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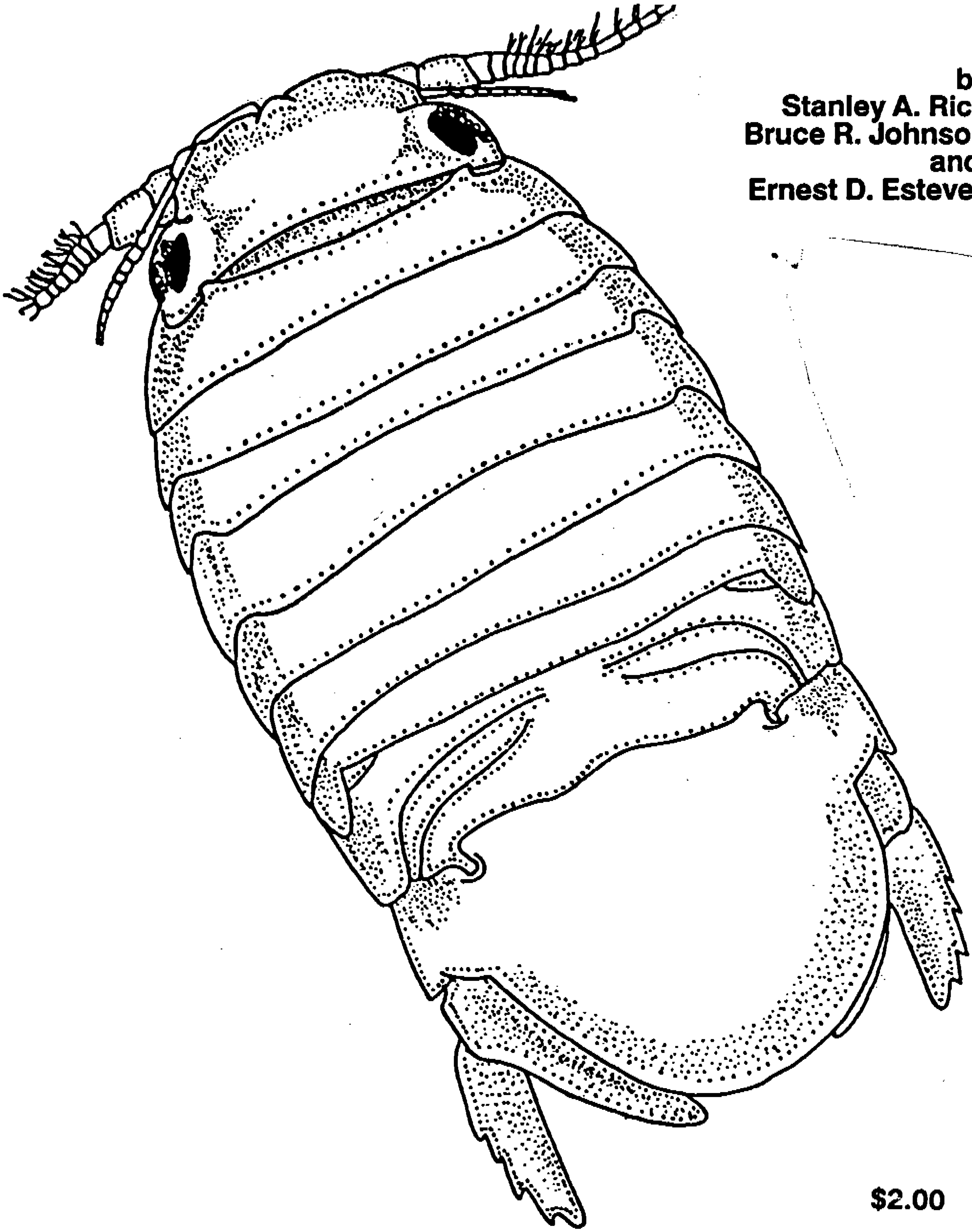
WOOD -BORING MARINE AND ESTUARINE ANIMALS IN FLORIDA



by
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INTRODUCTION

The activities of wood boring marine organisms have been a subject of concern to man since the early Greek and Roman times (Turner, 1959). Practically any wooden structure placed in the marine environment for an extended period of time becomes a target for one or more groups of wood boring organisms. Marine wood borers occur on all non-polar coastlines of the world and in the deep sea. Most common wood borers belong to the Crustacea (Orders Amphipoda and Isopoda) or the Mollusca (Families Teredinidae {shipworms}, Pholadidae {pholads} and Mytilidae {mussels}) although wood boring sponges, bryozans, phoronids, barnacles, and sea urchins have been reported (Menzies and Turner, 1957). Wood deterioration caused by soft rot fungi and certain bacteria in the marine environment are not discussed in this report.

By far the most significant threats to wooden structures in the marine environment are posed by the shipworms, isopods, and pholads. Each species of borer has a preference for certain environmental conditions. For example, one type of boring isopod may be found predominantly in high salinity water while another species of isopod may be found predominantly in low salinity water. Some species of borers have a wide range of tolerance to temperature, salinity, and dissolved oxygen while other species have a relatively narrow range of tolerance. The environmental conditions, along with other factors described below, will largely determine the type of wood borer, if any, that can inhabit and thrive at a particular location.

Deterioration of wooden structures in the marine environment tends to occur more rapidly in Florida waters than in other geographical regions of the continental United States. Pressure treated lumber that may have an expected useful life of 20 to 30 years in other areas may be reduced to structural failure in less than 10 years in Florida (Johnson, 1986). Two main factors contribute to the severity of borer attack in Florida. First, the water temperature throughout most of Florida never gets cold enough to kill or severely retard the activities of wood borers. This results in year-round attack and subsequent shortening of the useful life for marine timber. The second reason has to do with the particular species of wood borers found in Florida. Two species of wood boring isopods (Subphylum Crustacea; Order Isopoda) are found throughout Florida waters and cause significant damage to wooden materials. These species are *Limnoria tripunctata* (gribble) and *Sphaeroma terebrans* (pill bug). In Florida waters, *Limnoria* displays a distinct tolerance to standard creosote treatments while *Sphaeroma* is quite tolerant of chromated copper arsenate (CCA) treatments.

The present report is a summary of the results from a Florida Sea Grant sponsored research project intended to assess the distribution and impact of the marine borer, *Sphaeroma terebrans* on wooden structures in

Florida waters. Data collection and analysis were conducted over a 30 month period beginning in July 1985 with site visits to all coastal areas of Florida except the Florida Keys. In the process of collecting data on *S. terebrans*, significant information was also collected on other marine wood borers throughout the state. Even though these other wood borers were not the primary objective of our study, they are included in this report for completeness and in hopes that this information will be useful to marina operators.

Sources of additional information on wood borers can be found in Conover and Reid (1975), Johnson (1986) and methods for repair of damaged timber and concrete have been summarized by Jones (1982).

STATEWIDE SURVEY DESCRIPTION

More than 100 sites along the Florida coast were reconnoitered with 90 of these sites surveyed for borer attack (Figure 1). Sixty-five sites were on the Gulf coast and 25 sites were on the Atlantic coast. Sites were distributed across a wide range of tidal and salinity conditions with 18 sites classified as tidal freshwater, 7 as brackish (occasionally affected by low salinities), 44 as estuarine (salinity less than seawater), and 21 as coastal (fully saline most of the time).

At each site, wooden structures were examined by the survey team and if wood deterioration due to animal borers was noted, a series of data sheets were filled out with information about the site. These data sheets included more than 50 items of information concerning the site such as type and treatment of wood, age of facility, water salinity, temperature, types of borers present, type of construction, etc.

Data sheets for all 90 sites were transferred to digital records and merged into a single report file. This document was used to identify correlations between types of borers present at sites and physical conditions that may have contributed to borer attack.

Of the 90 sites surveyed, 67 sites were marinas (Figure 2). At 18 of these marinas (27%), some untreated wood was exposed in water. Forty-one of the marinas (61%) employed a combination of creosote treated and CCA treated timber. Only four marinas (6%) used exclusively CCA or ACA (ammoniacal copper arsenite) treated timber.

Characteristic burrows and /or live wood borers were found in pressure treated wood at 47 of the marina sites (70%). Creosote treated pilings, when present, were attacked by borers at 79% of the marinas while CCA/ACA treated pilings, when present, were attacked at only 16% of the marinas. It should be noted that creosote pilings have been in general use for many decades longer than CCA/ ACA treated pilings and the above data

Figure 1. Location of the 90 sites around Florida where information was collected on *Sphaeroma* and other wood-borers.

