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THE COMPOSITION, SEASONAL OCCURRENCE
AND REPRODUCTIVE PERIODICITY OF
THE PHAEOPHYCEAE (BROWN ALGAE)
IN NEW HAMPSHIRE¹

ARTHUR C. MATHIESON AND EDWARD J. HEHRE²

Until recently there have been few published accounts of the marine algae of New Hampshire (Farlow, 1881; Collins, 1900, 1901, 1903, 1906; Croasdale, 1941; Wood & Straughan, 1953; Doty & Newhouse, 1954). However, since the mid 1960's we have conducted a variety of floristic and ecological investigations of New Hampshire seaweeds in order to interpret better their diversity, distribution, and abundance. In the present account we attempt to summarize all known records of brown algae from New Hampshire with four primary objectives as follows: (1) to describe the species composition of the brown algae in New Hampshire; (2) to record their seasonal occurrences; (3) to determine, where possible, species reproductive periodicities, and; (4) to characterize their local distribution within coastal and estuarine habitats.

STUDY AREA AND METHODS

Seasonal collections and observations of littoral and sublittoral brown algae in New Hampshire were made at numerous coastal and estuarine sites (Table I) from 1965-1980. Detailed habitat descriptions of several of the collecting sites, as well as general accounts of the New Hampshire coastal zone are given elsewhere (e.g. Hehre & Mathieson, 1970; Mathieson & Fralick, 1972; Mathieson, Hehre, & Reynolds, 1981; Mathieson, Reynolds, & Hehre, 1981; Norall & Mathieson, 1976). Two major open coastal and two primary estuarine areas occur within the state (Figs. 1 and 2, Table I): (1) the Isles of Shoals, an interstate set of islands which are located approximately 9 miles SSE of Portsmouth; four of these islands are in New

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Table I Summary of collection sites

Geographical Area	Number and/or names of permanent stations	Sites with at least 2 years of seasonal collections	Sites with at least 2 years of monthly collections	Pertinent references
(1) Isles of Shoals	Anderson Ledge	×		Mathieson 1979
	Appledore Island	×		
	Cedar Island	×		
	Duck Island	×		
	Lunging Island	×		
	Malaga Island	×		
	Smuttnose Island	×		
	Star Island	×		
	White Island	×		
(2) Nearshore open coast from Portsmouth to Seabrook	14 sites		×	
	Jaffrey Point, Newcastle (70° 42' 49" W, 43° 03' 22" N)		×	Mathieson, Hehre, & Reynolds, 1981
	Bound Rock, Seabrook (70° 48' 45" W, 42° 53' 30" N)		×	Daly and Mathieson 1977

(3) Hampton-Seabrook Estuary System	49 total sites	×		Mathieson & Fralick 1972
	Blackwater River – 11 sites	×		
	Brown River – 13 sites	×		
	Hampton River – 18 sites	×		
	Hampton Harbor – 7 sites	×		
(4) Great Bay Estuary System	166 total sites	×		Mathieson, Reynolds, & Hehre, 1981
	Great Bay – 16 sites	×		
	Crommet Creek, Durham (70° 53' W, 43° 05' 52" N)		×	
	Nannies Island, Newington (70° 51' 47" W, 43° 04' 08" N)		×	
	Thomas Point, Newington (70° 51' 56" W, 43° 04' 53" N)		×	
	Weeks Point, Greenland (70° 51' 42" W, 43° 03' 32" N)		×	
	Little Bay – 21 sites	×		
	Adams Point, Durham (70° 52' 07" W, 43° 05' 43" N)		×	
	Cedar Point, Durham (70° 51' 08" W, 43° 07' 45" N)		×	
	Dover Point, Dover (70° 49' 42" W, 43° 07' 07" N)		×	
	Durham Point, Durham (70° 52' 10" W, 43° 07' 14" N)		×	
	Bellamy River – 10 sites	×		
Coheco River – 17 sites	×			

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Table I Continued

Geographical Area	Number and/or names of permanent stations	Sites with at least 2 years of seasonal collections	Sites with at least 2 years of monthly collections	Pertinent references
	Lamprey River – 9 sites	×		
	Oyster River – 14 sites	×		
	Headwater at route 108 Durham (70° 55'06" W, 43° 07'52" N)		×	
	Piscataqua River – 59 sites	×		
	Atlantic Heights, Portsmouth (70° 46'08" W, 43° 05'36" N)			Mathieson et al. 1977
	Normandeau Schiller site #16, just east of the Schiller Power generating station (70° 46'51" N, 43° 05'41" W)		8 years of continuous seasonal collections	
	ibid. #17, at end of Long Reach Farm, Eliot, Maine (70° 46'52" W, 43° 06'02" N)		8 years of continuous seasonal collections	
	ibid. #20, near Schiller Power Plant, Newington (70° 47'47" W, 43° 06'15" N)		8 years of continuous seasonal collections	

ibid. #40, near Simplex Pier, Newington (70° 47' 47" W, 43° 06' 15" N)		8 years of continuous seasonal collections
ibid. #44, area just west of Simplex Pier and Union Oil Terminal, Newington (70° 47' 58" W, 43° 06' 28" N)		8 years of continuous seasonal collections
Salmon Falls River — Squamscott River 16 sites	×	
Chapman's Landing (70° 55' 43" W, 43° 02' 24" N)		×
Winnicut River 4 sites	×	

