Population data for including bluefin tuna in the NWACS ecosystem model

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SEDAR 102 WP-03: Population data for including bluefin tuna in the NWACS ecosystem model

A working paper prepared for the 2025 ASMFC benchmark assessment of Atlantic menhaden ecosystem reference points

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Introduction

A preliminary review of diet studies on highly migratory species (e.g., tuna, billfish, and shark species) identified bluefin tuna as having the strongest trophic connection to Atlantic menhaden (Table 1). The workgroup agreed to pursue the inclusion of this species as a predator in the NWACS-full ecosystem model. To this end, I have assembled here some of the necessary data elements representing this species: average diet composition, biomass and mortality time series, and spatial-seasonal distribution.

Average Diet Composition

Six diet studies were identified for western Atlantic bluefin tuna, which provided 14 separate estimates of diet composition. Sample sizes ranged from 42 to 568 stomachs (n = 1800 in total), with four studies coming from the Gulf of Maine region, one from Virginia, and one from North Carolina (Table 2). All studies reported diet composition as percent by weight. After assigning all prey items to the NWACS prey categories, a weighted average diet composition was calculated across all studies. Weighting factors were assigned by first calculating the proportion of the total reported values for three metrics: stomachs examined, study area (in km2), and years of study. These proportions were then averaged across the three categories to obtain the weighting factor used to calculate the average diet composition. Approximately 14% of the average diet composition was attributed to "*unidentified fish*". This prey category was subsequently apportioned to each of the "*identified*" fish prey categories, commensurate with their share of the total fish prey in the average tuna diet.

Overall, 23% of the average bluefin tuna diet was attributed to large Atlantic menhaden, which was the most significant prey category (Table 3; Figure 1). Other major prey categories included herring, squid, mackerel, and other small pelagic fishes.

Total Biomass and Mortality

The western Atlantic stock of bluefin tuna was last assessed in 2021 by the ICCAT (Tsukahara et al., 2021). A Stock Synthesis integrated statistical catch-at-age model provided the derived quantities of total population biomass and mortality rate (Z) by year from 1950 through 2020, with projected values through 2024 (Table 4; Figure 2).

Spatial-Seasonal Distribution

For summarizing the spatial distribution of bluefin tuna, the spatial domain of the NWACs model was broken into following regions: Gulf of Maine (GOM); Southern New England (SNE); Mid-Atlantic (MA); Chesapeake Bay (CB); and North Carolina (NC). These regions were further separated into shallow and deep subregions, according to the 30 m isobath. All areas deeper than 1000 m (beyond the continental shelf) were considered outside the model domain (Figure 3).

There have been numerous studies of bluefin tuna movements in the Western Atlantic using pop-up satellite tags (PSATs). Ben Galuardi (NOAA Fisheries, formerly with the Large Pelagics Research Center, under the direction of Molly Lutcavage) compiled the relocated positions across several of these studies to create seasonal utilization distributions (at a 0.1-degree resolution) representing n = 395 individual bluefin tuna tagged between 2002 and 2016 (Galuardi et al., 2010, 2012, 2018; Figure 4). The fraction of the volume of each utilization distribution that fell within each sub-region was then calculated, ignoring any predictions that occurred over land.

The fraction of the western Atlantic bluefin tuna population that occurred within the model domain varied seasonally from a low of 10% in Spring (April-June) to a high of 58.4% in Fall (October-December)(Table 5). The GOM-Deep sub-region had the greatest amount of space use by bluefin tuna, with a maximum of 50.5% of the utilization distribution volume in Fall.

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Tables and Figures

Table 1. Preliminary review of diet studies of highly migratory species.

