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CONTENTS

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Biological Sciences

BRYOZOAN-ALGAL ASSOCIATIONS IN COASTAL AND CONTINENTAL SHELF WATERS OF EASTERN FLORIDA

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ABSTRACT: *Surveys of Bryozoa occurring on algal substrata were carried out in the shallow subtidal and deep (30-90 m) continental shelf waters of the Florida East Coast. Twenty-eight species of bryozoans were found on 12 species of algae in the shallow subtidal. Thirty-six species of bryozoans were found on 12 species of algae at the continental shelf stations.* Membranipora tuberculata *and* Thalamoporella gothica floridana *were the most common bryozoan species in the coastal collections, and* Aetea sica *and* Microporella ciliata *in the continental shelf collections. No bryozoans were found on noncalcified Chlorophyta. The calcified Chlorophyta and the more massive species of Phaeophyta and Rhodophyta were the preferred substrata.**

ASSOCIATIONS between bryozoans and algae have been noted since Darwin (1845). Other early workers on these associations include Busk (1852), Joliet (1877), and Hincks (1880). More recent work (Ryland, 1959; Crisp and Williams, 1960; Ryland and Stebbing, 1971; Hayward, 1973; Hayward and Harvey, 1974) has increased our understanding of the ecological bases of these relationships (e.g., the role of the larvae in substratum selection). Only 3 studies have described ectoproct-algal associations in specific regions. Rogick and Croasdale (1949) described bryozoan species found on algae in localities ranging from New Hampshire to Buzzards Bay, collected from intertidal to 18 m depths. Ryland (1962) has listed such associations for the coast of Wales in the intertidal and shallow subtidal zones. Pinter (1969) has discussed bryozoan-algal associations in intertidal habitats of southern California.

No one has made a study of bryozoan-algal associations *per se* in warm

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water regions, although observations of the occurrence of particular species of bryozoans on algae is found in taxonomic works on these regions, e.g., Maturo (1957) notes 14 species of Bryozoa occurring on algae in the Beaufort, N.C. region. We examine ectoproct-algal associations in a subtropical region, the Atlantic coast of Florida. Previous studies have concentrated on intertidal habitats. We compare collections made from the intertidal and shallow subtidal waters with collections taken from deeper continental shelf waters (30-90 m).

METHODS—Algae and bryozoans were collected at 4 coastal localities along the Atlantic coast of Florida and at 8 stations on the East Florida Continental Shelf (Fig. 1). The coastal collections were made in 1975 as part of a larger survey (Winston, in prep.) and were carried out opportunistically. Two collections (27-III-75, 24-IV-75), were made in the Indian River in a seagrass bed located on the north side of Sebastian Inlet (Station 1). Several species of algae grow as detached clumps tumbling among the seagrasses (Eiseman and Benz, 1975). Only *Solieria tenera* supported bryozoans. The other collections were made along the open coast. Six collections of drift *Sargassum* were made at 3 locations: North Beach, Fort Pierce (Station 2); Walton Rocks (Station 3) and Seminole Shores (Station 4), Hutchinson Island (11-II-75, 24-VI-75, 25-VI-75, 4-VII-75, 8-IX-75, 6-X-75). These locations are all stretches of sandy barrier beach where drift algae were abundant after several days of onshore winds. Both eupelagic and attached species were examined, grouped here as *Sargassum* spp. because of the difficulties in determining the species of fragmentary plants. The attached species *Sargassum filipendula* and the pelagic *S. natans* and *S. fluitans* are most commonly encountered in this area. After a storm in late June one large collection containing many algal species was made just north of the North Beach breakwater in Fort Pierce. This sample consisted of attached algae washed loose from the subtidal beach-rock ledges (to 10 m) and sub- and intertidal rocks of the breakwater itself.

Continental shelf algae and bryozoans were collected by lockout divers from the JOHNSON-SEA-LINK (JSL) submersibles in September and November, 1977. Locations of each station are shown in Fig. 1. JSL I-442 (6 Sept.; 90 m; 15.6 °C) and JSL II-292 (18 Nov.; 89.7 m; 16.0 °C) (Station 5) were on a large rocky mound east of St. Lucie Inlet, Martin County, Florida. The area is subject to upwelling and high turbidity (nepheloid layers). The temperatures at the time of sampling are typical for the station, but temperatures as high as 26.7 °C and as low as 8 °C have been recorded. Currents on the mound are usually less than 10 cm/sec, but slow shifting of water masses seems to be a common occurrence. At a nearby station water temperatures on one occasion changed 12 °C in 9 hr (J. Reed, pers. comm.). *Oculina* coral with its associated community and hydroids, bryozoans and echinoids are the dominant invertebrates.

Stations 6-10 (JSL I-444; 7 Sept.; 71.5 m; 20.0 °C; JSL I-445; 7 Sept.; 49.4 m; 27.0 °C; JSL I-447; 8 Sept.; 42.4 m; 26.8 °C; JSL I-448; 8 Sept.; 58.0

m; 15.1°C; JSL I-450; 9 Sept.; 27.3 m; 28.0°C) are east of Singer Island, Palm Beach County, Florida. These are in a rubble zone with very little bottom relief. Nepheloid layers have not been observed here, and upwelling is much less common than at the St. Lucie Inlet Stations. Prevailing temperatures are 22-28°C, but temperatures as low as 9°C have been recorded. Prevailing currents in this area are 20-45 cm/sec. Currents up to 165 cm/sec have been observed. Sponges, hydroids and bryozoans are the

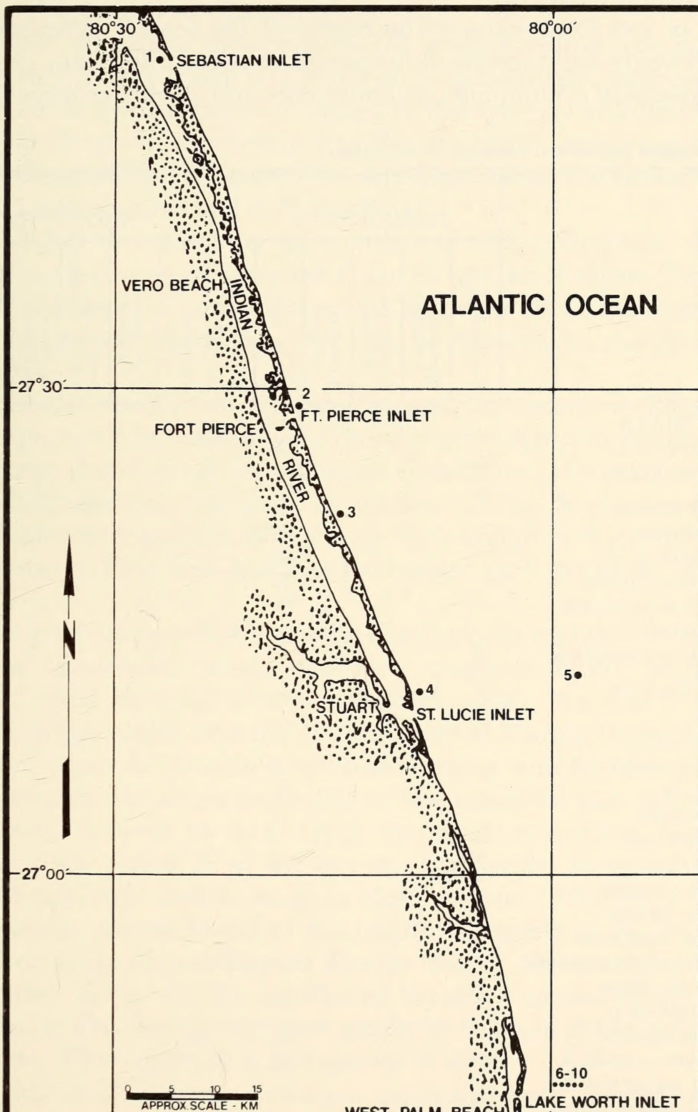

FIG. 1. The Indian River and Singer Island region of Florida, showing the locations of Stations 1-10. Station 1, Sebastian Inlet; 2, North Beach, Ft. Pierce; 3, Walton Rocks; 4, Seminole Shores; 5, St. Lucie Mound; 6-10 Singer Island, Transect.

primary sessile invertebrates at these stations. Small amphipods, decapods and polychaetes are common among the fronds of the larger algae and in the crevices of the rubble.

Algae and bryozoans from the coastal stations were examined while alive. Those from the continental shelf stations were preserved in 5% seawater-formalin and returned to the laboratory for subsequent study. Voucher specimens for the algae species are in the Harbor Branch Foundation Herbarium (HBFH).

Results and Discussion—The results of the coastal collections are in Table 1. Twenty-eight species of bryozoans were recorded from 12 species of algae: 2 species of cyclostomes, 6 ctenostomes and 20 cheilostomes. No bryo-

Table 1. Coastal Bryozoans associated with algae.

	PHAEOPHYTA				RHODOPHYTA							
	Sargassum spp.	*Spatoglossum schroederi*	*Dictyopteris delicatula*	*Turbinaria turbinata*	*Solieria tenera*	*Gracilaria mammillaris*	*Gracilaria armata*	*Cryptonemia crenulata*	*Bryothamnion seaforthii f. disticha*	*Bryothamnion triquetrum*	*Laurencia* sp.	undetermined red alga
CYCLOSTOMATA												
Crisia micra					X							
Tubulipora lunata	X											
CTENOSTOMATA												
Amathia distans					X							X
Bowerbankia sp. A					X·							
Bowerbankia gracilis					X							
Bowerbankia imbricata					X			X				
Nolella stipata					X							
Zoobotryon verticillatum	X											
CHEILOSTOMATA												
Aetea sica	X										X	
Beania hirtissima									X	X		
Beania intermedia			X		X							X
Bugula sp. B.					X							
Bugula neritina					X							
Bugula minima	X										X	
Electra bellula	X	X										
Escharoides costifer	X											
Hippothoa hyalina	X											
Lagenicella marginata	X											
Membranipora tuberculata	X			X		X		X				
Microporella ciliata	X											
Pasythea tulipifera								X	X			
Savignyella lafontii					X							
Scrupocellaria regularis					X							
Synnotum aegyptiacum											X	
Thalamoporella falcifera	X											
Thalamoporella gothica		X					X		X	X		
Vittaticella contei	X										X	
Watersipora subovoidea					X							

zoans were recorded on Chlorophyta. Fourteen bryozoan species occurred on 4 species of Phaeophyta and 20 bryozoan species were found on 8 species of Rhodophyta.

The greatest number of bryozoan species were found on *Solieria tenera* (Rhodophyta) (12 bryozoan species) and *Sargassum* spp. (Phaeophyta) (12 bryozoan species). Four species of bryozoans were recorded from *Laurencia* sp. (Rhodophyta) and 3 each from *Cryptonemia crenulata* and *Bryothamnion seaforthii f. disticha* (Rhodophyta).

The most abundant bryozoan in the coastal collections was *Membranipora tuberculata* which was found on *Sargassum* spp. most commonly, but occurred on 3 other species of algae (1 Phaeophyta and 2 Rhodophyta). *Thalamoporella gothica floridana* was also abundant, occurring on 4 algal species (3 Rhodophyta, 1 Phaeophyta) and *Beania intermedia* was found on 3 species (2 Rhodophyta and 1 Phaeophyta).

Table 2 lists the results of the continental shelf collections. Thirty-six species of bryozoans were recorded from 12 species of algae: 3 species of cyclostomes, 3 species of ctenostomes and 30 species of cheilostomes. Sixteen species of bryozoans occurred on 2 species of Phaeophyta and 30 species of Rhodophyta.

The greatest number of bryozoan species was found on Rhodophyta. Eighteen species of bryozoans were found on *Rhodymenia pseudopalmata* and 12 species occurred on *Petroglossum undulatum*. The calcareous green alga *Udotea flabellum* supported 14 species. Of the bryozoans reported, *Aetea sica* and *Microporella ciliata* were both found on 6 species of algae. *Mimosella verticillata* and *Escharoides costifer* each occurred on 4 algal species.

Table 3 gives the numbers of species of bryozoans recorded from algae in 4 different geographic areas: the New England Coast (Rogick and Croasdale, 1949), the coast of Wales (Ryland, 1962), the coast of southern California (Pinter, 1969) and the Atlantic coast of Florida (this paper). It is evident that algae do provide a substratum for a considerable number of bryozoan species. In temperate regions where intertidal and subtidal rocks are commonly covered by large algae this is not surprising. Rogick and Croasdale (1949) found 29 of the 84 ectoproct species known at the time from the Woods Hole area to occur on algae. Ryland (1959) notes that most of the bryozoan species found in the intertidal regions of the British Isles are found on algae. In subtropical Florida waters, the intertidal algae are much smaller. However, the number of bryozoan species found on algal substrata is similar, though very few epiphytic Bryozoa are found in the intertidal zone. They occur on a few species of algae.

Only this study records bryozoans associated with algae from water deeper than 40 m. Thirty-six species were found on algae from deeper water (42-90 m), slightly more than in shallow water of the same region. When the species lists from the 2 collections are examined, however, (Tables 1 and 2) it can be seen that there is little similarity. Only 6 species of cheilostomes:

Aetea sica, *Escharoides costifer*, *Microporella ciliata*, *Scrupocellaria regularis*, *Synnotum aegyptiacum* and *Thalamoporella falcifera* and 2 species of ctenostomes: *Amathia distans* and *Nolella stipata* occur in both collections. Thus, the total number of species for both deep and shallow waters off the Florida East Coast is relatively large (56 species).

TABLE 2. Continental shelf Bryozoans associated with algae.

	CHLOROPHYTA				PHAEO-PHYTA			RHODOPHYTA				
	Halimeda discoidea	*Udotea flabellum*	*Dictyota dichotoma*	*Botryocladia occidentalis*	*Champia parvula*	*Maripelta* sp.	*Petroglossum undulatum*	*Peysonnelia rubra*	*Rhodymenia pseudopalmata*	*Searlesia subtropica*	*Waldoia antillana*	CALCAREOUS NODULES
CYCLOSTOMATA												
Diaperoecia sp.		X	X				X		X			
Disporella sp.		X	X				X		X		X	
Tubulipora sp.		X							X			
CTENOSTOMATA												
Amathia distans		X					X	X				
Mimosella verticillatum				X	X				X		X	
Nolella stipata		X						X				
CHEILOSTOMATA												
Aetea anguina								X	X	X		
Aetea sica	X	X		X			X	X	X			
Antropora sp.							X		X			
Bracebridgia subsulcata		X					X		X			
Caberea boryi						X						
Celleporaria albirostris							X	X	X			
Chorizopora brogniarti								X	X			
Cleidochasma contractum								X				
Cleidochasma porcellanum	X	X						X				
Escharoides costifer	X	X					X		X			
Floridina antigua												X
Gemelliporella glabra				X					X			
Halophila johnstoniae	X	X										
Hippoporina sp.												X
Hippothoa flagellum									X			
Lagenicella marginata									X			
Margaretta buski	X											
Microporella ciliata	X	X					X		X	X	X	
Parasmittina sp.							X					
Parellisina curvirostris								X				
Parellisina latirostris								X				
Petraliella bisinuata		X										
Reptadeonella costulata								X				
Rhynchozoon spicatum		X										
Scrupocellaria regularis									X			
Smittina smittiella							X		X			
Synnotum aegyptiacum	X											
Thalamoporella falcifera		X					X				X	
Trematooecia aviculifera												X
Tremoschizodina lata												X

TABLE 3. Number of species of Bryozoans recorded from algae in 4 geographic areas.

LOCATION	CHLOROPHYTA	PHAEOPHYTA	RHODOPHYTA	ALL GROUPS COMBINED
New England Coast (Rogick & Croasdale 1949)*[1] Intertidal-subtidal	4/3[3]	25/11	26/23	29/27
Welsh Coast (Ryland, 1962) Intertidal-subtidal	4/2	21/10	16/11	21/23
S. California Coast (Pinter, 1969)[2] Intertidal-subtidal	7/4	8/11	10/30	17/45
E. Florida Coast (Total)	16/2	16/5 +	41/17	46/24
– Coastal (Intertidal-subtidal)	0/0	14/4 +	20/9	28/12
– Continental Shelf	16/2	2/1	30/9	36/12

[1]Entoproct excluded. [2]Only algae supporting bryozoans included. [3]No. of spp. of bryozoans/no. of spp. of algae.

There is an obvious difference in number of species of bryozoans on non-calcified Chlorophyta and on the other algal groups. Rogick and Croasdale (1949) recorded 4 bryozoans from 3 species of green algae. These were chiefly represented by colonies only a few zooids in size. Pinter (1969) listed 7 species of bryozoans encrusting 4 species of green algae from California. These Bryozoa were branching forms attached by only a few basal zooids or rhizoids and very small colonies of *Cryptosula pallasiana* encrusting *Ulva lobata*. We found no bryozoans on non-calcified green algae, though these algae were present in the collections.

There could be several reasons for the lack of bryozoans on green algae. The body forms of green algae are less robust than those of most red and brown algae. These green algae are filamentous or delicate (1 or 2 cell layers thick) sheets and lack of strength and rigidity to support large bryozoan colonies. Surface texture and chemical nature of the algal cell walls are other possible explanations. When the walls of green algae are fortified with calcium carbonate, as in *Udotea flabellum* and *Halimeda discoidea* from the deep water Florida locations (Table 2) they can be a desirable substratum (7 species recorded from *Halimeda* and 14 from *Udotea*). Other massive Chlorophyta (*Caulerpa* spp. and *Codium* spp.) were common in our deep water collections but supported no bryozoans although hydroids are common on these species.

Red and brown algae seem about equal in the numbers of bryozoan species they support. From these data it is impossible to say that one or the other group is preferred by bryozoans. From this survey as well as the previous studies it appears that some species of brown and red algae are much more suitable than others as substrata for bryozoans and this suitability is probably due to a variety of factors, ranging from body form and persistence (length of life) to surface texture and chemistry.

Bryozoans occurring on algae could be put in 3 general categories with respect to substratum type (1) species limited to algal substrata; (2) species found on algae but also capable of living and reproducing on other substrata; (3) species usually found on other substrata ("accidental" on algae). Very few species fall into the first category. Morphologically these appear to be flexible sheet-like colonies covering a great deal of algal surface. *Membranipora membranacea* is found on kelps, chiefly *Laminaria* spp. in the Atlantic (Ryland, 1962) and the giant kelp *Macrocytsis* in the Pacific (Pinter, 1969; Woollacott and North, 1971). In the Florida collections 2 species of this type occurred, *Membranipora tuberculata* and *Thalamoporella falcifera.* These species were found on most drifting *Sargassum* plants examined and occurred only rarely on other algae and never on non-algal substrata.

The second category consists of species which show a strong algal "preference", but which are found on more than one species of algae and which may be found on other substrata as well. These are also species with flexible sheet-like colonies which encrust a large proportion of the algal surface. In New England *Electra pilosa* occurs on 17 algal species (Rogick and Croasdale, 1949) and in Wales on 19 algal species (Ryland, 1962). *Electra pilosa* can cover large areas of the algae, but it also occurs more rarely on other substrata such as shells, stones, hydroids and other bryozoans (Ryland, 1962). In the Florida collections *Thalamoporella gothica floridana* forms extensive unilaminar crusts over the fronds and stipes of red and brown algae in shallow water (Table 1), but may also occur as unilaminar crusts and bilaminar frills on hydroid stems and solid substrata.

A second morphological type of bryozoan common on algal substrata is characterized by a determinate or semideterminate growth pattern (spots or dots). These have a small colony size (2-5 mm dia) and a large ratio of reproductive units to total zooids of the colony. The round colonies of the lichenoporid cyclostomes are excellent examples, and they are common on algae, but the most abundant cheilostomes are often of this type also (e.g., *Escharoides costifer*, *Smittina smittiella* and the "deep water" form of *Microporella ciliata*). One colony of *Microporella ciliata* from the Florida continental shelf collections (JSL I-450) had 32 zooids of which 12 were ovicelled. Some of these species (e.g., *Escharoides costifer*) seem to have a life cycle characterized by small size and rapid reproduction. Other species, like *Microporella ciliata*, appear to have more than 1 morphology and/or reproductive pattern depending on whether they are growing on algae or another substratum. Only further study will tell whether life-histories are variable and substratum dependent or whether 2 separate species are involved.