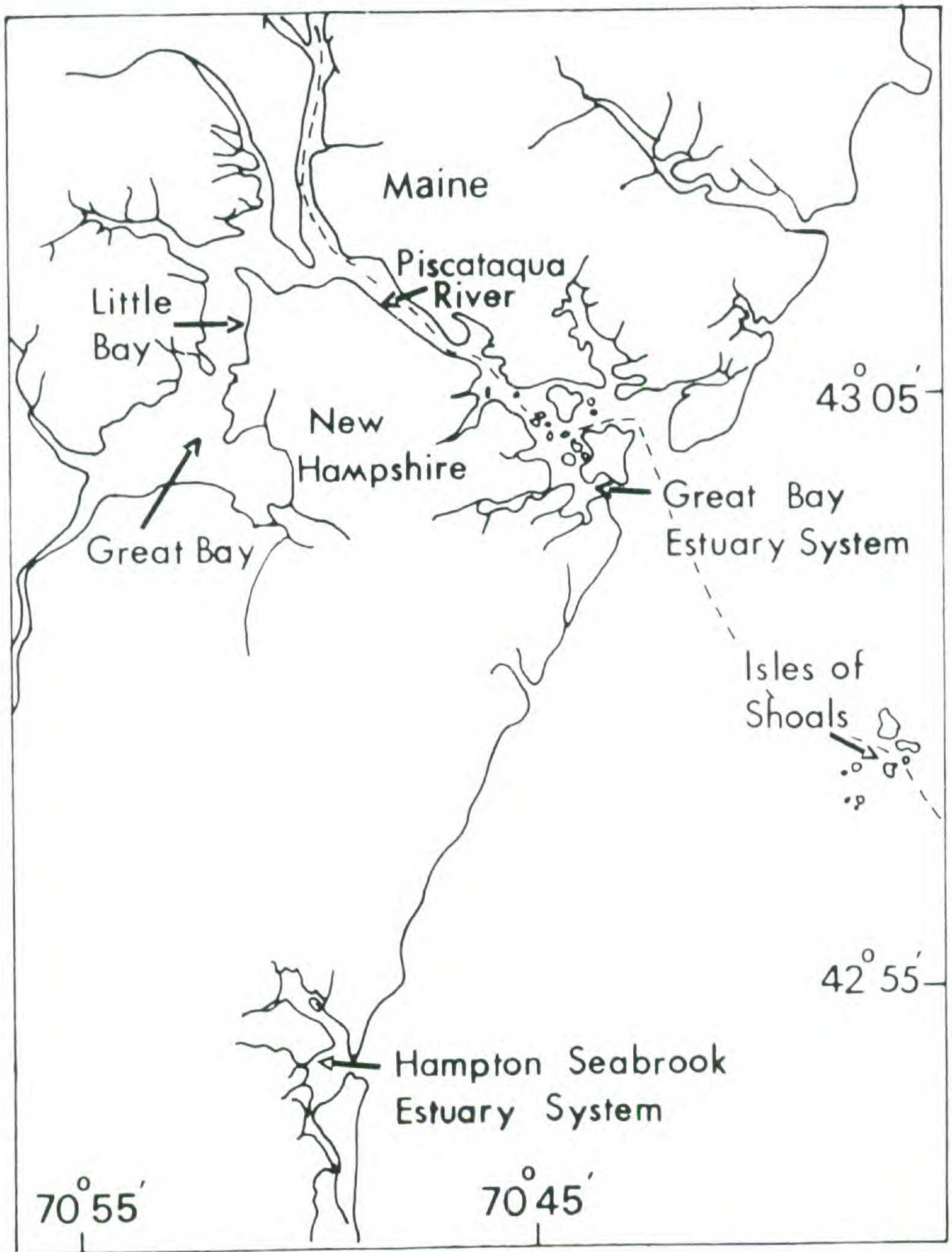


Figure 1. The New Hampshire coastal zone

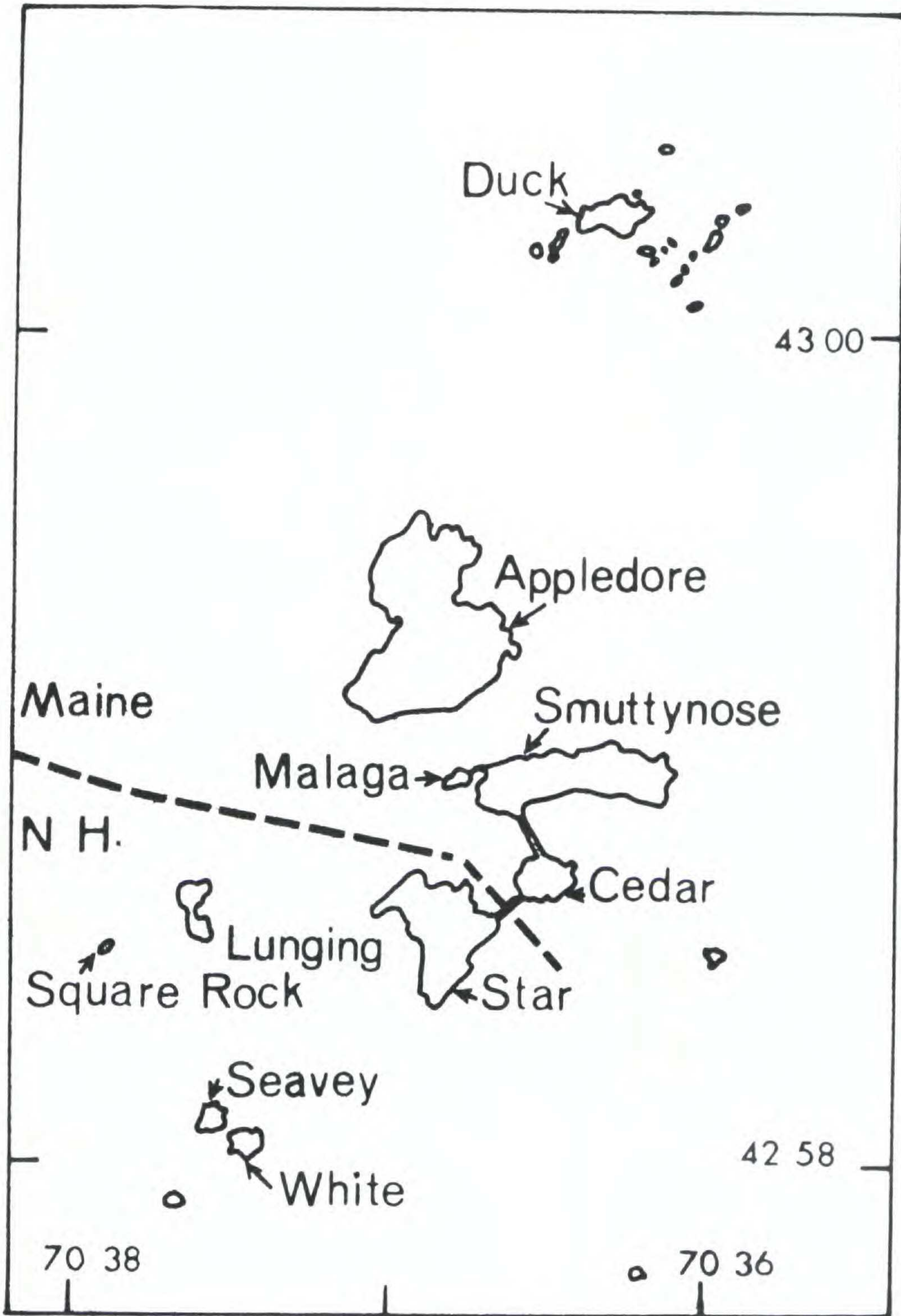


Figure 2. The Isles of Shoals, New Hampshire — Maine

Hampshire (i.e. Lunging, Seavey, Star, and White; (2) the near-shore open coast and adjacent salt marshes between Seabrook and Portsmouth; (3) the Hampton-Seabrook Estuary System that includes Hampton Harbor and three major tributaries (i.e. the Blackwater, Brown, and Hampton Rivers); (4) the Great Bay Estuary System that includes Great Bay, Little Bay, the Piscataqua River, and seven other major tributaries (Bellamy, Cocheco, Lamprey, Oyster, Salmon Falls, Squamscott, and Winnicut Rivers).

