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The deep-water macroalgal community of the East Florida continental shelf (USA)*

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ABSTRACT: The deep-water macroalgal community of the continental shelf off the east coast of Florida was sampled by lock-out divers from two research submersibles as part of the most detailed year-round study of a macroalgal community extending below routine SCUBA depths. A total of 208 taxa (excluding crustose corallines) were recorded; of these, 42 (20.2 %), 19 (9.1 %), and 147 (70.7 %) belonged to the Chlorophyta, Phaeophyta, and Rhodophyta, respectively. Taxonomic diversity was maximal during late spring and summer and minimal during late fall and winter. The number of reproductive taxa closely followed the number of taxa present; when reproductive frequency was expressed as a percentage of the species present during each month, two peaks (January and August) were observed. Most perennial species had considerable depth ranges, with the greatest number of taxa observed from 31 to 40 m in depth. Although most of the taxa present also grow in shallow water (i.e. <10 m), there were some species whose distribution is limited to deeper water. The latter are strongly dominated by rhodophytes. This community has a strong tropical affinity, but over half the taxa occur in warm-temperate areas. Forty-two new records (20 % of the taxa identified) for Florida were listed; this includes 15 taxa which previously had been considered distributional disjuncts in this area. The phaeophyte *Halopteris filicina* is a new addition to the flora of the western Atlantic. Although more studies are needed, it appears that the deep-water flora may be relatively continuous over a large portion of the tropical and subtropical western North Atlantic. The traditional practice of considering Cape Canaveral as a biogeographical boundary may only be appropriate for shallow water. This study demonstrates the need for additional floristic work on macroalgal communities, especially from deep water, before more detailed biogeographical analyses can be performed and suggests that deep-water species could be important in experimental approaches to macroalgal biogeography.

INTRODUCTION

A major breakthrough in the study of deep-water macroalgae has been the development of research submersibles (Earle, 1985). Although phycological studies employing submersibles have been limited, it appears that deep-water algal communities are especially well-developed in the tropical and subtropical western North Atlantic (Littler et al., 1985, 1986; Hanisak & Blair, in press). These communities include many species that previously have been considered rare or not described at all (Hanisak & Blair, in press).

Early collections of deep-water macroalgae in the tropical and subtropical western

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North Atlantic were made by naturalists such as Louis Agassiz and Archibald Menzies. Taylor (1930, 1942) and Howe & Taylor (1931) recorded many new species, some of which are still only known from their original collections. In the Gulf of Mexico, Taylor (1928)

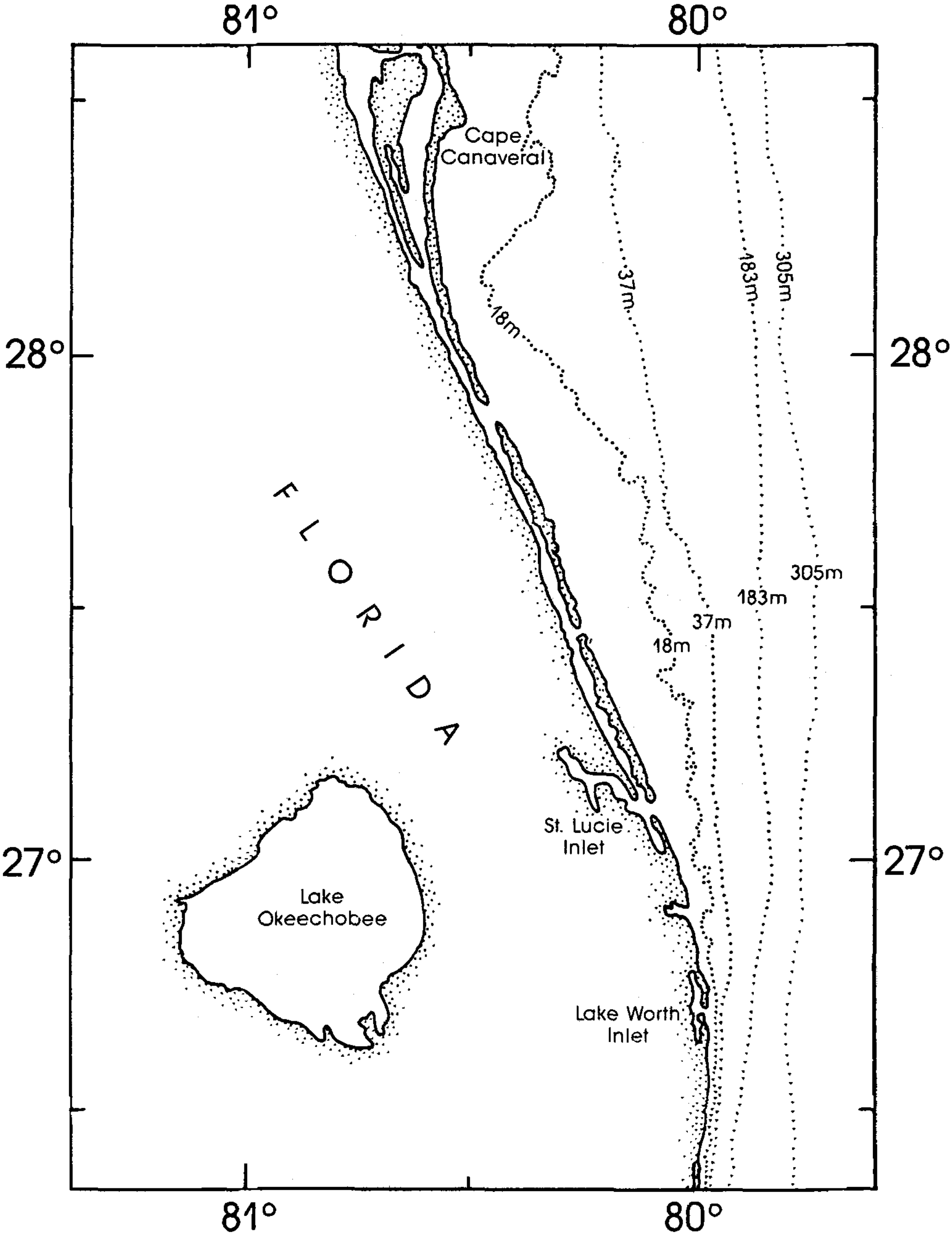

Fig. 1. Map of the study area. Collections were made east of Lake Worth, Jupiter, and St. Lucie Inlets, approximately on the 80° longitude line. Depths are in meters (redrawn from Avent & Stanton, 1979)

collected benthic macroalgae via dredging to depths greater than 100 m. More recent work (Dawes & van Breedveld, 1969; Cheney & Dyer, 1974; Eiseman & Blair, 1982) has added to the available knowledge of the deep-water macroalgae of the Gulf.

The most extensive study of deep-water macroalgae in the western Atlantic has been made along the continental shelf of North Carolina (Schneider, 1974, 1975a, b, 1976, 1984; Schneider & Reading, in press; Schneider & Searles, 1973, 1975, 1976; Searles, 1972, 1984a, b; Searles & Schneider, 1978, 1980) and South Carolina (Wiseman & Schneider, 1977; Schneider & Eiseman, 1979; Blair & Hall, 1981). Yet despite the tremendous activity on the Carolina flora, relatively scant attention has been paid to macroalgae off the extensive eastern coast of Florida, with investigations having concentrated on relatively shallow-water communities (e.g. Phillips, 1961; Juett et al., 1976; Benz et al., 1979; Hall & Eiseman, 1981).

Given the lack of knowledge of the deep-water macroalgal community of the continental shelf off the coast of Florida (USA), Eiseman (1978) initiated a survey of this community with the research submersibles Johnson-Sea-Link I and Johnson-Sea-Link II in an area from St. Lucie Inlet to the Lake Worth Inlet near Palm Beach (Fig. 1). Eiseman and his colleagues described several new species from these collections (Schneider & Eiseman, 1979; Eiseman, 1979; Eiseman & Moe, 1981; Eiseman & Norris, 1981), but no detailed report of these collections was ever made. During studies of the deep-water macroalgal communities in nearby Bahamian waters (Hanisak & Blair, in press; Hanisak et al., unpubl.), the value of the earlier Florida collections became apparent. As part of a project to catalogue and verify the holdings of the Harbor Branch Herbarium (HBFH), an opportunity arose to review and reexamine these earlier collections.

This paper presents information on the seasonal and depth distribution, reproductive phenology, and biogeographic affinities of the macroalgal community of the eastern continental shelf of Florida. This study is particularly important for two reasons: (1) it is the most detailed year-round study on a macroalgal community extending below routine SCUBA depths, and (2) the study site is located near Cape Canaveral, an important biogeographic boundary that has been designated as delineating the warm-temperate and tropical floras (Humm, 1969; van den Hoek, 1975, 1984; Searles, 1984b).

