The Wilson Journal of Ornithology 124(1):66–72, 2012

FORAGING OVER *SARGASSUM* BY WESTERN NORTH ATLANTIC SEABIRDS

MARY L. MOSER[1,2,4] AND DAVID S. LEE[3]

ABSTRACT.—Drifting reefs of *Sargassum* (a brown alga) are used by a variety of pelagic seabirds in the western Atlantic Ocean. We examined gut contents from 964 individuals of 39 seabird species collected 5 to 60 km off the coast of North Carolina for evidence of *Sargassum* use. *Sargassum* pieces or *Sargassum*-associated prey were found in nine of 10 Procellariiformes species and less frequently among Charadriiformes (12 of 25 species). No *Sargassum*-associated prey was found in Pelecaniformes examined, but observational data indicated that Atlantic tropicbirds (*Phaethon lepturus and P. aethereus*) and Masked Boobies (*Sula dactylatra*) commonly foraged over *Sargassum*. Four species were considered *Sargassum* specialists, having frequencies of occurrence >25% and high volumes of *Sargassum*-associated prey: Audubon's Shearwater (*Puffinus lherminieri*), Royal Tern (*Thalasseus maximus*), Bridled Tern (*Onychoprion anaethetus*), and Red-necked Phalarope (*Phalaropus lobatus*). Seven species fed in *Sargassum* to a lesser extent, and nine species had ingested *Sargassum* pieces, but contained no *Sargassum*-associated prey. It is likely that other seabird species forage regularly over *Sargassum*, as our conclusions are based on relatively small sample sizes taken during random sampling in the open ocean. Our conservative analysis and extensive observational data indicate the *Sargassum* community is critical for feeding for some western North Atlantic seabirds. Degradation of *Sargassum* habitats by oil development, harvest, and/or ocean acidification would undoubtedly have negative effects on fitness of these birds. *Received 22 March 2011. Accepted 7 October 2011.*

Consolidated reefs of floating pelagic brown algae of the genus *Sargassum* are important and recurring features of tropical and sub-tropical marine environments. Holopelagic *S. natans* and *S. fluitans* support a diverse and abundant fish and invertebrate fauna in the western Atlantic Ocean (Fine 1970, Settle 1993, Casazza and Ross 2008). Recent remote sensing data indicates *Sargassum* reefs originate in the northwestern Gulf of Mexico in June each year and are advected into the western Atlantic in early summer by the Loop Current, moving northward with the Gulf Stream (Gower and King 2011). The floating weed moves to the south and west in fall and winter, becoming less buoyant with age. The circulation of *Sargassum* is consistent among years and is driven by predictable currents and trade winds (Gower and King 2011).

Floating *Sargassum* can be extensive, yet ephemeral habitat for seabirds. Airborne imagery indicated that drift lines of the algae extend for continuous lengths of at least 5 km and primarily consist of 20–80 m^2 reefs of *Sargassum* (Marmorino et al. 2011). Satellite images indicate *Sargassum* slicks can be even larger, ranging from 100 to 1,000 m in width and up to hundreds of kilometers in length (Gower et al. 2006). However, consolidated drift lines of *Sargassum* off the coast of Florida start to disintegrate as wind speeds exceed 5 m/sec (Marmorino et al. 2011). The amount of pelagic *Sargassum* in the North Atlantic was estimated at 0.54 metric tons/km^2 in the Gulf Stream and 0.02 metric tons/km^2 over the Continental Shelf, for a combined standing crop of >50,000 metric tons off the Carolinas (Howard and Menzies 1969). Gower and King (2011) estimated the wet weight of *Sargassum* in the Atlantic has regularly exceeded 1.8 million metric tons during the past decade and that even greater amounts can occur in the Gulf of Mexico. Thus, *Sargassum* reefs are important feeding stations and possible roosting sites for pelagic seabirds (Haney 1986).