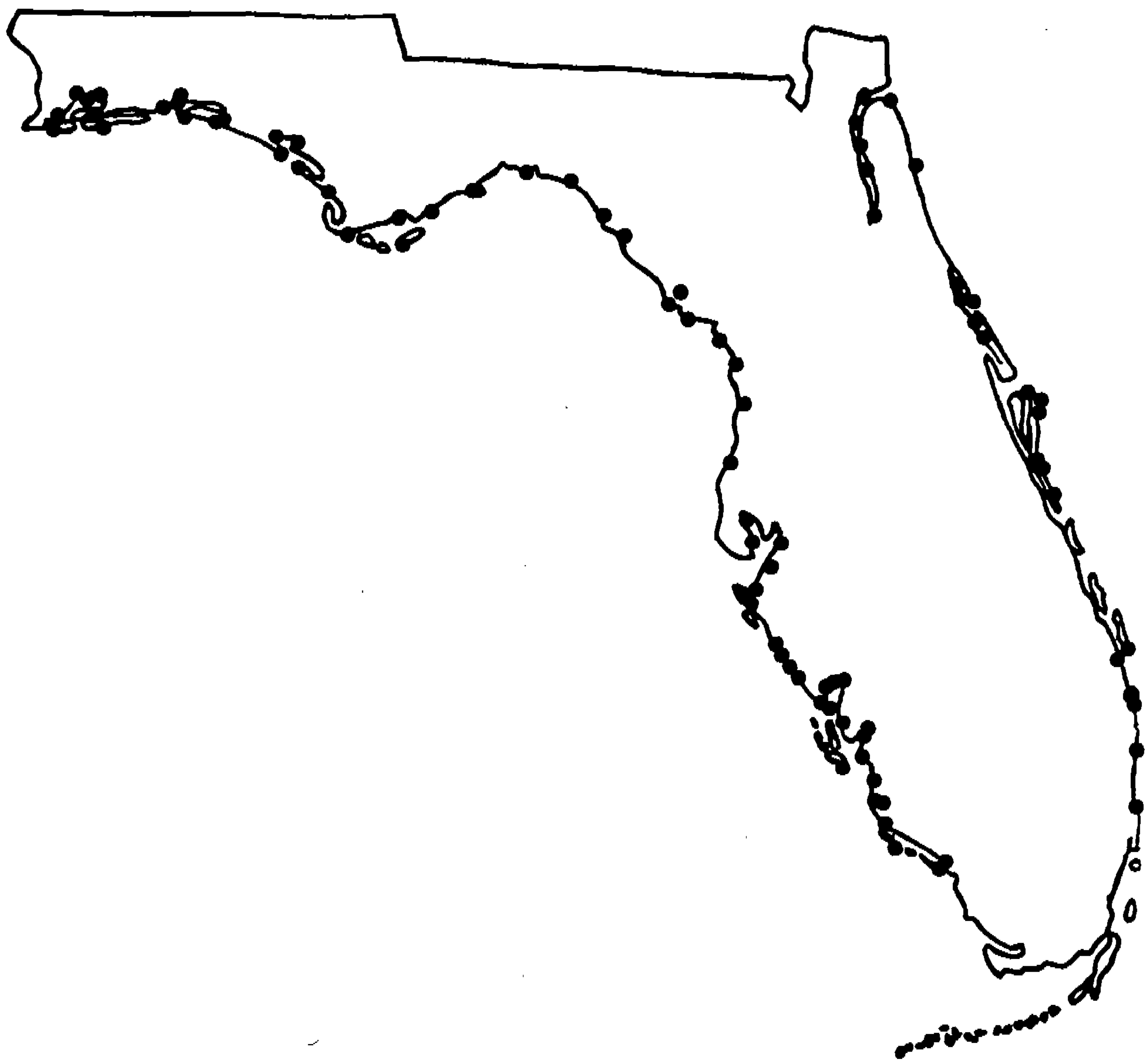
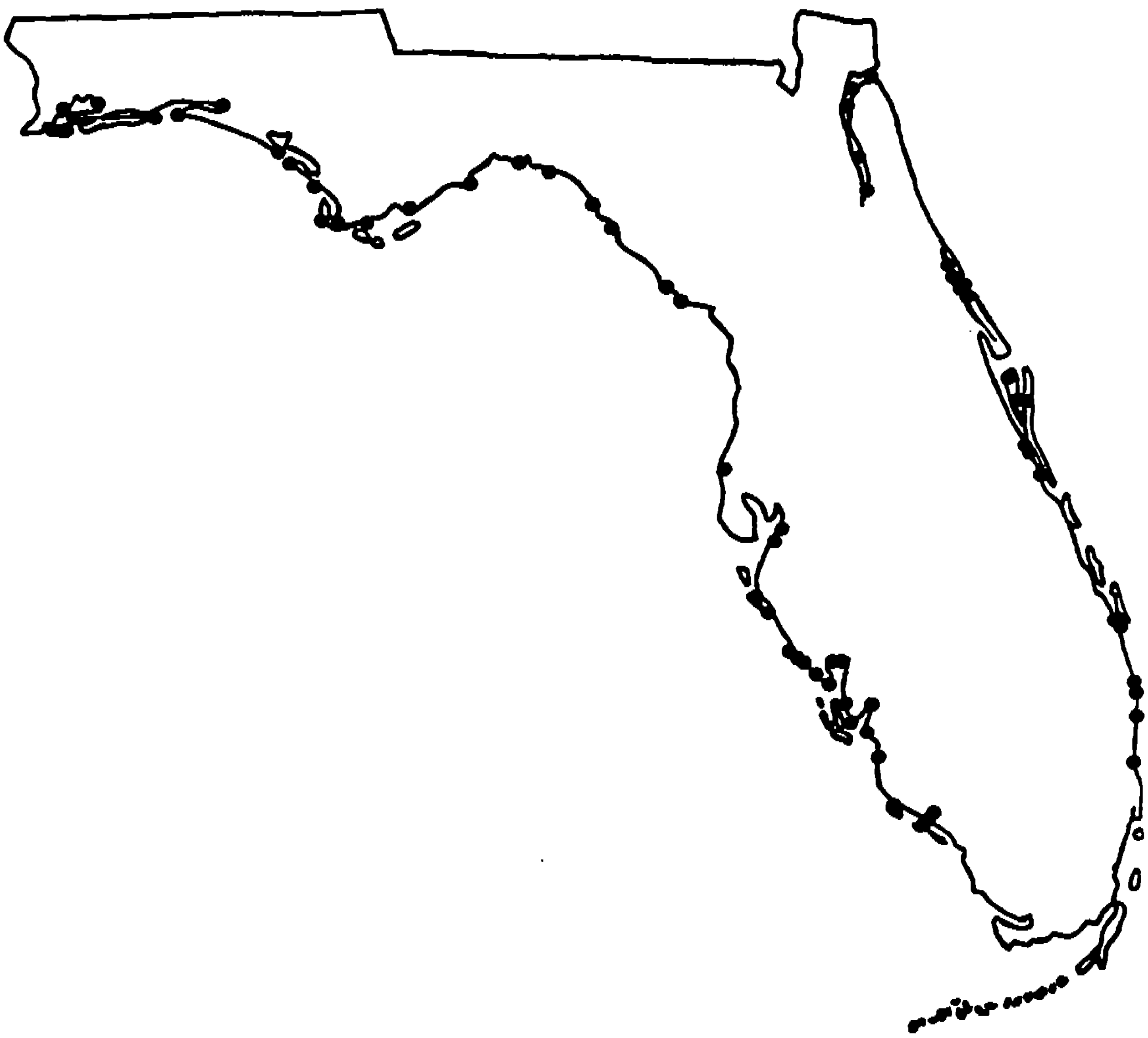


Figure 2. Location of 67 marinas that were visited and assessed for wood-borer damage.



may reflect this difference in exposure as well as possible differences in preservatives.

TYPES OF WOOD BORERS ENCOUNTERED

The species of wood boring organisms identified from our survey sites are listed in Table 1. A list of associated species, though not primarily borers, are included in Table 2. The list of associated organisms (Table 2) is not intended to be exhaustive but rather representative of what might be expected in Florida. Of the wood borers encountered in this study, the isopods, shipworms, and pholads were responsible for the majority of damage to timber.

Wood Boring Isopods

Two species of wood boring isopods were identified from samples: *Sphaeroma terebrans* and *Limnoria tripunctata* (Figure 3). Even though both species are isopods, they differ greatly in their mode of attack, nutritional requirements, and environmental tolerance.

Sphaeroma terebrans Bate (Figure 3)

Sphaeroma tends to occur in low salinity waters being found at 56% of the freshwater sites visited (Figure 3). *Sphaeroma* was identified at only 33% of the sites classified as marine. Thirty of the marina sites visited (45%) had current or historical evidence of attack by this borer. Normally, *S. terebrans* inhabits natural wood like cypress, cedar, palm, pine, and especially mangrove prop roots in estuarine habitats to southern Florida. Recently, this borer has been found living in black needle rush (*Juncus roemerianus*) and leatherfern (*Acrostichum aureum*) in estuarine and brackish marshes. *Sphaeroma* will readily colonize other wooden materials including pilings, fenders, bulkheads, ship hulls, and planking. Non-wood materials like rope, carpet, fire hose, soft rock and foam can also provide habitat for this borer.

Sphaeroma can inhabit such a wide variety of materials largely due to the fact that these animals do not consume wood as their primary food source. Laboratory and field observations suggest that *S. terebrans* feeds primarily on suspended material such as suspended sediment, microscopic algae, and bacteria that are filtered out of the water by the borer using modified appendages. Since *S. terebrans* does not consume the material in

Table 1. Marine wood boring organisms encountered at study sites in Florida. (see Table 2 for associated organisms)

Scientific Name	Common Name	Phylum
Sphaeroma terebrans	isopod, pill bug	Arthropoda
Limnoria tripunctata	isopod, gribble	Arthropoda
Bankia fimbriatula	shipworm	Mollusca
Bankia martensi	shipworm	Mollusca
Mytilopsis leucophaeta *	false mussel	Mollusca
Martesia striata	pholad, boring clam	Mollusca
Ischadium recurvum *	hooked mussel	Mollusca
Geukensia demissa *	ribbed mussel	Mollusca
Branchidontes exustus *	scorched mussel	Mollusca

*these species are generally not responsible for initial damage to wood but inhabit and enlarge burrows of other primary wood borers

TABLE 2. Animals found associated with fouling and boring communities at survey sites (see Table 1 for borers).

Mollusks:

Cerithiopsis greeni
Hydrobiidae sp.
Littorina angulifera
Melampus coffeus
Mitrella lunulata
Mytillidae sp.
Neritina unsca

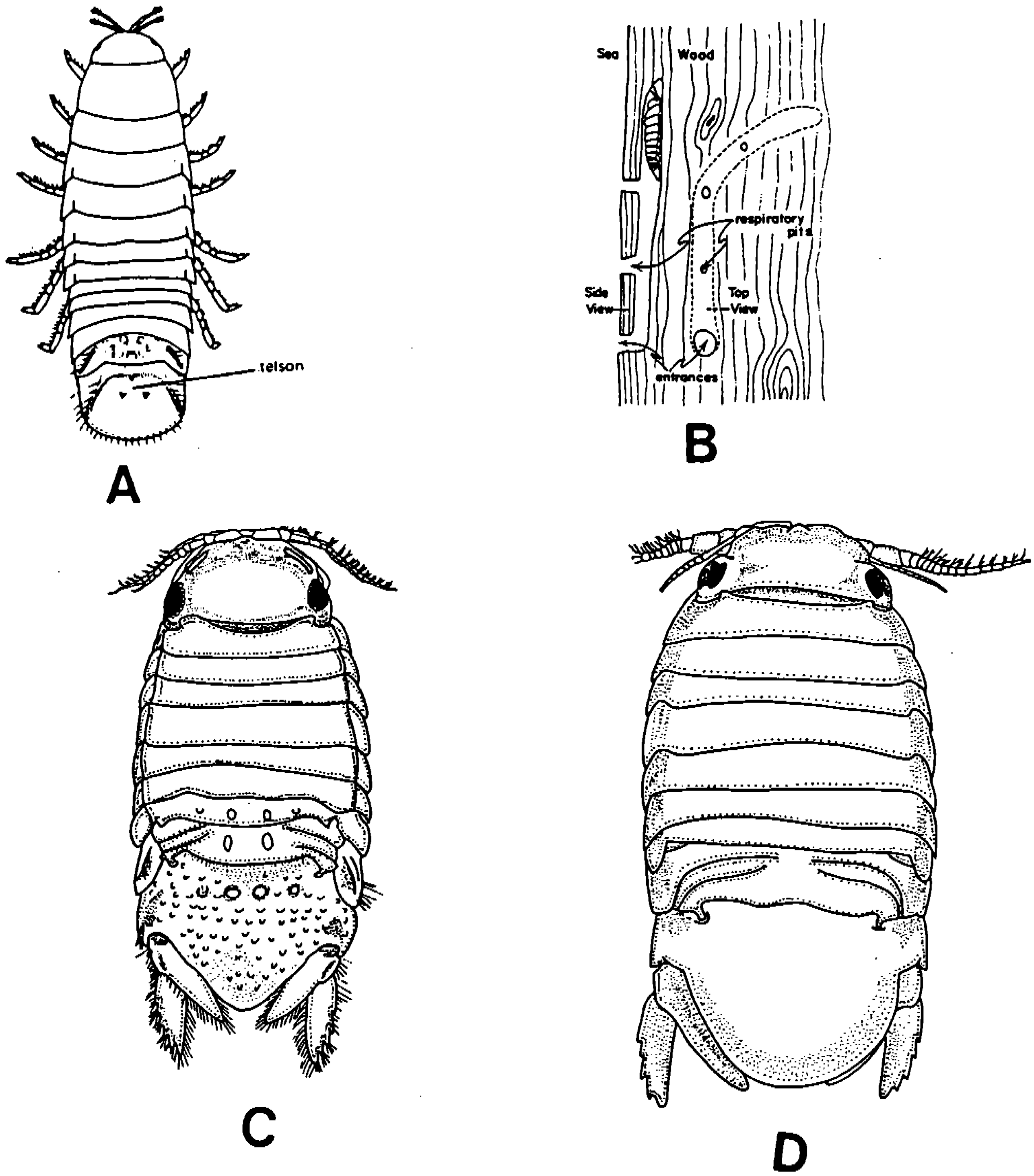
Crustaceans:

Ampelisca sp.
Balanus amphitrite
Balanus eburneus
Balanus improvisus
Chthamalus fragilis
Cirolana parva
Corophium sp.
Elasmopsis levis
Eurypanopeus depressus
Gitanopsis sp.
Hargaria rapax
Harpacticoid copepod
Hyale cf. plumulosa
Melita "nitida" complex
Pachygrapsus transversus
Sphaeroma quadridentatum
Sphareoma walkeri
Sphaeromidae sp. A
Sphaeromidae sp. B
Talitridae sp.
Tanaidacea sp.
Uca minax

Other Taxa:

Anthozoa unid. sp.
Chironomidae spp.
Hymenoptera unid. sp.
Lepidoptera unid. sp.
Nemertea unid. sp.
Platyhelminthes unid. sp.