MATERIALS AND METHODS

The deep-water macroalgal community of the east Florida continental shelf was sampled during a series of submersible cruises initiated by Dr. N. J. Eiseman (Eiseman, 1978). The principal collecting sites were located off of Lake Worth Inlet, with less frequent sampling off of St. Lucie and Jupiter Inlets (Fig. 1). Although the substratum at these sites is primarily sand with few algae present, benthic macroalgae do grow on occasional areas of rubble or reefs. These sites were sampled at irregular intervals from July 1974 to June 1983. All months of the year were sampled during these collections with the exception of February.

Seawater temperature was measured during some, but not all collections. Mean monthly water temperatures at depths of 30–50 m were between 20 and 25 °C for all months. Temperatures were more variable at greater depths, but usually ranged from 15 to 20 °C between 60 and 92 m. Significantly lower temperatures (9–12 °C) were occasionally observed during the summer months at these greater depths when periods of upwelling occurred.

Collections were made by lock-out divers from the research submersibles Johnson-Sea-Link I and Johnson-Sea-Link II at depths of ca 24–98 m. Occasional collections at shallower depths were not included in this communication. In total, 171 submersible dives were made on 34 cruises; most of the effort (23 cruises, 143 submersible dives) was concentrated during 1976–1979, when at least 4 cruises a year, with at least one cruise each season, were made. Collection depths were measured by a pressure gauge on the submersible and were accurate to ± 0.5m. The algae were rough sorted aboard ship, preserved in 5 % seawater-formalin, and returned to the laboratory for identification. Presence of reproductive structures was noted when observed. Following the initial identification of the specimens, voucher specimens were deposited in the Harbor Branch Herbarium (HBFH).

During 1984, we initiated the first efforts at cataloguing the contents of HBFH; a large portion of its holdings was from the collections initiated by Eiseman. Despite the obvious importance of these collections, only a few species descriptions and range extensions have been reported (Eiseman, 1979; Schneider & Eiseman, 1979; Eiseman & Moe, 1981; Eiseman & Norris, 1981). However, before even a species list of these collections could be generated, it was necessary to verify and update identifications previously made. In this process, ca 4000 records were examined. This effort was expedited significantly by Wynne's checklist (1986) that synthesized the recent taxonomic changes made in the tropical and subtropical western Atlantic.

Our systematic list within macroalgal divisions follows that of Wynne (1986); crustose corallines are not included. Monthly occurrence and reproductive phenology as well as the mean depth and range of depths for each taxon were tabulated. Because of the nearness of the site to the important "biogeographical boundary" at Cape Canaveral (located ca 150–190 km north of the stations in this study), we were interested in determining the "biogeographic affinity" of the individual species in the macroalgal community. For this biogeographical information, we relied primarily on species lists and distribution records previously prepared by Kapraun (1980, 1984), Searles & Schneider (1978), South & Tittley (1986), and Taylor (1960). Additional information on these biogeographic affinities, as well as previous records for Florida, was obtained from numerous references cited by Wynne (1986).

RESULTS

A total of 208 taxa were recorded during this study (Table 1). Of these 42 (20.2 %), 19 (9.1 %), and 147 (70.7 %) belonged to the Chlorophyta, Phaeophyta, and Rhodophyta, respectively (Table 2). A significant portion of these species was found year-round; less frequently occurring species were usually collected during the summer (Table 3). The number of taxa (Table 2) was highest during late spring and summer (May–July) and lowest during late fall and winter (November–January). Although not quantified, macroalgal abundance was visually correlated with macroalgal diversity and had the same seasonal pattern.

Many species of the east Florida continental shelf were reproductive throughout the year, with the number of reproductive taxa highest in the summer (June to August) near

Table 1. Systematic list (excluding crustose corallines) identified during the study

- Chlorophyta
  - Tetrasporales
    - Palmellopsidaceae
      - ?*Palmophyllum* sp.
  - Ulvales
    - Ulvaceae
      - *Ulva lactuca* Linnaeus
      - *Ulva rigida* C. Agardh
  - Siphonocladales
    - Siphonocladaceae
      - *Struvea pulcherrima* (J. E. Gray) Murray & Boodle
      - *Struvea ramosa* Dickie
    - Valoniaceae
      - *Ventricaria ventricosa* Olsen & West
  - Cladophorales
    - Anadyomenaceae
      - *Anadyomene saldanhae* Joly & Oliveira
      - *Cystodictyon pavonicum* J. Agardh
      - *Microdicyton boergesenii* Setchell
    - Cladophoraceae
      - *Chaetomorpha clavata* (C. Agardh) Kützing
      - *Cladophora coelothrix* Kützing
      - *Cladophora dalmatica* Kützing
      - *Cladophora pellucidoidea* van den Hoek
      - *Cladophora sericea* (Hudson) Kützing
  - Caulerpales
    - Bryopsidaceae
      - *Bryopsis hypnoides* Lamouroux
      - *Bryopsis pennata* Lamouroux
      - *Bryopsis plumosa* (Hudson) C. Agardh
      - *Derbesia marina* (Lyngbye) Kjellman
    - Codiaceae
      - *Codium carolinianum* Searles
      - *Codium decorticatum* (Woodward) Howe
      - *Codium isthmocladum* Vickers
      - *Codium taylori* Silva
    - Caulerpaceae
      - *Caulerpa fastigiata* Montagne
      - *Caulerpa mexicana* Sonder ex Kützing
      - *Caulerpa microphysa* (Weber-van Bosse) Feldmann
      - *Caulerpa prolifera* (Forsskål) Lamouroux
      - *Caulerpa racemosa* var. *macrophysa* (Kützing) Taylor
      - *Caulerpa racemosa* var. *peltata* (Lamouroux) Eubank
      - *Caulerpa racemosa* var. *racemosa* (Forsskål) J. Agardh
      - *Caulerpa sertularioides* (S. G. Gmelin) Howe
    - Udoteaceae
      - *Avrainvillea elliotii* A. and E. S. Gepp
      - *Halimeda discoidea* var. *platyloba* Børgesen
      - *Halimeda gracilis* Harvey ex J. Agardh
      - *Halimeda tuna* (Ellis & Solander) Lamouroux
      - *Halimeda tuna* f. *platydisca* (Decaisne) Barton
      - *Penicillus dumentosus* (Lamouroux) Blainville
      - *Udotea conglutinata* (Ellis & Solander) Lamouroux

Table 1 (Continued)

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  -
    -
      - *Udotea cyathiformis* Decaisne
      - *Udotea flabellum* (Ellis & Solander) Lamouroux
      - *Udotea spinulosa* Howe
      - *Pseudocodium floridanum* Dawes & Mathieson
  - Dasycladales
    - Dasycladaceae
      - *Neomeris annulata* Dickie
- Phaeophyta
  - Sporochnales
    - Sporochnaceae
      - *Nereia tropica* (W. Taylor) W. Taylor
      - *Sporochnus bolleanus* Montagne
      - *Sporochnus pedunculatus* (Hudson) C. Agardh
  - Scytosiphonales
    - Scytosiphonaceae
      - *Colpomenia sinuosa* (Endlicher) Derbes & Solier in Castagne
  - Syringodermatales
    - Syringodermataceae
      - *Syringoderma floridana* Henry
  - Sphacelariales
    - Sphacelariaceae
      - *Halopteris filicina* (Grateloupe) Kützing
  - Dictyotales
    - Dictyotaceae
      - *Dictyopteris delicatula* Lamouroux
      - *Dictyopteris hoytii* W. Taylor
      - *Dictyopteris plagiogramma* (Montagne) Vickers
      - *Dictyota bartayresii* Lamouroux
      - *Dictyota cervicornis* Kützing
      - *Dictyota dichotoma* (Hudson) Lamouroux
      - *Dictyota divaricata* Lamouroux
      - *Lobophora variegata* (Lamouroux) Womersley
      - *Spatoglossum schroederi* (C. Agardh) Kützing
      - *Stypopodium zonale* (Lamouroux) Papenfuss
  - Fucales
    - Sargassaceae
      - *Sargassum cymosum* C. Agardh
      - *Sargassum hystrix* J. Agardh
      - *Sargassum hystrix* var. *buxifolium* Chauvin in J. Agardh
- Rhodophyta
  - Compsopogonales
    - Erythropeltidaceae
      - *Erythrotrichia carnea* (Dillwyn) J. Agardh
  - Nemaliales
    - Acrochaetiaceae
      - *Audouinella daviesii* (Dillwyn) Woelkerling
    - Galaxauraceae
      - *Galaxaura marginata* (Ellis & Solander) Lamouroux
      - *Galaxaura oblongata* (Ellis & Solander) Lamouroux
      - *Galaxaura obtusata* (Ellis & Solander) Lamouroux
      - *Scinaia complanata* (Collins) Cotton
      - *Scinaia complanata* var. *intermedia* Børgesen
      - *Scinaia incrassata* Eiseman

