enhance ecosystem stability and resilience. Food web models are increasingly being utilized by fisheries managers as ecological prediction tools because they provide the capability to simulate the entire ecosystem from primary producers to top predators to fisheries. Food web models can serve to inform single species assessment and management and are capable of generating reference points (Walters et al. 2005) and ecosystem-level indicators (Coll et al. 2006; Fulton et al. 2005).

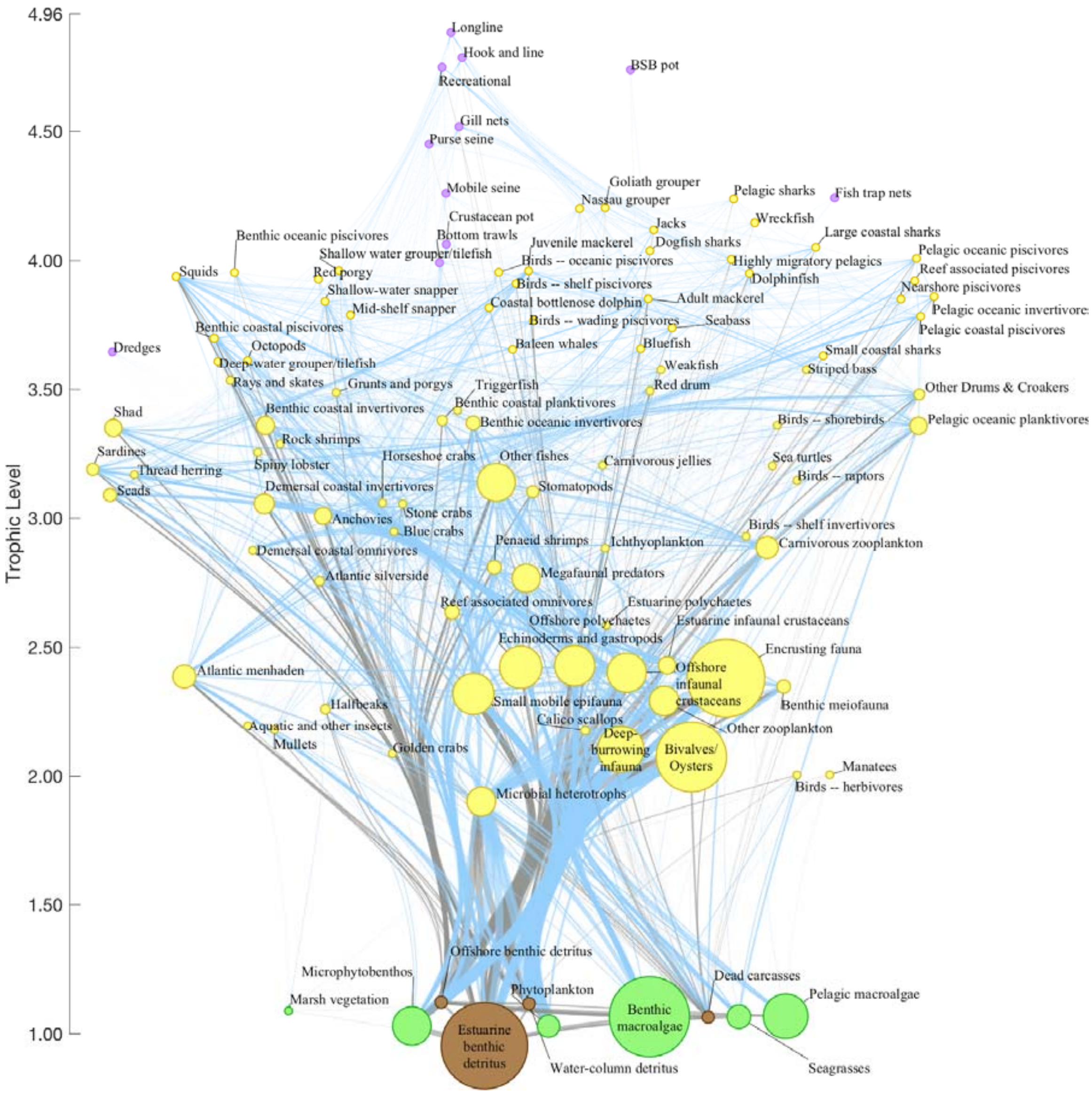

Figure 1-1. The marine food web of the South Atlantic Bight, based on the latest iteration of the SAB Ecopath model as described in Okey et al (2014), based originally on a preliminary model by Okey and Pugliese (2001). Nodes are colored based on type (green = producer, brown = detritus, yellow = consumer, purple = fleet). Blue for all edges except flows to detritus, which are gray. Diagram produced by Kelly Kearney, UW Joint Institute for the Study of the Atmosphere and Ocean and NOAA Alaska Fisheries Science Center, April 2015.