Runner-like growth forms are also frequent on algal substrata. These include the cheilostomes (e.g., *Aetea* spp. and *Beania intermedia*) as well as the ctenostomes (e.g., *Bowerbankia* spp. and *Mimosella verticillata*). Runner-like growth forms may be a life-strategy adapted to unstable substrata, including many estuarine forms (Jackson, 1978; Winston, 1976; Buss, 1978).

The final category consists of species characteristic of other substrata (rocks, corals, shells, wood, etc.). Colonies of these species when found on algae may have their normal growth form, but are usually small and lack reproductive structures. In the Florida collections the occurrence of *Bracebridgia subsulcata* and *Gemelliporella glabra* on algae appear to be examples of this. These species are commonly found on sand and coral bottoms. Colonies found on algae were small, usually consisting of encrusting bases only. None of those in our collections had developed ovicells.

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Physical Sciences

HYDROGRAPHIC FEATURES OF FORT PIERCE INLET, FLORIDA

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ABSTRACT: *Circulation of the Fort Pierce Inlet and adjacent portions of the Indian River on Florida's Central East Coast was investigated during a 2 yr period. The currents were predominantly tidally driven, with wind effects becoming more important in the shallower areas of the Indian River and with increasing distance from the Inlet area. Variations in the salinity structure of the waters in the inlet area occur largely with the tidal stage.**

THE inlet at Fort Pierce, Florida (27°28'N 80° 18'W) is 1 of 3 tidal inlets connecting the Atlantic Ocean with the southern portion of the Indian River. The latter is part of an extensive barrier island estuarine lagoonal system extending along the central east coast of Florida. Coastal oceanic water passing through the inlets of Fort Pierce, Sebastian and St. Lucie (41 km to the north, 37 km to the south of Fort Pierce, respectively) encounters fresh water from tributaries that empty into the Indian River on its western bank. The fresh water sources are near the inlets and flow into the adjoining parts of the Indian River.

A study of the circulation and waters encountered in sections of the Indian River adjoining the Fort Pierce Inlet, required an investigation of the currents and water structures in an area encompassing the Fort Pierce Inlet and harbor. Preliminary results and the salient hydrographic features observed during this 2 yr investigation (mostly during the summer months) are described.

DESCRIPTION OF STUDY AREA—The present inlet and main ship channel at Fort Pierce is man-made, replacing a natural, but ephemeral inlet and channel, which had been located about 2 mi further north (Walton, 1974). The main channel is maintained at a depth of 7 m and extends from the ocean through the inlet into the Indian River where it intersects and crosses the Intracoastal Waterway to end in a basin forming the Fort Pierce harbor. A

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large shallow (~1 m) grass flat, locally referred to as Jim Island flats, lies to the north of the main channel and is partially exposed at low tide. This area is separated from a deeper (~2 m) north-south aligned channel on its eastern side by a sill which is partially exposed at mean water (Fig. 1).

The Fort Pierce Inlet exerts a broad influence on the circulation and waters in the northern and southern adjoining sections of the lagoon and in the near coastal zone (von Zweck et al., 1974, 1975, 1976). The effect of tidal action at the inlet extends about 35 km into the northern branch of the river. The water passing through the inlet has been observed to move as far as 7-8 km north from the inlet area. The discharge from the inlet into the ocean is easily recognizable by its color as it spreads along the beach (Sedwick, 1973).

The largest source of fresh water in the study area is Taylor Creek which is part of a Florida Flood Control System and enters the Indian River on its western bank in the northern part of the study area (Fig. 1).

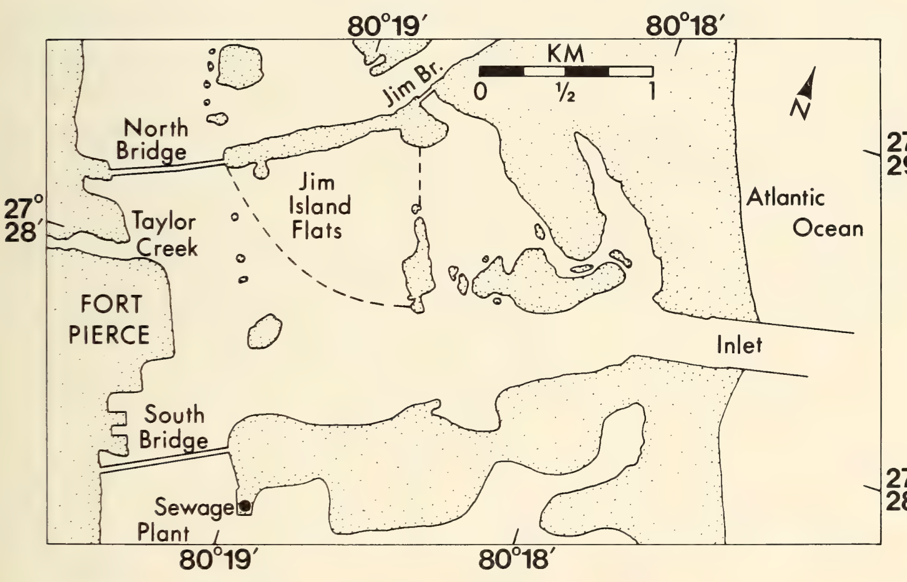


FIG. 1. Map of area under investigation.

The oceanic tide and the tide within the inlet area is essentially semidiurnal with a very weak diurnal component. Sedwick (1973) reported an average oceanic tidal range of about 1 m at the inlet entrance and 0.2 m at the Fort Pierce City Dock, corresponding to an 80% reduction in tidal range. The National Ocean Survey tidal height tables show a lag of the Fort Pierce tide behind the ocean tide of 2.5 hr for low tide and 2 hr for high tide.

OBSERVATIONAL PROCEDURES—Salinity, temperature and current data were collected under varying tidal and meteorological conditions at sites located throughout the Fort Pierce Inlet and harbor area, as well as the adjoining sections of the Indian River. This effort was complemented by hourly vertical salinity, temperature and current profiles, and meteorological observations from a number of 13 hr anchor stations at selected sites.

A direct readout CSTD was used for the vertical salinity and temperature profiles; current speeds and directions were measured using direct readout current meters and drogue drift observations. In an attempt to better determine the overall circulation pattern, a comprehensive dye drift study was undertaken (Richardson, 1977). The dye study was carried out under both flood and ebb conditions by releasing premeasured amounts of dye near the time of maximum flow and observing their motion and dispersal by aerial photography.

Circulation—The circulation in the Fort Pierce Inlet and harbor area is predominantly tidally driven. Tidal harmonic analysis of a 29 da current record from the inlet shows that approximately 93% of the variance of the current flow can be accounted for by tidal constituents.

The most probable surface current patterns for the Fort Pierce Inlet and harbor area near the period of maximum flood and ebb flows are in Figs. 2 and 3, respectively. These patterns represent composites of dye drift observations obtained on 14, 16, and 24 July 1975 under flooding conditions and on 6 and 7 August 1975 under ebbing conditions. The dye drift patterns were obtained from visual observations from the air and from boats at times of maximum tidal flow, as predicted for the Fort Pierce Inlet by the *Tidal Current Tables* (National Ocean Survey, 1975).

Similar composites for tidal flows at a depth of 1.5 m were formed for the same area from drogue drift observations collected during 1974. Figs. 4 and 5 present these subsurface currents within ± 1 hour of the predicted max-

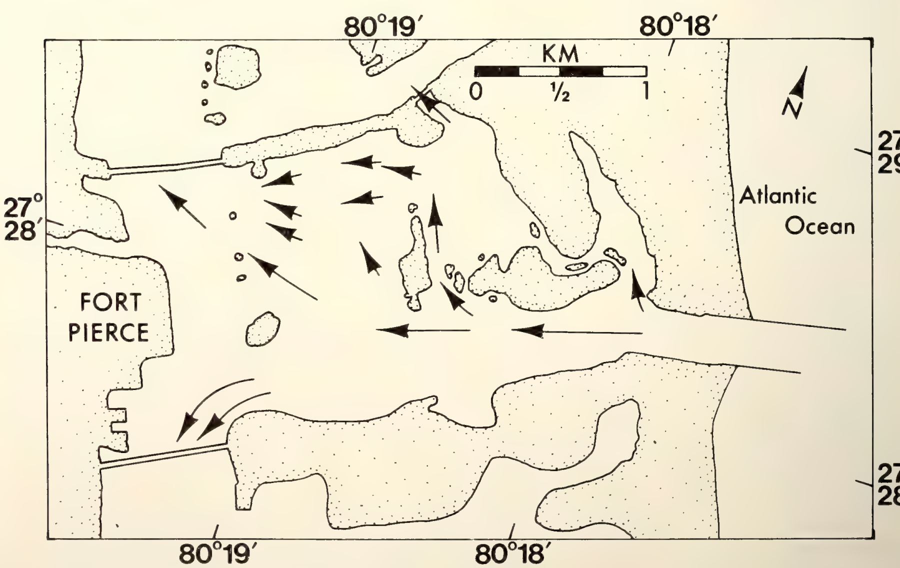


Fig. 2. Surface flood current pattern.

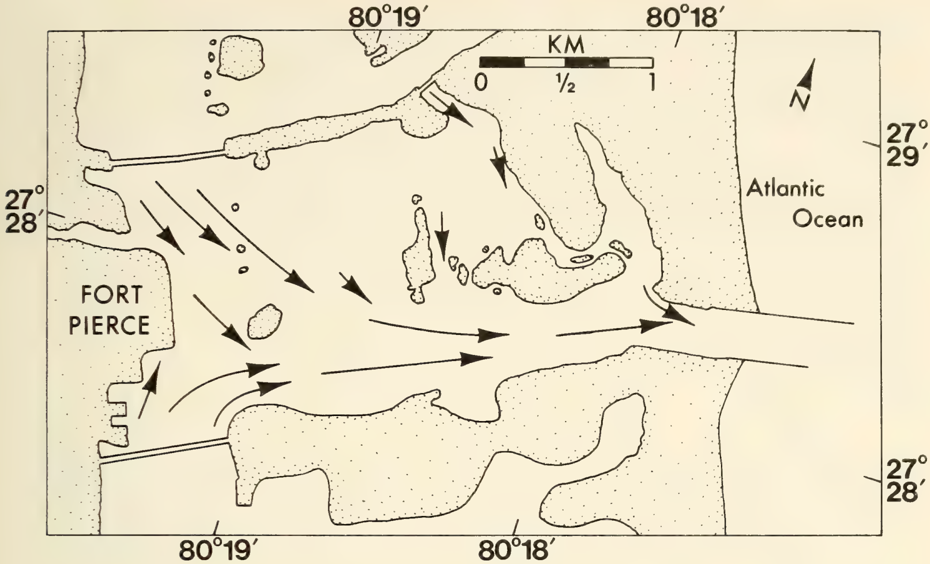


FIG. 3. Surface ebb current pattern.

imum ebb and flood currents. Ratios of estimated observed currents speeds to the predicted speeds for the inlet are shown next to the arrows indicating the paths of the drogue.

The current patterns conform closely to the local bathymetry, with major flows occurring in the larger channels. The flow across the Jim Island

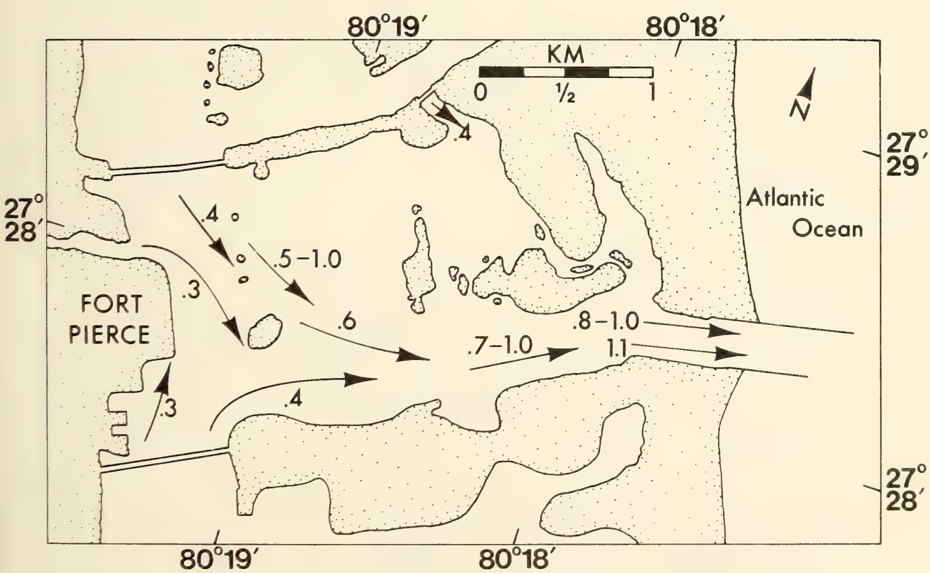


FIG. 4. Subsurface ebb current pattern.

TABLE 1. Volume transports (m^3/sec) at time of maximum currents predicted by NOS Tidal Current Tables.

	EBB (m^3/sec)	FLOOD (m^3/sec)
Transect 1 (North Bridge)	**	550
Transect 2 (South Bridge)	1100	1100
Transect 3 (Inlet)	1400	1900
Transect 4 (Jim Creek)	200	300
Transect 5 (Taylor Creek)	60	20
Sewage Treatment Plant	1-2*	1-2*

*Data supplied by the City of Fort Pierce.
**Data not available.

flats is generally weak because the east-west flow is reduced by the sill on its eastern boundary. The outflow at the mouth of Taylor Creek is confined in a shallow (~0.5m) surface layer and is directed into the Indian River while the flow of the deeper layer in this area reverses its direction with the flood and ebb tide.

Table I gives estimates of transports entering and leaving the study area near times of maximum ebb and flood flow. These estimates were obtained by vertical and horizontal integrations of the velocity profiles measured along a number of transects.

Data for volume transport at North Bridge at ebb tide are unavailable, it is however reasonable to assume that this transport is approximately the

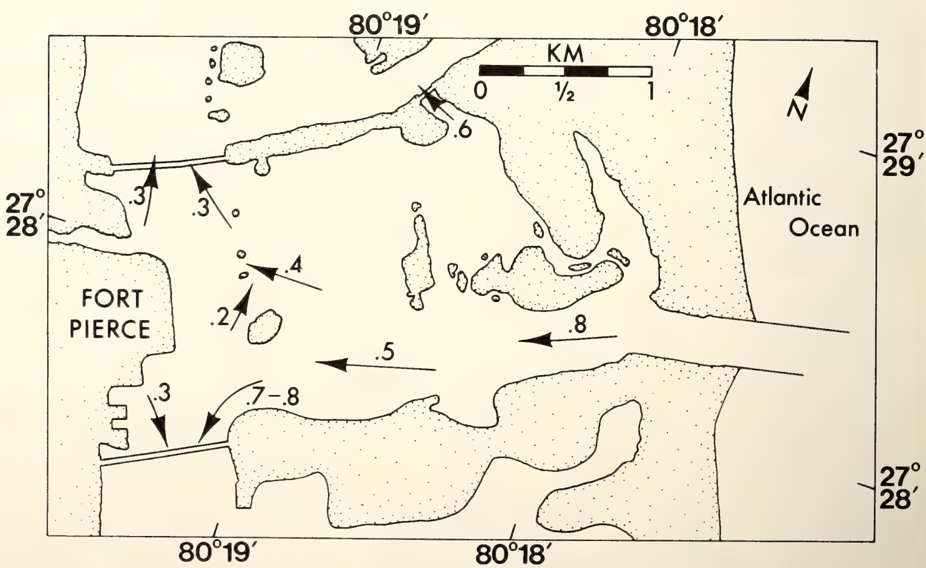
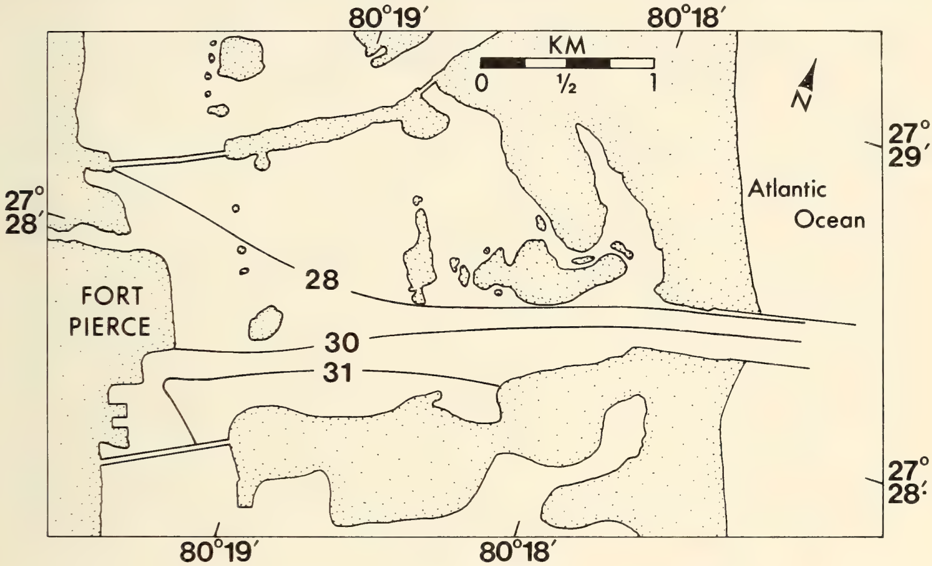


FIG. 5. Subsurface flood current pattern.

same at flood tide. This would result in an underestimation of the transport through the inlet.

SALINITY AND TEMPERATURE—The horizontal and vertical salinity structure of the water in the inlet/harbor area is predominantly controlled by the stage of the tide and the tidal currents.

Representative surface and subsurface (2 m depth) salinity distributions for both ebb and flood tide are shown in Figs. 6a, b and 7a, b respectively.



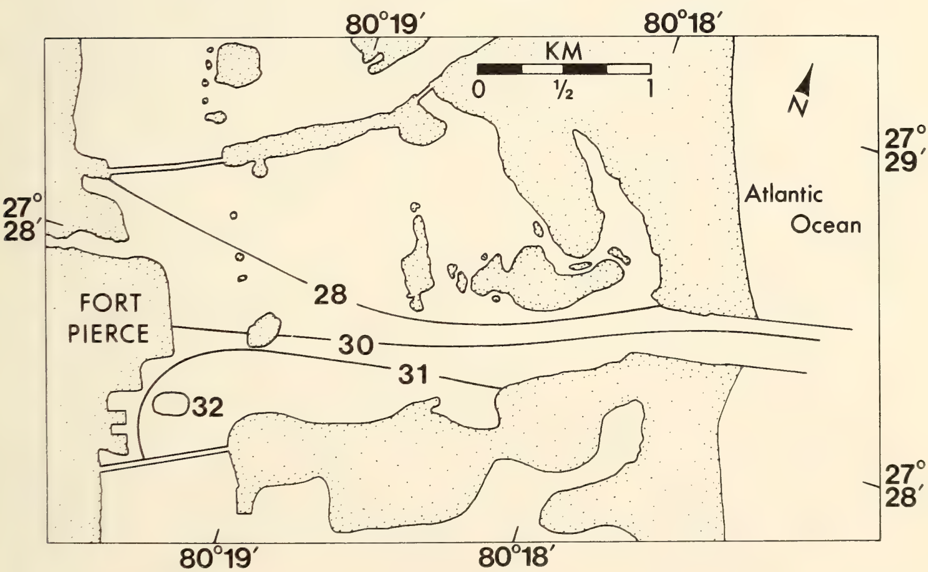
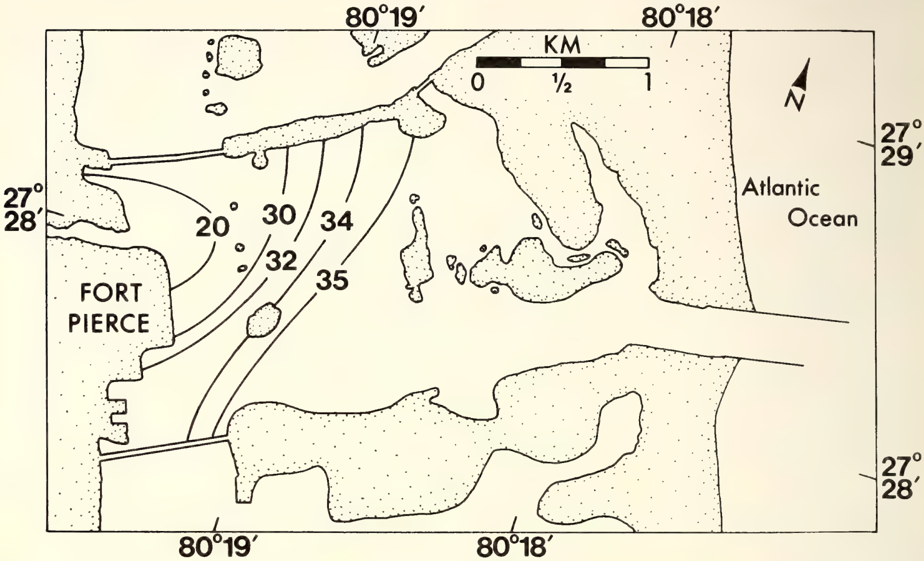


FIG. 6a. Surface salinity distribution during ebb tide.

