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Seasonal Occurrence and Variation in Standing Crop of a Drift Algal Community in the Indian River, Florida[1]

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Abstract

Monthly collections of unattached, free-drifting macroalgae were made from September 1975 through August 1976 at three stations in a seagrass bed near Ft. Pierce, Florida. The most common species were *Dictyota dichotoma*, *Acanthophora spicifera*, *Hypnea cervicornis*, *H. musciformis*, and *Spyridia filamentosa*. *Chondria tenuissima* occurred as a winter-spring dominant. Seasonal changes in standing crop of these plants are described. Total algal biomass maxima occurred in spring and early fall when water temperatures ranged from 23 to 27 °C and light energy averaged 400 to 500 Langleys/day. Minimum total biomass occurred in summer. Frequency distributions of algal biomass were contagious in September and from January to May suggesting aggregated populations. Low randomness (ρ) values in the other months are suggestive of a regular distributional pattern. Problems involved in sampling this community are discussed and comparisons with other studies are presented.

Introduction

The drift algal community, as defined for this study, includes unattached free-drifting macroalgae and associated epiphytes. Plants that become members of this community initially develop on substrata such as seagrasses, shells, rocks, and sponges, and break loose when they reach a large size. The community can play a role similar to other macrobenthic plants in providing oxygen, food, and space for small organisms. Observations of seasonal occurrence and changes in standing crop are important in evaluating this community's contribution to an ecosystem.

Drift algae in the Indian River lagoon, Florida East Coast (Fig. 1), are known from three studies. Phillips (1961) reported 59 drift species from quarterly collections made over a two year period in the vicinity of St. Lucie Inlet. In a one year study conducted in association with a seasonal biomass survey of the seagrass *Halodule wrightii*, Eiseman and Benz (1975) recorded 31 species of unattached, free-drifting macroalgae from six stations between Mosquito Lagoon and St. Lucie Inlet. Gilbert (1976) studied the seasonal variation in

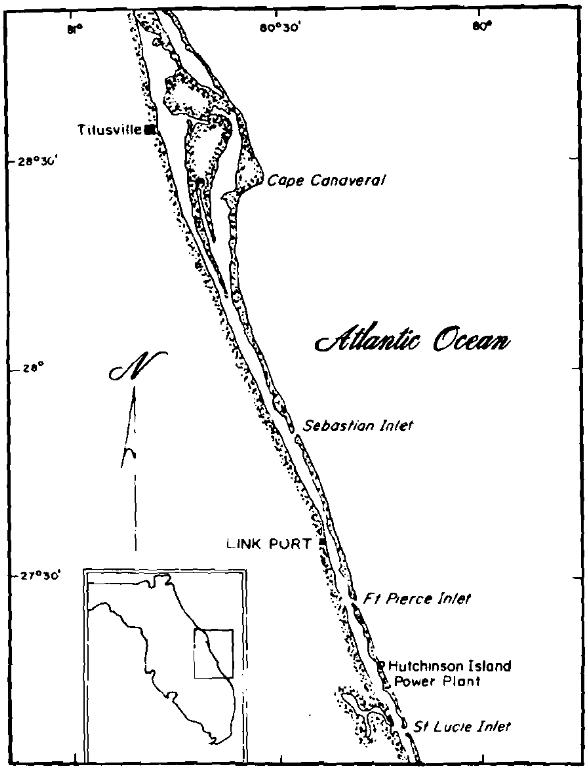

Fig. 1. Map of the Indian River region of Florida

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standing crop of benthic plants near Titusville, including the macroalgae *Gracilaria verrucosa* and *Acanthophora spicifera.*

Several other studies have contributed to the knowledge of drift algal communities in Florida. Roessler (1971) showed the importance of *Laurencia* mats in providing animal habitats in Card Sound. Josselyn (1975) found seasonal changes in biomass and growth rates for *Laurencia obtusa* and *L. poitei* at this location. Hamm and Humm (1976) reported 65 species of drift algae (including epiphytes) in the Anclote estuary on the Florida West Coast. *Laurencia obtusa* and *L. poitei* were also the dominant drift species at this locality.