Specimens were collected either on foot within the littoral zone (Lewis, 1964) or by SCUBA diving within the sublittoral zone (Mathieson, 1979). Samples were brought to the laboratory (fresh) for identification, determination of reproductive structures, and processing of voucher specimens. The nomenclature of South (1976) was applied in most cases. Herbarium voucher specimens of each taxon were prepared from a wide variety of sites, either monthly or seasonally, and deposited in the Albion R. Hodgdon Herbarium of the University of New Hampshire (NHA).

PHENOLOGY AND DISTRIBUTION

Figure 3, which is based upon the data in Table II, illustrates the monthly occurrence and reproduction of phaeophycean taxa within the state. The number of taxa/month showed a pronounced seasonal pattern. The lowest numbers of brown algae were recorded in December and January, while the highest were noted in August. Reproductive levels of brown algae were highest in late fall-winter and lowest in the summer. Thus, the highest levels of reproduction occurred when the lowest number of taxa were recorded while the opposite reproductive pattern was apparent during periods of highest species numbers. In comparing the seasonal occurrence of the phaeophycean flora, 30 taxa (45%) were considered to be perennials, while 36 taxa (55%) were interpreted as annuals (Fig. 4). Details on longevity and seasonal occurrence are summarized in Table II and in the following annotated checklist.

A summary of the local distribution of phaeophycean taxa in the four major coastal-estuarine areas in New Hampshire is shown in Figure 4. The highest diversity of brown algae was found at the two open coastal areas, with 47 taxa occurring at the Isles of Shoals and 48 taxa from the 18 miles of open coast between Seabrook and Portsmouth. In contrast, 36 taxa were collected from the Great Bay

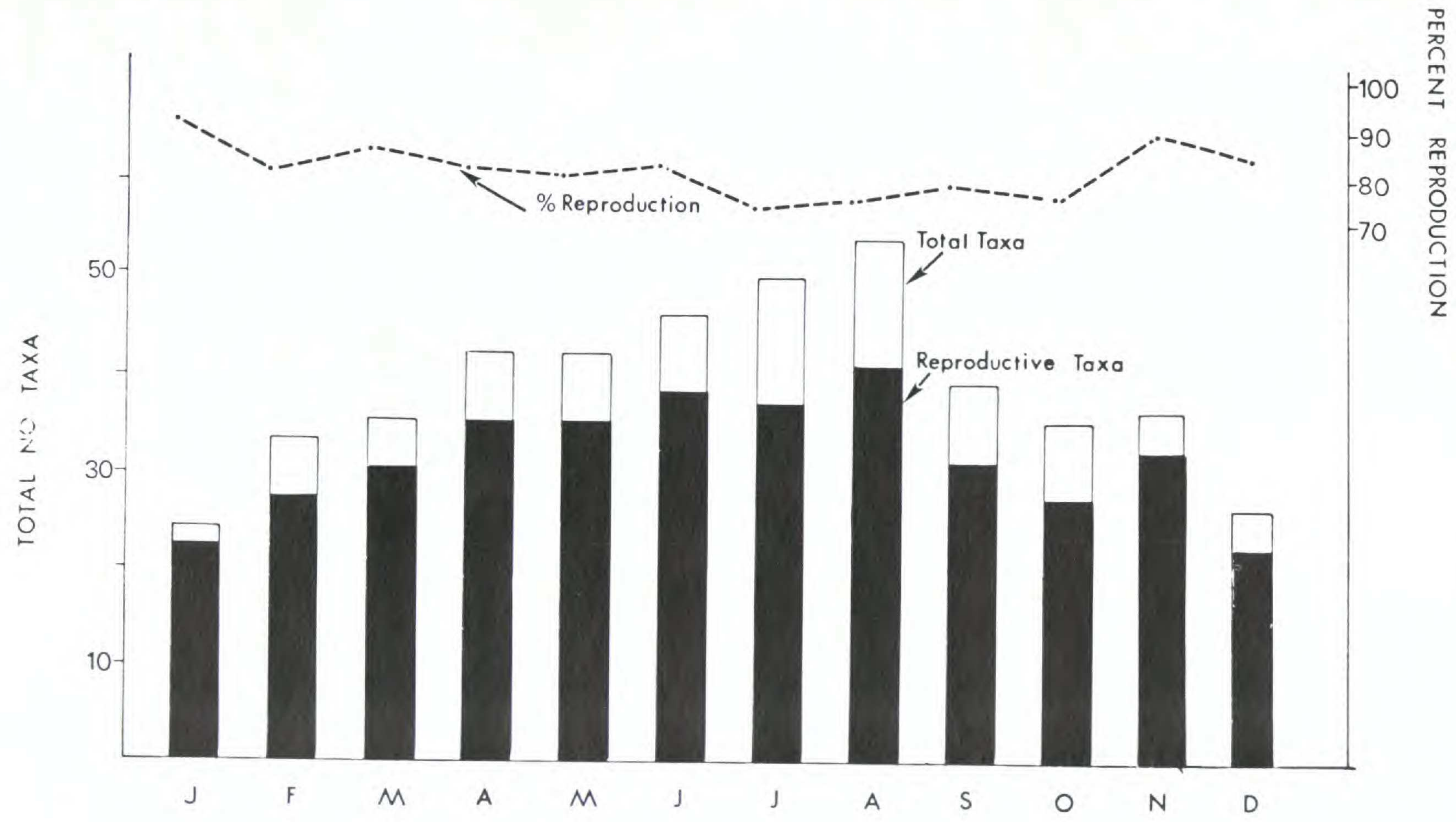


Figure 3. Monthly occurrence and reproduction of phaeophycean taxa in New Hampshire.