Table 1 (Continued)

- Gelidiales
  - Gelidiaceae
    - *Gelidium americanum* (W. Taylor) Santelices
    - *Pterocladia capillacea* (S. G. Gmelin) Bornet & Thuret
- Bonnemaisoniales
  - Bonnemaisoniaceae
    - *Asparagopsis taxiformis* (Delile) Trevisan (*Falkenbergia* stage)
- Corallinales (excluding crustose forms)
  - Corallinaceae
    - *Amphiroa rigida* var. *antillana* Børgesen
    - *Amphiroa tribulus* (Ellis & Solander) Lamouroux
    - *Jania adhaerens* Lamouroux
- Gigartinales
  - Nemastomataceae
    - *Nemastoma gelatinosum* Howe
    - *Platoma cyclocolpa* (Montagne) Schmitz
    - *Predaea feldmannii* G. De Toni
    - *Predaea masonii* (Setchell & Gardiner) G. De Toni
    - *Titanophora incrustans* (J. Agardh) Børgesen
  - Hypneaceae
    - *Hypnea cervicornis* J. Agardh
    - *Hypnea spinella* (C. Agardh) Kützing
    - *Hypnea volubilis* Searles
  - Wurdemanniaceae
    - *Wurdemannia miniata* (Duby) J. Feldmann & Hamel
  - Solieriaceae
    - *Eucheuma isiforme* (C. Agardh) J. Agardh
    - *Meristotheca floridana* Kylin
    - *Sarcodiotheca caribaea* W. Taylor
    - *Solieria filiformis* (Kützing) Gabrielson
  - Gracilariaceae
    - *Gelidiopsis planicaulis* (W. Taylor) W. Taylor
    - *Gracilaria ?cuneata* Areschoug
    - *Gracilaria curtissiae* J. Agardh
    - *Gracilaria mammilaris* (Montagne) Howe
    - *Gracilaria occidentalis* (Børgesen) Bodard
- Cryptonemiales
  - Peyssonneliaceae
    - *Peyssonnelia inamoena* Pilger
  - Dumontiaceae
    - *Acrosymphyton caribaeum* (J. Agardh) Sjostedt
    - *Dudresnaya bermudensis* Setchell
    - *Dudresnaya crassa* Howe
    - *Dudresnaya patula* Eiseman & J. Norris
  - Halymeniaceae
    - *Cryptonemia crenulata* (J. Agardh) J. Agardh
    - *Cryptonemia luxurians* (C. Agardh) J. Agardh
    - *Cryptonemia* sp.
    - *Halymenia agardhii* De Toni
    - *Halymenia bermudensis* Collins & Hervey
    - *Halymenia floresia* (Clemente) C. Agardh
    - *Halymenia floridana* J. Agardh
    - *Halymenia gelinaria* Collins & Howe

Table 1 (Continued)

- *Halymenia hancockii* W. Taylor
- *Halymenia integra* Howe & W. Taylor
- *Halymenia rosacea* Howe & W. Taylor
- *Halymenia vinacea* Howe & W. Taylor
- Kallymeniaceae
  - *Callophyllis* sp.
  - *Cirrulicarpus carolinensis* Hansen
  - *Kallymenia* sp.
  - *Kallymenia westii* Ganesan
- Rhodymeniales
  - Champiaceae
    - *Champia parvula* (C. Agardh) Harvey
    - *Lomentaria baileyana* (Harvey) Farlow
  - Rhodymeniaceae
    - *Agardhinula browneae* (J. Agardh) De Toni
    - *Botryocladia occidentalis* (Børgesen) Kylin
    - *Botryocladia pyriformis* (Børgesen) Kylin
    - *Chrysymenia agardhii* Harvey
    - *Chrysymenia enteromorpha* Harvey
    - *Chrysymenia halymenioides* Harvey
    - *Chrysymenia planifrons* (Melvill) J. Agardh
    - *Coelarthrum albertisii* (Piccone) Børgesen
    - *Gloioderma atlanticum* Searles
    - *Gloioderma blomquistii* Searles in Schneider & Searles
    - *Gloioderma rubisporum* Searles
    - *Halichrysis peltata* (W. Taylor) P. Huvé & H. Huvé
    - *Leptofauchea rhodymenioides* W. Taylor
    - *Maripelta atlantica* Eiseman & Moe
    - *Rhodymenia divaricata* Dawson
    - *Rhodymenia pseudopalmata* (Lamouroux) Silva
- Ceramiales
  - Ceramiaceae
    - *Anotrichium barbatum* (J. E. Smith) Nägeli
    - *Anotrichium tenue* (C. Agardh) Nägeli
    - *Antithamnion antillanum* Børgesen
    - *Antithamnion cherminieri* (Nasr)
    - *Antithamnionella atlantica* (Oliviera) Schneider
    - *Antithamnionella breviramosa* (Dawson) Wollaston in Womersley & Bailey
    - *Antithamnionella flagellata* (Børgesen) Abbott
    - *Antithamnionella ?latiaxis* Abbott
    - *Antithamnionella* sp.
    - *Balliella pseudocorticata* (Dawson) D. Young
    - *Callithamniella tingitana* (Schousboe ex Bornet) Feldman-Mazoyer
    - *Callithamnion cordatum* Børgesen
    - *Callithamnion halliae* Collins
    - *Callithamnion uruguayense* W. Taylor
    - *Centroceras clavulatum* (C. Agardh in Kunth) Montagne in Durieu de Maisonneuve
    - *Ceramium comptum* Børgesen
    - *Ceramium fastigiatum* f. *flaccida* H. Petersen
    - *Ceramium flaccidum* (Kützing) Ardissone
    - *Ceramium leptozonum* Howe
    - *Ceramium* sp.
    - *Compsothamnion thuyoides* (J. E. Smith) Schmitz

Table 1 (Continued)

- *Diplothamnion jolyi* van den Hoek
- *Grallatoria reptans* Howe
- *Griffithsia globulifera* Harvey ex Kützing
- *Griffithsia heteromorpha* Kützing
- *Griffithsia* sp.
- *Gymnothamnion elegans* (Schousboe in C. Agardh) J. Agardh
- *Pterothamnion plumula* (Ellis) Nägeli
- *Spermothamnion investiens* (P. & H. Crouan in Schramm & Mazé) Vickers
- *Spermothamnion macromeres* Collins & Hervey
- *Spermothamnion repens* (Dillwyn) Rosenvinge
- *Spermothamnion speluncarum* (Collins & Hervey) Howe
- *Tiffaniella gorgonea* (Montagne) Doty & Meñez
- *Tiffaniella saccorhiza* (Setchell & Gardner) Doty & Meñez
- *Wrangelia argus* (Montagne) Montagne
- *Wrangelia bicuspidata* Børgesen

- Delesseriaceae
  - *Apoglossum ruscifolium* (Turner) J. Agardh
  - *Branchioglossum minutum* Schneider & Searles
  - *Branchioglossum prostratum* Schneider
  - *Calonitophyllum medium* (Hoyt) Aregood
  - *Cryptopleura ramosa* (Hudson) Kylin ex Newton
  - *Grinnellia americana* var. *caribaea* W. Taylor
  - *Hypoglossum anomalum* Wynne & Ballantine
  - *Hypoglossum hypoglossoides* (Stackhouse) Collins & Hervey
  - *Hypoglossum tenuifolium* (Harvey) J. Agardh
  - *Martensia pavonia* (J. Agardh) J. Agardh
  - *Nitophyllum punctatum* (Stackhouse) Greville
  - *Nitophyllum wilkinsoniae* Collins & Hervey
  - *Searlesia subtropica* (Schneider) Schneider & Eiseman
- Dasyaceae
  - *Dasya baillouviana* (S. G. Gmelin) Montagne
  - *Dasya collinsiana* Howe
  - *Dasya corymbifera* J. Agardh
  - *Dasya crouaniana* J. Agardh
  - *Dasya punicea* Meneghini in Zanardini
  - *Dasya rigidula* (Kützing) Ardissone
  - *Dictyurus occidentalis* J. Agardh
  - *Heterosiphonia crispella* var. *laxa* (Børgesen) Wynne
- Rhodomelaceae
  - *Acanthophora muscoides* (Linnaeus) Borg
  - *Bryothamnion seaforthii* (Turner) Kützing
  - *Chondria cnicophylla* (Melvill) De Toni
  - *Chondria collinsiana* Howe
  - *Chondria curvilineata* Collins & Hervey
  - *Chondria polyrhiza* Collins & Hervey
  - *Herposiphonia secunda* f. *secunda* (C. Agardh) Falkenberg
  - *Herposiphonia secunda* f. *tenella* (C. Agardh) Wynne
  - *Laurencia chondrioides* Børgesen
  - *Laurencia lata* Howe & W. Taylor
  - *Laurencia pinnatifida* (Hudson) Lamouroux
  - *Lophocladia trichoclados* (C. Agardh) Schmitz
  - *Micropeuce mucronata* (Harvey) Kylin
  - *Polysiphonia binneyi* Harvey

Table 1 (Continued)

Polysiphonia ferulacea Suhr ex J. Agardh
Polysiphonia havanensis Montagne
Polysiphonia sphaerocarpa Børgesen
Waldoia antillana W. Taylor
Wrightiella blodgettii (Harvey) Schmitz
Wrightiella tumanowiczii (Gatty) Schmitz

the period of maximal taxonomic diversity (Table 2). However, when reproductive frequency was expressed as a percentage of reproductive species to the number of species present in each month, two peaks (January and August) were apparent (Table 2).