In this study seasonal occurrence of drift algae and changes in biomass of the dominant species are described from a seagrass bed in the Indian River near Ft. Pierce, Florida.

Methods

The study was conducted in a seagrass flat of approximately 50 hectares near Ft. Pierce Inlet (Fig. 2). The dominant seagrasses are *Halodule wrightii* Ascherson and *Syringodium filiforme* Kützing. *Thalassia testudinum* Banks *ex* König and Sims, *Halophila englemanni* Ascherson and an undescribed species of *Halophila* are present in lesser abundance. Water depth over the flat ranges from intertidal to about 1 m at mean low water. Tidal flushing through the inlet and freshwater input from Taylor Creek drainage canal influence the site (von Zweck *et al.* 1974).

From September 1975 through August 1976 three stations were sampled monthly with a 0.25 m^2 square quadrat. Ten replicates were taken at each station. Station A (27°28.35'N, 80°19.15'W) was nearest the intracoastal waterway and Taylor Creek. Station B (27°28.50'N, 80°19.90'W) was in a quiet protected cove fringed by mangroves and Station C (27°28.10'N, 80°18.85'W) was near the inlet channel. Temperature and salinity measurements were taken at each station at the time of sampling. Light energy was recorded with an Eppley^R pyrheliometer located at Link Port about 8 kilometers north of the study site. All unattached macroalgae were collected from within randonly tossed quadrats. Plants were returned to the laboratory alive, sorted and identified. Animals and epiphytes were removed and identified. Plants were rinsed of salt, dried at 90°C for 48 hours and weighed.

Results

Sixty-three species were identified, including epiphytes. There were three Cyanophyta (5%), 12 Chlorophyta (19%), 9 Phaeophyta (14%), and 39 Rhodophyta (62%). Collection records for each month and each station are given in Table I. The most common species throughout most of the year were *Dictyota dichotoma*, *Acanthophora spicifera*, *Hypnea cervicornis*, *H. musciformis*, and *Spyridia filamentosa.* Seasonal dominants include the

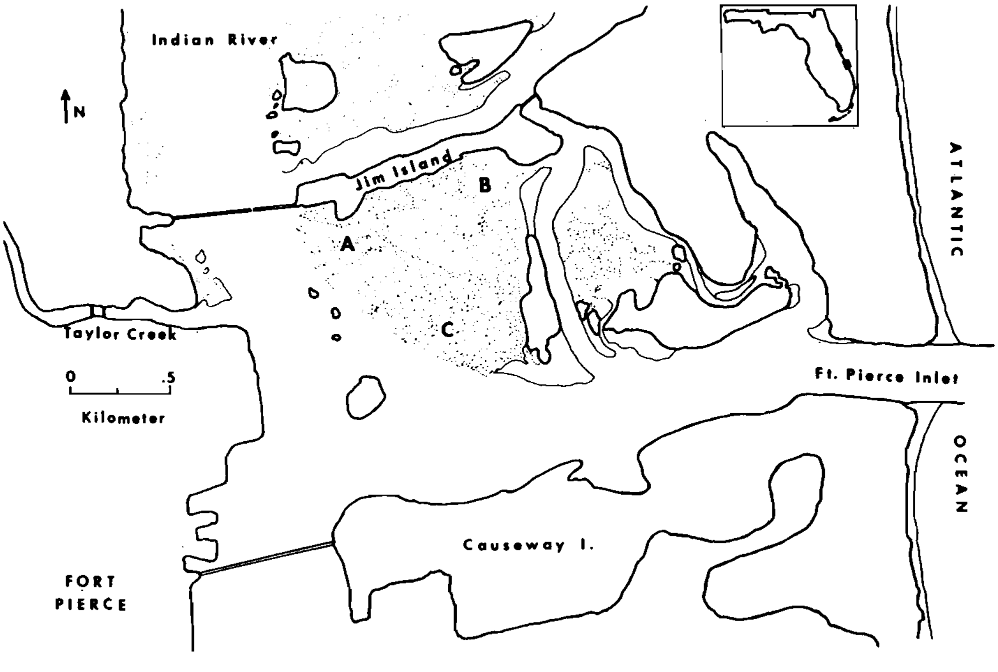

Fig. 2. Map of the study site near Ft. Pierce, Florida. The three sampling areas are designated, A, B, C.

