diploproa*)

Splitnose rockfish rarely occur in the Gulf of Alaska. They occur over soft bottoms at depths of 80-800 m, but typically occur shallower than 450 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. diploproa* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile splitnose rockfish largely occur in the eastern gulf off southeast Alaska (Figure 234). Only twenty-seven juvenile splitnose rockfish were observed. Most were observed south of Cape Ommaney, although some were also observed along the shelf break off Yakutat. There were only two observations of adult splitnose rockfish, both occurred along the shelf break in the eastern gulf. There were not a sufficient number of observations to model juvenile or adult darkblotched rockfish distributions.

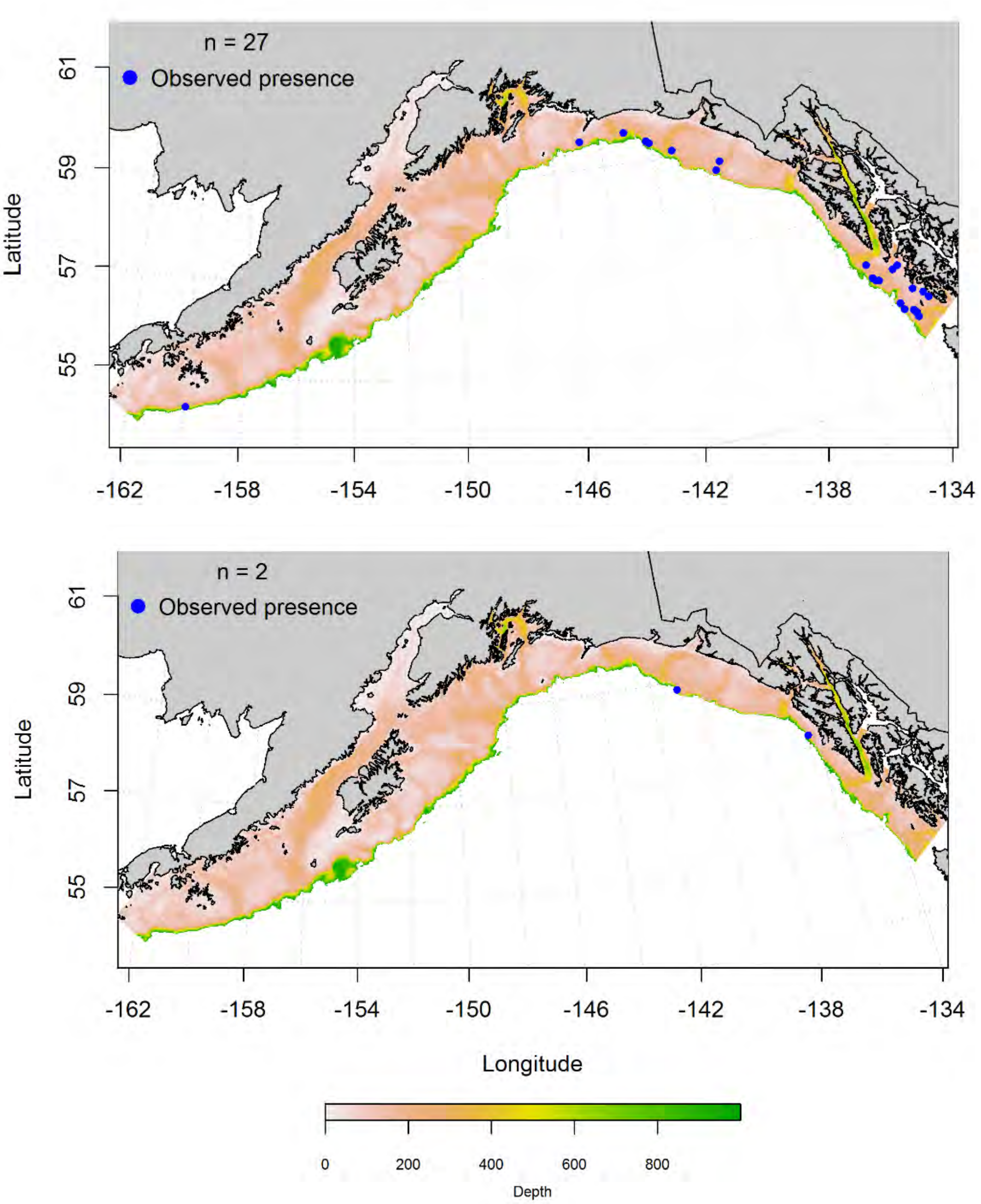


Figure 234. -- Locations of catches of juvenile and adult *S. diploproa* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. diploproa* in the Gulf of Alaska -- There were no observations of juvenile or adult splitnose rockfish from commercial fisheries data.

Gulf of Alaska *S. diploproa* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for splitnose rockfish could not be predicted.

greenstriped rockfish (*Sebastes elongatus*)

Greenstriped rockfish largely occur in the central and eastern Gulf of Alaska. They are found over sandy or silty bottoms at depths of 12-495 m, but are most common between 100-250 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. elongatus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile greenstriped rockfish largely occur on the outer-shelf in the eastern Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and ocean color were the most important variables predicting habitat suitability (relative importance 41.2 and 25.2 respectively). The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the testing data was 0.86, indicating a good model fit. The percent of correctly classified observations was 92% for the training data and 86% for the test data. Summer habitat for juvenile greenstriped rockfish habitat was predicted to largely occur on the outer-shelf off southeast Alaska, particularly south of Cape Ommaney (Figure 235). In addition high suitably habitats were also predicted to occur at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations.

Summer bottom trawl survey data indicate adult greenstriped rockfish largely occur on the outer-shelf in the eastern Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and ocean color were the most important variables predicting habitat suitability (relative importance 54.6 and 15.9 respectively). The AUC for the training data was 0.97, indicating an excellent model fit. The AUC for the testing data was 0.82, indicating a good model fit. The percent of correctly classified observations was 93% for the training data and 82% for the test data. Summer habitat for adult greenstriped was predicted to occur along the outer-shelf off southeast Alaska (Figure 236). In addition, high suitably habitats were also predicted to occur at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations.

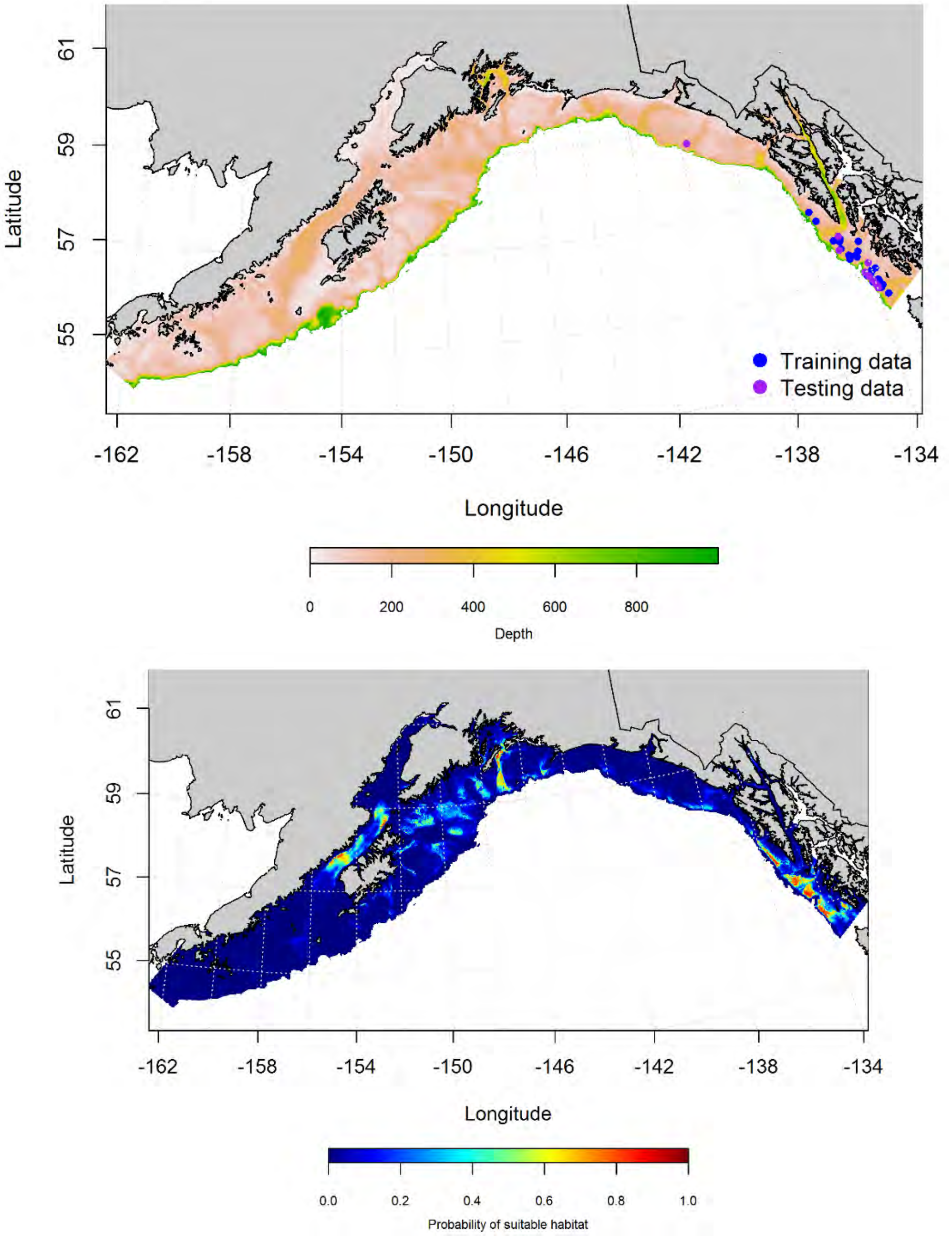


Figure 235. --Locations of trawl survey catches of juvenile *S. elongatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. elongatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

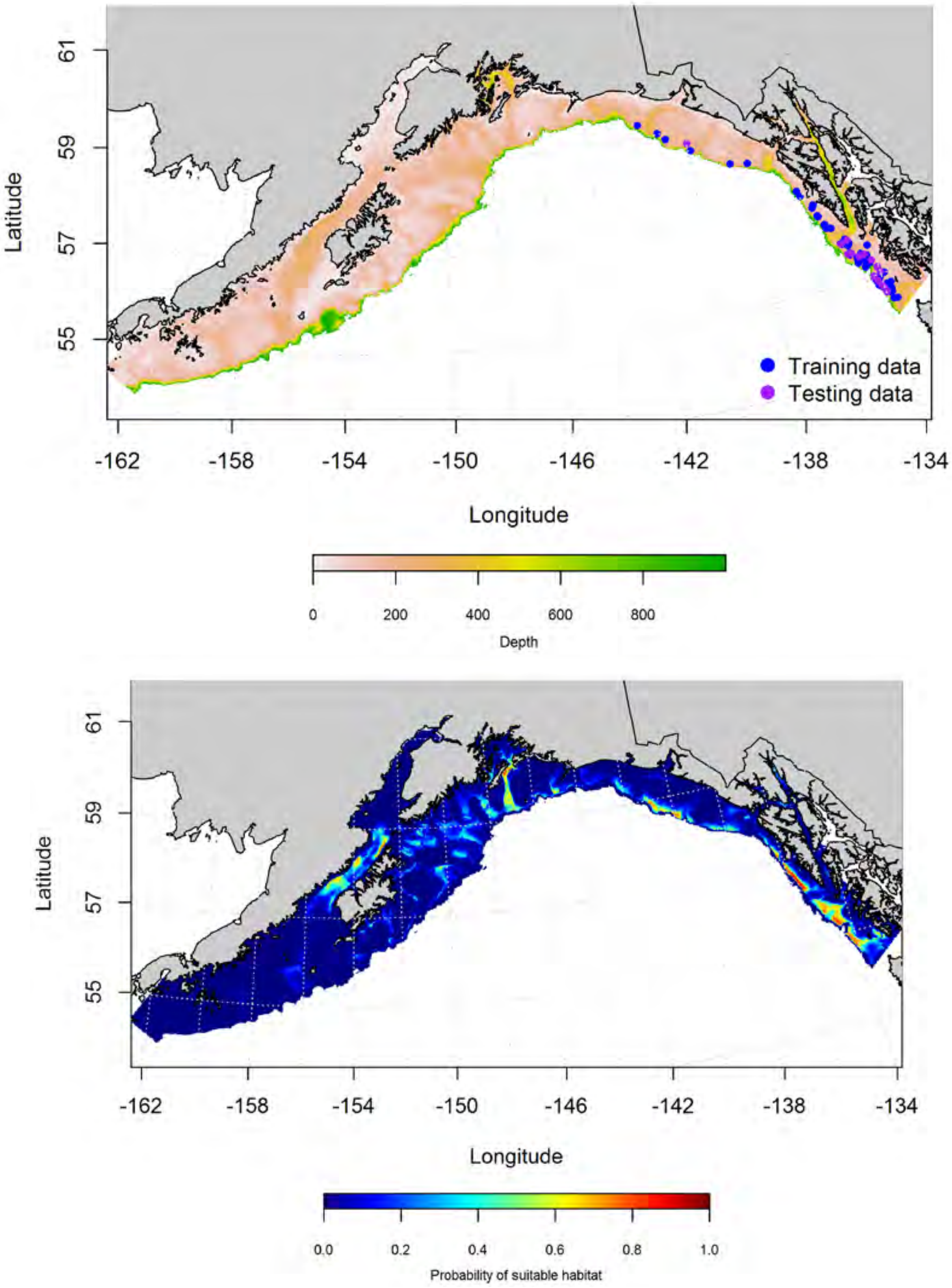


Figure 236. --Locations of trawl survey catches of adult *S. elongatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. elongatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. elongatus* in the Gulf of Alaska -- There were no observations of juvenile or adult greenstriped rockfish from commercial fisheries data.

Gulf of Alaska *S. elongatus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for greenstriped rockfish was predicted to predominantly occur off southeast Alaska. Because the early life history stages of most rockfish, including greenstriped rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile greenstriped rockfish, based on trawl survey observations, was predicted to occur along the outer-shelf off southeast Alaska (Figure 237). In addition EFH for juvenile greenstriped rockfish was also identified off at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations. EFH for adult greenstriped rockfish similar to that of the juveniles, and it was predicted to predominantly occur along the outer-shelf off southeast Alaska. Additional adult EFH were also identified off at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations

EFH for greenstriped rockfish based on observations from commercial catches could not predicted.

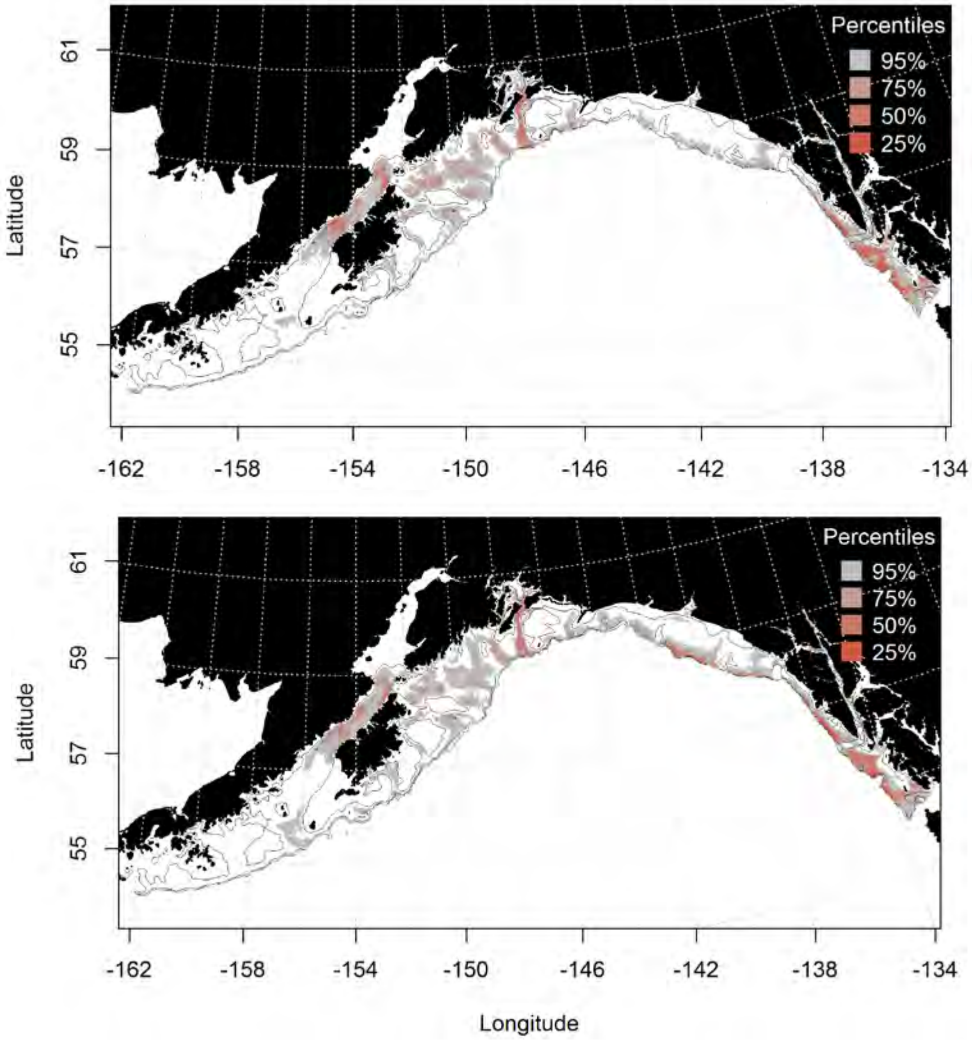


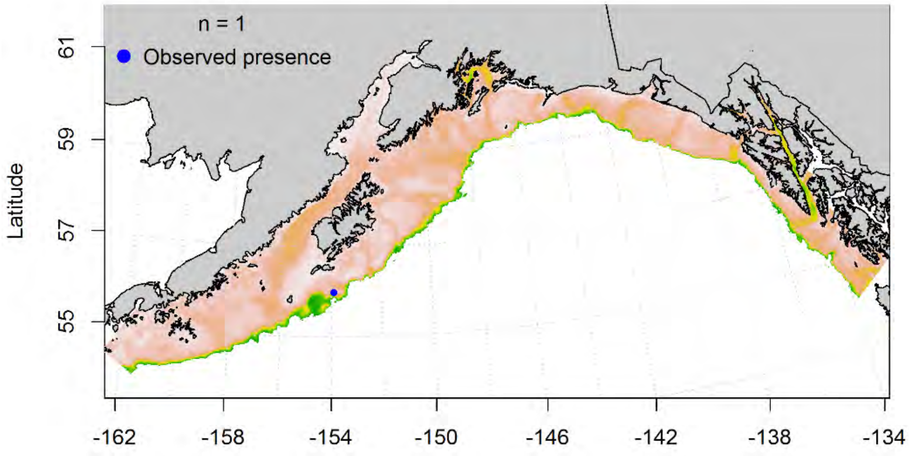
Figure 237. -- Predicted summer essential fish habitat for *S. elongatus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

widow rockfish (*Sebastes entomelas*)

Widow rockfish are largely occur in the central and eastern portions of the Gulf of Alaska. They are found around offshore reefs, seamounts, and in midwater from the near surface to depths of 600-800 m; but are unusually observed shallower than 350 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. entomelas* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile widow rockfish largely occur in the eastern gulf off southeast Alaska (Figure 238). Only a single juvenile widow rockfish was observed, it occurred on the outer-shelf off of Kodiak Island. There were only twenty-two observations of adult widow rockfish. Most occurred along the outer-shelf in the eastern gulf off southeast Alaska. There were also a few widely dispersed individuals along the outer-shelf in the central and western gulf. There were not a sufficient number of observations to model juvenile or adult widow rockfish distributions.



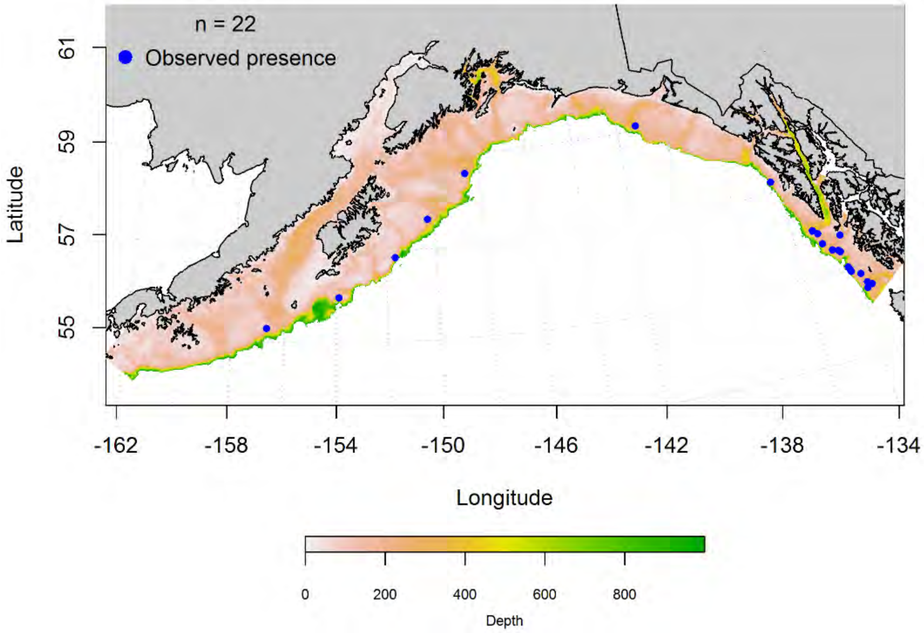


Figure 238. -- Locations of catches of juvenile and adult *S. entomelas* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. entomelas* in the Gulf of Alaska -- There were no observations of juvenile or adult widow rockfish from commercial fisheries data.

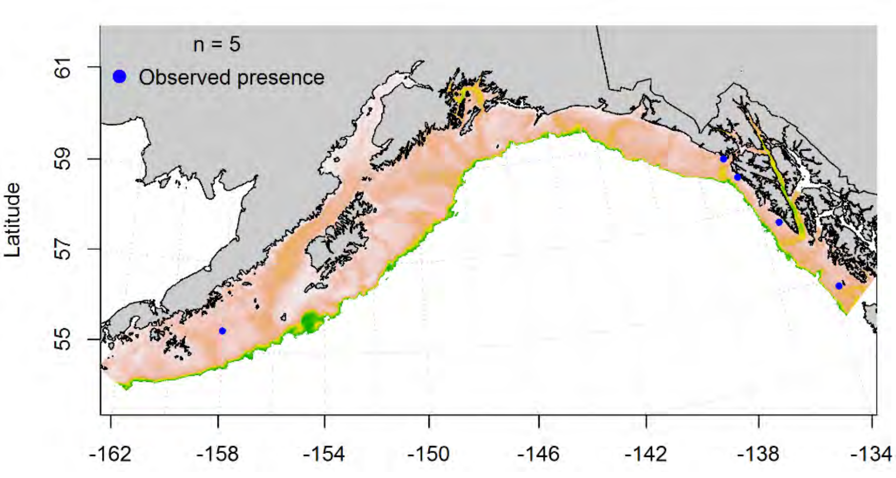
Gulf of Alaska *S. entomelas* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for widow rockfish could not be modeled for any life history stages.

yellowtail rockfish (*Sebastes flavidus*)

Yellowtail rockfish occur throughout the Gulf of Alaska. They typically are observed in schools around offshore reefs at depths from 50-250 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. flavidus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile yellowtail rockfish largely occur in the eastern gulf off southeast Alaska (Figure 239). Only five juvenile yellowtail rockfish was observed, most occurred in nearshore waters off southeast Alaska. There were only thirty-eight observations of adult yellowtail rockfish. Most occurred along in the eastern gulf off southeast Alaska. There were also a few widely dispersed individuals on in the central and western gulf. There were not a sufficient number of observations to model juvenile or adult yellowtail rockfish distributions.



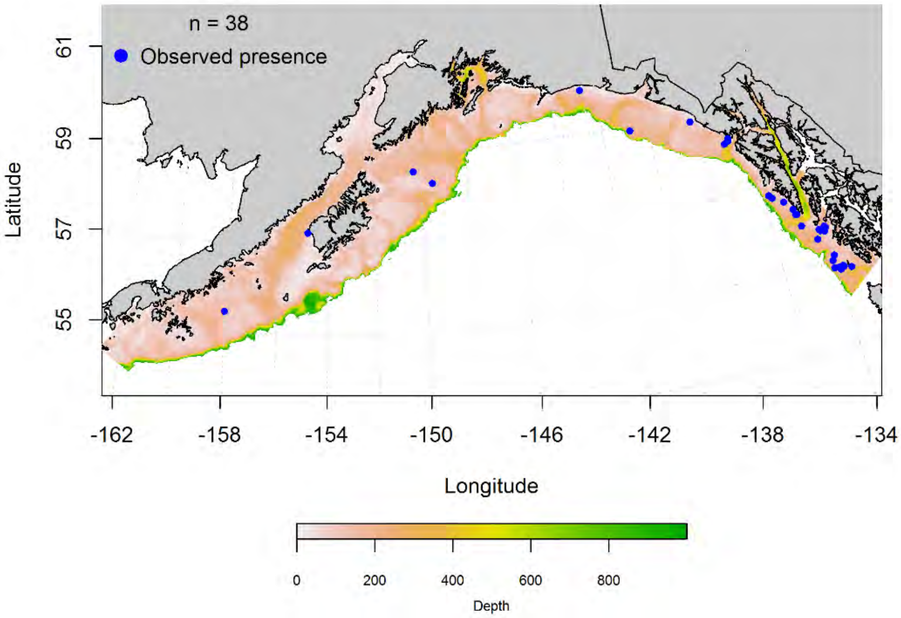


Figure 239. -- Locations of catches of juvenile and adult *S. flavidus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. flavidus* in the Gulf of Alaska -- There were no observations of juvenile or adult yellowtail rockfish from commercial fisheries data.

Gulf of Alaska *S. flavidus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for yellowtail rockfish could not be modeled for any life history stages.

rosethorn rockfish (*Sebastes helvomaculatus*)

Rosethorn rockfish largely occur in central and eastern portion of the Gulf of Alaska. They are typically observed around rocky reefs and seamounts , at from 125-350 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. helvomaculatus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile rosethorn rockfish largely occur on the outer-shelf in the eastern Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 56.2 and 29.5 respectively). The AUC for the training data was 0.97, indicating an excellent model fit. The AUC for the testing data was 0.88, indicating a good model fit. The percent of correctly classified observations was 93% for the training data and 88% for the test data. Summer habitat for juvenile rosethorn rockfish habitat was predicted to largely occur on the outer-shelf off southeast Alaska, particularly from Yakutat south to Dixon Entrance (Figure 240). In addition high suitably habitats were also identified at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations.

Adult rosethorn rockfish largely occur along the outer-shelf off southeast Alaska (Figure 241). Summer bottom trawl survey data indicate adult rosethorn rockfish also largely occur off southeast Alaska. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 62.8 and 23.5

respectively). The AUC for the training data was 0.98, indicating an excellent model fit. The AUC for the testing data was 0.85, indicating a good model fit. The percent of correctly classified observations was 94% for the training data and 85% for the test data. In addition high suitably habitats were also identified at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations.

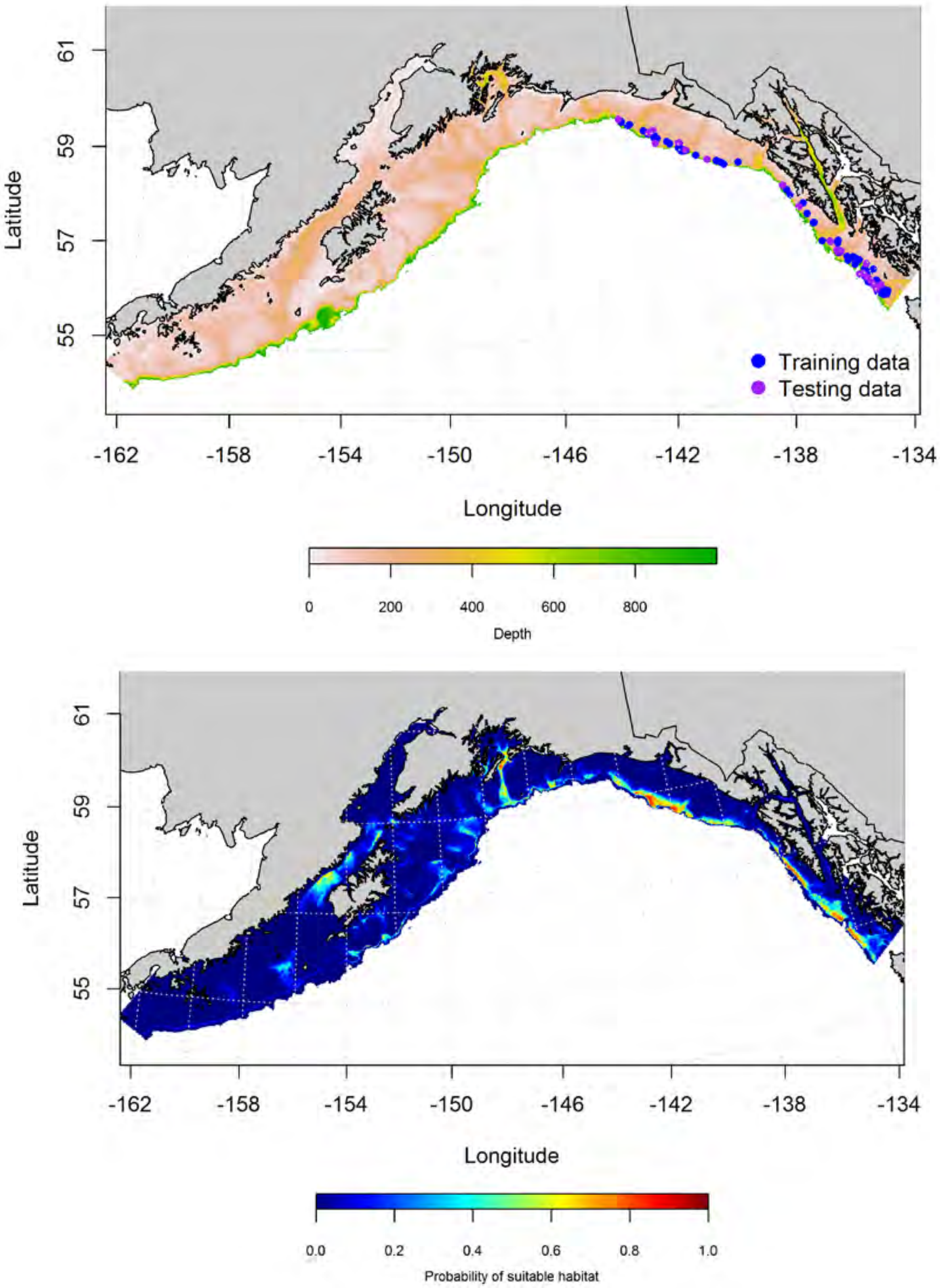


Figure 240. -- Locations of trawl survey catches of juvenile *S. helvomaculatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. helvomaculatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

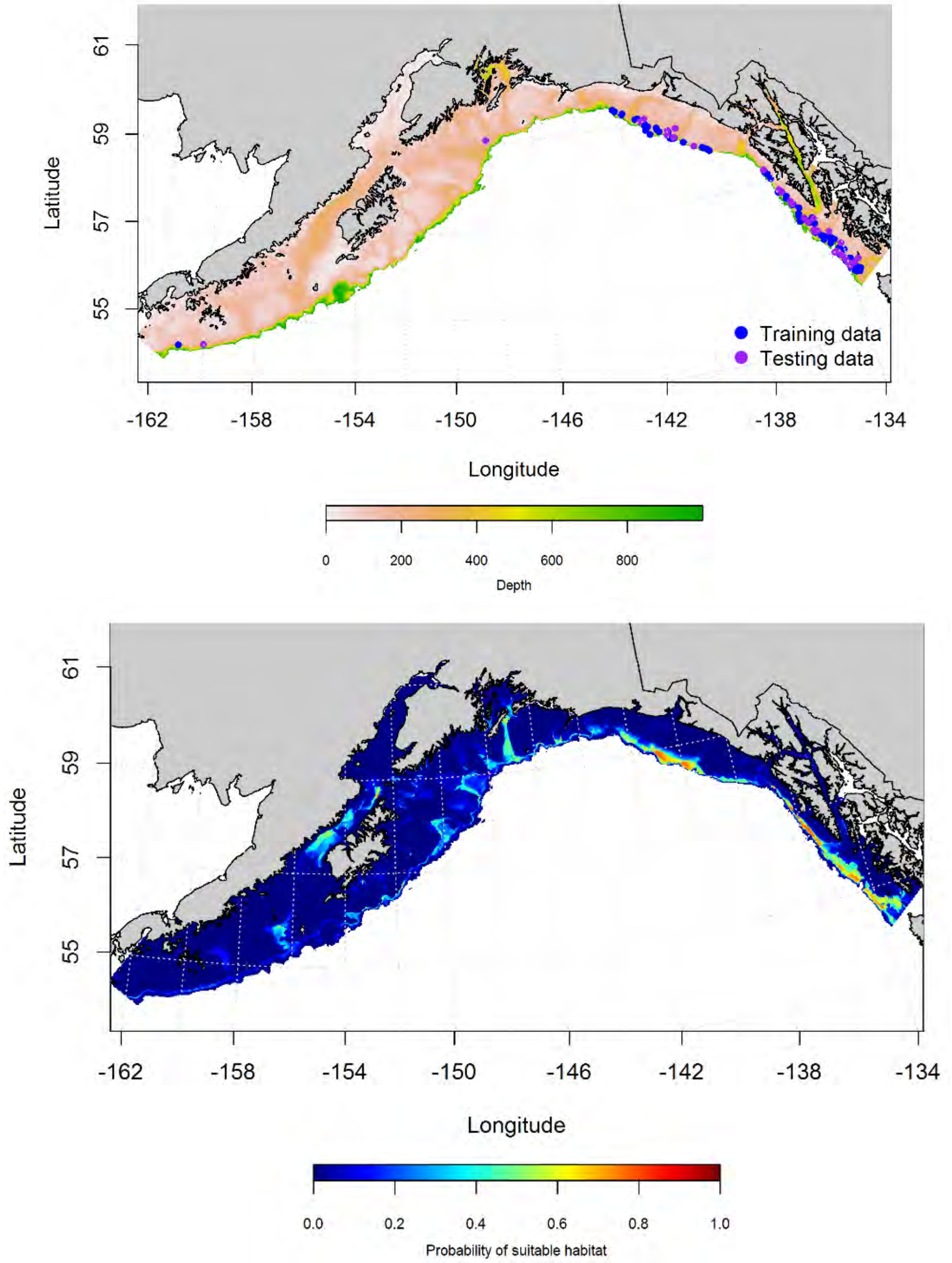


Figure 241. -- Locations of trawl survey catches of adult *S. helvomaculatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. helvomaculatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. helvomaculatus* in the Gulf of Alaska -- There were no observations of juvenile or adult rosethorn rockfish available from commercial fisheries data.

Gulf of Alaska *S. helvomaculatus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Rosethorn rockfish was predicted to predominantly occur off southeast Alaska in Gulf of Alaska. Because the early life history stages of most rockfish, including rosethorn rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp. Please see section 20.4 of this report for analysis of EFH for the early life history stages of rockfish.

Summer EFH for juvenile, based on trawl survey observations, was predicted to largely occur along the outer-shelf in the eastern gulf (Figure 242). In addition EFH for juvenile rosethorn rockfish was also identified at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations. EFH for adult rosethorn rockfish was predicted to be similar to that of the juveniles, and it was predicted to largely occur along the outer-shelf off in the eastern gulf (Figure 31.3). Additional, EFH for adult rosethorn rockfish were also identified off at the entrance to Prince William Sound and in Shelikof Strait; however, these predictions were not supported by any observations

EFH for rosethorn rockfish based on observations from commercial catches could not predicted.

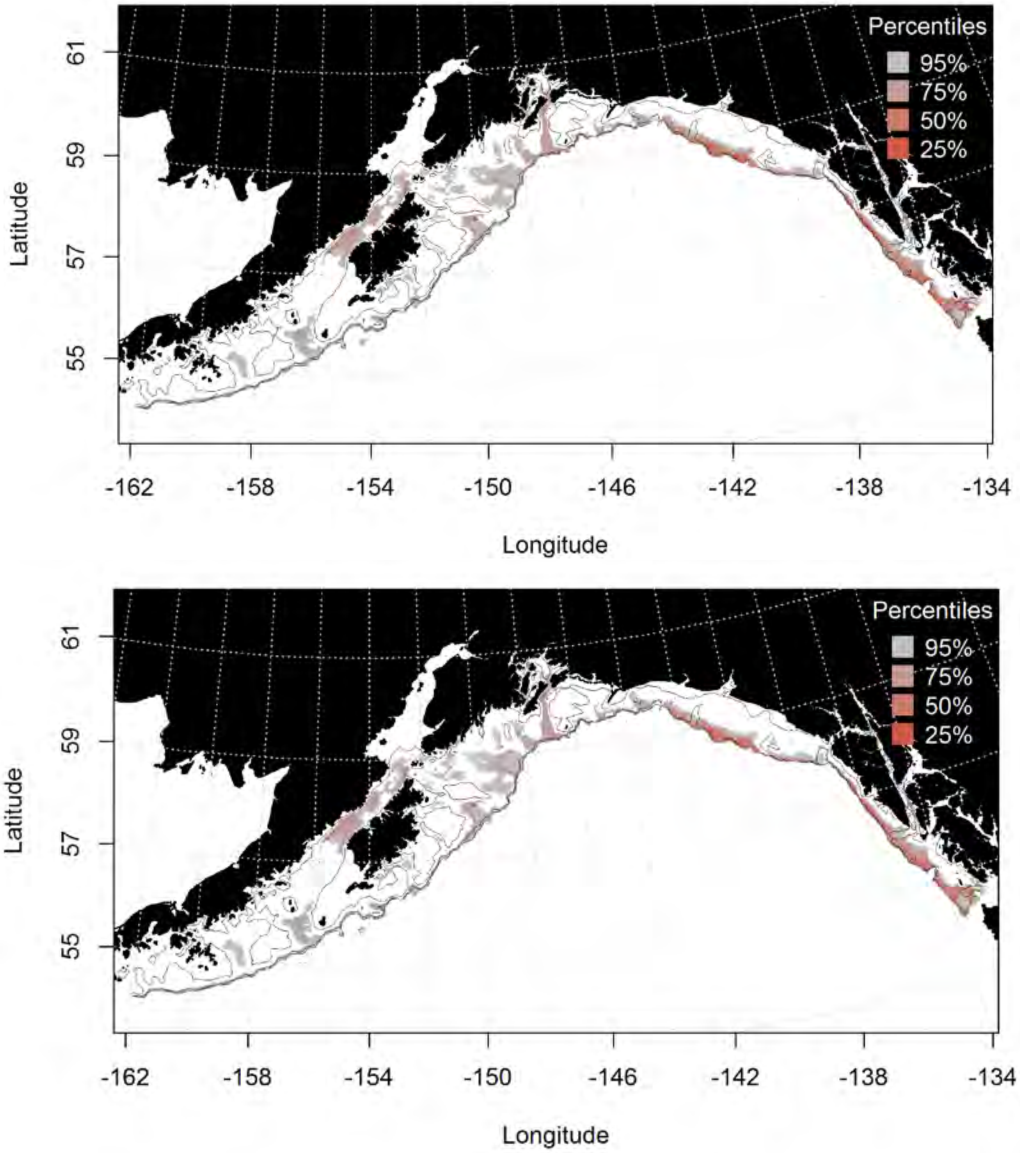


Figure 242. -- Predicted summer essential fish habitat for *S. helvomaculatus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

quillback rockfish (*Sebastes maliger*)

Quillback rockfish largely occur in the central and eastern portion of the Gulf of Alaska. They are found on or close to rocky bottoms and reefs down to 274 m depth, but usually occur at less than 145 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. maliger* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile quillback rockfish largely occur in shallow waters in the central and eastern Gulf of Alaska. There were only thirteen observations of juvenile quillback rockfish. The greatest concentration of observations occurred in inshore waters off southeast Alaska (Figure 243). Observations also occurred in nearshore waters off the Kenai Peninsula and in the vicinity of Sand Point on the Peninsula.

Summer bottom trawl survey data also indicate adult quillback rockfish occur in shallow waters in the central and eastern Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and ocean color were the most important variables predicting habitat suitability (relative importance 38.4 and 31.6 respectively). The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.83, indicating a good model fit. The percent of correctly classified observations was 85% for the training data and 83% for the test data. Summer habitat for adult quillback rockfish habitat was predicted to occur along the inshore waters off southeast Alaska (Figure 244). In addition, high suitably habitats were also identified east of Prince William Sound and in nearshore waters around Kodiak Island and the Alaska Peninsula; however, these predictions were not supported by any observations.

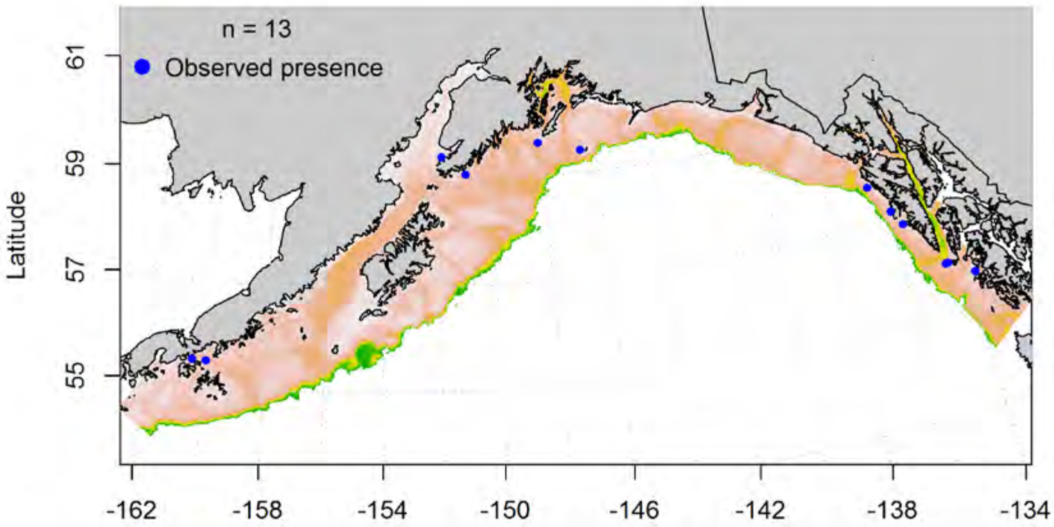
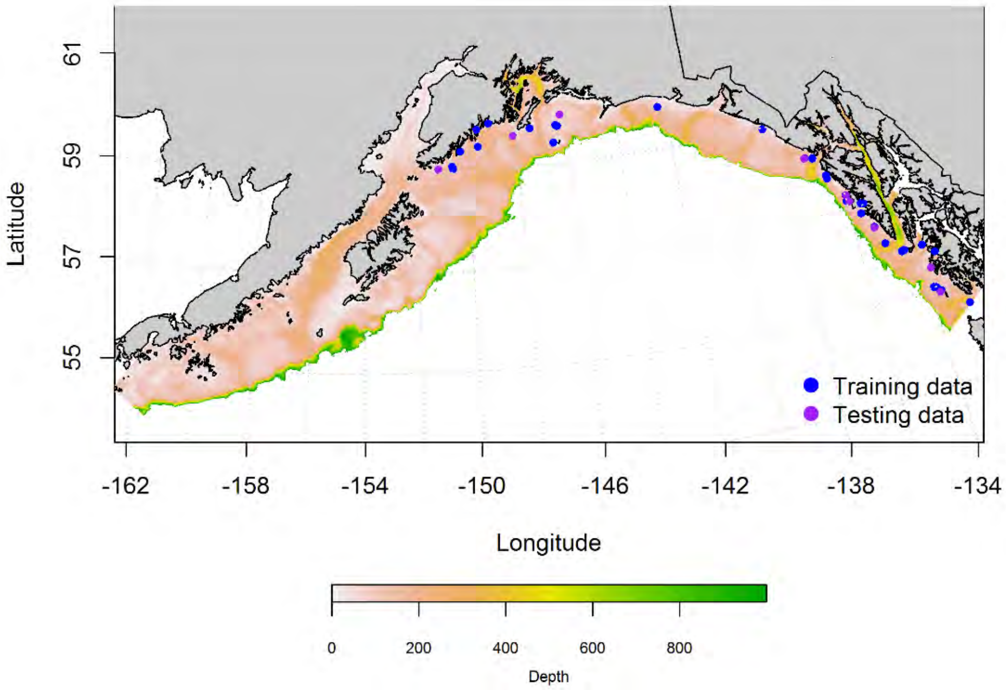


Figure 243. -- Locations of catches of juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys of the Gulf of Alaska.