FIG. 6b. Subsurface salinity distribution during ebb tide.

During ebb flow the influence of Taylor Creek water on the surface salinities extends across the Intracoastal Waterway into the inlet. The water in the inlet itself is vertically well mixed by the turbulent flow. In the beginning stages of the ebb tide, water from Taylor Creek passes over the Jim Island flats, as the ebb progresses, the flow moves off the flats and through a channel at its southern edge. A flood tide forces the freshwater back, forming a distinct salt wedge at the mouth of Taylor Creek. Although this salt wedge is



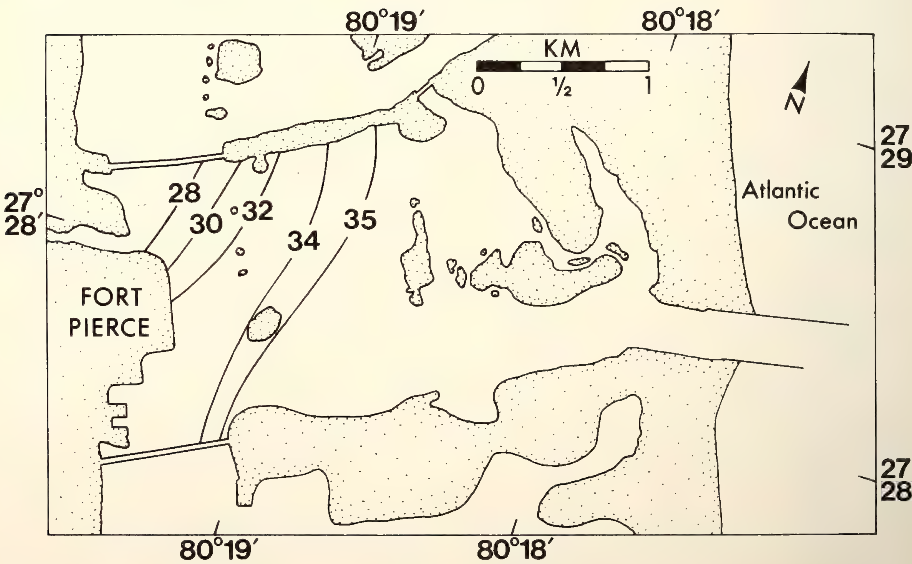
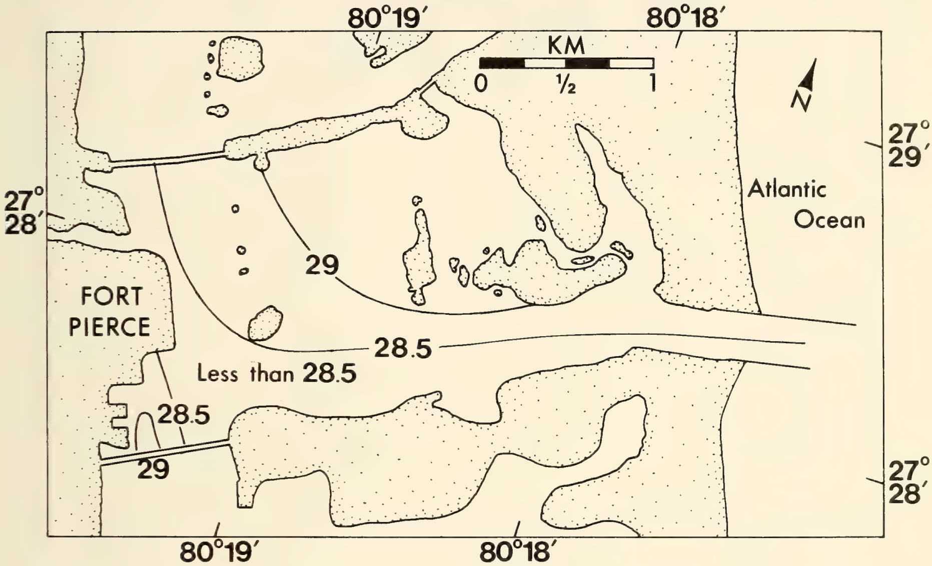


Fig. 7a. Surface salinity distribution during flood tide.

Fig. 7b. Subsurface salinity distribution during flood tide.

observed during both ebb and flood tide, it is most pronounced at an incoming tide. Vertical salinity differences up to 30 ppt have been observed at the mouth of the creek.

The thermal structure of the inlet area waters is shown in Figs. 8a, b (surface and subsurface temperatures at ebb tide) and 9a, b (surface and subsurface, flood tide). These figures represent a composite temperature distribution based on numerous sampling days between January and August



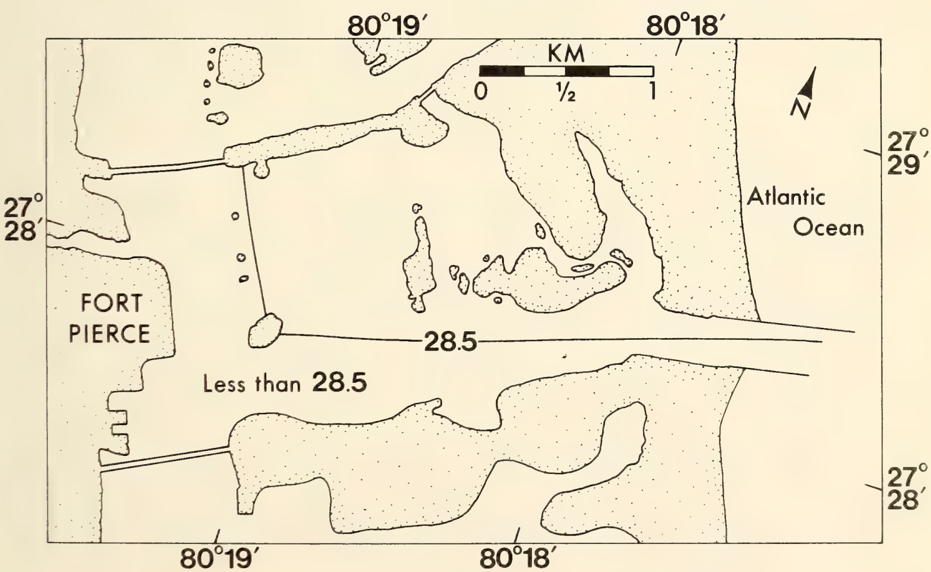
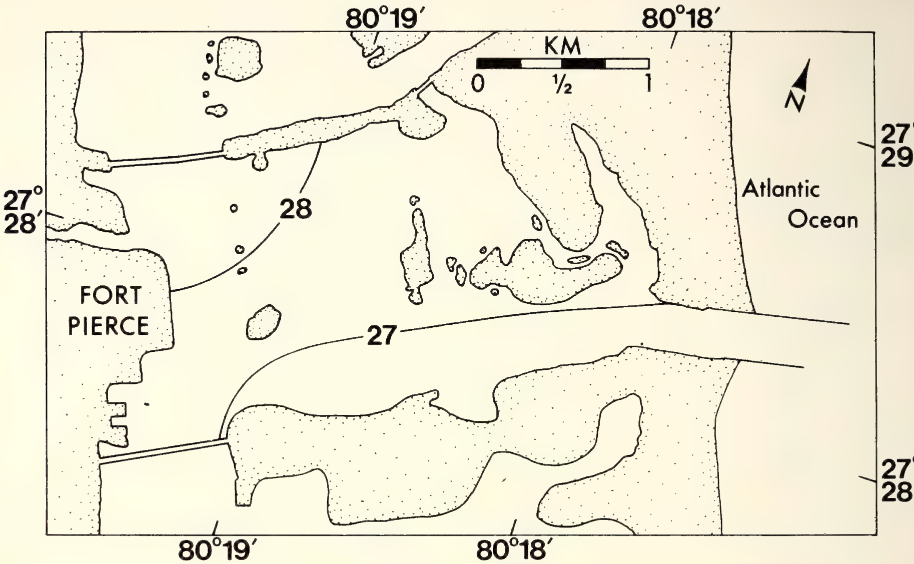


FIG. 8a. Surface temperature distribution during ebb tide.

FIG. 8b. Subsurface temperature distribution during ebb tide.

1974, and represent a typical thermal distribution for this area; no large horizontal temperature differences were consistently observed. Taylor Creek appeared to be a source of slightly warmer water, in contrast to the cooler ocean water entering this area during a flood tide. The very shallow waters of the Jim Island grass flat were one of the warmer areas. Under ebb conditions, the largest temperature difference found in the inlet area is slightly



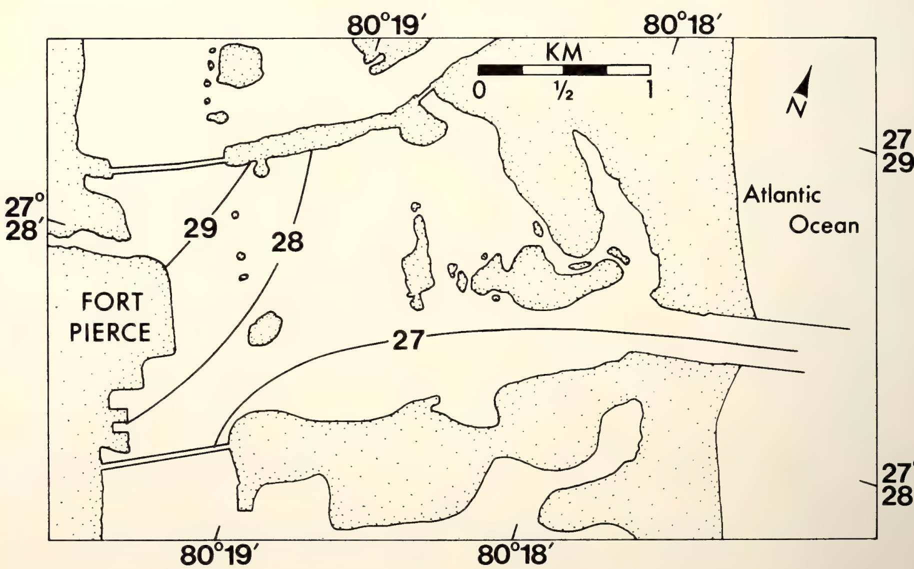


Fig. 9a. Surface temperature distribution during flood tide.

Fig. 9b. Subsurface temperature distribution during flood tide.

more than one half degree Celsius, while for flood conditions, the range is over 2° Celsius.

Three different waters are encountered in the inlet area and can be visually identified as to their sources by their distinctive colors. Taylor Creek water is dark brown due to high concentrations of tannic acid; Indian River water has a brownish-green tint and the coastal oceanic water is bluish-green. As these waters are moved by the tidal currents, sharp interfaces are formed between them. Because there exists a high correlation between the color of the water and its salinity, the sharp color interfaces also point out salinity discontinuities. The downstream portions of the interfaces disappear by vertical and horizontal mixing.

SUMMARY: 1. The circulation present in the Fort Pierce Inlet area is predominantly tidally driven. Wind driven currents modify the circulation pattern over the shallow Jim Island tidal flats.

2. Salinity of the inlet waters is governed largely by the tidal flow, with higher salinities being observed during a flood tide, and lower salinities during an ebb. The Taylor Creek outflow affects salinities to varying degrees depending on the state of the tide by creating horizontal salinity gradients. A salt wedge exists at the mouth of Taylor Creek during both phases of the tidal flow, but is more pronounced during the flood.

3. The thermal structure appears to be relatively constant, with the largest temperature variation encountered being slightly more than 2° Celsius.

4. The circulation pattern is largely affected by topographical features, including islands, shoal areas, grass flats, and dredged channels.

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Engineering Sciences

WATER BUDGET COMPUTATION IN LAKE OKEECHOBEE

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Abstract—*The water budget computation for Lake Okeechobee is a complicated procedure not only because the existing marsh vegetation zones can transpire large quantities of lake water to the air, but also because of the 2 different types of evaporation pans may affect the accuracy of estimating lake's evaporation. A model that considers the marsh zone evapotranspiration and evaporation pan differences was developed to compute the lake's water budget. This new method was found more precise not only in computing the water budget for Lake Okeechobee, but also to reduce the sum of storage deviation by about 94% as compared with conventional method for the past 26 yr.* *

Lake Okeechobee is located approximately 320 km north of the southern tip of the Florida Peninsula (Fig. 1). The lake is about 55 km long and 48 km wide, with the long axis running north and south. The surface area is about 1805 km^2. Lake Okeechobee is the second largest fresh water lake in the United States. Its average depth is approximately 3 m which has an average volume of 5.4 billion m^3. In other words, a 1 m of stage deviation equals approximately one-third of the volume of the lake. The bottom elevations range from sea level to approximately 4.6 m msl. The basin is saucer-shaped, with well over half the lake's bottom being 1.5 m msl or less. The southern and western shoes of the lake consist of extensive marsh areas. A smaller marsh area is found along the northeastern shore of the lake. The lake is enclosed by a 129 km levee system with control structures designed primarily for water supply and flood control purposes.

The lake is the major reservoir for storing the surface water and a main source of water supply to south Florida, which includes the Everglades Agricultural Area, Everglades National Park and low east coast area. The lake is currently under stress from both increasing nutrient input and the consequency of increasing the lake's regulation stage for the additional water storage. However, one unsolved hydrologic problem is the volume of the lake. According to the Corps of Engineer's (COE) water budget computation records (COE, 1969-74), the lake has overestimated 87.42 cm of the stage as compared with historical recorded stage. This deviation is equivalent to about 1.6 billions m^3 which is nearly 30% of the entire lake storage volume. Davis and Marshall (1975) found that imbalance of Lake Okeechobee's water budget used in their study limits the significance of the nutrient loadings budgets. One of the possible sources of the stage deviation (the dif-

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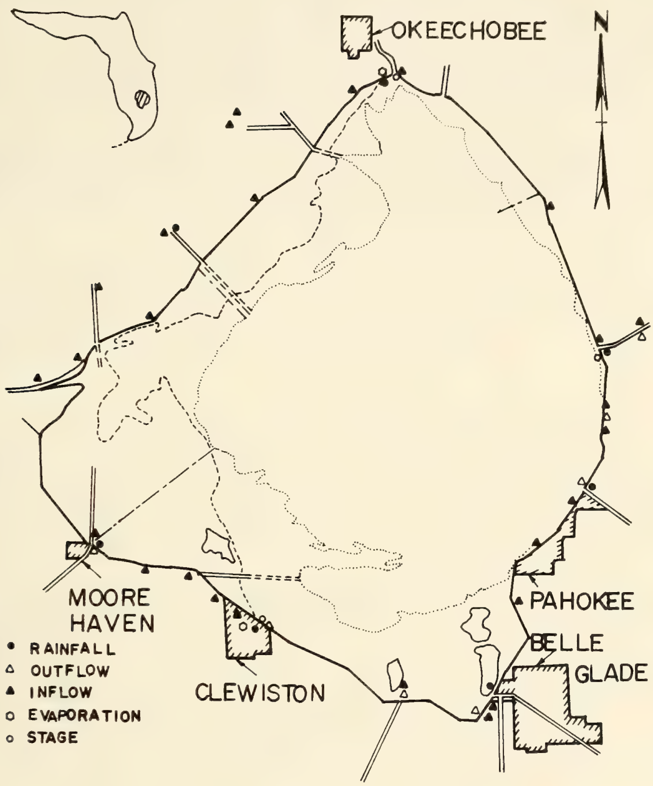

FIG. 1. Hydrological data recording stations in Lake Okeechobee, Florida.

ference between the computed stage and the recorded stage) was the evapotranspiration from the marsh zone (Shih, 1976). Another factor which may affect the accuracy of water budget computation is the adjustment of pan evaporation coefficient correlated to the different types of evaporation pans used to estimate the lake evaporation. My objectives were two-fold: (1) to develop a method to compute the water balance for the Lake Okeechobee; and (2) to compare the difference of the sum of stage deviation between conventional and modified methods with and without considering the marsh zone evapotranspiration.

METHODOLOGY—The continuity equation applied by the Corps of Engineers (1952-77) to compute the water budget for the Lake Okeechobee was used in this study. The storage in time (t = a month) was calculated as:

$$V_t = V_{t-1} + I_t + A_{wt} \bullet R_t - A_{wt} \bullet E_t - O_t \quad (1)$$

where: V_t = Storage at the end of the t month;

V_{t-1} = Storage at the end of the (t − 1) month;

I_t = Inflow during t month;
R_t = Rainfall during t month;
E_t = Evaporation during t month;
O_t = Outflow during t month; and
A_{wt} = Area of water surface at the end of the t month.

Fig. 1 shows, a broad area on the west side of the lake contains a marsh zone which can transpire a large quantity of water to the air (Shih, 1976). Thus, the equation can be rewritten as:

$$V_t = V_{t-1} + I_t + A_t \bullet R_t - A_{wt} \bullet E_t - A_{mt} \bullet ET_t O_t \qquad (2)$$

where: ET_t = Evapotranspiration from marsh zone during t month;
A_{mt} = Area of marsh zone at the end of the t month; and
$A_t = A_{wt} + A_{mt}$.

Based on the study conducted by Meyer and Hull (1969), the estimate of seepage around Lake Okeechobee is approximately 0.052 m^3/sec/km/m head between the lake and the borrow canal. This is a negligible amount compared with the lake's total volume. Therefore, the seepage factor was not included in the above calculations.

There are 2 types of evaporation pans used around the lake. The pan installed near the HGS2 and HGS6 Structures are Colorado Sunken Pan and U.S. Weather Bureau Class A Land Pan, respectively. Those 2 types of pans can be utilized in 2 methods for estimating the lake evaporation. The first does not consider the data modification between those 2 pans. This method is currently accepted by the Corps of Engineers to compute the water budget in Lake Okeechobee. The lake evaporation is expressed as:

$$E_t = X_1 \bullet (PE_{1t} + PE_{2t})/2 \qquad (3)$$

where: PE_{1t} = Evaporation from Colorado Sunken Pan at HGS2 Structure during t month;
PE_{2t} = Evaporation from U.S. Weather Bureau Class A Pan at HGS6 Structure; and
X_1 = Pan evaporation coefficient, (0.865 was chosen by COE).

The second method considers the data modification between those 2 pans. The ratio between the Colorado Pan and Class A Pan is 0.815 which was used by the Corps of Engineers study between 1952 and 1954. The lake evaporation is established from:

$$E_t = (PE_{1t} + 0.815\, PE_{2t})/2 \qquad (4)$$

After applying equation 3 into equation 1, one arrives at the following:

$$V_t = V_{t-1} + I_t + A_{wt}[R_t - 0.865\,(PE_{1t} + PE_{2t})/2] - O_t \qquad (5)$$

The equation 5 will be referred to as the method currently used by Corps of Engineers and designated as WOET method.

Substituting the equation 4 into equation 1 gives:

$$V_t = V_{t-1} + I_t + A_{wt}[R_t - (PE_{1t} + 0.815\,PE_{2t})/2] - O_t \tag{6}$$

Equation 6 is designated as a water budget computation associated with the data modification between Colorado Pan and Class A Pan, i.e. WMP method.