Tab. I. Drift algae species composition and seasonal occurrence at Stations A, B, and C. Epiphytic species are noted by "e".

	1975				1976							
	S	O	N	D	J	F	M	A	M	J	J	A
CYANOPHYTA (3)												
Anabaena fertillissima Rao								e				
Calothrix crustacea Thuret	e											
Microcoleus lyngbyaceus (Kützing) Crouan							C	e	e	e	e	C
CHLOROPHYTA (12)												
Acetabularia calyculus Quoy et Gaimard	C											
Caulerpa sertularioides (Gmelin) Howe	B		C									
Chaetomorpha gracilis Kützing	e											
C. linum (Muller) Kützing	e											
C. minima Collins et Hervey										e		
Cladophora delicatula Montagne										e		e
C. prolifera (Roth) Kützing	C		B									
Enteromorpha chaetomorphoides Bøргesen										e		
E. compressa (Linnaeus) Greville	C											
E. erecta (Lyngbye) J. Agardh							e					
E. plumosa Kützing	e											
Percursaria percursa (C. Agardh) J. Ag.	e											e
PHAEOPHYTA (9)												
Cladosiphon occidentalis Kylin						C		C	A			
Dictyopteris delicatula Lamouroux								C				
Dictyota cervicornis Kützing				C		A						
D. dichotoma (Hudson) Lamouroux	AC	ABC	AB	AC	AB	AB	BA	BC	ABC		A	
D. divaricata Lamouroux	C		B									AC
Giffordia mitchelliae (Harvey) Hamel				C	AC	e	e	e	e			
Rosenvingea intricata (J. Agardh) Børgesen				A	AB	B	B	AB	AC			
Sargassum natans J. Meyer								C				
S. hystrix J. Ag. v. *buxifolium* (Chauvin) J. Ag.				C								
RHODOPHYTA (39)												
Acanthophora muscoides (Linnaeus) Bory	C											
A. spicifera (Vahl) Børgesen	ABC	ABC	ABC	AC	AB	B	ABC	ABC	ABC	ABC		AC
Botryocladia occidentalis (Børgesen) Kylin									C			
Bryothamnion seaforthii (Turner) Kützing	C	C		C	B			C	C			C
B. triquetrum (Gmelin) Howe	C											
Centroceras clavulatum (C. Agardh) Montagne	e			e	e	B						
Ceramium byssoideum Harvey					e	e						
C. fastigiatum (Roth) Harvey					e							
f. flaccida H. E. Peterson										e		e
Champia parvula (C. Agardh) Harvey								e				
Chondria collinsiana Howe	e											
C. floridana (Collins) Howe									C			
C. tenuissima (Goodenough et Woodward) C. Ag.					B	BC	BC	BC	B			
Crouania attenuata (Bonnemaison) J. Ag.									e			
Cryptonemia luxurians (Mertens) J. Ag.										C		
Dasya rigidula (Kützing) Ardissone	e				e			e	e			
Erythrotrichia carnea (Dillwyn) J. Ag.										e		
Eucheuma isiforme (C. Ag.) v. *denudatum* Cheney								C				
Gelidiopsis intricata (C. Agardh) Vickers							C		C			
Gracilaria blodgettii Harvey						B						
G. armata (C. Ag.) J. Agardh						BC	C					C
G. foliifera (Forsskål) Børgesen	BC											
v. *angustissima* (Harvey) Taylor	B											C
G. mammillaris (Montagne) Howe				C		C						
G. verrucosa (Hudson) Papenfuss	BC					BC	B		C			C
Griffithsia globulifera Harvey	e											
Heterosiphonia secunda (C. Agardh) Ambronn					e							
H. pecten-veneris (Harvey) Falken v. *laxa* Taylor											e	e
H. tenella (C. Agardh) Ambronn	e	e	e	e	e	AC			e	e		
Hypnea cervicornis J. Agardh	ABC	ABC	ABC	AC	AB	B	AC	e	C	C	A	AC
H. musciformis (Wulfen) Lamouroux	C			C	A	BC	ABC	ABC	AC	C		
H. spinella (C. Agardh) Kützing									C	C		
Laurencia obtusa (Hudson) Lamouroux												C
Lophosiphonia saccorhiza Collins et Hervey										e		
Neoagardhiella baileyi (Harvey *ex* Kützing) Wynne & Taylor								C				
Polysiphonia macrocarpa Harvey					e							
Solieria tenera (J. Ag.) Wynne & Taylor	C						C		C			
Spyridia filamentosa (Wulfen) Harvey	ABC	AB	AB	AC	AB	BC	AC	ABC	C	C	e	AC