In terms of depth distribution, the number of taxa recorded was highest at depths of 31–40 m (Table 4) and decreased as depth increased; this decline was more gradual for rhodophytes than for chlorophytes and phaeophytes. Most perennial species had considerable depth ranges (Table 5). Only two chlorophytes had a mean depth greater than 50 m; one of these was *Bryopsis hypnoides* which was collected only once during this study, and the other was ?*Palmophyllum* sp. which was collected frequently and was the deepest occurring chlorophyte, being found to depths of 92 m. Similarly, although six phaeophytes had mean depths in excess of 50 m, five of these (*Dictyopteris hoytii, Nereia tropica, Sporochnus bolleanus, S. pedunculatus,* and *Syringoderma floridana*) seldom occurred; only one brown alga, *Halopteris filicina*, was collected regularly at depths greater than 50 m. Like ?*Palmophyllum* sp., *H. filicina* was collected at depths greater than 90 m. As depth increased, the relative proportion of red algae present in the community increased; 25 species of rhodophytes had a mean depth greater than 50 m. Of these, a perennial assemblage of deep-water rhodophytes was apparent and consisted of *Apoglossum ruscifolium, Compsothamnion thuyoides, Halymenia gelinaria, H. hancockii, Kallymenia* sp., *Maripelta atlantica, Nitophyllum punctatum, Peyssonnelia inamoena,* and *Searlesia subtropica*. Three species (*A. ruscifolium, P. inamoena,* and *S. subtropica*) were found at the greatest depth sampled (98 m).

Examination of previously published distribution records established the biogeographical affinities of the taxa present on the east Florida continental shelf (Table 5). Approximately half of the taxa were restricted to one biogeographical zone, but the rest occurred in two or three biogeographical zones along the east coast of the Americas (Table 6). The flora of the east Florida continental shelf has an obvious tropical affinity (Tables 5, 6); 87 % of the taxa in this study were previously collected in tropical waters. This tropical affinity was consistent for the three divisions (85.0–92.9 %). A strong warm-temperate element (52.4 % of the total flora have been reported from warm-temperate waters north of Florida; 42.1–55.8 % range for the three divisions) is also present, but less than 10 % of the taxa have been reported from cold-temperate waters.

Five taxa are currently considered to occur only in transitional areas between the warm temperate and tropical zones (Table 6); these are *Halopteris filicina* (new record for the western Atlantic); *Dudresnaya patula, Scinaia incrassata, Syringoderma floridana* (only reported for the east Florida continental shelf); and *Maripelta atlantica* (limited to transitional areas in Florida, both east and west coasts).

Forty-two new records for Florida were found during this study (Table 5, 7); this is

Table 2. Number of genera (G), species (S), and taxa (T) within three macroalgal divisions and reproductive frequency in this study

Month	Chlorophyta			Phaeophyta			Rhodophyta			Total			Reproductive taxa	
	G	S	T	G	S	T	G	S	T	G	S	T	N	% of total
January	4	5	5	4	4	4	26	32	32	134	41	41	19	46.3
February	–	–	–	–	–	–	–	–	–	–	–	–	–	–
March	14	19	19	7	7	7	51	69	69	72	95	95	38	40.0
April	13	20	21	5	6	6	52	69	69	70	95	96	35	36.5
May	12	15	16	8	10	10	58	83	84	78	108	110	37	33.6
June	14	22	22	8	11	11	55	87	87	77	120	120	45	37.5
July	13	18	19	11	14	14	60	92	93	84	124	126	42	33.3
August	10	13	14	6	7	7	44	67	68	60	87	89	42	47.2
September	11	16	17	4	6	6	43	62	62	58	84	85	22	25.9
October	9	15	17	7	7	7	38	61	61	54	83	85	26	30.6
November	7	11	14	3	3	3	31	36	36	41	50	53	18	34.0
December	10	16	16	7	8	8	40	56	56	57	80	80	22	27.5
Total for entire study	19	39	42	11	19	19	79	145	147	109	203	208	–	–
Percent of total by division	17.4	19.2	20.2	10.1	9.4	9.1	72.5	71.4	70.7	100.0	100.0	100.0	–	–

Table 3. Seasonal distribution and reproductive phenology of macroalgal taxa (excluding coralline crusts) for the deep-water macroalgal community of the east Florida continental shelf. No collections were made in February. X = present, with no reproductive structures observed; F = female; M = male; S = sporophytic; R = reproductive, not determinable if gametophytic or sporophytic

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Chlorophyta												
Anadyomene saldanhae			X		X	X	X	X	X	X		
Avrainvillea elliotti			X									
Bryopsis hypnoides					X							
Bryopsis pennata				X	X		X					
Bryopsis plumosa				X		X						
Caulerpa fastigiata						X						
Caulerpa mexicana						X			X		X	X
Caulerpa microphysa			X	X	X	X	X				X	X
Caulerpa prolifera									X	X	X	X
Caulerpa racemosa var. *macrophysa*			X	X	X	X	X	X	X	X	X	X
Caulerpa racemosa var. *peltata*				X	X		X	X			X	
Caulerpa racemosa var. racemosa									X	X	X	
Caulerpa sertularioides						X						
Chaetomorpha clavata							X					
Cladophora coelothrix										X		
Cladophora dalmatica				X								
Cladophora pellucidoidea												X
Cladophora sericea				X								
Codium carolinianum			X							X		
Codium decorticatum								X				
Codium isthmocladum	X		X	X	X	X	X	R	X	X	R	X
Codium taylori	X		X	X		X	X	X	X	X		
Cystodictyon pavonicum			X			X			X			X
Derbesia marina			R		X	X	X	X				X
Halimeda discoidea var. *platyloba*	X		X	X	X	X	X	X	X	X	X	X
Halimeda gracilis			X	X		X	X		X	X		X
Halimeda tuna										X	X	
Halimeda tuna f. *platydisca*										X	X	
Microdictyon boergesenii			X	X	X	X	X					
Neomeris annulata				X								

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
?Palmophyllum sp.	X		X	X		X		X			X	
Penicillus dumentosus								X	X			
Pseudocodium floridanum			X	X	X	X	X		X	X	X	X
Struvea pulcherrima			X	X	X	X	X	X			X	X
Struvea ramosa			X	X	X	X	X		X	X		X
Udotea conglutinata												X
Udotea cyathiformis				X		X						
Udotea flabellum	X		X	X	X	X	X		X			X
Udotea spinulosa									X			
Ulva lactuca			X	X	X	X	X	X	X	X		
Ulva rigida							X	X		X		
Ventricaria ventricosa			X	X	X	X	X	X	X	X	X	X
Phaeophyta												
Colpomenia sinuosa							X					
Dictyopteris delicatula			X	X	X	X	X	X		X		X
Dictyopteris hoytii					X	X	X					
Dictyopteris plagiogramma											X	
Dictyota bartayresii							X	X	X			
Dictyota cervicornis							X					
Dictyota dichotoma	X		S	X	X	X	X	X	X	X		X
Dictyota divaricata				X	X	X			X			X
Halopteris filicina	X		S	X	X		X	X	X	X	X	X
Lobophora variegata	X		X		X	X	X	X	X	X		X
Nereia tropica							X					
Sargassum cymosum			X									
Sargassum hystrix					X	X	X					
Sargassum hystrix var. buxifolium												X
Spatoglossum schroederi			X	X	X	X	X	X		X		X
Sporochnus bolleanus						X	X			X		
Sporochnus pedunculatus						X						
Stypopodium zonale	R		X	X	X	X	X	X	X	X	X	X
Syringoderma floridana					X	X	X					