Studies to date have used observations of seabird behavior around *Sargassum* reefs to reach conclusions about why seabirds are attracted to this habitat (Haney 1985, 1986). We examined the gut contents of 39 species of pelagic seabirds for evidence of foraging over *Sargassum*. Percent frequency of occurrence, numerical abundance, and volume of *Sargassum*-associated prey were used to ascertain the relative extent of *Sargassum* foraging exhibited by the species sampled. These data were supported by extensive visual observation of marine birds feeding in pelagic habitats off the coast of North Carolina. Our objectives were

[1] Zoology Department, North Carolina State University, Raleigh, NC 27695, USA.

[2] Current address: Northwest Fisheries Science Center, National Marine Fisheries Service, 2725 Montlake Boulevard East, Seattle, WA 98112, USA.

[3] The Tortoise Reserve, P. O. Box 7082, White Lake, NC 28336, USA.

[4] Corresponding author; e-mail: mary.moser@noaa.gov

to: (1) identify seabird species that rely most heavily on pelagic *Sargassum* for feeding, and (2) document prey items most frequently targeted by these birds.

METHODS

Gut content analysis from 964 individual seabirds of 39 species collected 5 to 60 km off the North Carolina coast was conducted as described in Moser and Lee (1992). In addition, visual observations of seabird foraging were made from a vessel during 231 day trips (averaging 1,201 seabird observations and 25.2 species/trip). Birds were collected during all seasons between 1975 and 1989, although fewer sampling and observation trips were made in winter. Observations and collections occurred over a wide geographic area in an attempt to census inshore coastal waters, the inner and outer Continental Shelf, and deeper waters over the Shelf's edge. Lee and Socii (1998) mapped the areas surveyed by month.

Documentation of *Sargassum* use was not the original focus of seabird collections or observations. The birds used in this study were collected opportunistically during their entire period of occurrence in North Carolina waters to obtain data on heavy metal accumulation, plastic ingestion, age and sex ratios, body temperature, parasite load, molt sequence, behavior, and ecology (e.g., Moser and Lee 1992, Lee 1995, Lee and Haney 1996). Foraging flocks quickly dispersed when approached by our survey boats and birds foraging over *Sargassum* were not targeted, nor were they particularly easier to collect. *Sargassum* is typically found in the vicinity of the outer Continental Shelf along the western wall of the Gulf Stream and, to a lesser extent, in wind rows within the Stream. Only 40% of the surveys were near the Shelf edge where *Sargassum* typically occurs, and the alga was frequently not in the immediate vicinity of our survey sites.

Contents from the stomach and gizzard of each bird were combined, and birds with empty upper digestive tracts were excluded from the analysis. Percent frequency of occurrence of *Sargassum* (leaves or bladders) and *Sargassum*-associated fauna was calculated for each seabird species (number of birds with prey 'A' divided by the total number of birds × 100). *Sargassum* associates were defined as those species (fish, crustaceans, and gastropods) that reside in *Sargassum* during the life history phase when ingested (following Dooley 1972, Settle 1993). Unidentifiable prey items were assumed not to be *Sargassum* associates, and the mean percent volume of *Sargassum*-associated prey in the digestive tract was used as a direct measure of the relative importance of *Sargassum* for foraging within species. Thus, our estimates of *Sargassum* use are conservative.

RESULTS

Gut contents of birds from three Orders, five families, 16 genera, and 39 species were analyzed. Twenty-one species (53.8%) had ingested *Sargassum* pieces or *Sargassum*-associated prey (Table 1). Birds were classified as *Sargassum* specialists (species that had >25% occurrence of *Sargassum*-associated prey), *Sargassum* users (those with up to 25% occurrence of *Sargassum* or associated prey), and *Sargassum* incidentals (species that contained only pieces of *Sargassum* and no associated prey). We regarded the presence of alga in digestive tracts as evidence of foraging associated with pelagic *Sargassum*. Its presence among gut contents that lacked any identifiable *Sargassum*-associated prey was probably a result of the bird's inability to rapidly digest the alga.