Threats to EFH and EFH-HAPCs from Changes in South Atlantic Food Web and Connectivity

The SAFMC finds that negative impacts to EFH and EFH-HAPCs can change South Atlantic food webs and connectivity for managed species. Table 1 following food webs and connectivity policy and research recommendations, presents a summary of South Atlantic fisheries and their designated EFH and EFH-HAPCs as presented in the SAFMC EFH User Guide (http://safmc.net/download/SAFMCEFHUsersGuideFinalNov16.pdf).

SAFMC Policies Addressing South Atlantic Food Webs and Connectivity

The SAFMC establishes the following policies to address South Atlantic food webs and connectivity, and to clarify and augment the general policies already adopted in the Habitat Plan and Comprehensive Habitat Amendment and Fishery Ecosystem Plan (SAFMC 1998a; SAFMC 1998b; SAFMC 2009a).

General Policies:

1. **Forage Fisheries** – Managers should consider forage fish stock abundances and dynamics, and their impacts on predator productivity, when setting catch limits to promote ecosystem sustainability. To do so, more science and monitoring information are needed to improve our understanding of the role of forage fish in the ecosystem. This information should be included in stock assessments, ecosystem models, and other fishery management tools and processes in order to support the development of sustainable harvest strategies that incorporate ecosystem considerations and trade-offs.
   Note: Initial preliminary definition and potential list of forage fish species presented in Appendix A.

2. **Food Web Connectivity** – Separate food webs exist in the South Atlantic, for example inshore-offshore, north-south, and benthic-pelagic, but they are connected by species that migrate between them such that loss of connectivity could have impacts on other components of the ecosystem that would otherwise appear unrelated and must be accounted for.

3. **Trophic Pathways** – Managers should aim to understand how fisheries production is driven either by bottom-up or top-down forcing and attempt to maintain diverse energy pathways to promote overall food web stability.

4. **Food Web Models** – Food web models can provide useful information to inform stock assessments, screen policy options for unintended consequences, examine ecological and economic trade-offs, and evaluate performance of management actions under alternative ecosystem states.

5. **Food Web Indicators** – Food web indicators have been employed to summarize the state of knowledge of an ecosystem or food web and could serve as ecological benchmarks to inform future actions.

6. **Invasive Species** – Invasive species, most notably lionfish, are known to have negative effects on ecologically and economically important reef fish species through predation and competition and those effects should be accounted for in management actions.

7. **Contaminants** – Bioaccumulation of contaminants in food webs can have sub-lethal effects on marine fish, mammals, and birds and is also a concern for human seafood consumption.

Research and Information Needs Addressing South Atlantic Food Webs and Connectivity

1. Scientific research and collection of data to further understand the impacts of climate variability on the South Atlantic ecosystem and fish productivity must be prioritized. This includes research on species distribution, habitat, reproduction, recruitment, growth, survival, predator-prey interactions and vulnerability.

2. Characterization of offshore ocean habitats used by estuarine dependent species, which can be useful in developing ecosystem models.

3. Scientific research and monitoring to improve our understanding of the role of forage fish in the ecosystem, in particular abundance dynamics and habitat use.

4. Basic data are the foundation of ecosystem-based fisheries management thus, fixing existing data gaps in the South Atlantic must be addressed first in order to build a successful framework for this approach in the South Atlantic.

5. NOAA in cooperation with regional partners develop and evaluate an initial suite of products at an ecosystem level to help prioritize the management and scientific needs in the South Atlantic region taking a systemic approach to identify overarching, common risks across all habitats, taxa, ecosystem functions, fishery participants and dependent coastal communities.