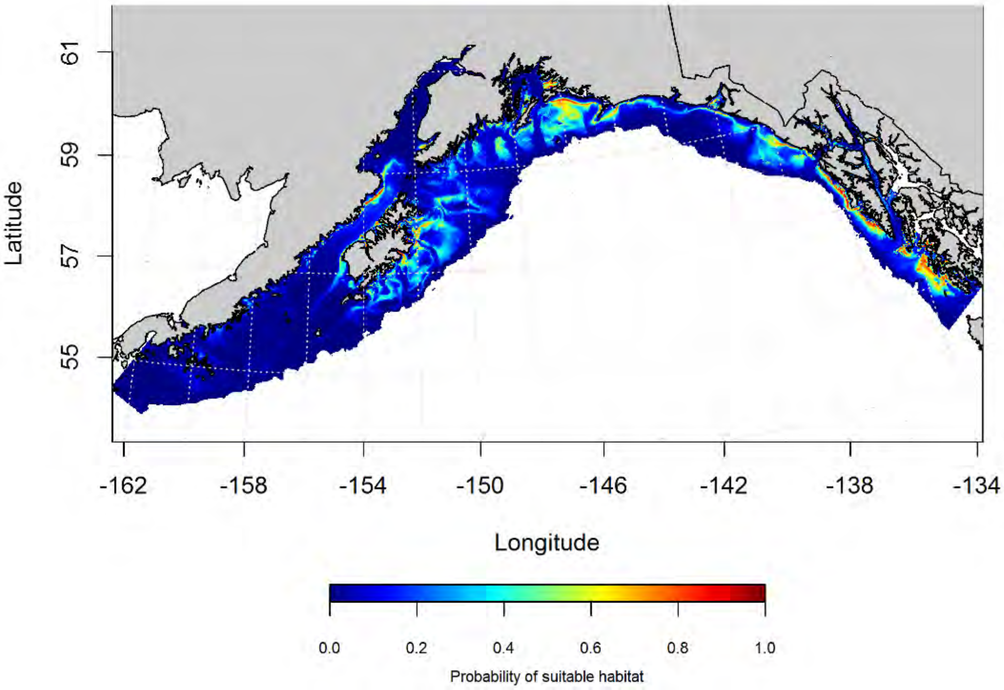


Figure 244. -- Locations of trawl survey catches of adult *S. maliger* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. maliger* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. maliger* in the Gulf of Alaska -- There were no observations of juvenile or adult quillback rockfish from commercial fisheries data.

Gulf of Alaska *S. maliger* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for quillback rockfish was predicted predominantly occur off southeast Alaska. Because the early life history stages of most rockfish, including quillback rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile quillback rockfish, could not be predicted. EFH for adult quillback rockfish was predicted to occur along the inshore waters off southeast Alaska (Figure 245). In addition, high suitably habitats were also identified east of Prince William Sound and in nearshore waters around Kodiak Island and the Alaska Peninsula; however, these predictions were not supported by any observations.

EFH for quillback rockfish based on observations from commercial catches could not predicted.

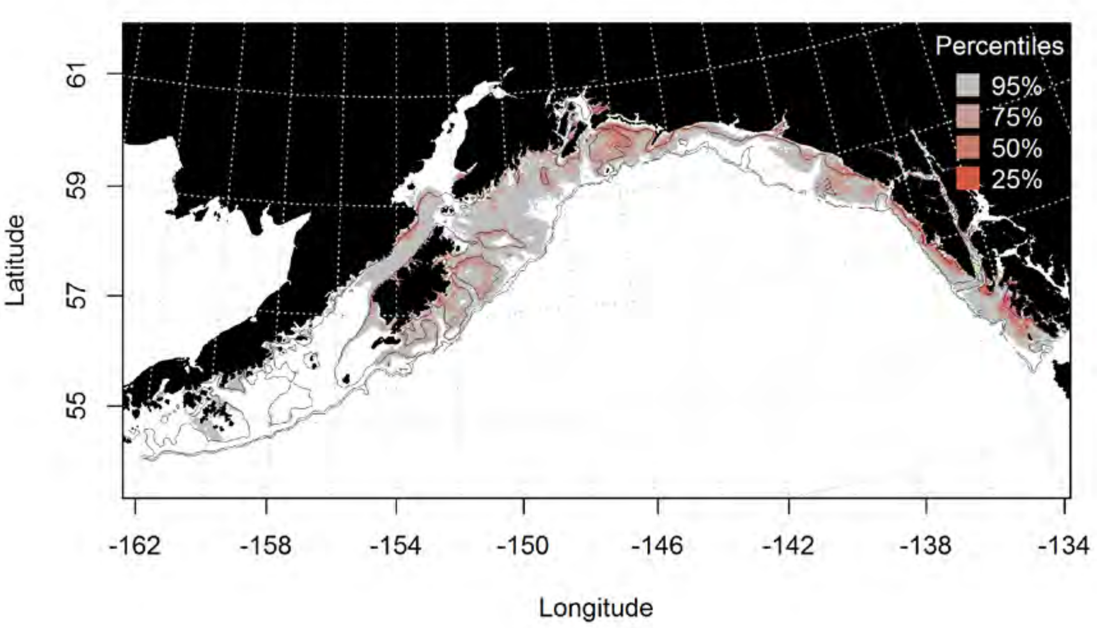


Figure 245. -- Predicted summer essential fish habitat for adults from summer bottom trawl surveys.

black rockfish (*Sebastes melanops*)

Black rockfish occur throughout much of the Gulf of Alaska. They usually occur in schools around rocky reefs, at depths from the near surface to 150 m (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. melanops* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate black rockfish occur across much of the Gulf of Alaska. There were only eleven observations of juvenile black rockfish, and most occurred in nearshore waters along the Alaska Peninsula west of Kodiak Island (Figure 246). There were thirty-three observations of adult black rockfish. They occurred from Cross Sound in southeast Alaska to the western end of the Alaska Peninsula. Most occurred in nearshore water; however, some individuals were observed on the middle- and outer-shelf as well. There were not a sufficient number of observations to model juvenile or adult black rockfish distributions.

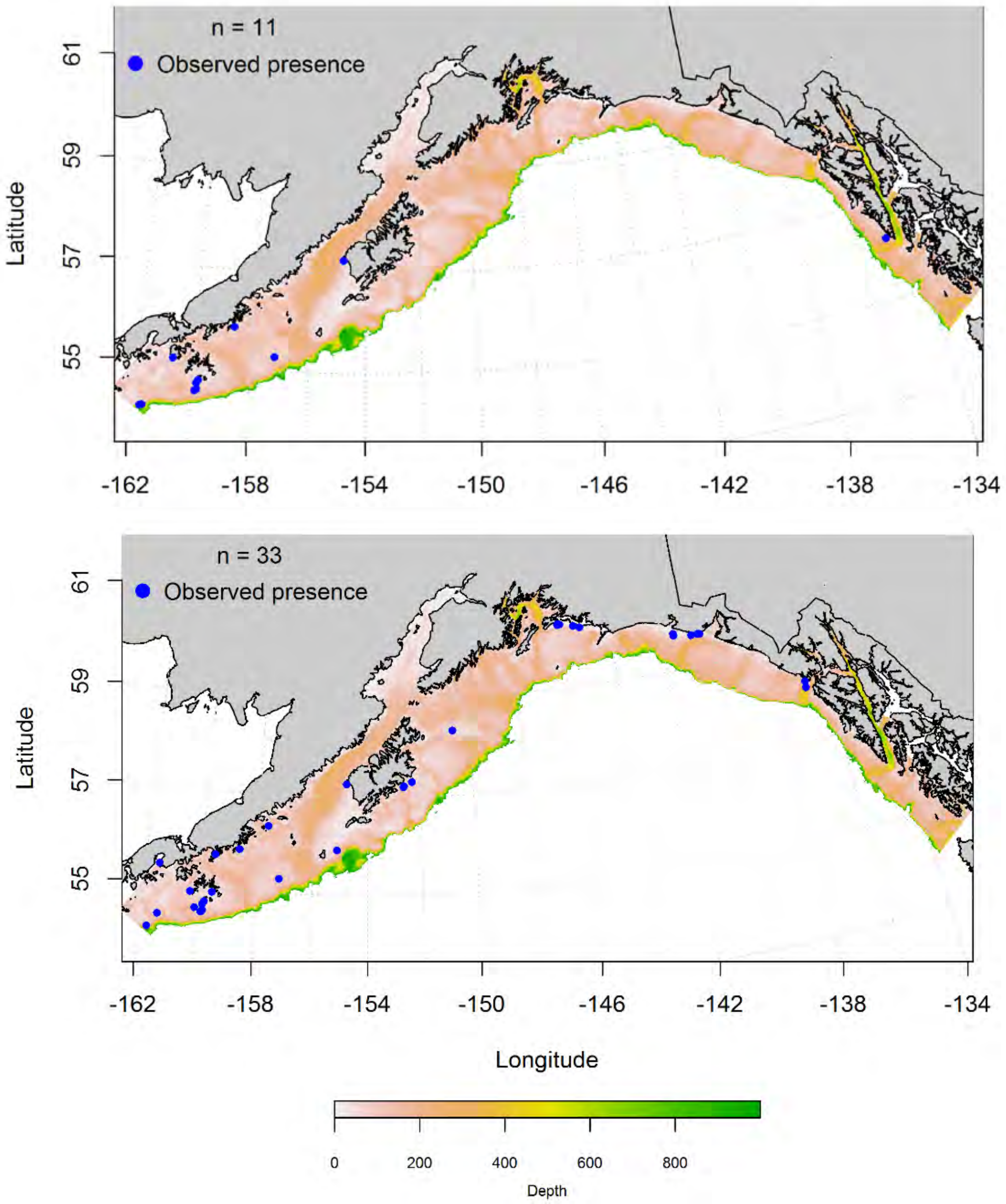


Figure 246. -- Locations of catches of juvenile and adult *S. melanops* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. melanops* in the Gulf of Alaska -- There were no observations of juvenile or adult black rockfish from commercial fisheries data.

Gulf of Alaska *S. melanops* Essential Fish Habitat Maps and Conclusions -- Black rockfish essential fish habitat could not be predicted for any life history stages.

blackspotted rockfish (*Sebastes melanostictus*)

Blackspotted rockfish are found throughout much of the Gulf of Alaska, they primarily occur on the upper slope and in deeper gullies between 201-500 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. melanostictus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile blackspotted rockfish largely occur in the deeper portions of the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 74.5 and 14.3 respectively). The AUC for the training data was 0.89, indicating a good model fit. The AUC for the testing data was 0.79, indicating a fair model fit. The percent of correctly classified observations was 80% for the training data and 79% for the test data. Juvenile blackspotted rockfish were predicted to occur in most of the deeper portions of the middle- and outer-shelf, including Shumagin and Shelikof Gullies on the Peninsula, along the edge of Albatross Bank and Amatuli Trough in the central gulf, and in Yakutat Valley and off Cape Ommaney in southeast Alaska (Figure 247).

Summer bottom trawl survey data also indicate adult blackspotted rockfish largely occur in the deeper portions of the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 74.6 and 21.6 respectively). The AUC for the training data was 0.94, indicating an excellent model fit. The AUC for the testing data was 0.81, indicating a good model fit. The percent of correctly classified observations was 88% for the training data and 81% for the test data. Summer habitat for adult blackspotted rockfish habitat was predicted occur on the shelf break and most of the deeper gullies and depressions including Amatuli Trough in the central gulf; and Yakutat Valley, Spencer Gully and off Cape Ommaney in southeast Alaska (Figure 248).

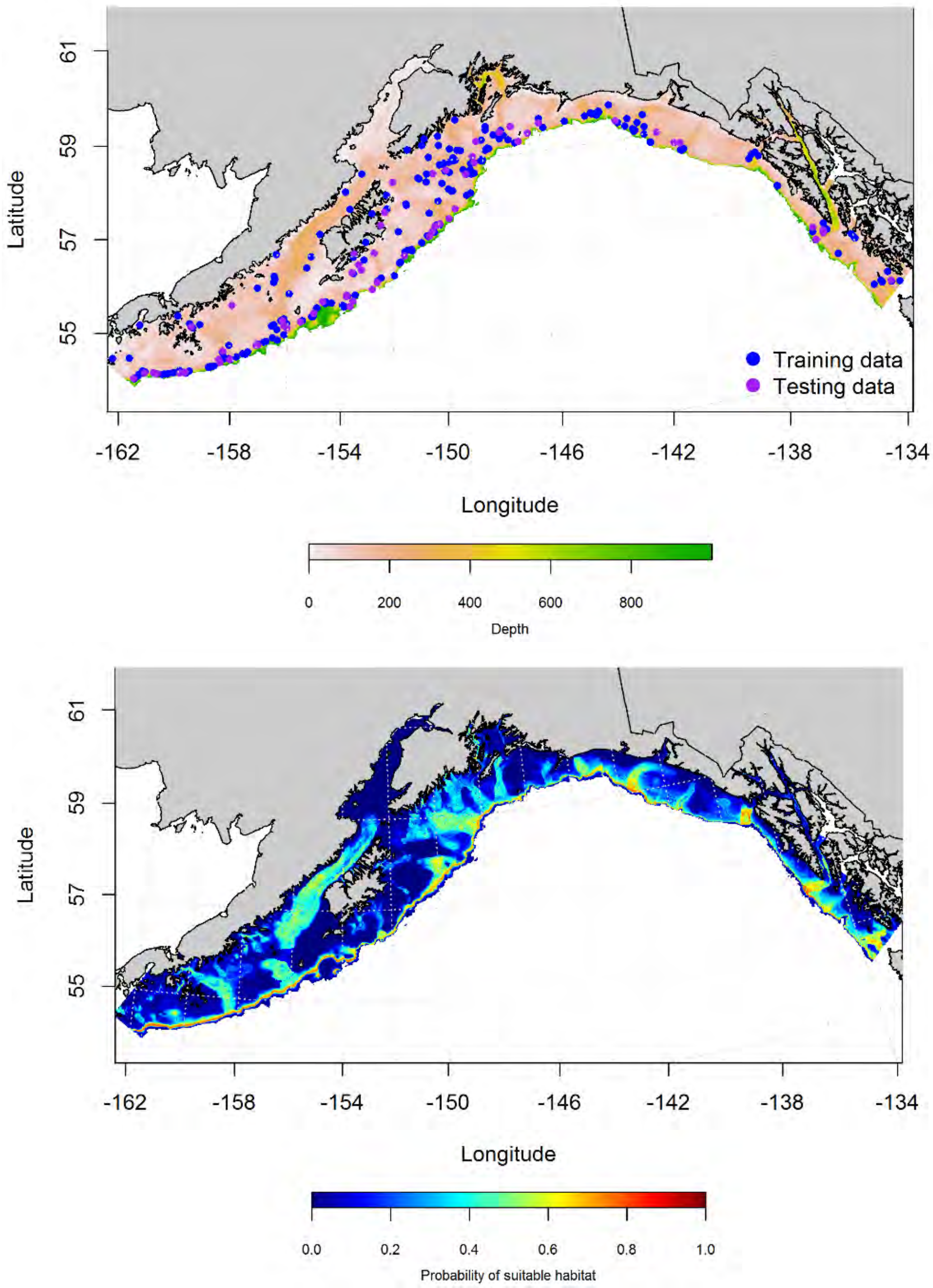


Figure 247. -- Locations of trawl survey catches of juvenile *S. melanostictus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. melanostictus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

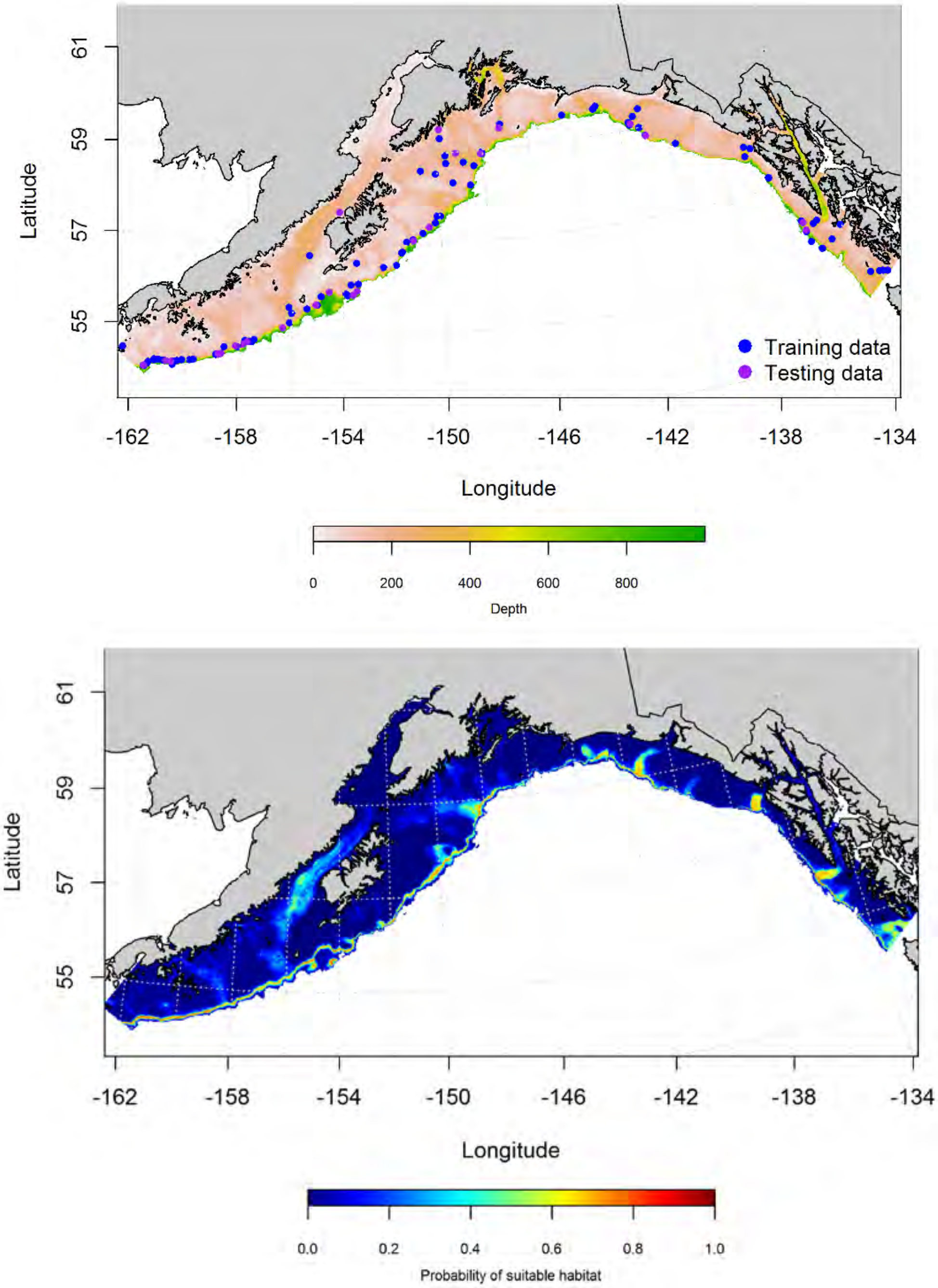


Figure 248. -- Locations of trawl survey catches of adult *S. melanostictus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. melanostictus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. melanostictus* in the Gulf of Alaska -- Commercial catch data indicate blackspotted rockfish largely occur along the shelf break and deeper portions of the outer-shelf. In the fall, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of blackspotted rockfish (relative importance = 51.2 and 27.5 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the test data was 0.76, indicating a poor model fit. The percent of observations correctly classified was 84% and 76% respectively, for the training and test data. In the fall, adult blackspotted rockfish habitat was predicted to occur along the shelf break and deeper portions of the middle- and outer-shelf (Figure 249).

In the winter, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of blackspotted rockfish (relative importance = 32.6 and 29.6 respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the test data was 0.84, indicating a good model fit. The percent of observations correctly classified was 88% and 84% respectively, for the training and test data. In the winter, adult blackspotted rockfish habitat was predicted to be more restricted, and to largely occur along the shelf break between Cape St. Elias and Kodiak Island. High suitability habits was also predicted to occur along the shelf break north of Spencer Gully in southeast Alaska (Figure 250).

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of blackspotted rockfish (relative importance = 74.2 and 17.7 respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the test data was 0.88, indicating a good model fit. The percent of observations correctly classified was 88% for both the training and testing data. In the spring, adult blackspotted rockfish habitat was predicted to occur along the shelf break and deeper portions of the middle- and outer-shelf in the GOA (Figure 251).

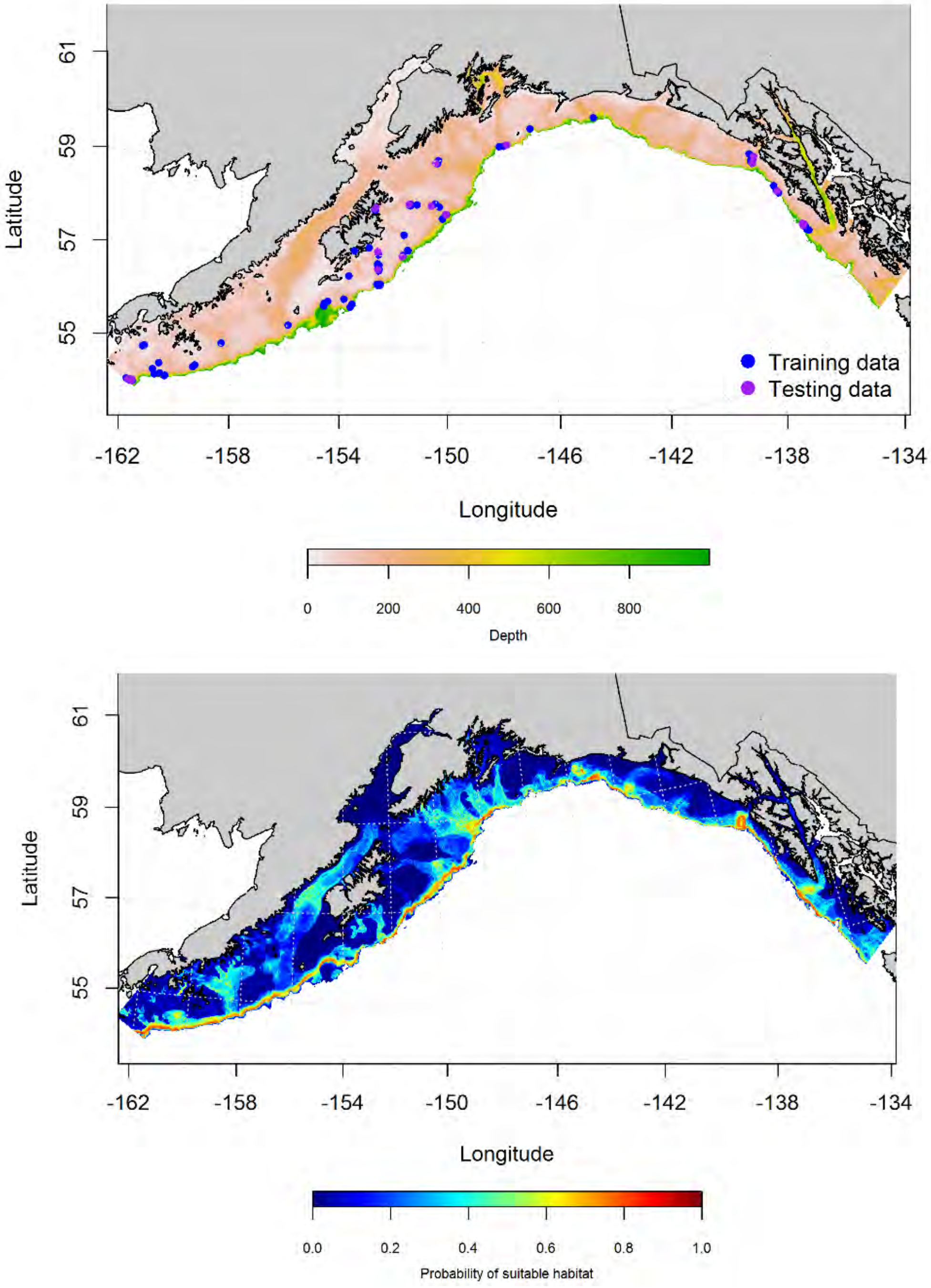


Figure 249. -- Locations of fall (September-November) commercial fisheries catches of *S. melanostictus* (top panel). Blue points were used to train the maximum entropy model predicting

the probability of the fall distribution of *S. melanostictus* commercial catches (bottom panel) and the purple points were used to test the model.

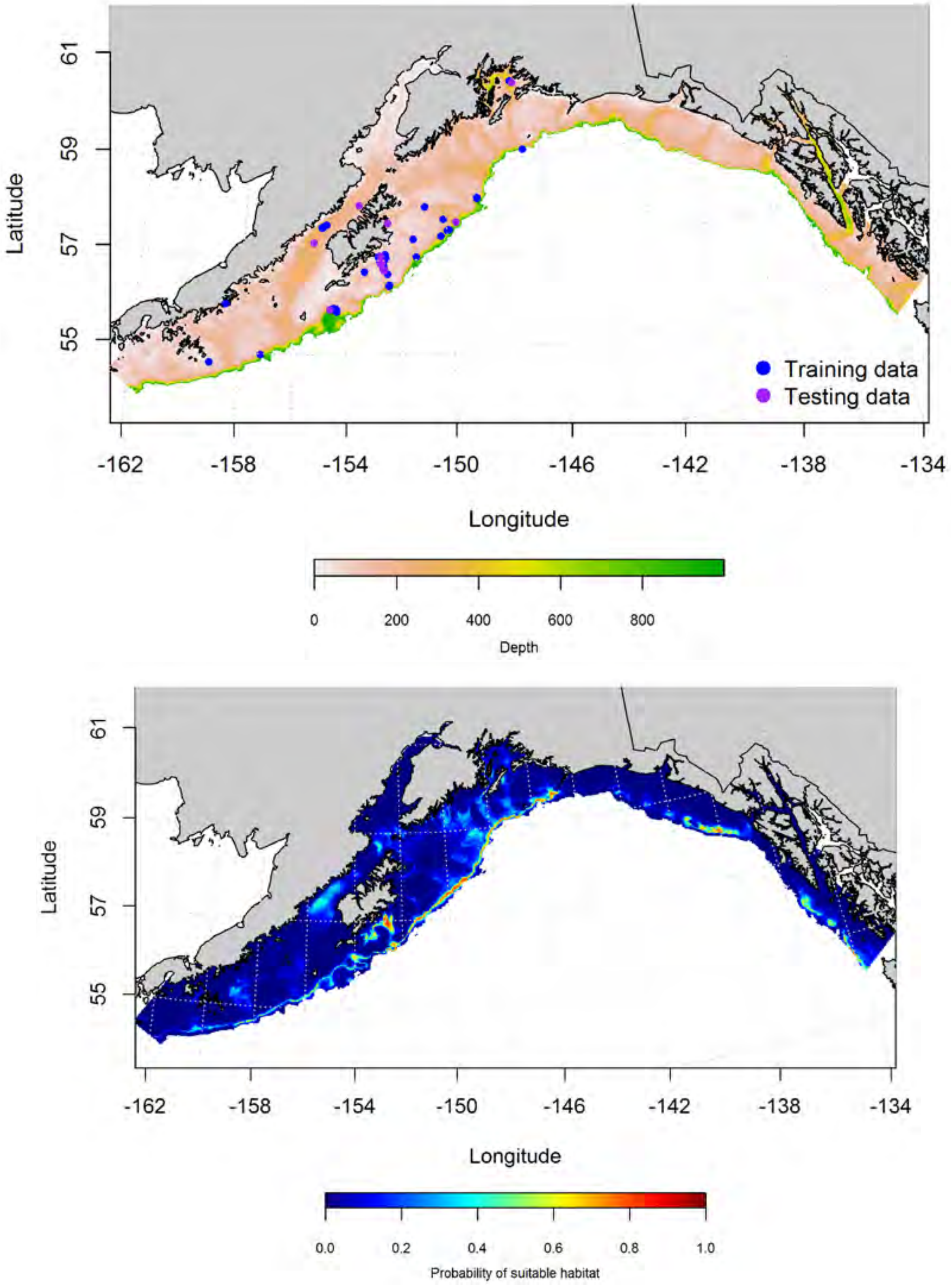


Figure 250. -- Locations of winter (December-February) commercial fisheries catches of *S. melanostictus* (top panel). Blue points were used to train the maximum entropy model predicting

the probability of the winter distribution of *S. melanostictus* commercial catches (bottom panel) and the purple points were used to test the model.

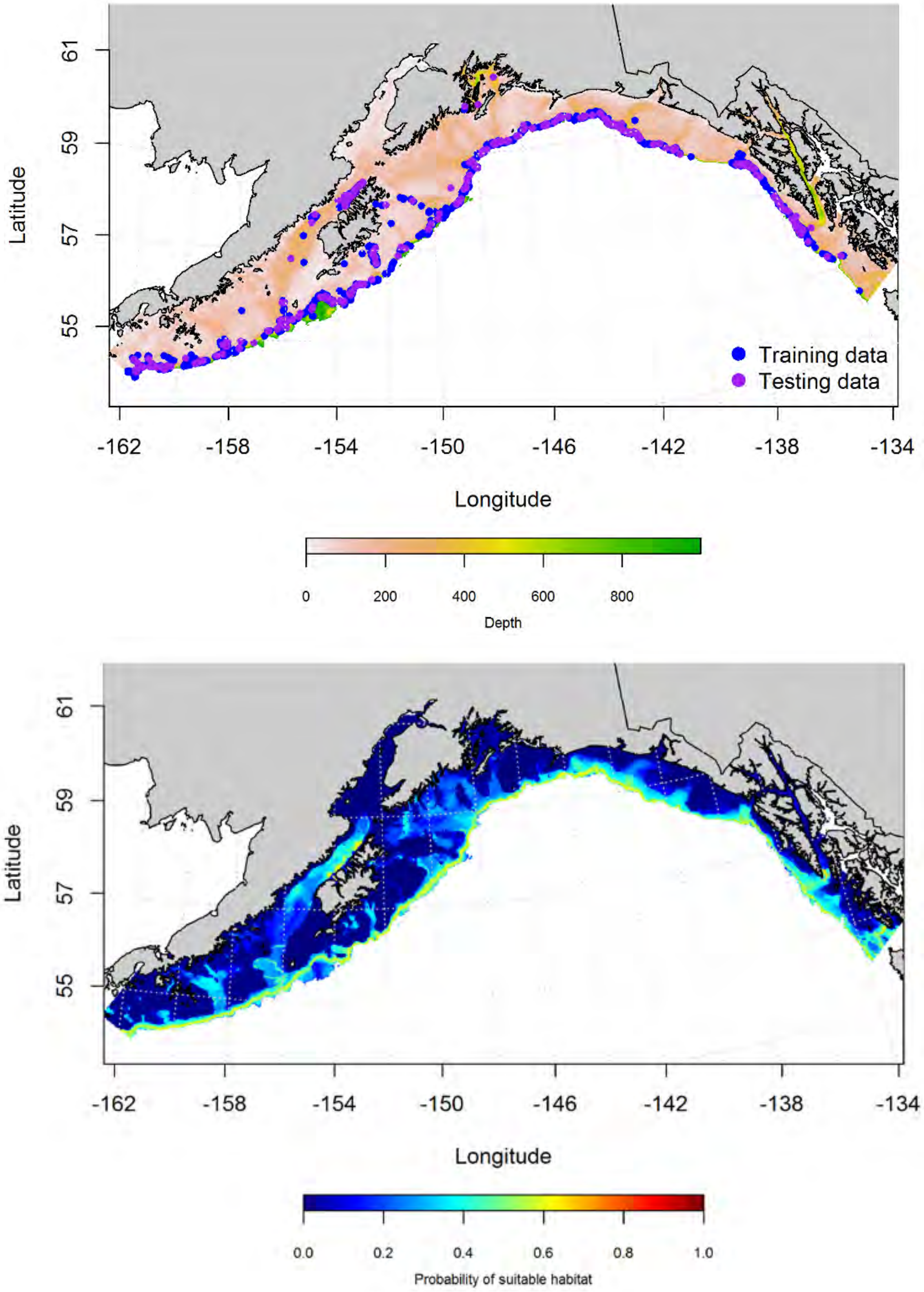


Figure 251. -- Locations of spring (March-May) commercial fisheries catches of *S. melanostictus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. melanostictus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. melanostictus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Blackspotted rockfish was predicted to predominantly occur off southeast Alaska. Because the early life history stages of most rockfish, including blackspotted rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile blackspotted rockfish, based on trawl survey observations, was predicted to occur along the deeper portions of the middle- outer-shelf throughout much of the GOA (Figure 252). EFH for adult blackspotted rockfish was predicted to be concentrated along the shelf break and deeper gullies and depressions in the outer-shelf across much of the GOA.

Spring and summer EFH for blackspotted rockfish, based on commercial fisheries data, was predicted to include most of the deeper portions of the middle- and outer-shelf shelf in the GOA. This included Amatuli Tough in the central gulf, as well as Yakutat Valley, Spencer Gully, and off Cape Ommaney in southeast Alaska (Figure 253). During the winter, EFH for blackspotted rockfish was predicted to largely occur along the shelf break between Cape St. Elias and Kodiak Island.

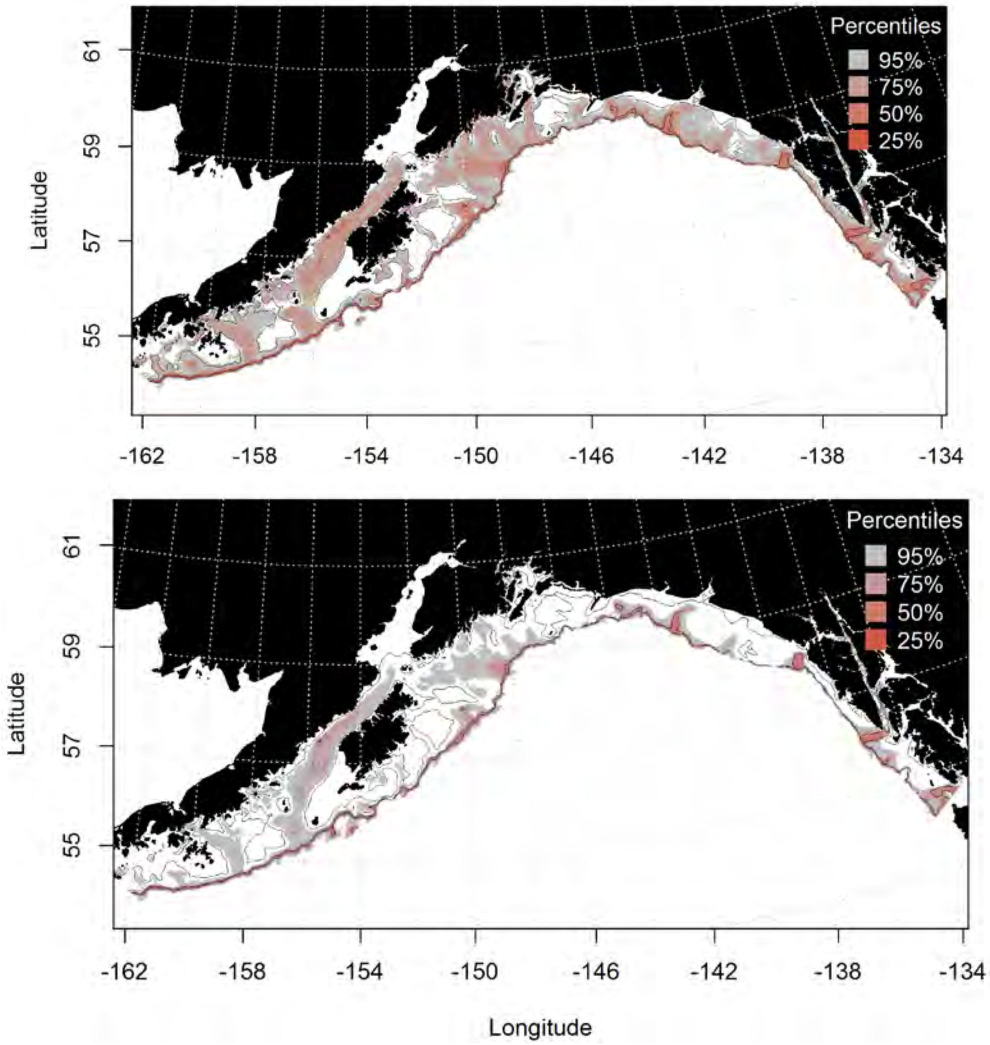


Figure 252. -- Predicted summer essential fish habitat for *S. melanostictus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

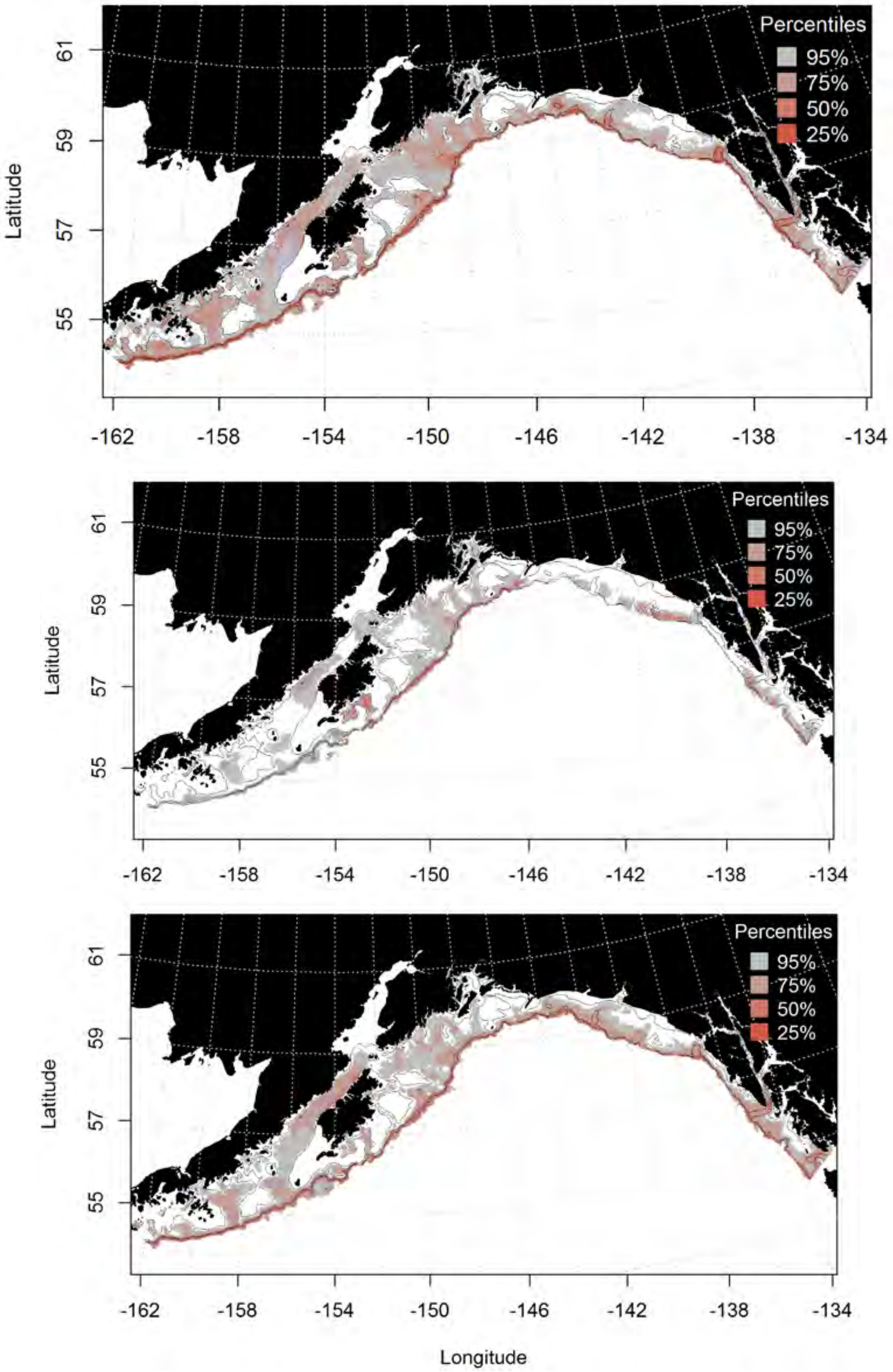


Figure 253. -- Essential fish habitat predicted for *S. melanostictus* during fall (top panel), winter (middle panel) and fall (bottom panel) from commercial catches.

canary rockfish (*Sebastes pinniger*)

Canary rockfish largly occur off southeast Alaska. They are typically found in schools around rocky reefs and hard bottom habitats, at between 50-250 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. pinniger* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile canary rockfish largely occur off southeast Alaska. There were only nineteen observations of juvenile canary rockfish. Most occurred in nearshore waters south of Chichagof Island in southeast Alaska (Figure 254). There were thirty-six observations of adult canary rockfish, and their distribution was approximately the same as the juveniles. There were not a sufficient number of observations to model juvenile or adult canary rockfish distributions.

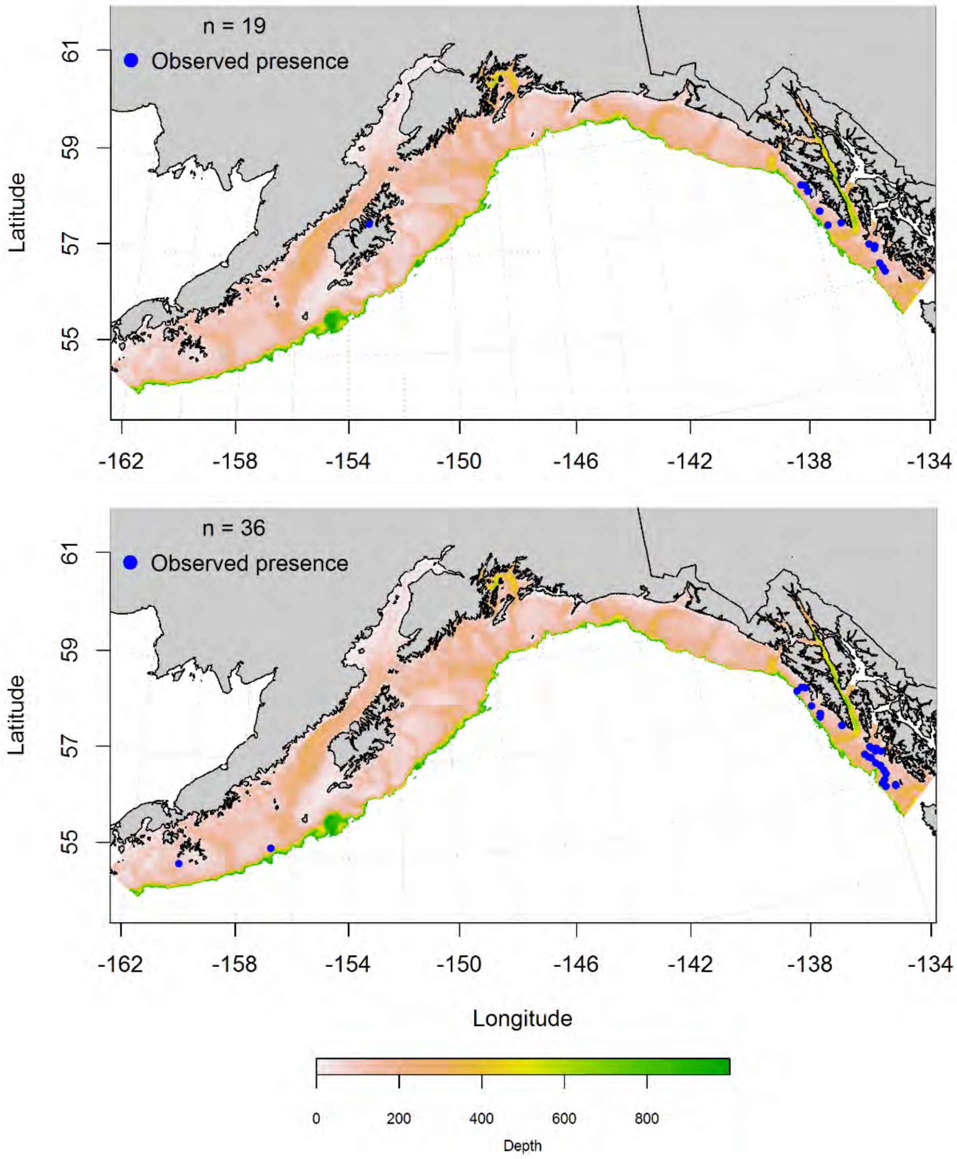


Figure 254. -- Locations of catches of juvenile and adult *S. pinniger* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. pinniger* in the Gulf of Alaska -- There were no observations of juvenile or adult canary rockfish from commercial fisheries data.