Figure 3. Isopods. **A**, *Limnoria tripunctata* adult, about 6 mm long by 3 mm wide (from Voss, 1976); **B**, diagram of *Limnoria* burrows in wood (from Schultz, 1969); **C**, *Sphaeroma terebrans* adult female, 10 mm long by 4 mm wide; **D**, *Sphaeroma quadridentatum* adult, 4.5 mm long by 3.5 mm wide(C & D) from Menzies and Frankenberg, 1966).



which it bores, it is little affected by standard preservatives such as CCA/ ACA or creosote (Cragg and Levy, 1981).

In fixed timber such as pilings, cross-brace, and bulkheads, the zone of attack by *S. terebrans* is mainly restricted to the intertidal zone where oxygen levels are high and suspended material is abundant. These borers can withstand several hours of exposure out of the water during low tide since they typically retreat into their burrows and remain inactive. *Sphaeroma* burrows are usually perpendicular to the surface of the wood (or other material), and round in cross-sectional shape (Figure 5). Most burrows penetrate only 1-3 cm into the wood and are blind-ended. The size of burrows and depth of penetration vary with the size of the animal. In active burrows, the animal can usually be seen at the blind end of the burrow facing inward. A current of water is produced by the beating of specialized appendages that carries food material into the burrow where it is filtered out of the water and consumed by the borer. Excavation of the burrow is accomplished using strong chitinized mouthparts.

Sphaeroma females brood their young on the ventral surface of the body and release the juvenile borers inside the maternal burrow. This ensures that when a suitable habitat is found and reproduction is successful, colonization will quickly follow as the juveniles gradually leave the parental burrow and establish independent burrows nearby. Adult *Sphaeroma* are good swimmers and will readily leave an over-crowded area or suboptimal habitat in search of more favorable surroundings. In this way, a colonizing population can be established at new marinas or other sites through infested boat hulls, drift wood, or flushing from upstream.

As noted in Table 2, at least two other known species of *Sphaeroma* occur in Florida waters. Unlike *S. terebrans,* these other species do not bore into wood or other materials since they lack chitinized mandibles. These other species, however, may co-occur with *S. terebrans* and may even inhabit abandoned burrows formed by *S. terebrans.* Since these species of *Sphaeroma* may be difficult to tell apart, an expert should be consulted prior to engaging in mitigative activities against *S. terebrans. Sphaeroma quadridentatum* is probably most commonly confused with *S. terebrans* but the former can be identified by its broadly rounded, smooth telson (Figure 3).

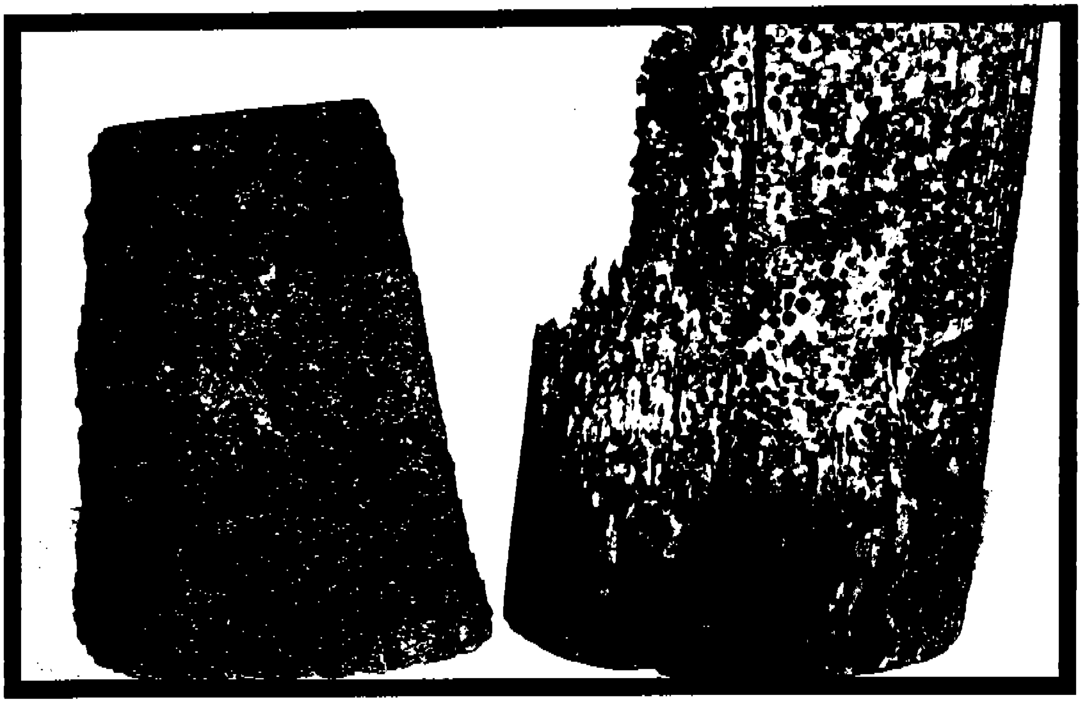
Limnoria tripunctata **Menzies (Figure 3)**

Limnoria prefers high salinity water and is intolerant of freshwater and brackish water. This borer was encountered at 19 (21%) of the sites visited including 11 marinas.

Unlike *Sphaeroma, Limnoria* is a primary consumer of wood. These borers use their mandibles to shred the wood and ingest it where digestion

Figure 4. Survey sites where *Sphaeroma terebrans* was actively or historically present.

Figure 5. Wood damage from borers. **A**, *Limnoria* attack on piling; **B**, *Sphaeroma* attack on piling; C, shipworm attack on planking (from Johnson, 1986).



A B

C

may be aided by symbiotic bacteria in the digestive track. Since *Limnoria* feeds upon wood, it is more restricted in its habitat, being unable to survive within materials that it cannot digest (like foam or carpet).

Limnoria burrows are small compared to *Sphaeroma* burrows with an opening of 1-2 mm. The animals are light in color and nearly transparent, measuring about 6-10 mm in length. Once penetration of the wood surface is achieved, the animals tend to burrow parallel to the surface producing long tunnels with frequent openings to the outside for water circulation. *Limnoria* prefers to burrow in the softer springwood and will avoid the harder grains and knots leaving a honeycomb skeleton of the original wood. The zone of attack, especially in vertical pilings, may be larger than that of *Sphaeroma* since *Limnoria* is not dependent upon suspended material near the water surface. The zone of *Limnoria* attack may be restricted by such factors as low oxygen levels in water near the bottom.

Limnoria females brood their young in ventral pouches and release the juveniles within the burrow matrix of the adults. The juveniles feed on the softer wood at first and gradually begin their own series of tunnels. Colonization of new habitats occurs through swimming of adults from heavily infected wood in ship hulls, drift wood, or adjacent wooden structures.

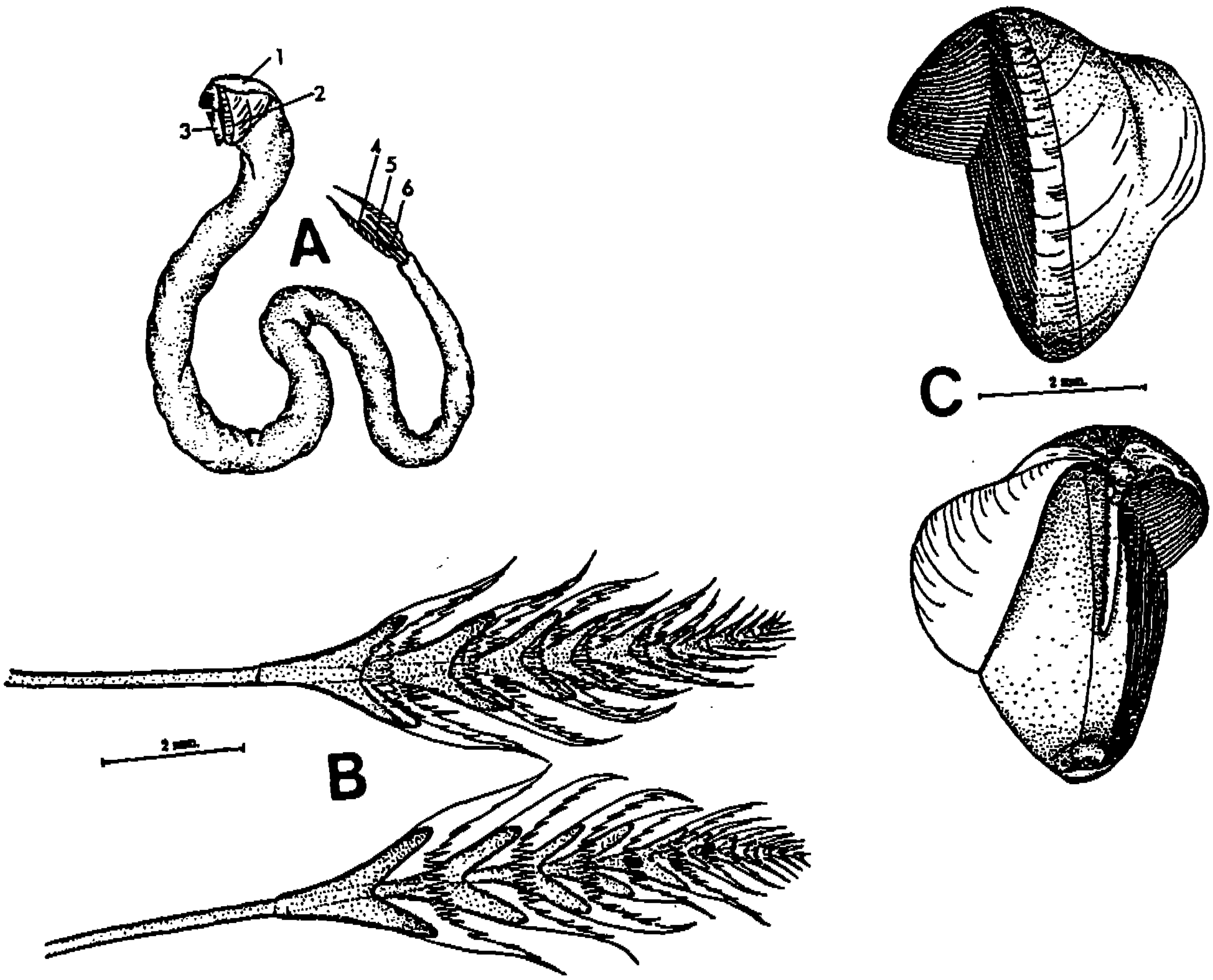
Shipworms (Family Teredinidae)

Shipworms are bivalve mollusks and represent highly modified clams (Figure 6). There were two species of shipworms identified during the present study (Table 1) however, 11 other species have been reported from Florida (Clapp Laboratories, 1950). Shipworms use their shell to excavate their burrows. The shell is relatively small and covers only the anterior end of the adult animal. A long worm-like body extends from the shell. In most species, the interior of the burrow is lined with a layer of white calcareous material produced by the animal. The only portions of the animal that may extend out of the burrow are the siphon tubes that the animal uses to pump water into and out of the burrow.

Shipworms ingest and digest the wood that is scraped loose by the rocking action of the shell. Since they feed upon the wood, they will continue to burrow and grow producing an ever lengthening tunnel as long as conditions are favorable. The adult size of the animal and its rate of burrowing vary among species but some species may reach a length of 120 cm and a diameter of 2.5 cm in about one year.