Evidence of *Sargassum* foraging was found in most Procellariiformes (9 of 10 species) and less frequently in Charadriiformes (12 of 25 species). It is possible that Sooty Tern (*Onychoprion fuscatus*) could be added to the species that use *Sargassum*, as four of 11 birds sampled contained flying fish (Exocoetidae). There was equivocal evidence from digestive tract analysis for *Sargassum* use by two of the four Pelecaniformes. Relatively few individuals of these species were collected. Our extensive visual observations of the pelagic members of this family indicated they forage over algal mats. Moreover, two of five White-tailed Tropicbirds (*Phaethon lepturus*) and two of three Red-billed Tropicbirds (*P. aethereus*) ingested flying fish.

Species that had no *Sargassum* or identifiable *Sargassum*-associated prey in their digestive tracts included: Band-rumped Storm-Petrel (*Oceanodroma castro*, $n = 12$), White-tailed Tropicbird ($n = 5$), Red-billed Tropicbird ($n = 3$), Northern Gannet (*Morus bassanus*, $n = 5$), Double-crested Cormorant (*Phalacrocorax auritus*, $n = 1$), Parasitic Jaeger (*Stercorarius parasiticus*, $n = 4$), Great Skua (*S. skua*, $n = 1$), Great Black-backed Gull (*Larus marinus*, $n = 1$), Herring Gull (*L. argentatus*, $n = 2$), Ring-billed Gull (*L. delawarensis*, $n = 2$), Arctic Tern (*Sterna paradisaea*,

$n = 2$), Caspian Tern (*Hydroprogne caspia*, $n = 2$), Forster's Tern (*S. forsteri*, $n = 3$), Gull-billed Tern (*Gelochelidon nilotica*, $n = 3$), Least Tern (*Sternula antillarum*, $n = 1$), Sandwich Tern (*Thalasseus sandvicensis*, $n = 8$), Sooty Tern ($n = 11$), and Brown Noddy (*Anous stolidus*, $n = 2$).

Four species of seabirds had frequencies of *Sargassum*-associated prey >25% and were considered *Sargassum* specialists (Table 1). The single Sabine's Gull (*Xema sabini*) sampled contained a seahorse (*Hippocampus* sp.), which is a *Sargassum* dweller. These gulls were observed following *Sargassum* drift lines during migration but, sample size did not support including this gull in the *Sargassum* specialists category. The four specialists contained almost exclusively *Sargassum*-associated prey, as evidenced by high volumes of identifiable prey items in their digestive tracts (Table 2). *Sargassum* users, birds that contained *Sargassum* prey less frequently (7 species), also contained high volumes of *Sargassum*-associated prey.

Most birds feeding in *Sargassum* contained small *Sargassum*-associated fishes (Table 2). The only exceptions were the two species of phalaropes, which had consumed Sargassum shrimp (*Latreutes fucorum*) and the *Sargassum*-associated gastropod, *Litiopa melanostoma*. This gastropod was also found in Cory's Shearwaters (*Calonectris diomedea*). Specialists fed on a minimum of seven *Sargassum*-associated fish species, and most measurable fish prey were <50 mm standard length (Table 2). However, Royal Terns (*Thalasseus maximus*) generally consumed slightly larger fish (range = 40–105 mm) than the other birds we examined (range = 6–75 mm). Filefish (*Monacanthus* sp.) occurred with the highest frequency in Audubon's Shearwaters (*Puffinus lherminieri*), Bridled Terns (*Onychoprion anaethetus*), and Royal Terns, but numerical abundance of filefish was highest only in Audubon's Shearwaters and Royal Terns (Fig. 1A, C). The mean number of filefish per bird was five. Bridled Terns (Fig. 1B) had the highest number of tetradontids (mean number of puffers/bird = 6) and also consumed large numbers of ostraciids (mean number of trunkfish/bird = 4).