Gulf of Alaska *S. pinniger* Essential Fish Habitat Maps and Conclusions -- Canary rockfish essential fish habitat could not be predicted for any life history stages.

northern rockfish (*Sebastes polyspinis*)

Northern rockfish are one of the most abundant rockfish species found in the Gulf of Alaska. They primarily occur in the western and central Gulf of Alaska, at less than 200 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. polyspinis* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile northern rockfish largely occur in the central and western Gulf of Alaska (Figure 255). The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 53.5 and 17.0 respectively). The AUC for the training data was 0.88, indicating a good model fit. The AUC for the testing data was 0.77, indicating a fair model fit. The percent of correctly classified observations was 80% for the training data and 77% for the test data. Summer habitat for juvenile northern rockfish habitat was predicted to include much of the middle- and outer-shelf in the central and western gulf High suitability habitats were predicted to occur along most of the offshore banks between Cape St. Elias and the Shumagin Islands; including Wessels Reef in the central gulf, Albatross and Portlock Banks off Kodiak Island, and Semidi Bank on the Alaska Peninsula.

Summer bottom trawl survey data indicates that adult northern rockfish largely occur in the western portion of the GOA (Figure 256).

The variables determined to be the best predictors of the occurrence of adult northern rockfish were latitude and longitude, tidal current, and depth. The AUC for the training data was 0.86, indicating a good model fit. The AUC for the testing data was 0.83, indicating a good model fit. The optimum threshold was only 0.08. The percent of observations correctly classified was 79% for the training data set, and 81% for the test data set. The most important variables predicting the abundance of adult northern rockfish were coral presence and depth. The best-fitting GAM explained 13% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult northern rockfish were predicted to occur along the outer-shelf west of Kodiak Island, and along the middle-shelf west of the Semidi Islands. They were predicated to be abundance across most of this area including, particularly along the middle-shelf west of the Semidi Islands (Figure 257). Portions of upper Cook Inlet were also predicted to have high abundances of adult northern rockfish; however, these prediction were not supported by any observations.

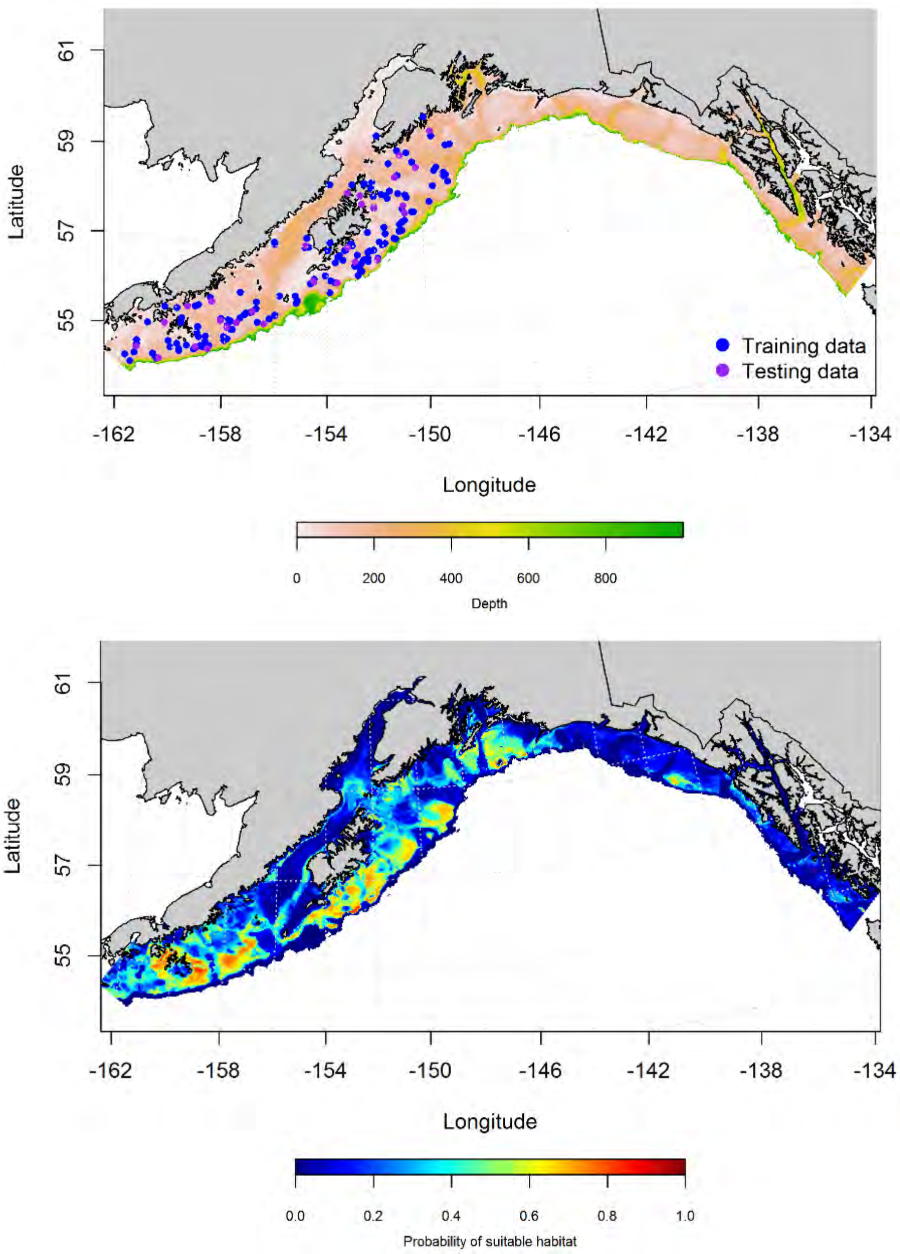


Figure 255. -- Locations of trawl survey catches of juvenile *S. polyspinis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. polyspinis* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Need points of Adults

Figure 256. -- Locations of catches of adult *S. polyspinis* from summer bottom trawl surveys of the Gulf of Alaska.

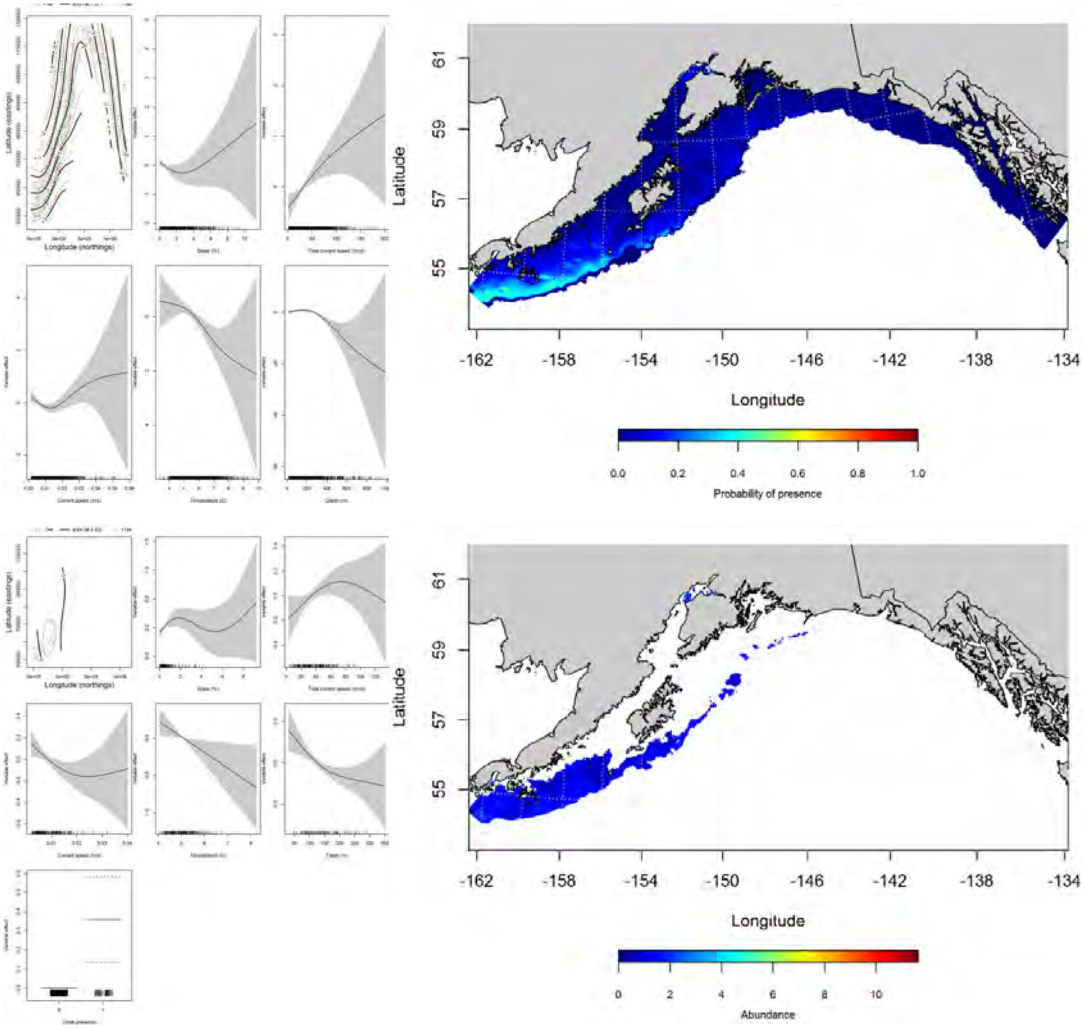
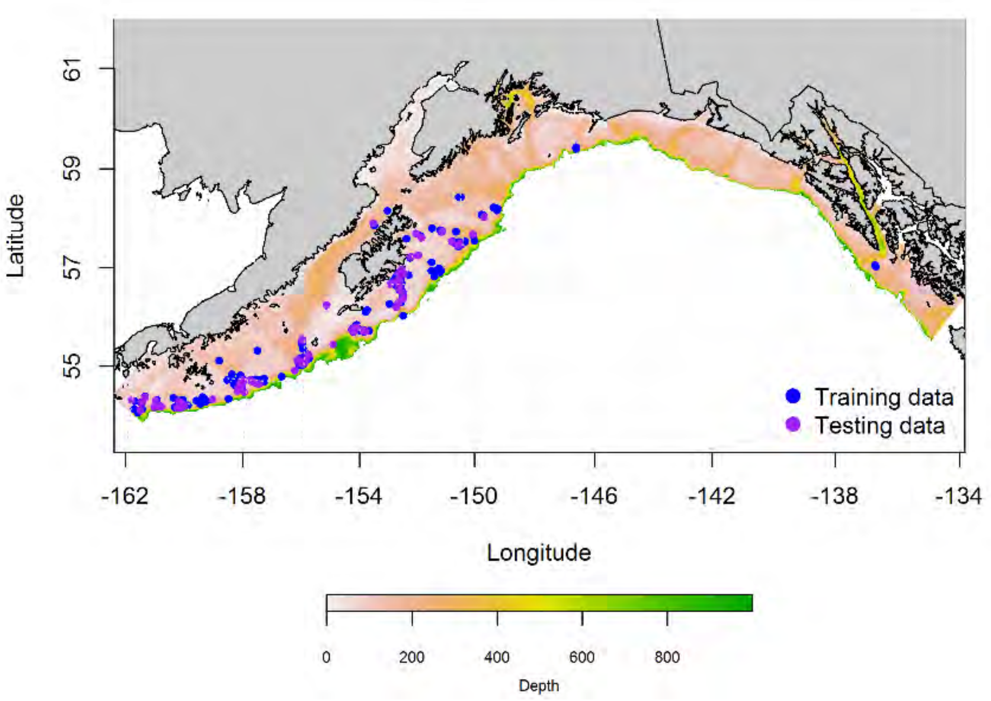


Figure 257. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. polyspinis* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska

Seasonal distribution of commercial fisheries catches of adult *S. polyspinis* in the Gulf of Alaska -- Commercial catch data of northern rockfish were only available from during the spring, and they indicate that northern rockfish largely occur along the western portion of the Gulf of Alaska. *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of northern rockfish (relative importance = 31.1 and 23.1 respectively). The AUC was 0.94 for the training data, indicating an excellent model fit. The AUC for the test data was 0.79, indicating a fair model fit. The percent of observations correctly classified was 85% and 79% respectively, for the training and test data. Adult northern rockfish were predicted to largely occur along the middle- and outer-shelf in the central and western gulf, most notably in Shelikof and Shumagin Gullies off the Alaskan Peninsula (Figure 258).



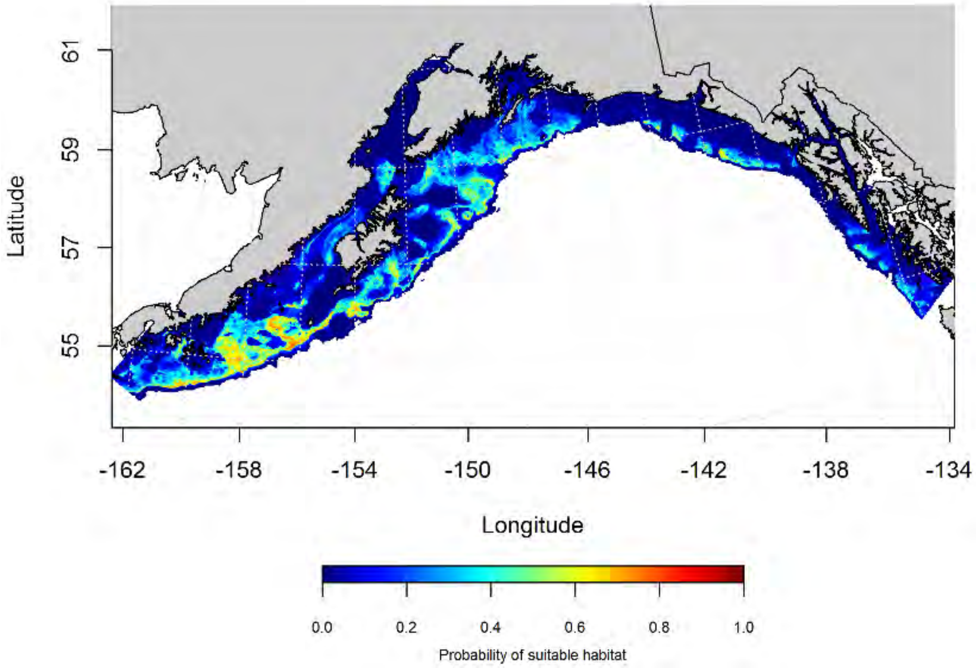


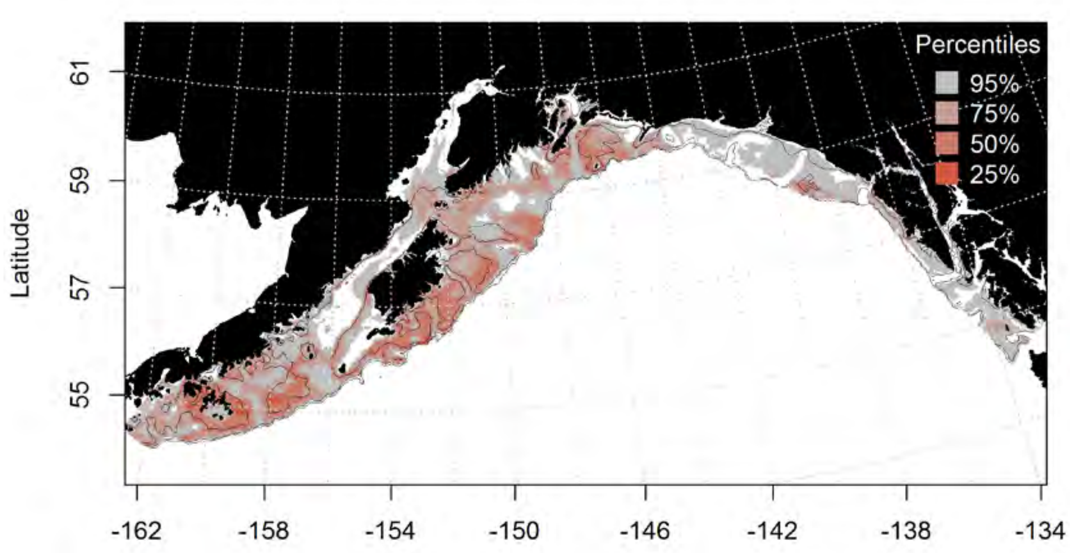
Figure 258. -- Locations of spring (March-May) commercial fisheries catches of *S. polyspinis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. polyspinis* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. polyspinis* Essential Fish Habitat Maps and Conclusions --

Essential fish habitat for Northern rockfish was predicted to occur predominantly off southeast Alaska. Because the early life history stages of most rockfish, including northern rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile northern rockfish, based on trawl survey observations, was predicted to include most of the western GOA (Figure 259). EFH for adult northern rockfish was predicted to primarily occur along the outer-shelf west of Kodiak Island, and the middle-shelf west of the Semidi Islands. EFH for adult northern rockfish was also predicted to occur in upper Cook Inlet; however, these prediction were not supported by any observations.

Spring EFH for northern rockfish, based on commercial fisheries data, was predicted include much of the middle- and outer-shelf shelf in the central and western GOA, including the edge of Portlock and Albatross Banks off Kodiak Island, and Shellikof and Shumagin Gully on the Alaska Peninsula (Figure 260). Portions of the eastern gulf were also predicted to be EFH; however, these predictions were not supported by any observations.



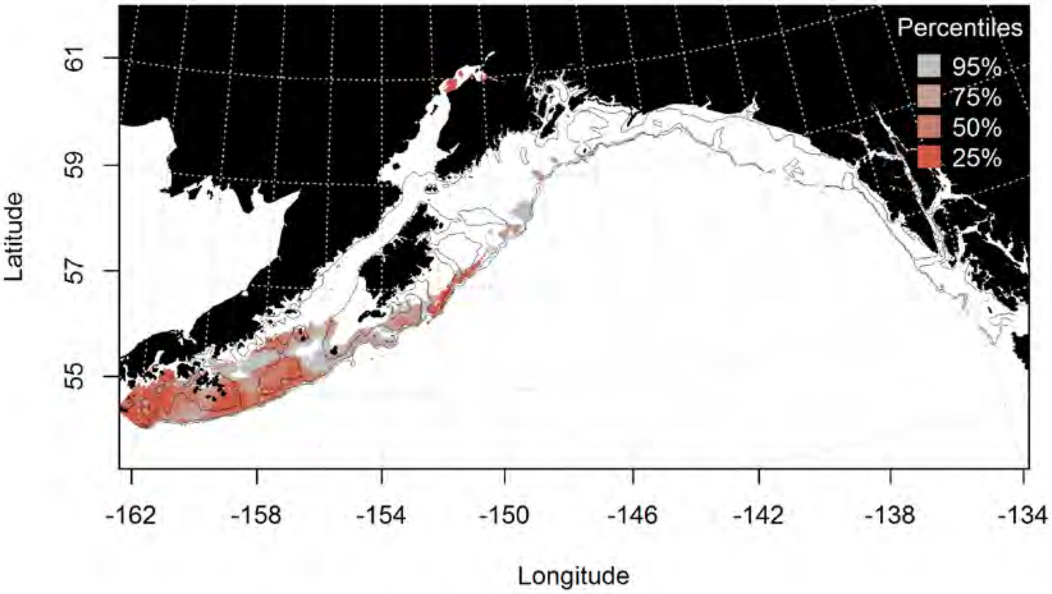


Figure 259. -- Predicted summer essential fish habitat for *S. polyspinis* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

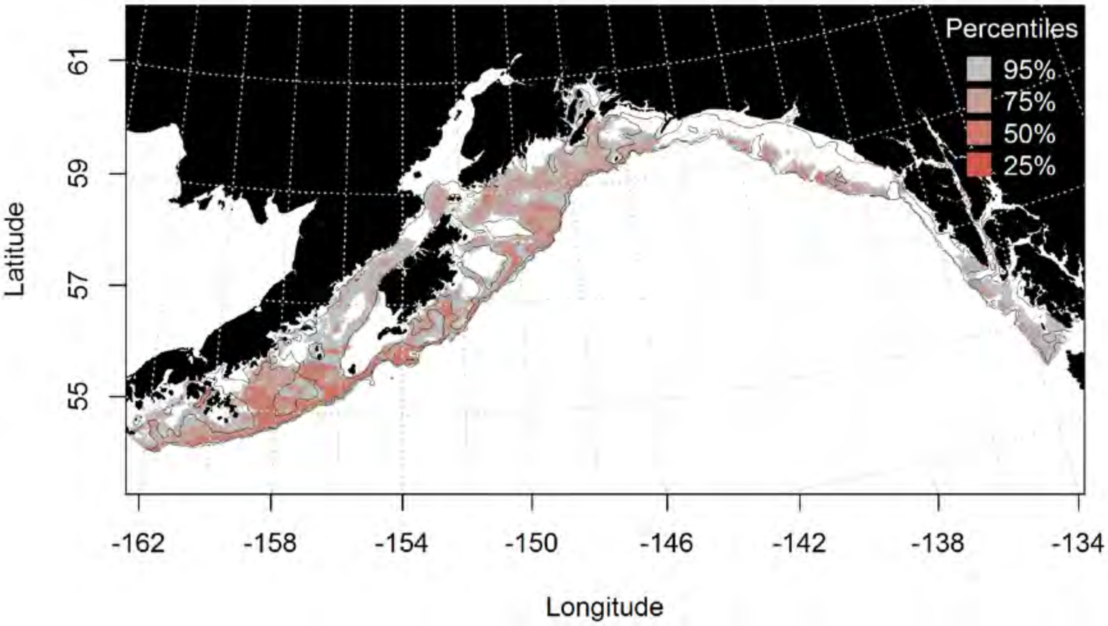


Figure 260. -- Essential fish habitat predicted for *S. polyspinis* during spring from commercial catches.

redstriped rockfish (*Sebastes proriger*)

Redstripe rockfish occur in southeast Alaska. They typically are found in schools over rocky bottoms, in from 100-300 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. proriger* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile redstriped rockfish largely occur on deeper portions of the shelf, particularly off southeast Alaska. The best-fitting *MaxEnt* model indicated that depth and ocean color were the most important variables predicting habitat suitability (relative importance 40.5 and 27.9 respectively). The AUC for the training data was 0.91, indicating an excellent model fit. The AUC for the testing data was 0.86, indicating a good model fit. The percent of correctly classified observations was 81% for the training data and 86% for the test data. Juvenile redstriped rockfish habitat were predicted to occur across much of of the middle- and outer-shelf, particularly in southeast Alaska south of Sitka, as well as along the outer-shelf in the central gulf (Figure 261). Portions of the Shelikof Strait, Barnabus Gully, and the entrance to Prince William Sound were also predicted to be high suitability habitat for juvenile northern rockfish; however, these predictions were not supported by any observations.

Data from the summer bottom trawl survey also indicates adult redstriped rockfish have a similar distribution as juveniles of the species. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 58.5 and 23.3 respectively). The AUC for the training data was 0.90, indicating an excellent model fit. The AUC for the testing data was 0.88, indicating a good model fit. The percent of correctly classified observations was 80% for the training data and 88% for the test data. Adult redstriped rockfish were predicted to occur across much of the outer-shelf, particularly south of Sitka (Figure 262). High suitability habitats were also predicted along the outer-shelf in the central and eastern gulf. Potions of Shelikof Strait and the the entrance to Prince William Sound were also predicted to be high suitability habitat for adult northern rockfish; however, these predictions were not supported by any observations.

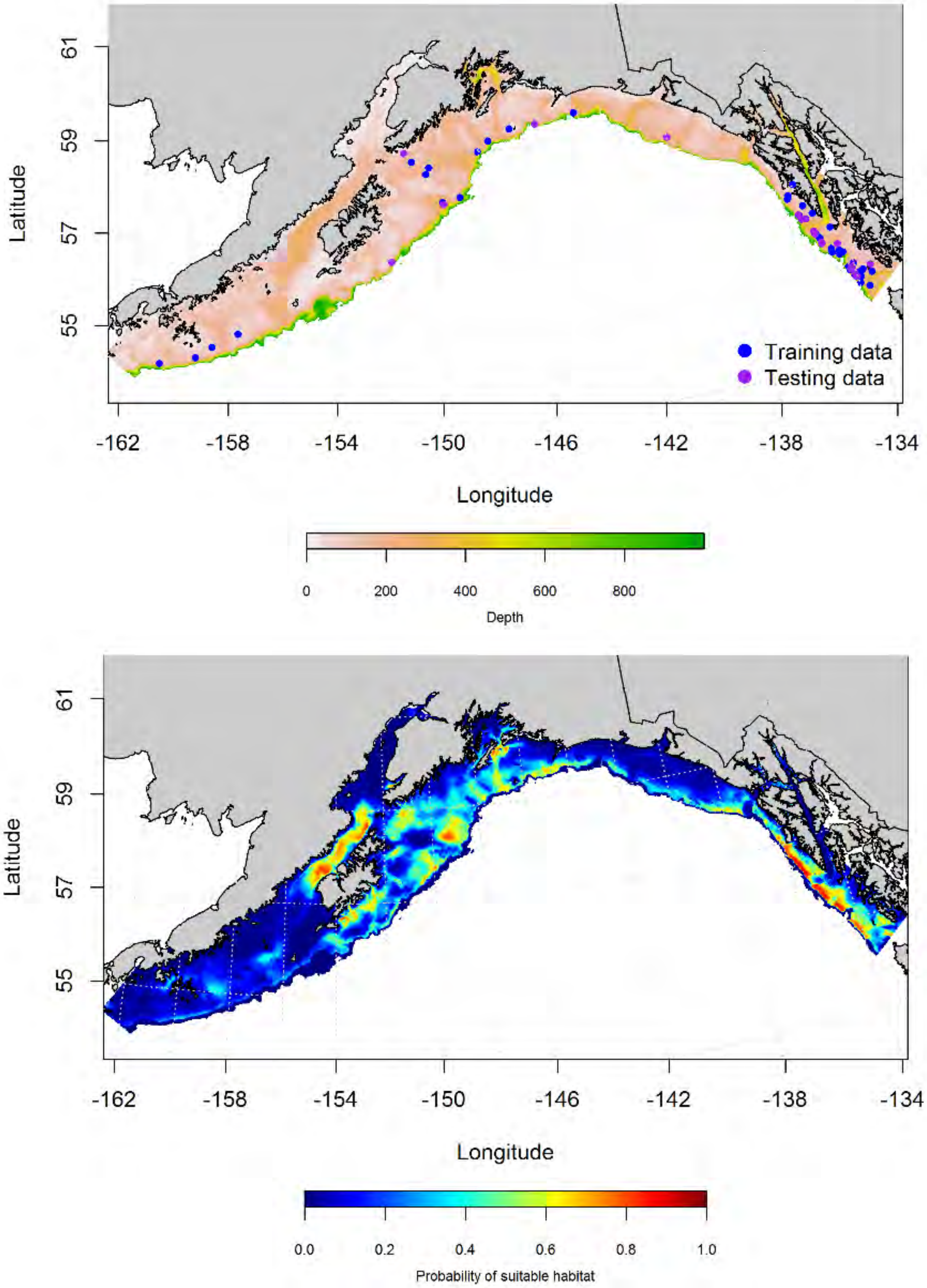


Figure 261. -- Locations of trawl survey catches of juvenile *S. proriger* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. proriger* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

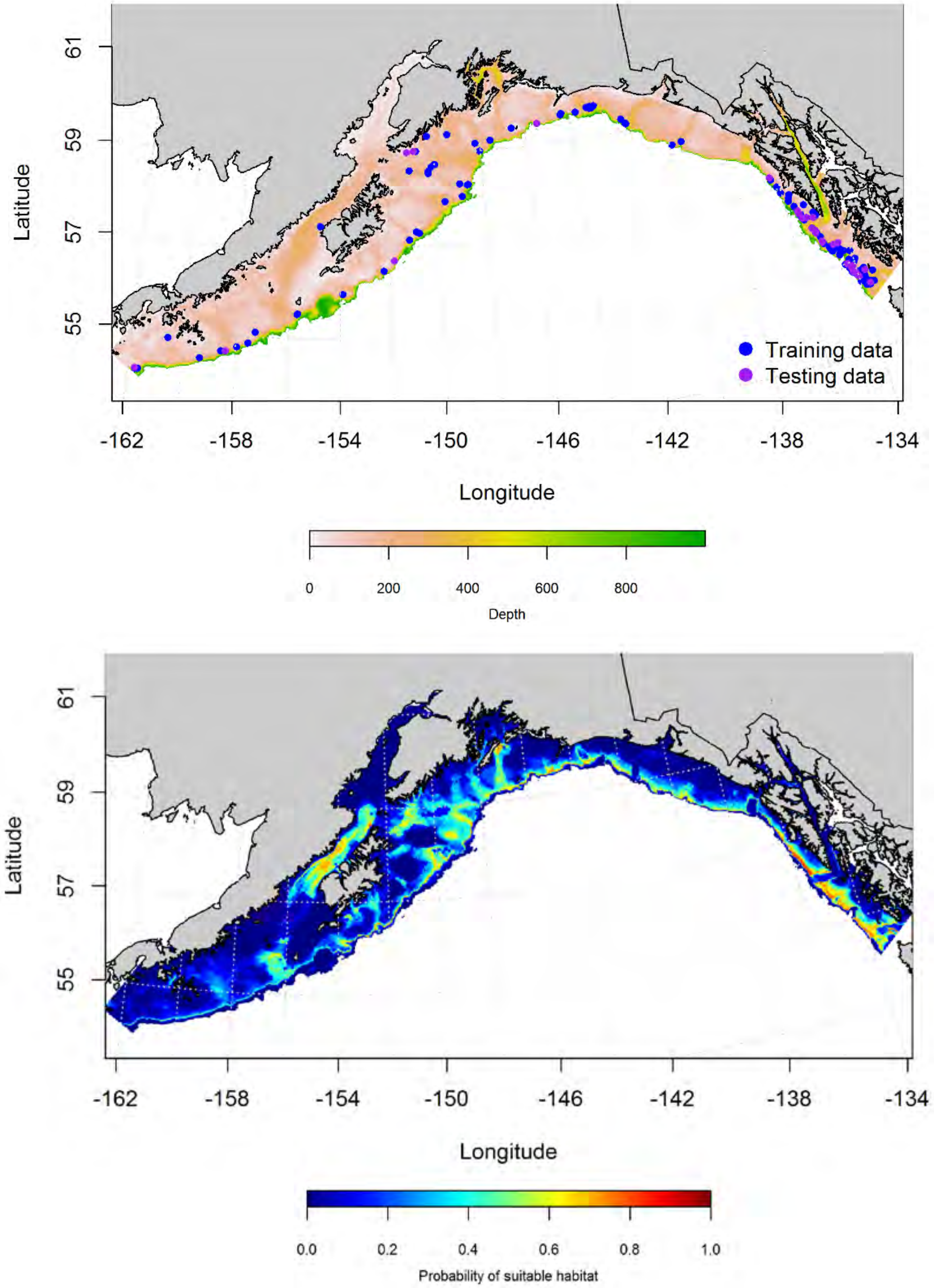


Figure 262. -- Locations of trawl survey catches of adult *S. proriger* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. proriger* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. proriger* in the Gulf of Alaska -- There were no observations of juvenile or adult redstriped rockfish from commercial fisheries data.

Gulf of Alaska *S. proriger* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for redstriped rockfish was predicted to predominantly occur off southeast Alaska. Because the early life history stages of most rockfish, including redstriped rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile redstriped rockfish, based on trawl survey observations, was predicted to occur over most of the deeper portions of the central and eastern GOA, particularly off southeast Alaska (Figure 263). Portions of Shelikof Strait and the entrance to Prince William Sound were also predicted to be EFH for juvenile redstriped rockfish; however, these prediction were not supported by any observations. EFH for adult redstriped rockfish was predicted to occur along the outer-shelf in central and eastern gulf. As with the juveniles portions of Shelikof Strait were also predicted to be EFH for adult redstriped rockfish; however, these prediction were not supported by any observations. Spring EFH for redstriped rockfish, based on commercial fisheries data, was also predicted to include much of the deeper portions of middle- and outer-shelf shelf in the central and western GOA. Portions Shelikof Strait and the entrance to Prince William Sound were also predicted to be EFH for adult redstriped rockfish; however, these predictions were not supported by any observations.

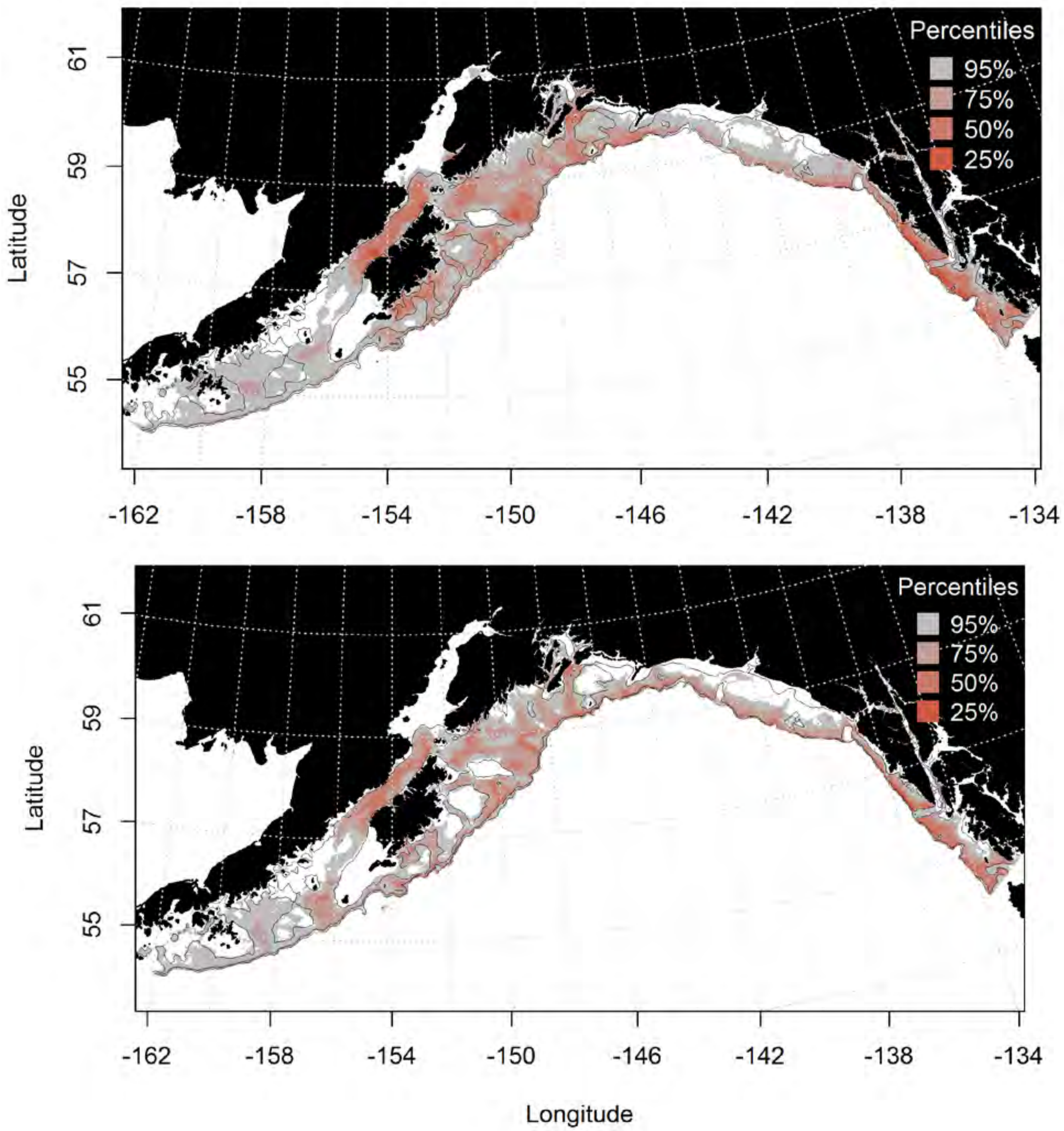


Figure 263. -- Predicted summer essential fish habitat for *S. proriger* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

yelloweye rockfish (*Sebastes ruberrimus*)

Yelloweye rockfish are infrequently caught throughout much of the Gulf of Alaska. They typically occur around rocky reefs and boulder fields, at between 50-400 m depth (Mecklenburg et al. 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. ruberrimus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data adult yelloweye rockfish occur across much of the deeper portions of the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 71.0 and 16.5 respectively). The AUC for the training data was 0.89, indicating a good model fit. The AUC for the testing data was 0.91, indicating an excellent model fit. The percent of correctly classified observations was 86% for the training data and 91% for the test data. Summer habitat for juvenile yelloweye rockfish habitat was predicted to occur across much of deeper portions of the middle- and outer-shelf, particularly along the shelf break in the vicinity of Wessels Reefs, Amatuli Trough, and the entrance to Cook Inlet in the central gulf and around the Shumagin Islands and Shumagin Gully in the western gulf (Figure 264). Barnabus Gully off Kodiak Island was also predicted to be high suitability habitat for juvenile yelloweye rockfish; however, these prediction were not supported by any observations.

Summer bottom trawl survey data indicate adult yelloweye rockfish occur throughout much of the middle- and outer-shelf in the GOA. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 61.3 and 10.4 respectively). The AUC for the training data was 0.88, indicating a good model fit. The AUC for the testing data was 0.80, indicating a good model fit. The percent of correctly classified observations was 81% for the training data and 80% for the test data. Summer habitat for adult yelloweye rockfish habitat was predicted to occur across much of the middle- and outer-shelf, particularly along the shelf break in the vicinity of Wessels Reefs and Amatuli Trough in the central gulf, and south of Sitka in southeast Alaska (Figure 265). Portions of Shelikof Strait, Barnabus Gully, and the entrance to Prince William Sound were also predicted to be high suitability habitat for adult yelloweye rockfish; however, these predictions were not supported by any observations.

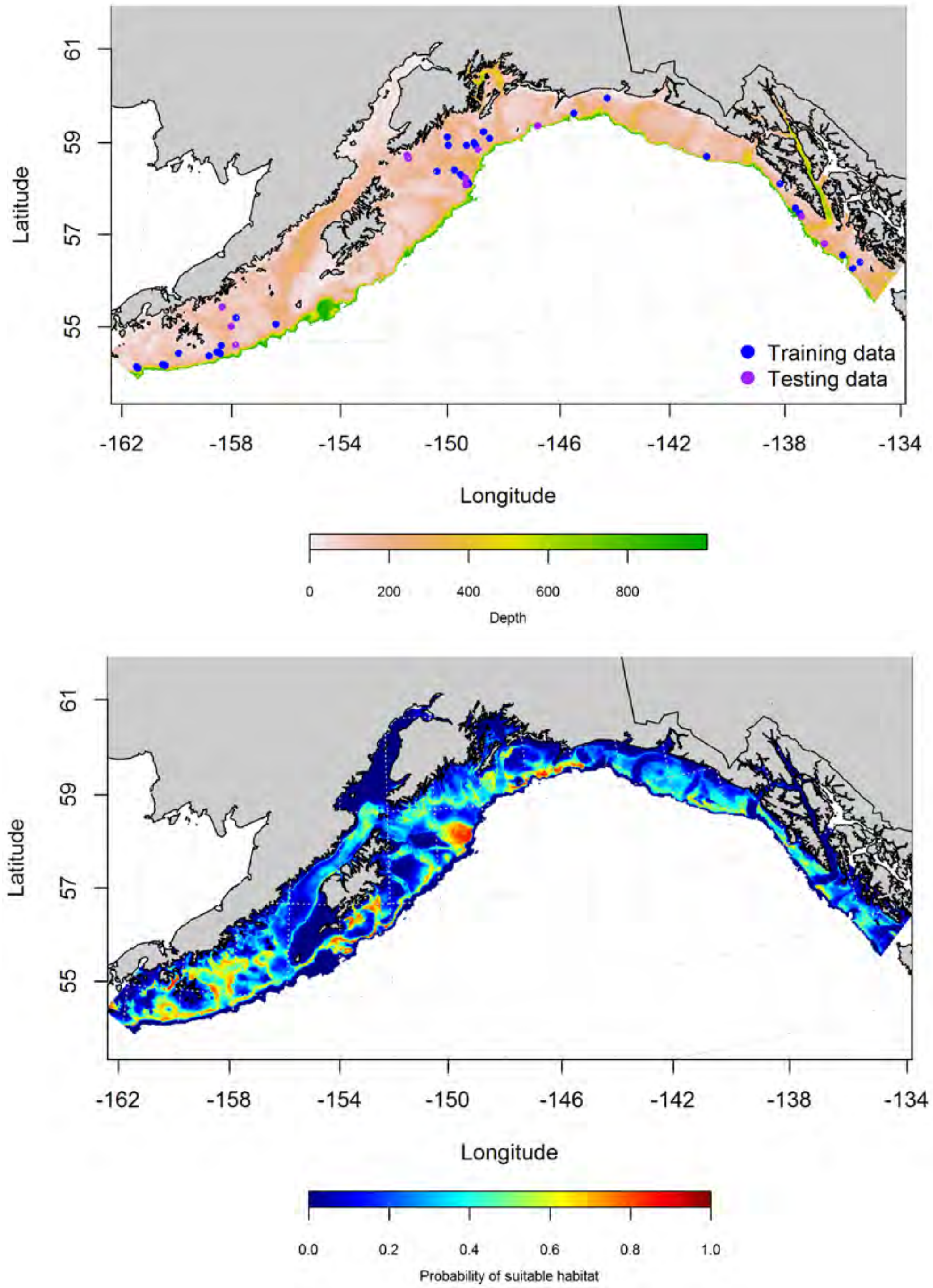


Figure 264. -- Locations of catches of juvenile *S. ruberrimus* during the AFSC summer bottom trawl survey (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. ruberrimus* (bottom panel) and the purple points were used to test the model.

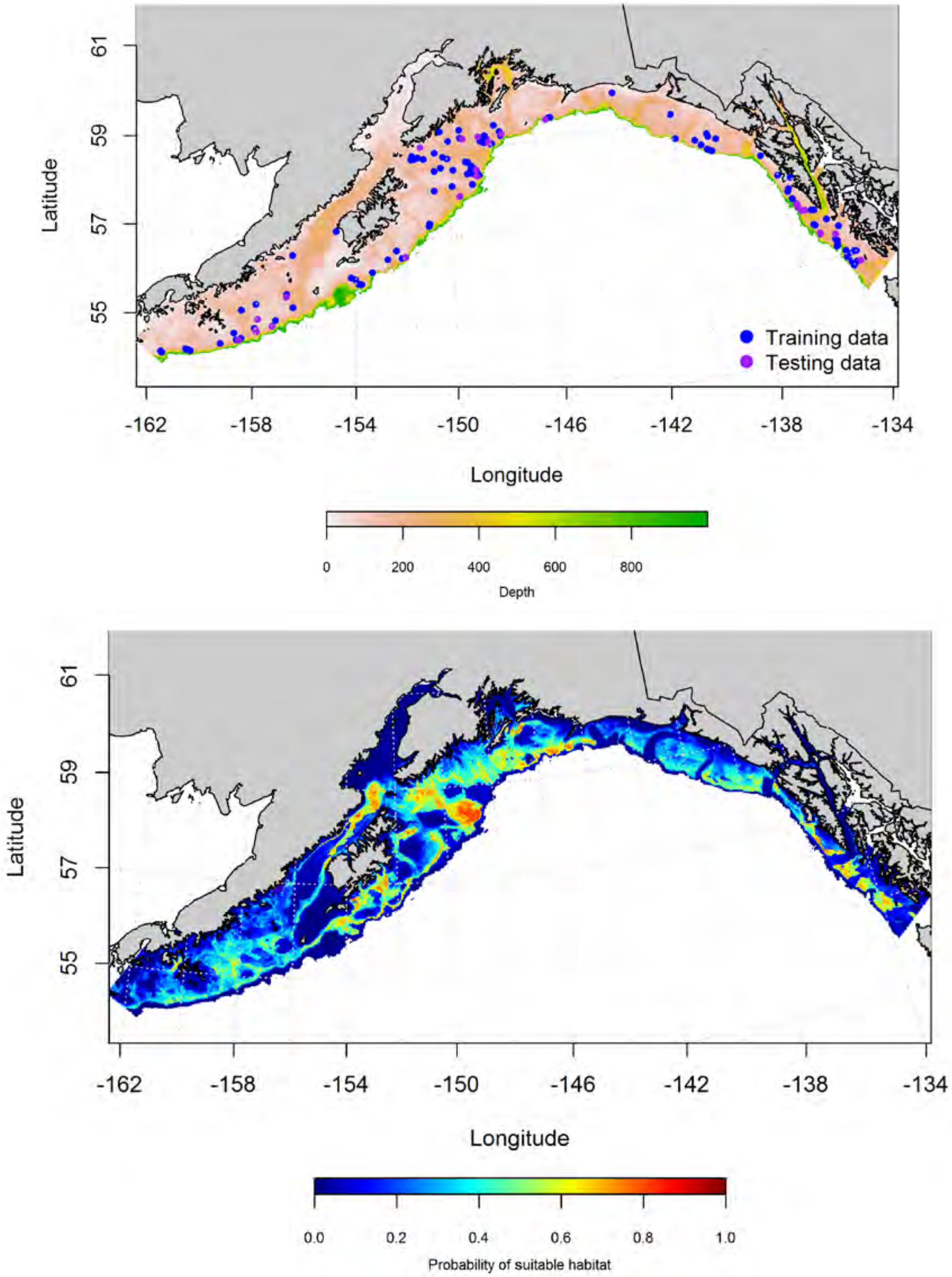


Figure 265. -- Locations of catches of adult *S. ruberrimus* during the AFSC summer bottom trawl survey (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *S. ruberrimus* (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. ruberrimus* in the Gulf of Alaska -- Commercial catch data indicate yelloweye rockfish largely occur along the outer-shelf and deeper portions of the middle-shelf in the western Gulf of Alaska. In the fall, *MaxEnt* modeling determined that bottom temperature and ocean color were the most important variables predicting the distribution of adult yelloweye rockfish (relative importance = 39.5 and 24.9 respectively). The AUC was 0.98 for the training data, indicating an excellent model fit. The AUC for the test data was 0.96, indicating an excellent model fit. The percent of observations correctly classified was 93% and 96% respectively, for the training and test data. In the fall, adult yelloweye rockfish were predicted to occur along the shelf break and deeper portions of the middle- and outer-shelf west of the Semidi Islands (Figure 266).