	Study Region						Number of Stomachs by Predator											
Study	Gulf of Maine	Georges Bank	Southern New England	Chesapeake Bay	Mid-Atlantic	Years	Bigeye thresher shark	Blue shark	Bluefin Tuna	Common thresher shark	Dusky shark	Porbeagle shark	Sand tiger shark	Sandbar shark	Sharpnose Shark	Shortfin mako shark	Silky shark	Swordfish
Bowman 2000	X	X	X		X	1964-1984	24			19		6	8	7		400	54	168
Kohler 1988		X	X		X	1972-1984		1199										
Olin 2023					X	2019-2022		1		2	4		7	14		1		
Chase 2002	X		X			1988-1992			798									
Butler 2010					X	2003-2005			448									
Nadeau 2021	X					2018-2019			375									
MEDMR 2022	X					2022			95									
Logan 2011	X					2004-2006			143									
Logan 2014	X					2004-2008			42									
Gelschleichter 1999					X	1980-1992					59		42		129			
Joyce 2002		X				1999-2001						1022						
Stillwell 1993		X	X		X	1972-1984								415				
Ellis 2007				X	X	1974-2002								608				
Link 2010	X	X	X		X	1968-2009									217			
Wood 2009			X		X	1972-2002										491		
Logan 2021		X				2007												39
						Total stomachs =	24	1200	1901	21	63	1028	57	1044	346	892	54	207
						Average % menhaden in diet =	0.0%	0.6%	27.0%	0.0%	1.6%	0.0%	6.3%	2.3%	0.0%	0.2%	16.9%	0.4%

Table 2. Summary of western Atlantic bluefin tuna Diet studies.

								Weights			
Study_Code	Years	Months	Size (cm)	Area	Region	Area (km^2)	N	N	Area	Years	Comb.
Chase_2002	1988-1992	Jul-Oct	157-285	Jeffreys Ledge	GOM	1200	123	0.07	0.01	0.11	0.06
Chase_2002	1988-1992	Jul-Oct	170-310	Stellwagen Bank	GOM	750	93	0.05	0.01	0.11	0.06
Chase_2002	1988-1992	Jul-Oct	213-289	Cape Cod Bay	GOM	1500	109	0.06	0.01	0.11	0.06
Chase_2002	1989-1991	Jul-Oct	145-297	Great South Channel	GOM	4000	183	0.10	0.03	0.07	0.07
Chase_2002	1989-1991	Jul-Oct	64-184	South of Martha's Vineyard	GOM	6500	48	0.03	0.05	0.07	0.05
Butler_2010	2003-2006	Dec-Jan	185-206	North Carolina	NC	2500	124	0.07	0.02	0.09	0.06
Butler_2010	2003-2006	Dec-Jan	> 206	North Carolina	NC	2500	324	0.18	0.02	0.09	0.10
Logan_2011	2005-2006	Jul-Sep	57-120	Virginia, 30-40 miles offshore	CB	6000	20	0.01	0.05	0.04	0.03
Logan_2011	2006-2006	Jul-Sep	121-151	Virginia, 30-40 miles offshore	CB	6000	22	0.01	0.05	0.02	0.03
Logan_2015	2004-2008	Jun-Oct	< 185	Jeffreys Ledge and Ipswich Bay	GOM	3500	18	0.01	0.03	0.11	0.05
Logan_2015	2004-2008	Jun-Oct	> 185	Jeffreys Ledge and Ipswich Bay	GOM	3500	100	0.06	0.03	0.11	0.06
Nadeau_2021	2018-2018	Jun-Oct	140-340	Penobscot Bay to Cape Cod	GOM	30000	209	0.12	0.23	0.02	0.12
Nadeau_2021	2019-2019	Jun-Oct	140-340	Penobscot Bay to Cape Cod	GOM	30000	166	0.09	0.23	0.02	0.12
MEDMR_2023	2022-2023	Jun-Oct	188-279	Penobscot Bay to Cape Cod	GOM	30000	245	0.14	0.23	0.04	0.14

Table 3. Average diet composition of western Atlantic bluefin tuna.