Invasion of wood by shipworms occurs during the larval phase of the life cycle. Shipworms produce free-swimming larvae that travel through the water for various lengths of time (1-30 days, depending upon the species) and eventually settle on a piece of wood and begin to burrow. The larvae at

Figure 6. Shipworm. **A**, whole animal showing cephalic hood(1), shell (2), foot (3), pallet (4), siphons (5 & 6); **B**, enlarged diagram of pallets from *Bakia fimbriatula*; **C**, shells of same (from Turner, 1966).



settlement are small (0.2-0.4 mm) and difficult to detect. They immediately begin to excavate a burrow upon settlement and achieve penetration within several hours. Shipworm attack often goes unnoticed until the timber fails since the entrance burrows are very small and the animal is almost entirely within the wood.

Pholads (Family Pholadidae)

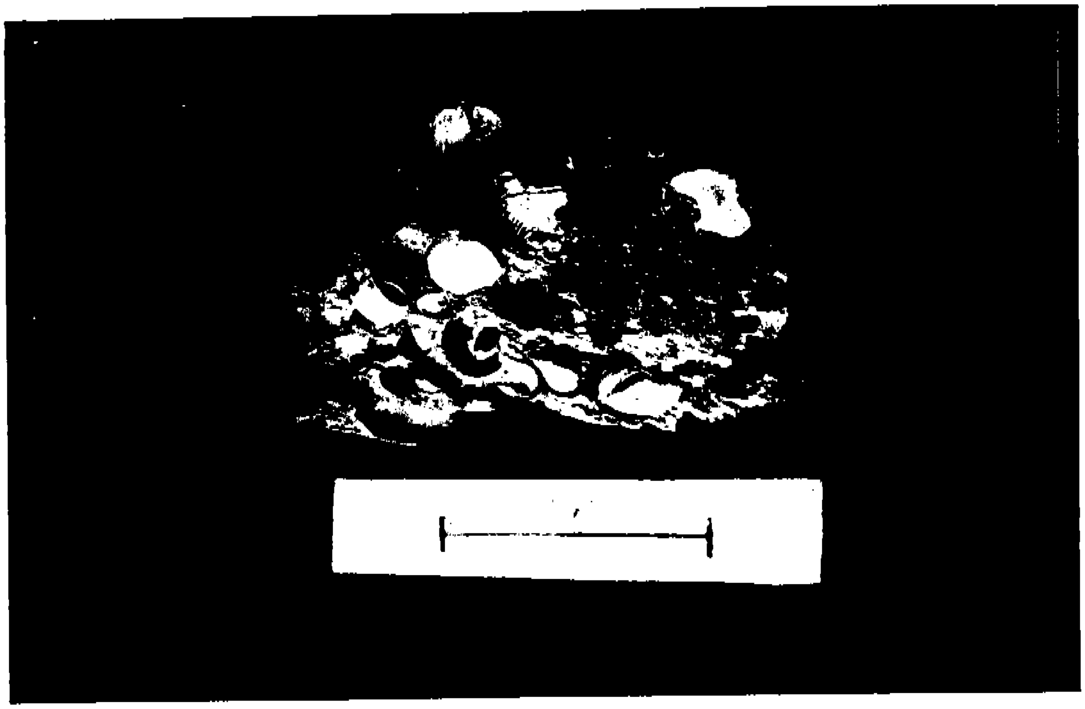
Pholads, like shipworms, are modified bivalve mollusks (Figure 7). Pholads differ from more typical clams in that they have 1-3 additional shell plates attached over the hinge and over the margins of the two primary shells. They do not, in general, cause as much damage to timber as shipworms since pholads only excavate burrows near the surface of the wood and do not consume the wood as a primary food source. Pholads feed on suspended material in the water and bore into wood or other material for shelter. Since they do not eat the substrate into which they bore, pholads may inhabit a wide variety of materials although each species has a preferred habitat. Various species of pholads have been reported to bore into sandstone, clay, rock, concrete, wood, and foam. *Martesia striata* was the only pholad encountered in the present study and preferred to bore into wood. A second genus of pholad, *Hiata,* has been reported in Florida (Clapp Laboratories, 1950).

Pholads produce free-swimming larvae as do shipworms and these larvae seek out new habitats appropriate for colonization. The larvae bore into the wood and establish the initial burrow. Feeding on phytoplankton and suspended material in the water, the pholad grows and enlarges its burrow through rasping movements of its shell at the innermost (anterior) end of the burrow. Burrows are pear-shaped, as is the shell of the animal, and oriented perpendicular to the surface of the wood or other material. The opening into the adult pholad burrow is generally larger (6 mm) than that of a shipworm. The burrow is not lined with calcareous material and penetrates the wood only 2-5cm. The shell usually remains in the burrow after the animal dies.

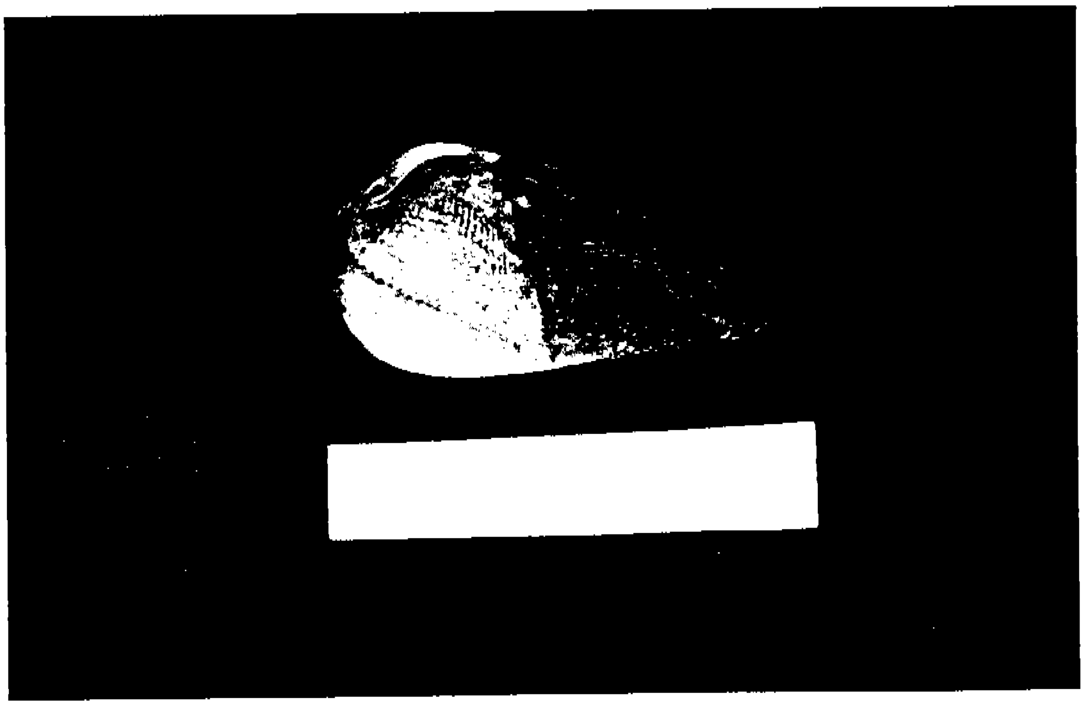
Other Borers

In addition to the shipworms, isopods, and pholads, several other wood boring species may be encountered in Florida marine environments. These include several species of mussels and amphipods of the genus *Chelura*. Table 1 includes four species of mussels that were identified from samples collected around the state. These mussels are not obligate borers and

Figure 7. Pholads. **A,** *Martesia* in wood; **B,** typical pear-shaped wood boring pholad.



A



B

commonly occur on surfaces other than wood. They settle on damaged wood and inhabit cracks and crevices for protection. Mussels may help to enlarge existing burrows as their shell grows but will not, by themselves, cause any substantial damage to wood. Mussels feed upon suspended material in the water and are commonly found in the intertidal zone on pilings.

The amphipod, *Chelura,* like the mussels is a secondary inhabitant of burrows formed by other species. *Chelura* commonly occurs along with *Limnoria*, using the borrows formed by the isopod. *Chelura* does not make a substantial contribution to wood deterioration on its own.

IDENTIFICATION OF WOOD BORERS AT SPECIFIC SITES

If intertidal or subtidal timber deterioration is a problem at a particular site, an attempt should be made to identify the specific organism(s) responsible for the attack. Collection and preservation of a sample of infested wood for examination by an expert is the most reliable method of diagnosis. Often, close examination of an infested timber by an informed owner/operator with particular attention to the appearance of the wood and the presence of burrows will reveal the identity of the wood boring organisms.

At any particular site, the type of wood borer present may change over time depending upon environmental conditions at the site and the presence of source populations nearby. For example, a site that had no history of shipworm attack may suddenly have a severe shipworm problem following a visit by an infested ship hull or piece of drift wood containing reproductive adult shipworms. The most reliable method for long-term monitoring of borer occurrence at specific sites is to suspend a small piece of untreated pine (1"x 2"x 4') from the high tide zone down to the mudline to collect available wood borers. These test panels can be retrieved periodically and examined to determine the identity of borers.

For existing pilings, crossbrace, or other timber, the following information may be useful in determining the type(s) of borers present.

Sphaeroma terebrans **(isopod)**

Animal Appearance: Figure 3; dark in color; adults up to 10mm long by 5 mm wide; flattened dorsoventrally (top to bottom); rolls into a ball if removed from burrow; two pair of short antennae on head; dorsal (top) surface with transverse (cross) rows of small tubercles (bumps) especially toward the posterior end; pleotelson (most posterior segment) with longitudinal rows of tubercles; telson pointed rather than broadly rounded.

Burrow Appearance: Figure 5; burrow opening cylindrical; up to 10mm in diameter; perpendicular to wood surface; 25 mm or less deep; animal, if present, head first in burrow.

Infected Timber Appearance: heavy infestation produces "honey comb" or "shotgun blast" appearance of burrows; pilings may have "hourglass" shape due to localized wood destruction.

Zone of Attack: typically only in intertidal zone; may be very narrow zone or rather wide depending upon tidal amplitude or river stage at the site.

Salinity Tolerance: prefers low salinity water, can live and thrive in tidal freshwater.

Natural Habitat: red mangrove, drift wood, black needle rush, leatherfern, other soft substrata.

Food Source: suspended material in the water

Limnoria tripunctata (isopod)

Animal Appearance: Figure 3; small in size (6-10 mm long by 2-3 mm or less wide); elongated; whitish or transparent; two pair of antennae on head; 3 tubercles on the pleotelson in a triangular arrangement.

Burrow Appearance: Figure 5; small openings (0.1-0.2 mm) at surface; burrows parallel to wood surface in softer springwood; network of tunnels present in area of attack; many openings along burrow for water circulation; attack usually confined to outermost surface of wood (little penetration into hard timber).

Infected Timber Appearance: finely porous wood surface due to many small burrows; surface of wood very soft, mushy, crumbles to the touch; pilings may have "hourglass" appearance or irregular constrictions in area of greatest attack.

Zone of Attack: may extend from intertidal zone down to mudline; often concentrated in the intertidal zone.

Salinity Tolerance: prefers full seawater salinity (30ppt and up); rarely occurs below 15ppt salinity.

Natural Habitat: any wooden material exposed to seawater

Food Source: wood

Shipworms (*Bankia, Teredo*)

Animal Appearance: Figure 6; elongate (up to 120 cm long but more commonly less than 25 cm) worm-like clam with shell restricted to one end; very fragile; conical tapering body, widest at shell end; pallets (segmented calcareous structures) at narrow end of body important for species identification

Burrow Appearance: Figure 5; long, winding tunnels within the wood with a single small opening to the outside; burrow opening may be plugged with calcareous material; burrow usually lined with a white layer of calcareous material.

Infected Timber Appearance: little exterior indication of infection except for small, round holes of burrow entrance; structural damage to timber may be substantial before any external signs of shipworms are visible.

Zone of Attack: from intertidal zone to mudline; some species prefer mudline area and adjacent area above; will vary depending upon presence of other borers, fouling organisms and crowding.