The evapotranspiration from the marsh zone is difficult to measure, but can be estimated from the evaporation of the lake's water surface:

$$ET_t = k \bullet E_t \tag{7}$$

where k is the evapotranspiration coefficient which can be estimated from the ratio between the average evapotranspiration from marsh zone and the average evaporation from lake's water surface:

$$k = \frac{1}{N_1} \sum_{i=1}^{N_1} ET_i \Big/ \frac{1}{N_2} \sum_{i=1}^{N_2} E_i \tag{8}$$

where: ET_i = Evapotranspiration from marsh zone during i year;
N_1 = Number of years for evapotranspiration data;
E_i = Evaporation of lake's water surface during i year; and
N_2 = Number of years for evaporation data.

Combining both equation 4 and 7 together with equation 2 gives:

$$V_t = V_{t-1} + I_t + A_{wt}[R_t - (PE_{1t} + 0.815\,PE_{2t})/2] + A_{mt}[R_t - k \bullet (PE_{1t} + 0.815\,PE_{2t})/2] - O_t \tag{9}$$

Equation 9 is designated as the same method of WMP except that the marsh zone evapotranspiration is considered, i.e. WMPE method.

There are 3 different periods which were considered to be involved in comparing the differences of the sum of storage deviation among WMP, WMPE and WOET methods. The first is the testing period (1969-74) which was a pilot period used by Shih (1976) to investigate the imbalance of Lake Okeechobee's water budget and will be used to test the degree of improvement after using the new methods. The second is the planning period (1963-74) which was used by the South Florida Water Management District (SFWMD) in 1977 for modeling the water use and supply development plan and will be used to examine the possible storage deviation involved in this period. The third is the recorded period (1952-77) which is chosen based on the availability of historical data and will be used to demonstrate the possible storage deviation involved in a longer historical period.

Results and Discussion—The monthly Lake Okeechobee water budget data which include rainfall, pan evaporation, inflow, outflow and stage were summarized from the Corps of Engineer's Monthly Water Budget Report (COE, 1952-77). The data recording sites are in Fig. 1.

The monthly water budget computed by the Corps of Engineers was based on the WOET model as given in equation 5. The sum of stage deviation was 284.4 cm for the past 26 yr. This 284.4 cm of overcomputed stage is equivalent approximately 5.1 billion m^3 of storage water which is about 93% of the volume of lake. The annual stage deviations are in Table 1. The results showed that the sum of stage deviations were 87.42 cm and 231.80 cm in the testing and planning periods, respectively. These stage deviations are respectively equivalent to 29 and 76% of the volume of lake. Average overestimated volumes per year were 5.0, 6.3, and 3.6% in the testing, planning and recorded periods, respectively. The computed storage was overestimated as compared with the recorded data for 21 out of 26 yr, or 81% of the time. This implies that not only the error is not randomly distributed, but also the computed storage has a tendency of large overestimation.

The monthly water budget was also computed by using the WMP model

Table 1. Storage deviations between computed and recorded stages in Lake Okeechobee, Florida. Three methods of the current Corps of Engineers method (WOET), the modified evaporation pan difference with (WMPE) and without (WMP) marsh zone evapotranspiration. (All measurements in centimeters).

Year	Recorded stage	Stage Deviation WOET	Stage Deviation WMP	Stage Deviation WMPE
1952	433.97	9.14*	3.50	1.49
1953	454.18	-10.33	-14.60	-17.31
1954	434.95	24.99	19.72	19.29
1955	411.33	14.66	10.27	3.81
1956	352.50	-35.63	-39.59	-48.89
1957	421.75	-32.28	-36.27	-38.41
1958	428.79	20.97	16.86	13.38
1959	443.85	-18.68	-22.65	-24.02
1960	456.93	29.20	24.90	23.62
1961	402.24	9.14	4.69	-8.17
1962	381.12	10.45	6.61	4.42
1963	398.19	38.62	34.05	26.85
1964	412.64	36.94	32.74	27.46
1965	426.96	27.80	23.96	20.15
1966	451.16	22.86	19.05	18.99
1967	412.30	18.14	13.72	4.24
1968	428.95	0.03	-3.81	-13.90
1969	453.51	-8.53	-13.32	-14.30
1970	440.86	0.91	-3.78	-6.19
1971	378.47	6.71	1.71	-5.67
1972	404.84	26.79	22.07	9.51
1973	408.34	45.42	40.60	31.00
1974	421.02	16.12	10.79	4.48
1975	406.42	9.91	4.02	-8.08
1976	411.54	9.85	4.42	-6.19
1977	412.18	11.28	6.01	-0.06
Sum (1952-77)		284.50	165.66	17.53
(1963-74)		231.80	177.76	102.63
(1969-74)		87.42	58.06	18.84

*Positive sign indicates that the computed stage is higher than the recorded stage, 30 cm of stage deviation equals approximately 10% of lake volume.

as given in equation 6. The results of annual stage deviation are in Table 1. The results showed that the sums of stage deviations were 58.06, 177.76, and 165.57 cm in the testing, planning and recorded periods, respecitvely. These stage deviations are respectively equivalent to about 19, 58 and 54% of the volume of lake. The sums of storage deviations are reduced respectively to 34, 23 and 42% in those 3 periods as compared with the WOET technique. On the average, 3.0, 4.8 and 2.1% of the volume per year were overestimated respectively in those 3 periods. The average of reducing the storage deviation in WMP method were about 2% each year. The years of overestimated storage deviation were 19 out of 26 yr. The distribution with 73% overestimate and 17% underestimate is similar to the WOET method; i.e., the computed storage has a tendency of large overestimation.

The water budget computation modified with marsh zone evapotranspiration was computed using equation 9. Before equation 9 can be applied, 2 parameters such as evapotranspiration coefficient k and the area of marsh zone existing in different lake stages must be determined. The quantity of evapotranspiration (ET) in the marsh zone was not available; however, Clayton (1949) conducted an ET study at the Agricultural Research and Education Center at Belle Glade, Florida, for sawgrass where the water table was maintained at 28 cm below the ground surface. Based on 7-yr of Clayton's data, the ET for sawgrass was 175.26 cm/year. The average evaporation for Lake Okeechobee as reported by COE (1952-77) was about 145.80 cm/yr. Therefore, the evapotranspiration coefficient (k) as defined in equation 8 is $175.26/145.80 \simeq 1.2$ which is also chosen in this study. The lake stage ranging between 3.5 and 4.6 m does contain some marsh zones within the lake (Shih, 1976). The surface area related to lake stage as reported by COE (1952-77) is also used to estimate the area of marsh zone above the lake water surface. To evaluate the improvement of WMPE technique, the lake geometry and hydrological data used in WOET and WMP are also used in WMPE model. The stage deviations between historical and WMPE results are in Table 1.

The results of WMPE method showed that the sum of stage deviations were 18.84, 102.63 and 17.53 cm in the testing, planning and recorded periods, respectively. These stage deviations are respectively equivalent to about 6.0, 3.0, and 6.0% of the volume of lake. On the average 1.0, 2.8 and 0.2% of the volume per year were overestimated respectively in those periods. The sum of storage deviations in those 3 periods are reduced respectively to 78, 56, and 94% as compared with the WOET method, and to 68, 42 and 89% as compared with WMP method. The years of overestimated storage deviation were 14 out of 26. The distribution with 53% overestimate and 47% underestimate is considerably symmetrical. Thus, the stage deviations seem more randomly distributed around the zero. These results of stage deviation with less values in those 3 periods and with more randomly distributed around the zero imply that the WMPE method is better than both WOET and WMP methods.

To investigate the performance of the WMP and WMPE methods in more detail it was considered necessary to compare the yearly storage deviation over 26 yr. Thus, the accumulated storage deviation from 1952 to 1977 is plotted in Fig. 2. The figure shows that the accumulated storage deviation in WMPE method is consistently lower than in WMP, and in WMP is lower than in WOET. Thus, as it considerably improved the Lake Okeechobee's water budget computation for the past 26 yr, the WMPE is more precise than the WMP, and the WMP is more precise than the WOET.

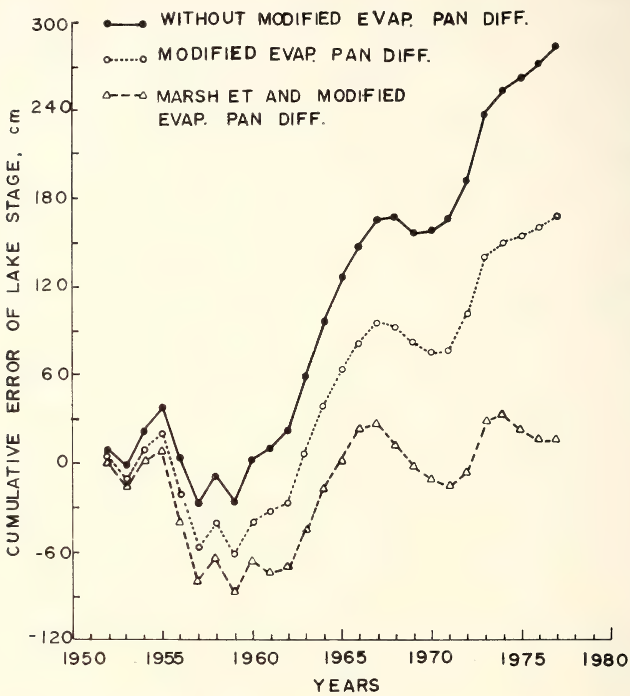

FIG. 2. The accumulated stage deviation among the methods of with and without modified the evaporation pan difference and marsh zone evapotranspiration.

However, Lake Okeechobee represents such a large and complex system that various factors such as its geometry, hydrologic data, evaporation from water surface, and evapotranspiration from marsh zone and their interactions should be studied further and in more details. Nevertheless, the result of this newly modified methods for water budget computation did show that the storage deviation was reduced significantly by as much as nearly 42% in WMP and 94% in WMPE as compared with the WOET method without changing the historical input data for the past 26 yr.

SUMMARY AND CONCLUSIONS—Two models including the modified evaporation pan difference (WMP) and the evapotranspiration of marsh zone within the lake (WMPE) were developed to compute the water budget for Lake Okeechobee, Florida. These newly developed methods were also compared with the conventional method (WOET). Monthly water budget data of Lake Okeechobee, Florida as reported by Corps of Engineers (COE, 1952-77) were used to demonstrate the techniques of model application. Three periods of testing (1969-76), planning (1963-74), and recorded period (1952-77) were used to compare the differences in the sum of storage deviations given by WOET, WMP, and WMPE methods.

The result of WOET method showed that the sum of stage deviations were 87.42 cm, 231.80 cm, and 284.50 cm in the testing, planning, and rec orded periods, respectively. These stage deviations are respecitvely equiavlent to 29, 76, and 93% of the total volume of lake.

The WMP method can reduce the sum of storage deviation by about 34, 23, and 42% respectively in those three comparison periods as compared with the WOET method. In general, the WMPE method was found more precise not only in computing the water budget for Lake Okeechobee, but also to reduce respectively the sum of storage deviation in those three periods by about 78, 56 and 94% as compared with the WOET method and 68, 42, and 89% as compared with the WMP method. Furthermore, the storage deviations in WMPE were scattered more randomly with time than that in WOET and WMP methods.

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Biological Sciences

HABITAT SEGREGATION OF FLORIDA CARPSUCKERS (OSTEICHTHYES: CATOSTOMIDAE: *CARPIODES*)

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ABSTRACT: Carpiodes cyprinus *and* C. velifer *were captured with a boat-mounted electrofishing apparatus in various habitats in the Escambia and Choctawhatchee rivers, and* C. cyprinus *was similarly captured in the Apalachicola River. There was much overlap in habitat, but in the Escambia River* C. cyprinus *occurred in mid-river more than would have been expected had the 2 species of carpsuckers been similarly distributed.* Carpiodes cyprinus *was concentrated in mid-river in late summer and early fall during low water in all 3 rivers, and during high water* C. cyprinus *occupied areas of reduced current. On the other hand,* C. velifer *occupied areas of reduced current in the Escambia and Choctawhatchee rivers throughout the year.* *

CARPIODES CYPRINUS and *C. velifer* inhabit large, slowly-flowing streams and lakes. These 2 carpsuckers are sympatric throughout much of the east-central United States from the Mississippi River east to the Appalachian Mountains (Forbes and Richardson, 1920; Harlan and Speaker, 1956; Hubbs and Lagler, 1958; Smith-Vaniz, 1968; Pflieger, 1975; Beecher, 1979). In northwest Florida these 2 fishes occurred together in the same 1 km segment of the Escambia River (Beecher, et al., 1977).

The morphological similarities of the 2 species render them potential competitors where they coexist. Their coexistence implies that they avoid competition to some degree, and preliminary observations suggested that *C. cyprinus* and *C. velifer* might segregate by habitat. To ascertain whether this was the case, I examined habitat occupation by these sympatric fishes in the Escambia and Choctawhatchee rivers and by an allopatric population of *C. cyprinus* in the Apalachicola River of northwest Florida.

METHODS AND MATERIALS—Carpsuckers were collected with a boat-mounted electric shocker during 2 separate periods. The first collection period was a 1-yr survey with repetitive sampling in a limited area of the Escambia River. In the second collection period I attempted to determine whether the pattern of habitat use observed during the first period was present in other streams and at a different time in the same stream. The primary goal of the second collection period was the collection of large numbers of specimens, which precluded repetitive sampling in areas as small as that sampled during the first period.

I collected carpsuckers in a 1 km segment of the Escambia River at least

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once each month during 1972. Sampling techniques and the location of the study area (station EJ) were described by Beecher, et al. (1977). As each fish was netted it was identified to species and was assigned a code of 1 through 14, corresponding to subjectively delineated habitat zones (Fig. 1 and Table 1). Data obtained earlier than May were too limited for analysis, so that only the data from May through December were considered.

In 1976-77 I collected carpsuckers at least once a month at the same Escambia River station (EJ), in the Choctawhatchee River upstream from the U.S. Hwy. 90 bridge at Caryville, Holmes-Washington counties (station CCA), and in the Apalachicola River upstream from the State Road 20 bridge between Bristol and Blountstown, Liberty-Calhoun counties (station AB). Stations in these river systems were described and mapped by Beecher (1979). During the 1976-77 study, lack of personnel prevented the recording of habitat data as each fish was netted, but at the end of each collection I

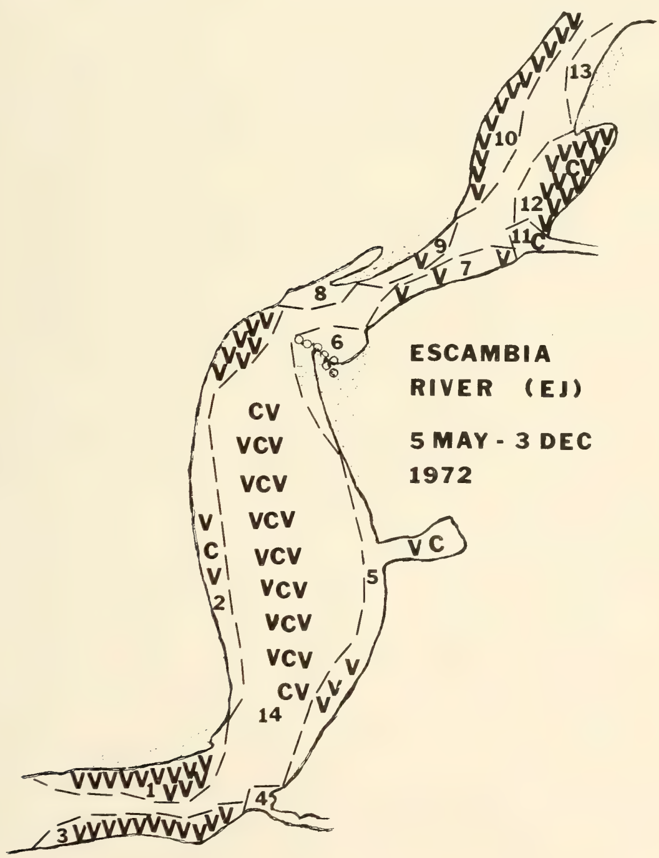

FIG. 1. Collection locations of *C. cyprinus* (C) and *C. velifer* (V) in a 1 km length of the Escambia River at station EJ during May-December, 1972. Stippling indicates sandbars; circles indicate gravel. Numerals indicate subjectively designated habitat zones (see Table 1) bounded by dashed lines. River flow is from upper right (NE) to lower left (SW).

recorded notes on the distribution of the carpsuckers within the different habitats. Because *C. cyprinus* showed the most habitat preference in 1972, I noted the habitat in which specimens of *cyprinus* were captured with reference to the habitat in which I collected most *velifer*.

Data obtained in 1972 at station EJ were analyzed using a chi-square test. Each of the habitat zones (Table 1, Fig. 1) was considered to be a cell (except where the expected numbers of either species < 1 for a habitat zone, in which case several habitat zones were combined as 1 cell having an expected number of individuals ≥ 1 for each species). The null hypothesis to be tested was that a fish of either species had the same probability of occurring in a given cell.

TABLE 1. Habitat utilization by *Carpiodes* in the Escambia River, May-December 1972. See Fig. 1 for map of habitat zones.

Habitat Zone	*C. cyprinus* Expected	*C. cyprinus* Observed	*C. velifer* Expected	*C. velifer* Observed	X^2
1 Slipbank	1.7	0	10.3	12	1.98
2 Cutbank	1.4	1	8.6	9	.13
3 Cutbank	1.5	0	9.5	11	1.74
5,7,9,11 Other shoreline	1.4	2	8.6	8	.30
10 Cutbank	1.7	0	10.3	12	1.98
12 Cove	1.9	1	12.1	13	.50
14 Mid-river	3.5	9	21.5	16	10.04
		13		81	16.67*

*df = 6; P < 0.02.

RESULTS—The distribution of Escambia River carpsuckers in the different habitat zones during May-December 1972 is plotted in Fig. 1. The 2 species showed great overlap in habitat, yet a chi-square value of 16.67 (df = 6) indicated that the 2 species were probably not ($P < 0.02$) distributed in the same manner. The mid-river zone (zone 14) contributed the greatest amount (60%) to the chi-square value (Table 1) and was therefore the site of most of the difference in distribution between the 2 species. Although both species were collected from mid-river, *C. cyprinus* occurred there more often than anywhere else, while *C. velifer* was more generally distributed.

During high water in winter, spring, and early summer, adult carpsuckers of both species were collected in areas of reduced current in the Escambia and Choctawhatchee rivers. Typically these habitats (zones 1, upstream end of 2, and 12 in Fig. 1) were located downstream from sandbars which formed at the insides of bends and extended downstream. Shallow (ca. 0.5-1 m at low water and 5-6 m at high water) bays often formed inshore from the downstream ends of sandbars (e.g., zone 12 in Fig. 1). A soft silt, clay, and sand substrate, current velocities ≤ 0.2 m/sec, and emergent willows (*Salix nigra*) and snags characterized such bays. This habitat was best developed in the Choctawhatchee River, where *C. velifer* reached its greatest abundance (Beecher, 1979).

During low water, from July or August to late October or November, *C. cyprinus* was absent from these bays and occurred instead in slightly swifter water (0.3-0.5 m/sec) along the outer edges of sandbars and in the mid-river channel, as seen at station EJ (fig. 1, Table 1). During low water, *C. velifer* was concentrated in the bays and areas of reduced current, although some were also collected in mid-river.

The pattern observed in the Escambia River in 1972 and in the Escambia and Choctawhatchee rivers in 1976-77 was of co-occurrence of the 2 species in areas of reduced current during high water in the winter and spring, followed by habitat segregation during low water in summer and fall. The habitat segregation was a result of a habitat shift by *C. cyprinus* from areas of reduced current during high water to areas of stronger current during low water. Most of the data in Fig. 1 were obtained during summer and fall low water.

An allopatric population of *C. cyprinus* in the Apalachicola River exhibited the same seasonal habitat shift from areas of reduced current during high water to areas of stronger current and deeper water during low water in the summer and fall.

Discussion—Hartman (1965) found that young rainbow trout (*Salmo gairdneri*) and young coho salmon (*Oncorhynchus kisutch*) segregated in the spring when population densities of both species were high, but in fall and winter, as population densities were reduced, habitat segregation broke down. Werner and Hall (1976) found that sunfishes, *Lepomis macrochirus* and *L. gibbosus*, contracted their habitat ranges when crowded together with *L. cyanellus* in contrast to greatly expanded habitat ranges in single species situations.