Table II. Seasonality, Reproductive Periodicity, Longevity, and Distribution of the Phaeophyceae in New Hampshire*

	Seasonality												Longevity	Local Distribution
	J	F	M	A	M	J	J	A	S	O	N	D		
<i>Agarum cribrosum</i>	U	U	U	U	U	U	U	U	U	U	U	U	Per	1, 2
<i>Alaria esculenta</i>		X	U	U	X	U	U	U	X	U	U	U	Per	1, 2
<i>Ascocyclus distromaticus</i>	P			P	P		P	P	P				A	1, 2
<i>Ascophyllum nodosum</i>	R	R	R	R	R	R	R	R	R	R	R	R	Per	1-4
<i>Ascophyllum nodosum</i> <i>ecad scorpioides</i>	R	R	R	R	R	R	X	X	X	X	X	X	Per	3, 4
<i>Asperococcus fistulosus</i>				U		U	U	U	U				A	1, 2
<i>Chorda filum</i>					X	U	U	U	U		U		A	1-4
<i>Chorda tomentosa</i>				X	U	U		U					A	1, 3, 4
<i>Chordaria flagelliformis</i>	U	U	U	U	U	U	U	U	U	U	U	U	A	1-4
<i>Cladostephus spongiosus</i> f. <i>verticillatus</i>		X											(?) Per	1
<i>Delamarea attenuata</i>				U	U	U					U		A	1, 4
<i>Desmarestia aculeata</i>	X	U	X	X	X	X	X	X	U	U	X	X	Per	1, 2
<i>Desmarestia viridis</i>	X	X	X	X	X	X	X	X	X				A	1, 2
<i>Desmotrichum undulatum</i>				P	P			P					A	1, 4
<i>Dictyosiphon foeniculaceus</i>			X	X	U	U	U	X	X	X			A	1, 2, 4
<i>Ectocarpus faciculatus</i>							P						A	1
<i>Ectocarpus siliculosus</i>	P	P	P	P	P	PU	P	P	P	P	P	P	A	1-4
<i>Elachista fucicola</i>	U	U	U	U	U	U	U	U	U	U	U	U	Per	1-4
<i>Elachista lubrica</i>							U						(?) Per	1
<i>Eudesme virescens</i>							U						A	1, 2
<i>Fucus distichus</i> ssp. <i>distichus</i>	R	R	R	R	R	R	R	R	R	R	R	R	Per	1, 2
<i>Fucus distichus</i> ssp. <i>edentatus</i>	R	R	R	R	R	R	R	R	R	R	R	R	Per	1-4
<i>Fucus distichus</i> ssp. <i>evanescens</i>	R	R	R	R	R	R	R	R	R	R	R	R	Per	1-4

<i>Fucus spiralis</i>	R	R	R	R	R	R	R	R	R	R	R	R	R	Per	1, 2, 4
<i>Fucus vesiculosus</i>	R	R	R	R	R	R	R	R	R	R	R	R	R	Per	1, 2
<i>Fucus vesiculosus</i> var. <i>spiralis</i>	R	R	R	R	R	R	R	R	R	R	R	R	R	Per	3, 4
<i>Giffordia granulosa</i>		P				P	P	P	P	P	P	P	P	A	1, 3, 4
<i>Giffodia sandriana</i>								P	P					A	4
<i>Giffordia secunda</i>								P						A	2
<i>Hecatonema terminalis</i>														A	—
<i>Isthmoplea sphaerophora</i>				U	U	U		U						A	1, 4
<i>Laminaria digitata</i>	U	U	U	U	U	U	U	U	U	U	U	U	U	Per	1, 2, 4
<i>Laminaria longicuris</i>		X	X	X	X	X	X	X	X	X	X	X		Per	1, 2, 4
<i>Laminaria saccharina</i>	U	U	U	U	X	X	X	X	U	X	U	U	U	Per	1-4
<i>Laminariocolax tomentosoides</i>			P	P				P		P		P	(?) A	2	
<i>Leathesia difformis</i>				U	U	U	U	U	U	U	U			A	1, 2
<i>Mikrosyphar porphyrae</i>					P		P	P						A	1
<i>Myrionema coronnae</i>		P	P	P	P	P	P	P	P	P	P			A	1, 2, 4
<i>Myrionema magnusii</i>														A	—
<i>Myrionema strangulans</i>						U	U	U						A	1, 2
<i>Petalonia fascia</i>	P	P	P	P	P	P	P	P	P	P	P	P	P	A	1-4
<i>Petalonia zosterifolia</i>			P	P	P			P			P	P	P	A	1, 2, 4
<i>Petroderma maculiforme</i>	U	U	U	U	U	U	U	U	U	U	U	U	U	Per	2, 4
<i>Pilayella littoralis</i>	PU	PU	PU	PU	PU	PU	U	U	U	U	PU	U	U	A	1-4
<i>Protectocarpus speciosus</i>		P	P	P	P	P	P		P	P	P			(?) A	1, 2
<i>Pseudolithoderma extensum</i>	U	U	U	U	U	U	U	U	U	U	U	U		P	1, 2, 4
<i>Punctaria latifolia</i>						X	P	P	P	X				A	2, 4
<i>Punctaria plataginea</i>						P	P	P						A	1, 2
<i>Ralfsia bornetii</i>		U	U	UP	U	U		U	U		U			(?) Per	1-4
<i>Ralfsia clavata</i>			U	U		U	U	U	U	U	U	U		(?) Per	2-4
<i>Ralfsia fungiformis</i>		X			X	X	X	X		X				Per	2
<i>Ralfsia verrucosa</i>	U	U	U	U	U	U	U	U	U	U	U	U	U	Per	1-4

Table II (continued)

	Seasonality												Longevity	Local Distribution
	J	F	M	A	M	J	J	A	S	O	N	D		
<i>Sacchorhiza dermatodea</i>						U	X	X					A	1, 2
<i>Scytosiphon lomentaria</i> var. <i>lomentaria</i>	P	P	P	P	P	P	P	P	P	P	P	P	A	1-4
<i>Scytosiphon lomentaria</i>		X	P										A	4
<i>Stictyosiphon griffithsianus</i>								U					Per	2
<i>Ulonema rhizophorum</i>						P							A	4
<i>Sphacelaria cirrosa</i>	U	PU		X		X	X	X	X	X	X	X	Per	1, 2, 4
<i>Sphacelaria fusca</i>							X						(?) Per	1
<i>Sphacelaria plumigera</i>							X	X					Per	2
<i>Sphacelaria plumosa</i>							X	X					(?) Per	2
<i>Sphacelaria racemosa</i>				X			X	X	X				(?) Per	2
<i>Sphacelaria radicans</i>			X		X	X	X	X	X	X	U	X	Per	2, 3
<i>Spongonema tomentosum</i>			P	P	P		P	P		P	P		(?) Per	1, 2
<i>Stictyosiphon griffithsianus</i>					U	U							A	4
<i>Ulonema rhizophorum</i>		P	P	P	P	P	P	P			P		A	1, 2, 4
Total species present by month	24	33	35	42	42	46	50	54	39	35	36	27		

Longevity

A = annual
Per = perennial

Seasonality/ Reproductive Structures

P = plurilocular sporangia
R = receptacle
U = unilocular sporangia
X = present

Local Distribution

1 = Isles of Shoals
2 = Nearshore open coast
3 = Hampton-Seabrook Estuary System
4 = Great Bay Estuary System

Estuary System, while only 19 taxa were noted from the Hampton-Seabrook Estuary System. Specific details on the coastal and/or estuarine distributional patterns of each species are given in Table II and in the annotated checklist.