Salinity Tolerance: generally prefer higher salinity conditions but some species occur in estuarine and brackish waters

Natural Habitat: any submerged wood

Food Source: primarily wood; secondarily suspended material

Table 3. **Resistance of commercially available wood preservatives to attack by *Sphaeroma terebrans* in Florida.**

Treatment	Replicates	Retention kg/m^3 (pcf)	Damage Index by Year[2] 1	2	3	4	5
None (control)	12		8.6	6.9	3.4	0.7	0
CCA-C	4	4.3 (.27)	8.8	8.2	6.2	2.8	1.0
	4	16.8 (1.05)	9.5	9.2	8.0	8.0	5.5
	4	41.2 (2.6)	9.8	9.8	9.0	9.0	9.0
Creosote[1]	4	192 (12)	10	9.5	7.5	8.0	7.0
	4	354 (22)	10	10	9.5	9.0	9.0
	4	496 (31)	10	10	9.5	9.2	9.2
Dual treatment	4		10	10	10	10	10
CCA		16 (1.0)					
Creosote[1]		368 (23)					

1 AWPA P-13 coal-tar creosote

2 Damage Index: 10= no *Sphaeroma* burrows; 9= light attack; 7= moderate attack
4= heavy attack; 0= destruction or loss of panel integrity

Table 4. Sensitivity of various Florida wood borers to standard wood preservatives. (CCA= chromated copper arsenate; ACA= ammoniacal copper arsenite; pcf= pounds per cubic foot)

BORER	TOLERANT OF	SENSITIVE TO
Sphaeroma terebrans	CCA, ACA, creosote	dual treatment
Limnoria tripunctata	creosote	CCA, ACA, dual treat.
Bankia and *Teredo* (shipworms)	<1.5 pcf CCA, ACA	≥2.5 pcf CCA, ACA, dual treat.
Pholads	CCA, ACA	creosote, dual treat.

Pholads (*Martesia, Hiata*)

Animal Appearance: Figure 7; pear-shaped clam, sometimes irregular in shape; body completely enclosed by sturdy shells; *Martesia striata* usually has a whitish shell, 5-30 mm long; other species may be tan to dark brown.

Burrow Appearance: burrows correspond to shape and size of shell; may be pear-shaped or shallow tunnels; usually perpendicular to wood surface; burrows enlarge inward as animal grows; burrow entrance usually small (but larger than that of shipworms); a portion of the shell may be visible at burrow entrance.

Infected Timber Appearance: small round entrance holes visible and sometimes part of shell visible; little other external sign of infestation.

Zone of Attack: usually subtidal (below low tide line) to mudline

Salinity Tolerance: varies among species, usually high salinity

Natural Habitat: any submerged wood or other soft material

Food Source: suspended material in water

TOLERANCE OF WOOD BORERS TO STANDARD WOOD PRESERVATIVES

The tolerance of wood borers to standard timber preservatives varies among species of borers and also varies within a species under different environmental conditions. For example, *Limnoria tripunctata* is quite capable of infesting and consuming creosote treated wood in Florida under favorable environmental conditions of high salinity, high dissolved oxygen, and low pollution levels. Under stressful environmental conditions such as low salinity, low dissolved oxygen or high pollution levels (and in more northern latitudes), *Limnoria* may be able to colonize untreated timber but not creosote treated timber. Field tests conducted at several different locations by different observers have produced a general picture of which wood borers in Florida are most affected by standard wood preservative treatments. Table 4 summarizes the general picture of borer tolerance to preservatives.

RECOMMENDATIONS FOR AVOIDING OR MINIMIZING ATTACK BY WOOD-BORERS

The best line of defense against wood-borers is to know your enemy. Through analysis of samples from existing damaged wood or through collection of wood-borers on untreated test panels, the organism(s) responsible for attacks on timber at a specific site should be determined. This may require the help of an expert or may be carried out by the owner/operator with assistance from this bulletin or other literature. If an outside expert is needed, the nearest college or university biology department or your local Sea Grant Extension agent would be the place to start. Once the boring organism(s) has been identified, the appropriate wood preservatives can be selected based upon information in Table 4.

In addition to selecting the most appropriate wood preservative, some simple site modifications can significantly retard subsequent attack by some wood-borers. Many of these modifications appear to be common sense but were not being done at numerous marinas that we visited. For example:

- Remove derelict wood from existing structures, basins, shorelines, and areas adjacent to the marina. Old damaged timber often contains dense populations of borers that will readily colonize the new timber used for replacement. Also, encourage your neighbors to remove derelict wood from their sites since wood borers may disperse over several miles as larvae or as adults.

- Never "sister" or "scab" new pilings onto old ones, especially if the old pilings are attacked. This practice facilitates invasion of the new wood by borers since all they have to do is walk from one piling to the next. Always remove old timber if there is any evidence of attack by borers.

- Avoid deploying untreated or poorly treated timber at your site. Untreated wood is rapidly colonized by borers and can provide a source area from which borers can attack more resistant treated timber. Deployment of one or two untreated test panels for collection and identification of wood-borers at a site will not cause a problem as long as the panels are retrieved at appropriate intervals. 27% of the marinas that we visited had untreated timber exposed to borer attack.

For identified wood-borers that feed primarily on suspended material in the water (*Sphaeroma*, pholads, mussels), the following measures may help to reduce infestation

- Reduce or retain stormwater runoff so that particulate matter is not added to the water and existing sediments are not resuspended. Stormwater particulates and resuspended sediment can provide valuable food material for the borers.

- Design or redesign basins so that fine sediments do not accumulate near the site. These sediments are easily resuspended by boat traffic and provide food for borers.

- Implement and enforce idle speed or "no wake" speed limits to reduce agitation of bottom water and resuspension of food material for borers.

For documented infestations of *Sphaeroma* specifically, the following actions will slow borer damage to timber.

- Replace or modify exposed foam in floating docks. *Sphaeroma* readily invades unprotected foam and uses this habitat as a source area for attack on timber.

- Repair damage to piling surfaces immediately, especially in the intertidal zone. This can be done by plugging the burrows with marine grade putty or epoxy. Several commercially available plastic or PVC piling wraps are also available. These wraps will suffocate existing borers and prevent new animals from entering the wood.

- Install new or replacement cross-bracing either above the high water line or below the low water line since *Sphaeroma* prefers to inhabit the zone in between tidelines.

- Remove or replace piling rubrailings or fenders that are made from carpet or other woven materials. These provide additional habitat for *Sphaeroma* and hide piling damage.

- Coordinate your activities with your neighbors, where appropriate, since most of these site modifications will not be effective if a source population of wood-borers is located nearby.

LONG-TERM STUDIES

As part of the original study plan, seven sites were selected for long-term monitoring of wood-borer attack with special reference to *Sphaeroma terebrans*. The location of these intensive study sites is shown in Figure 8. Each site had an active population of *S. terebrans* while other wood-borers were also present at some sites. An array of test panels was deployed at each site (except for the Myakka River site which was the subject of an intensive environmental study conducted in 1986) and included both commercially available wood preservatives and an experimental treatment. Twelve wooden test panels were deployed at each site on two suspension racks designed to clamp onto pilings. Three replicate panels of three different wood treatments plus an untreated control were distributed on the two racks at each site.

As of this writing, the test panels have only been exposed for about two years and show limited attack (Table 5). However, they seem to be following a similar pattern of degradation to panels installed in 1984 at another Florida location (Table 3). Continued monitoring of these test sites is being coordinated by one of us (BRJ) and additional information on the performance of the various treatments will be available in future publications.

120d

Figure 8. Location of seven Florida sites for long-term monitoring of borer attack.

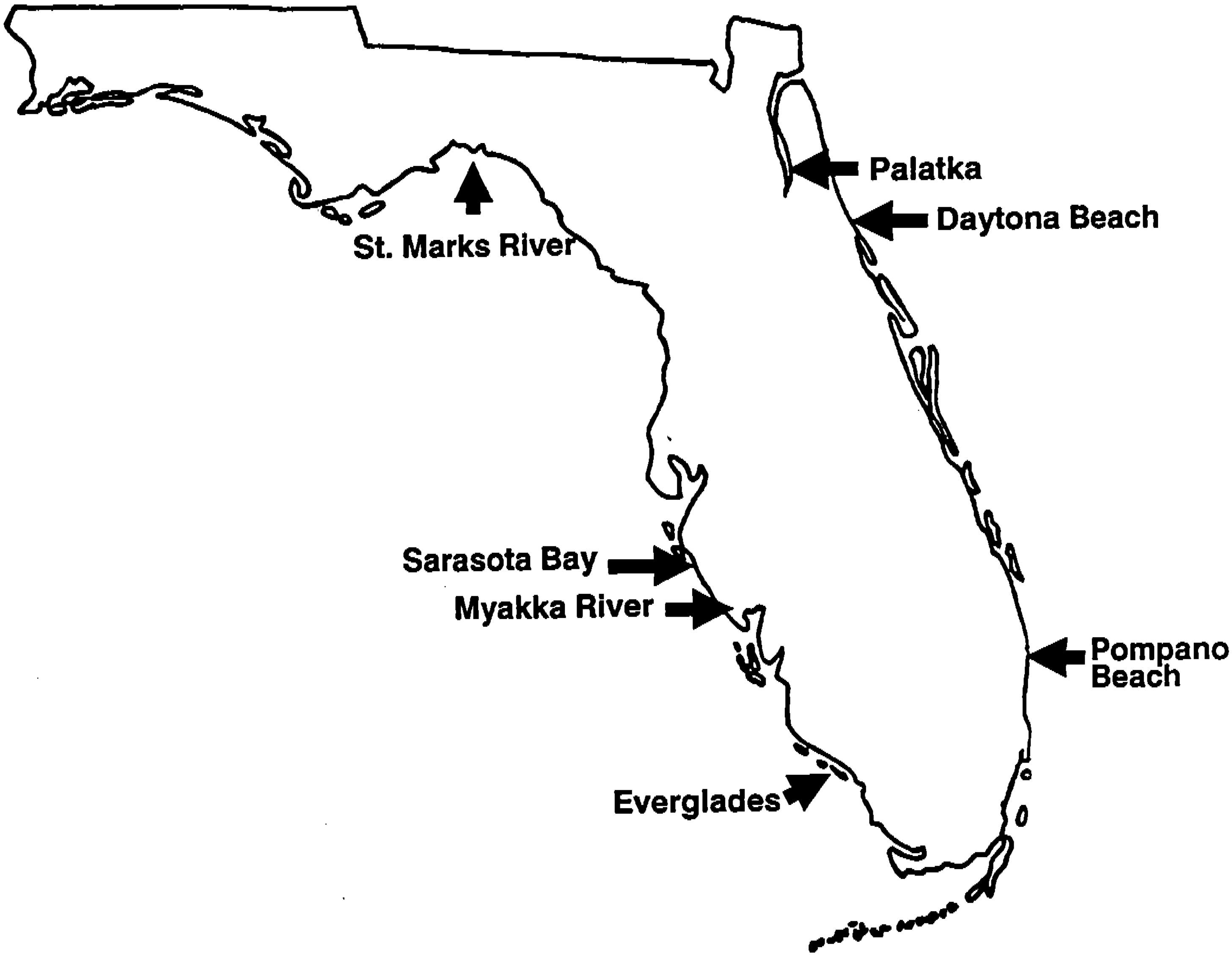


Table 5. Condition of Test Panels After Two Years at Six Florida Sites.

Site	Salinity (ppt)	Mean Rating*			
		Untreated Control	Chlorinated Rubber	CCA (2.5 pcf)	Creosote (25 pcf)
St. Marks River	8	0	10	9.7	9.7
Sarasota Bay	35	6	8.3	10	10
Barron River (Everglades City)	28	3.7	9	10	10
Intercoastal (Pampano Beach)	32	0	2.3	9	9
Halifax River (Daytona Beach)	16	9	9	10	10
St. Johns River (Palatka)	0	1.3	9.7	10	10

* Damage Index: 10= no *Sphaeroma* burrows; 9= light attack; 7= moderate attack 4= heavy attack; 0= destruction or loss of panel integrity

LITERATURE

Clapp Laboratories, Inc. *Harbor reports on marine borer activities compiled for the Bureau of Yards and Docks.* U. S. Navy, Civil Engineer Corps, Wash. D.C. NavDocks P-43, 1950.