Prey Category	Average % of Diet
Atlantic menhaden - large	22.94
Atlantic herring	19.32
small pelagic - other	18.41
Atlantic mackerel	9.05
Squid	6.48
Bluefish - medium	4.00
Hakes	3.10
Not food	2.95
Megabenthos - Filterers	1.88
Spiny dogfish - small	1.87
Shrimp and Similar Species	1.75
Demersal omnivores - other	1.39
Butterfish	1.27
Demersal benthivores - other	1.17
Cod - medium	1.14
Medium pelagic - other	0.90
Alosines	0.88
Skates	0.79
Haddock	0.44
Macrobenthos - crustaceans	0.43
Cod - large	0.42
Other primary producers	0.07
Micronekton	0.04
Weakfish - medium	0.03
Sharks - coastal	0.01
Gelatinous zooplankton	0.01
Macrobenthos - molluscs	0.00

Table 4. Total population biomass (metric tons) and mortality rate for western Atlantic bluefin tuna (Tsukahara at al., 2021). Note that years 2021-2024 are projections.

Year	Biomass (t)	Z	Year	Biomass (t)	Z
1950	261,315	0.113	1988	30,948	0.241
1951	261,027	0.112	1989	29,651	0.258
1952	260,615	0.112	1990	29,114	0.228
1953	260,659	0.111	1991	28,429	0.246
1954	260,270	0.111	1992	27,792	0.233
1955	260,068	0.110	1993	27,611	0.226
1956	260,103	0.109	1994	27,647	0.223
1957	260,446	0.110	1995	28,379	0.226
1958	260,468	0.111	1996	28,475	0.225
1959	259,691	0.113	1997	28,548	0.216
1960	258,234	0.112	1998	28,877	0.218
1961	257,231	0.112	1999	28,800	0.246
1962	258,119	0.120	2000	28,614	0.242
1963	252,021	0.148	2001	28,473	0.231
1964	236,813	0.181	2002	28,255	0.230
1965	213,112	0.179	2003	27,266	0.209
1966	191,897	0.150	2004	27,770	0.196
1967	176,611	0.141	2005	27,873	0.187
1968	163,385	0.127	2006	28,860	0.183
1969	154,111	0.120	2007	29,638	0.164
1970	145,826	0.127	2008	30,798	0.173
1971	135,014	0.150	2009	32,092	0.194
1972	123,006	0.138	2010	33,310	0.196
1973	115,392	0.151	2011	34,589	0.173
1974	107,635	0.144	2012	35,996	0.171
1975	98,527	0.170	2013	37,571	0.168
1976	89,661	0.212	2014	39,221	0.168
1977	80,393	0.239	2015	40,741	0.176
1978	70,848	0.236	2016	41,960	0.170
1979	63,028	0.260	2017	42,991	0.164
1980	55,233	0.269	2018	44,823	0.173
1981	48,217	0.279	2019	45,883	0.179
1982	41,873	0.169	2020	46,783	0.171
1983	40,022	0.220	2021	48,065	0.180
1984	37,421	0.219	2022	49,545	0.222
1985	35,497	0.237	2023	49,650	0.216
1986	33,396	0.233	2024	50,248	0.219
1987	32,168	0.218			

Table 5. Estimated fraction of the western Atlantic bluefin tuna population within the NWACS model domain, and within each NWACS sub-region.

Sub-Region	Winter	Spring	Summer	Fall
GOM-Shallow	0.7%	0.1%	0.2%	2.5%
GOM-Deep	20.4%	1.7%	5.6%	50.5%
MA-Shallow	0.4%	0.1%	0.4%	0.3%
MA-Deep	3.4%	1.4%	4.2%	2.7%
SNE-Shallow	0.2%	0.0%	0.1%	0.1%
SNE-Deep	1.8%	0.2%	1.0%	1.1%
CB-Shallow	0.2%	0.1%	0.2%	0.1%
CB-Deep	0.8%	0.4%	0.8%	0.7%
NC-Shallow	1.4%	1.7%	0.6%	0.1%
NC-Deep	2.8%	4.4%	1.3%	0.2%
Full Domain	32.1%	10.0%	14.4%	58.4%