ANNOTATED CHECKLIST

Sixty-six taxa of phaeophycean algae from coastal and estuarine environments within New Hampshire are recorded in the following checklist. Four taxa were rare and only collected once (i.e., *Cladostephus spongiosus* f. *verticillatus*, *Elachista lubrica*, *Giffordia secunda*, and *Sorocarpus micromorus*). Fourteen species are newly recorded. Two of these represent range extensions on the northeastern coast of North America. Thus, *Cladostephus spongiosus* f. *verticillatus* was previously known from New York to southern Massachusetts (Taylor, 1962), while *Protectocarpus speciosus* was earlier recorded from the Canadian Maritime Provinces (South, 1976). Collins (1900) recorded two taxa from the state, namely *Myrionema magnusii* (as *Ascocyclus orbicularis*) and *Hecatonema terminalis* (as *Ectocarpus terminalis*), which we have neither collected nor observed as herbarium specimens. Both plants are small epiphytic species, which might have been missed due to their uncommon occurrence.

* = a range extension on the northeastern coast of North America.
 ** = a new record for New Hampshire.

PHAEOPHYCEAE

Agarum cribrosum (Mert.) Bory

Common on the open coast, epilithic (0 to -32m), unilocular sporangia recorded each month. Perennial.

Alaria esculenta (L.) Grev.

Common on exposed open coastal sites, epilithic (0 to -18m), unilocular sporangia recorded each season. Perennial.

Ascocyclus distromaticus Taylor

Uncommon, epiphytic on *Palmaria palmata* (0 to -10m) on the open coast. Collected each season, plurilocular reproductive organs observed in each collection. Annual.

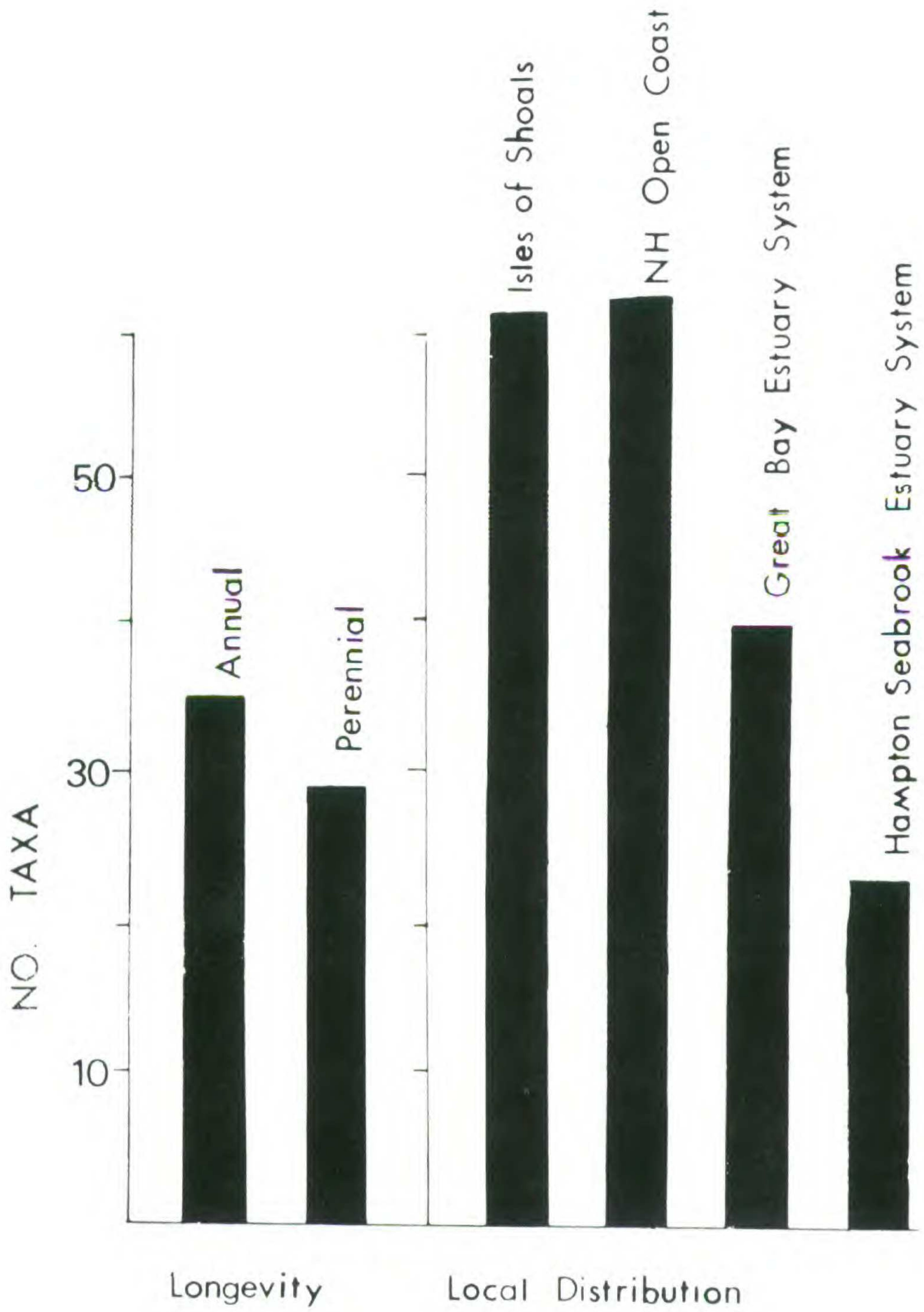


Figure 4. The longevity and local distribution of phaeophycean taxa in New Hampshire.

Ascophyllum nodosum (L.) Le Jol.