In the spring, *MaxEnt* modeling determined that bottom temperature and ocean color were the most important variables determining the distribution of adult yelloweye rockfish (relative importance = 39.5 and 24.9 respectively). The AUC was 0.98 for the training data, indicating an excellent model fit. The AUC for the test data was 0.96, indicating an excellent model fit. The percent of observations correctly classified was 93% for the training and 96% for the testing data. In the spring, adult yelloweye rockfish habitat was predicted to primarily occur on the middle- and outer-shelf in the western gulf, around the Semidi and Shumagin Islands (Figure 267). In high suitability habitat was predicted to occur along the shelf break in much of the western and central gulf.

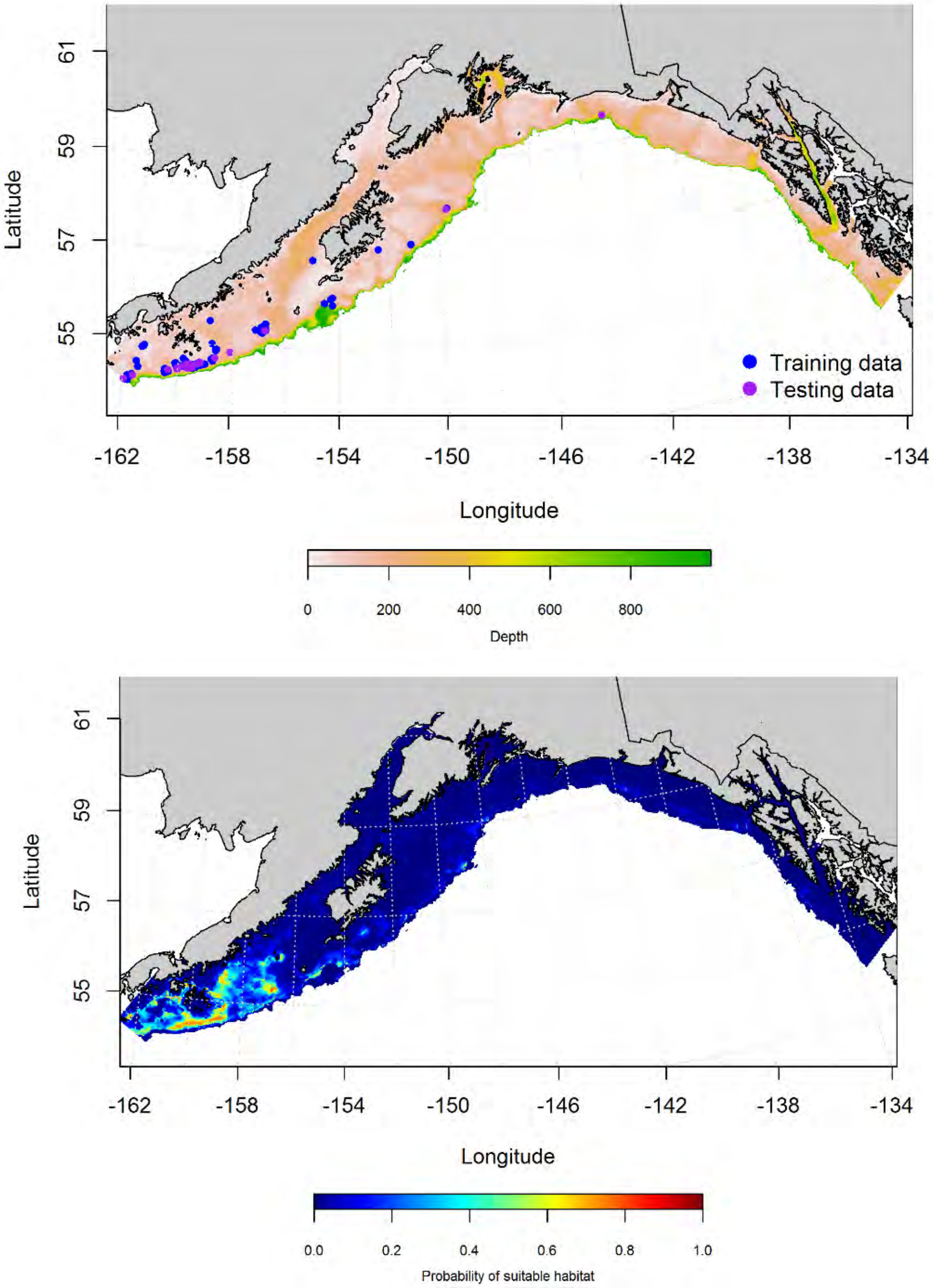


Figure 266. -- Locations of fall (September-November) commercial fisheries catches of *S. ruberrimus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *S. ruberrimus* commercial catches (bottom panel) and the purple points were used to test the model.

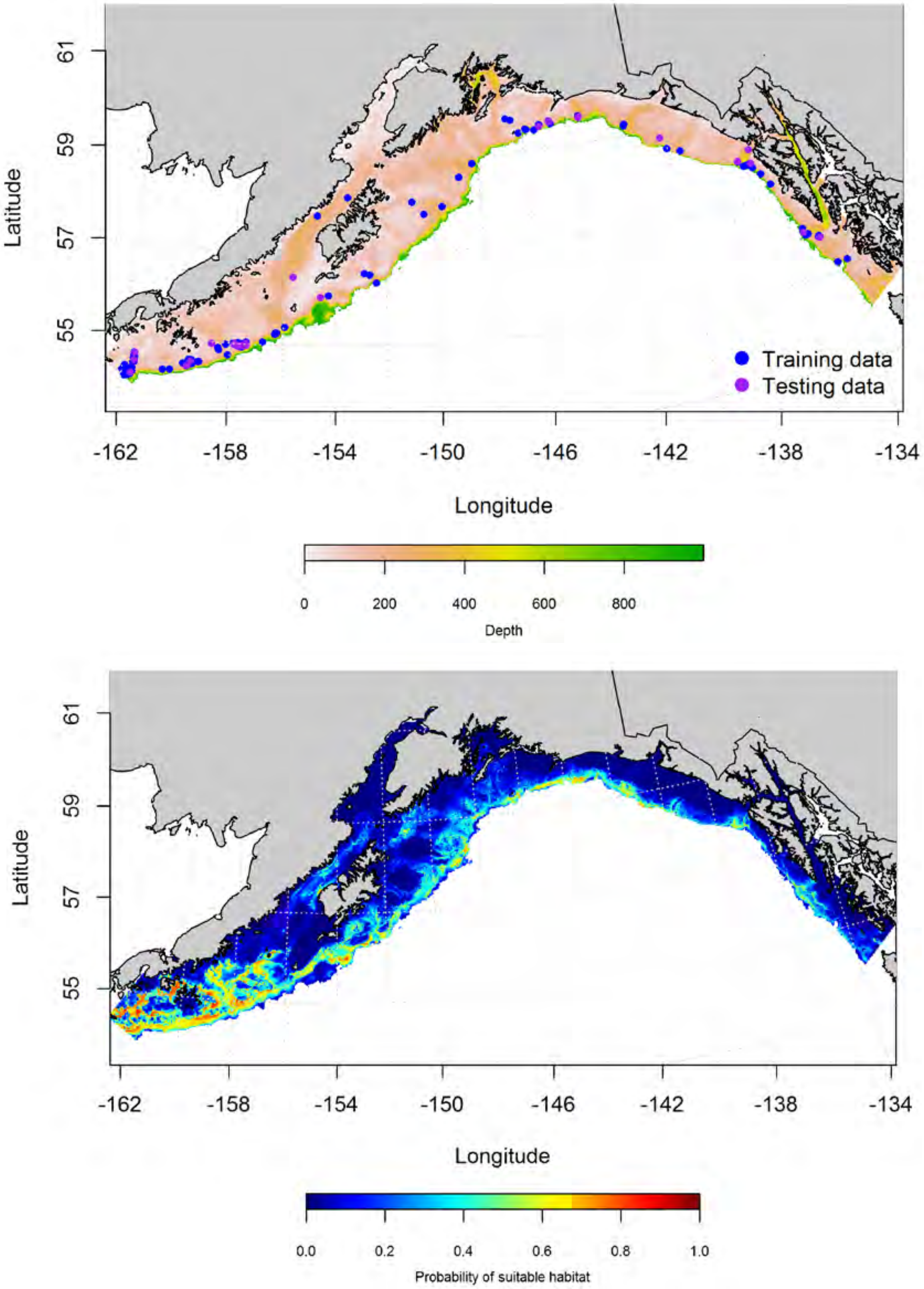


Figure 267. -- Locations of spring (March-May) commercial fisheries catches of *S. ruberrimus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. ruberrimus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. ruberrimus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for yelloweye rockfish was predicted to included large portions of the middle- and outer-shelf in the GOA . Because the early life history stages of most rockfish, including yelloweye rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile yelloweye rockfish, based on trawl survey observations, was predicted to occur in most of the deeper portions of the GOA. In particular high suitability habitat was predicted to occur in the vicinity of Wessels Reefs and Amatuli Trough in the central gulf, and the around the Shumagin Islands and Shumagin Gully in the western gulf (Figure 268). Barnabus Gully off Kodiak Island was also predicted to be EFH for juvenile yelloweye rockfish; however, these prediction were not supported by any observations. EFH for adult yelloweye rockfish was predicted to occur on much of the middle- and outer-shelf. As with the juvenile, portions of the Shelikof Strait and Barnabus Gully were predicted to be high suitability habitat for adult yelloweye rockfish; however, these predictions were not supported by any observations.

Fall EFH for yelloweye rockfish, based on commercial fisheries data, was predicted include portions deeper portions of the middle- and outer-shelf west of the Semidi Islands (Figure 269). Spring EFH for yelloweye rockfish, based on commercial fisheries data, was predicted include much of the deeper portions of the outer-shelf throughout the GOA, as well as portions of the middle-shelf west of the Semidi Islands.

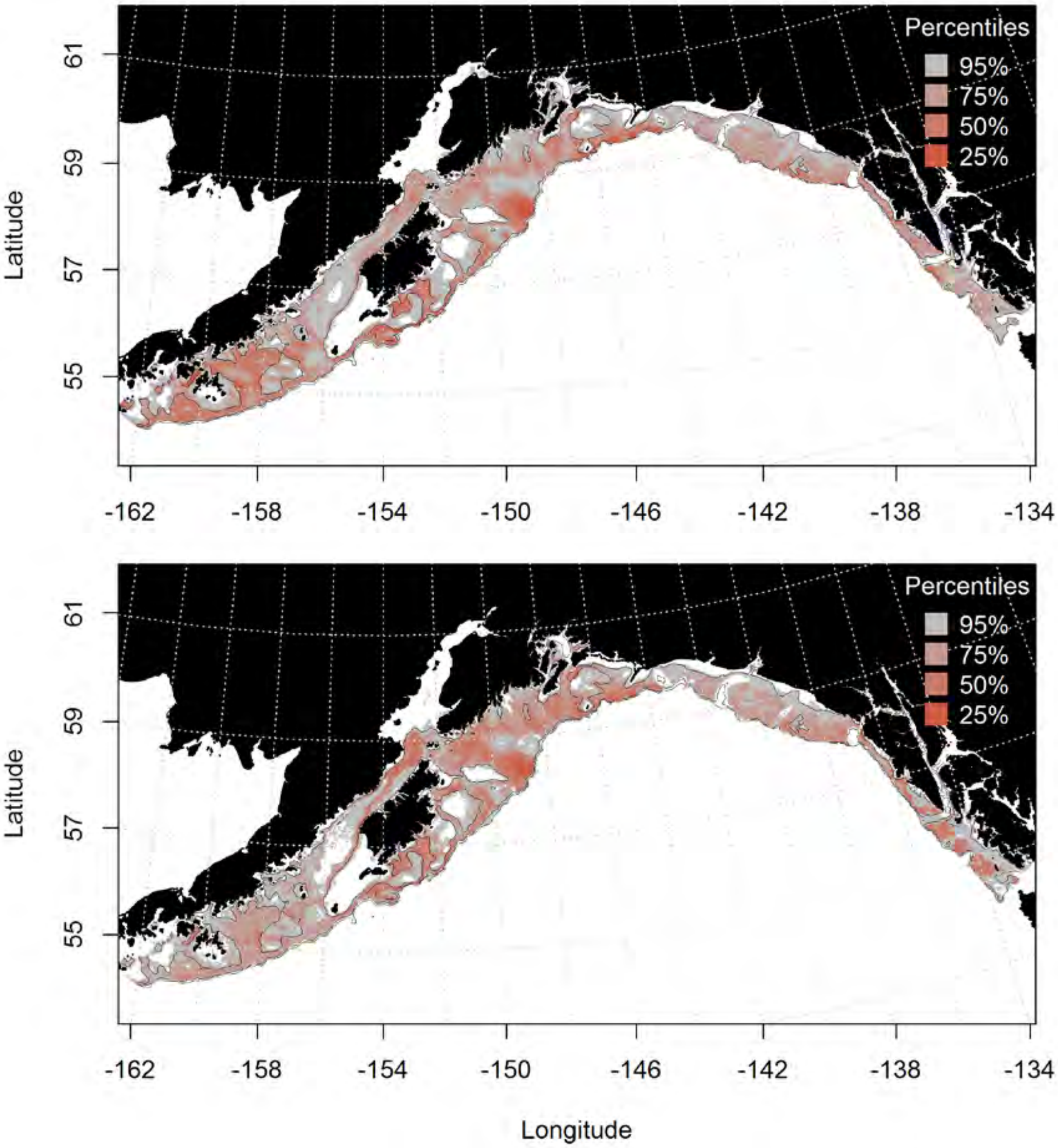


Figure 268. -- Predicted summer essential fish habitat for *S. ruberrimus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

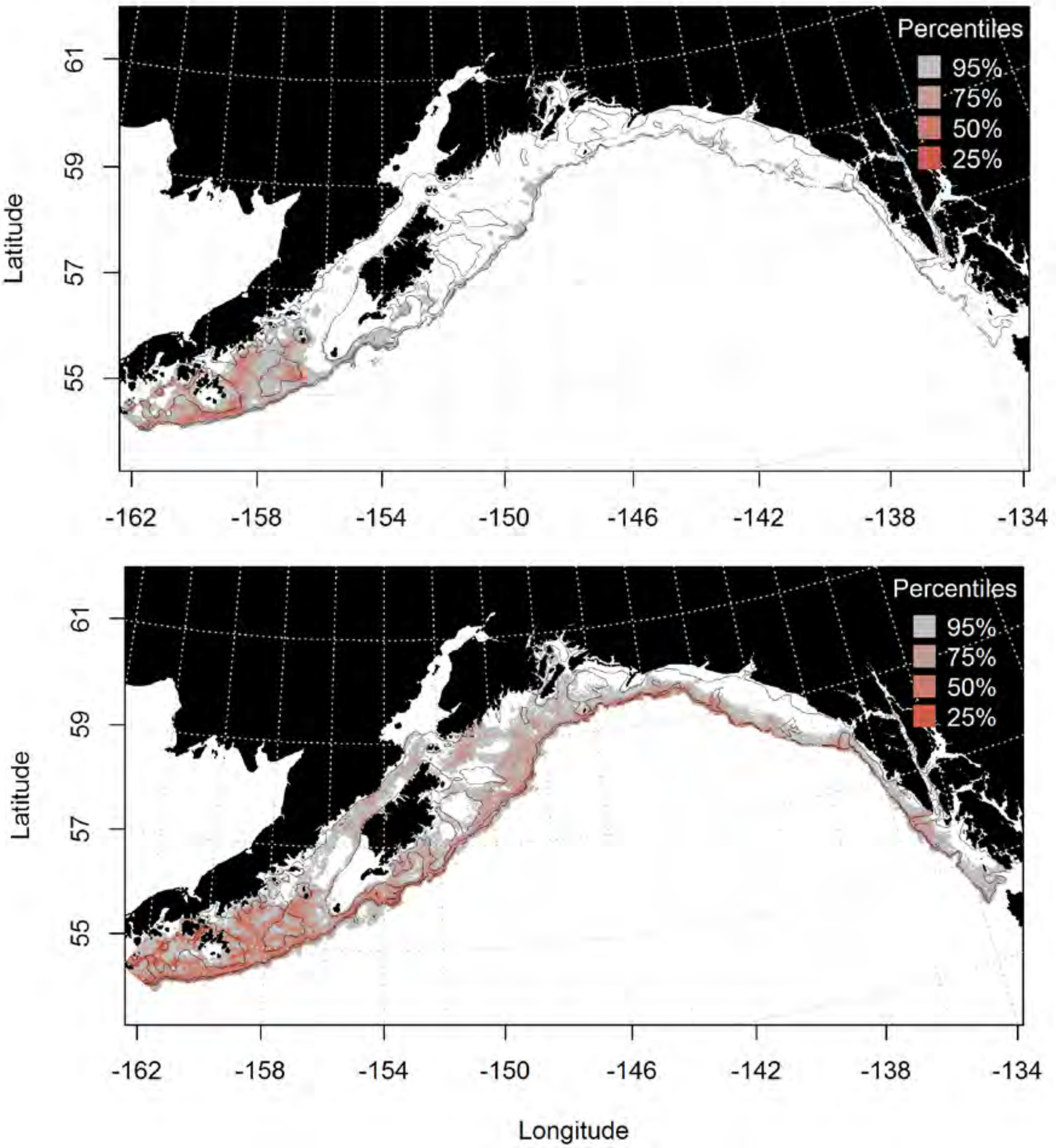


Figure 269. -- Essential fish habitat predicted for *S. ruberrimus* during fall (top panel) and spring (bottom panel) from commercial catches.

dusky rockfish (*Sebastes variabilis*)

Dusky rockfish occur though much of the Gulf of Alaska, and they are one of the most abundant rockfish found there. They typically occur between 101 to 200 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. variabilis* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile dusky rockfish occur across much of the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 74.4 and 8.7 respectively). The AUC for the training data was 0.86, indicating a good model fit. The AUC for the testing data was 0.85, indicating a good model fit. The percent of correctly classified observations was 77% for the training data and 85% for the test data. Juvenile dusky rockfish were predicted to occur across much of middle-shelf, particularly in the vicinity of Wessels Reefs in the central gulf; on Albatross and Portlock Banks off Kodiak Island; and around the Shumagin Islands on the Alaska Peninsula (Figure 270).

Summer bottom trawl survey data indicate adult dusky rockfish, also occur across much of the middle- and outer-shelf (Figure 271).

The variables determined to be the best predictors of the occurrence of adult dusky were depth, latitude and longitude, and temperature. The AUC for the training data was 0.95, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was 0.33. The percent of observations correctly classified was 89% for the training data set, and 94% for the test data set. The most important variables predicting the abundance of juvenile dusky were depth, latitude and latitude and temperature. The best-fitting GAM explained 24% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult dusky were predicted to occur on the inner- and middle-shelf across much of the western gulf (Figure 272). They were predicted to be abundant across most of this same area, particularly around Kodiak and the Shumagin Islands. High abundances were also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

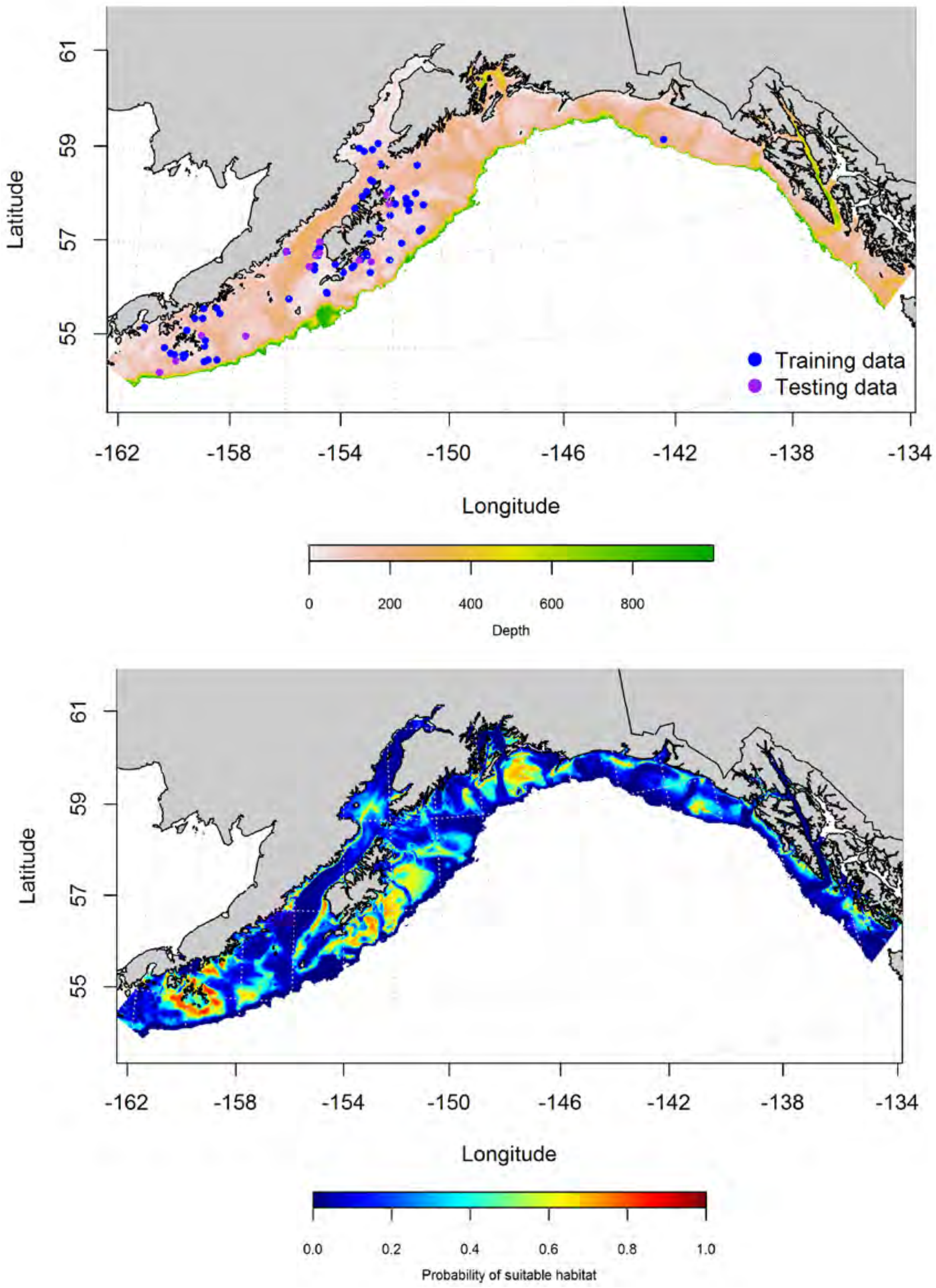


Figure 270. -- Locations of trawl survey catches of juvenile *S. variabilis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. variabilis* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

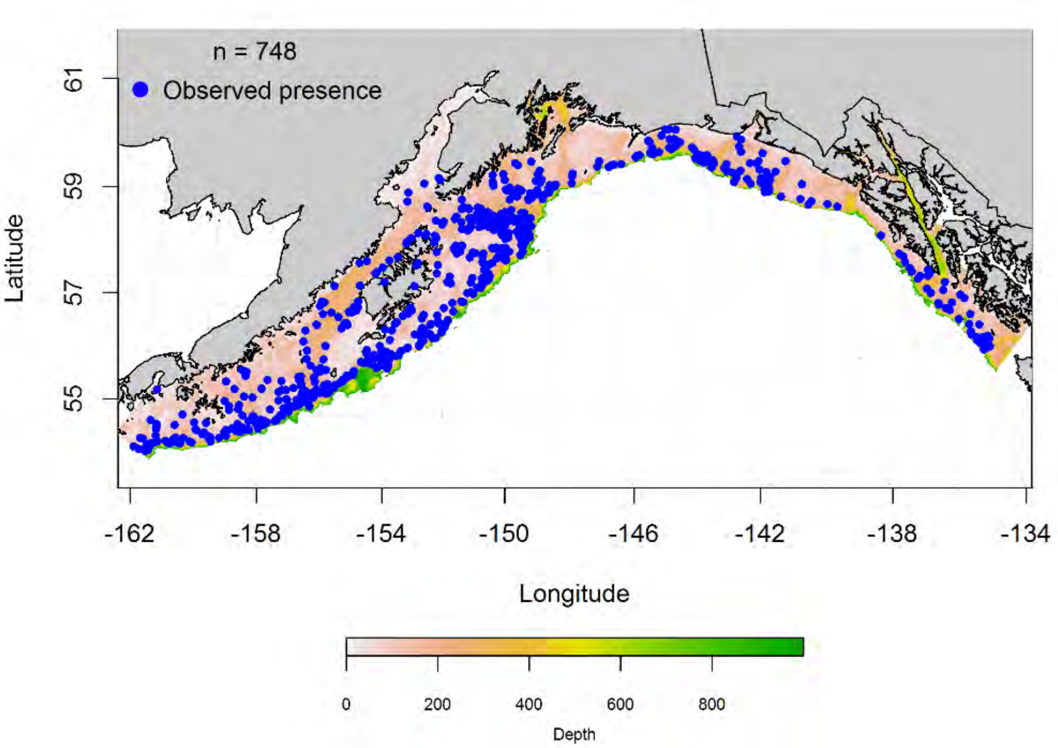


Figure 271. -- Locations of catches of adult *S. variabilis* from summer bottom trawl surveys of the Gulf of Alaska.

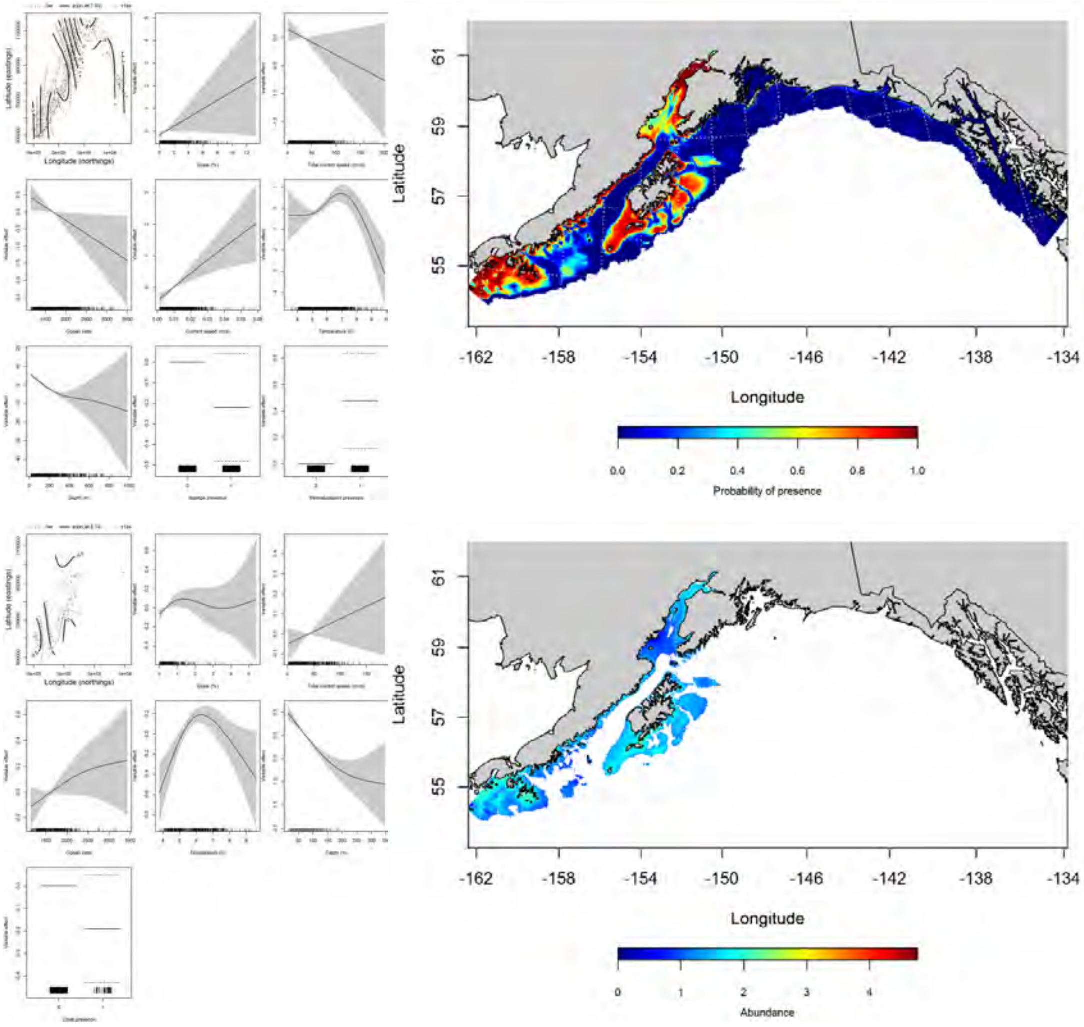


Figure 272. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. variabilis* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. variabilis* in the Gulf of Alaska -- Commercial catch data indicate dusky rockfish largely occur along the outer-shelf and deeper portions of the middle-shelf in the western Gulf of Alaska. In the fall, *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of adult dusky rockfish (relative importance = 29.8 and 19.2 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The percent of observations correctly classified was 82% and 83% respectively, for the training and test data. In the fall, adult dusky rockfish were predicted to occur along the deeper portions of the middle- and outer-shelf in the central and western gulf (Figure 273).

In the winter, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables predicting the distribution of adult dusky rockfish (relative importance = 25.5 and 20.2 respectively). The AUC was 0.93 for the training data, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The percent of observations correctly classified was 85% and 83% respectively, for the training and test data. In the winter, adult dusky rockfish were predicted to occur along much of the middle-shelf in the central and western gulf, particularly off Albatross and Portlock Banks (Figure 274).

In the spring, *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of adult dusky rockfish (relative importance = 25.9 and 25.4 respectively). The AUC was 0.90 for the training data, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The percent of observations correctly classified was 82% for the training and 83% for the test data. In the spring, adult dusky rockfish were predicted to occur in most of the deeper portions of the middle- and outer-shelf, particularly in Shelikof and Shumagin Gullies in the western gulf (Figure 275).

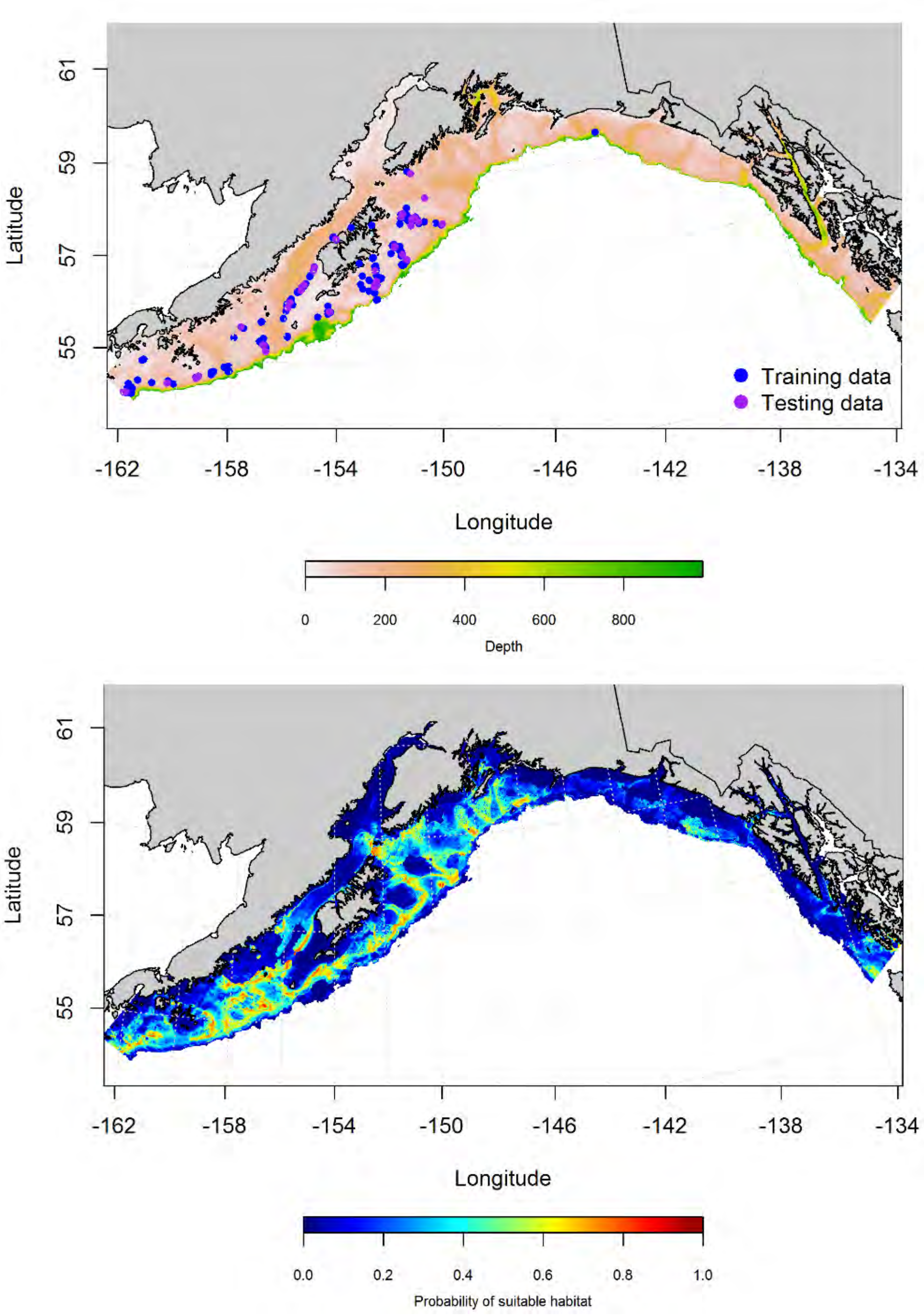


Figure 273. -- Locations of fall (September-November) commercial fisheries catches of *S. variabilis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *S. variabilis* commercial catches (bottom panel) and the purple points were used to test the model.

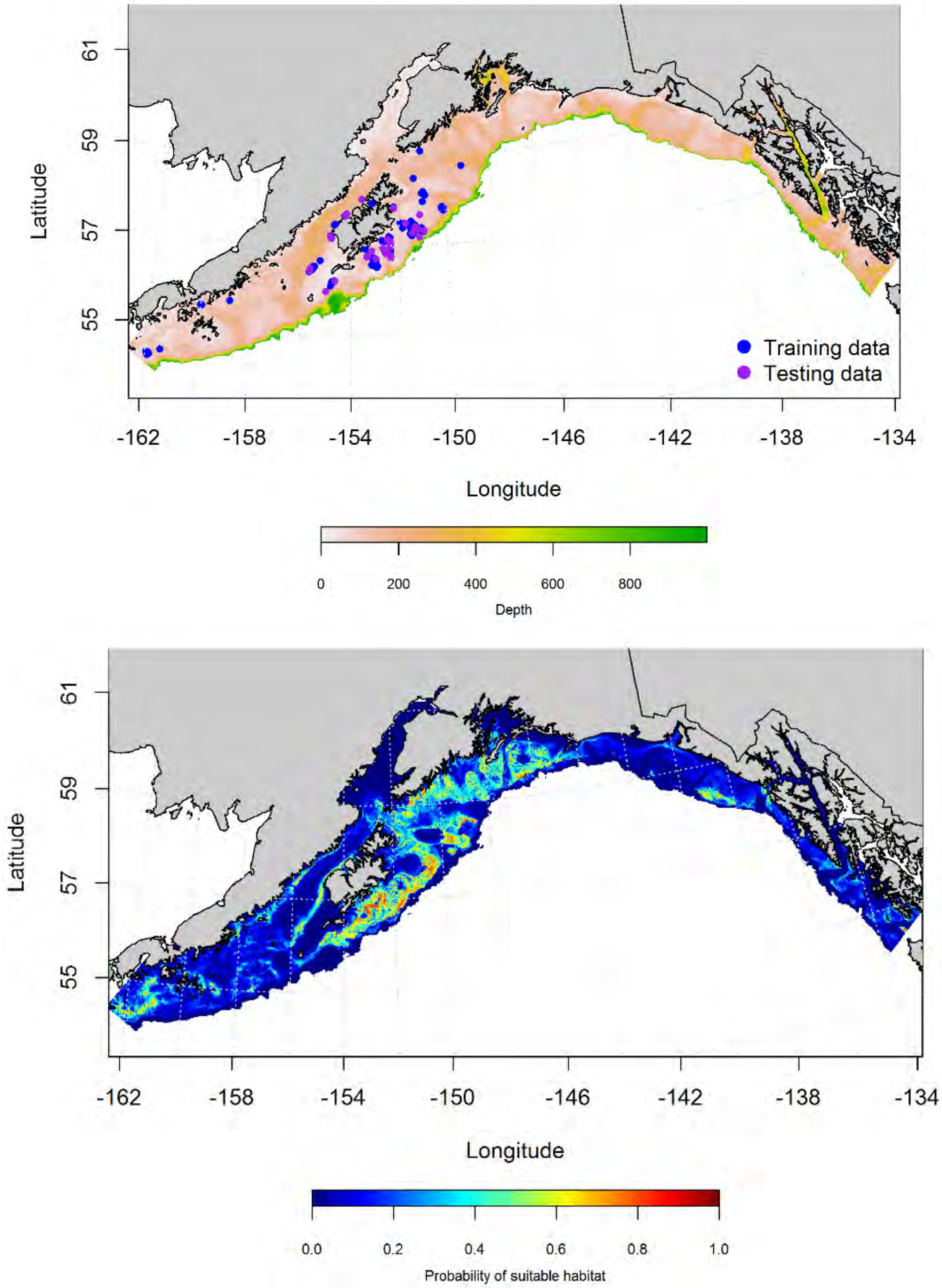


Figure 274. -- Locations of winter (December-February) commercial fisheries catches of *S. variabilis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *S. variabilis* commercial catches (bottom panel) and the purple points were used to test the model.

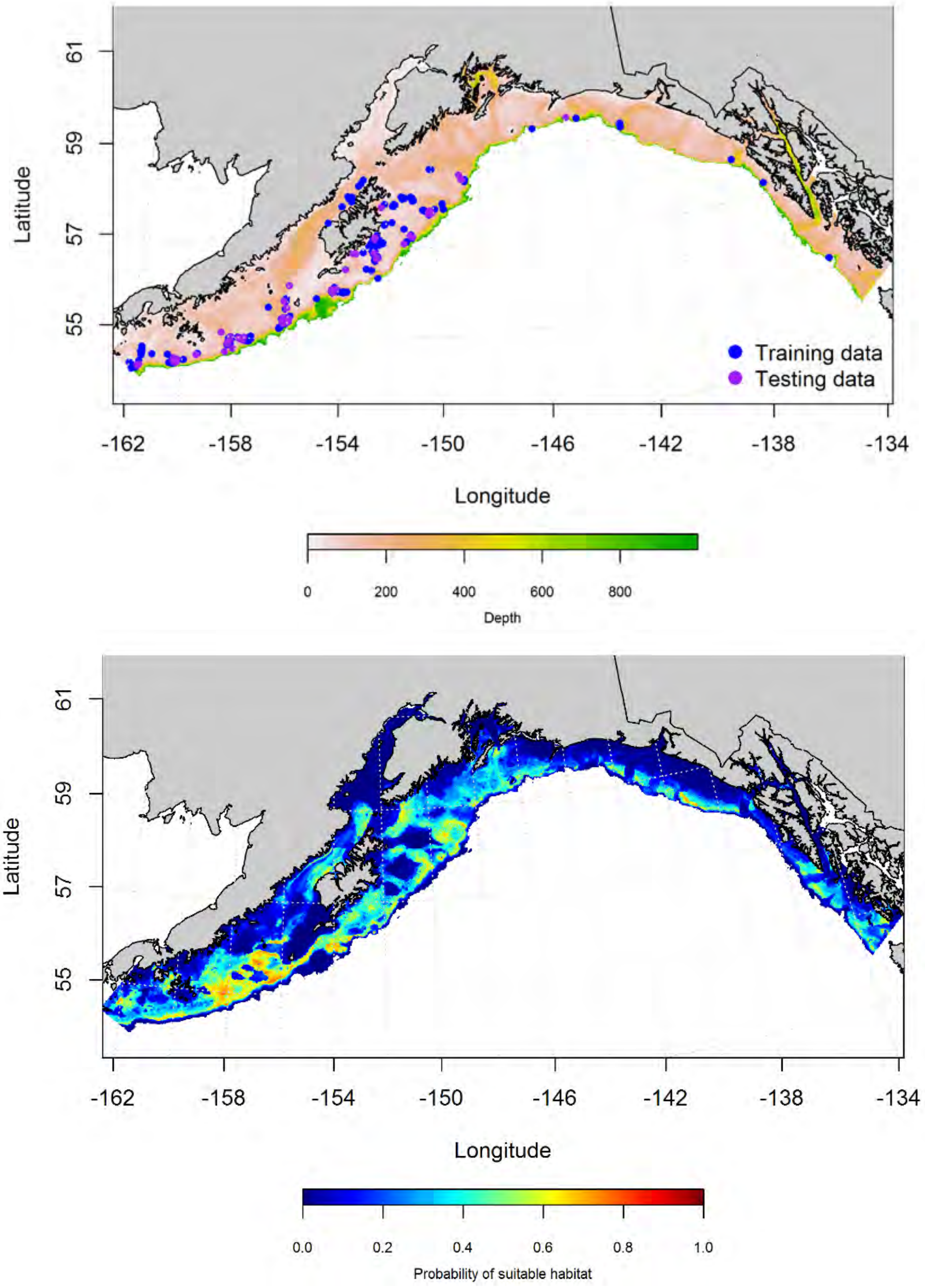


Figure 275. -- Locations of spring (March-May) commercial fisheries catches of *S. variabilis* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. variabilis* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. variabilis* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for dusky rockfish predicted was predicted to occur primarily off southeast Alaska. Because the early life history stages of most rockfish, including dusky rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile dusky rockfish, based on trawl survey observations, was predicted to occur across much of middle-shelf; particularly in the vicinity of Wessels Reefs in the central gulf, on Albatross and Portlock Banks off Kodiak Island, and around the Shumagin Islands on the Alaska Peninsula (Figure 276). EFH for adult dusky rockfish was predicted to occur on the inner- and middle-shelf in the western gulf, particularly around Kodiak and the Shumagin Islands. EFH for adult dusky was also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

Fall EFH, based on commercial fisheries data, was predicted include much of deeper portions of the middle- and outer-shelf in the central and western gulf (Figure 277). Winter EFH for dusky rockfish, based on commercial fisheries data, was predicted include much of the middle-shelf in the central and western gulf, particularly off Albatross and Portlock Banks (Figure 39.9). In the spring, adult dusky rockfish habitat was predicted to most of the deeper portions of the middle- and outer-shelf in throughout the gulf, particularly in Shelikof and Shumagin Gullies in the western gulf.