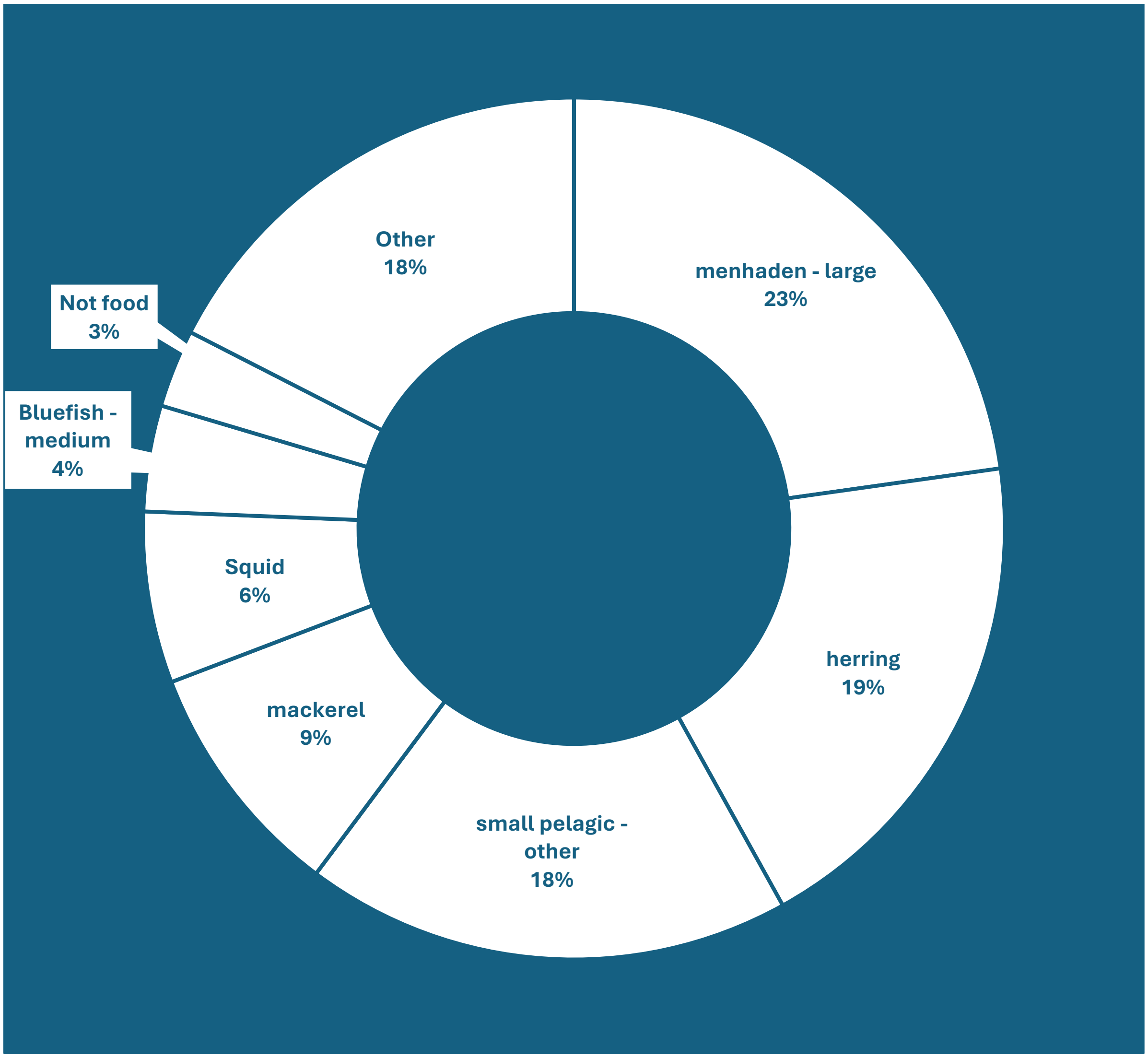

Figure 1. Average diet composition of western Atlantic bluefin tuna

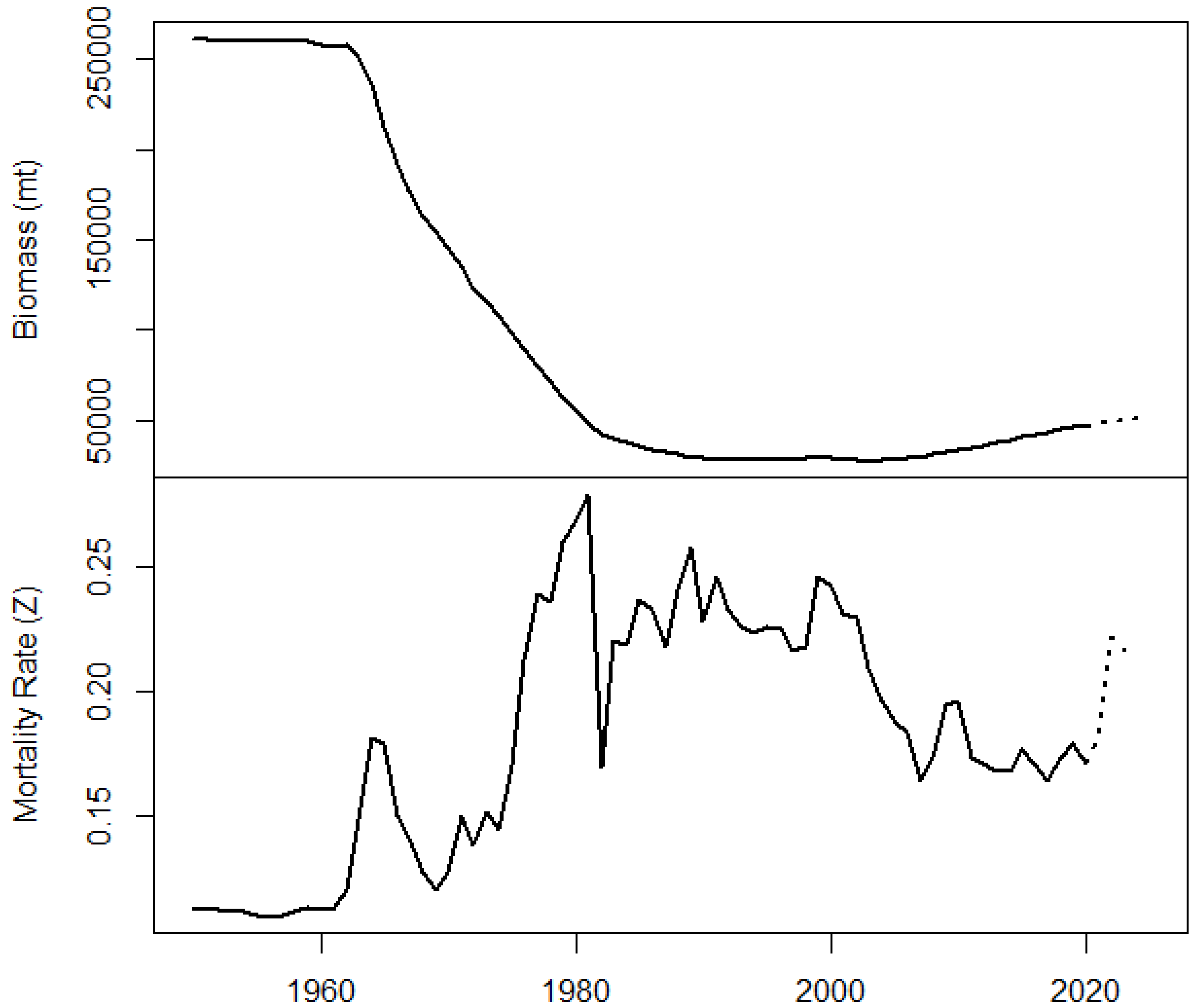

Figure 2. Total population biomass (metric tons) and mortality rate (Z) of the western Atlantic bluefin tuna, as estimated by the 2021 ICCAT stock assessment.