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Rhodophyta												
Acanthophora muscoides				X			M					
Acrosymphyton caribaeum											S	
Agardhinula browneae	FS		X	FS	F	FS	FS	FS	FS	FS	FS	FS
Amphiroa rigida var. *antillana*				X		X	X					
Amphiroa tribulus				X		X	X					X
Anotrichium barbatum							X					
Anotrichium tenue				X	X		X	M	X			
Antithamnion antillanum	S		MS	FS	MS	S	MS	F				S
Antithamnion cherminieri			X				X					
Antithamnionella atlantica							X					
Antithamnionella breviramosa	S		S	FS	S	S	FS	S	X	S		X
Antithamnionella flagellata							X			X		
Antithamnionella ?latiaxis				S								
Antithamnionella sp.			X		X	X						X
Apoglossum ruscifolium	X		MS	MS	FM	FMS	FMS	FS	FS	FMS	S	F
Asparagopsis taxiformis							X					
Audouinella daviesii							S					
Balliella pseudocortita				X				X				
Botryocladia occidentalis	X		X	X	X	X	X	X	X	X	X	X
Botryocladia pyriformis	X		F	F	FS	FS	FS	FS	F	X		X
Branchioglossum minutum	FS				S	X	X	FMS		S	X	S
Branchioglossum prostratum			FS	S	S	MS	S	S	S	MS		X
Bryothamnion seaforthii			X									
Callithamniella tingitana					X	X		X				
Callithamnion cordatum				FM	X	FM	X		X			
Callithamnion halliae			S		FMS	X	M	X	S	MS		X
Callithamnion urguayense					X			X		X		X
Callophyllis sp.			F	X		X	F	F				
Calonitophyllum medium			S		X	X						X
Centroceras clavulatum									X			
Ceramium comptum			X	S	S	X	X			X		X
Ceramium fastigiatum f. *flaccida*					S							

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Ceramium flaccidum							X					X
Ceramium leptozonum	F		S	F	S	FS	F	FMS		X		
Ceramium sp.							X					
Champia parvula			X	X	X	F	X	X	X	X		S
Chondria cnicophylla					X							
Chondria collinsiana											S	
Chondria curvilineata							X					
Chondria polyrhiza									X			
Chrysymenia agardhii	X					F	F	FS	X			
Chrysymenia enteromorpha			F	S	S	F	F	MS	X			X
Chrysymenia halymenioides					X			X				
Chrysymenia planifrons				X	X	FS	FS	FS	F	FS	F	
Cirrulicarpus carolinensis			X		X		X					
Coelarthrum albertisii			X	X	X	X	X	X				X
Compsothamnion thuyoides	X		S	F	FS	FS	X	F	FS	FMS	X	X
Cryptonemia crenulata			X	X			X		X	X		X
Cryptonemia luxurians			X	X	X		X		X	X		
Cryptonemia sp.	X									X		
Cryptopleura ramosa	X		X		S	FS	FS		F	FS		X
Dasya baillouviana			S	X		FM						
Dasya collinsiana			X	X								X
Dasya corymbifera						M		FS	X		S	
Dasya crouaniana	X		MS		S	FS		FMS	S	S		
Dasya punicea				S	FS	S	FS		X	M		X
Dasya rigidula			X	X	X	X	X	X		X		
Dictyurus occidentalis			X	X	X	X					X	
Diplothamnion jolyi			S	X	X	X	X	X				X
Dudresnaya bermudensis					X							
Dudresnaya crassa					FS	X	S					
Dudresnaya patula			X	F	F	FM						
Erythrotrichia carnea						X						
Eucheuma isiforme									X			
Galaxaura marginata						S	X		X	X		X

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Galaxaura oblongata												X
Galaxaura obtusata			X	X		X	X		X	X	X	X
Gelidiopsis planicaulis	X											
Gelidium americanum	X		X	X	X		X					X
Gloioderma atlanticum			F	F	F	FS	X	X	X	X		
Gloioderma blomquistii			F	F	F			X	M	X	F	
Gloioderma rubisporum			X	X	F	S	X	F	X			
Gracilaria ?cuneata	S		S	S	FS	F	F	X	F	F	F	S
Gracilaria curtissiae						X						
Gracilaria mammillaris	F		X	F	F	F	FM	F	F	F	F	F
Gracilaria occidentalis	X		X	X	X	X	X	X	X	X		S
Grallatoria reptans			S			X						
Griffithsia globulifera							X					
Griffithsia heteromorpha					X	X		X				
Griffithsia sp.			X		X	X	X	X	X	X		
Grinnellia americana var. *caribaea*			FM	FS	FMS	FMS	FS	S	X			X
Gymnothamnion elegans			X			F				X		
Halichrysis peltata					X	X					X	
Halymenia agardhii	X		X		X	X	FS			X		
Halymenia bermudensis						X		X	X	X	X	
Halymenia floresia									X			
Halymenia floridana								F	X			
Halymenia gelinaria			X	F	F		F	X	F	X		FS
Halymenia hancockii			X		S			X	X	X		F
Halymenia integra						X	X	FS				
Halymenia rosacea						F	X	FS	X	FS		
Halymenia vinacea	F		F	F	X	FS	F	F	S	F	X	X
Herposiphonia secunda							X					
Herposiphonia secunda f. *tenella*				X		X	X					
Heterosiphonia crispella var. *laxa*	S		S	FS	S	X	S		X	S		S
Hypnea cervicornis					X						X	X
Hypnea spinella				X	X		X			X		
Hypnea volubilis	X		X	X	X	X	X	X	X	X	X	X

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Hypoglossum anomalum	X		S	S	S	S	S	X		X		FS
Hypoglossum hypoglossoides								X				
Hypoglossum tenuifolium	M		FMS	FMS	FMS	FMS	FMS	FMS	FMS	MS	X	MS
Jania adhaerens									X			
Kallymenia sp.	FS		F	X	X	X	X	X	X	FM	F	FMS
Kallymenia westii						X	F	X	X	X	F	X
Laurencia chondrioides			X				X					
Laurencia pinnatifida				F	X	X	X		X		S	X
Leptofauchea rhodymenioides	S		FS	FMS	FMS	FS	FMS	FS	S	FS	X	FS
Lomentaria baileyana			X	X	X		F	X		X		
Lophocladia trichoclados				F	X		F	F		X	X	
Maripelta atlantica	FS		FS	FMS	FMS	FS	FMS	FS	X	F	X	FS
Martensia pavonia			X	X		S	X	S	X			
Meristotheca floridana	F		S	S		F		F	X	F	F	X
Micropeuce mucronata					X							
Nemastoma gelatinosum					X	X	F	F				
Nitophyllum punctatum	S		S	X	X	FS	X	M		X		S
Nitophyllum wilkinsoniae	S		FS	S	MS	S	S	S	MS	S	S	
Peyssonnelia inamoena	S		S	S	S	S	S	FS	S	S	S	S
Platoma cyclocolpa					X		X					
Polysiphonia binneyi						X						
Polysiphonia ferulacea						X		F				
Polysiphonia havanensis							X					
Polysiphonia sphaerocarpa					X	S						
Predaea feldmannii					X	F	X					
Predaea masonii						F	F					
Pterocladia capillacea					X							
Pterothamnion plumula			X		X		FS	S		S		
Rhodymenia divaricata						F	X			X		
Rhodymenia pseudopalmata			X	X	X	X	X	X		X		X
Sarcodiotheca divaricata			X	X		X	S	X		X	X	X
Scinaia complanata				X	FM	FM	FM	F	M	F		
Scinaia complanata var. *intermedia*					X			F				

Table 3 (Continued)

Taxa	J	F	M	A	M	J	J	A	S	O	N	D
Scinaia incrassata						F	F					
Searlesia subtropica	S		FMS	S	FMS	FMS	FMS	FMS	FMS	FMS	FM	FMS
Solieria filiformis				X	X		X		X		S	
Spermothamnion investiens			S			S						S
Spermothamnion macromeres									S			
Spermothamnion repens				X								
Spermothamnion speluncarum					X					X	X	S
Tiffaniella gorgonea							X				X	
Tiffaniella saccorhiza					F			FM			X	
Titanophora incrustans				S		X	X	F	X			
Waldoia antillana			S	S	X	X	S	S	S	X	X	X
Wrangelia argus			X	S	S	X	M					
Wrangelia bicuspidata			X						X			
Wrightiella blodgettii						X						
Wrightiella tumanowiczii			S		X	X			X			M
Wurdemannia miniata				X	X		X		X	X		X

Table 4. Number of macroalgal taxa (excluding crustose corallines) as a function of depth on the east Florida continental shelf