Conover, David, O. and George K. Reid. *Distribution of the boring isopod* Sphaeroma terebrans: *a threat to the mangroves of southwestern Florida.* Science 182: 173-174, 1975.

Cragg, S. M. and C. R. Levy. *Attach by the crustacean,* Sphaeroma *on CCA-treated softwood in Papua New Guinean waters.* International Journal of Wood Preservation, Vol. 1 (4), 1981, pp. 161-168.

Estevez, Ernest D. and Joseph L. Simon. *Systematics and ecology of* Sphaeroma *(Crustacea: Isopoda) in the mangrove habitats of Florida.* In: G.E. Walsh, Ed, Proceedings of the International Symposium on Biology and Management of Mangroves. University of Florida. 1974, pp. 286-304.

Johnson, Bruce R. *Protection of timber bulkheads from marine borers.* In: J. Grahm, Ed. Timber Bulkheads. Geotech. Spec. Pub. No. 7: Proceedings, Geotechnical Engineering Division of the American Society of Civil Engineers, 1986, pp 16-34.

Jones, C.P. *Deterioration and repair of timber and concrete pilings.* Marine Advisory Bulletin MAP-27, Florida Sea Grant College Program. 1982, 14 pp.

Menzies, Robert J. and Dirk Frankenberg. *Handbook of the common marine isopod crustacea of Georgia.* Univ. of Georgia Press. 1966. 93pp.

Menzies, Robert J. and Ruth D. Turner. *Distribution and importance of marine wood borers in the United States.* Symp. on Wood for Marine Use and Protection from Marine Organisms. Amer. Soc. for Testing and Materials, Special Tech. Publ. 200, 1957.

Schultz, George A. *How to know the marine isopod crustaceans.* W.C. Brown Company, Dubuque, Iowa. 1969, 359 pp.

Turner, Ruth D. *Status of systematic work in the Teredinidae.* In: Marine Boring and Fouling Organisms, D.L. Day (ed). Univ. of Washington Press, 1959.

Turner, Ruth D. *A survey and illustrated catalogue of the Teredinidae (Mollusca: Bivalvia).* Museum of Comparative Zoology, Harvard University. 1966, 265 pp.

Voss, Gilbert L. *Seashore life of Florida and the Caribbean.* Banyan Books, Miami. 1976, 199 pp.

Table 5. Mean and percent biomass (g $dwt^{-1}m^{-2}$) and energetics ($kilocal.^{-1}m^{-2}$) of the three plant components (seagrasses, attached algae, drift algae) of a seagrass bed off Seahorse Key channel near Cedar Key, on the west coast of Florida. See Table 1 for sample sizes, standard deviations, code to species and ratio.

Date 1982-83	Species	Biomass Component	Biomass Percent	Energetics Component	Energetics Percent	Ratio E to B
29 June	1A	386 (± 63)	79	926	78	2.4
	1B	94 (± 60)	19	225	19	2.4
	1C	9 (± 19)	2	28	3	3.1
	3J	0.4 (± 0.1)	0	1	0	2.5
	Total	489		1180		2.4
24 Sept.	1A	105 (± 65)	31	220	30	2.1
	1B	212 (± 128)	63	446	62	2.1
	3D	0.5 (± 1)	0	1	0	2.0
	3E	19 (± 21)	6	55	8	2.9
	3F	1 (± 1)	0	2	0	2.0
	Total	338		724		2.1
20 Nov.	1A	52 (± 68)	47	115	38	2.2
	1B	52 (± 51)	47	145	48	2.8
	1C	0.3 (± 0.7)	0.4	1	0.5	3.3
	3D	0.5 (± 0.6)	0.6	1	0.5	2.0
	3F	19 (± 6)	5	39	13	2.1
	Total	124		301		2.4
28 Jan.	1A	34 (± 11)	62	100	60	2.9
	1B	20 (± 9)	36	64	39	3.2
	3F	0.3 (± 0.5)	1	0.6	0	2.0
	3J	1 (± 2)	1	1	1	1.0
	Total	55		166		3.0
1 April	1A	18 (± 8)	37	56	35	3.1
	1B	31 (± 14)	63	106	65	3.4
	Total	49		162		3.3
23 May	1B	256 (± 102)	100	819	99	3.2
	3E	1.0 (± 0.5)	0	3	1	3.0
	Total	256		822		3.2
29 July	1A	409 (± 151)	71	1189	65	2.9
	1B	171 (± 220)	29	647	35	3.8
	Total	580		1836		3.2

Table 6. Mean and percent biomass (g dwt^{-1}m^{-2}) and energetics (kilocal.$^{-1}$m^{-2}) of the three plant components (seagrasses, attached algae, drift algae) of a seagrass bed in Weeki Wachee River Bay on the west coast of Florida. See Table 1 for sample sizes, standard deviations, code to species and ratio.

Date 1982-83	Sepcies	Biomass Component	Biomass Percent	Energetics Component	Energetics Percent	Ratio E to B
29 June	1A	83 (± 39)	72	267	75	3.2
	2B	4 (± 9)	3	10	3	2.5
	2E	10 (± 21)	9	32	9	3.2
	3J	18 (± 8)	16	46	13	2.6
	Total	115		355		3.1
10 Sept.	1A	101 (± 62)	99	275	99	2.7
	1C	0.5 (± 1)	0.7	2	0.7	4.0
	3F	0.4 (± 0.2)	0.3	0.7	0.3	1.8
	Total	103		278		2.7
20 Nov.	1A	130 (± 135)	99	311	99	2.4
	3C	0.2 (± 0.4)	1	1	1	5.0
	Total	130		312		2.4
28 Jan.	1A	187 (± 78)	80	242	86	1.3
	2A	7 (± 16)	3	12	4	1.7
	3C	5 (± 11)	2	10	4	2.0
	3F	6 (± 13)	2	14	5	2.3
	3G	4 (± 37)	12	9	3	2.3
	Total	209		282		1.3
1 April	1A	167 (± 86)	74	434	91	2.6
	3C	2 (± 1)	1	6	1	3.0
	3F	49 (± 37)	23	133	7	2.7
	3H	5 (± 6)	2	6	1	1.2
	Total	223		579		2.5
23 May	1A	51 (± 29)	41	152	42	3.0
	3C	1 (± 3)	1	18	5	3.0
	3F	72 (± 30)	58	191	53	2.7
	Total	125		361		2.9
29 July	1A	108 (± 49)	51	237	70	2.2
	3J	102 (± 42)	49	103	30	1.0
	Total	210		340		1.6

Table 7. Mean and percent biomass (g dwt^{-1}m^{-2}) and energetics (Kilocal.$^{-1}$m^{-2}) of the three plant components (seagrasses, attached algae, drift algae) of a seagrass bed in Homosossa River Bay on the west coast of Florida. See Table 1 for sample size, standard deviations, code to species, and ratio.

Date 1982-83	Species	Biomass Component	Biomass Percent	Energetics Component	Energetics Percent	Ratio E to B
30 June	1A	345 (± 502)	32	1103	28	3.2
	1B	560 (± 306)	52	1849	47	3.3
	2A	132 (± 12)	1	464	12	3.5
	3C	3 (± 7)	0	8	0	2.7
	3J	162 (± 106)	15	487	12	3.0
	Total	1202		3911		3.3
10 Sept.	1A	282 (± 248)	50	816	49	2.9
	1B	259 (± 183)	46	804	48	3.1
	3A	10 (± 15)	2	32	2	3.2
	3J	9 (± 13)	2	22	1	2.4
	Total	560		1674		3.0
20 Nov.	1A	200 (± 379)	49	514	43	2.6
	1B	206 (± 63)	50	660	56	3.2
	3F	3 (± 6)	1	7	1	2.3
	Total	409		1171		2.9
28 Jan.	1A	180 (± 123)	40	448	41	2.5
	1B	141 (± 130)	31	286	26	2.0
	2A	76 (± 58)	17	234	21	3.1
	3C	0.7 (± 1)	1	2	0	2.9
	3F	50 (± 65)	11	133	12	2.7
	Total	448		1103		2.5
1 April	1A	418 (± 52)	41	955	61	2.3
	1B	137 (± 76)	48	467	30	3.4
	2A	19 (± 23)	7	88	6	4.6
	3C	2 (± 2)	0	7	1	3.5
	3F	11 (± 10)	4	20	1	1.8
	3G	9 (± 3)	0	21	1	2.3
	Total	596		1558		2.6
23 May	1A	147 (± 123)	16	485	28	3.3
	1B	270 (± 213)	73	1078	62	4.0
	2A	18 (± 25)	5	71	4	3.9
	3C	4 (± 2)	0	6	1	1.5
	3F	11 (± 13)	3	53	3	4.8
	3G	11 (± 8)	3	34	2	3.1
	Total	462		1727		3.7
29 July	1A	632 (± 204)	59	1075	63	1.7
	1B	148 (± 349)	28	296	17	2.0
	2A	129 (± 101	12	322	19	2.5
	3F	3 (± 5)	1	14	1	4.7
	Total	912		1707		1.9

Table 8. Water temperature, T, and salinity, S, for seven seagrass beds on the west coasts of Florida (see Fig. 8 and 9 for code to sites).

	SITES													
	CRB		AMI		IBI		ANR		WWR		HSR		CDK	
	T	S	T	S	T	S	T	S	T	S	T	S	T	S
1982														
17 May	26	30	26	36	28	33								
13 June	29	27	30	34	30	33								
25 June	27	24	28	34	28	28								
29 June							32	26	32	14	30	26	28	25
16 July	29	25	30	35	29	34								
6 Aug	27	22	28	32	29	32								
27 Aug	29	24	30	32	32	29								
10 Sep							27	28	27	7	25	16	27	27
17 Sep	29	26	29	33	28	32								
8 Oct	30	21	28	32	28	29								
29 Oct	22	24	21	29	20	26								
19 Nov	-	27	-	31	-	28								
20 Nov							23	28	24	14	22	18	20	30
10 Dec	22	28	22	31	20	32								
31 Dec	18	28	21	34	20	31								
1983														
21 Jan	19	26	15	32	15	30								
28 Jan							16	30	14	21	14	18	12	28
11 Feb	17	21	17	32	15	28								
4 Mar	20	20	18	32	17	28								
25 Mar	17	27	15	31	12	25								
1 Apr							19	25	19	12	17	20	16	23
15 Apr	25	28	23	33	22	30								
6 May	24	22	21	32	19	28								
23 May							29	33	28	16	26	16	28	27
27 May	28	30	28	35	26	31								
17 June	28	26	28	32	27	32								
8 July	30	25	29	34	30	32								
29 July							30	31	28	11	28	26	29	27

Table 9. The mean standing stock + 1 standard deviation (SS + S.E.) expressed as grams dry weight^{-1}m^{2}, percent of the total standing stock (TSS) and seasonal ranges (highest and lowest dry wt^{-1}m^{2}) of *Thalassia testudinum*, all seagrasses, all seaweeds (drift and attached algae), and total biomass over the 14 month study (May, 1982 to July, 1983) of seven seagrass beds on the west coast of Florida. The seven west coast sites were Cockroach Bay (CRB) in Tampa Bay, Anna Maria Sound (AMI) at the mouth of Tampa Bay and 5 open coast sites: Indian Bluff Island (IBI), Anclote River Anchorage (ANR), Weeki Wachee River Bay (WWR), Homosassa River Bay (HSR), and at Seahorse Key off Cedar Key (CDK).