DISCUSSION

Gut content analysis identified four *Sargassum* specialists, while visual observations indicated that several additional species target this habitat for feeding. Audubon's Shearwater, Royal Tern, Bridled Tern, and Red-necked Phalarope (*Phalaropus lobatus*) contained relatively high levels of *Sargassum*-associated prey. The single Sabine's Gull examined contained a *Sargassum*-associated prey item and this species was observed to follow *Sargassum* drift lines. Visual observations indicated Bridled Terns regularly associated with *Sargassum* patches and tended to use the mats and associated flotsam as roosting sites (Duncan and Harvard 1980, Haney 1986). Our observational data also indicated that Masked Boobies (*Sula dactylatra*) and the two species of tropicbirds target *Sargassum* patches while feeding as also reported by Haney et al. (1999).

Diet analysis underestimated prey from *Sargassum* habitat and excluded some seabird species. For example, the digestive tracts of Bridled Terns in our study contained insects of terrestrial origin, which we did not consider to be *Sargassum* associates (5 consumed Lepidoptera, 6 ate Coleoptera, 2 ate Hymenoptera, and 6 contained unidentified insects). Haney et al. (1999) reported insects were the second most common food item in Bridled Terns. These insects may have been resting on *Sargassum* mats when ingested. We commonly observed both species of Atlantic tropicbirds feeding around *Sargassum* reefs. Flying fish were recovered from their digestive tracts, but this was not direct evidence of *Sargassum* use, as flying fish regularly occur where *Sargassum* is absent (Casazza and Ross 2008). We observed tropicbirds as they plunged near and sometimes under the *Sargassum*. The same was true of Masked Boobies, a species seen infrequently off the Carolinas but usually in association with *Sargassum*.

Some seabird species may not feed directly over *Sargassum*, but the alga is critical habitat for certain life stages of their fish prey. For example, flying fish can represent >50% of the total diet of the two tropicbirds collected off North Carolina (Lee et al. 1981, Lee and Irvin 1983) and flying fish are important prey in other parts of their range (Lee and Walsh-McGehee 1998). Flying fish use *Sargassum* for spawning and rearing, and *Sargassum* is essential habitat for these and other fish species (Casazza and Ross 2008). Thus, *Sargassum* contributes indirectly to the fitness of tropicbirds and other seabirds, notably Sooty Terns and Masked Boobies.

Sargassum specialists used a variety of foraging modes, including surface-seizing, plunging (aerial diving), pursuit plunging/diving, pattering, and

TABLE 1. Frequency of occurrence (%) of *Sargassum* and *Sargassum*-associated prey in western North Atlantic seabirds. Species having >25% occurrence of *Sargassum*-associated prey were considered *Sargassum* specialists; those with <25% associated prey were classified as *Sargassum* users, and species that contained only pieces of *Sargassum* were *Sargassum* incidentals. Mean percent volume of fish prey is in parenthesis. Primary season of occurrence of seabirds off North Carolina from Lee (1986, 1995).