brown alga *Rosenvingea intricata* and the red alga *Chondria tenuissima*. *Giffordia* species grow in large masses on seagrass blades in winter and break off to become entangled in the drift. *Microcoleus lyngbyaceus*, a bluegreen alga that grows abundantly in the warmer months as a mat over the bottom and on the seagrasses, can contribute to the drift when gas accumulation causes parts of the mat to break away and float to the surface.

The most common species at Stations A, B and C are those common elsewhere in the lagoon. Fewest species were collected at Station A near the Taylor Creek outfall. The greatest number of species were collected at Station C, the station nearest the inlet. These included many species from the nearby coastal reefs, such as *Dictyopteris delicatula*, *Botryocladia occidentalis*, *Bryothamnion seaforthii*, *B. triquetrum*, *Chrondria floridana*, *Cryptonemia luxurians*, *Gelidiopsis intricata*, *Gracilaria mammillaris* and *Solieria tenera*. None of the coastal species dominated the flora during any season.

Species numbers were highest in September and May and lowest in October and July (Fig. 3). Species numbers declined at the same periods as biomass values (c.f. Fig. 4). However, species numbers increased rapidly during the following months while biomass remained low.

Monthly biomass values for each station were examined for contributions by principal species, and for effects of locality and time of sampling. Analysis of variance indicated that only monthly effects were significant. Thus biomass values for all stations were combined for further consideration of seasonal variation.

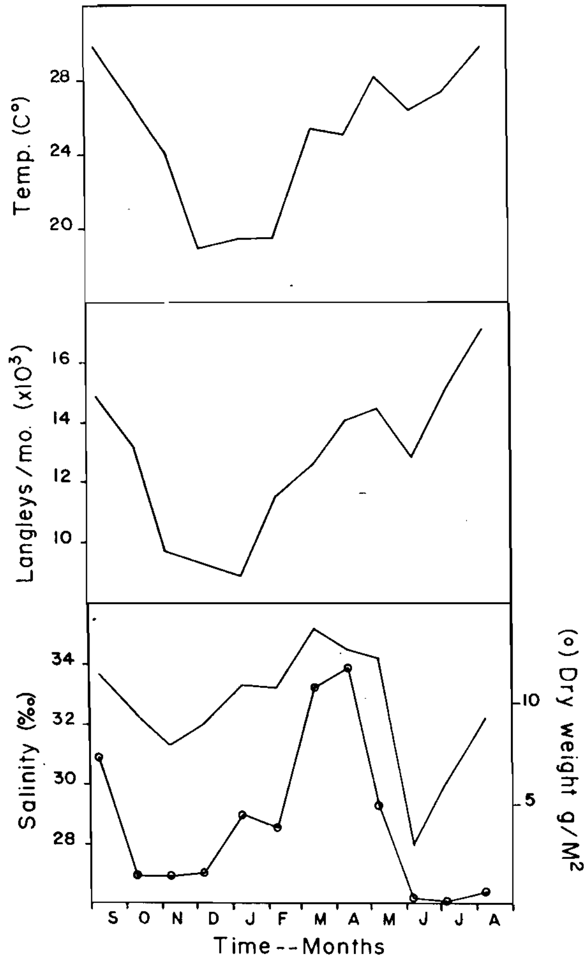

Fig. 4. Monthly temperature, light and salinity readings are compared with total biomass (g dry wt/m²).