Depth range (m)	Chlorophyta		Phaeophyta		Rhodophyta		Total
	n	% of total	n	% of total	n	% of total	n
≤30	25	24.3	6	5.8	74	70.5	105
31–40	32	20.2	12	7.6	114	72.2	158
41–50	25	17.9	12	8.6	104	73.8	141
51–60	14	13.1	14	13.1	80	74.1	108
61–70	1	2.1	4	8.3	44	89.8	49
71–80	1	2.4	4	9.5	37	88.1	42
81–90	1	3.6	2	7.1	25	89.3	28
91–100	1	5.6	1	5.6	16	88.9	18

20 % of the flora of the east Florida continental shelf. In addition, *Antithamnionella ?latiaxis* would be a new record for Florida if its tentative identification is verified. Fifteen of these new records were previously considered to be distribution disjuncts between the well-studied North Carolina flora and more tropical areas to the south. Fourteen records were considered to be northern extensions, and eight records were southern extensions. *Halopteris filicina*, a European species, is a new addition to the flora of the western Atlantic. The three additional records considered to be western extensions were previously recorded for the Bahamas at the same approximate latitude as that of the sites of our study. In addition, we have confirmed the occurrence of *Agardhinula browneae* in Florida which Searles (1984b) had considered uncertain because previous specimens were drift material.

Two taxonomical notes should be made. First, on re-examination of the records attributed by Eiseman (1979) to *Petroglossum undulatum* they have been reassigned to *Gracilaria ?cuneata*. Thus, we cannot confirm the presence of *Petroglossum* in Florida. Second, *?Palmophyllum* sp. appears to be an undescribed species that we have previously observed in the Bahamas and the Gulf of Mexico (Hanisak, unpublished). It is the same taxon as the undescribed "palmelloid green" of Littler et al. (1985, 1986).

DISCUSSION

The study of deep-water macroalgal communities has been limited by the ability of phycologists to make direct, in situ observations in the sea. Until recently, knowledge of these plants has been limited, primarily restricted to information obtained from dredging records or from collections of rare and unusual algae occasionally cast ashore following severe storms. Various dredging techniques were important in early attempts at assessing the composition of deep-water macroalgal communities (e.g. David et al., 1904; Taylor, 1928; Humm, 1956; Adey & MacIntyre, 1973; De Wreede & Jones, 1973; Doty et al., 1974). However, such limited methods provide only a fragmented, and poorly quantified, glimpse of deep-water communities.

With the introduction of SCUBA in the 1950's, phycologists were able to extend their direct observations of macroalgal communities from the intertidal zone to the shallow subtidal (i.e. to depths of ca 30 m) and maximally to a depth of ca 65 m (e.g. Gilmartin,

Table 5. Mean depth, depth range, and biogeographical affinities of the taxa identified during this study

Species	Depth (m)		Biogeographical affinities		
	Mean	Range	Cold temperate	Warm temperate	Tropical
Chlorophyta					
•*Anadyomene saldanhae*	39	29–47	–	–	X
Avrainvillea elliotti	28	28	–	–	X
Bryopsis hypnoides	54	54	X	X	X
Bryopsis pennata	43	34–56	–	X	X
Bryopsis plumosa	33	33	X	X	X
Caulerpa fastigiata	27	27	–	–	X
Caulerpa mexicana	36	24–45	–	–	X
Caulerpa microphysa	33	24–56	–	–	X
Caulerpa prolifera	39	24–58	–	X	X
Caulerpa racemosa var. *macrophysa*	35	24–50	–	–	X
Caulerpa racemosa var. *peltata*	40	33–44	–	X	X
Caulerpa racemosa var. *racemosa*	35	32–39	–	–	X
Caulerpa sertularioides	42	39–45	–	–	X
Chaetomorpha clavata	34	34	–	–	X
Cladophora coelothrix	39	39	–	–	X
Cladophora dalmatica	25	25	X	X	X
Cladophora pellucidoidea	34	34	–	X	X
•*Cladophora sericea*	49	49	X	X	–
Codium carolinianum	34	34	–	X	–
Codium decorticatum	42	42	–	X	X
Codium isthmocladum	40	24–58	–	X	X
Codium taylori	33	24–50	–	–	X
Cystodictyon pavonicum	38	38–39	–	–	X
•*Derbesia marina*	45	28–58	X	X	–
Halimeda discoidea var. *platyloba*	34	24–46	–	–	X
•*Halimeda gracilis*	37	26–48	–	–	X
Halimeda tuna	36	34–39	–	–	X
Halimeda tuna f. *platydisca*	39	34–43	–	–	X
Microdictyon boergesenii	39	25–56	–	X	X
Neomeris annulata	25	25	–	–	X
•?*Palmophyllum* sp.	60	27–92	–	–	X
Penicillus dumentosus	28	27–28	–	–	X
Pseudocodium floridanum	43	24–59	–	–	X
Struvea pulcherrima	45	24–58	–	X	X
•*Struvea ramosa*	49	28–59	–	X	X
Udotea conglutinata	39	39	–	X	X
Udotea cyathiformis	34	25–42	–	X	X
Udotea flabellum	33	26–39	–	X	X
Udotea spinulosa	27	27	–	–	X
Ulva lactuca	45	28–58	X	–	X
Ulva rigida	50	45–58	X	X	X
Ventricaria ventricosa	43	27–59	–	–	X

Table 5 (Continued)

Species	Depth (m)		Biogeographical affinities		
	Mean	Range	Cold temperate	Warm temperate	Tropical
Phaeophyta					
Colpomenia sinuosa	48	34–71	–	X	X
Dictyopteris delicatula	41	25–59	–	X	X
**Dictyopteris hoytii*	58	56–59	–	X	X
Dictyopteris plagiogramma	24	24	–	–	X
Dictyota bartayresii	45	34–54	–	–	X
Dictyota cervicornis	40	40	–	X	X
Dictyota dichotoma	40	25–59	X	X	X
Dictyota divaricata	36	27–58	–	–	X
***Halopteris filicina*	86	46–98	–	–	–
Lobophora variegata	39	29–58	–	X	X
Nereia tropica	59	59	–	–	X
Sargassum cymosum	40	40	–	–	X
Sargassum hystrix	43	40–45	–	–	X
Sargassum hystrix var. *buxifolium*	38	38	–	–	X
Spatoglossum schroederi	48	38–58	–	X	X
Sporochnus bolleanus	54	45–59	–	–	X
Sporochnus pedunculatus	62	45–80	–	X	X
Stypopodium zonale	35	25–54	–	–	X
Syringoderma floridana	73	56–90	–	–	–
Rhodophyta					
Acanthophora muscoides	41	25–57	–	–	X
Acrosymphyton caribaeum	43	43	–	–	X
Agardhinula browneae	50	34–90	–	X	X
Amphiroa rigida var. *antillana*	27	26–27	–	–	X
Amphiroa tribulus	31	26–36	–	–	X
**Anotrichium barbatum*	59	59	–	X	X
Anotrichium tenue	40	36–44	X	X	X
**Antithamnion antillanum*	35	25–54	–	–	X
Antithamnion cherminieri	48	44–50	–	–	X
**Antithamnionella atlantica*	52	50–53	–	X	X
**Antithamnionella breviramosa*	42	26–87	–	X	X
**Antithamnionella flagellata*	60	50–71	–	X	X
+*Antithamnionella ?latiaxis*	51	51	–	–	X
Antithamnionella sp.	40	33–58	–	–	–
Apoglossum ruscifolium	63	38–98	–	X	X
Asparagopsis taxiformis	34	34	–	–	X
**Audouinella daviesii*	44	44	X	X	X
**Balliella pseudocorticata*	44	44	–	–	X
Botryocladia occidentalis	36	25–58	–	X	X
Botryocladia pyriformis	44	27–59	–	X	X
Branchioglossum minutum	38	32–43	–	X	–
Branchioglossum prostratum	44	32–92	–	X	–
Bryothamnion seaforthii	28	28–29	–	X	X
**Callithamniella tingitana*	38	29–42	–	X	X
Callithamnion cordatum	38	25–74	–	X	X

Table 5 (Continued)