Species	Primary season of occurrence	*n*	*Sargassum*		Fish	Crustacean	Gastropod
			Prey	Pieces			
Sargassum specialists							
Audubon's Shearwater *Puffinus lherminieri*	late Apr–Nov	100	59.0	15.0	48.0 (89.2)	0	0
Red-necked Phalarope *Phalaropus lobatus*	mid Apr–early Jun; mid Jul–Oct	37	62.2	16.2	0	0	45.9
Royal Tern *Thalasseus maximus*	mid Mar–late Oct	20	40.0	0	40.0 (91.0)	0	0
Bridled Tern *Onychoprion anaethetus*	mid May–mid Oct	58	31.0	0	31.0 (79.0)	0	0
Sabine's Gull *Xema sabini*	Mar–May; Sep–Oct	1	100.0	0	100.0 (100.0)	0	0
Sargassum users							
Great Shearwater *Puffinus gravis*	mid Mar–mid Nov	50	48.0	44.0	2.0 (100.0)	0	2.0
Cory's Shearwater *Calonectris diomedea*	mid May–mid Nov	136	30.1	26.0	0.7 (50.0)	0	2.9
Manx Shearwater *Puffinus puffinus*	mid Oct–mid Jun	13	23.1	15.4	7.7 (100.0)	0	0
Red Phalarope *Phalaropus fulicarius*	mid Oct–Apr	92	10.9	1.1	0	7.6	2.2
Laughing Gull *Leucophaeus atricilla*	year round	11	54.5	54.5	18.2 (100.0)	18.2	0
Bonaparte's Gull *Chroicocephalus philidelphia*	Sep–Mar	31	16.1	6.4	9.7 (98.3)	0	0
Common Tern *Sterna hirundo*	Apr–Sep	43	18.6	7.0	11.6 (80.0)	0	0
Sargassum incidentals							
Sooty Shearwater *Puffinus griseus*	late May–early Jun	5	40.0	40.0			
Black-capped Petrel *Pterodroma hasitata*	year round	55	16.4	16.4			
Leach's Storm-Petrel *Oceanodroma leucorhoa*	mid May–early Jun; mid Sep–early Nov	8	12.5	12.5			
Wilson's Storm-Petrel *Oceanites oceanicus*	mid Apr–early Sep	122	3.3	3.3			
Northern Fulmar *Fulmarus glacialis*	late Oct–Apr	32	3.1	3.1			
Long-tailed Jaeger *Stercorarius longicaudus*	mid Sep–mid Oct; May	13	15.3	15.3			
Pomarine Jaeger *S. pomarinus*	late Mar–Jun; late Oct–early Nov	33	15.1	15.1			
Black Tern *Chlidonias niger*	late Apr–early May; mid Jul–mid Sep	6	16.7	16.7			
Black-legged Kittiwake *Rissa tridactyla*	early Nov–Mar	30	20.0	20.0			

TABLE 2. Frequency of occurrence (%) and size range (standard length in mm) of individual fish taxa ingested by three *Sargassum* specialists: Audubon's Shearwater (n = 48), Bridled Terns (n = 16), and Royal Terns (n = 8).

	Frequency of occurrence (%) and size range (mm)		
	Audubon's Shearwater	Bridled Tern	Royal Tern
Exocoetidae (flying fish)	6.2 (40–60)	6.2 (30)	0
Syngnathidae (pipefish)	0	6.2 (23)	0
Priacanthus sp. (bigeye)	4.2 (15)	12.5 (20)	0
Heteropriacanthus cruentatus (glasseye)	2.1 (45)	0	0
Caranx sp. (jack)	14.6 (45–50)	0	12.5 (70)
C. hippos (crevalle jack)	2.1 (25)	0	0
Decapterus sp. (scad)	4.2	6.2	0
Trachurus lathami (rough scad)	2.1 (75)	0	0
Stromateidae (butterfish)	4.2 (15)	12.5 (30–40)	12.5
Psenes sp. (driftfish)	0	0	12.5 (70–105)
Balistidae (triggerfish)	8.3 (15–20)	25.0 (20)	0
Aluterus sp. (filefish)	12.5 (40)	0	12.5 (40)
Monacanthus sp. (filefish)	68.8 (15–50)	31.2 (10–22)	62.5 (40)
Monacanthus ciliatus (fringed filefish)	2.1 (25)	0	0
Stephanolepis hispidus (planehead filefish)	2.1 (30–52)	0	12.5 (45)
Lactophrys sp. (trunkfish)	0	12.5 (6–10)	0
Chilomycterus sp. (burrfish)	0	0	12.5
Sphoeroides sp. (puffer)	2.1 (7–12)	18.7 (10–20)	0
S. maculatus (northern puffer)	0	6.2 (10–12)	0

dipping (following Ashmole 1971). We observed Audubon's Shearwater feeding near the surface, either by shallow diving (1–2 m), surface-seizing, or hydroplaning in and around *Sargassum* reefs. However, in the Bahamas, this shearwater feeds by pursuit diving during the nesting season with dives averaging 7.6 m (n = 136) to a maximum of 29 m (Mackin 2004). Phalaropes, which prey on aquatic invertebrates in shallow pools in the tundra by surface feeding (Haney 1985), use the same behavior when seizing snails and crustaceans from *Sargassum* mats. The spinning behavior associated with phalarope feeding in freshwater habitats (Obst et al. 1996) was not observed at sea. *Sargassum*-associated prey taken by small seabirds were rarely >50 mm, indicating these birds picked prey from within the alga, as opposed to diving beneath it where larger fish are typically found (Moser et al. 1998). An advantage of foraging in *Sargassum* reefs is that piscivorous predators drive prey up into the *Sargassum* mats, where it is more accessible to the smaller-bodied seabirds (Safina and Burger 1985, Haney 1986).