6. NOAA in cooperation with regional partners develop risk assessments to evaluate the vulnerability of South Atlantic species with respect to their exposure and sensitivity to ecological and environmental factors affecting their populations.

7. NOAA coordinate with ongoing regional modeling and management tool development efforts to ensure that ecosystem management strategy evaluations (MSEs) link to multispecies and single species MSEs, inclusive of economic, socio-cultural, and habitat conservation measures.

8. NOAA develop ecosystem-level reference points (ELRPs) and thresholds as an important step to informing statutorily required reference points and identifying key dynamics, emergent ecosystem properties, or major ecosystem-wide issues that impact multiple species, stocks, and fisheries. Addressing basic data collection gaps is critical to successful development of ELRPs.

9. Continued support of South Atlantic efforts to refine EFH and HAPCs is essential to protect important ecological functions for multiple species and species groups in the face of climate change.

Habitats designated as EFH and EFH-HAPCs by the SAFMC (Table 1), if negatively impacted, can change South Atlantic food webs and connectivity for managed species.

Table 1. Habitats designated as Essential Fish Habitat (EFH), their associated managed fisheries/species, and EFH-HAPCs (Source: SAFMC EFH Users Guide 2016).

Essential Fish Habitat	**Fisheries/Species**	**EFH- Habitat Areas of Particular Concern**
Wetlands		
Estuarine and marine emergent wetlands	Shrimp, Snapper Grouper	Shrimp: State designated nursery habitats Mangrove wetlands
Tidal palustrine forested wetlands	Shrimp	
Submerged Aquatic Vegetation		
Estuarine and marine submerged aquatic vegetation	Shrimp, Snapper Grouper, Spiny lobster	Snapper Grouper, Shrimp
Shell bottom		
Oyster reefs and shell banks	Snapper Grouper	Snapper Grouper
Coral and Hardbottom		
Coral reefs, live/hardbottom, medium to high rock outcroppings from shore to at least 600 ft where the annual water temperature range is sufficient.	Snapper Grouper, Spiny lobster, Coral, Coral Reefs and Live Hard/bottom Habitat	The Point, Ten Fathom Ledge, Big Rock, MPAs; The *Phragmatopoma* (worm reefs) off central east coast of Florida and nearshore hardbottom; coral and hardbottom habitat from Jupiter through the Dry Tortugas, FL; Deepwater CHAPCs
rock overhangs, rock outcrops, manganese-phosphorite rock slab formations, and rocky reefs		Snapper-grouper [blueline tilefish]
Artificial reefs	Snapper Grouper	Special Management Zones
Soft bottom		
Subtidal, intertidal non-vegetated flats	Shrimp	
Offshore marine habitats used for spawning and growth to maturity	Shrimp	
Sandy shoals of capes and offshore bars	Coastal Migratory Pelagics	Sandy shoals; Capes Lookout, Fear, Hatteras, NC; Hurl Rocks, SC;
troughs and terraces intermingled with sand, mud, or shell hash at depths of 150 to 300 meters		Snapper-grouper [golden tilefish]
Water column		
Ocean-side waters, from the surf to the shelf break zone, including Sargassum	Coastal Migratory Pelagics	
All coastal inlets	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
All state-designated nursery habitats of particular importance (e.g., PNA, SNA)	Coastal Migratory Pelagics	Shrimp, Snapper-grouper
High salinity bays, estuaries	Cobia in Coastal Migratory Pelagics	Spanish mackerel: Bogue Sound, New River, NC; Broad River, SC
Pelagic Sargassum	Dolphin	
Gulf Stream	Shrimp, Snapper-grouper, Coastal Migratory Pelagics, Spiny lobster, Dolphin-wahoo	
Spawning area in the water column above the adult habitat and the additional pelagic environment	Snapper-grouper	

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Appendix A. Potential list of potential forage species and definition.

Note: Species highlighted constitute a preliminary list of non-managed forage fish species.