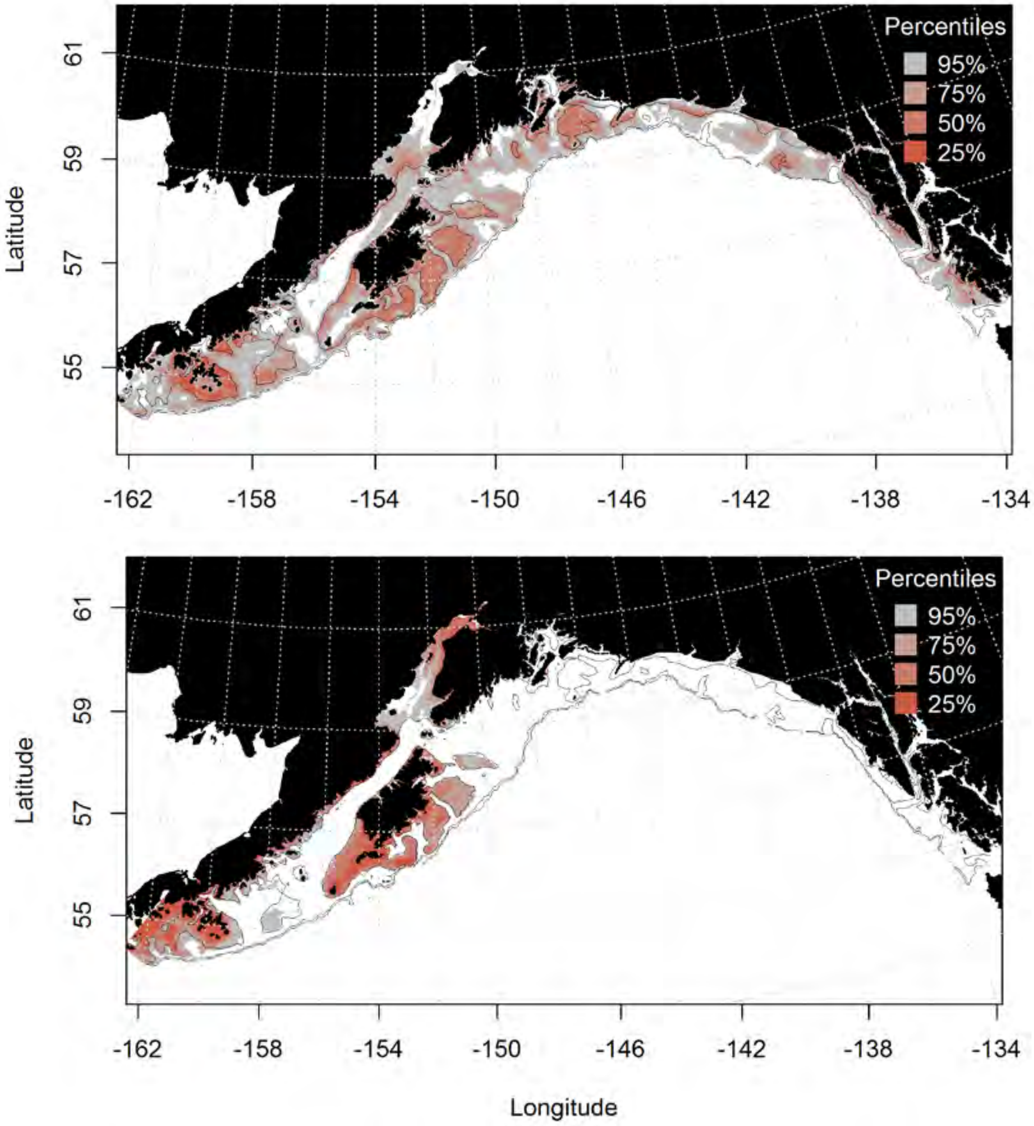


Figure 276. -- Predicted summer essential fish habitat for *S. variabilis* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

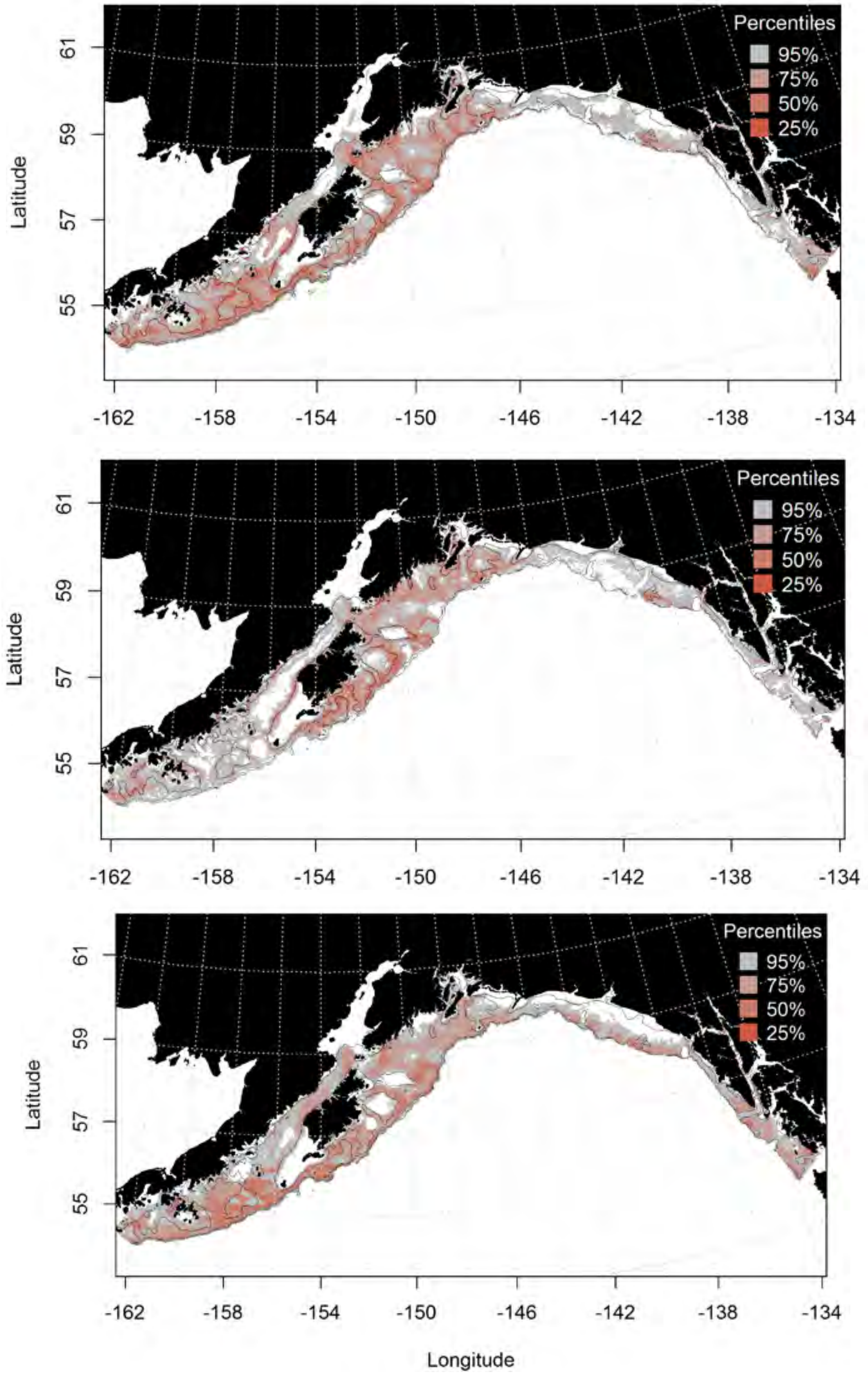


Figure 277. -- Essential fish habitat predicted for *S. variabilis* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

harlequin rockfish (*Sebastes variegatus*)

Harlequin rockfish occur infrequently and in modest numbers throughout much of the Gulf of Alaska. They occur primarily between 101 to 200 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. variegatus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile harlequin rockfish largely occur in the middle- and outer-shelf in the Gulf of Alaska. The best-fitting *MaxEnt* model indicated that temperature and depth were the most important variables predicting habitat suitability (relative importance 36.5 and 27.9 respectively). The AUC for the training data was 0.87, indicating a good model fit. The AUC for the testing data was 0.85, indicating a good model fit. The percent of correctly classified observations was 80% for the training data and 85% for the test data. Juvenile harlequin rockfish were predicted to occur across much of middle-and outer-shelf; particularly off southeast Alaska, and in the vicinity Portlock Bank and Wessels Reefs in the central gulf (Figure 278). Juvenile harlequin rockfish are also predicted to be abundant in Shelikof Strait; however, these predictions were not supported by any observations.

Summer bottom trawl survey data also indicate that adult harlequin rockfish, occur across much of the middle- and outer-shelf in the Gulf of Alaska (Figure 279).

The variables determined to be the best predictors of the occurrence of adult harlequin rockfish were latitude and longitude, sponge presence, and temperature. The AUC for the training data was 0.91, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was only 0.08. The percent of observations correctly classified was 84% for the training data set, and 81% for the test data set. The most important variables predicting the abundance of adult harlequin were depth, pennatulacean presence, and latitude and longitude. The best-fitting GAM explained 2% of the variability in CPUE in the training data and 18% of the variability in the test data. Adult harlequin rockfish were predicted to have a patchy distribution across much of the outer-shelf. They were predicted to be abundant though much of this area, particularly between Cape St. Elias and Portlock Bank in the central gulf, and to the east of Alsek Valley in southeast Alaska (Figure 280). Adult harlequin were also predicted to be abundant in Cook Inlet; however, these predictions were not supported by any observations.

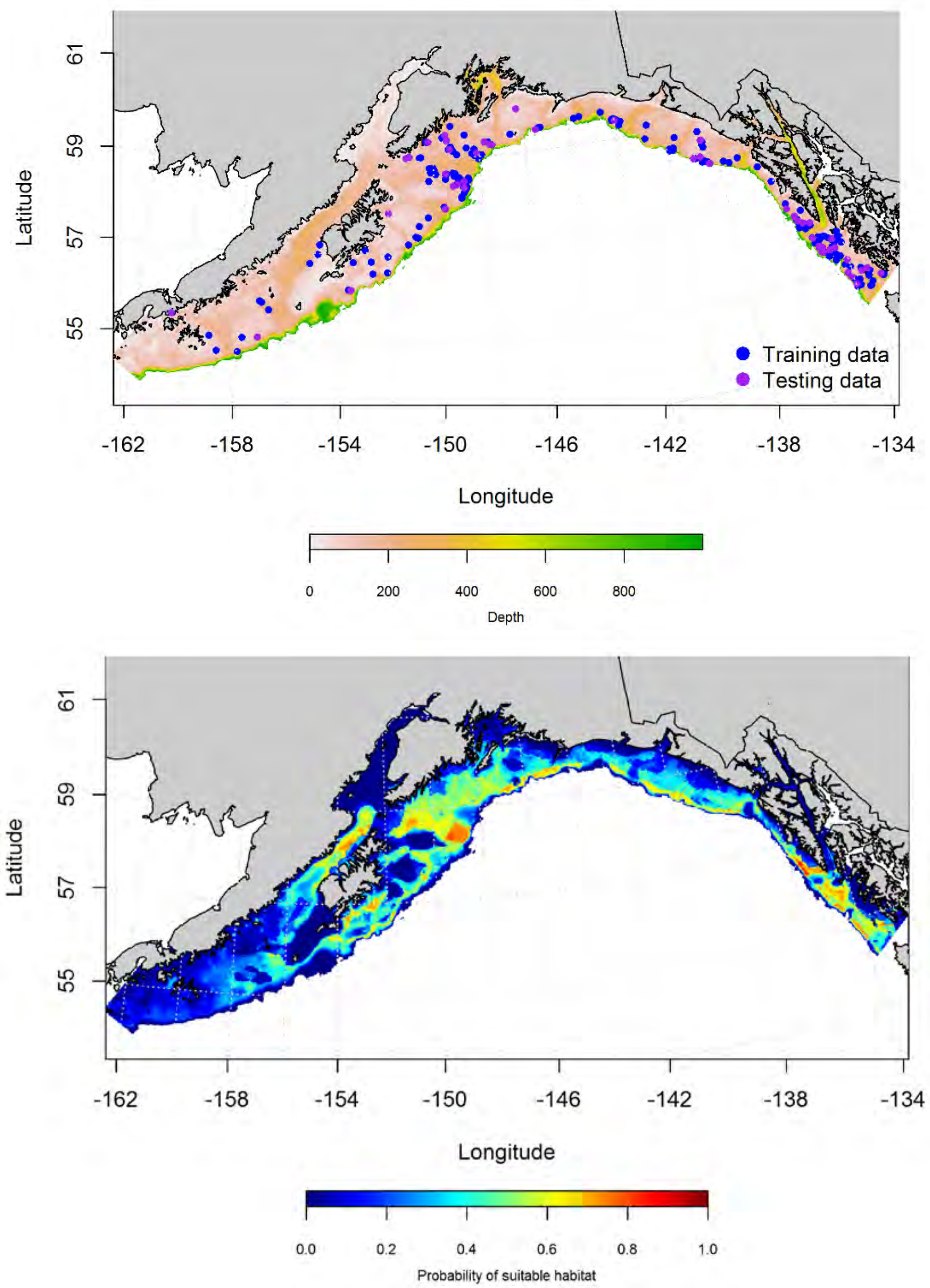


Figure 278. --Locations of trawl survey catches of juvenile *S. variegatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. variegatus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

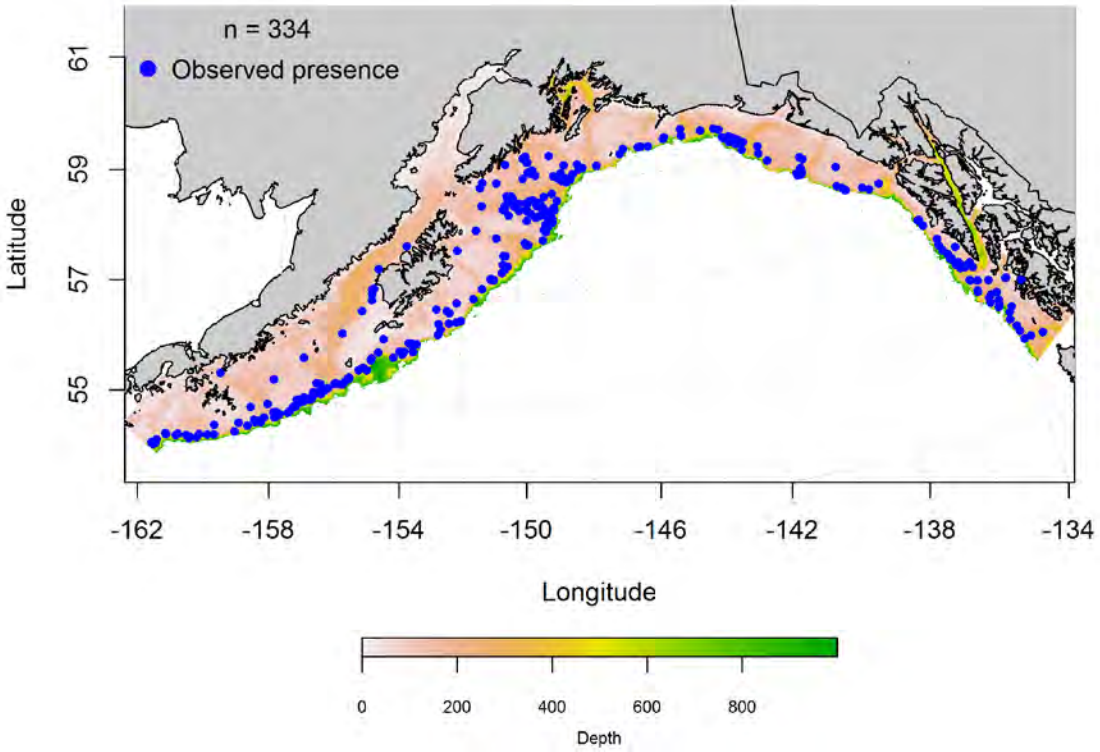


Figure 279. -- Locations of catches adult *S. variegatus* (top and bottom, respectively) from summer bottom trawl surveys of the Gulf of Alaska.

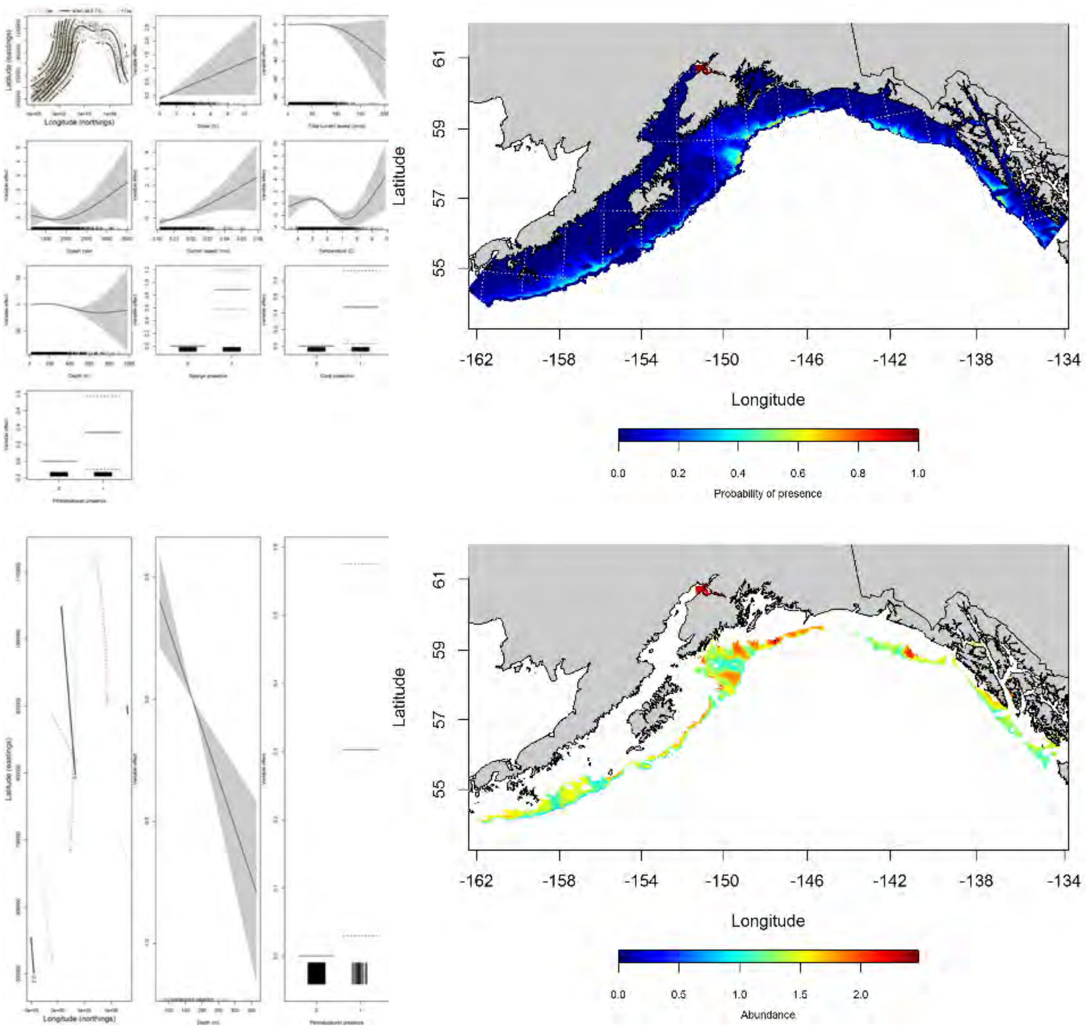


Figure 280. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering adult *S. variegatus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. variegatus* in the Gulf of Alaska -- Commercial catch data for harlequin rockfish were only available from during spring. They indicate harlequin rockfish largely occur on the middle- and outer shelf in the western GOA. *MaxEnt* modeling determined that tidal current and depth were the most important variables predicting the distribution of adult harlequin rockfish (relative importance = 31.2 and 30.1 respectively). The AUC was 0.99 for the training data, indicating an excellent model fit. The AUC for the test data was 0.82, indicating a good model fit. The percent of observations correctly classified was 93% and 82% respectively, for the training and test data. In the fall, adult harlequin rockfish were predicted to occur primarily along the deeper portions of the middle- and outer-shelf in the central and western gulf, particularly in Shelikof and Shumagin Gullies, and to a lesser extent along the deeper portions of Albatross and Portlock Banks (Figure 281).

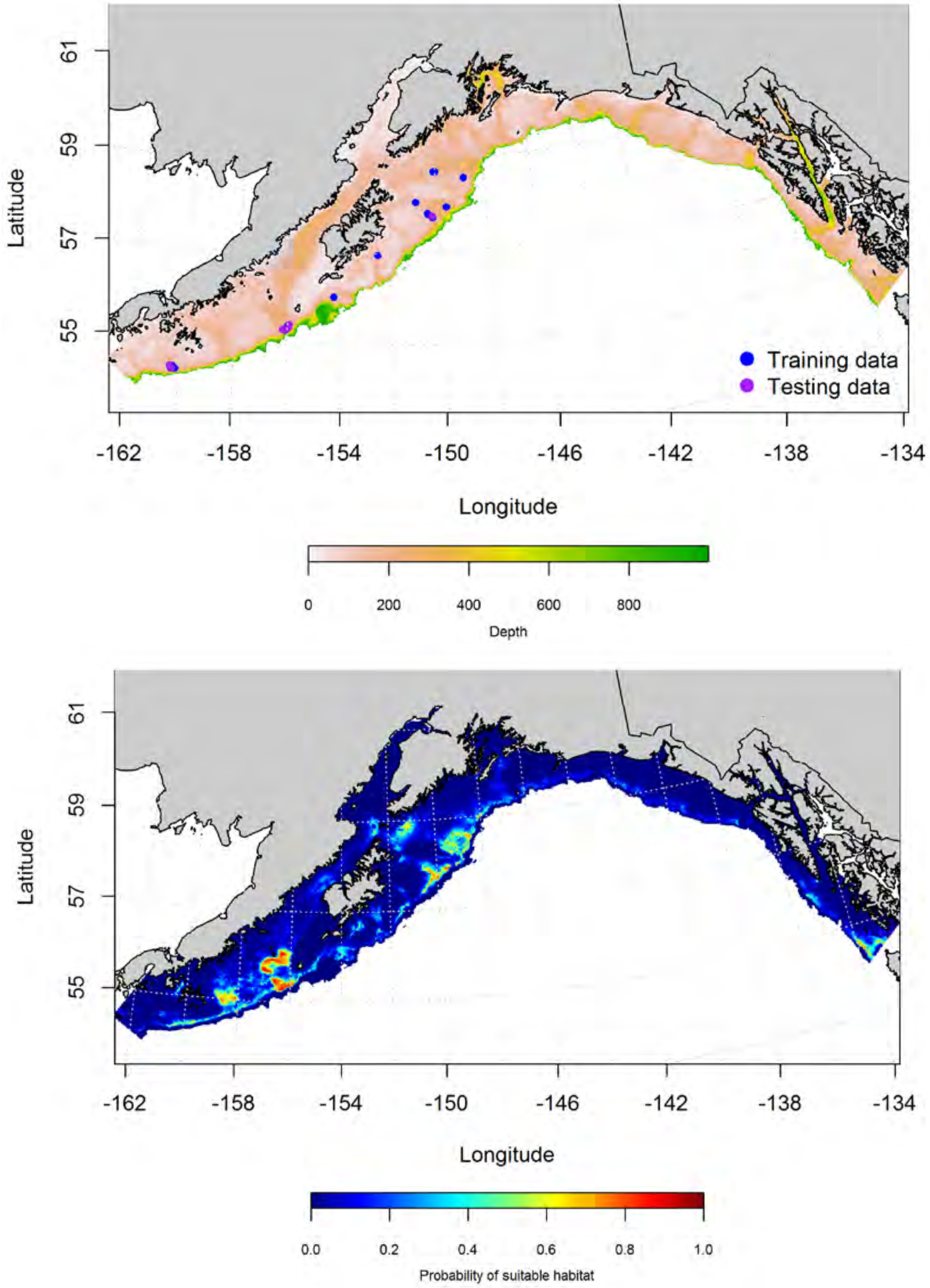


Figure 281. -- Locations of spring (March-May) commercial fisheries catches of *S. variegatus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. variegatus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. variegatus* Essential Fish Habitat Maps and Conclusions --

Harlequin rockfish essential fish habitat predicted by modeling occurred predominantly off southeast Alaska in Gulf of Alaska. Because the early life history stages of most rockfish, including harlequin rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile harlequin rockfish, based on trawl survey observations, was predicted to occur across much of middle-and outer-shelf, particularly off southeast Alaska and the central gulf (Figure 282). Juvenile harlequin rockfish are also predicted to be abundant in Shelikof Strait; however, these predictions were not supported by any observations. EFH for adult harlequin rockfish was predicted to occur on the outer-shelf throughout much of gulf. EFH for adult harlequin is also predicted to occur in Cook Inlet; however, these predictions were not supported by any observations.

Spring EFH for adult harlequin rockfish, based on commercial fisheries data, was predicted to largely be restricted to the western gulf, particularly Shelikof and Shumagin Gullies among the Alaska Peninsula, and the outer edges of Portlock and Albatross Bank off Kodiak Island (Figure 283**).**

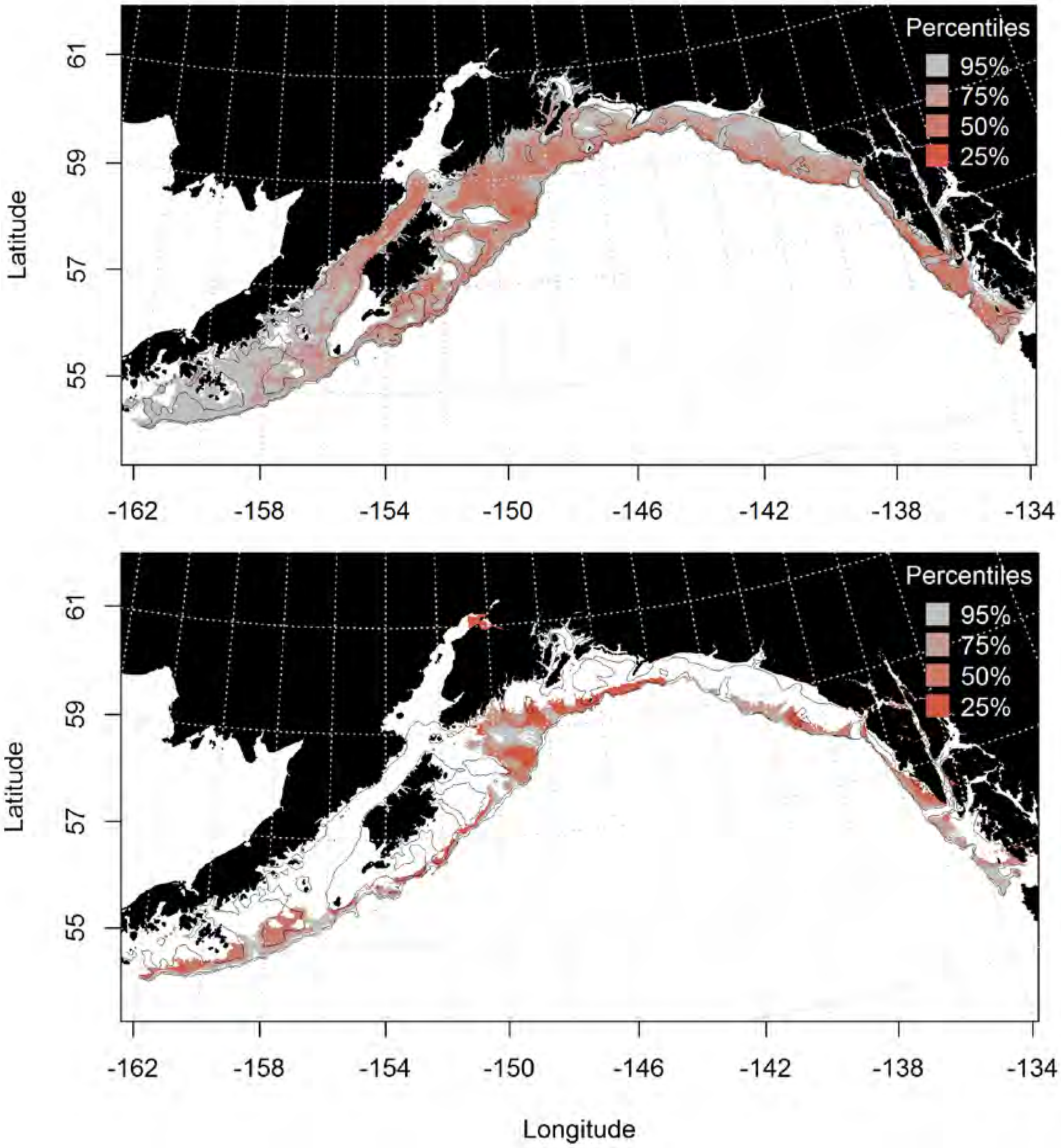


Figure 282. -- Predicted summer essential fish habitat for *S. variegatus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

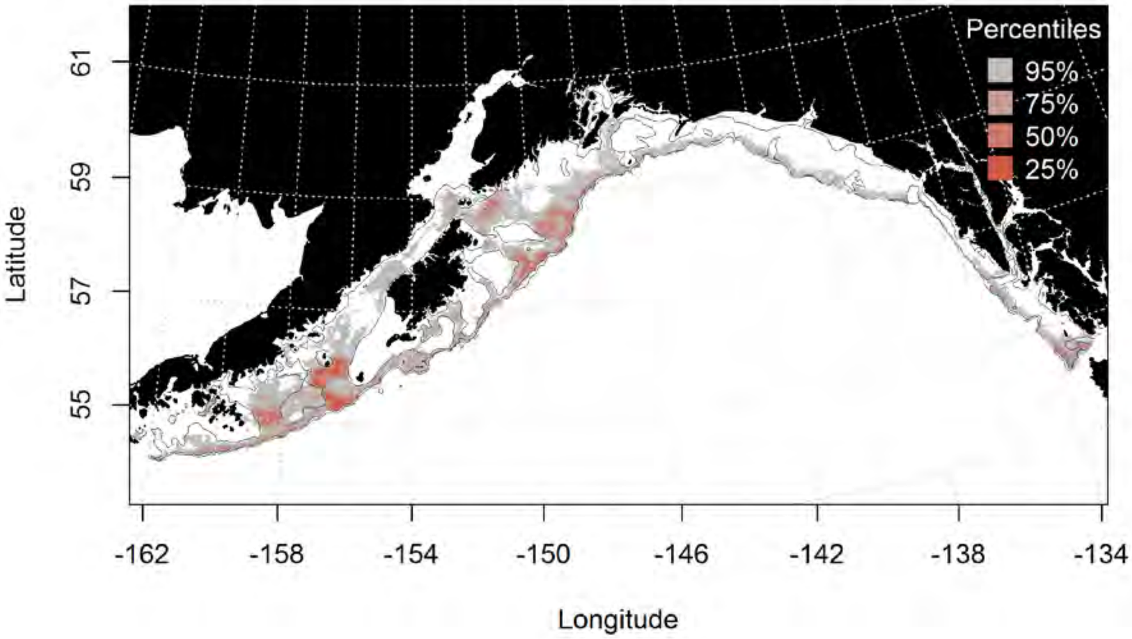


Figure 283. -- Essential fish habitat predicted for *S. variegatus* during spring from commercial catches.

pygmy rockfish (*Sebastes wilsoni*)

Pygmy rockfish are infrequently caught in the Gulf of Alaska. They usually offshore occur in the central and eastern portion of the gulf, at between 29-274 m depth (Mecklenburg et al., 2002).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. wilsoni* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate pygmy rockfish largely occur in the eastern and central Gulf of Alaska. Juvenile and adult pygmy rockfish were difficult to consistently separate and therefore they were aggregated together during the analysis of trawl survey data. The best-fitting *MaxEnt* model indicated that depth and slope were the most important variables predicting habitat suitability for pygmy rockfish (relative importance 29.0 and 28.2 respectively). The AUC for the training data was 0.89, indicating a good model fit. The AUC for the testing data was 0.75, indicating a fair model fit. The percent of correctly classified observations was 80% for the training data and 75% for the test data. Pygmy rockfish were predicted to have a patchy distribution along the middle- and outer-shelf in the eastern and central gulf. The highest suitably habits were predicted to occur off southeast Alaska and in an area south of Yakutat Valley (Figure 284). Pygmy rockfish were also predicted to be abundant in Shelikof Strait; however, these predictions were not supported by any observations.

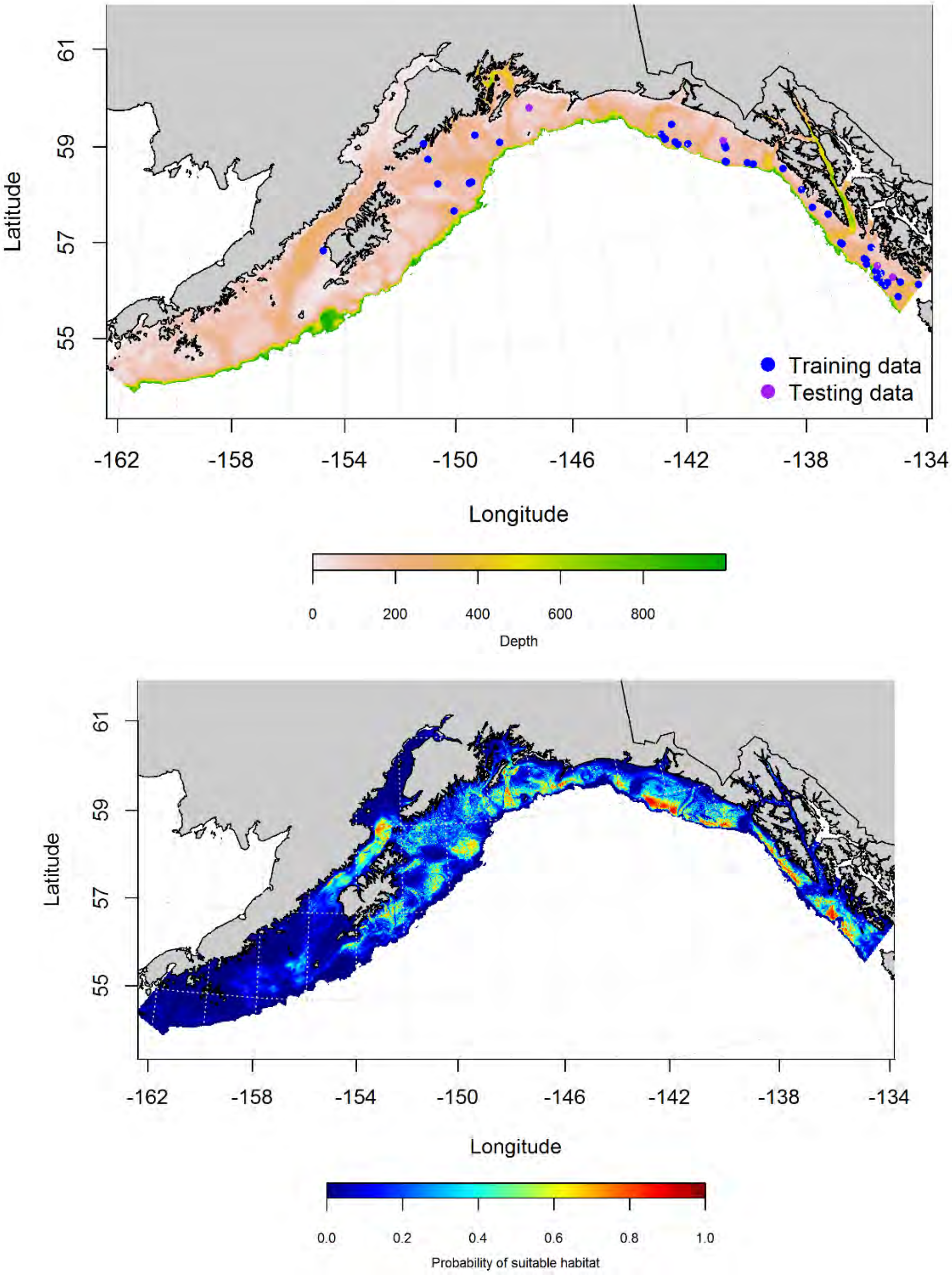


Figure 284. -- Locations of trawl survey catches of *S. wilsoni* all life stages combined (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution *S. wilsoni* all life stages combined based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *S. wilsoni* in the Gulf of Alaska -- There were no observations of pygmy rockfish from commercial fisheries data.

Gulf of Alaska *S. wilsoni* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for pygmy rockfish was predicted to occur primarily off southeast Alaska. Because the early life history stages of most rockfish, including pygmy rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for pygmy rockfish, based on trawl survey observations, was predicted to occur across much of middle-and outer-shelf, particularly off southeast Alaska and in the central gulf (Figure 285). EFH for pygmy was also predicted in Shelikof Strait; however, these predictions were not supported by any observations.

No EFH could be predicted for Pygmy rockfish based on from commercial fisheries data.

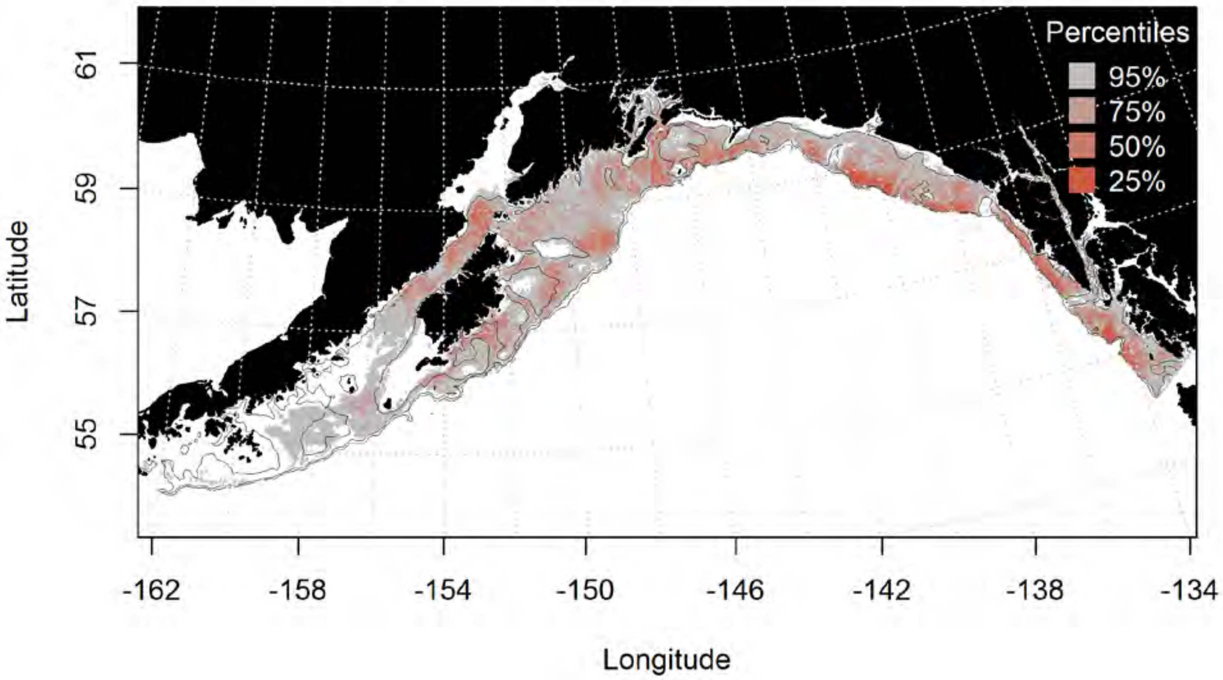


Figure 285. -- Predicted summer essential fish habitat for *S. wilsoni* all life stages combined from summer bottom trawl surveys.

sharpchin rockfish (*Sebastes zacentrus*)

Sharpchin rockfish predominantly occur in the eastern and central portion of the Gulf of Alaska, and are rarely captured west of Kodiak Island. They almost exclusively occur at between 101 and 300 m (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *Sebastes* spp. in the Gulf of Alaska -- The early life history stages of most rockfish (*Sebastes* spp.) are difficult to consistently differentiate by species in the field. Consequently analysis of early life history stages of these species was conducted at the genus level, *Sebastes* spp.

Spring and summer distribution of juvenile and adult *S. zacentrus* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile sharpchin rockfish occur much of the middle- and outer-shelf in the Gulf of Alaska. The variables determined to be the best predictors of the occurrence of juvenile sharpchin rockfish were latitude and longitude, sponge presence, and temperature. The AUC for the training was 0.96, indicating an excellent model fit. The AUC for the test data was 0.83, indicating a good model fit. The optimum threshold was only 0.09. The percent of observations correctly classified was 89% for the training data set, and 83% for the test data set. The most important variables predicting the abundance of juvenile sharpchin rockfish were current speed and depth. The best-fitting GAM explained 24% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile sharpchin rockfish were predicted to occur across much of the middle- and outer-shelf in the central and eastern gulf. In particular, high suitability habitat was predicted to occur from Yakutat south to Dixon Entrance (Figure 286).

Summer bottom trawl survey data also indicates that adult sharpchin rockfish largely occur across much of the middle- and outer-shelf in the GOA (Figure 287).

The best-fitting *MaxEnt*)HGAM?) model indicated that depth and temperature the most important variables predicting habitat suitability (relative importance 58.6 and 19.0 respectively). The AUC for the training data was 0.92, indicating an excellent model fit. The AUC for the testing data was 0.79, indicating a fair model fit. The percent of correctly classified observations was 85% for the training data and 79% for the test data. Adult sharpchin rockfish habitat were predicted to occur and to be abundant along much of the deeper portions of the middle- and outer-shelf and; particularly in the eastern gulf. They were also predicted to be abundant in Shelikof Strait and Shelikof Gully; however, these predictions were not supported by any observations (Figure 288).

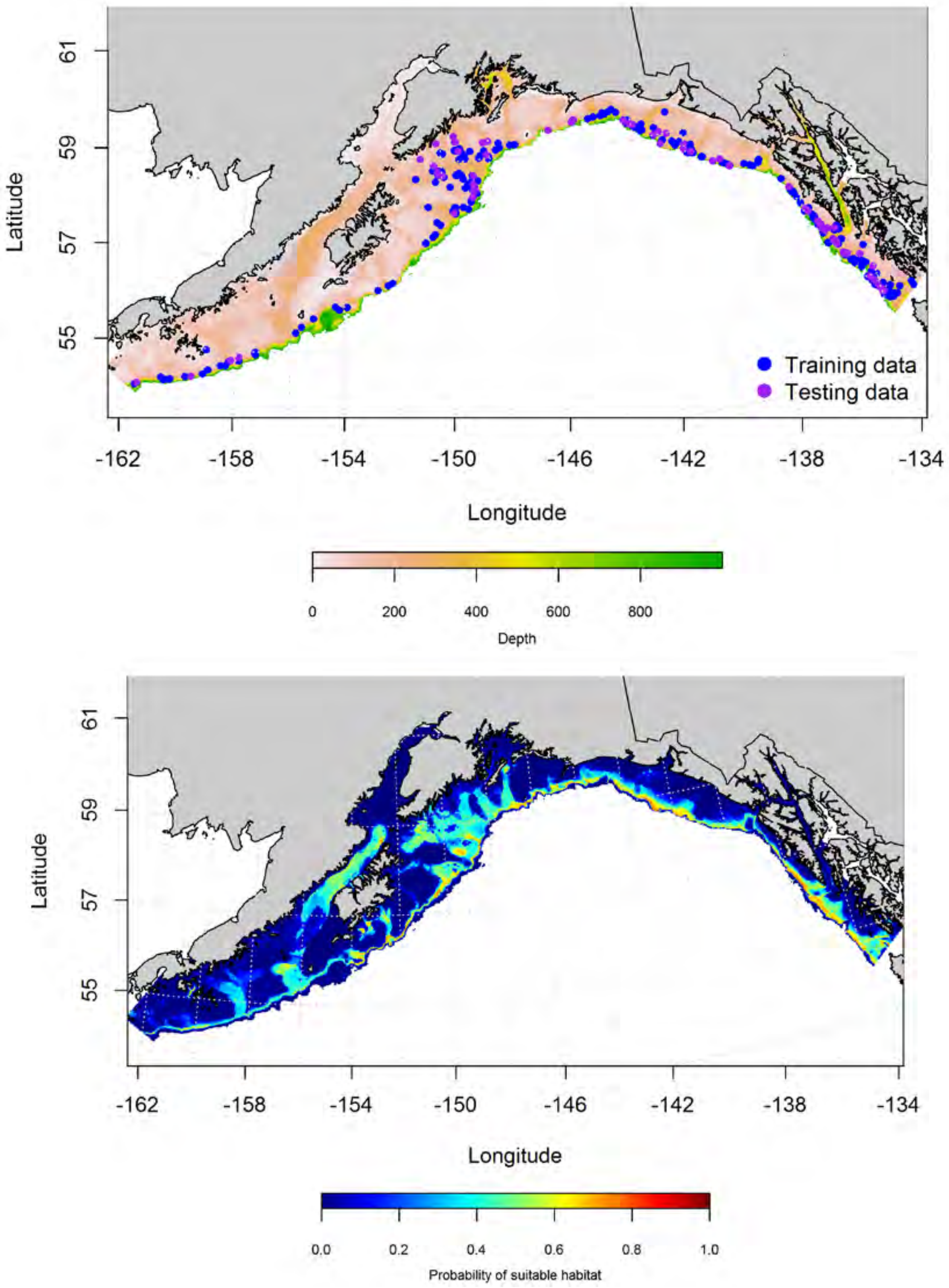


Figure 286. -- Locations of trawl survey catches of juvenile *S. zacentrus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *S. zacentrus* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

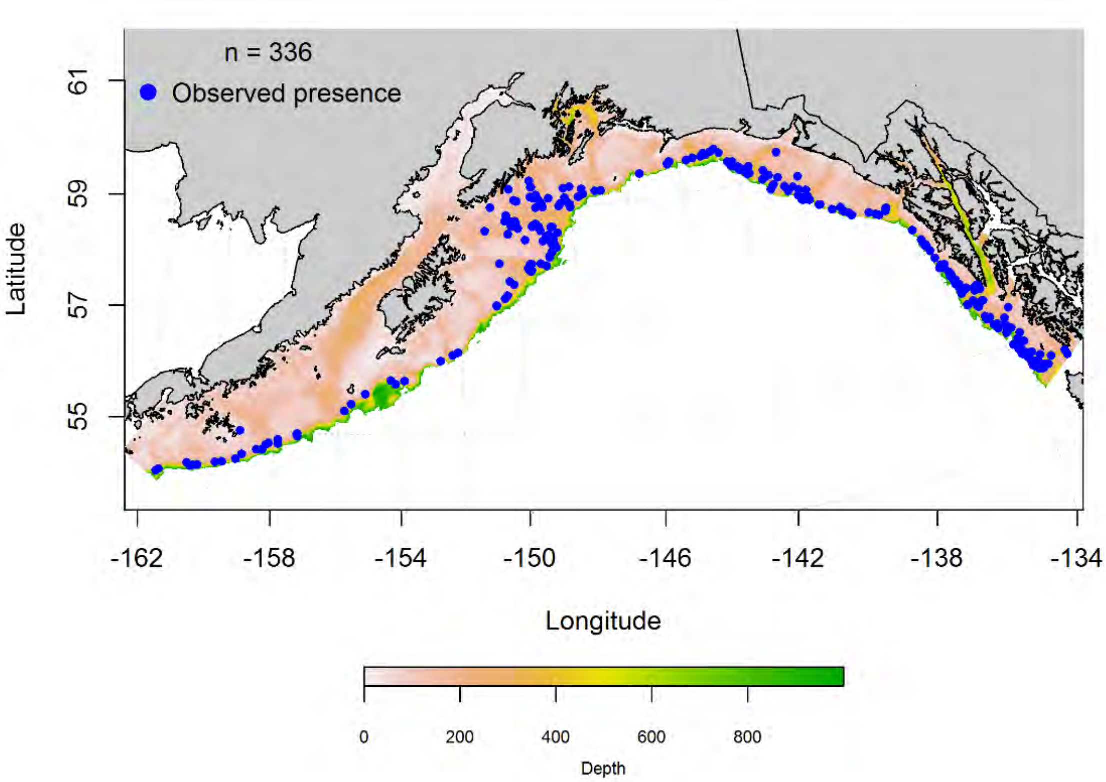


Figure 287. -- Locations of catches adult *S. zacentrus* from summer bottom trawl surveys of the Gulf of Alaska.