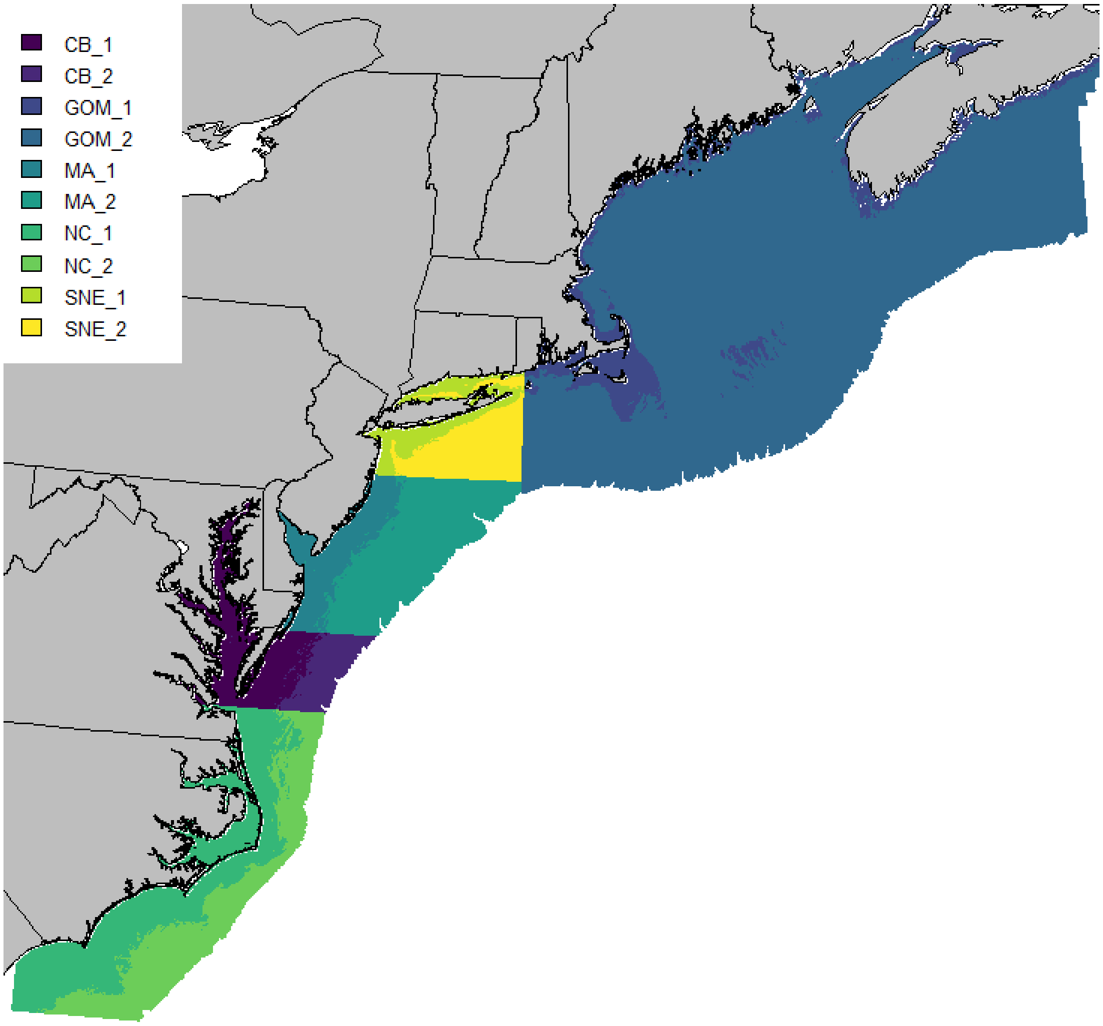

Figure 3. NWACS model domain and sub-regions.