Final Report SEAMAP-SA		Period 05/01/2006 - 04/30/2011,									
Table 2.5											
Abundance, biomass, and occurrence by species. Values are for 2006-2010 calendar years. Ranking is by total number of individuals. Top 50 species of 215											
CommonName	Species	Number Rank	Total Number	% of Total Abundance	Biomass (kg)	%of Total BioMass	Number of Occurrences	% of Occurences	CumPct Number	Rank Biomass	CumPct Biomasss
Atl bumper	Chloroscombrus chrysurus	1	1368597	35.34	18645.26	6.76	979	61.57	35.34	5	46.21
Atl croaker	Micropogonias undulatus	2	467821	12.08	24544	8.89	871	54.78	47.42	2	25.33
spot	Leiostomus xanthurus	3	342689	8.85	19807.84	7.18	1121	70.5	56.27	3	32.51
white shrimp	Litopenaeus setiferus	4	141041	3.64	3779.69	1.37	809	50.88	59.91	14	64.34
striped anchovy	Anchoa hepsetus	5	140732	3.63	1244.2	0.45	961	60.44	63.54	27	73.97
moonfish	Selene setapinnis	6	128782	3.33	2173.18	0.79	1001	62.96	66.87	20	69.92
cannonball jellyfish	Stomolophus meleagris	7	127957	3.3	45368.66	16.44	723	45.47	70.17	1	16.44
scup/porgy	Stenotomus sp.	8	120165	3.1	4249.36	1.54	505	31.76	73.27	11	59.99
pinfish	Lagodon rhomboides	9	87700	2.26	4134.76	1.5	623	39.18	75.53	12	61.49
banded drum	Larimus fasciatus	10	68273	1.76	5041.15	1.83	775	48.74	77.29	9	56.81
butterfish	Peprilus triacanthus	11	68083	1.76	1801.7	0.65	852	53.58	79.05	22	71.34
star drum	Stellifer lanceolatus	12	67465	1.74	1279.21	0.46	462	29.06	80.79	26	73.52
Southern kingfish	Menticirrhus americanus	13	63683	1.64	6310.79	2.29	1181	74.28	82.43	7	52.86
harvestfish	Peprilus paru	14	61621	1.59	2706.34	0.98	986	62.01	84.02	16	66.41
Atl thread herring	Opisthonema oglinum	15	56675	1.46	1427.48	0.52	977	61.45	85.48	25	73.06
brown shrimp	Farfantepenaeus aztecus	16	49209	1.27	759.13	0.28	548	34.47	86.75	32	75.62
breif squid	Lolliguncula brevis	17	48151	1.24	555.35	0.2	1263	79.43	87.99	33	75.82
Atl cutlassfish	Trichiurus lepturus	18	46126	1.19	2442.13	0.88	599	37.67	89.18	19	69.13
silver seatrout	Cynoscion nothus	19	43987	1.14	2448.59	0.89	659	41.45	90.32	18	68.25
northern searobin	Prionotus carolinus	20	38652	1	430.23	0.16	712	44.78	91.32	34	75.98
weakfish	Cynoscion regalis	21	35781	0.92	3000.54	1.09	670	42.14	92.24	15	65.43
Atl menhaden	Brevoortia tyrannus	22	27118	0.7	842.86	0.31	206	12.96	92.94	30	75.04
spider crab	Libinia dubia	23	23998	0.62	74.19	0.03	496	31.19	93.56	44	76.6
squid sp	Loligo spp.	24	21515	0.56	316.24	0.11	485	30.5	94.12	36	76.22
bay anchovy	Anchoa mitchilli	25	20415	0.53	31.27	0.01	442	27.8	94.65	49	76.69
bluefish	Pomatomus saltatrix	26	20169	0.52	1763.96	0.64	531	33.4	95.17	23	71.98
silver perch	Bairdiella chrysoura	27	19695	0.51	826.85	0.3	292	18.36	95.68	31	75.34
inshore lizardfish	Synodus foetens	28	19482	0.5	1537	0.56	830	52.2	96.18	24	72.54
pigfish	Orthopristis chrysoptera	29	14141	0.37	1086.03	0.39	418	26.29	96.55	28	74.36
spadefish	Chaetodipterus faber	30	7942	0.21	369.7	0.13	416	26.16	96.76	35	76.11
Spanish mackerel	Scomberomorus maculatus	31	7906	0.2	1008.44	0.37	781	49.12	96.96	29	74.73
Atl sharpnose shark	Rhizoprionodon terraenovae	32	7778	0.2	4522.38	1.64	973	61.19	97.16	10	58.45
lady crab	Ovalipes stephensoni	33	5630	0.15	45.44	0.02	421	26.48	97.31	47	76.66
shortfinger anchovy	Anchoa lyolepis	34	5515	0.14	19.94	0.01	225	14.15	97.45	50	76.7
irridescenct swimming crab	Portunus gibbesii	35	5165	0.13	47.12	0.02	462	29.06	97.58	46	76.64
Atl lookdown	Selene vomer	36	5078	0.13	183.14	0.07	408	25.66	97.71	38	76.37
hogchocker	Trinectes maculatus	37	4903	0.13	161.57	0.06	296	18.62	97.84	39	76.43
windowpane	Scophthalmus aquosus	38	4137	0.11	100.84	0.04	410	25.79	97.95	41	76.51
bullnose ray	Myliobatis freminvillei	39	3844	0.1	12041.15	4.36	330	20.75	98.05	6	50.57
lesser blue crab	Callinectes similis	40	3774	0.1	45.23	0.02	375	23.58	98.15	48	76.68
bonnethead shark	Sphyrna tiburo	41	3670	0.09	4091.41	1.48	561	35.28	98.24	13	62.97
butterfly ray	Gymnura micrura	42	3561	0.09	2626.05	0.95	470	29.56	98.33	17	67.36
fringed flounder	Etropus crossotus	43	3514	0.09	80.22	0.03	575	36.16	98.42	42	76.54
cownose ray	Rhinoptera bonasus	44	3437	0.09	19154.01	6.94	196	12.33	98.51	4	39.45
king mackerel	Scomberomorus cavalla	45	3216	0.08	218.23	0.08	280	17.61	98.59	37	76.3
bluntnose stingray	Dasyatis sayi	46	2896	0.07	5847.42	2.12	490	30.82	98.66	8	54.98
spotted hake	Urophycis regius	47	2827	0.07	76.87	0.03	189	11.89	98.73	43	76.57
ocellated flounder	Ancylopsetta quadrocellata	48	2599	0.07	102.39	0.04	414	26.04	98.8	40	76.47
leopard sea robin	Prionotus scitulus	49	2498	0.06	62.75	0.02	284	17.86	98.86	45	76.62
clearnose skate	Raja eglanteria	50	2410	0.06	2138.9	0.77	300	18.87	98.92	21	70.69