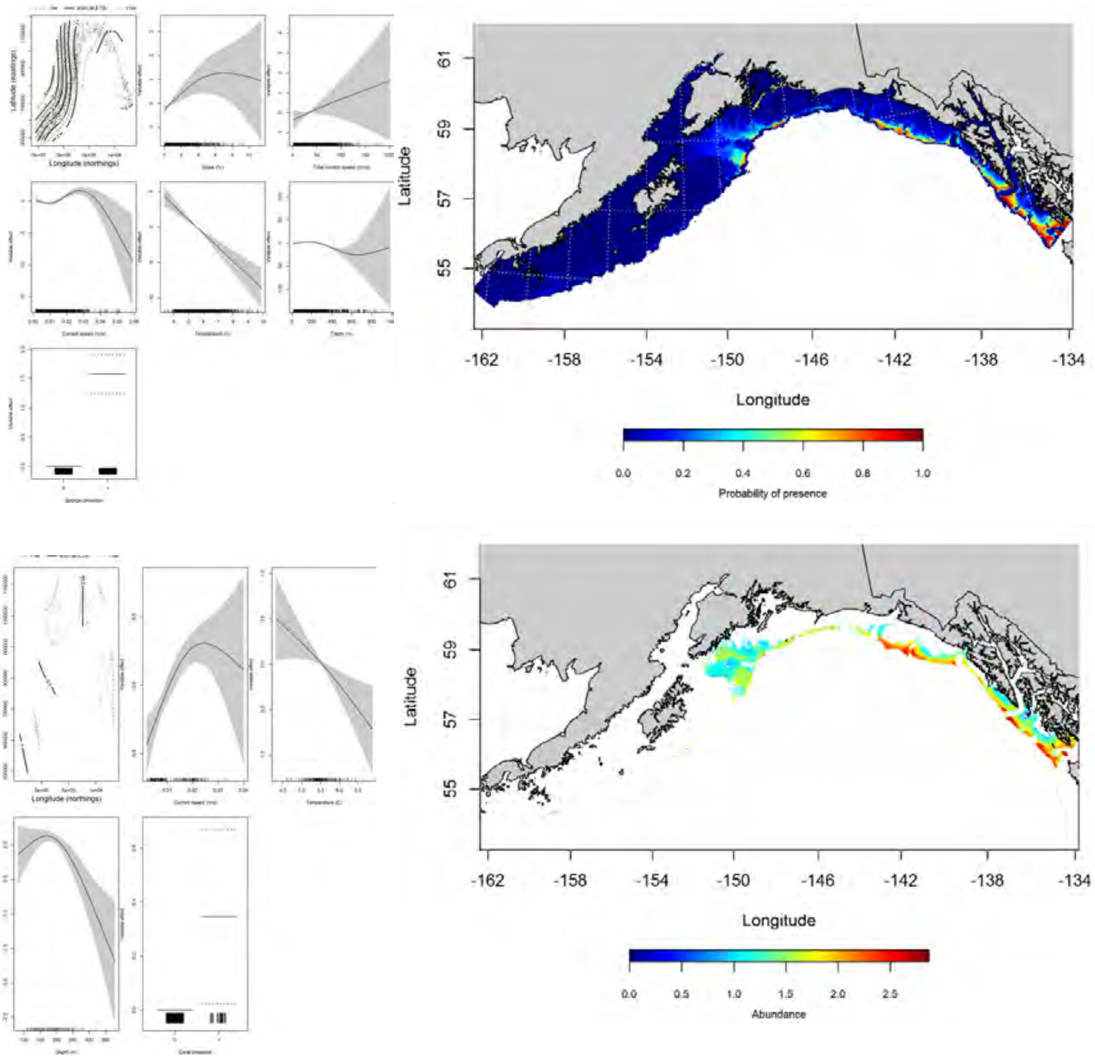


Figure 288. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *S. zacentrus* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *S. zacentrus* in the Gulf of Alaska -- Commercial catch data of sharpchin rockfish were rare and only available only during the spring. *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of adult sharpchin rockfish (relative importance = 42.1 and 23.5 respectively). The AUC was 0.97 for the training data, indicating an excellent model fit. The AUC for the test data was 0.95, indicating an excellent model fit. The percent of observations correctly classified was 91% and 95% respectively, for the training and test data. In the spring, adult sharpchin rockfish were predicted to occur along the outer-shelf in the western gulf, particularly in the Shelikof and Shumagin Gullies (Figure 289).

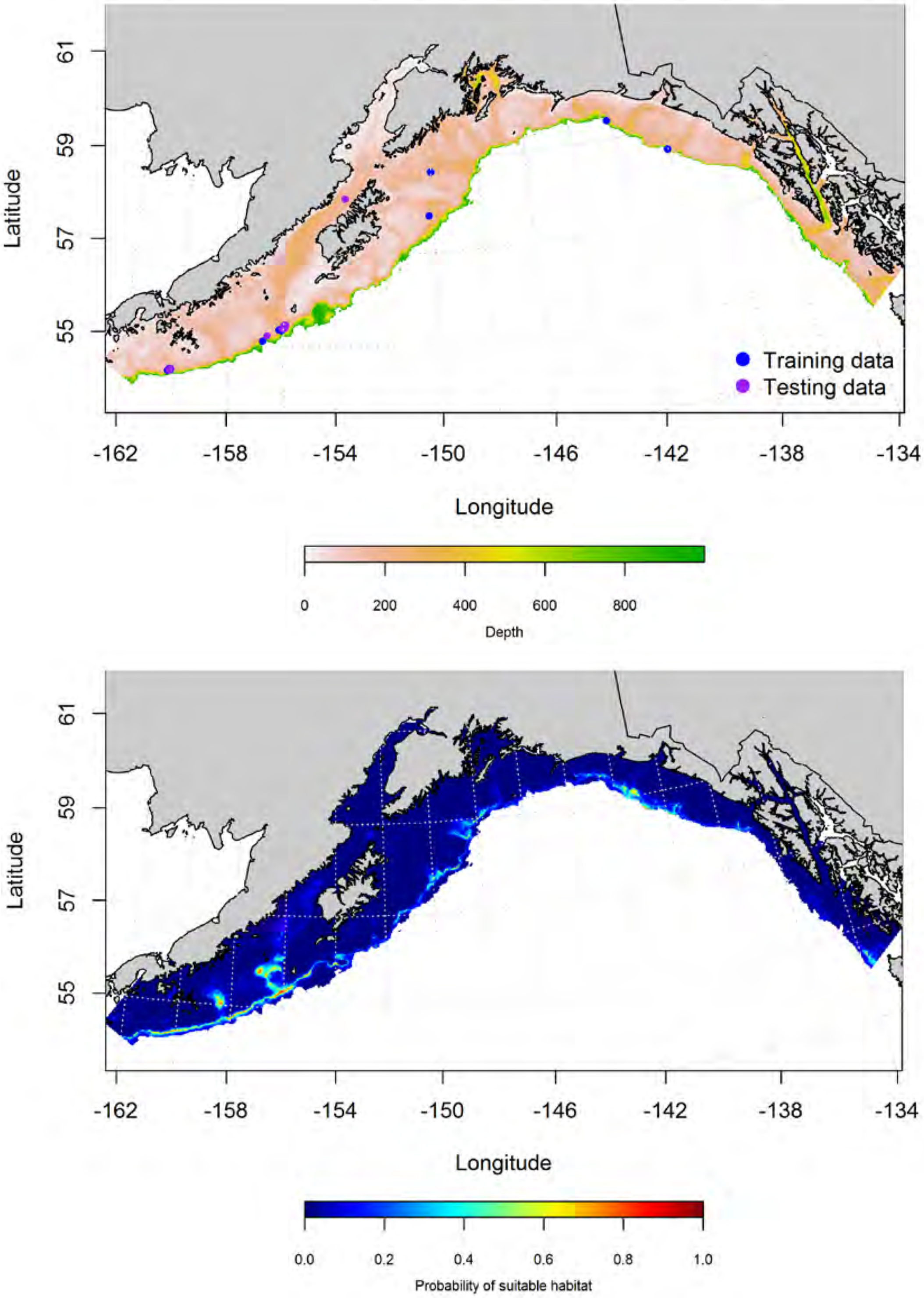


Figure 289. -- Locations of spring (March-May) commercial fisheries catches of *S. zacentrus* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *S. zacentrus* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *S. zacentrus* Essential Fish Habitat Maps and Conclusions -- Essential fish habitat for Sharpchin rockfish was predicted to occur predominantly off southeast Alaska. Because the early life history stages of most rockfish, including sharpchin rockfish, are difficult to differentiate, models of EFH were developed at the genus level, *Sebastes* spp.

Summer EFH for juvenile sharpchin rockfish, based on trawl survey observations, was predicted to occur across much of the outer-shelf, particularly off southeast Alaska and to a lesser extent in the central gulf (Figure 290). EFH for adult sharpchin rockfish was predicted to include much of the outer-shelf. EFH for adult sharpchin rockfish were also predicted to be abundant in Shelikof Strait and Shelikof Gully; however, these predictions were not supported by any observations.

Spring EFH for adult sharpchin rockfish, based on commercial fisheries data, walmost exclusively occurred in the western gulf, particularly around Shelikof and Shumagin Gullies (Figure 291).

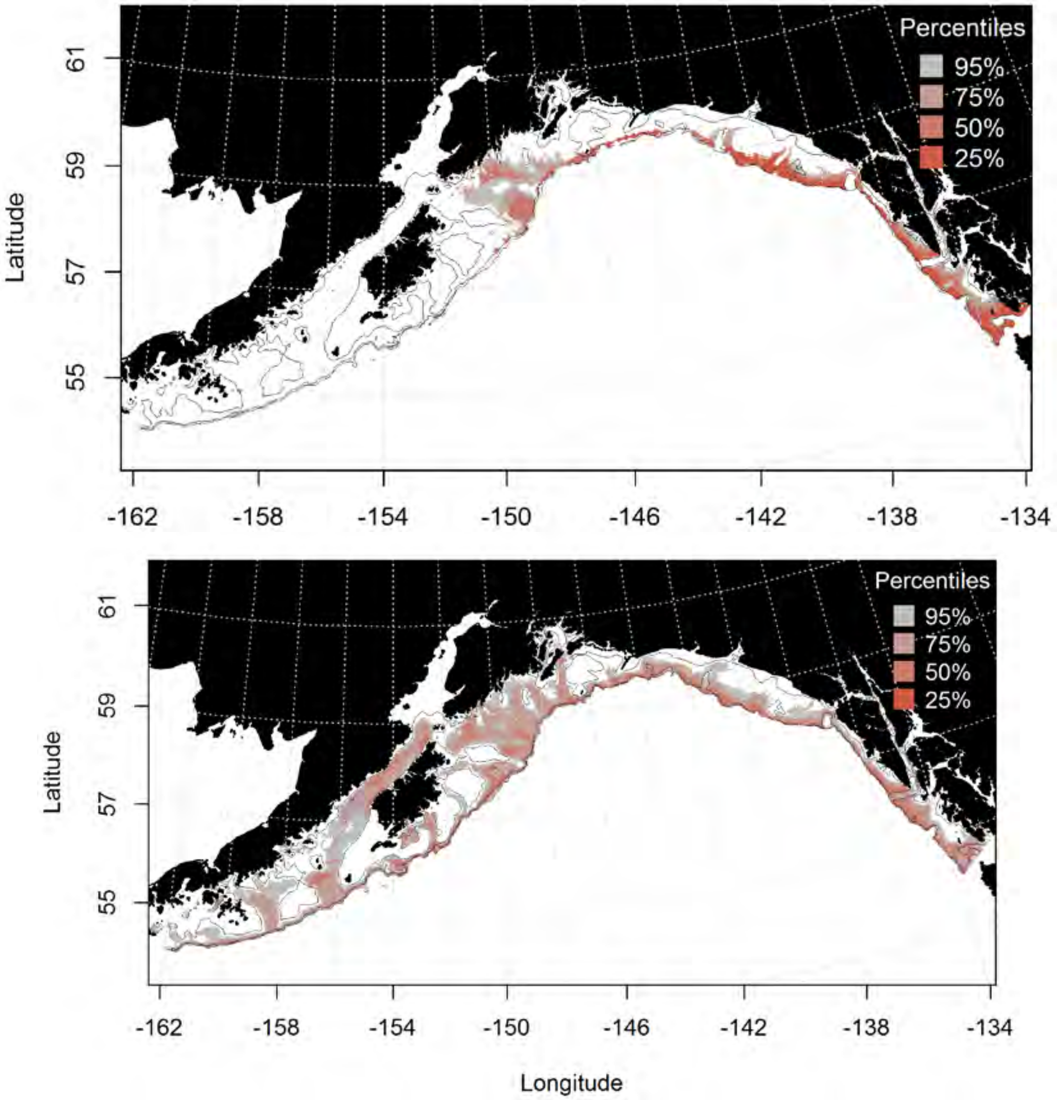


Figure 290. -- Predicted summer essential fish habitat for *S. zacentrus* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

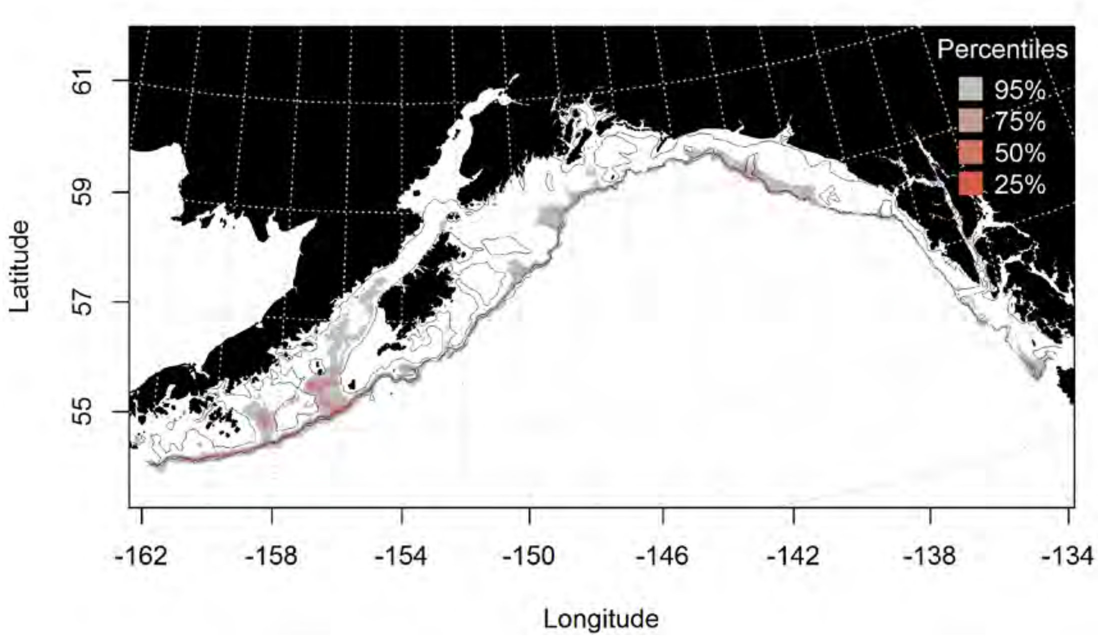


Figure 291. -- Essential fish habitat predicted for *S. zacentrus* during spring from commercial catches.

Skates

Aleutian skate (Bathyraja aleutica)

Aleutian skate primarily occur in the western Gulf of Alaska. They are found down to 700 m depth; however, they are most abundant at less than 300 m depth (von Szalay et al. 2010).

Seasonal distribution of early life history stages of *B. aleutica* in the Gulf of Alaska -- No observations of any early life history stages of Aleutian skate occurred in the EcoFOCI database.

Spring and summer distribution of juvenile and adult *B. aleutica* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate Aleutian skate occur over much of the central and western Gulf of Alaska (Figure 292).

The variables determined to be the best predictors of the occurrence of juvenile Aleutian skate were latitude and longitude, depth, and tidal current. The AUC for the training data was 0.82, indicating a good model fit. The AUC for the testing data was 0.83, indicating a good model fit. The optimum threshold was only 0.07. The percent of observations correctly classified was 75% for the training data set, and 77% for the test data set. The most important variables predicting the abundance of juvenile Aleutian skate were depth and latitude and longitude. The best-fitting GAM explained 4% of the variability in CPUE in the training data and 18% of the variability in the test data. Juvenile Aleutian skate were predicted to occur and to be abundant in Shelikof Strait and Shelikof Gully, as well as to a lesser extent along the shelf break in the central and western gulf (Figure 293). High abundances were also predicted to occur in portions of Prince William Sound; however, these were not supported by any observations.

Summer bottom trawl survey data indicates that adult Aleutian skate largely occur in the western gulf. The best-fitting *MaxEnt* model indicated that temperature and depth the most important variables predicting habitat suitability (relative importance 43.8 and 40.2 respectively). The AUC for the training data was 0.86, indicating a good model fit. The AUC for the testing data was 0.62, indicating a poor model fit. The percent of correctly classified observations was 76% for the training data and 62% for the test data. Adult Aleutian skate were predicted occur in much of the central and western gulf, particularly in Shelikof Strait and Shelikof Gully (Figure 294). High abundances were also predicted to occur off southeast Alaska; however, these predictions were not supported by any observations.

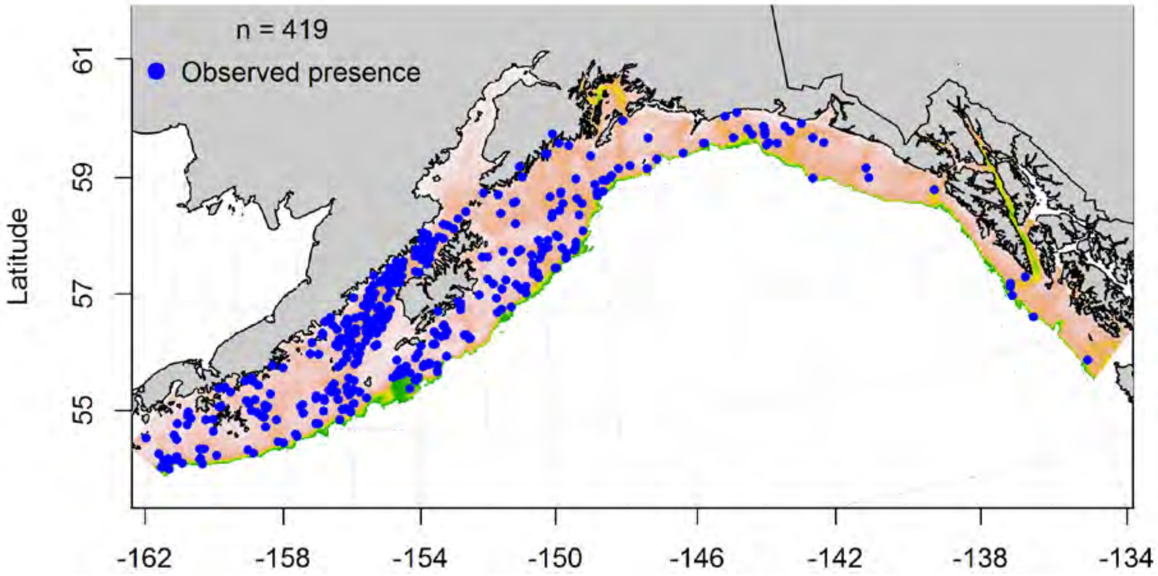


Figure 292. -- Locations of catches of juvenile *B. aleutica* from summer bottom trawl surveys of the Gulf of Alaska.

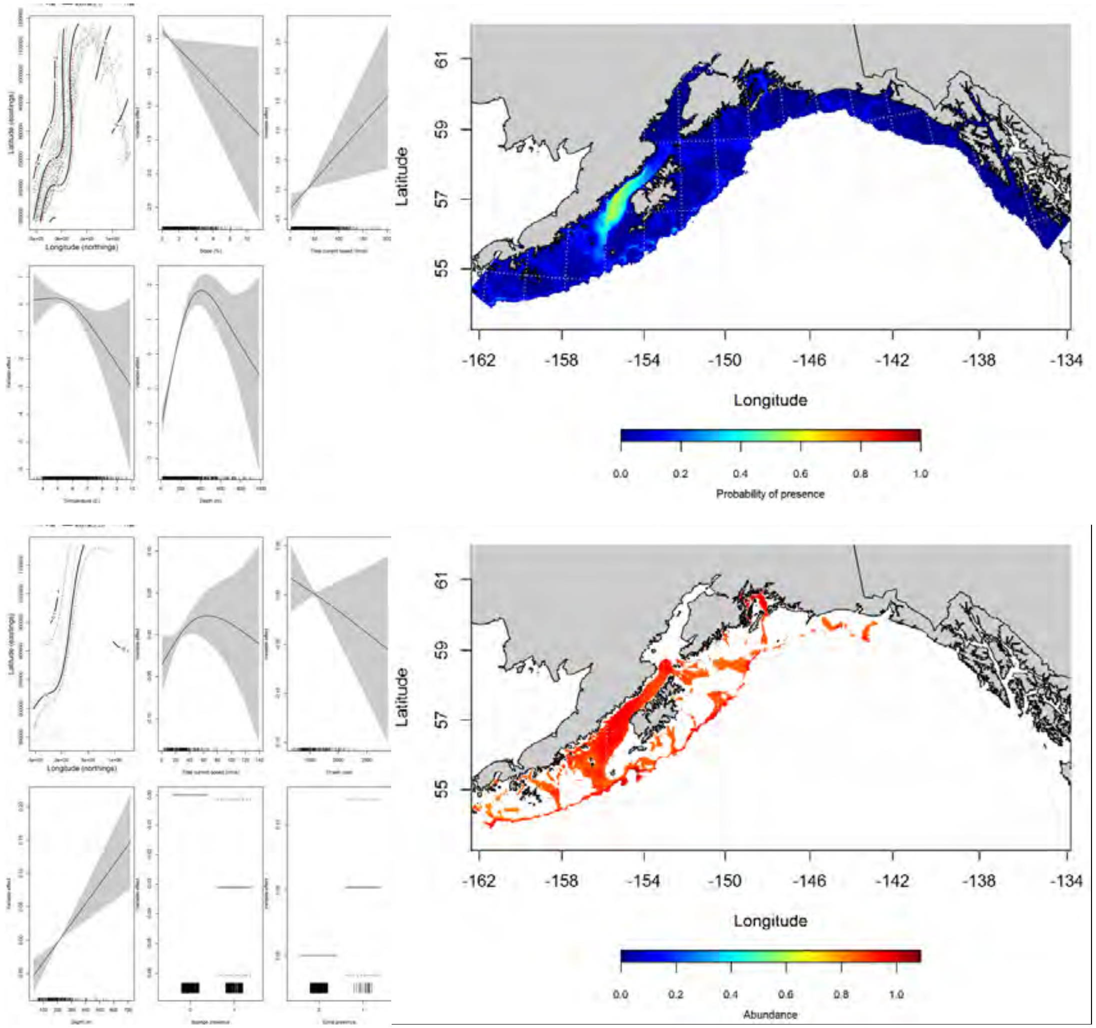


Figure 293. -- Best-fitting generalized additive model (GAM) effects of retained habitat variables (left panel) alongside the GAM predictions of the probability of encountering juvenile *B. aleutica* over those habitats (right panel) from summer bottom trawl surveys of the Gulf of Alaska. **Possible scaling issue P/A plot may need to replot**

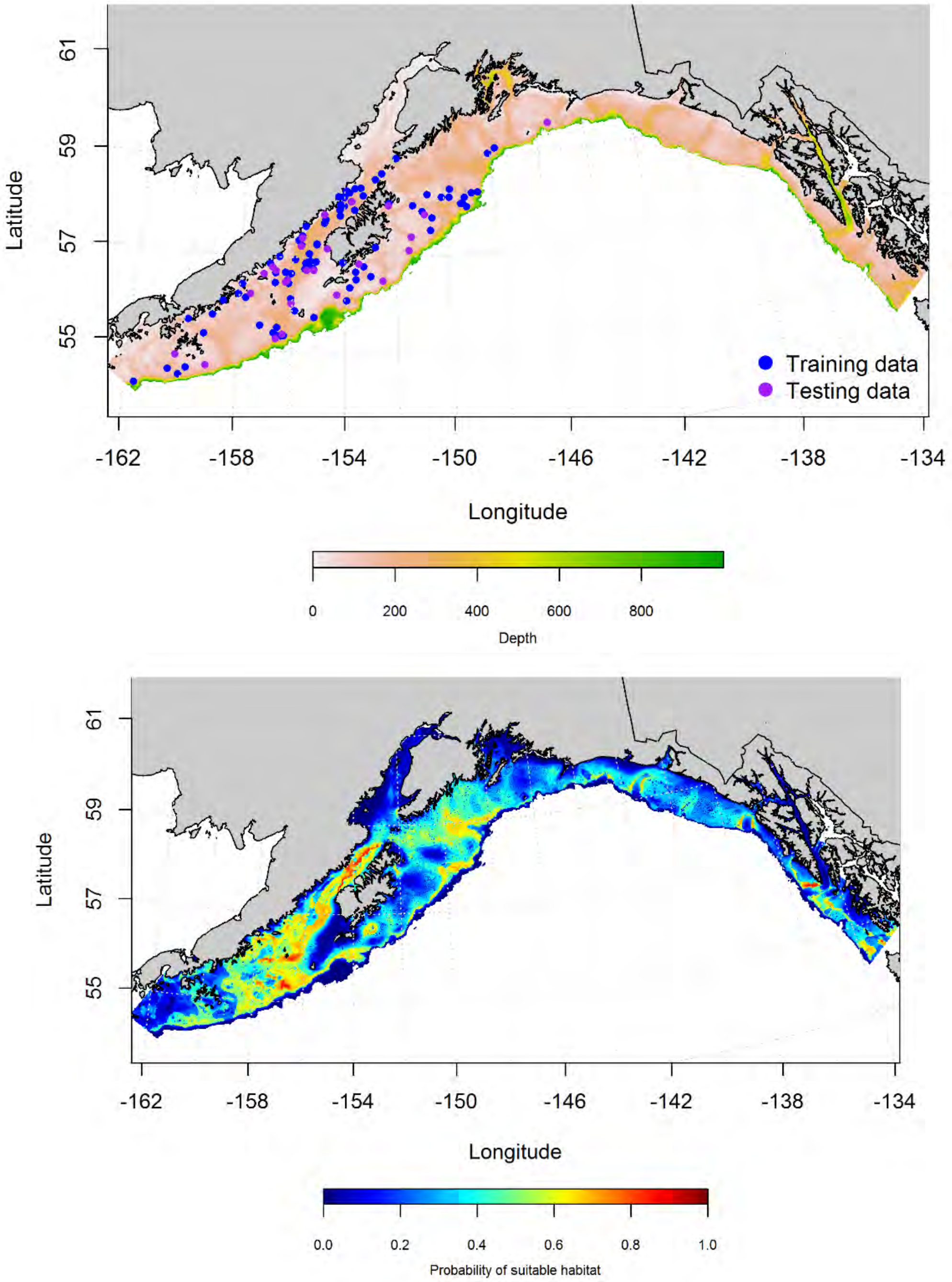


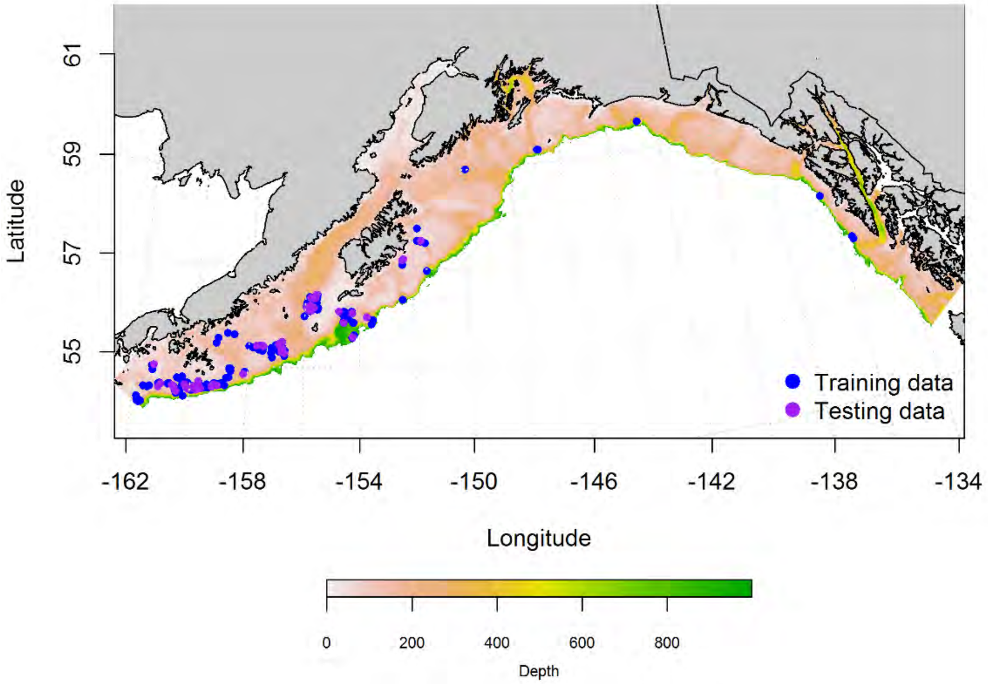
Figure 294. --Locations of trawl survey catches of adult *B. aleutica* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *B. aleutica* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *B. aleutica* in the Gulf of Alaska -- Commercial catch data indicate Aleutian skate largely occur on the middle- and outer-shelf in the western GOA. In the fall, *MaxEnt* modeling determined that ocean color and depth were the most important variables predicting the distribution of Aleutian skate (relative importance = 54.0 and 14.6 respectively). The AUC for the training data 0.95, indicating an excelent model fit. The AUC for the test data was 0.84, indicating a good model fit. The percent of observations correctly classified for the training data was 89%, and it was 84% for the test data. In the fall, the habitat with the highest predicted suitability for adult Aleutian skate included most of the deeper water along the middle- and outer-shelf, west of Kodiak Island (Figure 295).

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of Aleutian skate (relative importance = 57.3 and 13.7 respectively). The AUC was 0.93 for the training data, indicating an excellent model fit. The AUC for the test data was 0.84, indicating a good model fit. The percent of observations correctly classified was 87% and 84% respectively, for the training and test data. In the winter, adult Aleutian skate habitat was predicted to occur along large portion of the middle-shelf in the western gulf, particularly around the Shumagin Islands, Semidi Bank, and around Kodiak Island (Figure 296). Localized areas of high suitability were also predicted at the entrance of Cook Inlet and off Icy Bay in the eastern gulf; however, these were not supported by any observations.

In the spring, *MaxEnt* modeling determined that depth and bottom temperature were the most important variables determining the distribution of Aleutian skate (relative importance = 65.4 and 21.3 respectively). The AUC was 0.92 for the training data, indicating an excellent model fit. The AUC for the test data was 0.79, indicating a fair model fit. The percent of observations correctly classified was 86% for the training and 79% for testing data. In the spring, adult

Aleutian skate were predicted to occur along the shelf break across the most of the Gulf of Alaska (Figure 297).



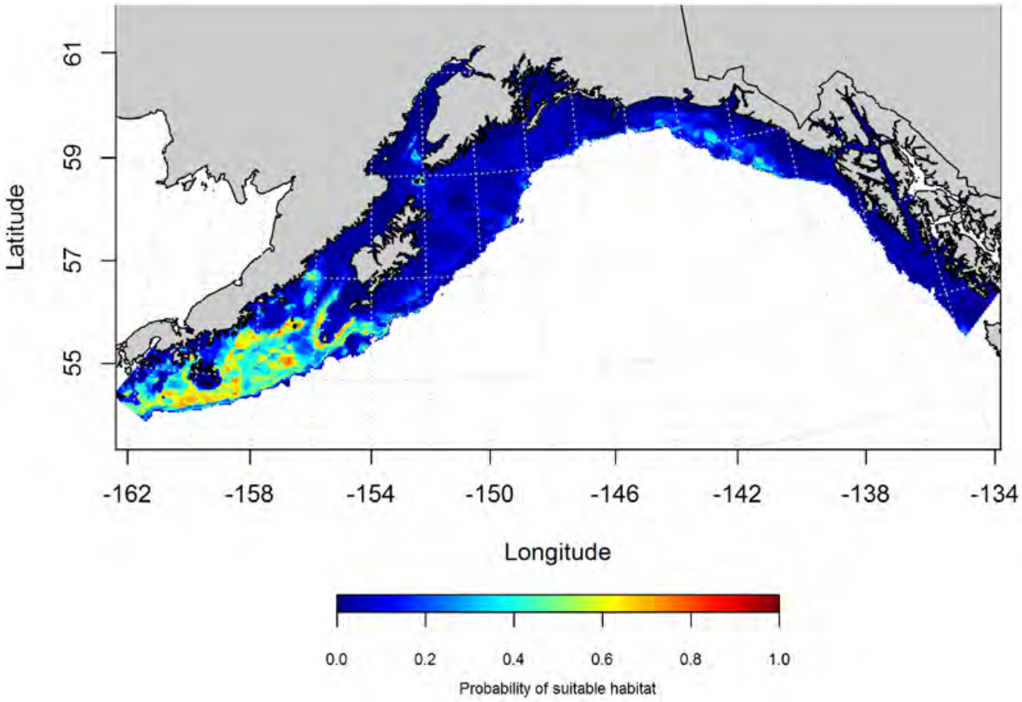


Figure 295. -- Locations of fall (September-November) commercial fisheries catches of *B. aleutica* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *B. aleutica* commercial catches (bottom panel) and the purple points were used to test the model.

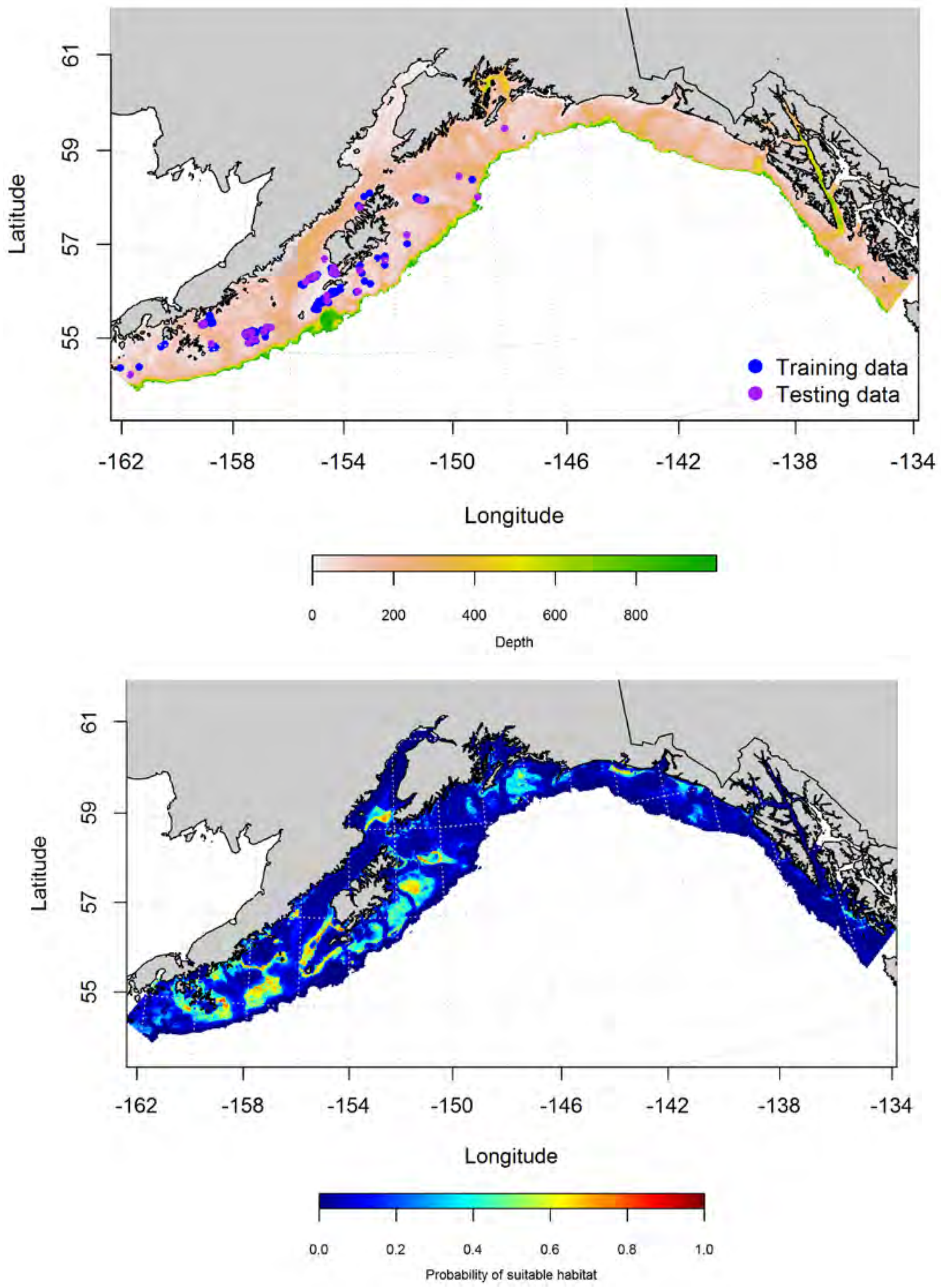


Figure 296. -- Locations of winter (December-February) commercial fisheries catches of *B. aleutica* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *B. aleutica* commercial catches (bottom panel) and the purple points were used to test the model.

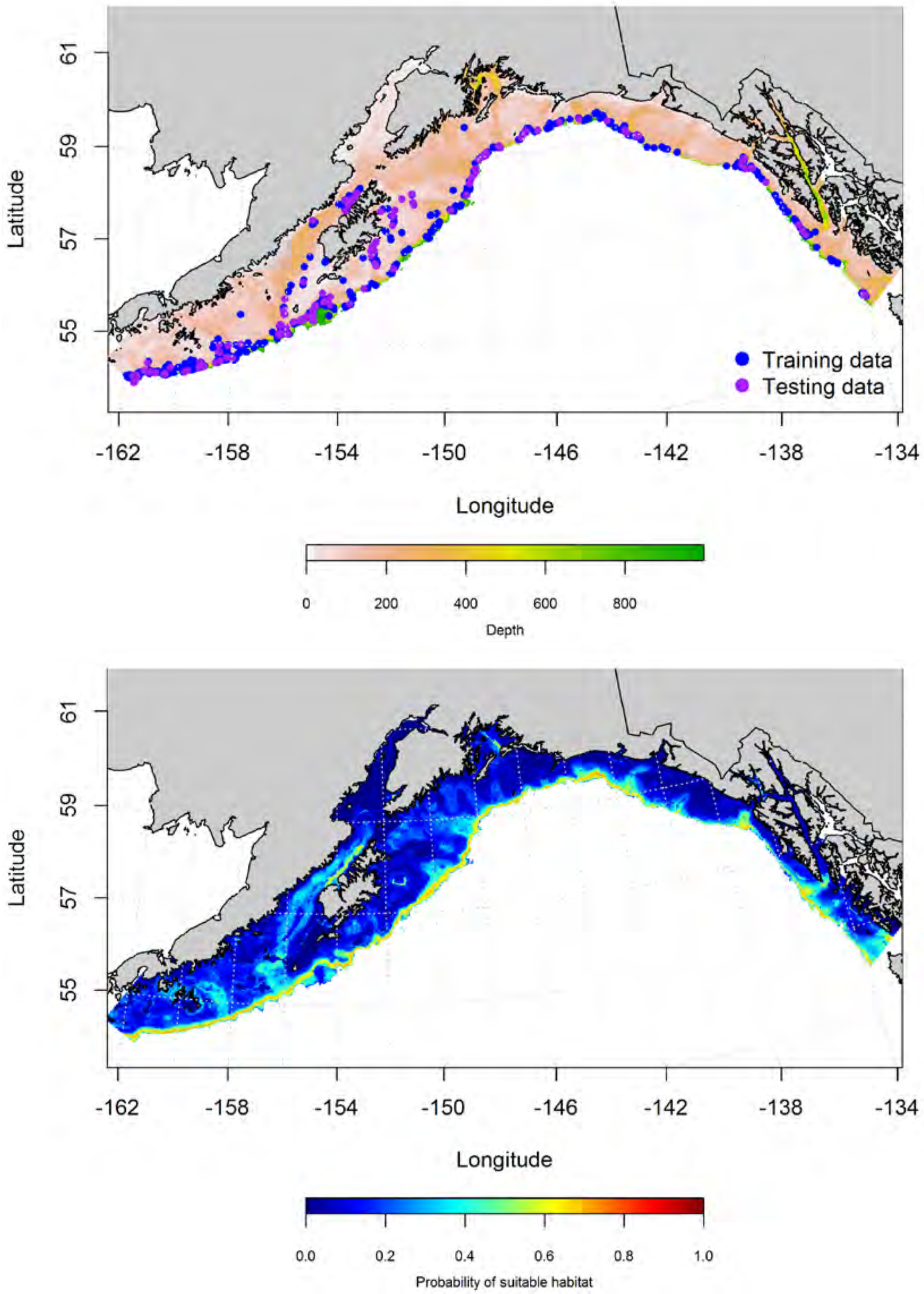


Figure 297. -- Locations of spring (March-May) commercial fisheries catches of *B. aleutica* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *B. aleutica* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *B. aleutica* Essential Fish Habitat Maps and Conclusions -- Summer EFH for juvenile Aleutian skate, based on trawl survey observations, was predicted to primarily occur in Shelikof Strait and Shelikof Gully, as well as along the shelf break in the central and western gulf (Figure 298). EFH for juvenile Aleutian skate was also predicted to occur in Prince William Sound; however, these predictions were not supported by any observations. EFH for adult Aleutian skate was predicted to be more extensive, and to include most of shelf in the GOA.

EFH for adult Aleutian skate in the fall, based on commercial catch data, included middle- and outer-shelf, west of Kodiak Island (Figure 44.8). In the fall, EFH for adult Aleutian skate was predicted to include large portions of the middle-shelf in the western gulf, particularly around the Shumagin Islands, Semidi Bank, and Albatross and Chirikof Banks off Kodiak Island (Figure 299). Localized areas of EFH were also predicted at the entrance of Cook Inlet and Icy Bay; however, these predictions were not supported by any observations. In the spring EFH for adult Aleutian skate was predicted to largely occur along the shelf break across the most of the GOA.