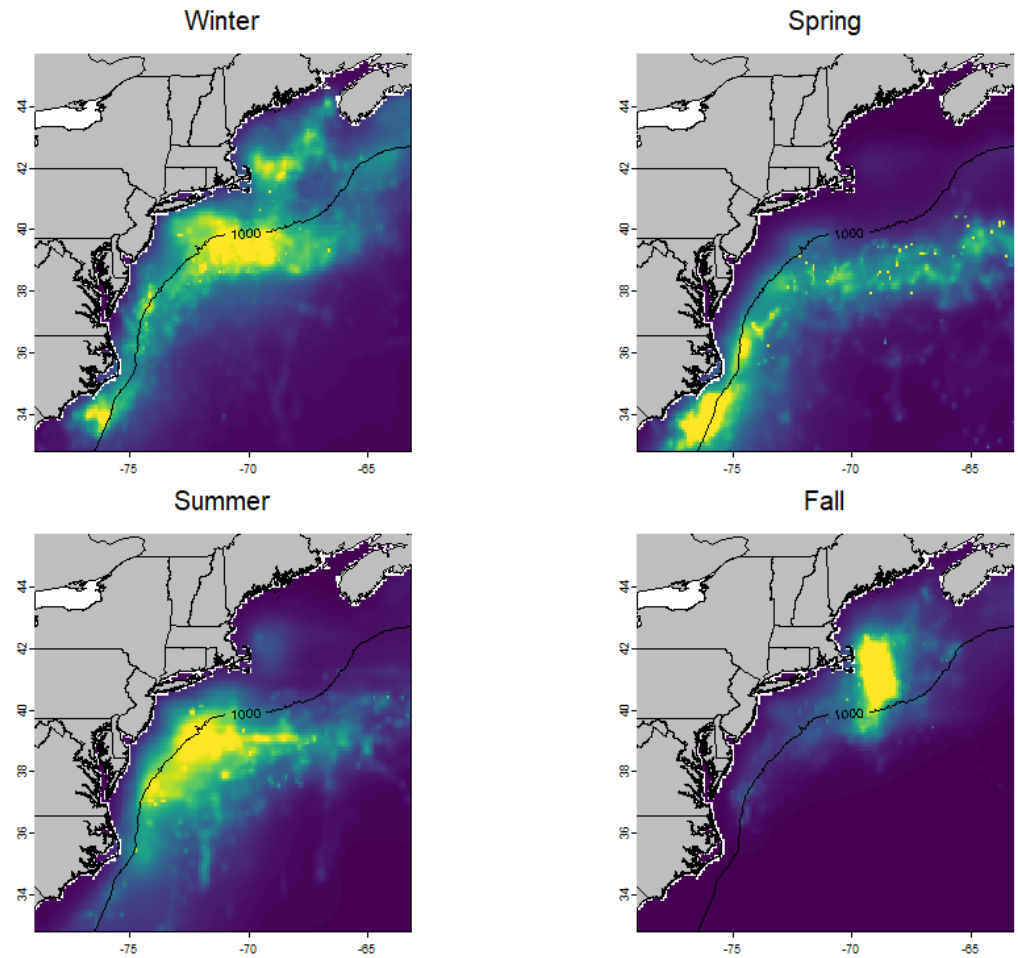

Figure 4. Predicted seasonal utilization distributions within the NWACS model domain for 395 bluefin tuna tagged on the western Atlantic continental shelf.