Abundant in semi-exposed and sheltered open coastal and estuarine sites, epilithic (0 to +2.0m). Although some reproductive receptacles are present every month, maximum fertility occurs in early spring (Josselyn & Mathieson, 1978, 1980; Mathieson et al., 1976). Perennial.

Ascophyllum nodosum (L.) Le Jol. ecad **scorpioides** (Reinke)
Hauck

Occasional as detached plants in estuarine habitats (Chock & Mathieson, 1976, in press); usually entangled amongst the culms of *Spartina alterniflora* (+0.15 to +1.5m). Although fertile receptacles are uncommon they have been recorded from January to June. Perennial.

Asperococcus fistulosus (Huds.) Hook.

Uncommon, on rocks and epiphytic on coarse seaweeds (0 to +0.5m) at the open coast. Collected during the spring and summer, with unilocular sporangia observed in each collection. Annual.

Chorda filum (L.) Stack.

Uncommon on the open coast, rare in estuarine (outer) areas. On rocks (0 to -8m) and collected from May to November, unilocular sporangia observed in each collection, except May. Annual.

Chorda tomentosa Lyngb.

Uncommon, on rocks (0 to -12m) in coastal and estuarine environments; the plant exhibits a broader estuarine distribution than *C. filum*. Collected during April to August, with unilocular sporangia observed between May and August. Annual.

Chordaria flagelliformis (O. F. Müll.) C. Ag.

Common on the open coast, less abundant in estuarine habitats. Epilithic and epiphytic (+0.1 to -8.0m). Present throughout the year. Unilocular sporangia recorded every month. Field studies in New England (Mathieson, Hehre, & Reynolds, 1981) and Iceland (Munda, 1979) suggest that forma *densa* Farlow is a juvenile stage of forma *typica*, as young spring specimens have short, dense lateral branches (3-10 mm). Aseasonal annual or biennial (Mathieson et al., loc. cit.).

***Cladostephus spongiosus f. verticillatus** (Lightf.) Lyngb.

Collected once during February. On rocks (+0.1m) at the Isles of Shoals. No reproductive structures observed in the single collection.

Although we have only seen the plant once, it is recorded in an unpublished checklist (Anon., 1975) from the Isles of Shoals. It was previously recorded from New York to southern Massachusetts, as well as being rare north of Cape Cod, (Taylor, 1962). ?Perennial (Sears, 1971).

*****Delamarea attenuata* (Kjell.) Rosenv.**

Uncommon, on rocks (+1.0 to +1.5m) at the Isles of Shoals and with a single estuarine collection near the mouth of the Piscataqua River. Found during April to November, with unilocular sporangia in each collection. Annual.

***Desmarestia aculeata* (L.) Lamour.**

A common epilithic species (0 to -26m) on the open coast. Unilocular sporangia observed in February, September, and October. Perennial.

***Desmarestia viridis* (O. F. Müll.) Lamour.**

Common, on rocks within low tide pools and the sublittoral zone (+0.2 to -20m) of the open coast. Collected from January to September. Annual.

***Desmotrichum undulatum* (J. Ag.) Reinke**

Uncommon, on *Chaetomorpha aerea* and *Cladophora sericea* in tide pools (+1.0 to +2.5m) at the Isles of Shoals, also on *Zostera marina* at a few estuarine habitats (0 to -3.0m). Collected during spring and summer, with plurilocular reproductive organs in each collection. Annual.

***Dictyosiphon foeniculaceus* (Huds.) Grev.**

Common on rocks or epiphytic on *Chordaria flagelliformis*. Present within or outside tide pools in the lower eulittoral (+0.1m), also extending to the sublittoral zone (-12m). Primarily found on the open coast, but with a few collections from outer estuarine sites—e.g., Piscataqua River. Collected from March to October, with unilocular sporangia observed during May to July. Collins (1900) and Croasdale (1941) record the forma *hippuroides* and variety *hispidus*. Our observations, as well as those of Jaasund (1965), suggest that the plant's morphology encompasses the short-branched variety *hispidus* and the exposed open-coastal forma *hippuroides*. Annual.

Ectocarpus fasciculatus Harvey

Collected once (July) at the Isles of Shoals (Star Island), epiphytic on *Laminaria* (Croasdale, 1941) and with plurilocular reproductive organs. Annual.

Ectocarpus siliculosus (Dillw.) Lyng.

Common on rocks and epiphytic (+0.3 to -20m). Found with plurilocular reproductive organs throughout most of the year. Unilocular sporangia observed in June. Aseasonal annual.

Elachista fucicola (Vell.) Aresch.

Common, epiphytic on *Ascophyllum nodosum*, occasionally on *Fucus* sp. Most abundant at the open coast, but with several estuarine records. Present with unilocular sporangia throughout the year. Perennial.

Elachista lubrica Rup.

Collected once (July) with unilocular sporangia, at the Isles of Shoals (Star Island), epiphytic on *Fucus* sp. (Croasdale, 1941). The species is also recorded in an unpublished checklist (Anon., 1975) from the Isles of Shoals. Perennial (?).

Eudesme virescens (Carm. ex Harv. in Hook.) J. Agardh

Collected twice in mid-summer (July), on rocks (+0.1 to -3.0m) from the open coast; unilocular sporangia observed in both collections. Summer annual.

Fucus distichus L. ssp. **distichus** L. emend. Powell

A common open coastal species, on rocks within high eulittoral tide pools (+2.0 to +3.5m); receptacles present throughout the year, but uncommon during June to August. Perennial.

Fucus distichus L. ssp. **edentatus** (DLP) Powell

Common on rocks at the open coast and with a few outer estuarine collections (+0.5 to -9.0m). Receptacles present throughout the year; however, major peaks of reproduction occur in the spring and late summer (E. Sideman, personal communication). The plant is often difficult to distinguish from *F. distichus* ssp. *evanescens*, particularly in the spring and in estuarine locales. Perennial.

Fucus distichus L. ssp. **evanescens** (C. Ag.) Powell

Common in estuarine habitats, less abundant on the open coast, where it is primarily found in semi-exposed to sheltered locations. Growing on rocks (+0.5 to -9.0m). Although receptacles are found throughout the year, reproduction is distinctly maximal in the spring at estuarine areas versus the spring and late summer at open coastal sites (E. Sideman, personal communication). The plant is often difficult to distinguish from *F. distichus* ssp. *edentatus* particularly when it is reproductively immature. Perennial.

Fucus spiralis L.

Common on the open coast, and with scattered estuarine populations. On rocks (+2.0 to +3.0m), often forming a distinct belt above *A. nodosum* and *F. vesiculosus*. Although receptacles are found throughout the year, the plant exhibits a pronounced summer reproductive maximum (Niemeck & Mathieson, 1976). Perennial.