Site	*Thalassia testudinum*				All Seagrasses				All Seaweeds				Total Standing Stock		
	Mean SS	+ SE	Percent of TSS	Seas. range	Mean SS	+ SE	Percent of TSS	Seas. range	Mean SS	+ SE	Percent of TSS	Seas. range	Mean TSS	+ SE	Seasonal range
CRB	47	75	20	242-0	156	124	677	401-0	89	12	39	396-0	231	174	712-17
AMI*	302	297	78	838-0	357	296	92	1069-121	37	50	9	110-0	386	297	1078-122
IBI*	266	112	56	576-135	321	123	67	411-62	143	135	30	596-23	477	178	873-202
ANR*	194	125	53	342-29	311	155	85	571-87	69	65	19	201-31	365	136	605-191
WWR*	118	47	74	187-51	119	47	76	187-51	41	38	26	102-0	159	52	223-103
HSR*	315	170	48	632-147	535	242	82	905-321	95	102	14	297-3	656	294	1202-409
CDK*	180	168	67	409-0	264	212	98	580-49	6	9	2	20-0	270	210	580-49
*Mean of Thalassia Dominated Sites.	229	77	59		320	136	83		69	46	18		389	171	

Table 10. Means and seasonal range of standing stock (SS g dry wt^{-1}m^{2}) of Thalassia testudinum as reported in previous studies.

Site	Mean SS	Seasonal Range	Reference.
Texas	373	(summer only)	Odum (1963)
Florida			
west coast	700	(summer only)	Bauersfeld et al. (1969)
Boca Ciega Bay	81		Pomeroy (1960)
Boca Ciega Bay	80	1198-320 (Aug.)	Taylor and Saloman (1969)
Tarpon Springs		820-601	Dawes et al. (1979)
Bear Cut, Miami	830	1800-700	Jones (1968)
Biscayne Bay, Miami	126(inshore)	230-30	Zieman (1975)
Biscayne Bay, Miami	280(offshore)	650-80	Zieman (1975)
Cuba	340(sheltered)	517-240 (Aug.)	Buesa (1972,1974)
	80(exposed)	80-76 (Aug.)	Buesa (1971-1974)
St. Croix	77		Zieman et al. (1979)
Jamiaca	249	330-170	Greenway (1976)
Puerto Rico	80		Burkholder et al. (1959)

Table 11. Means and seasonal range (summer only) of standing stock (SS g dry $wt^{-1} m^{2}$) of *Zostera marina* as reported in previous studies.

Site	Mean SS	Seasonal Range	Reference
Denmark, Vellerup Vig		226 (Aug.)-58 (Mar.)	Sand-Jensen (1975)
		226 (Aug.)-12 (Apr.)	Sand-Jensen (1983)
		920-272	Peterson (1914)
		487-210	Grøntved (1957)
Russa-Bering Sea		895-31	Vozzhinskaya (1964)
Russa-Black Sea		550-166	Zenkevitch (1963)
France, Roscoff		260-92	Jacobs (1979)
North America			
Massessuchtus		29-5	Conover (1958)
Rhode Island		175 (Aug.)-2 (Apr.)	Thorne-Miller et al. (1983)
Chesapeake Bay		225 (July)-50 (Apr.)	Wetzel and Penhale (1983)
New York		2445-133	Burkholder and Dohney (1968)
New Jersey		426-110	Moeller (1964)
North Carolina	172	335-50	Thayer et al. (1977)
Japan		235-70	Kitz and Harada (1962)
Alaska	466	1840-62	McRoy (1970)
California		421-32	Keller and Harris (1966)

Figures 1-7. Bimonthly means of seagrass biomass (solid line, g dry wt.$^{-1}$ m^{-2}) and energetics (dashed line, kcal^{-1} m^{-2}) for seven sites on the west coast of Florida. Circles are equal to no more than 1/2 a S.D., the white portion of the circle shows percent of the dominant seagrass and the black portion the percent of other seagrass species.

Figure 1. Halodule wrightii at Cockroach Bay (CRB) mouth in Tampa Bay Florida based on means of triweekly collections. Another seagrass, Thalassia testudinum was dominant in May and June, 1982 and again in July, 1983.

Figure 2. Thalassia testudinum at Anna Maria Island Sound (AMI) at the mouth of Tampa Bay, Florida based on means of triweekly collections. Syringodium filiforme beds occurred intermixed with T. testudinum and these beds were randomly sampled in the spring and fall of 1982.

Figure 3. Thalassia testudinum at Indian Bluff Island (IBI) on the west coast of Florida based on means of triweekly collections. Although a mixed bed occurred, T. testudinum dominated throughout the study.

Figure 4. Thalassia testudinum at Anclote River anchorate (ANR) on the west coast of Florida based on means from biomonthly collections. The seagrass bed is a mixture of the three species.

Figure 5. Thalassia testudinum at Cedar Key on the Seahorse Key channel(CDK) on the west coast of Florida based on means of bimonthly samplings. Syringodium filiforme is a codominant at the site.

Figure 6. *Thalassia testudinum* at Weeki Wachee River Bay (WWR) on the west coast of Florida based on bimonthly samplings. The low salinity site supports pure stands of the seagrass.

Figure 7. *Thalassia testudinum* at Homosassa River Bay (HSR) on the west coast of Florida based on bimonthly collections. *Syringodium filiforme* occurred as well.

Figure 8 and 9. Proximate constituents of the dominant seagrass from seven sites on the west coast of Florida expressed as bimonthly means. Ash (A), soluble and insoluble carbohydrate (C), protein (dark portion of circle) and lipid (line) are expressed as percents of the circle and kilocalories are given in parentheses below for each bimonthly mean.

Figure 8. Proximate constituents of the dominant seagrasses for three sites near Tampa Bay: Indian Bluff Island (IBI) on the west coast, Anna Maria Island Sound (AMI) at the mouth of Tampa Bay, and Cockroach Bay mouth (CRB) in Tampa Bay. Data is based on means of triweekly collections.

Figure 9. Proximate constituents of the dominant seagrasse, *Thalassia testudinum*, for four sites on the west coast of Florida: Anclote River anchorage (ANR), Weeki Wachee River Bay (WWR), Homosassa River Bay (HSR), and Seahorse Key channel at Cedar Key (CDK). Data is based on means of bimonthly collections.

Figure 10 and 11. Bimonthly means of the dominant seaweek biomass (Fig. 10, g dry wt.$^{-1}$ m^{-2}) and energetics (Fig. 11, kcal^{-1} m^{-2}) at three sites near Tampa Bay (see Fig. 8 for code to sites). Circles are no more than 1/2 a S.D. and the bimonthly means are based on triweekly samplings.

Figure 12. Proximate constituents of the dominant drift seaweeds from the three sites near Tampa Bay, Florida. See Fig. 8 for code to graph and sites.

Figure 13 and 14. Mean biomass (Fig. 13, g dry wt.$^{-1}$ m^{-2}) and energetics (Fig. 14, kcal^{-1} m^{-2}) of all macrophytic components for the three seagrass beds near Tampa Bay, Florida based on means of triweekly collections. Seagrass (S), drift seaweeds (D), and attached algae (dark portion of circle) are presented as percent of the circle with mean total biomass (Fig. 13) and energetics (Fig. 14) given in parentheses below each mean. See Fig. 8 for code to sites.

Figure 15 and 16. Mean biomass (Fig. 15, g dry wt.$^{-1}$ m^{-2}) and energetics (Fig. 16, kcal^{-1} m^{-2}) of all macrophytic components for four seagrass beds on the west coast of Florida. See Fig. 13 and 14 for code to circles and Fig. 9 for code to sites.

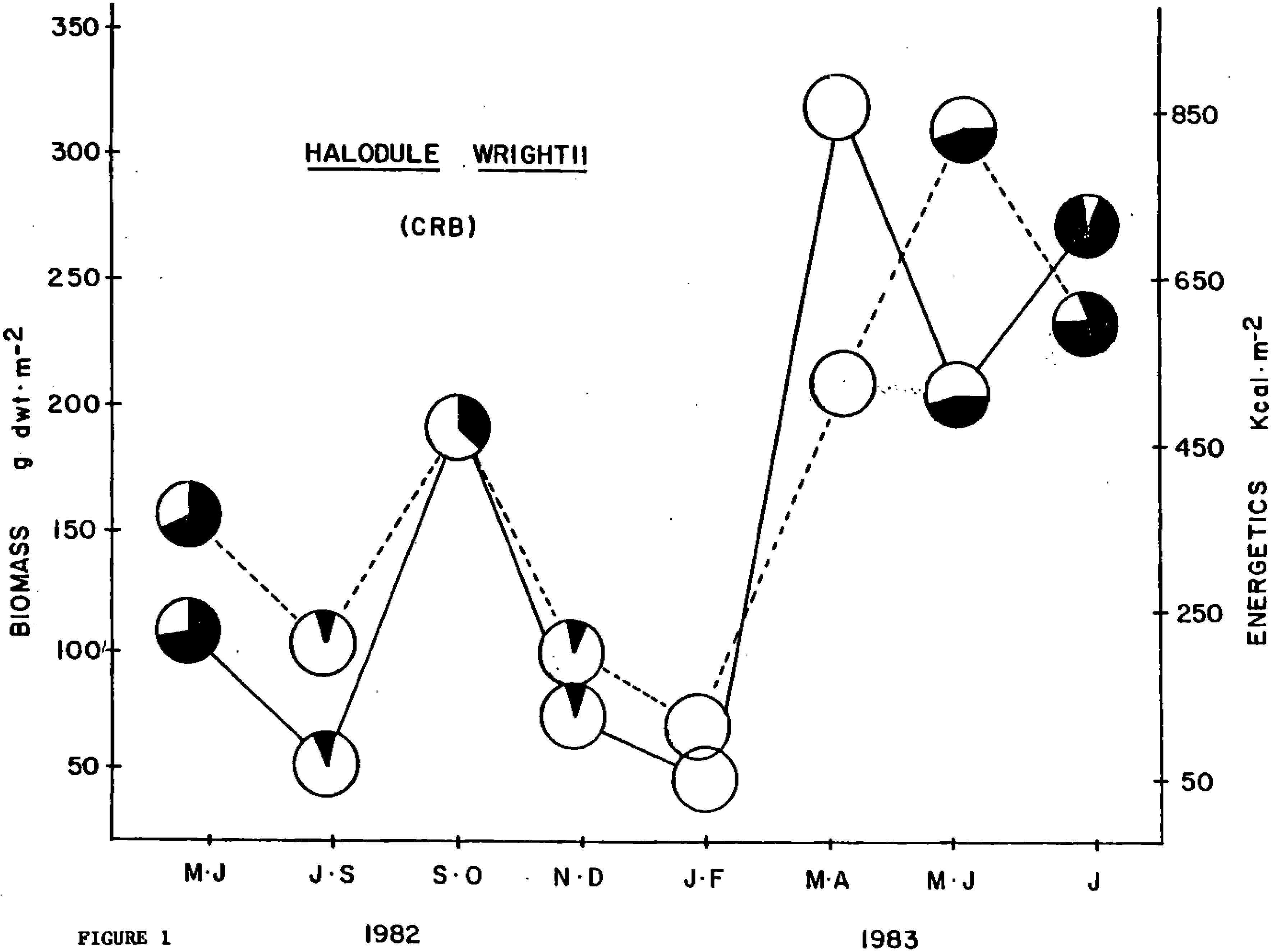

HALODULE WRIGHTII
(CRB)
BIOMASS g dwt · m-2
ENERGETICS Kcal · m-2
350
300
250
200
150
100
50
850
650
450
250
50
M·J
J·S
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 1