In Ohio, Woodward (1973) found no habitat differences between *C. cyprinus* and *C. velifer*. Comparison of ecological data for Illinois collections of carpsuckers indicated that the primary habitat difference between these 2 species was in substrate preference: *C. velifer* was a generalist, occurring frequently over gravel, sand, and mud substrates, while *C. cyprinus* was seldom collected over mud, which is associated with reduced currents (Forbes and Richardson, 1920). Pflieger (1975) reported that *C. velifer* was less tolerant of turbidity and siltation than the other carpsuckers (*C. carpio* and *C. cyprinus*) in Missouri.

In the Choctawhatchee and Escambia rivers, adult *C. cyprinus* and *C. velifer* had similar habitat preferences during high water. Vanicek (1961) found a similar situation for Iowa carpsuckers. During low water *C. cyprinus* in Iowa occupied deeper water while *C. velifer* occurred in riffles. No riffles existed in Florida streams I investigated, but *C. cyprinus* moved into mid-river areas of higher current velocity and deeper water during low water, while many *C. velifer* remained in areas of reduced current.

During low water the 2 species of carpsucker were segregated by habitat. Both species were generalists which treated food as a fine-grained resource (Beecher, 1979), and would be expected, if they were competing, to segregate by habitat rather than by food type (MacArthur and Levins, 1964; MacArthur, 1968). Growth rates, fat deposition, seasonal occupation of sandbars, and, possibly, population density and spawning season were characters which appeared to provide evidence of competition (Beecher, 1979). Thus, in Florida, coexisting *Carpiodes* behaved as would have been expected if they were competing species which were food generalists.

Low water might be the period of the least availability of food for carpsuckers because reduced flow would be expected to transport less food, and the area of substrate on which to forage would be reduced. Feeding rates, as estimated from the proportion of empty guts, were lowest in winter (Beecher, 1979). The exact relationship between temperature and feeding rate in carpsuckers is unknown. High temperatures (up to 31 C), which occur in late summer, might produce a high demand for food with a high metabolic rate in carpsuckers. The food of these 2 species was very similar: overlap in gut contents and gut content particle size was as great in conspecific comparisons as in between-species comparisons (Beecher, 1979). Either food or space could be limiting. By shifting habitat into deeper, swifter water, *C. cyprinus* might avoid competition with its congener during low water. The habitat shift of *C. cyprinus* in the Apalachicola River in the absence of congeners indicated that this seasonal habitat shift was selective rather than interactive segregation (see Brian, 1956).

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Biological Sciences

ASYMMETRICAL TWINNING IN *CHRYSEMYS SCRIPTA ELEGANS*, WITH A REVIEW OF CHELONIAN TWINNING (REPTILIA: TESTUDINES)

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Abstract: *A pair of asymmetrical twin turtles is described and illustrated. Twinning in which 2 completely separate individuals have been produced, and eggs in which 2 or more blastodiscs have been reported are discussed. A summary of all previously published accounts of chelonian twinning is presented.**

There have been no previously published reports of asymmetrical twinning in the red-eared turtle, *Chrysemys scripta elegans*. In view of the paucity of information on complete twinning in turtles which has accumulated during the past half-century, we herein present a description of 2 asymmetrical specimens of *C. s. elegans*, and a summary of all published accounts of complete twinning in chelonians. We have not included the more common conditions of partial (i.e., incomplete) twinning which involve double or duplex (two-headed, double-tailed), or polymelous (supernumerary-limbed) turtles. Only twinning in which 2 separate individuals have been produced, and eggs in which 2 or more blastodiscs have been reported are considered.

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Our specimens were obtained from an oviducal egg removed for incubation on 18 June. The egg had failed to hatch by 3 December, so was opened at that time. The twins were then photographed, killed, and preserved. The following measurements (in millimetres) are of the autosite (larger twin) and of the parasite (smaller twin). Autosite: carapace length, 29.6; carapace width, 23.4; yolk sac length, 26.5; yolk sac width, 15.4; yolk sac thickness, 11.0. Scutes number 13 right marginal (12 + 1 supernumerary) and 12 left marginal. Possession of an extra marginal scute is a minor anomaly occasionally seen in apparently healthy adult turtles. Carapace size and shape are within normal limits as defined by Cagle (1950). Parasite: carapace length, 9.0; carapace width, 6.9. The parasitic twin is positioned below the right forelimb of the autosite in the chorioallantoic membrane (see Fig. 1), and its carapace is inverted and pressing against the common yolk sac. The left half of the parasite failed to develop.

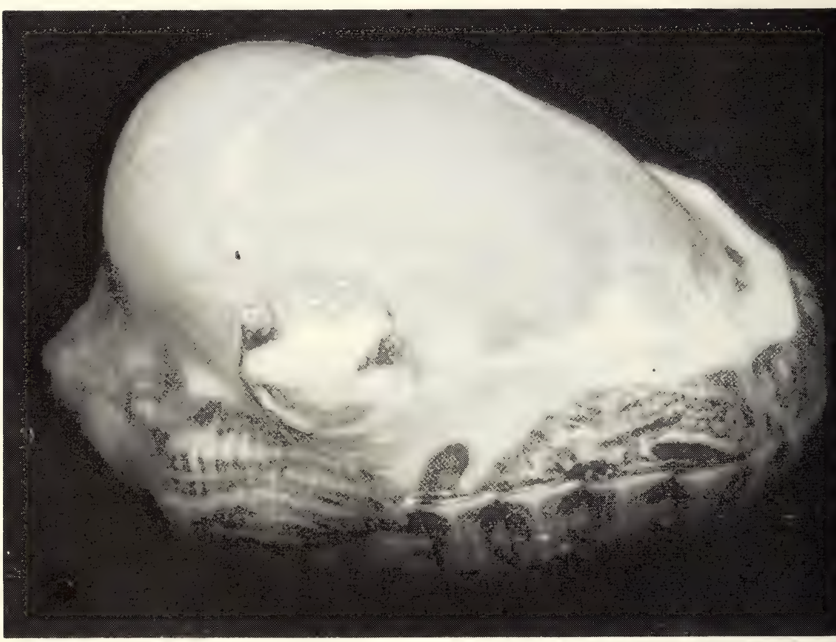

FIG. 1. Ventrolateral view of asymmetrical twins of *Chrysemys scripta elegans* showing placement of parasitic twin ventral to right forelimb of autosite.

The parasite's plastron (ventral view) is grossly distorted in that the scutes are quite irregularly shaped, though readily recognizable as scutes (Fig. 2A). The umbilical region is displaced from the midline to the left side of the embryo, so that the umbilicus enters the left bridge. The plastron ground color is ivory. The parasite's carapace (in dorsal view) is grossly distorted and the scutes (barely recognizable individually) are unusually small and very irregularly fragmented (Fig. 2B). The numerous fissures in the central area of the carapace are darkly pigmented; the ground color is

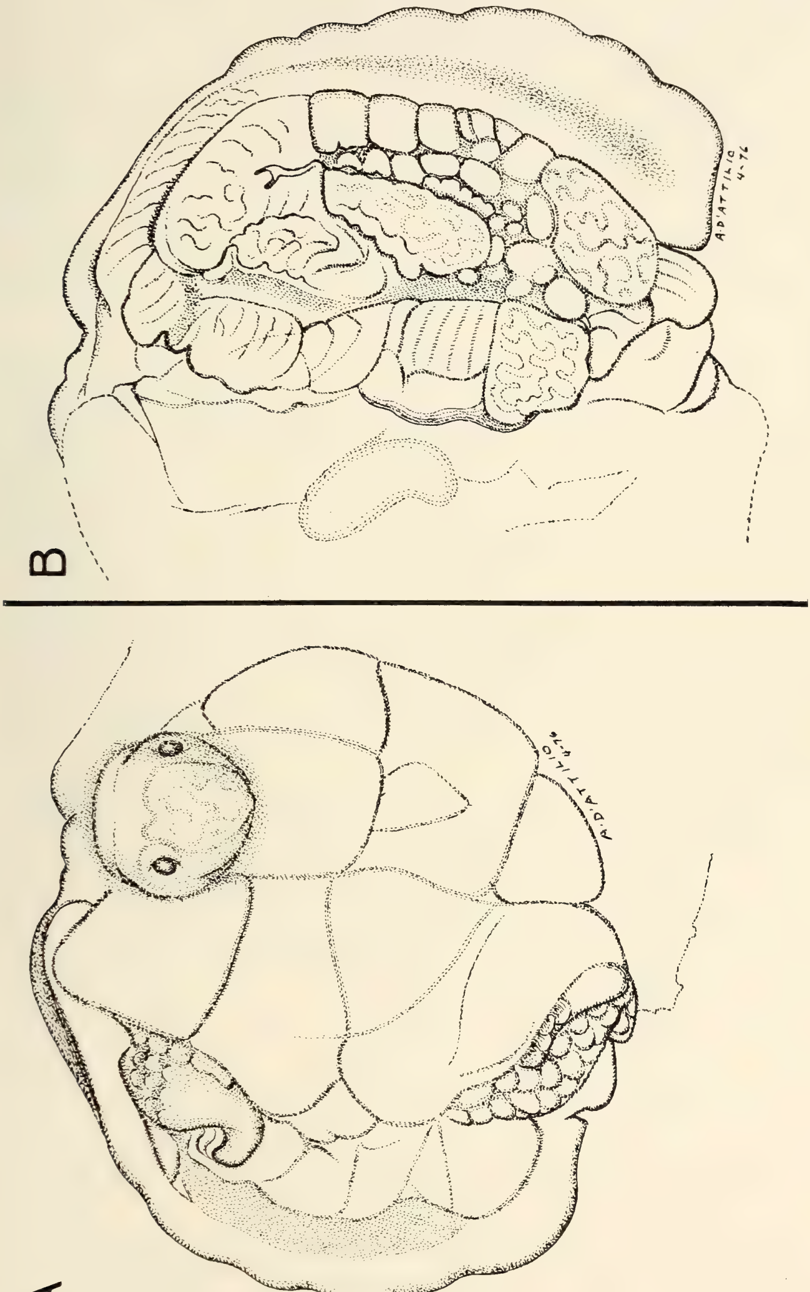

FIG. 2. Enlarged ventral (A) and dorsal (B) views of parasitic twin of *Chrysemys scripta elegans*. Anterior end of twin is near the top in both views.

tan. The parasite's head is quite deformed, with the right eye markedly rudimentary, and the left eye more normally developed with a cornea clearly distinguishable. The snout region is flat, enlarged, and grossly deformed. A mouth is present, but its shape is irregular. The head is very light tan. The parasite's right forelimb is flipper-like and scutellated, whereas the left forelimb is not developed. The malformed right hindlimb is stump-like, but scutellated; the left hindlimb is not developed. Limb color is very light tan. The developmental failure of the left side may be due to positional causes (i.e., the pressure of the left side against the yolk sac may have inhibited its development).

The autosite and its attached parasitic twin are deposited in the herpetology collection of the San Diego Natural History Museum (SDNHM—62406).

Discussion—According to Crooks and Smith (1958), twins and partial twinning anomalies (which would imply symmetry) are not uncommon in reptiles. Completely separate and normally developed twins in oviparous reptiles seem rare. However, they may occur in greater numbers than have been reported because, to observe the incidence of such twinning, the investigator must compare number of eggs in a clutch with number of resulting hatchlings, or else open the eggs prior to hatching. Newman (1923) stated that twinning is relatively rare in turtles because the critical embryonic stage has passed when eggs are laid. Hildebrand (1938) observed only 1 set of twins in some 100,000 diamondback terrapins (*Malaclemmys terrapin*) hatched during 25 yr. Yntema (1970) reported 23 sets of twins (either identical or fraternal) in 2228 eggs of the snapping turtle (*Chelydra serpentina*) over 5 nesting seasons.

Twinning is presently known from 62 specimens in 5 families, 9 genera, and 10 species of chelonians over wide geographic ranges as indicated in Table 1. Documented cases comprise: (1) double or multiple blastodiscs observed in eggs opened before time of hatching, (2) two dead twins unequal or equal in size at time of hatching, (3) one live plus one dead twin unequal in size, and (4) two live hatchlings of equal size. Double blastodiscs have been the most frequently recorded condition.

Several etiological factors have been proposed regarding twinning. Hildebrand (1938) speculated that unfavorable conditions (excessive moisture, desiccation, hypoxia, and rapid temperature fluctuation) during incubation may be responsible. Fujiwara (1964) implicated mechanical injury during oviposition. Glaesner (1924) doubted that fusion of 2 normal embryos was responsible, but did not dismiss the possibility.

Although it may be fortuitous, one can see that most species in Table 1 are aquatic or amphibious, and have a parchment-like eggshell (permitting changes in egg volume due to water flux), which may cause the embryo to be more vulnerable to the factors implicated in twinning and other embryonic developmental anomalies.

TABLE 1. A summary of known cases of complete twinning in chelonians. Classification follows Gaffney (1975).

Taxa	Number of Pairs (condition; miscellaneous)	Authority
CHELONIIDAE		
Caretta caretta	7	Fujiwara (1964)
Chelone [= Chelonia] mydas	3	Glaesner (1924)
CHELYDRIDAE		
Chelydra serpentina	1 (both dead)	Horning (1963)
Chelydra serpentina	23 (12 eggs with 1 live and 1 dead, separate blastodiscs in remaining)	Yntema (1970)
Chelydra serpentina	1 (both live)	Yntema (1971)
DERMOCHELYIDAE		
Dermochelys coriacea	5 (all dead)	Deraniyagala (1933)
Dermochelys coriacea	2 (both live)	Hughes et al. (1967)
EMYDIDAE		
Chrysemys picta	2 (twinned blastodiscs)	Yntema (1970)
Chrysemys scripta elegans	1 (both? dead)	This study
Malaclemmys terrapin centrata	1 (both live)	Hildebrand (1938)
Emys orbicularis	13 (double blastodiscs)	Dehnel (1929)
Emys orbicularis	1 (separate embryonic discs)	Dehnel (1948)
Terrapene carolina major	1 (both dead)	Tucker and Funk (1976)
Terrapene carolina triunguis	1 (1 live, 1 dead)	Crooks and Smith (1958)
TESTUDINIDAE		
Gopherus polyphemus	1 (both live)	Hunsaker (1968)

We believe the incidence of twinning in turtles is greater than has been reported because observation requires either the opening of eggs prior to hatching or else comparison of egg number *versus* number of turtles at hatching time. Also, we suspect that many anomalies are produced in early cleavage stages, probably from extrinsic factors at the time of or soon after oviposition. Because unincubated eggs from the same clutch contained small amounts of chlorinated hydrocarbon pesticides (DDT derivitives and Mirex®), chemical teratogenesis may be involved in the present case. Clearly, there is need for additional observation and experimental investigation of this phenomenon.

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Social Sciences

THE MENTALLY RETARDED OFFENDER: AN AREA OF GROSS NEGLECT

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Abstract: *The greatest problem facing the criminal justice system appears to be identification of mental retardation. Upon identification the criminal justice system and mental retardation system argue responsibility for the mentally retarded offender who consequently often falls between the cracks of the 2 systems. Approximately 23,000 persons, or 10% of the nation's prison population are retarded. Prison culture has a negative impact upon development of the retarded offender. Housing the mentally retarded offender in an institution for the mentally retarded is inadequate. Consensus firmly supports the need for special treatment facilities and community-based programs. Several advocacy programs have been implemented to defend the rights of the mentally retarded offender. Funding is desperately needed to support in-depth study and pilot projects in this area of gross neglect.**

Purpose and Scope—Beginning October, 1977 as an assignment for the Region VII, Human Rights Advocacy Committee, State of Florida, a study was performed to discover factors contributing to the current status of the

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mentally retarded criminal offender throughout the nation. We wanted to discover parameters of the existing treatment and needs of the mentally retarded offender (MRO) throughout the United States. A letter of inquiry was sent to agencies in all 50 states and the District of Columbia. Responses were received from all states and the District of Columbia except: Maine, Mississippi, Montana, New Hampshire, New Jersey, North Dakota, Rhode Island, South Carolina, South Dakota and Virginia.

Reception assessment and diagnostic centers are essential to identify the MRO. This offender requires individualized treatment and education. Consensus indicates that minimal separation from community life is conducive to mental maturation of the retarded. The longer such persons are incarcerated or institutionalized the less their opportunities to deal with and therefore learn to cope with the real world. It is generally agreed every effort should be made to resort first to day-care and outpatient hospital programs. In cases where commitment to state or county residential facilities is necessary, every effort should be made to move the offender toward a community day care program as soon as possible. It is imperative that the MRO be assured his legal rights.

IDENTIFYING THE MRO—Overall response indicated the crucial time for identifying the MRO is initial intake. After a person is sentenced identification is too late to offer diversion.

The Massachusetts Bar Association (MBA) (1977) has published a handbook for attorneys as a guide to effect advocacy for the mentally retarded client. MBA's Specialized Training and Advocacy Program (STAP) provides training to court personnel, attorneys, police, and corrections personnel in recognizing retarded offenders and in effectively meeting their needs.

Two years ago the State of Georgia Department of Human Resources (1977) attempted a diversion project. This project, through an extensive network of presentence evaluations, sought to identify the mentally retarded person and make judges aware of possible alternatives to incarceration. This project was not successful due mainly to lack of referrals. Presentence evaluations were left to the discretion of the judge rather than mandated. Judges were reluctant to order the necessary evaluations. The Department recommends future program development include a heavy educational component for judges and attorneys.

Differentiating Between Mental Retardation (MR) and Mental Illness: Court personnel, attorneys, police and corrections personnel are often unaware of the differences between MR and mental illness. The American Association on Mental Deficiency (AAMD) definition of MR (1973) is generally accepted: "MR refers to significantly subaverage general intellectual functioning existing concurrently with deficits in adaptive behavior and manifested during the developmental period (Massachusetts Bar Association, 1977).

Significantly subaverage general intellectual functioning refers to limited learning capacity as measured by a score of 70 or below on a standardized, individually administered intelligence test. The average score is 100. Adaptive behavior refers to the effectiveness or degree with which the individual meets the standards of personal independence and social responsibility expected of his age and cultural group. Developmental period is from conception to 18 yr. of age. The AAMD insists that a deficit in adaptive behavior must be combined with a deficit in measured intelligence in order to classify an individual as retarded.

AAMD defines mental illness as ". . . a substantial disorder of thought, mood, perception, orientation or memory which grossly impairs judgment, behavior, capacity to recognize reality or ability to meet the ordinary demands of life" (Massachusetts Bar Association, 1977). Whereas the definition of retardation emphasizes intellectual functioning and deficits in adaptive behavior, emphasis is on impairment and disorientation of normal behavioral processes when defining mental illness. Retardation involves a permanent deficit. Mental illness involves a temporary, remediable difficulty.

I.Q. Tests: The validity of I.Q. tests is questioned as a means of determining retardation. It is difficult to disentangle retardation from cultural deprivation. I.Q. tests are considered by many to be culturally biased. Individually administered intelligence tests are costly. Consequently, group I.Q. tests are often administered under adverse conditions which compound errors of measurement.

In Michigan Boys Training School I.Q. tests show over 85% of the boys in the mentally retarded range. However, according to Michigan Community Development Services (1977), once an education plan has been implemented they no longer appear to function in that range. Scores consistently show 1.3-1.7 yr gain. True organic retardation would prohibit this accelerated growth.

THE MENTALLY RETARDED PRISON POPULATION—Miles Santamour, special consultant to the President's Committee on Mental Retardation, says about 23,000 retarded people are in prison in the United States. This is about 10% of the nation's prison population (Ognibene, 1977). The following responses support Santamour's statement regarding retarded prison population. In 1976: Georgia-10%, with 15% projected by 1978 (Georgia Department of Offender Rehabilitation, 1977); Maryland-9% (Maryland Division of Correction, 1977); Massachusetts-10% (The Commonwealth of Massachusetts Parole Board, 1977); Missouri-9.5% (Missouri Division of Corrections, 1977); Ohio-12.7% (The Supreme Court of Ohio, 1977); Texas-10% (Texas Department of Corrections, 1977); Wisconsin-8.3% juvenile and 7.0% adult (Wisconsin Division of Corrections, 1977).