Prey types in digestive tracts provided additional information about seabird feeding. Both frequency of occurrence and numerical abundance of fish prey in Bridled Terns indicated they select relatively uncommon members of the *Sargassum* fish fauna: tetradontids (puffers), ostraciids (trunkfishes), stromateids (driftfish), and priacanthids (bigeyes) (Dooley 1972, Settle 1993). However, these fishes may occur at the periphery of *Sargassum* patches, where they are less frequently collected during *Sargassum* sampling with nets (Casazza and Ross 2008). In contrast, Royal Terns, Audubon's Shearwaters, and Red Phalaropes fed on prey that are dominant members of the *Sargassum* community: filefishes, jacks, and Sargassum shrimp (Fine 1970, Dooley 1972, Settle 1993, Casazza and Ross 2008). Haney (1986) found a significant relationship between bird body size and *Sargassum* patch size. We noted that large-bodied Royal Terns contained relatively large prey; but this was likely a function of their feeding mode (plunging) rather than *Sargassum* patch size.

Sargassum foraging was documented during all months of the year despite the *Sargassum* mat structure and attendant fish community changing seasonally and in response to weather (Moser et al. 1998, Casazza and Ross 2008, Gower and King 2011). Fine (1970) noted that faunal composition in *Sargassum* collected from the Gulf Stream and Sargasso Sea was similar, but that non-colonial macrofauna were more abundant in spring than in fall. This may affect the way seabirds use *Sargassum* habitat. Royal Terns

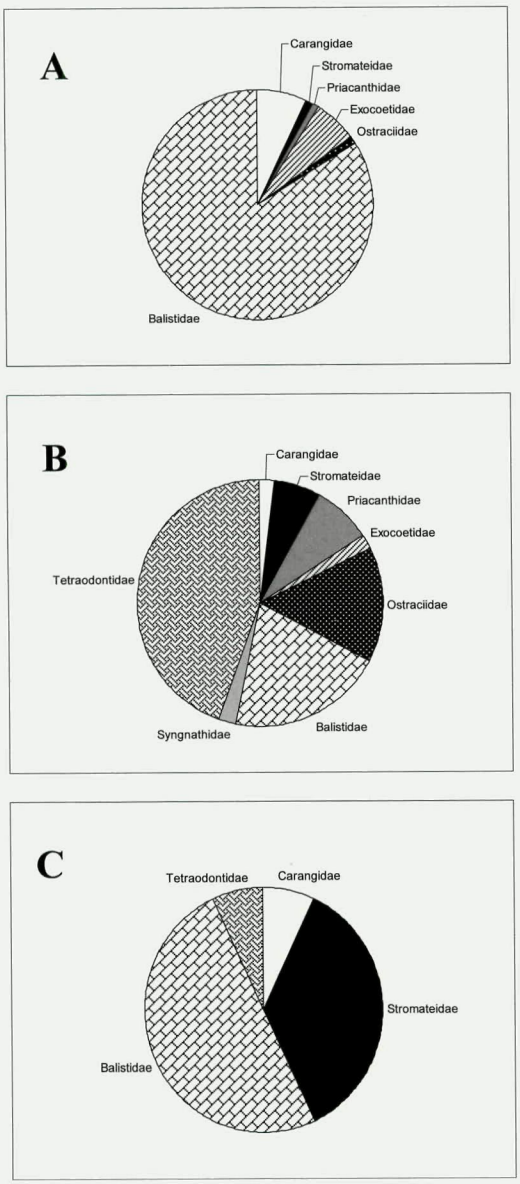

FIG. 1. Numerical percentage (numbers of prey item 'A' divided by the total number of prey items × 100) of *Sargassum*-associated fishes in the digestive tracts of Audubon's Shearwaters (A) (n = 48), Bridled Terns (B) (n = 16), and Royal Terns (C) (n = 8).