Figure 4 compares temperature, light and salinity with total biomass/m²/month. Because of the similar readings among the stations for both temperature and salinity, these measurements were averaged for each month. Langleys represent light energy integrated over the sampling period. Biomass variation corresponds well to variations in temperature, salinity, and light, declining in mid-fall then rising in mid-winter and continuing to increase until the onset of the rainy season in May. Biomass remained low during the summer months when temperature and light energy were highest. Biomass was highest in the spring when water temperatures ranged from 23 to 27 °C, light energy averaged 400 to 500 Langleys/day and salinity readings were 33 to 34 $^0/_{00}$. Multiple regression analysis of total biomass versus these environmental parameters showed little correlation with any one factor. Variables appeared to have a synergistic effect on standing crop, with a multiple correlation coefficient (R^2) of 0.65.

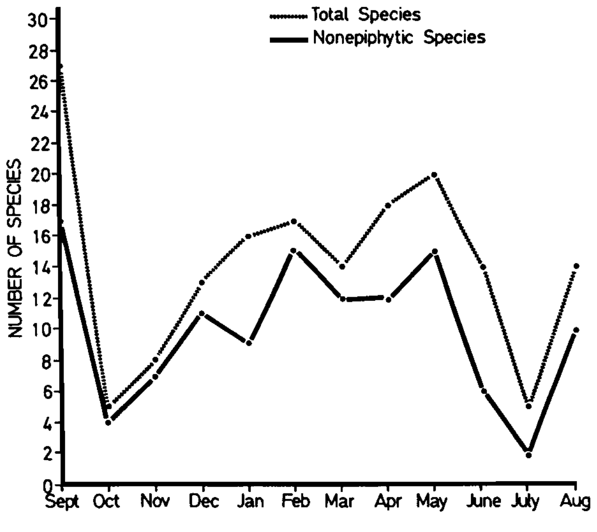

Fig. 3. Species richness, by month

Major species in terms of contribution to total biomass for 12 months are listed in Table II. Although not collected at Station A, *Chondria tenuissima* makes up

Tab. II. Yearly total biomass for the major species

	Dry Weight (g)	% of Total
Acanthophora spicifera	455.8	31
Chondria tenuissima	405.3	28
Dictyota dichotoma	260.2	18
Hypnea spp.	164.0	11
Spyridia filamentosa	31.7	2
Giffordia mitchelliae	20.7	1
Gracilaria spp.	19.7	1
Rosenvingea intricata	11.9	1
Other	78.8	5
Total	1448.1	

28% of the yearly total biomass, second only to *Acanthophora spicifera* (31%). The third highest contributor is the brown alga *Dictyota dichotoma* which comprises almost 20% of the total.

Mean monthly standing crop values for *Acanthophora spicifera*, *Dictyota dichotoma*, *Hypnea* spp., *Spyridia filamentosa*, *Chondria tenuissima* and *Rosenvingea intricata* are illustrated in Figure 5. *Acanthophora spicifera* and *Hypnea* spp. have similar seasonal patterns. Biomass of these species declined in the late fall along with decreases in temperature and light energy, rising again in late winter and steadily increasing during the spring. Biomass declined sharply in May with the beginning of the rainy season (May–August) and warm summer months. *Dictyota dichotoma* increased in the cooler fall months, decreased during late winter low tides, and then increased again during spring months until May. Little *Dictyota* was collected in the summer months. *Spyridia filamentosa*, though less abundant throughout the year, had a winter maximum similar to *D. dichotoma*, as well as spring and late summer maxima similar to *A. spicifera* and *Hypnea* spp. The most dramatic variation in standing crop occurred with *Chondria tenuissima*. Although this species was present for only five months (January–May), it concontributed more to total biomass than any other species, except *A. spicifera*.

Combined biomass values for all species were partitioned into discrete weight classes and were tabulated into frequency distributions for each month. These distributions were analyzed for tendencies of the data to cluster about particular values. Following Pielou (1969), we refer to these distributions as "contagious".

Analysis of contagious distributions requires a null hypothesis that all weight classes are represented with equal probability. The appropriate test statistic is calculated as follows:

$$\rho\,(s^2, \bar{x}) = (n-1)\,\frac{s^2}{\bar{x}}$$

ρ is distributed as χ^2 with $(n-1)$ degrees of freedom (Snedecor and Cochran 1967). In the above expression, s^2 and $\bar{x}$ denote the variance and mean for samples of size n, respectively. Results of these tests are summarized in Table III.