Prison Culture: Most states report the MRO is housed with the general prison population. In some states instruction is individualized and basic skills are stressed. Within the prison culture the retarded offender is out of step with the dominant characteristics of the average inmate population. The MRO's training needs call for habilitation rather than rehabilitation.

Because of his desire to be accepted, the maladaptive consequences of his social behavior become intensified as the MRO assumes the values of the prison culture. His needs for protection from abuse and exploitation are intensified. The staff of correctional facilities are ill-equipped to meet the needs of this population (U.S. Department of Justice, 1977).

The prison culture has a negative impact upon development of the retarded offender, and thus delays his development. As he has a greater tendency to be persuaded and manipulated, the negative impact of the subculture on the MRO is much greater than its impact on the average inmate. Because of the retarded person's delayed development, behavior learned in prison is less apt to be reversed.

Is Institutionalization the Answer: In institutions for the mentally retarded, the MRO victimizes the other residents and disrupts routine. He presents security risks and training needs which institutions are ill-equipped to handle. Within an institution facility design and staffing patterns are geared toward meeting the needs of the docile multi-handicapped individual. The MRO is more sophisticated, more intelligent and better able to mask his limitations (U.S. Department of Justice, 1977).

It is generally agreed in the field of retardation that some place other than existing state institutions for the mentally retarded should be the choice of residency for habilitation and training of the retarded offender. The Florida Department of Health and Rehabilitative Services (1977) gives 2 reasons why institutional settings are inadequate: 1) they deny the MRO normal community living experience, and 2) they force the learning of institutionally adaptive but community maladaptive behavior.

RESPONSIBILITY FOR ASSISTING THE MRO—A current study underway in Cleveland, Ohio has revealed a severe problem related to responsibility for assisting the MRO (The Supreme Court of Ohio, 1977). The Criminal Justice System (CJS) assumes the mentally retarded person is not responsible for his actions and thus should not be part of the CJS. The CJS sees mental retardation as the deciding factor as to whether or not an individual should enter the system. The Mental Retardation System sees crime as the deciding factor as to whether an individual should enter the system. Many retarded offenders are falling between the cracks of the 2 systems and not being helped by either.

ALTERNATIVES TO INCARCERATION OR INSTITUTIONALIZATION—Consensus firmly supports the need for special treatment facilities and community based programs. Due to the negative impact of prison culture the MRO should not be housed in a prison setting. More secure and supportive residential facilities are drastically needed.

The Director of a group home in Ohio which has experienced considerable success with the MRO says: "If a MRO is treated with worth and dignity, he will see himself as having worth and dignity and his behavior will reflect this view . . ." (Ohio Youth Commission, 1977). This behavior can be accomplished by establishing homes characterized by support and respect. Application processes for the MRO must be changed. The community must be educated as to the growth potential of the mentally retarded.

LEGAL RIGHTS—Santamour says very little legislative action dealing with retarded offenders has been taken (Ognibene, 1977). Such offenders, he says, sometimes are not given their rights at the time of arrest. They waive jury trials and do not understand how to obtain a lawyer. They readily confess. About 90% of them are convicted for the crime for which they were arrested because they don't know how to plea bargain. According to Santamour: They spend more time in prison than other persons for the same crime because they do not plea bargain. They do not participate in rehabilitation programs because there are no rehabilitation programs for them so they do not receive parole and probation. They are taken advantage of by other prisoners. They cannot adjust so they get no time off for good behavior.

Santamour believes the retarded offender should be considered for indeterminate sentence and have parole opportunities. He stressed the need for habilitative rather than rehabilitative training.

Specialized Training and Advocacy Program (STAP): STAP, sponsored by the MBA, makes every effort to insure the MRO's legal rights (Massachusetts Bar Association, 1977). The MRO often has difficulty understanding the consequence of his actions. He is very suggestible and may be induced into trouble by others. He is unable to understand his rights if arrested. The MRO wishes to please others so much that he "confesses" to crimes he did not commit. He has difficulty communicating with court personnel.

These and other characteristics of the retarded offender must be recognized in the courts to insure fair treatment and to prevent a recurrence of criminal behavior. Though their crimes should not be excused, these people need special support in order to receive full protection of the laws.

STAP provides each of the courts its own advocate. This advocate, with STAP's psychologist and vocational rehabilitation specialist, will perform an in-depth assessment of the client's functional abilities. With the client's participation, referrals to community resources will be developed.

STAP will assist attorneys in private practice and criminal justice personnel from courts statewide with information on case law, assessments and services. STAP's legal staff will provide consulting services to attorneys representing retarded clients and in certain cases will provide direct legal services.

West Virginia Advocates for the Developmentally Disabled (WVADD): On 12 September 1977 John D. Rockefeller IV, Governor of the State of West Virginia by Executive Order designated the nonprofit corporation entitled West Virginia Advocates for the Developmentally Disabled (WVADD) as the agency for implementation of a protection and advocacy system. Implementation of this system will serve to protect the individual rights of and to advocate for persons with developmental disabilities (Rhodes, 1977).

WVADD will strive to educate members of the legal profession by providing consultation to attorneys. WVADD will provide information on individual rights, and referral to appropriate agencies as well as back-up support to an individual who is advocating for himself. The agency will follow-along to see that individual cases are solved and/or progressing.

These advocates will provide training and information materials to consumers, professionals and the general public related to the rights and special needs of mentally retarded persons. WVADD is attempting to achieve broad-based community support for its program recognizing that an aware, concerned and involved public will greatly facilitate the achievement of WVADD's goal: ". . . the enjoyment by the developmentally disabled of their full rights" (Rhodes, 1977).

Crisis Intervention: A bureau for crisis intervention advocacy is planned in Texas to assist mentally retarded persons who get into trouble with the law (Texas Department of Corrections, 1977).

ILLINOIS CASE STUDY—In early 1975, 50 case studies were completed for a project conducted in Chicago (Correctional Services, 1975). The sample consisted of 19 adult males, 7 adult females (ranging in age from 18-54), 8 juvenile males and 16 juvenile females (ranging in age from 14-17) distributed throughout the criminal justice system from pre-trial to after discharge. This sample was predominantly black and poor. The I.Q. of the sample ranged from 69-53. Seventeen adults were involved in vocational programs, 4 adults were involved in educational programs; however, none of these programs was specifically designed for the retarded. Employed adults were working in low paying jobs that required little or no skill. Most adults and all juveniles were single.

All subjects in the sample of juveniles had long histories of poor academic performance, with a history of truancy that brought this juvenile to the attention of the courts. There existed a wide gap between the law and services provided by the educational system.

WASHINGTON CASE STUDY—There are no adullt or juvenile corrections programs designed specifically for the mentally retarded offender in the state of Washington (Washington Department of Social and Health Services, 1977). Adult Corrections Division study in February 1977 of their 4 moderate-maximum security facilities revealed the following:

Purdy Treatment Center for Women—11 MRO's. Ages 20-50; 10 black, 1 white; I.Q. range 75 and below; offense pattern predominantly assault, prostitution, and possession of controlled substance. High proportion of black residents probably represents the effect of environmental deprivation.

Washington Corrections Center—Male adult prison—10 MRO's. I.Q. range 79 and below. Ages 20-32; 1 black, 3 Indian, 2 Mexican, 4 caucasian; offense pattern possession, larceny, rape, and burglary.

Washington State Reformatory—6 MRO's. Five black, 1 white. I.Q. range 79 and below; offense pattern 3 to person and property, 2 to property only, and 1 to person only.

Washington State Penetentiary—17 MRO's. Eight black, 9 white; I.Q. range not given; ages 15-47; offense pattern assault, larceny, burglary, rape.

Tennessee Case Study—State Prison—28 MRO's studied in January 1977 MRO Pilot Project. Male offenders, average I.Q.—64.71; 16 black, 12 white; ages 20-51; offense pattern assault, burglary, rape, murder. Average sentence 12.07 yr (Tennessee Department of Correction, 1977).

Ohio Case Study—A study was conducted in Cleveland, Ohio in September 1977 by an Ad Hoc Committee (The Supreme Court of Ohio, 1977). This study outlined a profile of the MRO entering the CJS in Ohio, in the following 5 examples:

Male, I.Q. 67, educational level 9th grade. Mother mentally retarded. Sexually abused as a child by older man and brother. First institutionalized at age 17.

Male, I.Q. 42, high school dropout. Beaten by stepfather at age 11. Went to live with father at age 16. Father open to long term institutionalization as the son stole from him and was difficult to control. First institutionalized at age 13.

Male, I.Q. 72, high school dropout. Mother I.Q. 54. Dependency charge was dropped after father returned home from serving a prison term. First institutionalized at age 11.

Male, I.Q. 73, educational level 8th grade. Family was nonsupportive. Mother was a bad influence. Brother has a criminal record. No prior institutionalization.

Male, I.Q. 58, high school dropout. Epileptic. Had been hospitalized many times since age 2. No indications of abuse in early home life. No prior institutionalization.

Some Steps In The Right Direction—Several states have made considerable progress toward improving the status of the mentally retarded criminal offender.

California-Mentally Ill Offenders' Unit (MIOU)—Recognizing the value of diagnosis and assessment, the County of Los Angeles, MIOU was established in November 1972 with one psychiatrist. The Unit now has 18 full-time professional staff with clerical backup (California, County of Los Angeles, 1977). MIOU averages approximately 1,500 patient contacts per month. Functions of the MIOU include identification, treatment and referral of the mentally retarded alleged offender.

Colorado-Closed Treatment Unit (CTU)—The Department of Institutions, Division of Developmental Disabilities recognizes the need for separate housing within an institutional setting (Colorado Department of Corrections, 1977). The Department projects an FY78-79 budget which identifies the development of CTU's as one of its high priorities. The Department recommends two, 30-bed units remodeled from existing facilities and a new 30-bed CTU. A basic evaluation and program will be outlined when admitted. A specified and objective set of criteria for discharge is to be established when admitted.

Florida-Retarded Defendant Program—The Retarded Defendant Program was implemented to assure the MRO his legal rights. Facilities are located at Florida State Hospital at Chattahoochee, and South Florida State Hospital in Hollywood (Florida Department of Health and Rehabilitative Services, 1977). This program is to evaluate the client's ability to stand trial for reasons of mental retardation and train the client to assist in his own defense.

Kansas-Housing for The Dangerous Mental Retardate—Realizing that the dangerous retardate requires special attention, a new unit for dangerous mental retardates was established at Larned State Hospital and began operation on 1 November 1977. Residents are housed in a one-story screened and fenced building. Within the building is a security-screened, locked ward with 30-resident capacity. Activities, dining facilities and sleeping quarters are in-house. Each resident has an individual treatment plan especially tailored to his education and training needs. He has an advocate to assist him in understanding his rights and responsibilities (Kansas, Larned State Hospital, 1977).

North Carolina-Deinstitutionalization Project for MR Youthful Offenders—The North Carolina Council on Developmental Disabilities has funded a project for deinstitutionalization services for MR youthful offenders. These services are to be established at the new Morrison Youth Center. The project has 2 components, 1) mental retardation specialists with an active caseload of 25-30 inmates, assigned to the Center, and 2) an outreach portion staffed with social workers, one assigned to each of the 6 prison geographic areas. Theoretical goals of this project are "to reduce the number of developmentally disabled youthful offenders who return to prison after release due to the nature of their debilitation and the lack of appropriate family, community and agency support" (North Carolina Council on Developmental Disabilities, 1977).

Tennessee-Five Year Plan For The MRO—Within the Department of Mental Health and Mental Retardation a Coordinating Committee has been established for the Office of Training and Rehabilitation for the MRO. On 10 November 1977 the Committee approved a program for the following: secure facility, 30 group homes each housing a total maximum of 70 wards, 90 juvenile foster homes each serving a total maximum of 40 wards. The plan also includes diagnostic and evaluation services, residential services, court liaison services, consultative services, staff development and training, and research and planning services (Tennessee Department of Mental Health and Mental Retardation, 1977).

Washington State-Correctional Setting—Aware of the special needs of the incarcerated MRO, the Washington State prison system provides maximum staff supervision and selected housing to minimize harassment of the MRO by other inmates. Prior to sentencing every effort is made to place the retarded person in some community program. Emphasis is placed on parole planning. Upon parole every effort is made to place the offender in a "sheltered workshop" type work environment (Washington Department of Social and Health Services, 1977).

The Ranier Training School takes in retarded offenders. In order to minimize antisocial or asocial behavior, there are no high security buildings or programs emphasizing the phenomena of criminality. Individuals are placed throughout the school and individual stratagems developed for them. This environment has proven to be conducive to improved behavior.

Conclusions—The crucial needs of the mentally retarded offender are apparent. It is essential to identify the MRO at time of initial intake into the CJS. His legal rights must be assured. He must be housed and trained according to his unique needs.

Overall response indicated concern for the MRO's special status. A few states have taken steps in the right direction; however, the existing status quo in the majority of states is due to lack of funding to support in-depth study and pilot programs. Correctional administrators, legislators and the general public must be made aware of the cruciality of this status quo. Every effort must be made to allocate funding to support in-depth study and pilot programs on behalf of this long overlooked victim of circumstance.

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Biological Sciences

BIRD REMAINS FROM TWO SOUTH FLORIDA PREHISTORIC SITES

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Abstract: *Bird remains from prehistoric sites may offer both significant archaeological information on the ecological conditions, types of habitats exploited, and settlement patterning at the time of human occupation, and zoological data regarding the past distribution of certain species of avifauna. The analysis of such remains from 2 South Florida middens, Fort Center in Glades County, and Boca Weir in Palm Beach County, provides evidence for possible year-round habitation at the former site and a winter settlement at the latter site. Furthermore, the recovery of a great auk, razor-billed auk, and great black-backed gull, may indicate a period of cooler climate in Florida at approximately A.D. 1000.**

The analysis of faunal remains from archaeological sites often provides valuable information on the ecological and climatic conditions at the time of prehistoric occupation, and on the past distribution and abundance of bird species (Parmalee, 1958). I discuss such information on 2 sites from South Florida, Fort Center (state archaeological site number 8-G1-13), and Boca Weir (state archaeological site number 8-Pb-56).

Fort Center (Glades County) is situated inland on Fisheating Creek west of Lake Okeechobee and consists of a number of low mounds, platform mounds, circular earthworks, as well as several middens. Radiocarbon analysis dates this site as being continuously occupied from 500 B.C.-A.D.1600. Excavations were conducted over 5 yr. (1966-1971) under the direction of Dr. William Sears and were funded by National Science Foundation Grant GS910 (Sears, 1971).

Boca Weir (Palm Beach County) is situated along the Atlantic coast at Highland Beach and comprises the southernmost section of a large beach midden. Ceramic seriation dates the site as being inhabited from as early as

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A.D. 500 until A.D.1600. Archaeological fieldwork took place in 1971-1972 under the supervision of John Furey (1972).

Fort Center and Boca Weir are located in different habitats. The former is situated near 3 environmental zones. Wet prairie grasslands are extensive and include such grasses as maiden-cane (*Panicum hemitomon*) as well as a number of sedges. Swamp forests consist primarily of hardwoods such as sweet bay (*Magnolia virginiana*) and gum (*Nyssa* spp.), and occasionally some cypress (*Taxodium* spp.) areas. Finally, freshwater areas include Lake Okeechobee, the largest lake in the Southeast, and numerous smaller bodies of water. Smaller habitats located farther away from the site are forests of cabbage palms (*Sabal palmetto*) to the north and freshwater marshes to the south (Davis, 1943).

Boca Weir, on the other hand, is located in a very different ecological setting. A coastal strand of sand beaches and dunes extends along the Southern Florida Atlantic coast from St. Lucie Inlet southward to Key Biscayne. The most common plants of this zone include seagrape (*Coccoloba unifera*), cabbage palm (*Sabal palmetto*), and sea oats (*Uniola paniculata*). Farther inland from the site are wet prairie grasslands, pine flatwoods, and swamp forests (Davis, 1943).

Although some changes have occurred in the environment of these 2 regions of South Florida since prehistoric times, the bird species identified indicate that the same habitats were present during aboriginal occupation. The 2 samples contained 202 identifiable bird bone fragments, 164 from Fort Center and 38 from Boca Weir.

Annotated List—The 29 species identified are discussed below. They include 23 from Fort Center and 12 from Boca Weir.

Podilymbus podiceps (Linnaeus). Pied -billed grebe. One bone, a left tarsometatarsus, from Fort Center. The tarsometatarsus differs in the 2 Florida genera of the Family Podicipedidae. The hypotarsus has 4 canals in *Podilymbus* and 3 canals in *Podiceps*.

Phalacrocorax auritus (Lesson). Double-crested cormorant. Five skeletal elements from Fort Center.

Anhinga anhinga (Linnaeus). Water turkey. One bone from Fort Center.

Ardea herodias and *Ardea herodias wardi* Ridgway. Great blue heron. Three bones were identified to the specific level (Fort Center) and 4 skeletal elements were classified to subspecies. The latter included the distal end of a left tarsometatarsus from Boca Weir and measured 17.2 mm at its widest width, slightly larger than the comparative specimens (maximum male measured 17.1 mm). The remaining 3 elements were from Fort Center and included: the glenoid facet of a right coracoid, i.e., widest width 8.7 mm (range-minimum female 7.8 mm to maximum male 8.9 mm); the distal end of a right coracoid, i.e., height of sternal facet 8.9 mm (range-minimum female 7.9 mm to maximum male 9.1 mm); and the proximal head of a right coracoid, i.e., width 14.7 mm (range-minimum female 13.0 mm to maximum male 14.6 mm), which was slightly larger than the comparative material.

Casmerodius albus (Linnaeus). Great egret. One bone from Fort Center and 5 from Boca Weir.

Egretta sp. Egrets. One skeletal element was recovered at Fort Center. The several species of this genus are practically identical in size and structure and consequently, identification to the species level was virtually impossible.

Eudocimus albus (Linnaeus). White ibis. A total of 48 adult skeletal elements and 9 juvenile ones was identified from Fort Center while another 7 bones were identified as possibly of this species. Young birds can be distinguished by the greater porosity or surficial pitting of the bones.

Branta canadensis (Linnaeus). Canada goose. One skeletal element from Fort Center.

Anser sp. Goose. One bone was recovered from Fort Center and may represent either *A. albifrons* or *A. caerulescens* (including the color phase *A. hyperboreus*). It is significantly smaller than female *Branta canadensis*.

Anas platyrhynchos. Mallard duck. Two skeletal elements from Fort Center.

Anas crecca Linnaeus. Green-winged teal. One bone from Fort Center.

Anas discors Linnaeus. Blue-winged teal. Three skeletal elements from Fort Center.

Aythya collaris (Donovan). Ring-necked duck. *A. affinis* (Eyton). Lesser scaup duck. Seven skeletal parts of *A. collaris* and 3 of *A. affinis* from Fort Center; 2 bones of *A. affinis* from Boca Weir. Because these 2 species are greatly similar both in size and skeletal morphology, some of the very fragmentary remains were identified only to genus. The brachial depression and brachialis scar in the humerus and ulna, respectively, of *A. affinis* exhibit a straighter and more pronounced medial ridge. The coracoid in *A. affinis* has a very deep fossa in the triosseal canal in contrast to a very shallow concavity in *A. collaris*. In the femur of *A. affinis*, the scar of M. flexor cruris lateralis is straight and slants dorso-ventrally while in *A. collaris*, it is vertical and has only a slight curve.

Oxyura jamaicensis (Gmelin). Ruddy duck. One bone from Boca Weir.

Mergus serrator Linnaeus. Red-breasted merganser. One bone from Boca Weir.

Cathartes aura (Linnaeus). Turkey vulture. Nineteen skeletal elements from Fort Center and 12 from Boca Weir.

Coragyps atratus (Bechstein). Black vulture. Five bones from Fort Center.

Accipiter striatus Vieillot. Sharp-shinned hawk. Eight skeletal elements from Fort Center.

Haliaeetus leucocephalus (Linnaeus). Bald eagle. Three bones from Fort Center.

Polyborus plancus (Jacquin). Audubon's caracara. Four skeletal elements from Fort Center.

Meleagris gallopavo Linnaeus. Turkey. Nine bones from Fort Center.