Species	Depth (m)		Biogeographical affinities		
	Mean	Range	Cold temperate	Warm temperate	Tropical
Callithamnion halliae	49	34–64	–	X	X
**Callithamnion urguayense*	46	39–53	–	–	X
Callophyllis sp.	51	38–70	–	–	–
**Calonitophyllum medium*	46	38–58	–	X	–
Centroceras clavulatum	30	30	–	X	X
**Ceramium comptum*	45	25–59	–	–	X
Ceramium fastigiatum f. *flaccida*	32	32	–	–	X
Ceramium flaccidum	30	26–33	–	X	X
Ceramium leptozonum	45	26–92	–	–	X
Ceramium sp.	34	34	–	–	–
Champia parvula	38	24–59	X	X	X
Chondria cnicophylla	32	29–36	–	–	X
Chondria collinsiana	24	24	–	–	X
Chondria curvilineata	34	34	–	X	X
Chondria polyrhiza	37	37	–	X	X
Chrysymenia agardhii	45	33–58	–	X	X
Chrysymenia enteromorpha	36	25–51	–	X	X
Chrysymenia halymenioides	41	41	–	–	X
Chrysymenia planifrons	52	25–72	–	–	X
**Cirrulicarpus carolinensis*	63	43–89	–	X	–
Coelarthrum albertisii	34	26–41	–	–	X
**Compsothamnion thuyoides*	60	37–93	–	X	X
Cryptonemia crenulata	44	33–93	–	X	X
Cryptonemia luxurians	43	27–59	–	X	X
Cryptonemia sp.	46	44–49	–	–	–
**Cryptopleura ramosa*	49	38–65	–	–	X
Dasya baillouviana	38	33–44	X	X	X
Dasya collinsiana	29	25–33	–	–	X
Dasya corymbifera	41	24–58	–	–	X
**Dasya punicea*	49	33–71	–	–	X
Dasya crouaniana	48	29–72	–	–	X
Dasya rigidula	45	34–55	–	X	X
Dictyurus occidentalis	29	24–39	–	–	X
**Diplothamnion jolyi*	36	26–42	–	–	X
**Dudresnaya bermudensis*	45	45	–	–	X
Dudresnaya crassa	53	43–58	–	X	X
Dudresnaya patula	46	33–58	–	–	–
Erythrotrichia carnea	50	50	X	X	X
Eucheuma isiforme	32	32	–	X	X
Galaxaura marginata	31	25–37	–	–	X
Galaxaura oblongata	39	39	–	–	X
Galaxaura obtusata	30	25–37	–	X	X
**Gelidiopsis planicaulis*	29	29	–	–	X
Gelidium americanum	31	26–34	–	X	X
Gloioderma atlanticum	37	30–55	–	X	–
Gloioderma blomquistii	45	36–59	–	X	–
Gloioderma rubisporum	34	26–45	–	X	–

Table 5 (Continued)

Species	Depth (m)		Biogeographical affinities		
	Mean	Range	Cold temperate	Warm temperate	Tropical
Gracilaria ?cuneata	42	25–58	–	–	X
Gracilaria curtissiae	39	39	–	X	X
Gracilaria mammillaris	42	24–74	–	X	X
**Graciliara occidentalis*	47	29–93	–	X	X
**Grallatoria reptans*	54	53–55	–	–	X
Griffithsia globulifera	34	34	X	X	X
**Griffithsia heteromorpha*	38	33–41	–	–	X
Griffithsia sp.	44	28–59	–	–	–
**Grinnellia americana* var. *caribaea*	50	40–74	–	X	X
Gymnothamnion elegans	72	58–92	–	–	X
Halichrysis peltata	44	32–55	–	X	X
Halymenia agardhii	39	26–70	–	X	X
Halymenia bermudensis	39	24–72	–	X	X
Halymenia floresia	26	24–28	–	X	X
Halymenia floridana	54	37–70	–	X	X
Halymenia gelinaria	53	27–72	–	X	X
**Halymenia hancockii*	70	34–93	–	X	X
**Halymenia integra*	44	28–54	–	–	X
**Halymenia rosacea*	52	27–88	–	–	X
Halymenia vinacea	49	24–74	–	X	X
Herposiphonia secunda	34	34	–	X	X
Herposiphonia secunda f. *tenella*	27	26–27	–	X	X
Heterosiphonia crispella var. *laxa*	36	25–58	–	X	X
Hypnea cervicornis	30	24–34	–	X	X
Hypnea spinella	30	25–34	–	–	X
Hypnea volubilis	35	24–50	–	X	–
Hypoglossum anomalum	39	27–70	–	–	X
Hypoglossum hypoglossoides	42	42	–	–	X
Hypoglossum tenuifolium	42	24–90	–	X	X
Jania adhaerens	30	30	–	X	X
Kallymenia sp.	54	34–87	–	–	–
Kallymenia westii	38	24–72	–	X	X
Laurencia chondrioides	32	26–40	–	–	X
**Laurencia pinnatifida*	32	24–37	–	X	X
Leptofauchea rhodymeniodes	49	27–93	–	X	X
Lomentaria baileyana	42	25–71	X	X	X
Lophocladia trichoclados	49	33–88	–	X	X
Maripelta atlantica	68	37–92	–	–	–
Martensia pavonia	32	25–42	–	–	X
Meristotheca floridana	49	33–65	–	X	X
Micropeuce mucronata	32	32	–	X	X
Nemastoma gelatinosum	41	32–57	–	–	X
Nitophyllum punctatum	52	27–92	–	–	X
**Nitophyllum wilkinsoniae*	41	27–58	–	X	–
Peyssonnelia inamoena	54	27–98	–	X	X

Table 5 (Continued)

Species	Depth (m)		Biogeographical affinities		
	Mean	Range	Cold temperate	Warm temperate	Tropical
*Platoma cyclocolpa	40	29–48	–	–	X
Polysiphonia binneyi	50	50	–	–	X
Polysiphonia ferulacea	41	39–42	–	X	X
Polysiphonia havanensis	34	34	–	X	X
Polysiphonia sphaerocarpa	42	38–45	X	X	X
*Predaea feldmanii	40	26–56	–	X	X
*Predaea masonii	52	34–59	–	X	X
*Pterocladia capillacea	29	29	–	–	X
Pterothamnion plumula	70	42–93	X	–	X
*Rhodymenia divaricata	42	27–50	–	X	–
Rhodymenia pseudopalmata	45	34–89	X	X	X
Sarcodiotheca divaricata	41	24–53	–	X	–
Scinaia complanata	39	25–58	–	X	X
Scinaia complanata var. intermedia	38	33–44	–	–	X
Scinaia incrassata	41	26–55	–	–	–
Searlesia subtropica	56	37–98	–	X	–
Solieria filiformis	28	24–34	X	X	X
Spermothamnion investiens	42	39–46	–	X	X
*Spermothamnion macromeres	41	41	–	–	X
Spermothamnion repens	94	94	X	X	X
Spermothamnion speluncarum	57	34–93	–	–	X
Tiffaniella gorgonea	56	42–90	–	–	X
Tiffaniella saccorhiza	60	43–90	–	–	X
Titanophora incrustans	40	29–50	–	–	X
*Waldoia antillana	38	25–56	–	–	X
Wrangelia argus	37	26–48	–	–	X
Wrangelia bicuspidata	32	28–37	–	–	X
Wrightiella blodgettii	27	27	–	–	X
Wrightiella tumanowiczii	36	32–39	–	X	X
Wurdemannia miniata	35	26–58	–	X	X

* indicates new record for Florida
** indicates new record for the western Atlantic Ocean
+ indicates tentative identification that would otherwise be a new record for Florida

1960). While these depths encompass the full depth distribution of macroalgae in many temperate areas, it was clear that macroalgae in the tropics and subtropics could grow at depths significantly greater than those that could be observed with SCUBA. Recent studies (e.g. Littler et al. 1985, 1986) have indicated that benthic macroalgae are capable of growing at much greater depths than previously believed and that the contribution to primary productivity by macroalgae growing on deep reefs in certain parts of the world could be significant.

This study has documented the species composition of a macroalgal community, at depths greater than those ever examined in such detail throughout the annual cycle. It

Table 6. Summary of biogeographical affinities for the taxa identified during this study based on the data presented in Table 5. CT = Cold Temperate; WT = Warm Temperate; T = Tropical; combinations of these indicate distribution in more than one biogeographical zone of the western North Atlantic. Taxa without a species epithet are listed as "not assignable"; taxa that are restricted to Florida near the transitional area between warm temperate and tropical zones are listed as "transitional"

Biogeographical affinity	Chlorophyta n	Phaeophyta n	Rhodophyta n	Total n
CT	0	0	0	0
CT–WT	2	0	0	2
WT	1	0	13	14
WT–T	12	7	58	77
T	22	9	55	86
CT–WT–T	4	1	11	16
CT–T	1	0	1	2
Transitional	0	2	3	5
Not assignable	0	0	6	6
Total	42	19	147	208

has also demonstrated the high diversity that can occur in deep-water macroalgal communities in subtropical and tropical waters where high water clarity permits a much deeper euphotic zone than traditionally considered (Hanisak & Blair, in press). Moreover, over 20 % of the taxa in this study were new records for Florida; this demonstrates the importance of studying deep-water communities in order to obtain adequate floristic information for a particular area. Prior to the initiation of this submersible study, the deep-water algae of eastern Florida were known only from drift material (Eiseman, 1979).