Fucus vesiculosus L.

An ubiquitous epilithic plant on the open coast, occasionally epiphytic on *A. nodosum* (+0.25 to +2.5m). The species is replaced within estuarine habitats by var. *spiralis* Farlow. Although fertile receptacles are found throughout the year, their maximum numbers occur during the spring (Mathieson et al., 1976). Perennial.

Fucus vesiculosus L. var. **spiralis** Farl.

A common estuarine plant, on small rocks and shingle (+1.0 to +2.0m). Occasionally found detached and entangled amongst the culms of *Spartina alterniflora*. Receptacles are present throughout the year, but exhibit a pronounced maximum during the spring (Mathieson et al., 1976). Perennial.

Giffordia granulosa (Smith) Hamel

Found occasionally in estuarine habitats and once at the open coast, epiphytic and epilithic (+0.3 to -3.0m). Collected during February and June to December; with plurilocular reproductive organs in each collection. Annual.

****Giffordia sandriana** (Zanard.) Hamel

Found twice (August and September) on rocks at a single estuarine site (-1.0 to -2.0m), plurilocular reproductive organs in both collections. Annual.

Giffordia secunda (Kütz.) Batters

Collected once (August), on rocks (−2.0m) at the open coast; with dimorphic plurilocular reproductive organs. Annual.

Hecatonema terminalis (Kütz) Kylin

Recorded by Collins (1900) from New Hampshire (as *Ectocarpus terminalis*), with no specific date nor collecting site. Annual.

****Isthmoplea sphaerophora** (Carm. ex Harv. in Hook.) Kjellman

Uncommon, epizoic on sertularians, as well as epiphytic on various coarse seaweeds (+0.2 to −3.0m). Collected during spring and summer; unilocular sporangia observed in each collection. Annual.

Laminaria digitata (Huds.) Lamour.

Common on rocks at the open coast (+0.1 to −18m), and with scattered estuarine populations in strong tidal rapid sites (Mathieson et al., 1977). Unilocular sporangia present year round but most abundant during the winter. Perennial.

Laminaria longicuris DLP

Occasional, on rocks (0 to −26.0m) in open coastal and estuarine habitats. No reproductive specimens observed. Perennial.

Laminaria saccharina (L.) Lamour.

Common in sublittoral habitats (0 to −26.0m) containing solid substratum. The taxon is more abundant than *L. digitata* in sheltered open coastal and estuarine habitats. Unilocular sporangia observed during each season but most abundant during the winter. Perennial.

Laminariocolax tomentosoides (Farl.) Kylin

Occasional, epiphyte of *Laminaria* spp. on the open coast. Found during March to December, with plurilocular reproductive organs observed in each collection. Annual (?).

Leathesia difformis (L.) Aresch.

Present from April to November at the open coast; most common during the summer. On rocks and various algae (+0.5 to −6.0m). Unilocular sporangia observed in each collection. Annual.

****Mikrosyphar porphyrae** Kuck.

Uncommon, endophytic within *Porphyra* spp. at the Isles of Shoals (+2.5 to −3.0m). Collected during May to August, with plurilocular reproductive organs in each collection. Annual.

****Myrionema coronnae** Sauv.

Common, on *Laminaria* spp. (0 to -11m) at the open coast and with a single estuarine record. Collected from February to November, with plurilocular reproductive organs in each collection. Annual.

Myrionema magnusii (Sauv.) Loiseaux

Recorded by Collins (1900) from New Hampshire (as *Ascocyclus orbicularis*), with no specific date nor collecting site. Annual.

Myrionema strangulans Grev.

Occasional, epiphytic on various seaweeds (+0.5 to -5.0m), particularly *Ulva lactuca*. Collected from June to August; primarily found on the open coast, but with a single estuarine record. Unilocular sporangia observed in each collection. Annual.

Petalonia fascia (O. F. Müll.) Kuntze

Common, epilithic and epiphytic from the upper eulittoral (in tide pools) to the sublittoral fringe zones (+2.3 to -0.1m). Present with plurilocular reproductive organs throughout the year, but most prevalent during the winter and spring. The plant alternates with *Ralfsia bornetii* and *R. clavata* (Edelstein, et al., 1970). Annual.

****Petalonia zosterifolia** (Reinke) O. Kuntze

Uncommon, on rocks (+0.2 to 0.0m), primarily at the open coast—but with a few estuarine collections. Found during March–December, and with plurilocular reproductive organs in each collection. Annual.

****Petroderma maculiforme** (Wollny) Kuck.

Common on rocks at several estuarine sites, less abundant at the open coast (0 to -8.0m). Present throughout the year, with unilocular sporangia observed in each collection. It is tolerant of consistently low, as well as fluctuating salinities. As noted by Wilce, et al. (1970), the taxon has a broad boreal-arctic distribution, extending from southern Massachusetts to the high arctic, northwest Greenland, and eastern Canadian archipelago. Perennial.

Pilayella littoralis (L.) Kjell.

Common, found throughout the year but most prevalent during the spring and early summer (Chock & Mathieson, in press). On rocks and epiphytic on coarse seaweeds (0 to +1.5m) in a wide

variety of coastal and estuarine habitats, extremely tolerant of salinity fluctuations. Unilocular sporangia recorded each month; plurilocular reproductive organs seen during January to June and October. Aseasonal annual.

***Protectocarpus speciosus** (Borg.) Kuck.

Occasional, epiphytic on *Chaetomorpha aerea* at the open coast (+0.1 to +1.5m). Collected during July to November, with plurilocular reproductive organs observed in each collection. Annual (?).

Pseudolithoderma extensum (Crouan frat.) S. Lund

A common crustose species, epilithic at numerous coastal and estuarine locations (0 to -8.0m). Collected with unilocular sporangia each month. Perennial.

Punctaria latifolia Grev.

Uncommon, epiphytic on *Zostera marina* and several seaweeds (0 to -3m) in estuarine and open coastal areas. Collected during June to October, with plurilocular reproductive organs observed from July to September. Annual.

Punctaria plantaginea (Roth) Grev.

Uncommon, collected between June and August on the open coast, epilithic (+0.1 to -3.0m). Plurilocular reproductive organs observed in each collection. Annual.

Ralfsia bornetii Kuck.

Occasional, growing on rocks (+1.5 to -11.0m) on the open coast and occasionally in estuarine habitats. Found throughout most of the year, unilocular sporangia in all collections, plurilocular reproductive organs seen only in April. As noted by Edelstein, et al. (1970) the plant is part of the life history of *Petalonia fascia*. Perennial (?).