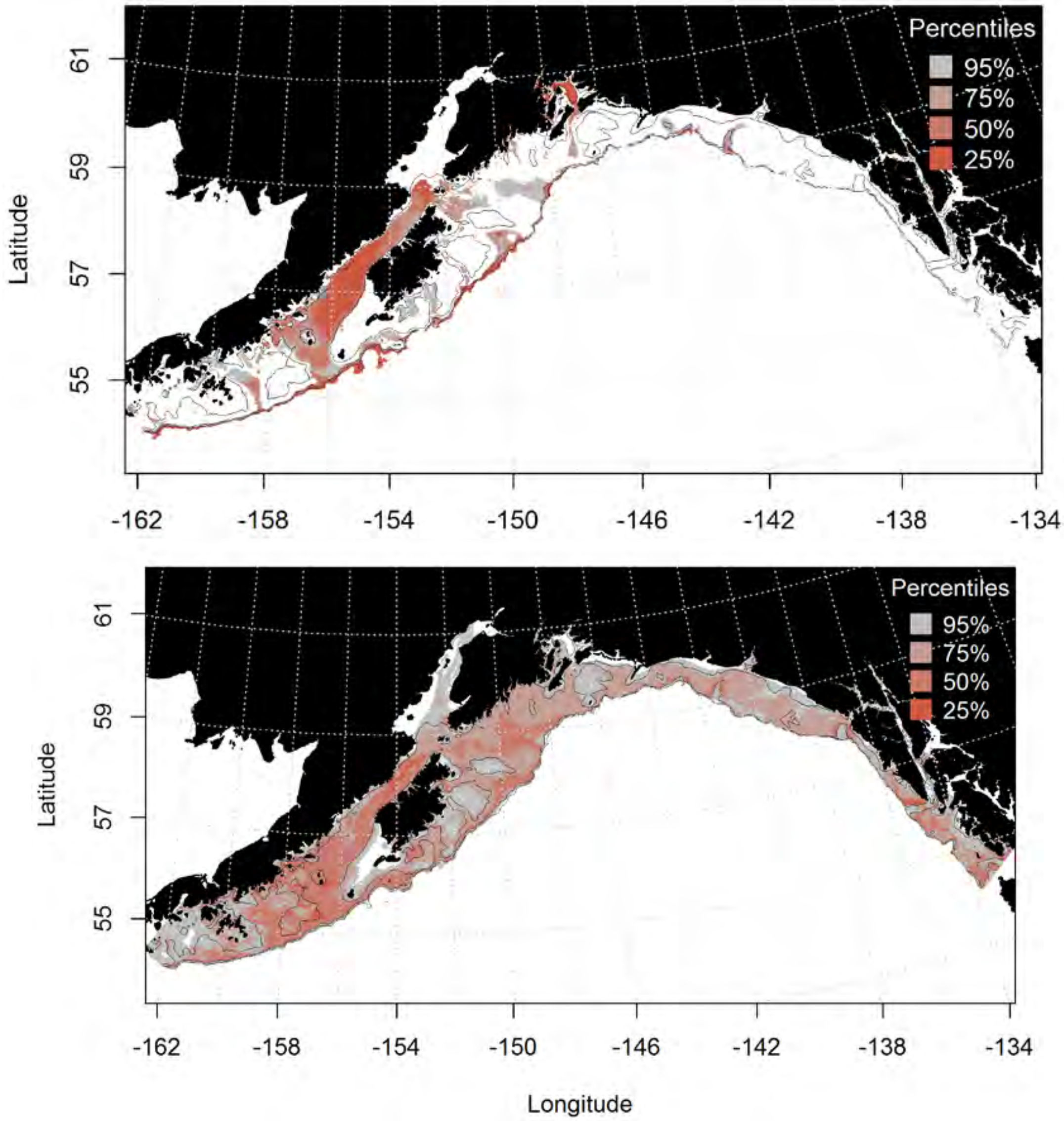


Figure 298. -- Predicted summer essential fish habitat for *B. aleutica* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

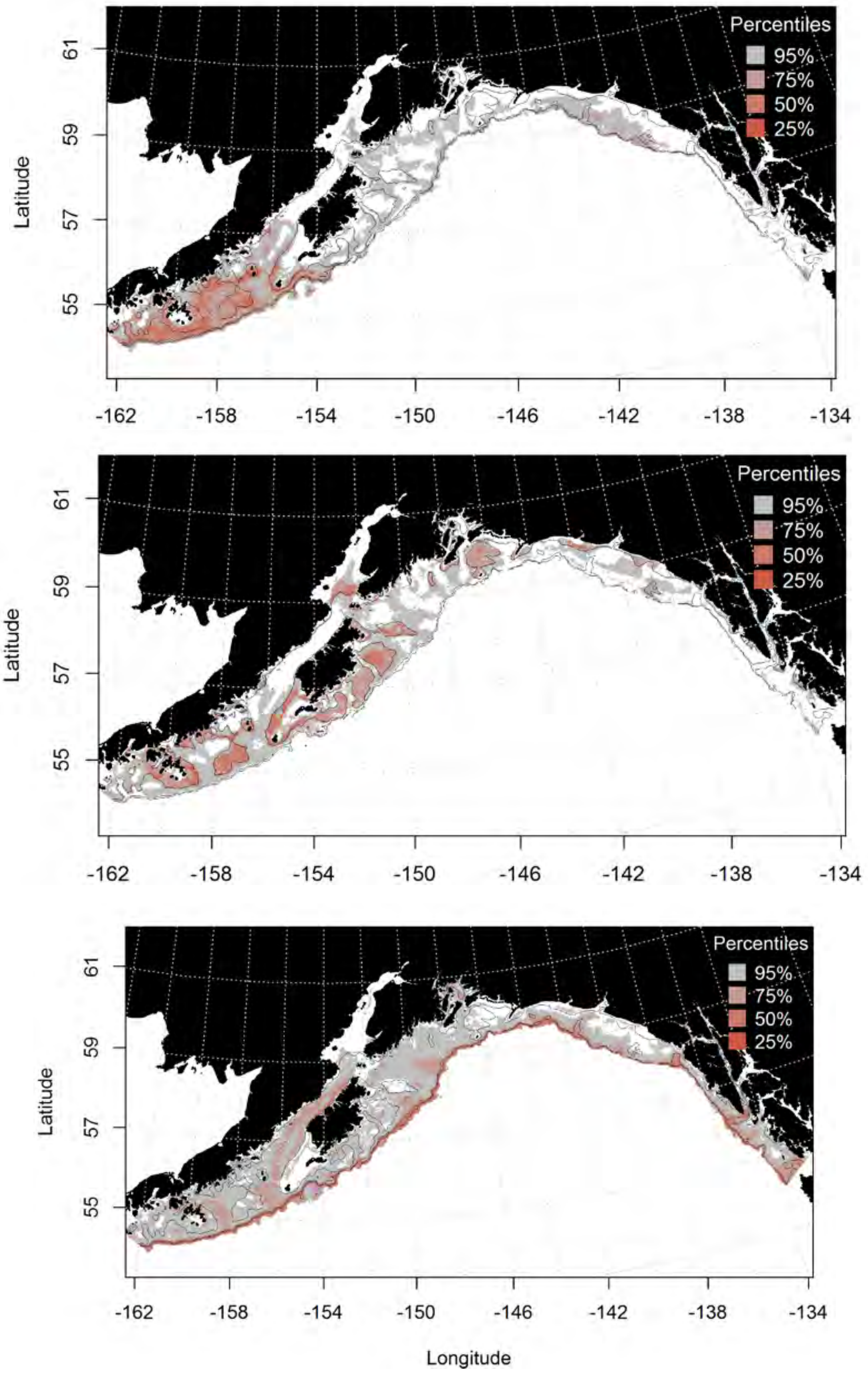


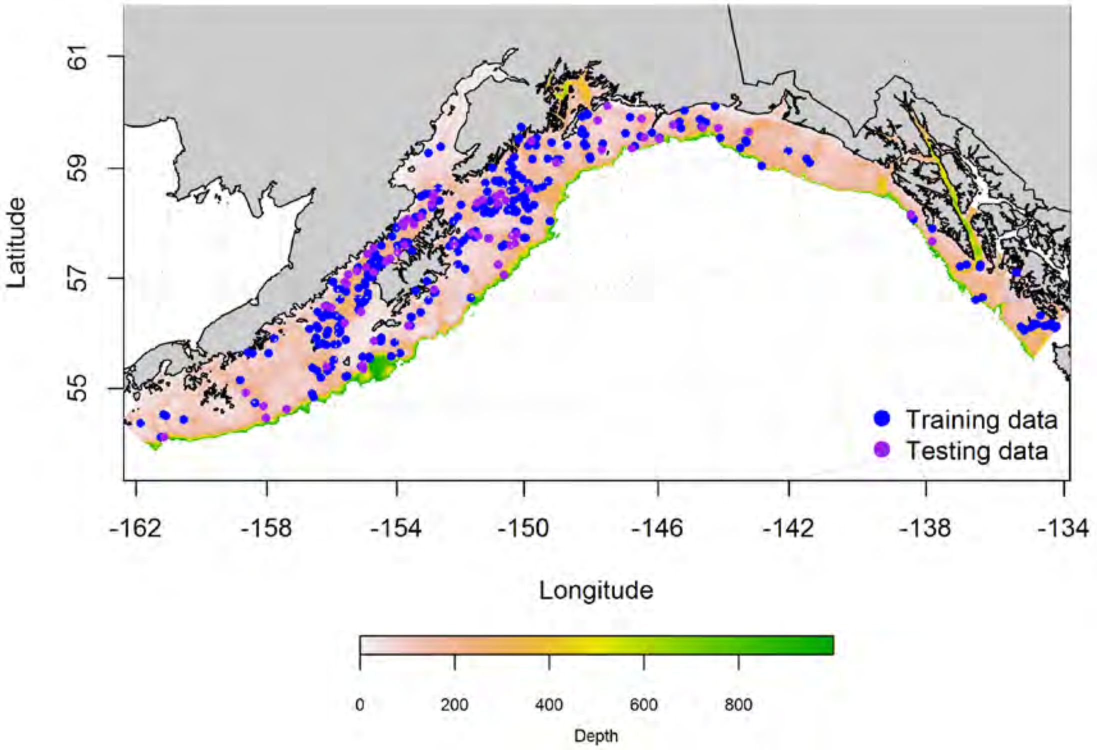
Figure 299. -- Essential fish habitat predicted for *B. aleutica* during fall (top panel), winter (middle panel), and spring (bottom panel) from commercial catches.

Bering skate (*Bathyraja interrupta*)

Bering skate occur in modest numbers throughout much of the Gulf of Alaska. They occur down to 500 m depth, but are most abundant between 101 to 300 m (von Szalay et al. 2010).

Spring and summer distribution of juvenile and adult *B. interrupta* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile bering skate occur over much of the central and western Gulf of Alaska (Figure 300). The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 58.3 and 22.1 respectively). The AUC for the training data was 0.81, indicating a good model fit. The AUC for the testing data was 0.72, indicating a fair model fit. The percent of correctly classified observations was 71% for the training data and 72% for the test data. Juvenile bering skate were predicted to occur in much of the deeper portions of the middle-shelf in the GOA, particularly in around the Sandman Reefs and in Shelikof Strait and Shelikof Gully in the western gulf, Marmot Gully in the central gulf, and off southeast Alaska.

Summer bottom trawl survey data indicate adult Bering skate largely occur in the western gulf. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 47.9 and 25.1 respectively). The AUC for the training data was 0.83, indicating a good model fit. The AUC for the testing data was 0.71, indicating a fair model fit. The percent of correctly classified observations was 75% for the training data and 71% for the test data. Summer habitat for adult bering skate habitat was predicted to occur across much of the shelf in the GOA; particularly in Shelikof Strait and Shelikof Gully, as well as in the vicinity of Portlock Bank (Figure 301). High abundances were also predicted to occur off southeast Alaska; however, these were not supported by any observations.



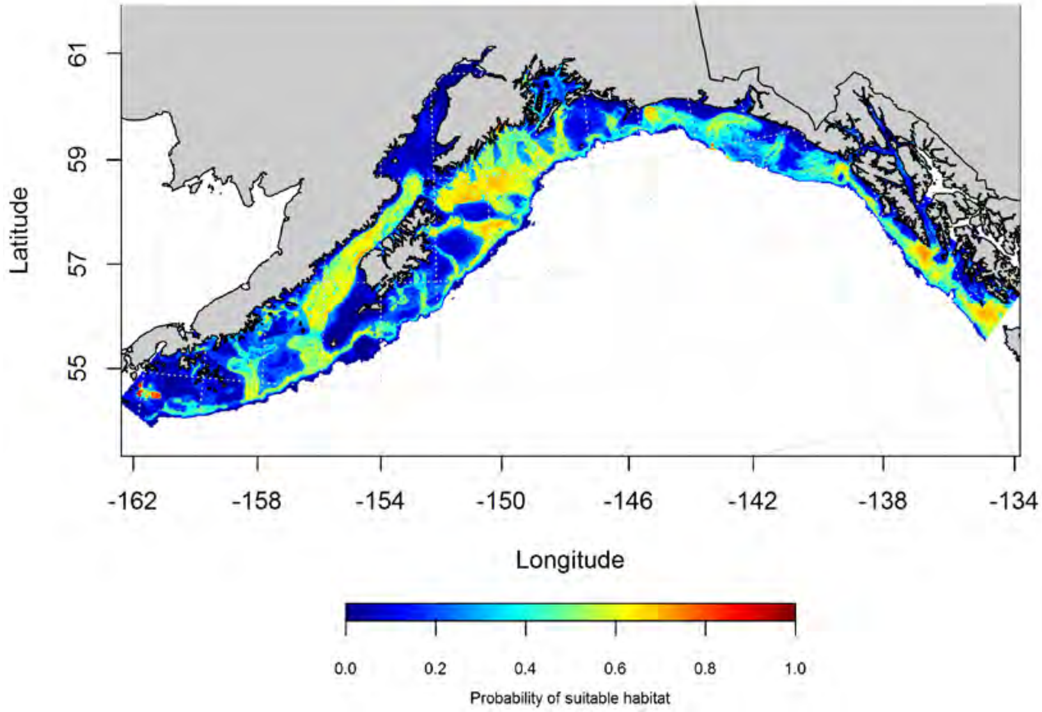
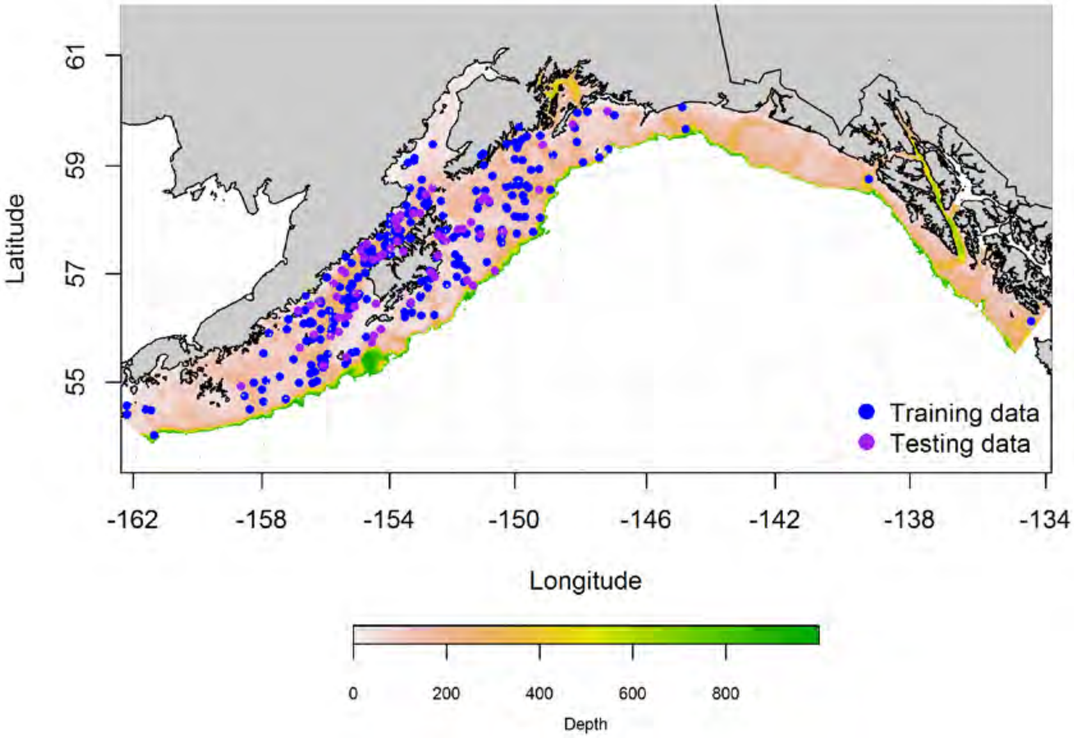


Figure 300. -- Locations of trawl survey catches of juvenile *B. interrupta* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *B. interrupta* based on trawl survey catches (bottom panel) and the purple points were used to test the model.



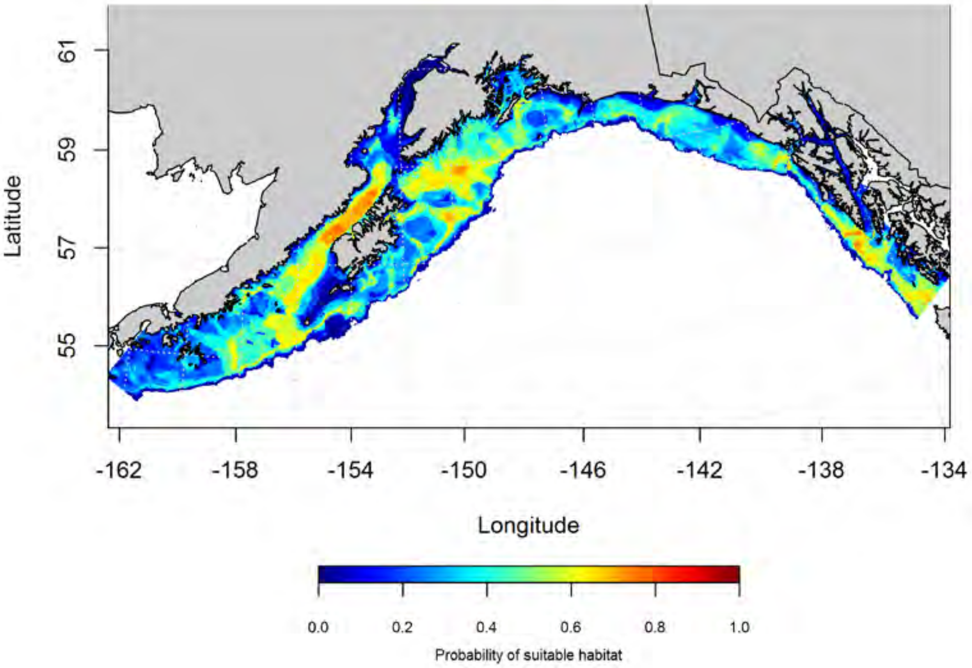


Figure 301. -- Locations of trawl survey catches of adult *B. interrupta* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *B. interrupta* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *B. interrupta* in the Gulf of Alaska -- No observations of Bering skate, from commercial catch data were available.

Gulf of Alaska *B. interrupta* Essential Fish Habitat Maps and Conclusions -- Summer EFH for juvenile Bering skate, based on trawl survey observations, was predicted to include much of the deeper portions of the middle-and outer-shelf in the central and western gulf (Figure 302). Summer EFH for adult Aleutian skate was predicted to be more extensive than that of the juveniles and it was predicted to include most of shelf; particularly in Shelikof Strait and Shelikof Gully as well as in the vicinity of Portlock Bank. EFH habitats for adult Aleutian skate were also predicted to occur off southeast Alaska; however, these were not supported by any observations

EFH for adult Aleutian skate could not be predicted, based on commercial catch data.

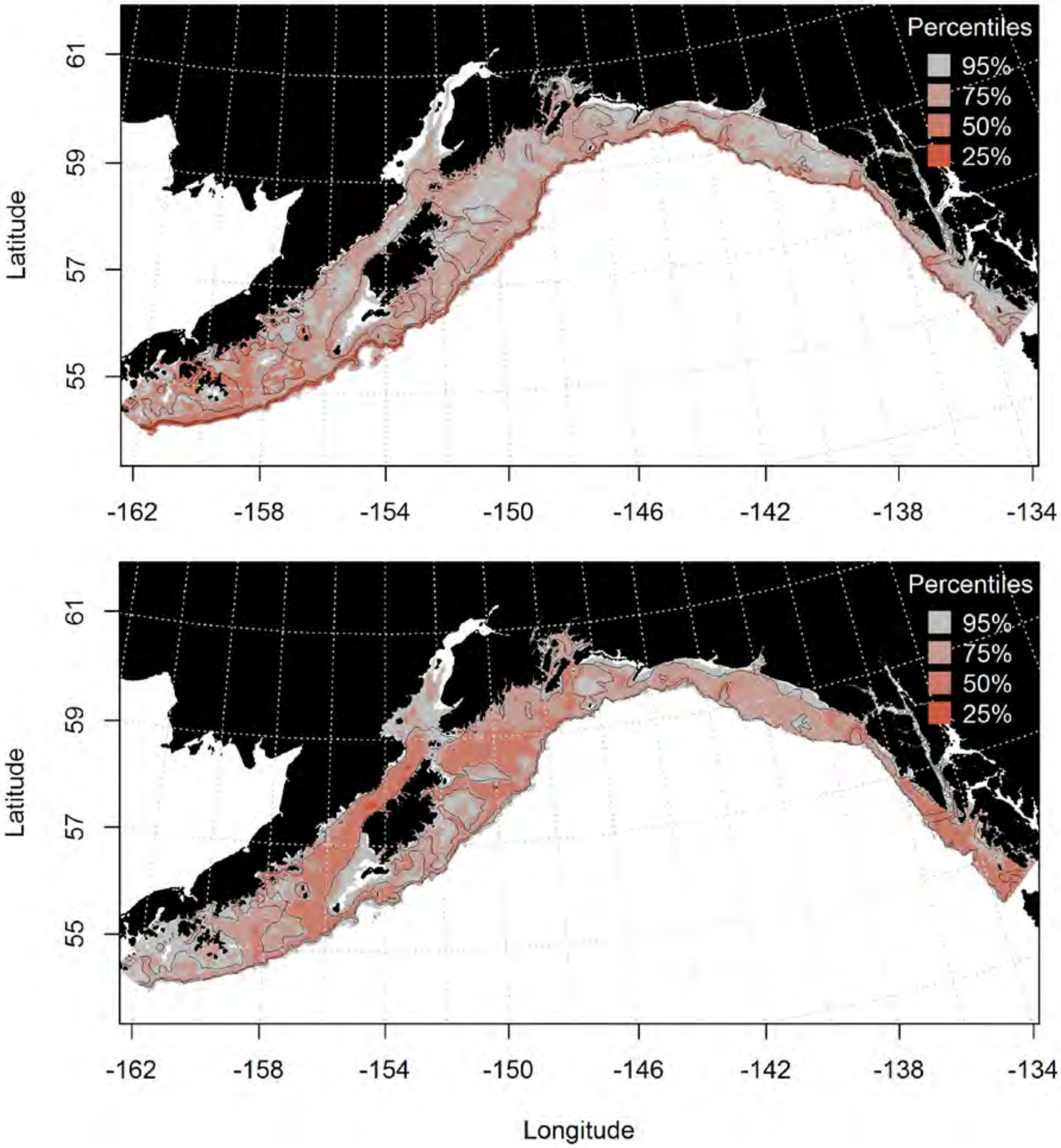


Figure 302. -- Predicted summer essential fish habitat for *B. interrupta* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

Alaska skate (*Bathyraja parmifera*)

Alaska skate are caught infrequently and in modest numbers in in the western Gulf of Alaska. They occur down to 300 m depth, but are most abundant in waters the less than 100 m depth (von Szalay et al. 2010).

Spring and summer distribution of juvenile and adult *B. parmifera* from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate juvenile Alaska skate occur over much of the western Gulf of Alaska. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 57.9 and 17.5 respectively). The AUC for the training data was 0.81, indicating a good model fit. The AUC for the testing data was 0.69, indicating a poor model fit. The percent of correctly classified observations was 78% for the training data and 69% for the test data. Summer habitat for juvenile Alaska skate habitat was predicted to occur across much of the deeper portions of the middle and outer-shelf in the western GOA, particularly in vicinity of the Semidi Island and in Shumagin Gully, as well as off southeast Alaska (Figure 303). A localized hot spot of high suitability habits was also predicted to occur off Cape Ommaney, but this was supported by only a single observations.

Summer bottom trawl survey data also indicate adult Alaska skate largely occur in the western gulf. The best-fitting *MaxEnt* model indicated that depth and current speed were the most important variables predicting habitat suitability (relative importance 49.8 and 36.4 respectively). The AUC for the training data was 0.74, indicating a fair model fit. The AUC for the testing data was 0.5, indicating a model failure. The percent of correctly classified observations was 70% for the training data and 50% for the test data. Summer habitat for adult Alaska skate habitat was predicted to include most of the middle- and outer-shelf in central and western GOA; particularly around the Shumagin Islands and Semidi Bank on the Alaska Peninsula; as well as Albatross and Portlock Bank off Kodiak Island (Figure 304). High abundances were also predicted to occur off southeast Alaska; however, these predictions were not supported by any observations.

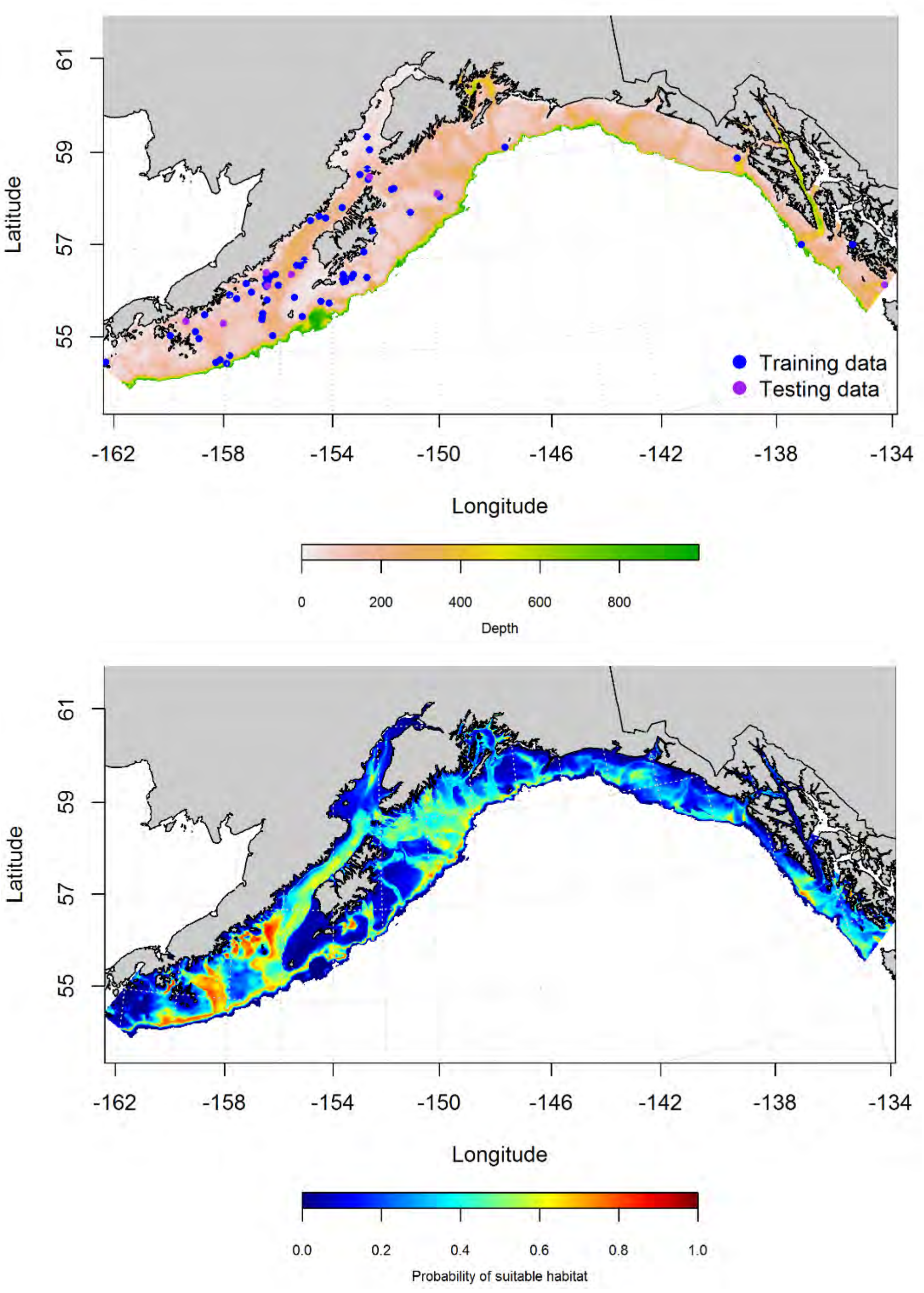


Figure 303. -- Locations of trawl survey catches of juvenile *B. parmifera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of juvenile *B. parmifera* based on trawl survey catches (bottom panel) and the purple points were used to test the model

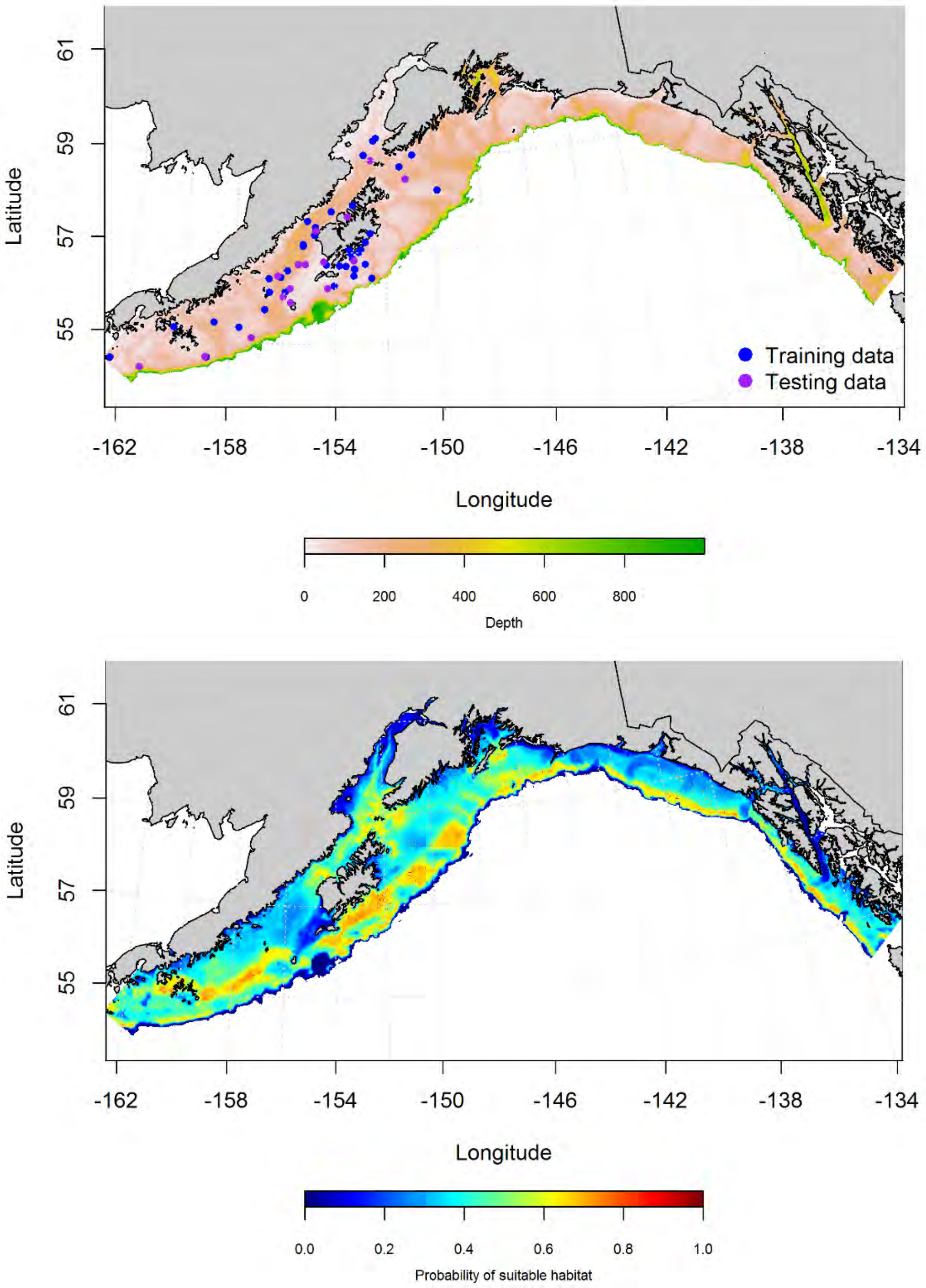
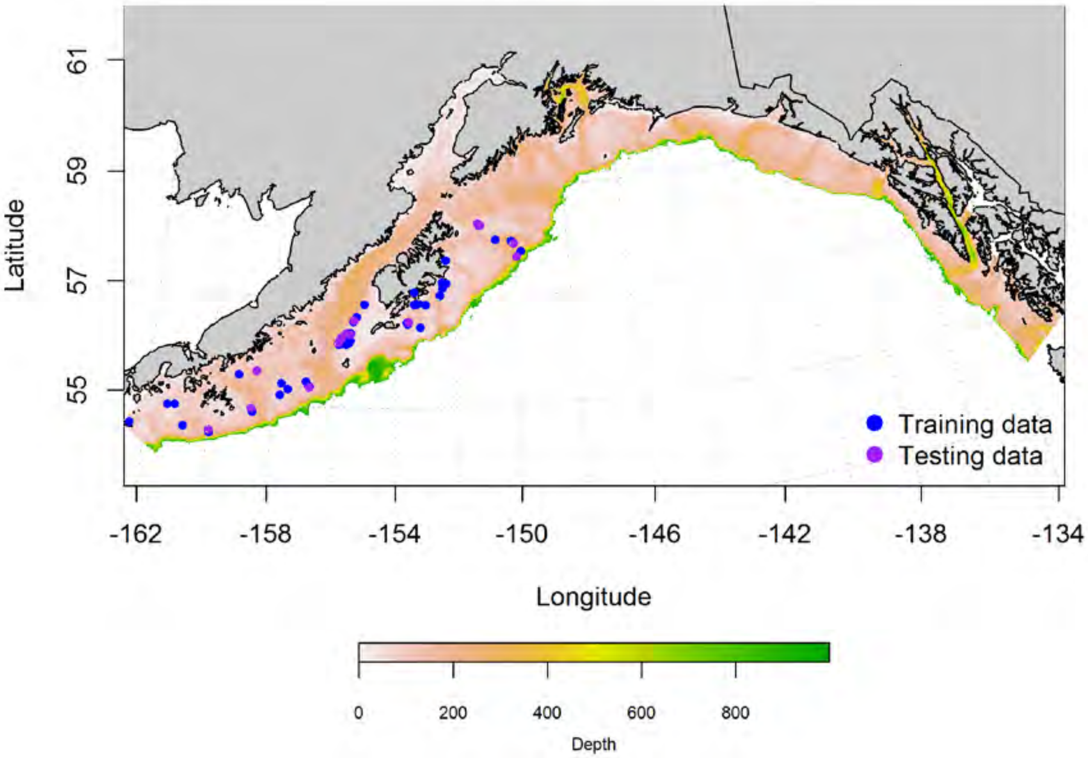


Figure 304. -- Locations of trawl survey catches of adult *B. parmifera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of adult *B. parmifera* based on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *B. parmifera* in the Gulf of Alaska -- Commercial catch data indicate Alaska skate largely occur on the middle- and outer-shelf in the western GOA. In the fall, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of Alaska skate (relative importance = 30.6 and 25.3 respectively). The AUC for the training data 0.83, indicating a good model fit. The AUC for the test data was 0.69, indicating a poor model fit. The percent of observations correctly classified for the training data was 73%, and it was 69% for the test data. In the fall, adult Alaska skate were predicted to largely occur along the edge of Chirikof Bank, west of Kodiak Island, and to a lesser extent on Albatross and Semidi Banks (Figure 305). There were also several localized hot spots along the Alaska Peninsula and the Barren Islands, between Kodiak and the Kenai Peninsula; these predictions were not supported by any observations.

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of Alaska skate (relative importance = 42.3 and 30.3 respectively). The AUC was 0.93 for the training data, indicating an excellent model fit. The AUC for the test data was 0.80, indicating a good model fit. The percent of observations correctly classified was 85% and 80% respectively, for the training and test data. In the winter, adult Alaska skate were predicted to occur along the edge of Chirikof Bank, west of Kodiak Island, and to a lesser extent on Albatross and Semidi Banks (Figure 306). There were also several localized hot spots along the Alaska Peninsula and the Barren Islands between Kodiak and the Kenai Peninsula; these were not supported by any observations.

In the spring, *MaxEnt* modeling determined that current speed and depth were the most important variables determining the distribution of Alaska skate (relative importance = 40.6 and 30.3 respectively). The AUC was 0.91 for the training data, indicating an excellent model fit. The AUC for the test data was 0.75, indicating a fair model fit. The percent of observations correctly classified was 84% for the training and 75% for testing data. In the spring, adult Alaska skate were predicted to occur in similar habitats as the juveniles, including Chirikof, Albatross and Semidi Banks (Figure 307). As with the juveniles, there were also localized areas of high suitability predicted to occur along the Alaska Peninsula and the Barren Islands; however, these predictions were not supported by any observations.



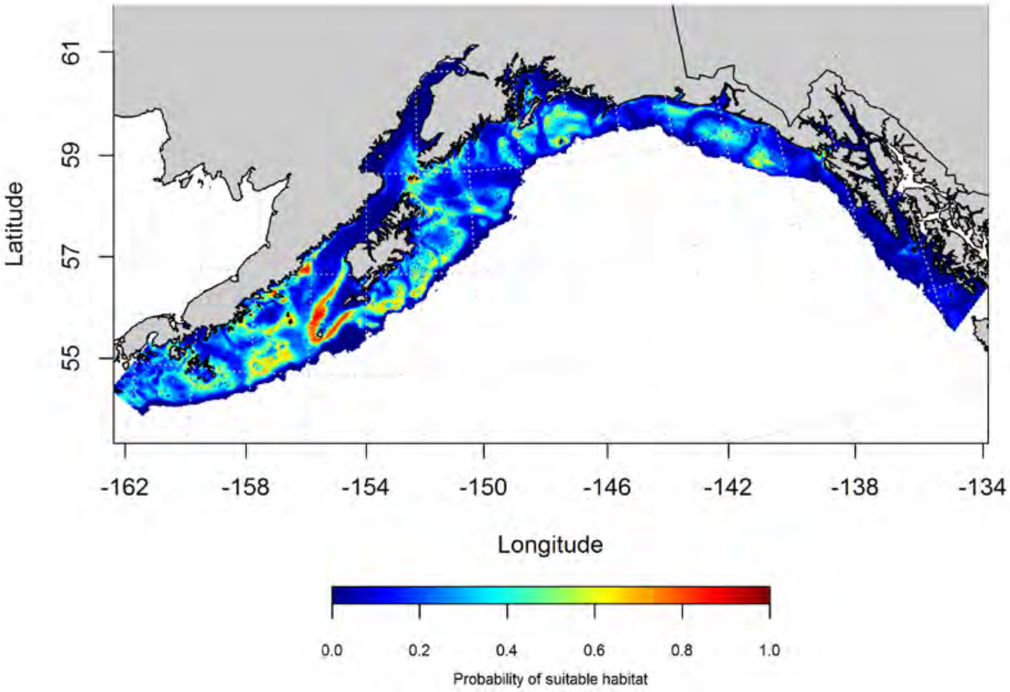


Figure 305. -- Locations of fall (September-November) commercial fisheries catches of *B. parmifera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *B. parmifera* commercial catches (bottom panel) and the purple points were used to test the model.

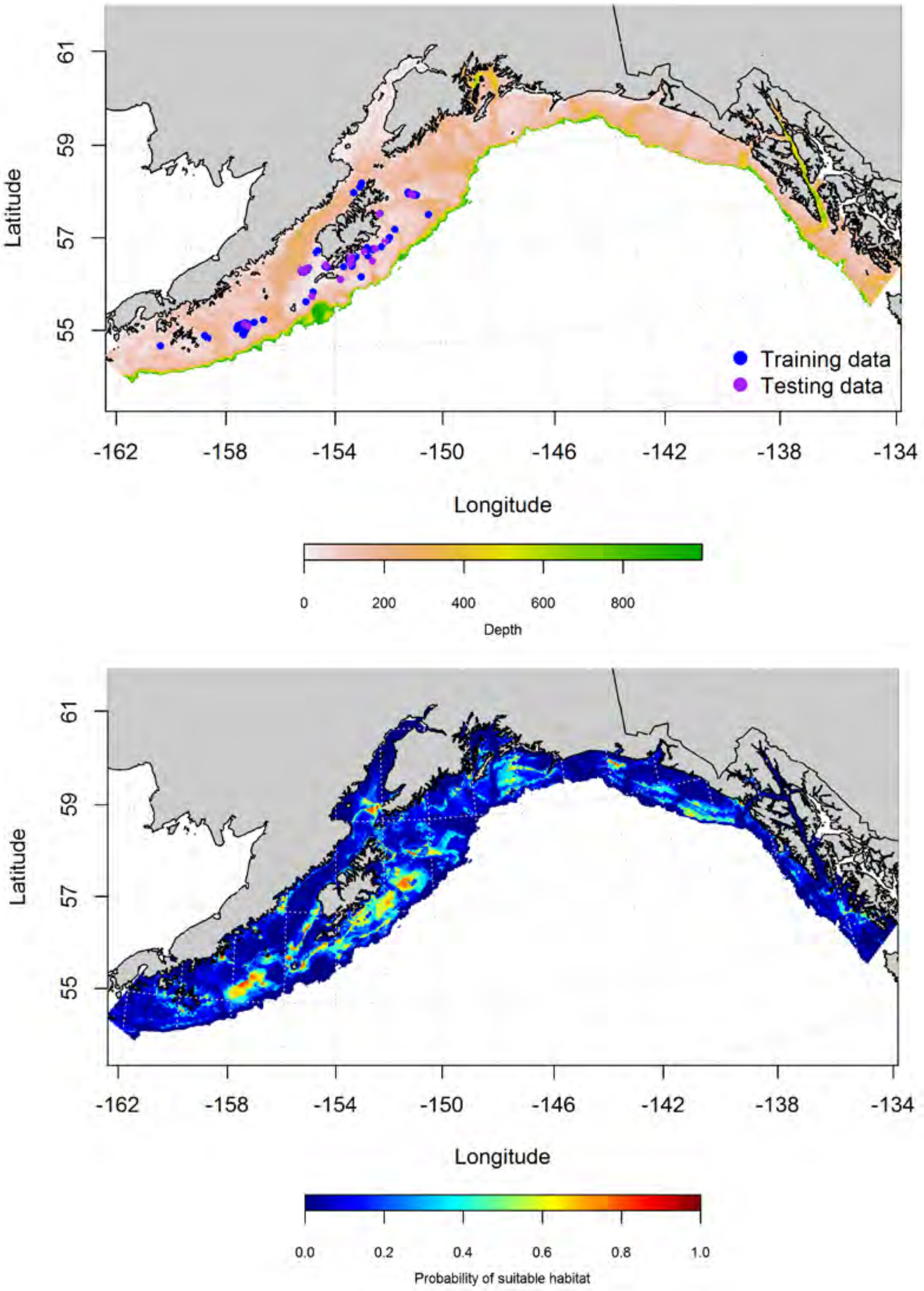


Figure 306. -- Locations of winter (December-February) commercial fisheries catches of *B. parmifera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *B. parmifera* commercial catches (bottom panel) and the purple points were used to test the model.