commute daily from Outer Banks nesting colonies to forage in *Sargassum* mats along the edge of the outer continental shelf, a round trip of up to 160 km or more (DSL, unpubl. data). Common (*Sterna hirundo*) and Black (*Chlidonias niger*) terns, and Sabine's Gulls seasonally migrate north and south, and likely use rows of *Sargassum* along the western edge of the Gulf Stream and drift lines within the Stream to both orient and feed.

Reduction in the *Sargassum* community would have negative effects on a number of western North Atlantic seabirds, based on digestive tract analysis and at-sea observations, including five tropical species considered to be of conservation concern (Schreiber 2000). Observations of Bermuda Petrels (*Pterodroma cahow*) and Roseate Terns (*Sterna dougallii*) indicated these Endangered Species also use *Sargassum* to forage. *Sargassum* use by seabirds in the Pacific and Indian oceans is unknown, but it is likely that many of the same species and their ecological counterparts exploit *Sargassum* reefs in those oceans as well. Commercial harvest threatens to reduce the standing crop of *Sargassum* in the western North Atlantic (Settle 1997), and there are possible negative impacts to *Sargassum* from oil and gas exploration on the outer Continental Shelf off the coast of North Carolina (Lee 1999). Seabird surveys in the Gulf of Mexico shortly after the Deepwater Horizon oil spill (April 2010) indicated *Sargassum* habitat was damaged by this event (J. C. Haney and DSL, unpubl. data). Global climate change and attendant ocean acidification may also affect *Sargassum* (Porzio et al. 2011). Significant reduction in the amount or quality of *Sargassum* habitat could reduce seabird abundance, influence marine distribution, alter seasonal movements, and/or jeopardize the birds' physiological condition.

ACKNOWLEDGMENTS

We thank S. W. Ross for help with fish identification and for reviewing an early version of this manuscript. H. J. Porter aided in gastropod identification. J. M. Butzerin, T. P. Good, J. C. Haney, W. A. Mackin, R. L. Pitman, and an anonymous reviewer provided helpful reviews of this manuscript. Funding for this study was provided in part by the National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, and U.S. Department of the Navy.

LITERATURE CITED

ASHMOLE, N. P. 1971. Seabird ecology and the marine environment. Pages 223–286 *in* Avian Biology (D. S. Farner and J. R. King, Editors). Volume I. Academic Press, New York, USA.

CASAZZA, T. L. AND S. W. ROSS. 2008. Fishes associated with pelagic *Sargassum* and open water lacking *Sargassum* in the Gulf Stream off North Carolina. Fishery Bulletin 106:348–363.

DOOLEY, J. K. 1972. Fishes associated with the pelagic *Sargassum* complex, with a discussion of the *Sargas-*

sum community. Contributions in Marine Science 16: 1–31.

DUNCAN, C. D. AND P. W. HARVARD. 1980. Pelagic birds of the northern Gulf of Mexico. American Birds 34:122–132.

FINE, M. L. 1970. Faunal variation on pelagic Sargassum. Marine Biology 7:112–122.

GOWER, J. AND S. KING. 2011. Distribution of floating *Sargassum* in the Gulf of Mexico and Atlantic Ocean mapped using MERIS. International Journal of Remote Sensing 32:1917–1929.

GOWER, J., C. HU, G. BORSTAD, AND S. KING. 2006. Ocean color satellites show extensive lines of floating Sargassum in the Gulf of Mexico. IEEE Transactions on Geoscience and Remote Sensing 44:3619–3625.

HANEY, J. C. 1985. Marine distribution, seasonal abundance, and ecology of phalaropes in the Georgia Embayment. The Oriole 50:21–31.