Grus canadensis (Linnaeus). Sandhill crane. Six skeletal elements from Fort Center and 2 from Boca Weir.

Aramus guarauna (Linnaeus). Limpkin. One bone from Boca Weir.

Rallus elegans Audubon. King rail. Two skeletal elements from Fort Center.

Larus marinus Linnaeus. Great black-backed gull. Three bones were recovered from Boca Weir. This species also has been identified from the Green Mound Midden, a prehistoric site, near Daytona Beach (Hamon, 1959). During this century, this uncommon winter visitant has been found as far south as the Florida Keys (Sprunt, 1954).

Sterna maxima (Boddaert). Royal tern. One skeletal element from Boca Weir.

Pinguinus impennis (Linnaeus). Great auk. One bone, a left ulna, slightly chipped at both ends, was identified from Boca Weir. The bone is rather large (59.1 mm in length from the highest point between the internal and external cotylae proximally to the lowest part of the external condyle distally) and 4 comparative specimens range from 53.9-55.2 mm in length. The great auk became extinct in 1844 (AOU, 1957:245). The midden deposit in which the auk was recovered represents an occupation spanning the years between A.D. 800 to 1200. This northern bird was flightless and thus migrated in the winter to the South Florida coast by swimming. Three previous records of the great auk from archaeological midden sites in Florida are from Summer Haven in St. Johns County (Brodkorb, 1960), Cotton Midden north of Ormond (Hay, 1902), and Castle Windy south of New Smyrna Beach (Weigel, 1958). The first 2 sites date from ca. 1000 B.C. (Bullen and Bullen, 1961; Griffin and Smith, 1954), and the Castle Windy site dates from approximately A.D. 1000 (Bullen and Sleight, 1959).

Alca torda Linnaeus. Razor-billed auk. Six bones were identified from Boca Weir. The skeleton of *A. torda* is greatly similar to that of the genus *Uria*, and consequently, identification is quite difficult. Nevertheless, the 2 genera may be differentiated. The proximal portion of the humerus in *Alca* has a process that juts outward from underneath the head, and the distal brachial depression is narrower and deeper in comparison to *Uria*. Also, the hyposternal process of the coracoid is more rounded in *Alca* than that of *Uria*. The prominence in the ulna for the anterior articular ligament appears as a flat raised surface in *Alca* in contrast to a slight concavity in *Uria*. The razor-billed auk has been recorded at one other Florida archaeological site, the Green Mound Midden (Hamon, 1959).

Discussion—The 2 avian samples examined for this study demonstrate the variety of birds used for food by the prehistoric occupants of Fort Center and Boca Weir. The contrast in the species recovered from these 2 sites reflects the different habitats available for exploitation. Birds constituted only a small portion of the diet of the 2 human populations and at Fort Center, mammals predominated while at Boca Weir, marine resources (bony and cartilaginous fish) provided the bulk of the diet.

Fort Center exhibits a total of 23 species, of which 15 are permanent and 8 are migratory residents. The most commonly taken resident birds include white ibis, herons, and turkey vulture (which may be found in freshwater marshes or inland lakes), as well as turkey, caracara, and sandhill crane (occupants of the wet prairie grasslands). A smaller number of migratory species were taken. Canada goose, ring-necked duck, blue-winged teal, green-winged teal, and lesser scaup all occur in the freshwater lakes and marshes of this region. The double-crested cormorant is a year-round resident with its numbers being increased by northern migrants during the colder months (Sprunt, 1954).

The presence of juvenile white ibis at Fort Center is an indication of spring or early summer occupation. In South Florida, ibises tend to nest in large colonies in late March and the young can be found in June (Sprunt, 1954).

Of the 12 species and subspecies at Boca Weir, 6 are resident and 6 are migratory. Of the former, the most common are turkey vulture (coastal strand and wet prairie grasslands) and great egret (swamp forests). Winter residents include such coastal birds as lesser scaup, red-breasted merganser, great black-backed gull, razor-billed auk, and great auk. The presence of the last 3 species suggests a period of cooler climate in Florida, possibly the one at A.D. 1000 (Brodkorb, 1960), and also a wider range in their distribution in prehistoric times. Furthermore, the recovery of winter birds at Boca Weir provides evidence for, at least, a winter occupation at that site.

Historical documentation further substantiates the role of birds in the aboriginal diet. Several early Spanish reports on the South Florida Indians mention the consumption of these animals. Fontaneda (see Swanton, 1946) for example, stated that the Indians ate the meat of birds whenever such game was available.

Although it is assumed that birds were exploited primarily for their meat, there is also written evidence that they were employed as a source of raw material in the manufacture of certain artifacts. Feathers, particularly those of turkey, were used by many Southeast Indian groups to make clothing, ornamentations, as well as to fletch arrows. Eagle feathers were employed as ornaments to the person and as marks of accomplishments, while crane and heron feathers were worn as part of headdresses. Claws were occasionally used to adorn the breachclout, and arrows were sometimes pointed with either bird bills or the spurs of turkey cocks (Swanton, 1946:251-253; 441; 573).

Mention should be made of the various effigy woodcarvings of both birds and mammals recovered in the ceremonial mounds of Fort Center. Of the former, eagles, hawks, spoonbills, and perching birds were represented (Sears, 1971). Future study may provide further insight into the significance of such animals within the religious and ceremonial sphere of the culture of the South Florida Indians.

Although the samples in this study are quite small, they provide some significant information on the types of occupation represented. At Fort Center, the data yield evidence for aboriginal habitation in winter, spring, and summer. This finding supports the hypothesis that the Indians at this site were residents most of the year (Sears, 1971). At Boca Weir, on the other hand, the presence of northern species suggests at least a winter occupation at that site. These data thus provide further insight into the prehistoric settlement patterning of the South Florida Indians.

ACKNOWLEDGMENTS—I express my gratitude to Pierce Brodkorb for providing access to his comparative specimen collection and for reading the original manuscript. Also, thanks to Elizabeth S. Wing for her guidance.

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Earth Sciences

DEPOSITIONAL HISTORY OF THE OOLITE OF THE MIAMI LIMESTONE FORMATION

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ABSTRACT: *The Pleistocene Miami Limestone Formation presently consists of the Miami Oolite and Key Largo Reef facies. It is proposed here that the Miami Oolite facies be considered as 2 separate units within the Miami Limestone Formation and penecontemporaneous to the Key Largo Reef limestone. The lower unit is called the Key West Oolite and the upper is called the Fort Dallas Oolite. The Fort Dallas unit is considered an eolian dune field formed by the breakdown of various oolitic marine bars across the mouth of Florida Bay, while the Key West unit is the remanents of some of these bars formed behind the Key Largo Reef in Sangamon time. This new division of the Miami Limestone Formation was based on field outcrops, above and below the water, the fossils, well cuttings, and an SEM study of the ooids.* *

THE term "Miami oolite" was applied to all the oolite on the mainland of the southern tip of Florida by Sanford (1909), but the oolite was first noticed in 1830 by an U.S. Army officer at outcrops along the New and Miami Rivers during the Seminole Indian Wars. Hunt (1862) was the first person to describe the oolites of the mainland of lower Florida and also of the lower Keys, in reports during the construction of Fort Taylor at Key West. He observed differences of quartz content and lithification between the Key West oolite and the Fort Dallas (now known as Miami) oolite. Featherstonhaugh (1829) first described the Key West oolite from samples from a 60m well at Key West at a Natural History conference in New York City and noted that it contained many fossils and had a fine grained, uniform texture with a yellowish appearance. Many others (Toumey, 1851; Agassiz, L., 1852; Shaler, 1890; Agassiz, A., 1875; Matson and Sanford, 1913, Griswald, 1896) have described both of these as separate oolite facies, but it was Cooke and Mossom (1929) who later combined the 2 limestones into the "Miami Oolite". In 1967, Hoffmeister and Multer divided the "Miami Oolite" formation into 2 further units: the upper unit as the oolite and the lower unit a bryozoan facies.

I believe that the Miami Limestone should be divided into the Key Largo Reef limestone and 2 oolite units: the upper unit the Fort Dallas oolite and the lower the Key West oolite (Fig. 1), and that the bryozoan facies of Hoffmeister and Multer (1968) should not be considered as a separate facies because only a few bryozoan together with other fossils have been found in the Fort Dallas Oolite and none underlying it in Florida Bay.

These 2 oolite units agree closely with the time-stratigraphic units Q4

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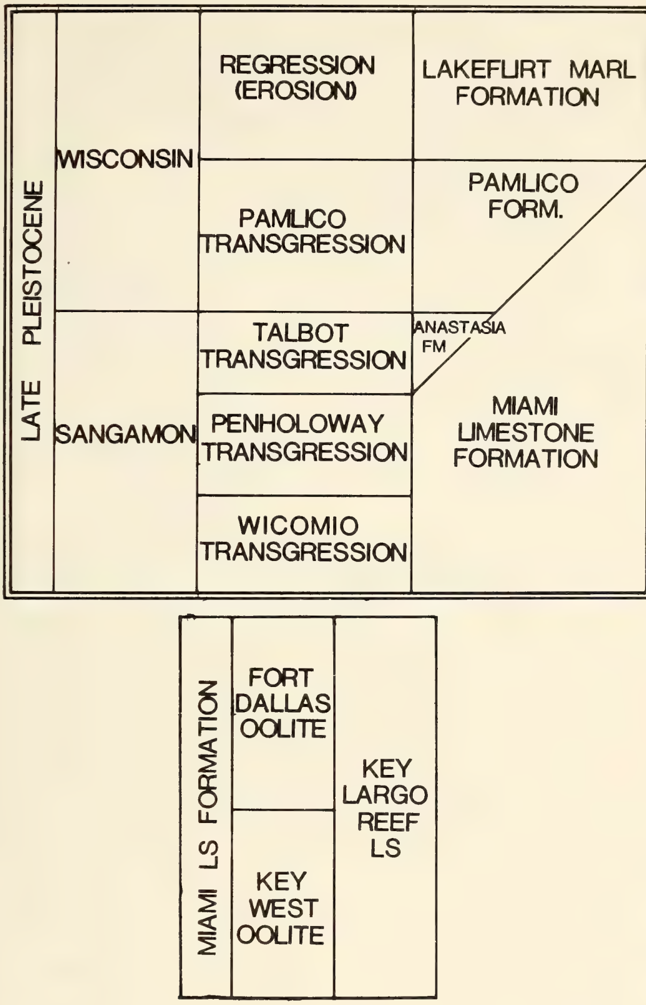

FIG. 1. The stratigraphy of the Miami Limestone Formation.

and Q5 as proposed by Enos and Perkins (1977), but differ in that I consider the Key West oolite to be the Q4 unit and the Fort Dallas oolite to be approximately equivalent to the Q5 unit. This difference is based on examination of 23 cores taken in Florida Bay that determined that the oolite underlay the floor of Florida Bay.

The distribution of the Fort Dallas and Key West oolite is shown in Fig. 2, and the Fort Dallas oolite stretches as far north in the Gulf to a point about 112 km west of Tampa Bay (Gould and Stewart, 1954). The Fort Dallas oolite is a soft white-to-yellow calcium carbonate which hardens upon exposure to air and water. White clean subangular to rounded quartz sand grains occur, throughout, sometimes even as small lenses. The nuclei of the ooids are usually white calcite crystals, and occasionally shell fragments and quartz grains, surrounded by from 1-5 layers of calcite. Vaughn (1910)

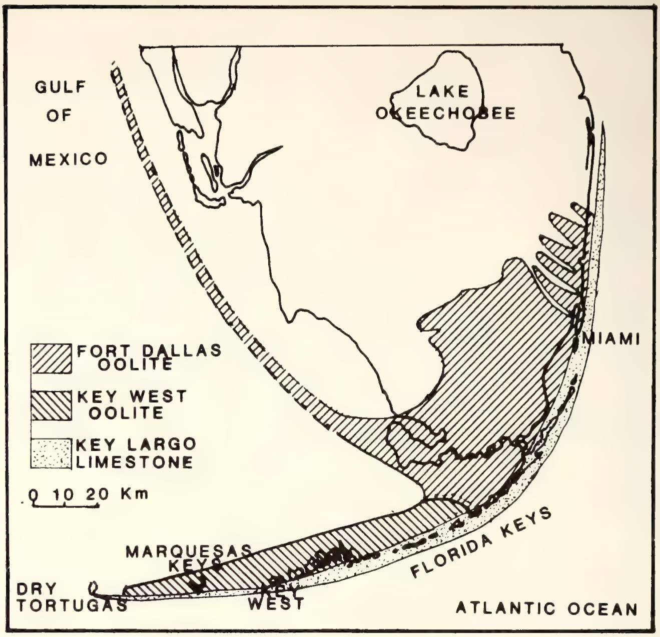

FIG. 2. The distribution of the Fort Dallas Oolite. Key West Oolite, and the Key Largo Limestone.

lists some 36 corals, molluscs and echinoids that have been found in the eastern flank of this facies. Cooke and Mossom (1929) found *Chione cancellata* to be abundant about 6 km west of Deerfield. Richards (1938) listed many pelecypods and gastropods found in this oolite, while White (1970) reports finding mangrove roots in the oolite of the Miami Ridge. During an examination of outcrops along the Miami River, Coral Gables Waterway, Silver Bluff, and the exposure at the LeJeune Road Bridge, some molluscs and coral fragments were found in the oolite. Steeply dipping cross-bedded structures truncated by horizontal beds are also common at the outcrops. They appear very similar to the paleodunes at Zanzar, Libya (Glennie, 1970) and the Bahamas (Ball, 1967). Parker and Cooke (1944) report finding large calcitic cone in cone structures in the cross-bedded oolite at the Hillsborough Canal, west of Deerfield. The thickness of the Fort Dallas oolite varies from place to place. At Cape Sable it is about 3m thick, at Ojus 12m, Fort Lauderdale 4m, Dania 13m, Miami 10m, Naranja 10m, Homestead 15m, and 10m at a well (W466) at the Dade-Collier County line, north of the Tamiami Trail.

The Key West oolite is of a fine-grained uniform texture, mostly white but sometimes yellowish in color, containing very little to no quartz sand, and it does not harden upon exposure. Many marine fossils are found in this oolite. Mossom (1925) reports many molluscs and foraminifera, and Weisbord (1974) lists some 27 corals, while ostracods and echinoid fragments have been reported in cuttings from a well (W972) on Big Pine Key. The Key

West oolite has been found west of the Marquesas, which islands are considered by Davis (1942) to be built up on a bank of this oolite. It is exposed at many places in the Lower Florida Keys and rises again to within 1m of the surface at Arsnicker Keys, north of Duck Key, in Florida Bay. The maximum thickness of the oolite is estimated to be about 12m, from data of many wells in the lower Florida Keys but Mossom (1925) reports 1 well at Key West going through 35m of solid oolite. The boundary between the Key West and Fort Dallas oolitic units is shown in Fig. 2.

An examination of the Pleistocene oolitic surface beneath Florida Bay was made using probes and short cores. The oolite was found at all sites throughout the Bay, even at the approximate site, north of Marathon, where Hoffmeister and Multer (1968) failed to recover oolite. On the basis of this 1 core, Hoffmeister and Multer (1968) considered that the oolite did not cover the floor of the Bay and so considered that the lower Florida Keys were formed as an isolated underwater ridge totally separated from that of the mainland.

Scanning Electron Microscope (SEM) analysis of each of the samples showed a distinction between the Fort Dallas oolite facies and the Key West oolite facies. The Fort Dallas oolite has a definite layer of calcite surrounding the nucleus and a possible meniscus type cement between grains (Fig. 3) indicative of eolianite. This was first reported by Ginsburg in 1957 who noted 2 clear calcite mosaic layers in samples from the Miami area. The Key West oolite has no definite mosaic of calcite around the nucleus (Fig. 4) and there appears to be a possible radial layer in some samples from a bank south of the Lower Arsnicker Keys, rather like that found by Ball (1967) around recent ooids from a submerged bar at Cat Cay in the Bahamas. Similar differences between the 2 types of oolite can be seen in the photographs of a recent publication by Scholle (1978).

The TH^{230} / U^{234} age dating of the Fort Dallas and Key West units by Osmond et al. (1965) and Brocker and Thurber (1965) findings are approximately the same. This may be true because the ages are for the formation of the oolite itself and not for formation of the eolian dunes and bars.

Depositional History—The Pleistocene history of deposition of the original oolite is that of a submerged oolitic bar across the bay and also behind the then existing Key Largo reef. The oolite was formed in the immediate area by the intermixing of the 2 different water chemistries, of the Gulf of Mexico and the Atlantic, over a broad shallow shelf in the presence of bacteria and algae. I consider this first submerged bar to have been formed across the entire mouth of Florida Bay. As the rise in sea level progressed during the Pleistocene, the first bar was moved further into the Bay and formed new bars in different positions across the Bay on the shallow platform, but retaining some part and building up other parts of the original first bar near the Lower Florida Keys. Further shoreward movements of the bars occur as the transgression progresses, until a final short bar is stretched across the Bay. Finally this bar is breached and a large channel is formed connecting the Bay to the Atlantic at Biscayne Bay. At the same time the oolite was built up on the northern shoreline, while only a small amount is retained as small bars (Fig. 5) parallel to and behind the reef. The rest of the oolite is moved through channels in the reef and offshore into the Florida Straits where it has been recovered in cores (Milligan, 1962).

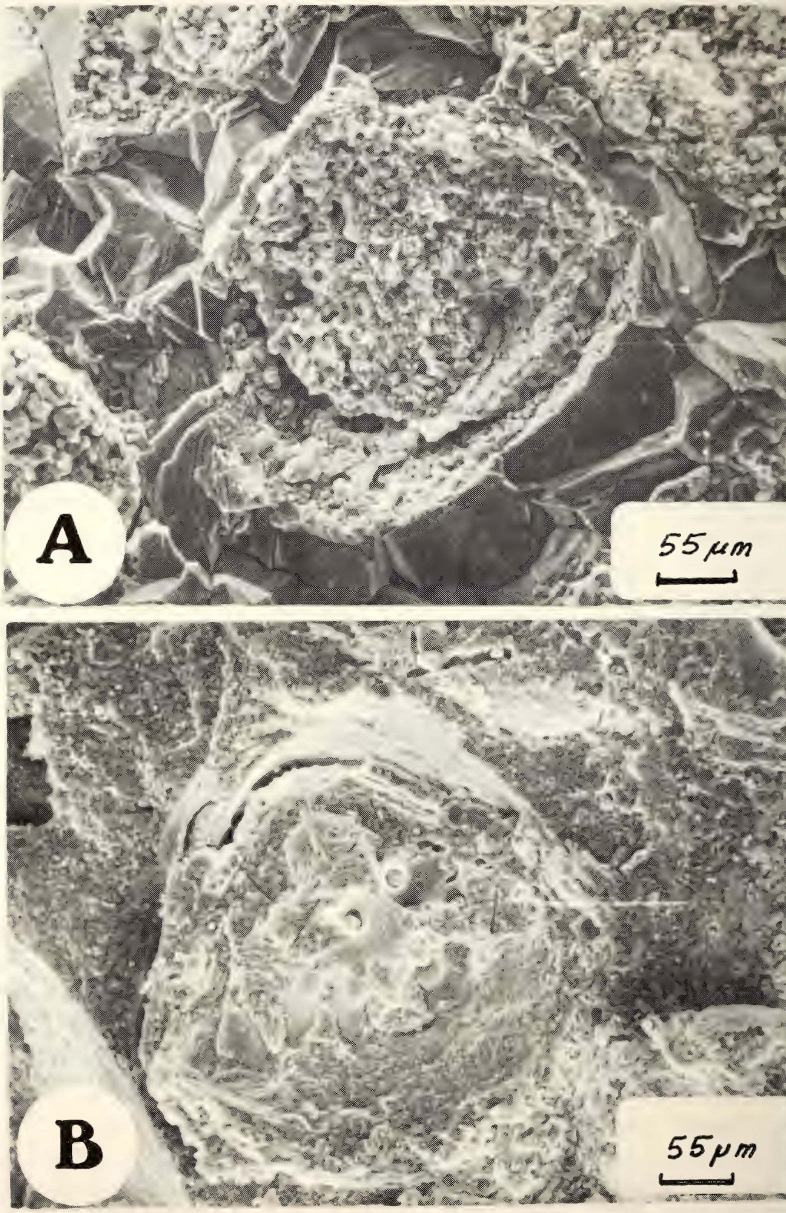

FIG. 3. SEM micrographs showing the differences and similarities of the Fort Dallas and the Key West oolites. A. Fort Dallas oolite—mozaic calcite cement surrounding ooid. B. Key West oolite—possible radial cement surrounding ooid.