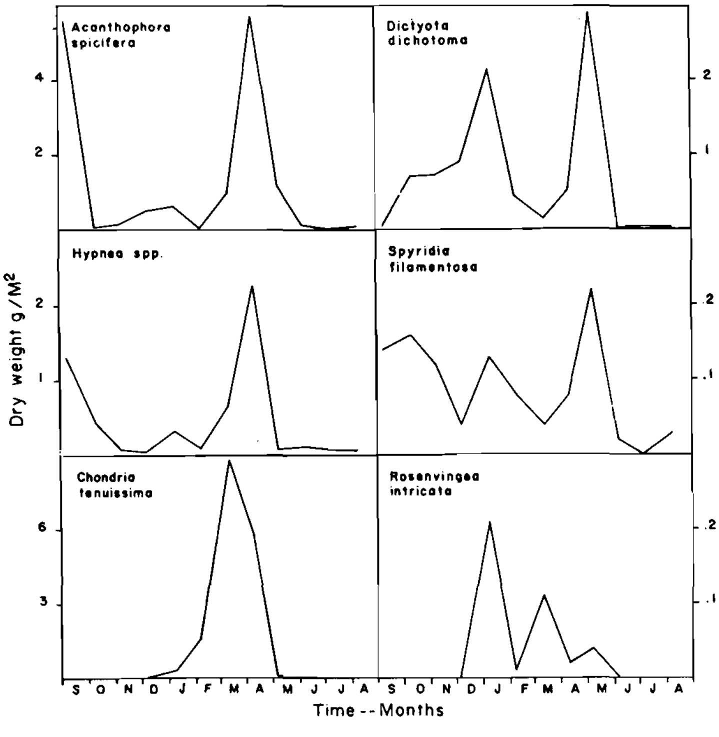

Fig. 5. Dry weights of six dominant species by month

In September when biomass is relatively high, contagion is highly significant (ρ = 197.4). This is due to the dominance of one species, *Acanthophora spicifera.* From October to December biomass values declined and populations had a random distributional pattern. All species were present with nearly equal weight and low density. Randomness statistic ρ was so low as to suggest regularity, which is a common small scale distributional pattern and is identified by small variance/mean ratios. In the χ^2 sens, ρ would be less than tabulated values at α = .05 for such distributions. Variances of sample populations exceed the means during January through May. Randomness statistic, ρ, is significant throughout this period except in March. Thus biomass of drift algae is clumped in late winter and spring. In June this pattern is broken. Species biomass values diminish as indicated by depressed means and variances. All species were represented by low biomass and a random pattern throughout the summer.

Invertebrates commonly found in the drift samples are listed in Table IV. These animals were not collected quantitatively, however subjective counts were made. Those most abundant in the samples were saved for identification. The amphipod *Cymadusa compta* was collected most often and in the greatest numbers.

Tab. III. Distribution statistics for monthly biomass totals

	Mean	Variance	ρ
September	8.675	122.319	197.402**
October	1.866	1.480	11.104
November	1.766	2.236	17.726
December	3.200	2.160	6.075
January	6.290	10.457	48.212*
February	4.538	6.653	42.516* (marginal)
March	5.969	7.946	38.605
April	6.036	9.269	44.533*
May	5.036	7.899	45.487*
June	3.534	3.919	32.159
July	3.269	2.040	18.097
August	3.934	2.859	21.075

* Significant in the χ^2 sense. α = .05, df = 29.
** Highly significant. α = .005.

Tab. IV. List of fauna common in the drift algae

polychaetes	*Branchiomma nigromaculata* *Platynereis dumerilii*
gastropods	*Diastoma varium* *Anachis avara* *Mitrella lunata*
isopods	*Cymdoce faxoni* *Erichsonella attenuata*
amphipods	*Cymadusa compta* *Ampithoe longimana*
decapods	*Periclimenes americanus* (shrimp) *Pelia mutica* (crab) *Panopeus occidentalis* (crab)

Discussion

This study is one of the few which specifically addresses drift algal communities in coastal bays and lagoons and is the only such study attempting to quantitatively describe the drift community as a whole. However, special problems exist in the sampling of free-drifting populations and statistical treatment of macrophyte biomass is consistently difficult. These problems are discussed below.