HANEY, J. C. 1986. Seabird patchiness in tropical oceanic waters: the influence of *Sargassum* "reefs". Auk 103:141–151.

HANEY, J. C., D. S. LEE, AND R. D. MORRIS. 1999. Bridled Tern (*Sterna anaethetus*). The birds of North America. Number 468.

HOWARD, K. L. AND R. J. MENZIES. 1969. Distribution and production of *Sargassum* in the waters off the Carolina coast. Botanica Marina 11–12:244–254.

LEE, D. S. 1986. Seasonal distribution of marine birds in North Carolina waters, 1975–1986. American Birds 40:409–412.

LEE, D. S. 1995. Marine birds off the coast of North Carolina. Chat 59:113–171.

LEE, D. S. 1999. Pelagic seabirds and the proposed exploitation for fossil fuels off North Carolina: a test for conservation efforts of a vulnerable international resource. Journal of the Elisha Mitchell Scientific Society 115:294–315.

LEE, D. S. AND J. C. HANEY. 1996. Manx Shearwater (*Puffinus puffinus*). The birds of North America. Number 257.

LEE, D. S. AND E. W. IRVIN. 1983. Tropicbirds in the Carolinas: status and period of occurrence of two tropical pelagic species. Chat 47:1–13.

LEE, D. S. AND M. C. SOCCI. 1998. Potential effects of oil spills on seabirds and selected other oceanic vertebrates off the North Carolina coast. Occasional Papers North Carolina Biological Survey 1998-1.

LEE, D. S. AND M. WALSH-MCGEHEE. 1998. White-tailed Tropicbird (*Phaethon lepturus*). The birds of North America. Number 353.

LEE, D. S., D. B. WINGATE, AND H. W. KALE II. 1981. Records of tropicbirds in the North Atlantic and upper Gulf of Mexico, with comments on field identification. American Birds 35:887–890.

MACKIN, W. A. 2004. Communication and breeding behavior of Audubon's Shearwaters. Dissertation. University of North Carolina, Chapel Hill, USA.

MARMORINO, G. O., W. D. MILLER, G. B. SMITH, AND J. H. BOWLES. 2011. Airborne imagery of a disintegrating *Sargassum* drift line. Deep Sea Research I 58:316–321.

MOSER, M. L. AND D. S. LEE. 1992. A fourteen-year survey of plastic ingestion by western North Atlantic seabirds. Colonial Waterbirds 15:83–94.

MOSER, M. L., P. J. AUSTER, AND J. B. BICHY. 1998. Effects of mat morphology on large *Sargassum*-associated fishes: observations from a remotely operated vehicle (ROV) and free-floating video camcorders. Environmental Biology of Fishes 51:391–398.

OBST, B. S., W. HAMNER, E. WOLANSKI, M. HAMMER, AND M. RUBEGA. 1996. Kinematics of phalarope spinning. Nature 384:121.

PORZIO, L., M. C. BUIA, AND J. M. HALL-SPENCER. 2011. Effects of ocean acidification on macroalgal communities. Journal of Experimental Marine Biology and Ecology 400:278–287.

SAFINA, C. AND J. BURGER. 1985. Common Tern foraging: seasonal trends in prey fish densities and competition with bluefish. Ecology 66:1457–1463.

SCHREIBER, E. A. 2000. Action plans for conservation of West Indian seabirds. Pages 182–191 *in* Status and conservation of West Indian seabirds (E. A. Schriber and D. S. Lee, Editors). Caribbean Ornithology Society Special Publication Number 1.

SETTLE, L. R. 1993. Spatial and temporal variability in the distribution and abundance of larval and juvenile fishes associated with pelagic *Sargassum*. Thesis. University of North Carolina, Wilmington, USA.

SETTLE, L. R. 1997. Commercial harvest of pelagic *Sargassum*: a summary of landings since June 1995. Pelagic habitat *Sargassum* and water column, South Atlantic Fishery Management Council essential fish habitat workshop Number 9: 7–8 October 1997. South Atlantic Fishery Management Council, Charleston, South Carolina, USA.