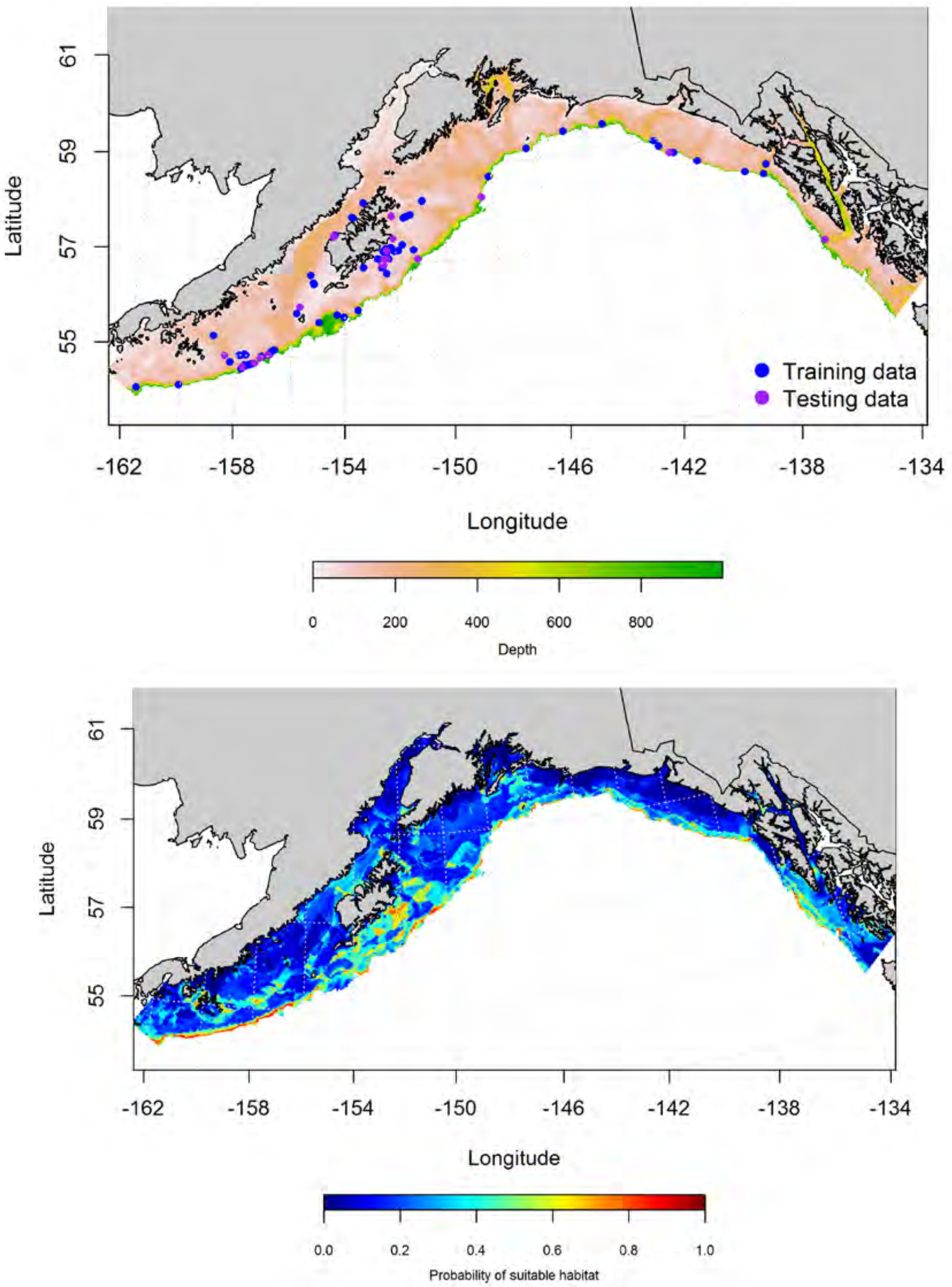


Figure 307. -- Locations of spring (March-May) commercial fisheries catches of *B. parmifera* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *B. parmifera* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *B. parmifera* Essential Fish Habitat Maps and Conclusions -- Summer EFH for juvenile Alaska skate, based on trawl survey observations, was predicted to include much of the deeper portions of the middle and outer-shelf in the western GOA. EFH habitats were also predicted to occur across much of the middle and outer-shelf in the central and eastern gulf; however, this was not supported by any observations (Figure 308). Summer EFH for adult Alaska skate was also predicted to include most of shelf in the western gulf, particular the outer-shelf. EFH habitats were also predicted to occur in the central and eastern gulf; however, these predictions were not supported by any observations.

Fall EFH for adult Alaska skate, based on commercial catch data, was predicted to occur across large portion of the middle-shelf in the western gulf, including Chirikof Bank, and to a lesser extent Albatross and Semidi Banks (Figure 309). EFH habitats were also predicted to occur off the central and eastern gulf; however, these predictions were not supported by any observations. Winter EFH for adult Aleutian skate was predicted to be more restricted, and largely occur around Kodiak Island including Semidi, Chirikof, and Albatross Banks. In the spring EFH for Alaska skate was predicted to largely occur along the shelf break and on Albatross Bank in the western gulf. EFH habitats were also predicted to occur in the central and eastern gulf; however, these predictions were not supported by any observations.

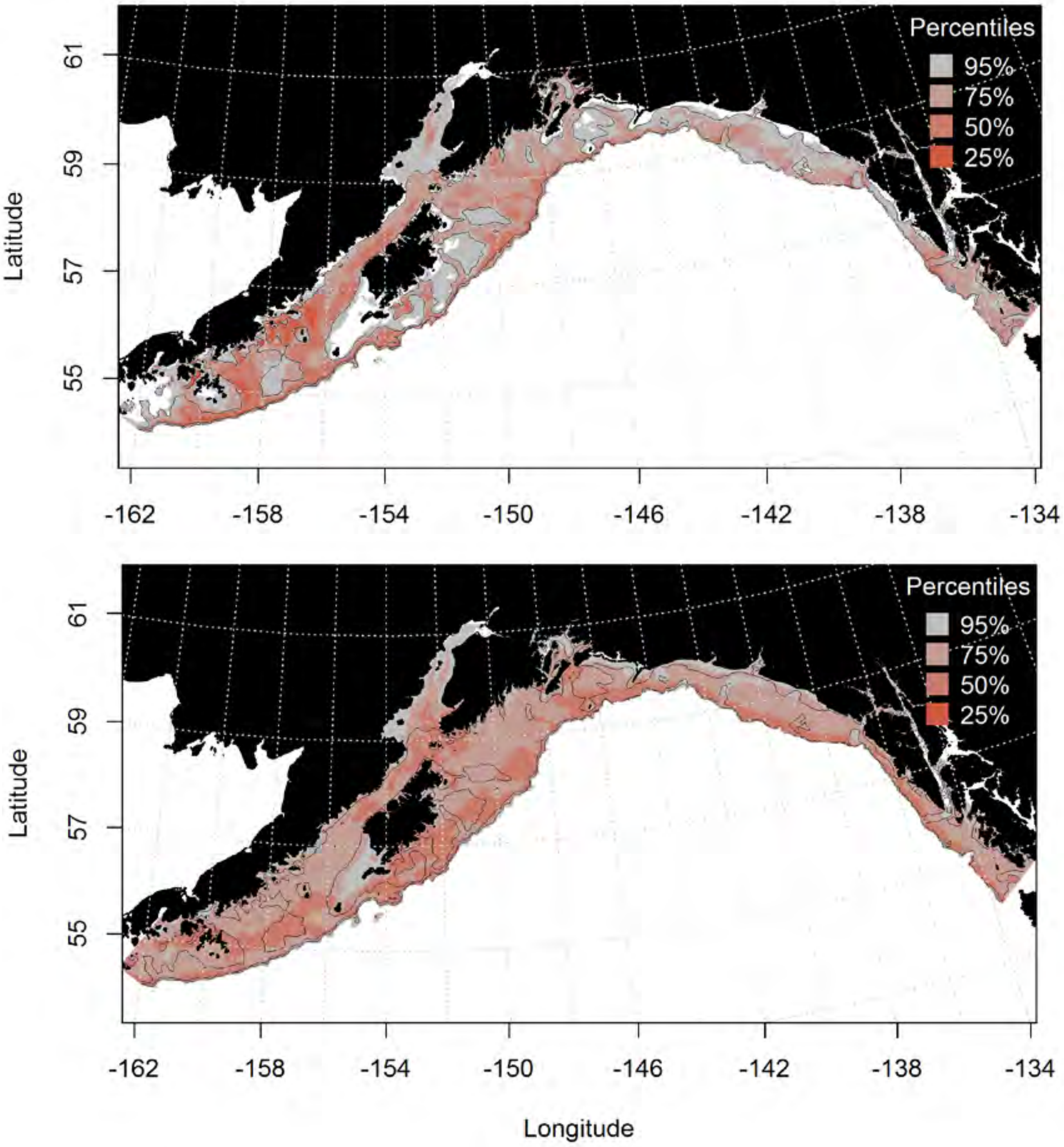


Figure 308. -- Predicted summer essential fish habitat for *B. parmifera* juveniles and adults (top and bottom panel, respectively) from summer bottom trawl surveys.

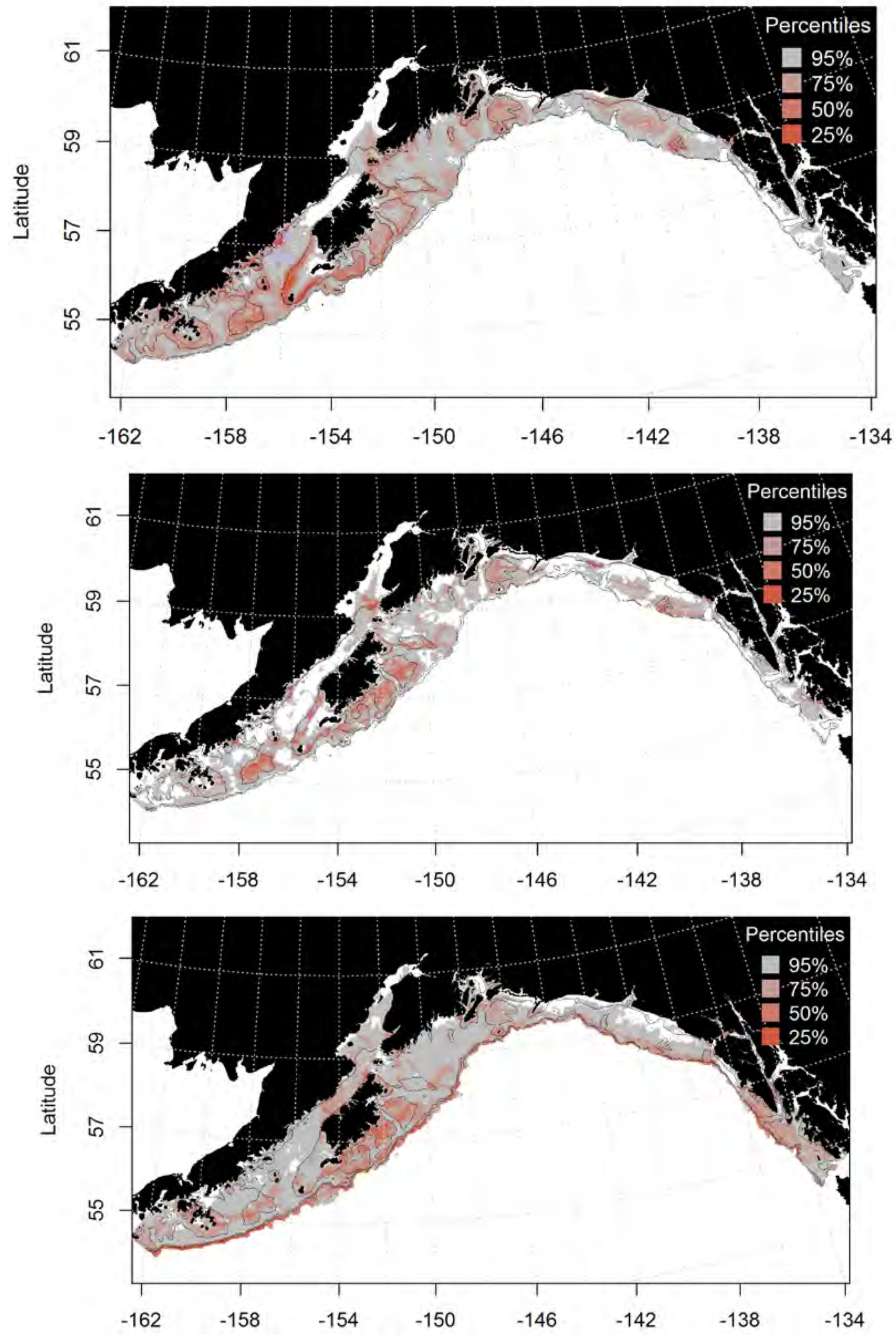


Figure 309. -- Essential fish habitat predicted for *B. parmifera* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches.

Invertebrates

Red king crab (*Paralithodes camtschaticus*) possibly cut due to limited data?

Red king crabs occur throughout much of the Gulf of Alaska, at are found at depths from 31-360 m (Stevens & Lovrish 2014).

Spring and summer distribution of juvenile and adult *P. camtschaticus* from bottom trawl surveys of the Gulf of Alaska -- There were only eighteen observations of red king crab during the summer bottom trawl survey in the Gulf of Alaska. Most occurred in the western gulf around Kodiak Island and the entrance to Cook Inlet, ranging in distribution from nearshore waters to along the outer shelf (Figure 310). There was insufficient data to model the distribution of snow crab based on summer trawl survey observations.

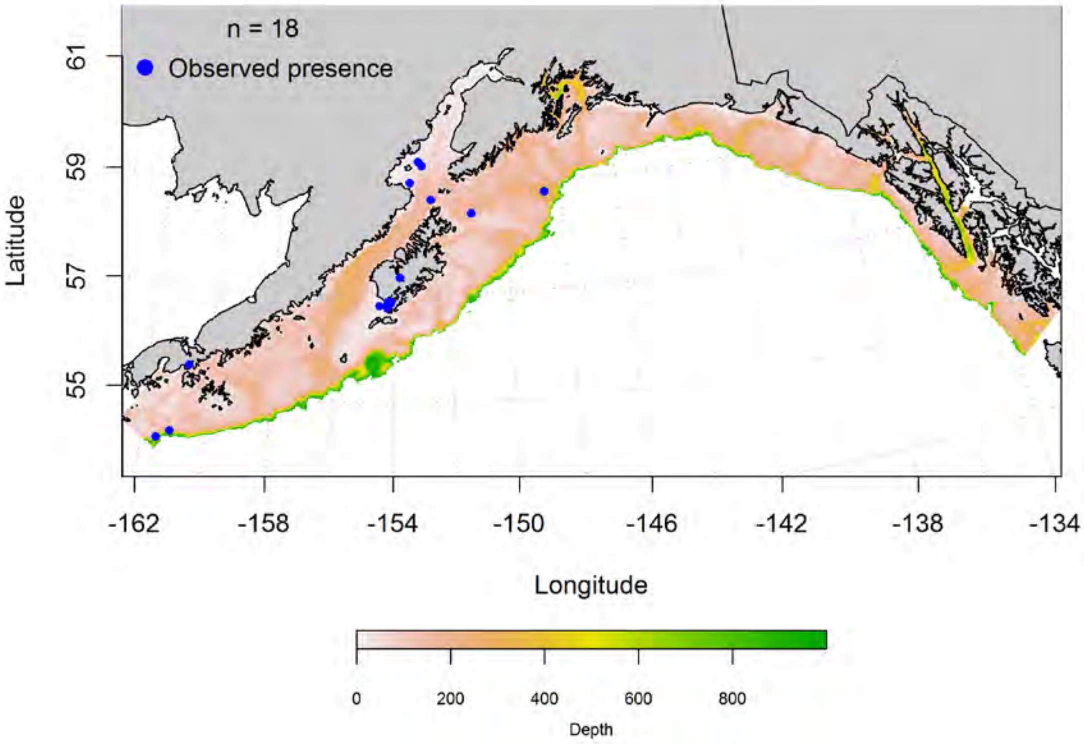


Figure 310. -- Locations of catches of *P. camtschaticus* all life history stages combined from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of adult *P. camtschaticus* in the Gulf of Alaska -- There were no observations of red king crab available from commercial catch data.

Gulf of Alaska *P. camtschaticus* Essential Fish Habitat Maps and Conclusions -- There was insufficient data to model the EFH for red king crab.

Golden king crab (*Lithodes aequispinus*) Possibly cut?

Golden king crab are found throughout much of the Gulf of Alaska, they occur at depth from 73-1,200 m (Stevens & Lovrish 2014).

Seasonal distribution of early life stages of *L. aequispinus* in the Gulf of Alaska -- No observations of golden king crab occurred in the EcoFOCI database.

Spring and summer distribution of *L. aequispinus* from bottom trawl surveys of the Gulf of Alaska -- There were only sixty-four observations of golden king crab during the summer bottom trawl survey in the Gulf of Alaska. Most occurred in the central and western gulf along the outer-shelf and in Shelikof Gully (Figure 311). There was insufficient data to model the distribution of snow crab based on summer trawl survey observations.

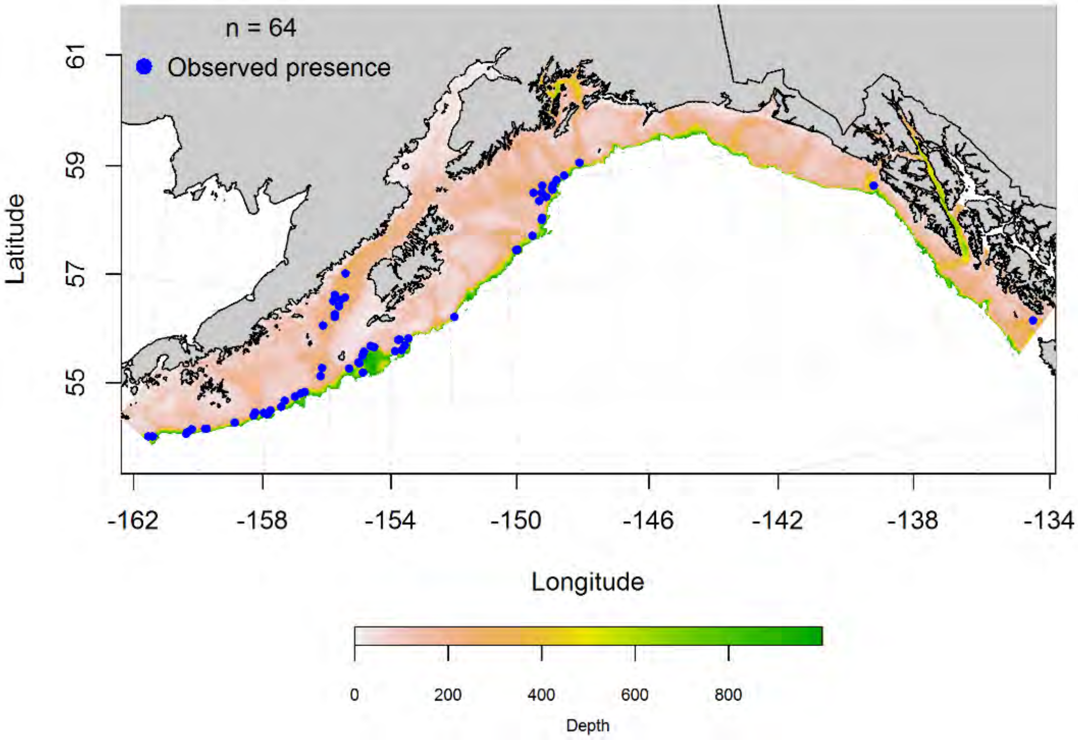


Figure 311. -- Locations of catches of *L. aequispinus* all life history stages combined from summer bottom trawl surveys of the Gulf of Alaska.

Seasonal distribution of commercial fisheries catches of *L. aequispinus* in the Gulf of Alaska -- There were no observations of golden king crab available from commercial catch data.

Gulf of Alaska *L. aequispinus* Essential Fish Habitat Maps and Conclusions -- There was insufficient data to model the EFH for golden king crab.

Octopus unidentified

Commercial fisheries observers do not identify octopus in commercial catches to species. The most common species in RACE summer bottom trawl surveys in this region is Pacific giant octopus (*Enteroctopus dofleini*). Unidentified octopus occur throughout much of the Gulf of Alaska, but are caught more frequently in the central and western GOA. The majority of octopus caught in pots occurred between 70-110 meters depth; while catches from longline vessels tended to occur deeper, 360-730 m depth (NPFMC 2014).

Spring and summer distribution of unidentified octopus for all life stages combined from bottom trawl surveys of the Gulf of Alaska -- Summer bottom trawl survey data indicate octopus occur over much of the Gulf of Alaska, particularly the central and western gulf. The best-fitting *MaxEnt* model indicated that depth and temperature were the most important variables predicting habitat suitability (relative importance 30.3 and 29.4 respectively). The AUC for the training data was 0.81, indicating a good model fit. The AUC for the testing data was 0.72, indicating a fair model fit. The percent of correctly classified observations was 71% for the training data and 72% for the test data. Giant pacific octopus were predicted to occur across much of the outer-shelf in the central and western GOA, particularly along the shelf break and in the vicinity of the Shumagin Islands (Figure 312).

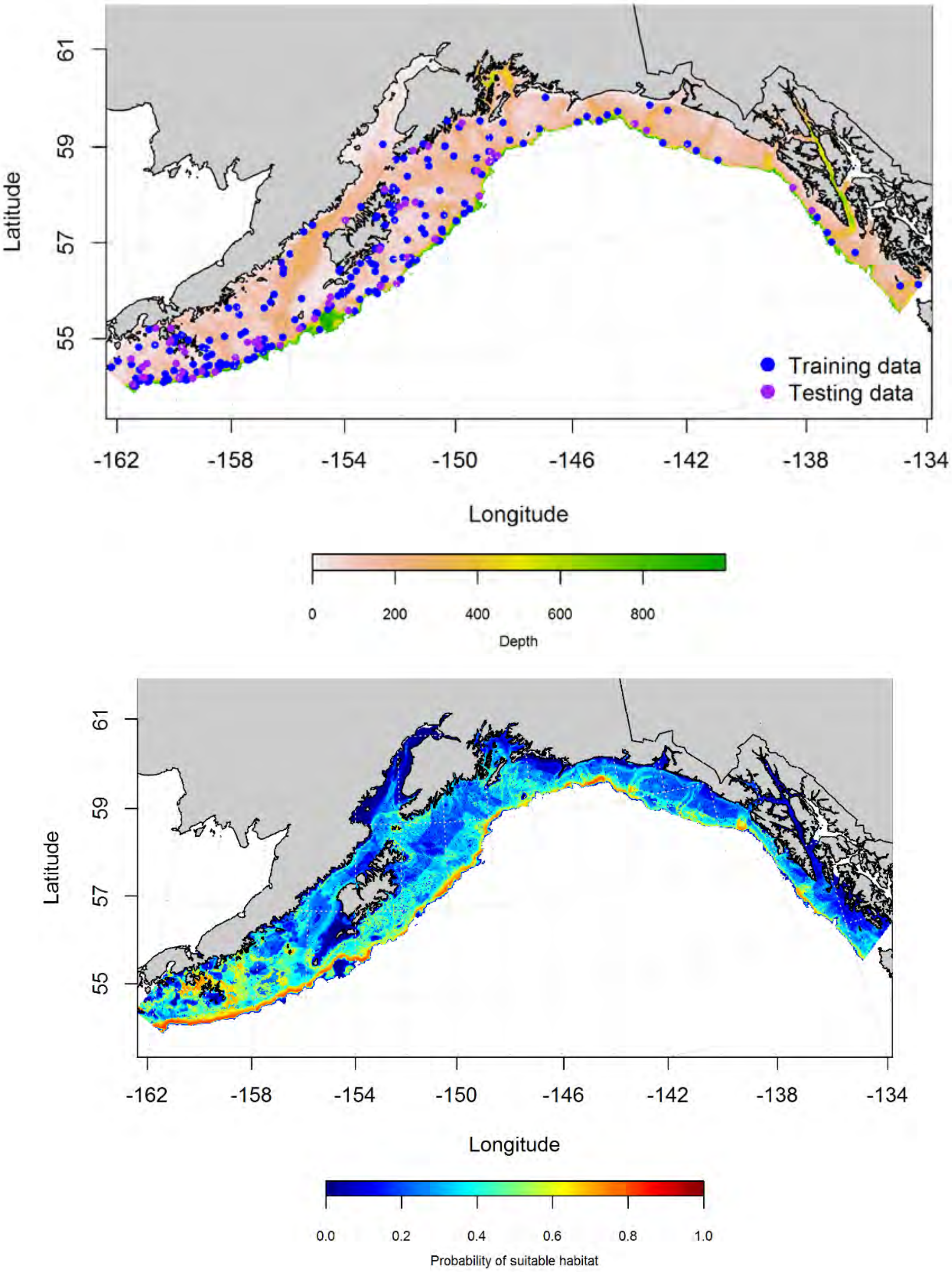


Figure 312. -- Locations of trawl survey catches of *E. dofleini* for all life stages combined (top panel). Blue points were used to train the maximum entropy model predicting the probability of the distribution of *E. dofleini* based for all life stages combined on trawl survey catches (bottom panel) and the purple points were used to test the model.

Seasonal distribution of commercial fisheries catches of adult *E. dofleini* in the Gulf of Alaska -- Commercial catch data indicates that giant pacific octopus largely occur in western Gulf of Alaska. In the fall, *MaxEnt* modeling determined that current speed and depth were the most important variables predicting the distribution of giant pacific octopus (relative importance = 42.7 and 40.0 respectively). The AUC for the training data 0.84, indicating a good model fit. The AUC for the test data was 0.71, indicating a fair model fit. The percent of observations correctly classified for the training data was 81%, and it was 71% for the test data. In the fall, giant pacific octopus was predicted to occur over large portions of the shelf, particularly in the central and western gulf (Figure 313). High suitability habitat was also predicted to occur off southeast Alaska; however, these predictions were not supported by any observations.

In the winter, *MaxEnt* modeling determined that depth and current speed were the most important variables predicting the distribution of giant pacific octopus (relative importance = 49.1 and 20.0 respectively). The AUC was 0.92 for the training data, indicating an excellent model fit. The AUC for the test data was 0.84, indicating a good model fit. The percent of observations correctly classified was 84%, for both the training and test data. In the winter, giant pacific octopus were predicted to largely occur around Kodiak Island, and to a lesser extent around the Shumagin Islands (Figure 314). High suitability habitat was also predicted at the entrance to Prince William Sound; however, these predictions were not supported by any observations.

In the spring, *MaxEnt* modeling determined that depth and tidal current were the most important variables predicting the distribution of giant pacific octopus (relative importance = 39.6 and 20.1

respectively). The AUC was 0.88 for the training data, indicating a good model fit. The AUC for the test data was 0.74, indicating a fair model fit. The percent of observations correctly classified was 86% and 80% respectively, for the training and test data. In the spring, the habitat with the highest predicted suitability for giant pacific octopus largely occurred along the shelf break (Figure 315).

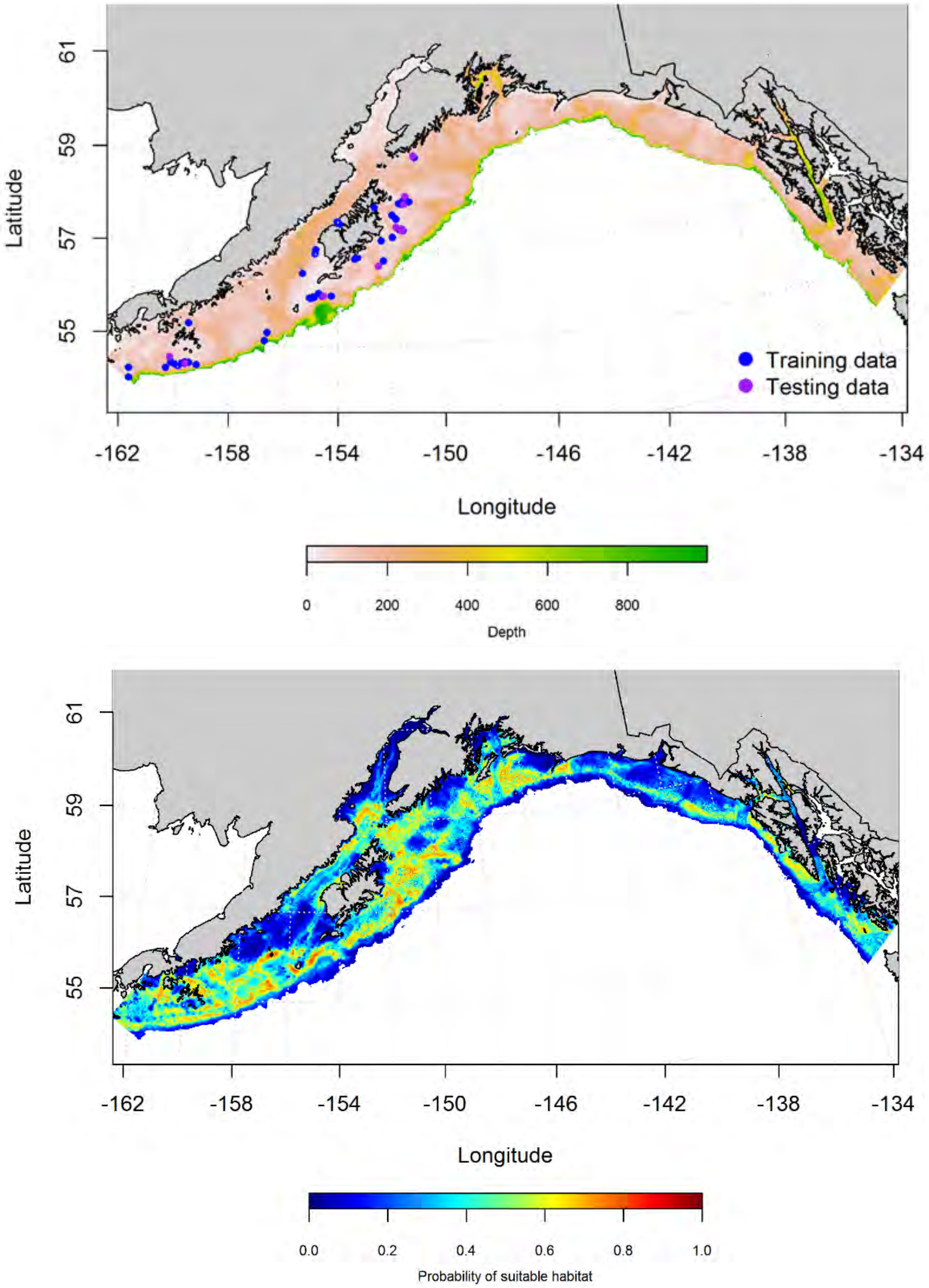


Figure 313. -- Locations of fall (September-November) commercial fisheries catches of *E. dofleini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the fall distribution of *E. dofleini* commercial catches (bottom panel) and the purple points were used to test the model.

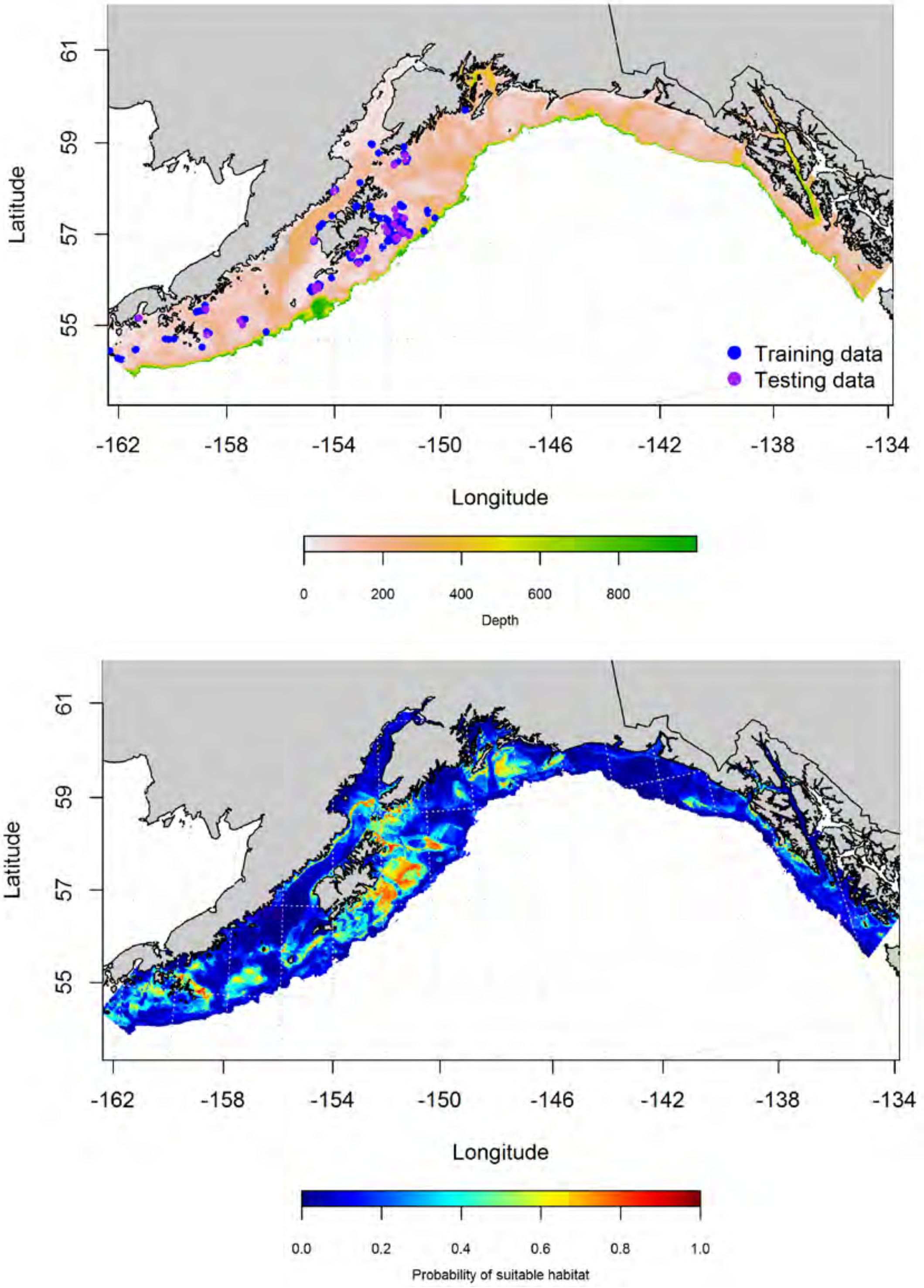
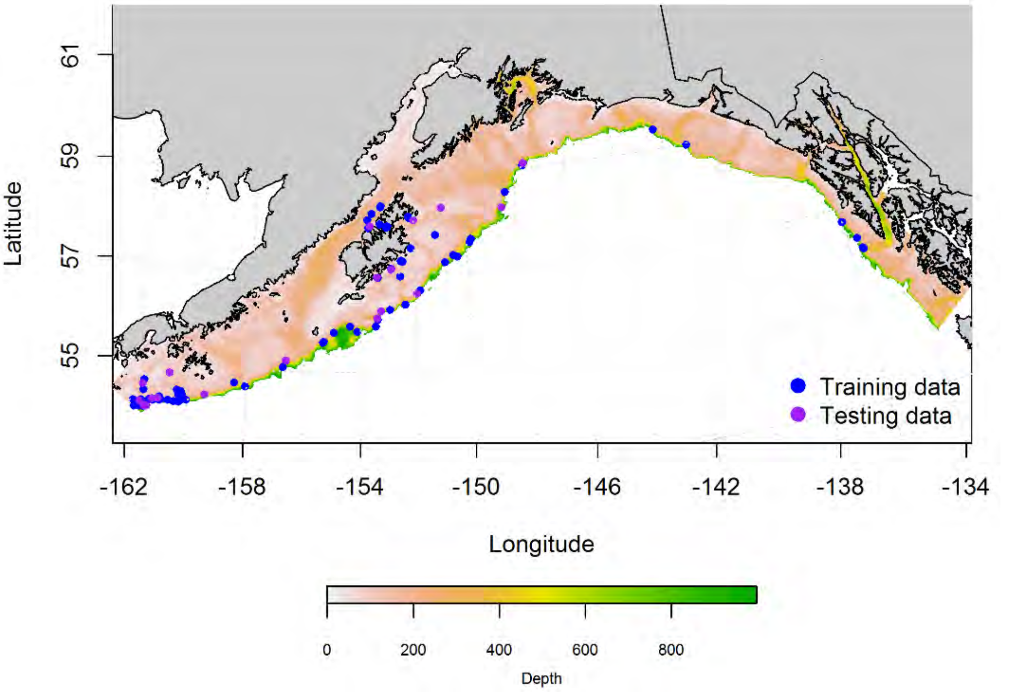


Figure 314. -- Locations of winter (December-February) commercial fisheries catches of *E. dofleini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the winter distribution of *E. dofleini* commercial catches (bottom panel) and the purple points were used to test the model.



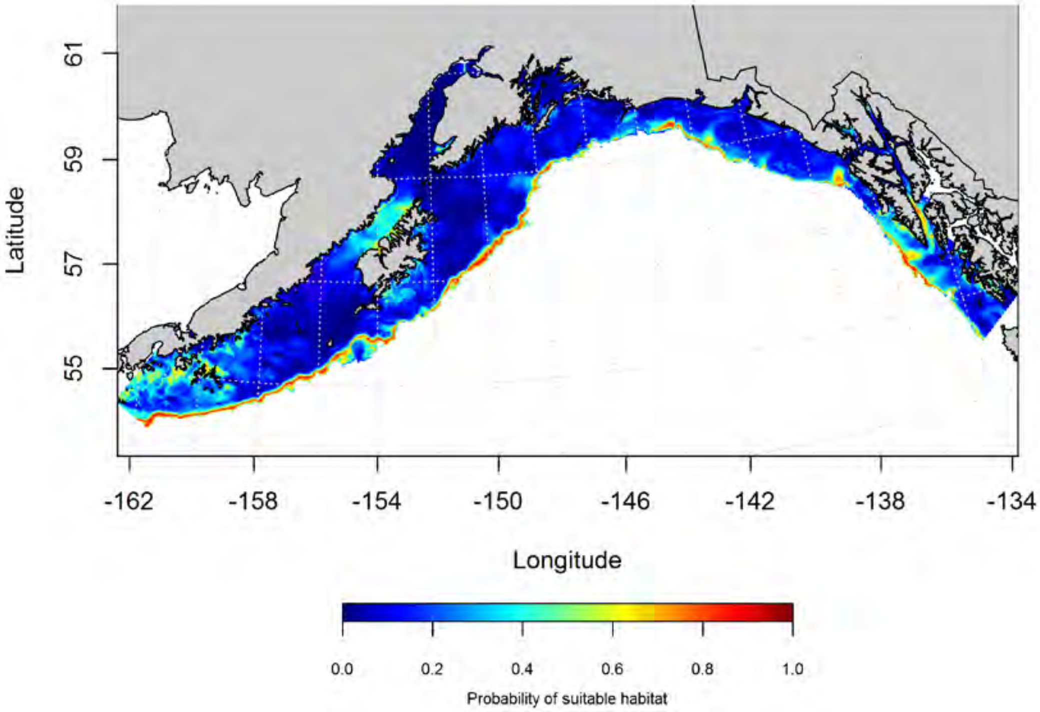


Figure 315. -- Locations of spring (March-May) commercial fisheries catches of *E. dofleini* (top panel). Blue points were used to train the maximum entropy model predicting the probability of the spring distribution of *E. dofleini* commercial catches (bottom panel) and the purple points were used to test the model.

Gulf of Alaska *E. dofleini* Essential Fish Habitat Maps and Conclusions -- Summer essential fish habitat for giant Pacific octopus, based on trawl survey observations, was predicted to occur over most of the shelf, particularly in the central and western gulf (Figure 316).

Fall EFH for giant Pacific octopus, based on commercial catch data, was predicted to most the shelf, particularly along the shelf break in the central and western gulf (Figure 317). Fall EFH was also predicted to occur off southeast Alaska; however, these predictions were not supported by any observations. In the winter, EFH for giant Pacific octopus was more restricted and it largely occurred around Kodiak Island, and to a lesser extent around the Shumagin Islands. Winter EFH was also predicted to occur at the entrance to Prince William Sound; however, these predictions were not supported by any observations. During the spring, EFH for giant Pacific octopus was predicted to largely occur along the shelf break throughout most of the GOA.

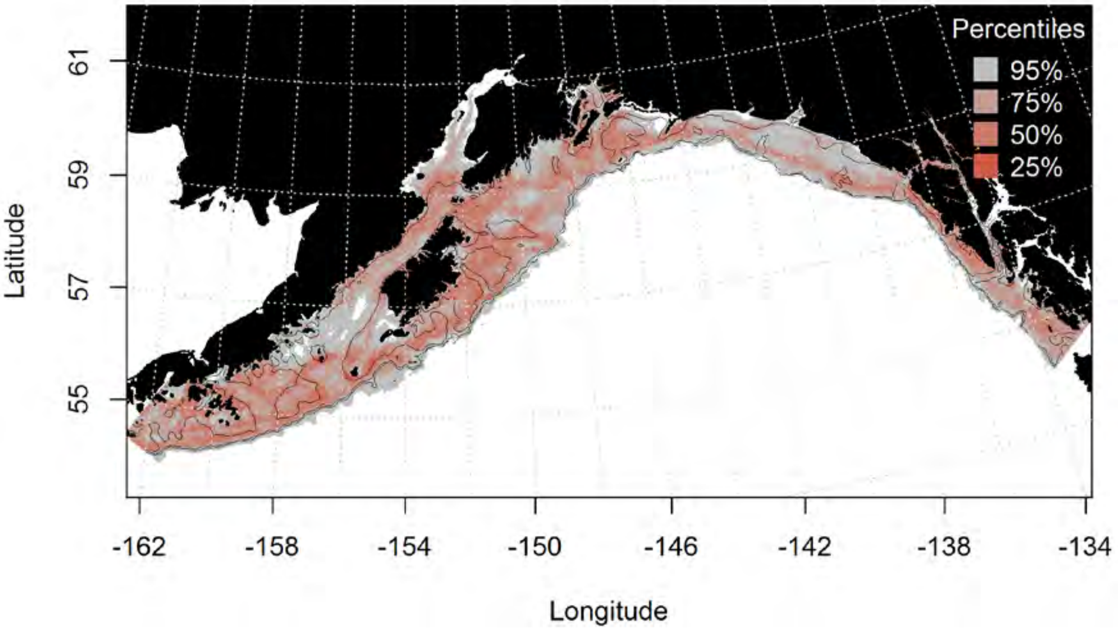


Figure 316. -- Predicted summer essential fish habitat for *E. dofleini* for all life stages combined from summer bottom trawl surveys.

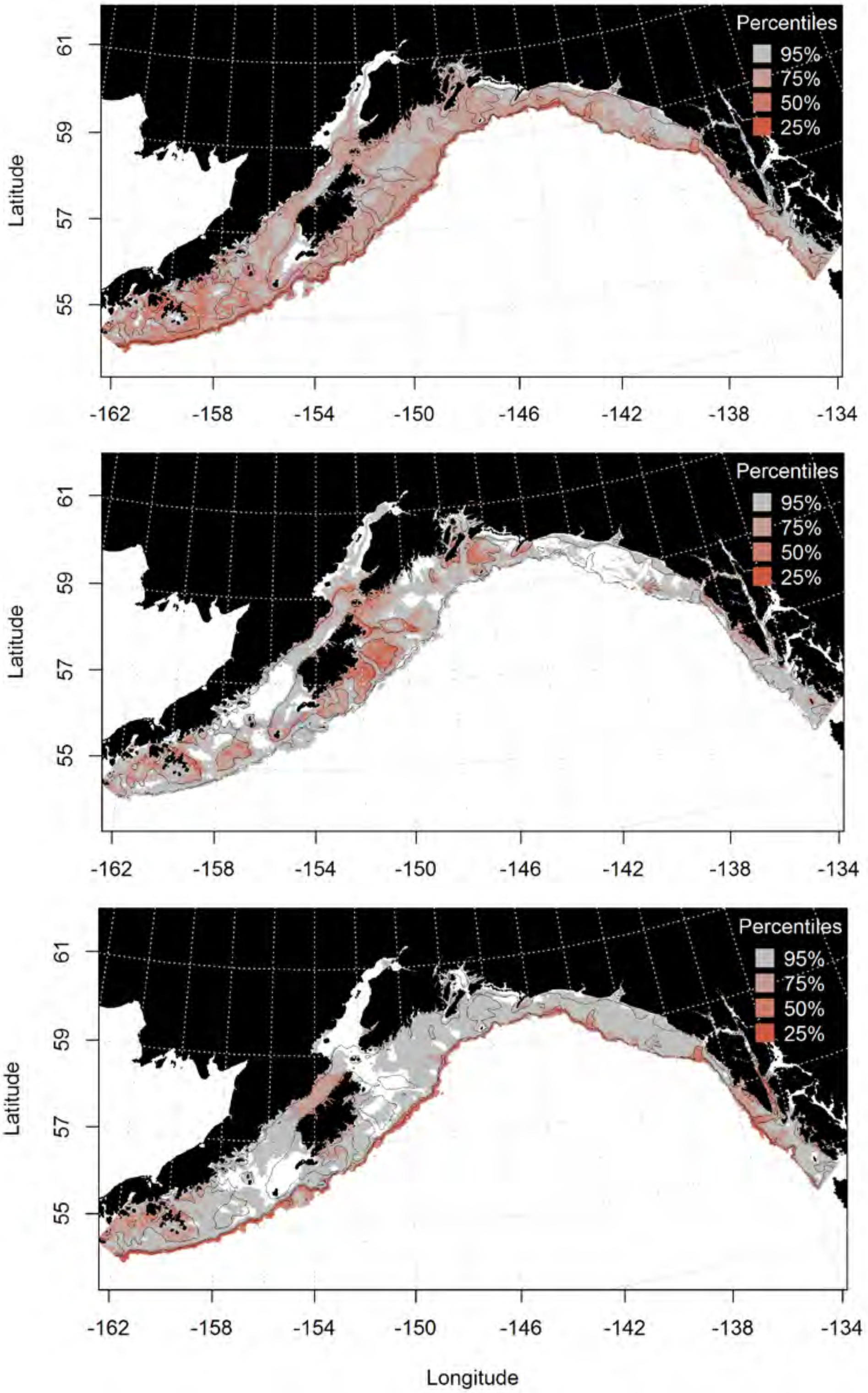


Figure 317. -- Essential fish habitat predicted for *E. dofleini* during fall (top panel), winter (middle panel) and spring (bottom panel) from commercial catches

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(references in yellow are needed and need to have format checked)

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