By plotting the species area curves (Goodall 1952), it was found that the ten replicate quadrats provided adequate sampling of the species present for all months at Stations A and B. In many cases, three to five replicates would have been sufficient. Livingston *et al.* (1976) have found that less than ten replicates were necessary to take 90% or more of the species in a population of attached macrophytes. For Station C, ten replicates provided adequate sampling of species present for every month except February and August. Since only two of 36 samples required more than ten replicates, it is concluded that species composition was adequately sampled.

Species composition agrees closely with Phillips' (1961) work at St. Lucie Inlet 40 kilometers south of Ft. Pierce. He reported as abundant all the species that are reported as dominant species in this study, except *Chondria tenuissima* which he did not collect, and *Dictyota dichotoma* whose abundance he described as rare. His seasonal findings do not agree with the findings of this study. He reported the number of species and biomass to be greatest in fall for unattached plants. Biomass observations were limited to visual estimations.

The species composition reported in other Florida drift algae studies is in close agreement with that found near Ft. Pierce Inlet, although the dominant species usually differ. Hamm and Humm (1976) report that *Laurencia obtusa* and *L. poitei* are the most abundant members of the drift algae during the winter months in the Anclote estuary. They found that *Laurencia obtusa* often comprised over 50% and *L. poitei* 30–45% of the drift. *Digenia simplex* and several species of *Sargassum* made up 5%. Although collected only once during this study *Laurencia obtusa* has been observed as a common member of the drift community in the Indian River lagoon near Titusville. Also, species of *Gracilaria* are often major components of the drift community, as reported by Eiseman and Benz (1975) for several locations in the lagoon.

Josselyn (1975) studied the seasonal changes in biomass and growth rates for the two common drift species in Card Sound, *Laurencia poitei* and *L. obtusa.* He found that the biomass increased from late September through March, then underwent a sharp decline during the summer. Growth was at a maximum in early spring and in late fall when water temperatures ranged between 20 to 25 °C and light levels were moderate. Though similarities in the biomass findings are apparent, biomass maxima for the present study occurred in spring and early fall. The summer decline observed here also occurs in Card Sound but has not been observed in more temperate areas (Conover 1958, 1964; Orris and Taylor 1973).

Field studies of macroalgal cover or biomass have long been made difficult by statistical limitations imposed by high variances which seem to be an inherent property of benthic macrophyte data. On the Pacific coast Hruby (1975), sampling algal cover with a 0.25 m^2 quadrat, found that more than the five replicates he used were needed to assume that the algal cover in the next sample would fall within 10% of the mean with a 90% probability. Using the equation for sample number (Snedecor and Cochran 1967) and the coefficients of variation for the plant cover, he calculated that in the month of May at least 60 replicates should have been taken to assume 90% probability that the next sample would fall within 10% of the mean for the dominant species. This number of replicates is logistically impossible for most investigations. Using confidence intervals, Livingston *et al.* (1976) showed that from two to thirty .06 m^2 quadrats were necessary to adequately sample biomass of a population of attached macroalgae in the northern Gulf of Mexico. Although no mention of the distribution of biomass values was made there was probably some contagion in this study also.

Even though the data of Livingston *et al.* (1976) suggest that biomass was adequately sampled in this study, we prefer to use a probabilistic test since this free-floating community often has a clumped spatial pattern resulting in some highly contagious distributions. Biomass data for January through May were combined and a frequency distribution was calculated using logarithms to the base 2 as the class interval. Thus successive intervals correspond to biomass doublings. This is appropriate for variates which appear to have logarithmic tendencies. Frequencies of biomass values within each class were plotted to form the histogram shown in Figure 6.