(Source: SEAMAP-SA Report Project: NA06NMF435002: September 2012)

Forage species: fish—small, short-lived and fast growing mid-trophic level species—are primary energy pathways in many marine food webs, and that they support other valuable fish stocks and many species of marine birds and mammals. Forage fish are presumed to be important in the SAB because they are food for valuable commercial and recreational species in this ecosystem, in addition to supporting other species in the broader biological community. SAB forage fish groups include Atlantic menhaden(*Brevoortia tyrannus*), halfbeaks (*Hemiramphus spp., Hyporhamphus unifasciatus*), anchovies (*Anchoa spp., A. mitchilli, A. hepsetus, Engraulis eurystole*), sardines (*Harengula jaguana*, *Sardinella aurita*), Atlantic silverside (*Menidia menidia*), scads (*Decapterus punctatus*, *Trachurus lathami*, *Selar crumenophthalmus*), shad (*Alosa spp.*), Atlantic thread herring (*Opisthonema oglinum),* mullets (*Mugil spp.*), and other pelagic oceanic planktivores such as lanternfish (*Diaphus spp.*), antenna codlet (*Bregmaceros atlanticus*), striated argentine (*Argentina striata*), chub mackerel (*Scomber japonicus*), and flyingfish (Exocoetidae).
Note: Squids (*Illex illecebrosus*, *Loligo pealei*) and shrimps (rock shrimps and penaeid shrimps) in this system also serve as forage (Pauly 1998, Anderson and Piatt 1999, Okey 2006), as do krill (Euphausiacea). These forage groups exhibit widely varying importance, *e.g*., interaction strengths, in the presently modelled context. (Source: Exploring the Trophodynamic Signatures of Forage Species in the U.S. South Atlantic Bight Ecosystem to Maximize System-Wide Values. Thomas A. Okey, Andrés M. Cisneros-Montemayor, Roger Pugliese, Ussif R. Sumaila)