Ralfsia clavata (Harv. in Hook.) Crouan frat.

Occasional, epilithic (+1.0 to -26.0m) at open coastal and estuarine areas. Observed during March to December with unilocular sporangia in all collections. As described by Edelstein, et al. (1970) it may be part of the life history of *Petalonia fascia*. Perennial (?).

Ralfsia fungiformis (Gunn.) Setch. et Gard.

Occasional, collected all seasons, on rocks (0 to -8m) at the open coast; no sporangia observed. Perennial.

Ralfsia verrucosa (Aresch.) J. Agardh

Common on rocks within the upper eulittoral (in tide pools) to the sublittoral zone (+2.2 to -26m) at a wide variety of coastal and estuarine sites. Unilocular sporangia observed each month. Perennial.

Saccorhiza dermatodea (DLP) J. Ag.

Uncommon, attached to rocks within the sublittoral zone (0 to -15m) on the open coast. Collected from June to August, with unilocular sporangia observed in June. Annual.

Scytosiphon lomentaria (Lyngb.) Link var. **lomentaria**

Common on rocks, occasionally epiphytic on coarse seaweeds (0 to +2.7m). Present with plurilocular reproductive organs throughout the year, but most prevalent during the winter and spring. Annual.

****Scytosiphon lomentaria** (Lyngb.) Link var. **complanatus** Rosenv.

Locally abundant at one estuarine site during February and March, on rocks (0 to -3m). Plurilocular reproductive organs observed in March. Clayton (1980) gives a detailed account of the complanate and cylindrical plants of *S. lomentaria*. She emphasizes that the two are distinct, although the taxonomic significance of their differences still requires further investigation. Annual.

Sorapion kjellmanii (Wille) Rosenv.

Recorded once (August) with unilocular sporangia; found on small rocks within the sublittoral zone (-6m) of a sandy open coastal site. Perennial.

****Sorocarpus micromorus** (Bory) Silva

Found once (June) with plurilocular reproductive organs, growing on rocks within the lower eulittoral zone (+0.1m) at an estuarine site. Annual.

Sphacelaria cirrosa (Roth) C. Ag.

Common on the open coast, less abundant in estuarine habitats, forming small tufts on vertical rock faces (+0.2 to +1.4m) and extending to -11.0m. It is often found under *Ascophyllum nodosum* and *Fucus vesiculosus* and occasionally as an epiphyte on both species. Present throughout the year, with plurilocular reproductive

organs observed in February, unilocular sporangia in January and February, propagules in June, July, September, and October. Perennial.

****Sphacelaria fusca** (Huds.) C. Ag.

Found once (July) at the Isles of Shoals on rocks within the lower eulittoral zone (0.1m). Biradiate propagules observed but no other reproductive structures. According to De Haas-Niekerk (1965) *S. fusca* equals *S. furcigera*. Perennial (?).

****Sphacelaria plumigera** Holmes

Recorded twice (July and August) on rocks (0 to -12m) from the open coast. Perennial.

Sphacelaria plumosa Lyngb.

Uncommon, collected during July and August on rocks (0 to -18m) at the open coast. Perennial (?).

Sphacelaria racemosa Grev.

Locally abundant on rocks within the sublittoral zone (0 to -18m) at the open coast. Collected during April and July to September. As suggested by Sears (1971) the plant is distinct from *S. arctica* (= *S. racemosa* var. *arctica* in Taylor, 1962). Perennial (?).

Sphacelaria radicans (Dill.) C. Ag.

Locally common on rocks (+0.1 to -12.0m) in sandy open coastal sites (Daly & Mathieson, 1977) and with a single outer estuarine collection. Collected during all seasons, unilocular sporangia present in November. Perennial.

Spongonema tomentosum (Huds.) Kutz.

Uncommon, epiphytic on furoid and other coarse algae (+0.2 to +0.5m) from the open coast. Collected during March to November with plurilocular reproductive organs in all but the March collection. Perennial (?).

****Stictyosiphon griffithsianus** (Le Jol.) Holmes *et* Batt.

Rare, collected three times during May and June at two estuarine locations. Epiphytic on *Palmaria palmata* within the upper sublittoral zone (0 to -3m) with unilocular sporangia observed in each collection. Annual.

Ulonema rhizophorum Foslie

A common epiphyte on *Dumontia contorta* (Kilar & Mathieson, 1978); seen from February to August and November with plurilocular reproductive organs observed in all collections. Annual.

DISCUSSION

The brown algal flora of New Hampshire exhibits a pronounced seasonal cycle (Figure 3) with the highest number of species in the summer and the lowest numbers in the winter. In contrast, the Phaeophyceae in more southerly areas like Florida usually show a winter or early spring maximum and a summer minimum (Earle, 1969, 1972; Mathieson & Dawes, 1975). Coleman and Mathieson (1975) suggest that the geographical differences in seasonal succession may be due to varying thermal regimes and amplitudes. Chapman (1964) and Williams (1948, 1949) also emphasize that seasonally dynamic floras and a wide range of annuals exist in areas with pronounced temperature fluctuations. The functional role of annuals in mediating the seasonal cycle of brown algae in New Hampshire is shown in Table II as there are two major groups of annuals: (1) aseasonal annuals that reproduce throughout the year and that are represented by successive populations, and; (2) seasonal annuals. Hehre and Mathieson (1970) have recorded similar characterizations of the marine rhodophycean annuals in New Hampshire.

A synthesis of the reproductive information in Table II (i.e. all 66 taxa) shows that the levels are highest in late fall-winter and lowest in the summer (Fig. 3). Similar patterns have been described by several other investigators (Scagel, 1966; Russell, 1973). Interestingly there was an apparent inverse relationship between total reproduction and species diversity (Fig. 3).

As might be expected, the greatest diversity of brown algae were found on the open coast of New Hampshire, with reduced numbers of species in estuarine habitats (Fig. 4). Other investigators (Doty & Newhouse, 1954; Mathieson & Fralick, 1972; Mathieson, Reynolds, & Hehre, 1981), have noted a similar estuarine reduction pattern which probably results from a lack of stable substratum and variable salinity, as well as temperature conditions. In turn, the greater diversity of brown algae within the Great Bay as compared to the Hampton-Seabrook Estuary Systems is probably due to its greater size, number of habitats, and availability of substrata (see Mathieson, Reynolds, & Hehre, 1981; Reynolds & Mathieson, 1975).

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