Since the variance/mean ratios for this period were significantly greater than unity, we attempted to find a negative binomial density function to fit the distribution. However, the success parameter for a function of that type was found to be near the limiting value, zero. Thus, a logarithmic series was selected as an alternative. This function is a member of the binomial family and has the following general form:

$$f(n) = \frac{\alpha}{n} x^n, 0 < n \leqslant \infty \qquad (1)$$

where α and x are constants which are proportional to the number of classes (biomass categories) and the number of samples, respectively. Symbol n denotes a category number. In our case nine biomass categories were clearly distinguishable. Drift algal biomass values exceeding 2^8 grams/m^2 are unlikely in the Indian River. Therefore, it was necessary to restrict the domain of (1) to values of $n \leqslant 8$. To accomplish this, the area subtended by f(n) to the right of n = 8 was folded to the left and apportioned equally among the nine categories. Thus the theoretical frequency for biomass values in the n^{th} class is given by:

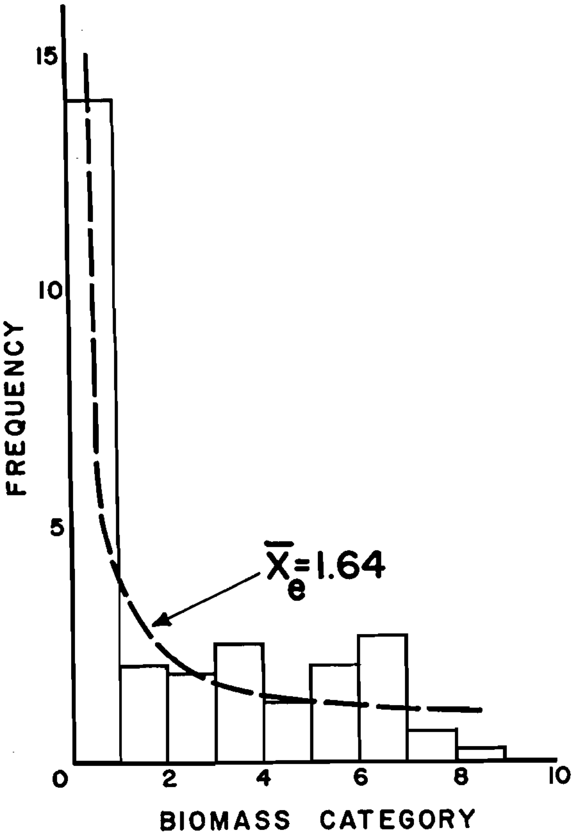

Fig. 6. Observed and predicted frequencies of biomass values for January through May. Histogram = observed values. Curve = predicted values. Mean biomass value, $\bar{x}_e$, is expressed in the logarithmic units (base 2) of the x-axis. In grams this equals 3.12.

$$\hat{f}(n) = \frac{\alpha}{n} x^n + \Phi, 0 < n \leqslant 8 \qquad (2)$$

$$\text{where } \Phi = \frac{1}{9} \int_{n=8}^{\infty} f(n)\, dn$$

For our data, parameters of (2) were found to be α = 2.171 and x = 0.984. A graph of (2) with these parameter values is also shown in Figure 6, as a dotted line running through the histogram.

Using the probability function (2) allows us to draw the following conclusions regarding the spatial pattern of drift algal biomass from January through May. Sampling the Indian River drift algal community at this site during January through May would yield a large proportion of biomass values near zero. That is, little or no drift algae would be found in a large number of samples. In our study, more than fifty percent of the samples contained no drift algae. Large clumps would occur seldom but with a predictable frequency. We obtained biomass values greater than eight grams in twenty one percent of the samples. Furthermore, values in biomass categories $n \geqslant 4$ should occur with nearly equal frequency, although in our case category 7 was represented more than any of these. The deviation from expected value of class 7 was sufficient to increase χ^2 beyond tabulated value. We regard this as a chance occurrence, and not a deficiency of the distributional model. Thus the close correspondence between observed and predicted values indicates adequate biomass sampling, even when biomass distributions are contagious.

Previous studies have shown that where drift algae are abundant, they are important providers of food, space and protection to many organisms. From collections taken with a 10' tri-net trawl, Roessler (1971) showed that catches of animals correlated well with seaweed weights. Zimmerman *et al.* (in press) found that in the Indian River *Cymadusa compta*, an amphipod commonly collected in the samples during this study, prefers drift algae as a food source over seagrass blades, seagrass epiphytes and detritus. Drift species used in their experiments included the dominant species reported in this study.

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