The oolite that was built up higher than sea level on the northern side of the Bay was eventually wind swept into dunes forming a dune field during Pamlico time (Fig. 6). During the sea level regression this dune field remained, forming the ridges that remain in part today. The effect of the regression on the southern side of the Bay was erosive causing the reef and

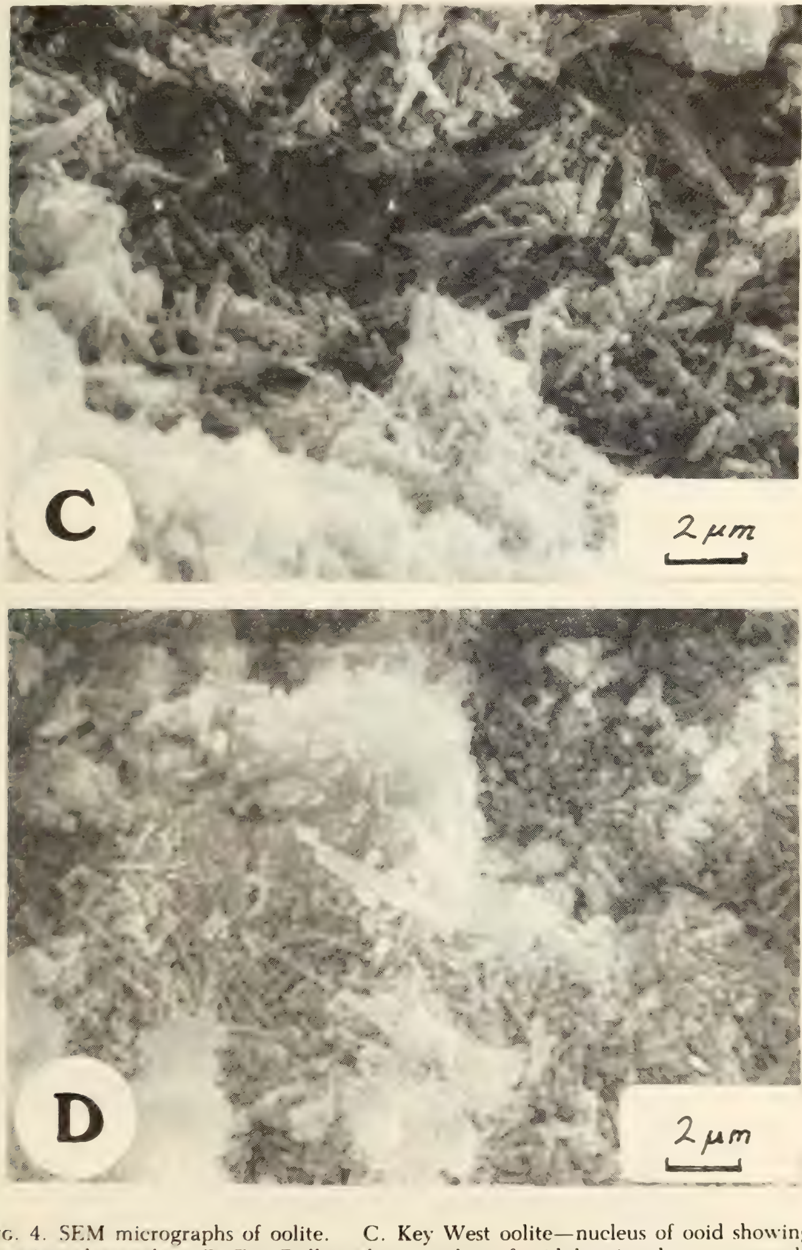

FIG. 4. SEM micrographs of oolite. C. Key West oolite—nucleus of ooid showing randomly oriented crystals. D. Fort Dallas oolite—nucleus of ooid showing the same crystal structure as the Key West oolite indicative of the same environment of deposition.

the bar to be plowed off to its present height. Many drainage channels and basins within the Florida Bay were formed during this regression, and further channels were cut into the oolite by circulatory currents when once again the Bay became restricted at its eastern end. The channels through the reef were enlarged by many major storms which have also helped in plowing

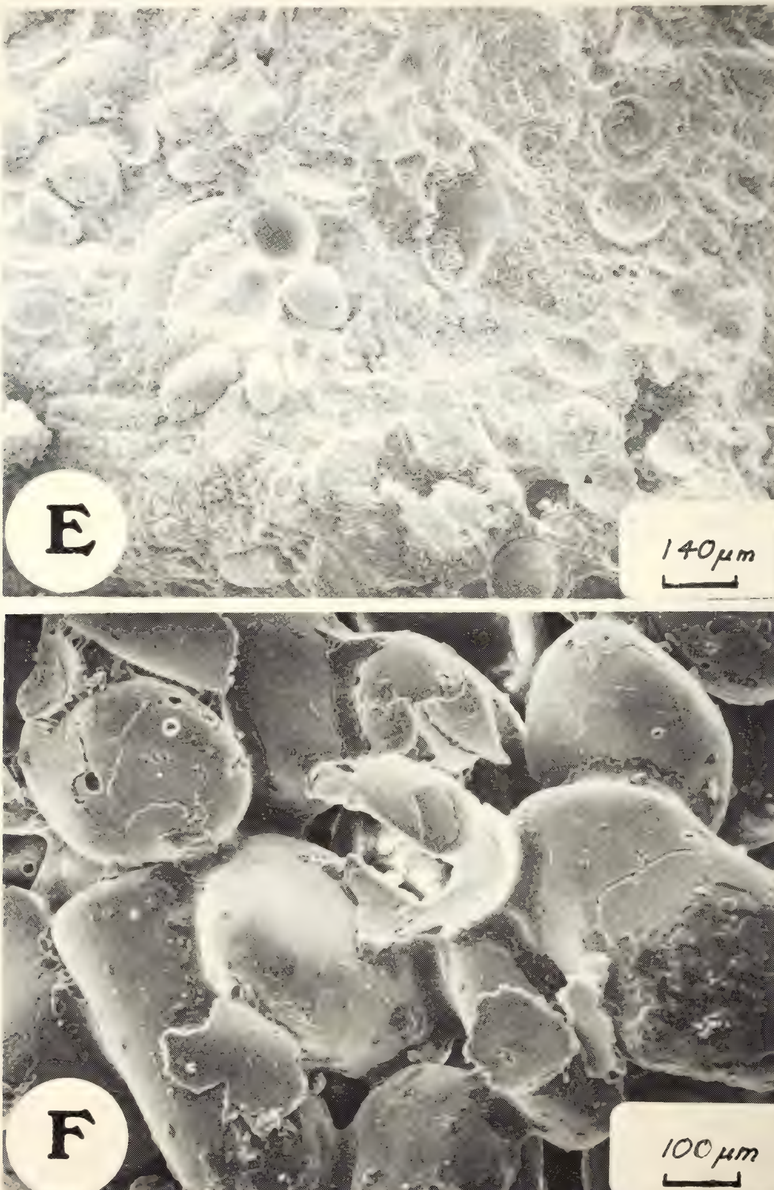

FIG. 5. SEM micrographs of: E. Key West oolite—variously shaped ooids and gastropod typical of a marine bar deposit. F. Eolian oolite from Cancun, Mexico—mozaic calcite cement surrounding ooids giving good porosity but low permeability.

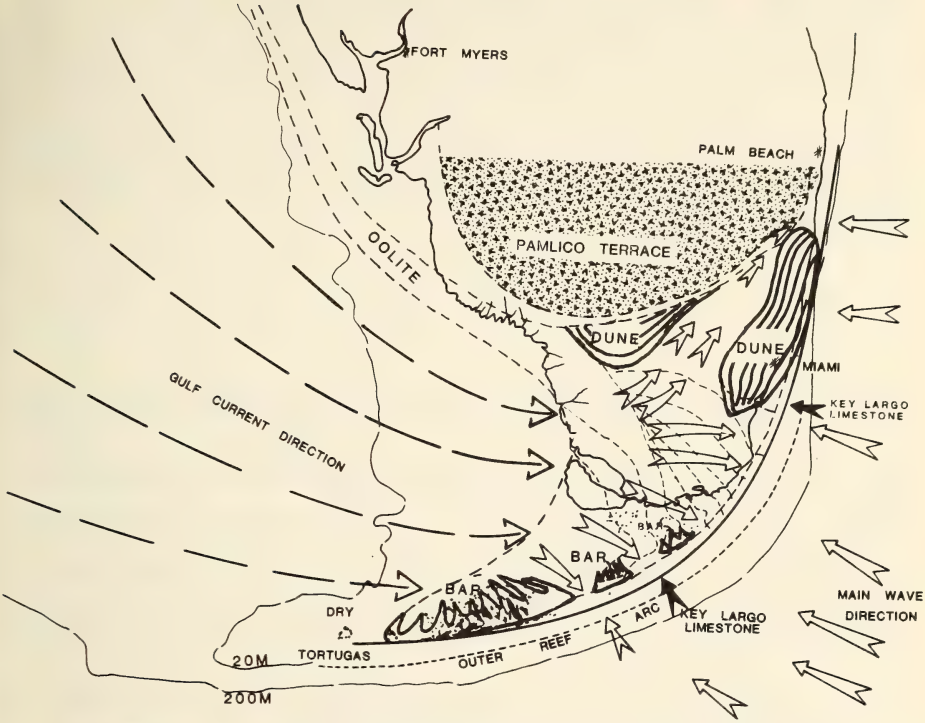

FIG. 6. The position of the Fort Dallas oolitic dunes and the Key West oolitic bars. The oolite was formed by the intermixing of the Gulf and Atlantic waters over a broad carbonate platform.

off many of the smaller oolitic bars, leaving them much as we see them today. The lowering of the sea level to its present level has caused further isolation of the bay, the exposure of some of the Key Largo Reef, and the formation of modern offshore reefs. This has resulted in restricting the chemical intermixing of the Gulf and Atlantic waters over a shallow shelf and so preventing the formation of oolite bars today.

CONCLUSIONS—The consideration that proposes 2 separate oolitic units in the Miami Limestone Formation gives one an understanding of the depositional history of the Pleistocene oolite of southern Florida. The proposal that 1 unit is eolianitic is based on the SEM analysis of the oolite which shows calcitic mosaic cement of the grain point contacts indicative of fresh water percolation. Also present in this unit are root casts in the oolite, fine-grained cross-bedded sets, the rapid decreasing of the dip angle upwards of the fine-grained beds in the outcrops, and the paleoerosional marks of hurricanes and storms along the eastern edges of the dunes. The proposal that the Key West oolite is of a marine bar is generally accepted in the literature. SEM micrographs show an absence of calcitic mosaiz cement and the present of radial cement indicative of a submerged bar. The differences between the 2 units, by their makeup and in the time and processes by which they were formed and laid down, warrant the separation into the proposed two separate units. These 2 units are called Fort Dallas and Key West Units, previously called the "Miami oolite", of the Miami Limestone Formation.

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ALLACTAEA LITHOSTROTA WILLIAMS, 1979: NEW RECORDS AND RANGE EXTENSION (DECAPODA:XANTHIDAE).—*Luis A. Soto*, Centro de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México, Apartado Postal 70-305, Mexico 20, D.F., Mexico.

ABSTRACT: *Additional records of the xanthid crab* Allactaea lithostrota *Williams, 1974 obtained at 4 localities in the West Indies Province extended its geographic range from North Carolina to the coast of Venezuela.**

WILLIAMS (1974) established the genus and species of the xanthid crab (*Allactaea lithostrota*) within the actaeid group to contain an unusual brachyuran obtained from collections of invertebrates made off the North Carolina coast, approximately southeast of Cape Lookout. The nature of the surface ornamentation observed in *A. lithostrota* makes this species unique among the American actaeas. The dorsal surface of the carapace displays large and small lobules arranged in a radiating pattern emanating laterally and anteriorly from the urogastric region. The large lobules blunt and smooth in aspect, are often clustered in triads that leave a small opening directed towards the front. The small lobules, on the other hand, are slightly sharp and are distributed along the posterior and anterolateral margins of the carapace (Fig. 1).

Up until now, the 3 male and 4 female specimens described by Williams from North Carolina were the only known records of this new xanthid. While studying the brachyuran collection obtained during the University of Miami Deep Sea Biology Program, presently kept at Rijksmuseum van Natuurlijke Historie, Leiden, Holland, I came across 4 additional females and 2 males of *A. lithostrota* taken at 4 different localities in the West Indies Province, by the R/V GERDA and the R/V PILLSBURY.

The material examined agreed in most respects with Williams' description. Even though the specimens had been kept in alcohol for quite some time, one of the males examined still exhibited a strong coloration on the dorsal surface. The large lobules on the anterior portion of the carapace displayed a reddish coloration whose intensity diminished towards the posterior margin. The smaller lobules in contrast, were of whitish color; spines and lobules on the upper surface of legs also had a reddish coloration; fingers of the chelipeds showed a dark tone not extended onto the manus.

All the specimens examined presented a typical xanthoid carapace,

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though in individuals of reduced size it tended to be squarish, while in the larger ones the carapace length represented approximately two thirds of the total width. In the 6 individuals studied, the carapace length and width ranged from 6.8-18.2 to 15.3-22.1 mm, respectively. To describe the magnitude of change between these 2 parameters, a simple linear regression was calculated adding for this purpose to our own data, the measurements given by Williams (1974) for the type material of *A. lithostrota*. A positive linear regression was obtained which is best expressed by the following: $Y = 0.628 + 1.29 X$. The close association between the 2 variables tested is reflected by the significant value of the correlation coefficient calculated: $r = +.99$.

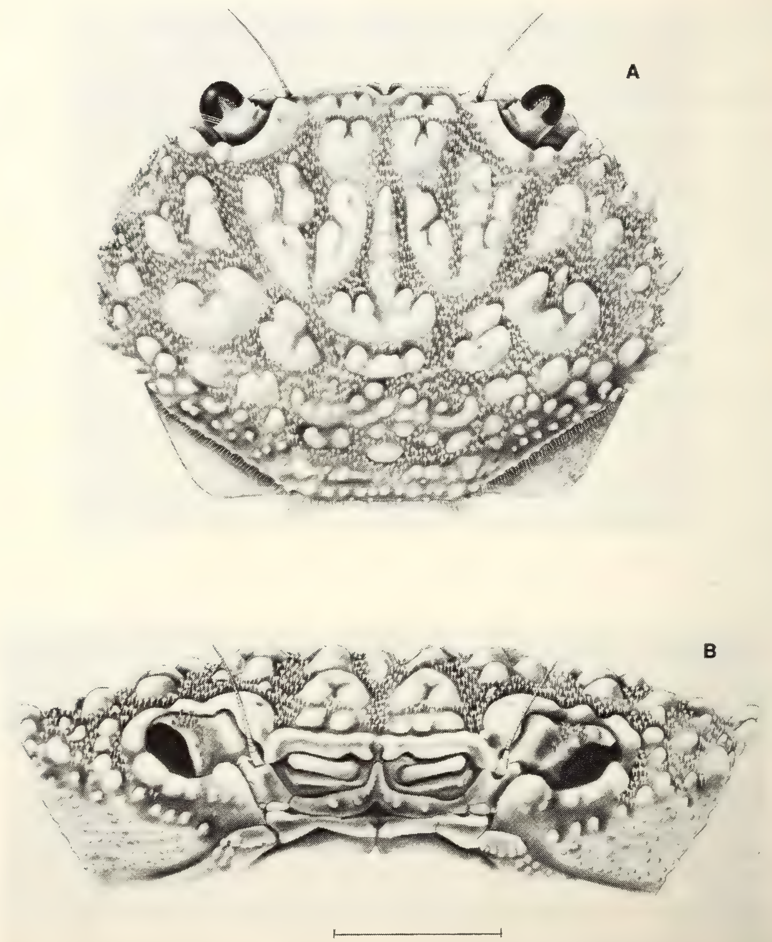

FIG. 1. A. Dorsal view of the carapace of *Allactaea lithostrota*. B. Fronto-orbital view. Scale line equal to 5 mm.

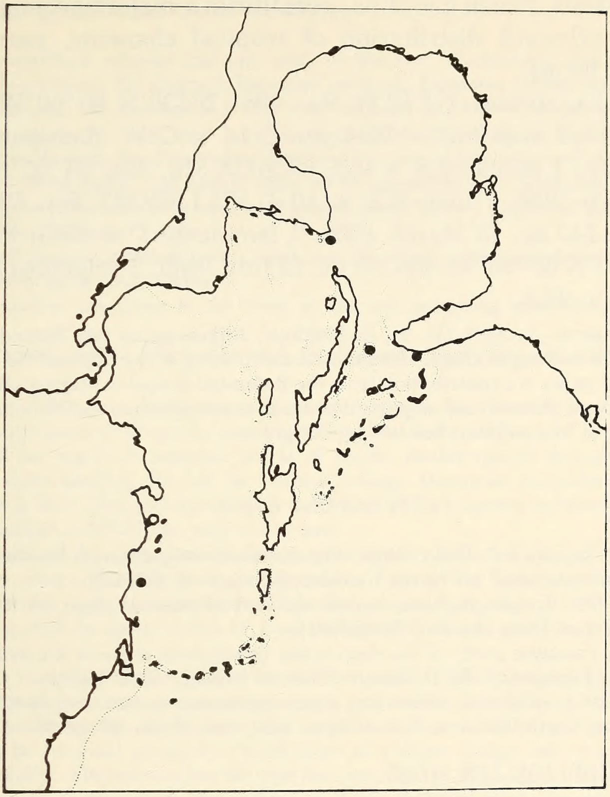

FIG. 2. Distributional range of *Allactaea lithostrota* in the tropical western Atlantic.

Two of the new records of *A. lithostrota* were taken by the R/V GERDA in the area of the straits of Florida, one on the continental shelf waters off Lake Worth at a depth of 77 m, and another in the proximity of Cay Sal Bank at 192 m (Fig. 2); in both localities the substrate was irregular, basically consisting of coral rubble. The other records were obtained by the R/V PILLSBURY from the outer continental shelf off Cape Catoche, Yucatán, at approximately 209 m and from the coast of Venezuela at about 86 m. In all these instances, the material examined was successfully collected with the aid of either a box or a triangular dredge; similar collecting devices were used by Willaims (1974) when he obtained type material of *A. lithostrota*.

As a result of these new records, the geographic range of *A. lithostrota* now extends from southeast of Cape Lookout, North Carolina to the coast of Venezuela. This type of distribution may correspond to that of a typical shelf faunal element which mainly inhabits the Caribbean region, though it is capable of maintaining reproductive populations along the southern coast of the United States as far north as Cape Hatteras, North Carolina (Soto, 1978). The evidence provided by Cerame-Vivas and Gray (1966) and more recently by Cutler (1975), strongly indicates that the area off Cape Hatteras and Cape Lookout, North Carolina, constitutes a major zoogeographic barrier in the northward distribution of tropical elements, particularly of shallow water forms.

Material Examined—GERDA Sta. 408, 26°36'N 80°00'W, 77 m, 22 September 1964, 1 male 8.2 × 10.4 mm C.L. × C.W. (carapace length by carapace width); 1 female 6.8 × 9.3; GERDA Sta. 984, 24°05'N 80°20'W, 192 m, 5 March 1968, 1 male 8.2 × 10.4; PILLSBURY Sta. 592, 21°00'N 86°23'W, 174-243 m, 15 March 1968, 1 female 10.7 × 15.3; PILLSBURY Sta. 736, 11°03'N 65°59'W, 69-155 m, 22 July 1968, 2 ovigerous female 16.7 × 23.1, 18.2 × 26.4.

Acknowledgments—I thank Dr. L. B. Holthuis, Rijksmuseum van Natuurlijke Historie, Leiden, Holland for making available the material and placing at my disposal the illustrations of *A. lithostrota*. This paper is a contribution from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, and is part of a series resulting from the National Geographic Society-University of Miami Deep-Sea Biology Program.

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