The deep-water community of the east Florida continental shelf is characterized by species of a tropical affinity, with many species capable of growing in the warm temperate waters of the Carolinas. The community appears to consist of a relatively stable assemblage of perennial species, with an influx of incidental, shorter-lived species, particularly in the summer months. Most of the taxa present grow in much shallower waters in Florida and more tropical areas to the south; there are also a number of species that appear, based on this and previous studies, to be more characteristic of deep water. These include: the chlorophytes *Cystodictyon pavonicum, Microdictyon boergesenii, ?Palmophyllum* sp., *Struvea pulcherrima*, and *S. ramosa*; the phaeophytes *Halopteris filicina, Sporochnus bolleanus, S. pedunculatus*, and *Syringoderma floridana*; the rhodophytes *Apoglossum ruscifolium, Chrysymenia enteromorpha, C. halymenioides, C. planifrons, Compsothamnion thuyoides, Halymenia floridana, H. hancockii, H. integra, H. vinacea, H. rosacea, Kallymenia westii, Leptofauchea rhodymeniodes, Maripelta atlantica, Meristotheca floridana*, and *Searlesia subtropica*. The increase in number of taxa at 31–40 m is probably more related to available substrate than depth per se; many species found only at depths greater than 30 m in this study have been found previously to grow in much shallower water.

Many basic questions about the nature of deep-water macroalgal communities are unresolved. For example, previous studies have provided conflicting evidence as to the

Table 7. New taxonomic records for Florida recorded during this study

Northern extensions	Southern extensions	Previous disjuncts	Western extensions	New to western Atlantic	Undescribed species
Anadyomene saldanhae	*Calonitophyllum medium*	*Anotrichium barbatum*	*Dudresnaya bermudensis*	*Halopteris filicina*	?*Palmophyllum* sp.
**Antithamnion antillanum*	*Cirrulicarpus carolinensis*	*Antithamnionella atlantica*	*Grallatoria reptans*		
Balliella pseudocorticata	*Cladophora sericea*	*Antithamnionella breviramosa*	*Spermothamnion macromeres*		
Callithamnion uruguayense	*Compsothamnion thuyoides*	*Antithamnionella flagellata*			
Ceramium comptum	*Dasya punicea*	*Audouinella daviesii*			
Cryptopleura ramosa	*Derbesia marina*	*Callithamniella tingitana*			
Diplothamnion jolyi	*Nitophyllum wilkinsoniae*	*Dictyopteris hoytii*			
Gelidiopsis planicaulis	*Rhodymenia divaricata*	*Gracilaria occidentalis*			
Griffithisia heteromorpha		*Grinellia americana* var. *caribaea*			
Halimeda gracilis		*Halymenia hancockii*			
Halymenia integra		*Laurencia pinnatifida*			
Halymenia rosacea		*Platoma cyclocolpa*			
Pterocladia capillacea		*Predaea feldmanii*			
Waldoia antillana		*Predaea masonii*			
		Struvea ramosa			

* *A. antillanum* was listed by Humm (1963), but this record was later identified as *A. cherminieri* by Oliviera (1969)

degree of seasonality in deep-water communities. Sears & Cooper (1978) suggested that such communities in the northwest Atlantic have a high degree of seasonal stability. In the Gulf of Mexico, investigators using dredging (e.g. Dawes & van Breedveld, 1969) had reported a similar stability in deep-water macroalgal communities. However, Cheney & Dyer (1974) using SCUBA in 25–60 m in the Gulf of Mexico, described a macroalgal community with a distinct tropical affinity and a seasonal pattern of abundance and diversity, both of which were maximal in the summer. This pattern of seasonality is similar to that observed on the east Florida continental shelf in the current study as well as that observed for the offshore flora of North Carolina (Schneider, 1976; Searles, 1984b). We believe that differences in the apparent seasonality of deep-water communities are primarily due to methods of collections. Dredging techniques appear to preferentially harvest larger plants, which are more likely to be considered perennials, than the more direct techniques involving SCUBA and submersibles.

The zonation patterns of macroalgal divisions observed for this community are consistent with what the model of Dring (1981) predicted for clear oceanic water, i.e. rhodophytes growing deeper than chlorophytes and phaeophytes, a pattern that appears to occur throughout the world (e.g. Gilmartin, 1960; Larkum et al., 1967; Drew, 1969; Agegian & Abbott, 1985; Hillis-Colinvaux, 1985; Littler et al., 1985, 1986). Humm & Taylor (1961) postulated a floral diversity gradient with depth in the Gulf of Mexico; this hypothesis was supported by the submersible observations of Eiseman & Blair (1982) who found a much greater tropical affinity of the deep-water flora of the northwest Gulf as compared to shallow-water habitats in this region. The same pattern has been observed for the North Carolina flora (Searles & Schneider, 1980). This flora-depth relationship also appears to be the case for the east coast of Florida although a thorough analysis of shallow-water macroalgal communities for this region is lacking.

Studies of deep-water communities, such as that off eastern Florida, have important biogeographical implications. Twenty percent of the taxa identified in this study were new records to Florida; this demonstrates the necessity of extensively sampling such communities before the floristic information of a given area can be considered adequate enough for detailed biogeographical analyses. This point has been previously made by Schneider & Searles (references cited previously) in their detailed analyses of the North Carolina offshore flora.

Perhaps most dramatic in terms of biogeographical distribution were the 15 new records for Florida that previously appeared to be distributional disjuncts. Schneider (1976, 1984) listed 22 taxa present in the Carolina flora with distributional disjuncts to the south; 13 of these are reported in the current study of the east coast of Florida. We believe, as Schneider (1976) suggested, that most if not all, of the remaining disjuncts are artifacts of collection. Moreover, our study substantiates a high degree of similarity between the Florida and Carolina floras; both are dominated by species with centres of distribution in the Caribbean (Schneider, 1976). The information to date suggests that the deep-water flora may be relatively continuous over a large portion of the western Atlantic. It would be desirable to conduct additional intensive floristic investigations in this region to verify this conclusion. Our observations also question the traditional practice (Stephenson & Stephenson, 1952; Humm, 1969; Searles, 1984b) of considering Cape Canaveral as a biogeographical boundary; its utility now appears to be limited to the shallow-water flora (i. e. <10 m).

While biogeographical investigations usually focus on latitudinal differences, there may also be significant floristic differences over short distances along a particular latitude. For example, recent studies in the Bahamas (Hanisak & Blair, in press), including sites only 100 km east of the West Palm Beach stations reported herein, have demonstrated a greater predominance of green algae in the deep-water flora than fleshy red and brown algae, in contrast to the predominance of red algae off eastern Florida. The deep-water chlorophytes of the Bahamas include the species reported herein for Florida, as well as additional species of *Halimeda*, and *Johnson-sea-linkia profunda*, an apparent endemic to the Bahamas. In both Florida and the Bahamas, however, the deepest macroalgal species are crustose corallines (not considered in this manuscript). Another difference between the Florida and Bahamian deep-water macroalgal communities is the rather sharp, vertical zonation patterns that are visually and statistically dramatic in the Bahamas (Littler et al., 1985, 1986; Hanisak & Blair, in press). These contrasts (dominance of chlorophytes versus rhodophytes, sharpness of zonation) are probably due to differences in habitat (gradual slopes versus vertical walls) and stability of conditions (water temperature and clarity are higher and more stable in the Bahamas). Lastly, the Gulf Stream between the Bahamas and Florida may serve as a distributional barrier for some deep-water macroalgae.

Clearly, deep-water macroalgal communities merit additional study in order to understand biogeographic patterns more fully. The major restraint to the study of deep-water macroalgae is the high operating costs involved with using submersibles (Earle [1985] cites a range of $ 7000 to $ 25 000 per day, including the cost of the support vessel). Perhaps the development of simpler, less expensive one-person submersibles (Earle, 1985) or unmanned, remotely operated vehicles (ROVs) will accelerate the exploration of deep-water benthic communities by phycologists.

As access to deep-water macroalgae increases, knowledge of all aspects of the biology of these organisms will be enhanced. Continued systematic studies will lead to the description of new species and will further our knowledge of marine biogeography. Deep-water species may be useful in experimental approaches to biogeography (such as studies by Cambridge et al., 1984, 1987; Guiry et al., 1987; Lüning, 1984; McLachlan & Bird, 1984; Yarish et al., 1984). An integration of the descriptive and experimental approaches will result in a more thorough understanding of the biogeographical patterns of marine macroalgae.

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