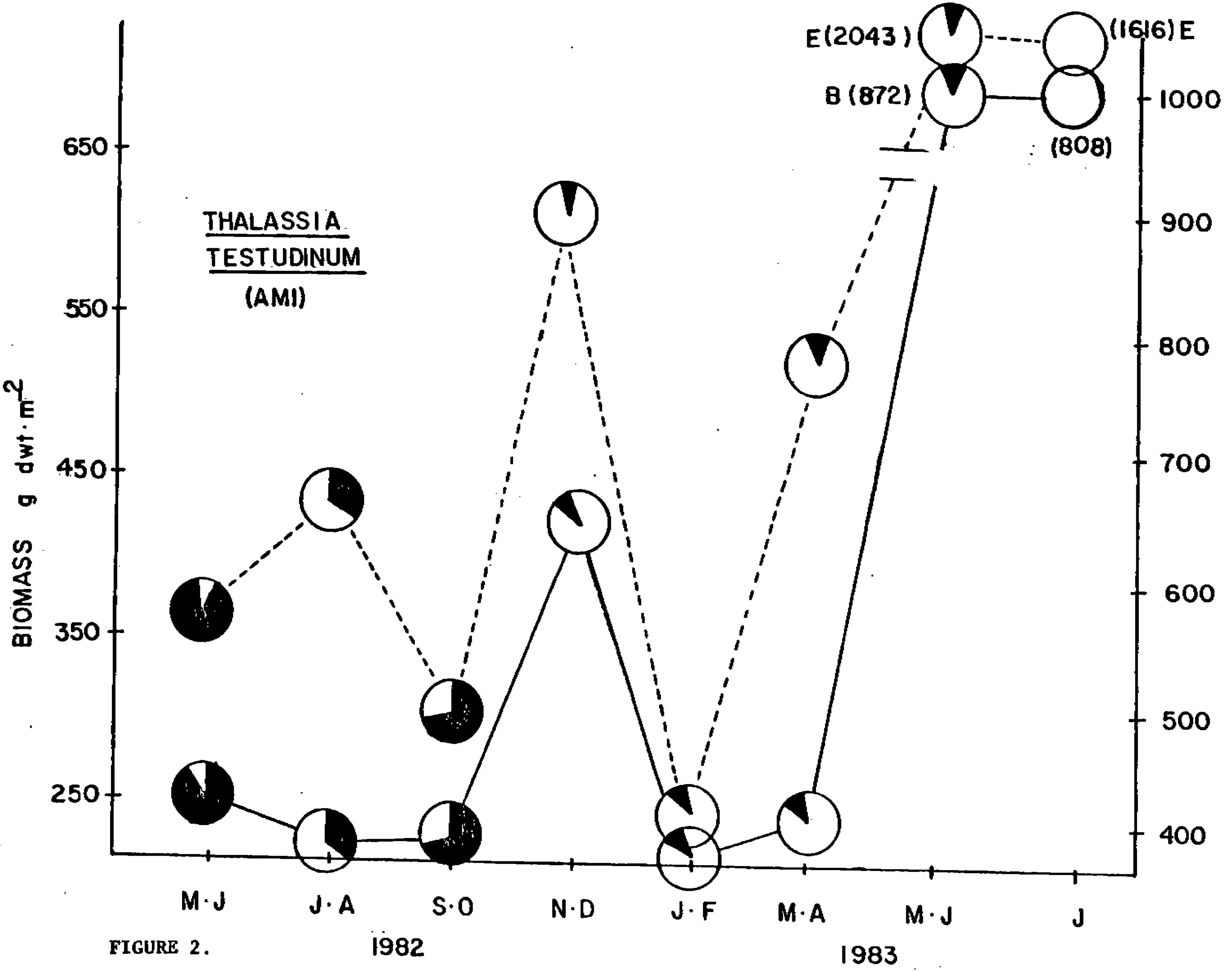

THALASSIA TESTUDINUM
(AMI)
E(2043)
(1616)E
B (872)
(808)
BIOMASS g dwt · m^-2
ENERGETICS Kcal · m^-2
650
550
450
350
250
1000
900
800
700
600
500
400
M·J
J·A
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 2.

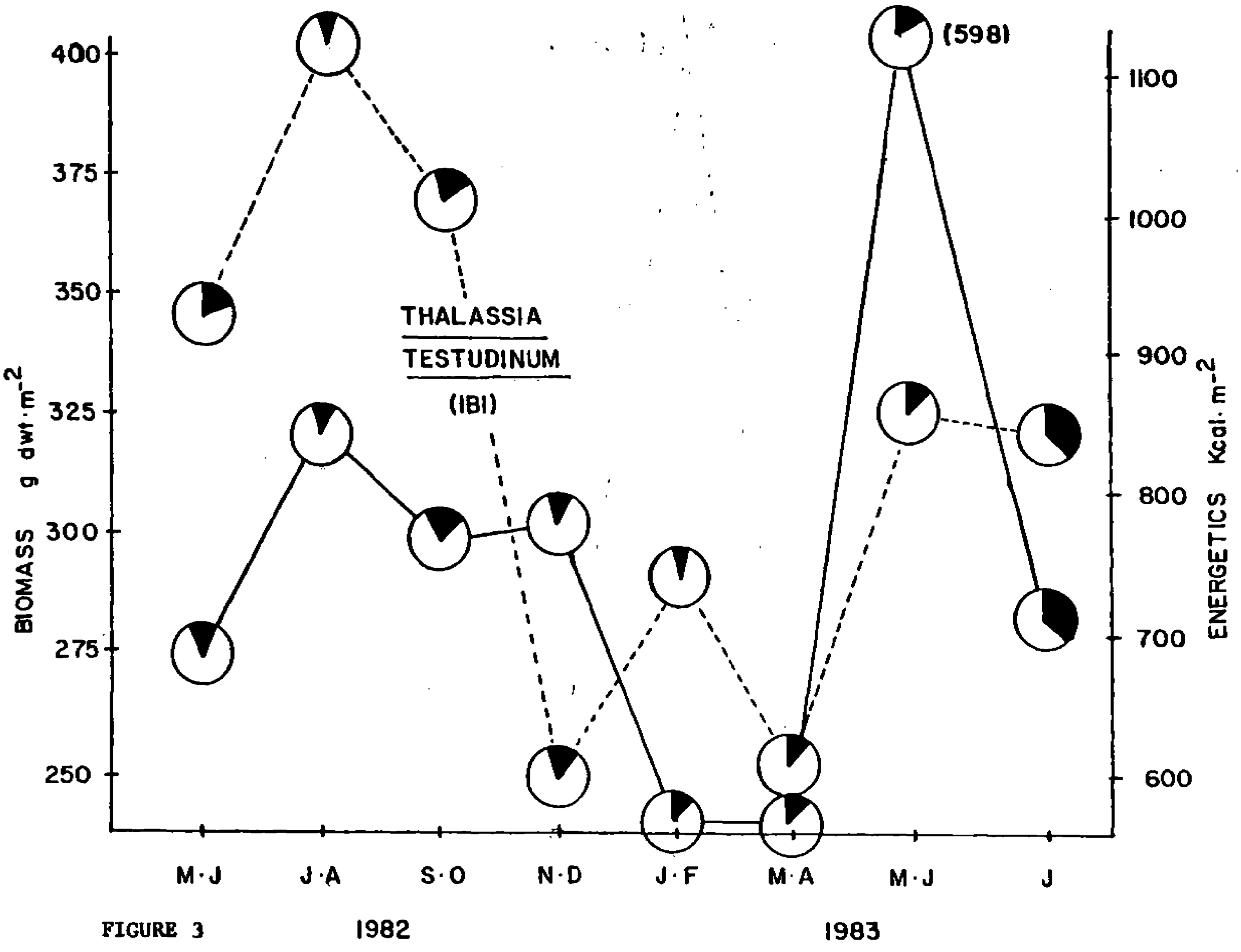

400
375
350
325
300
275
250
BIOMASS g dwt·m-2
THALASSIA
TESTUDINUM
(IBI)
(598)
1100
1000
900
800
700
600
ENERGETICS Kcal·m-2
M·J
J·A
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 3

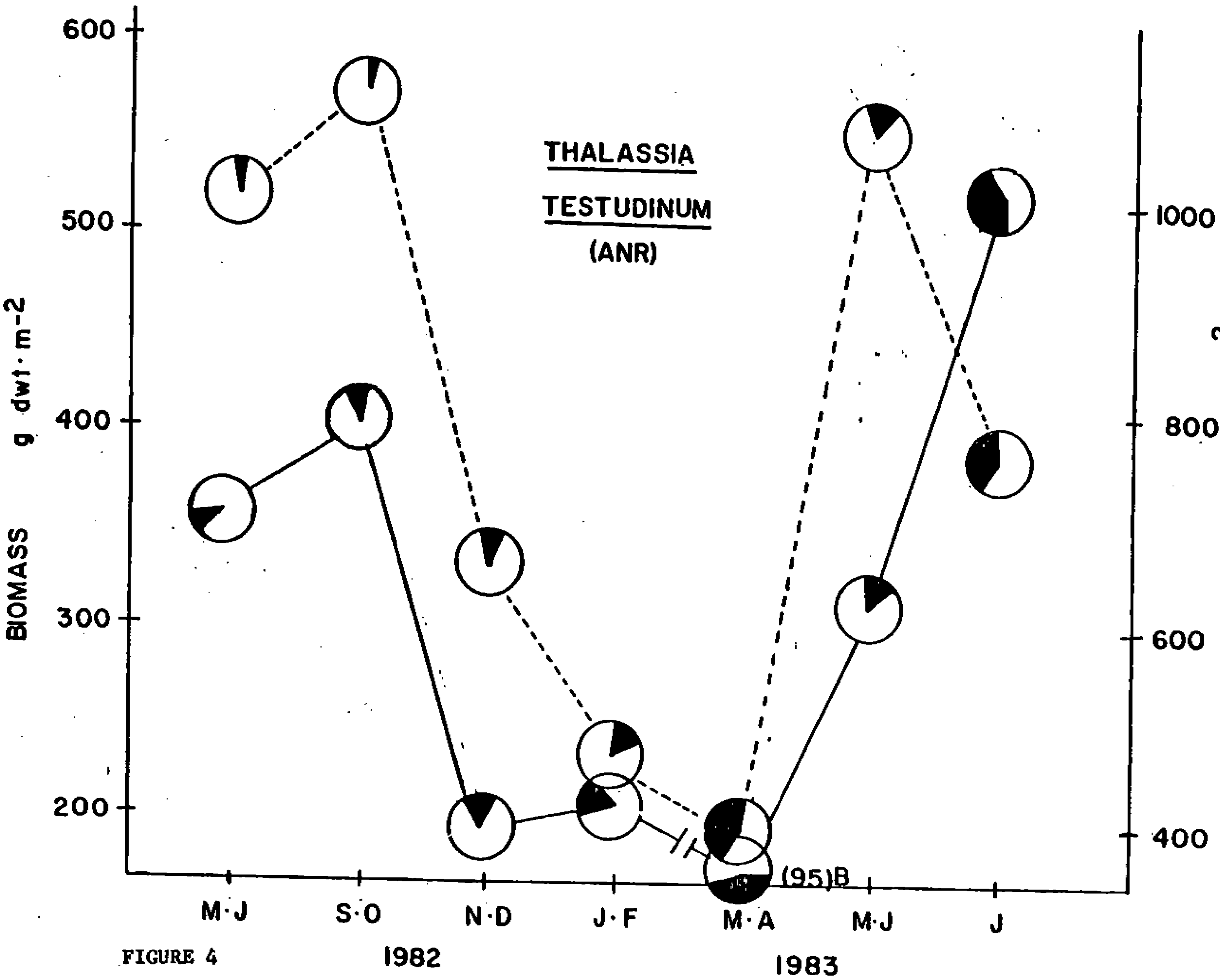

THALASSIA
TESTUDINUM
(ANR)
600
500
400
300
200
BIOMASS g dwt · m-2
1000
800
600
400
ENERGETICS Kcal · m-2
(95)B
M·J
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 4

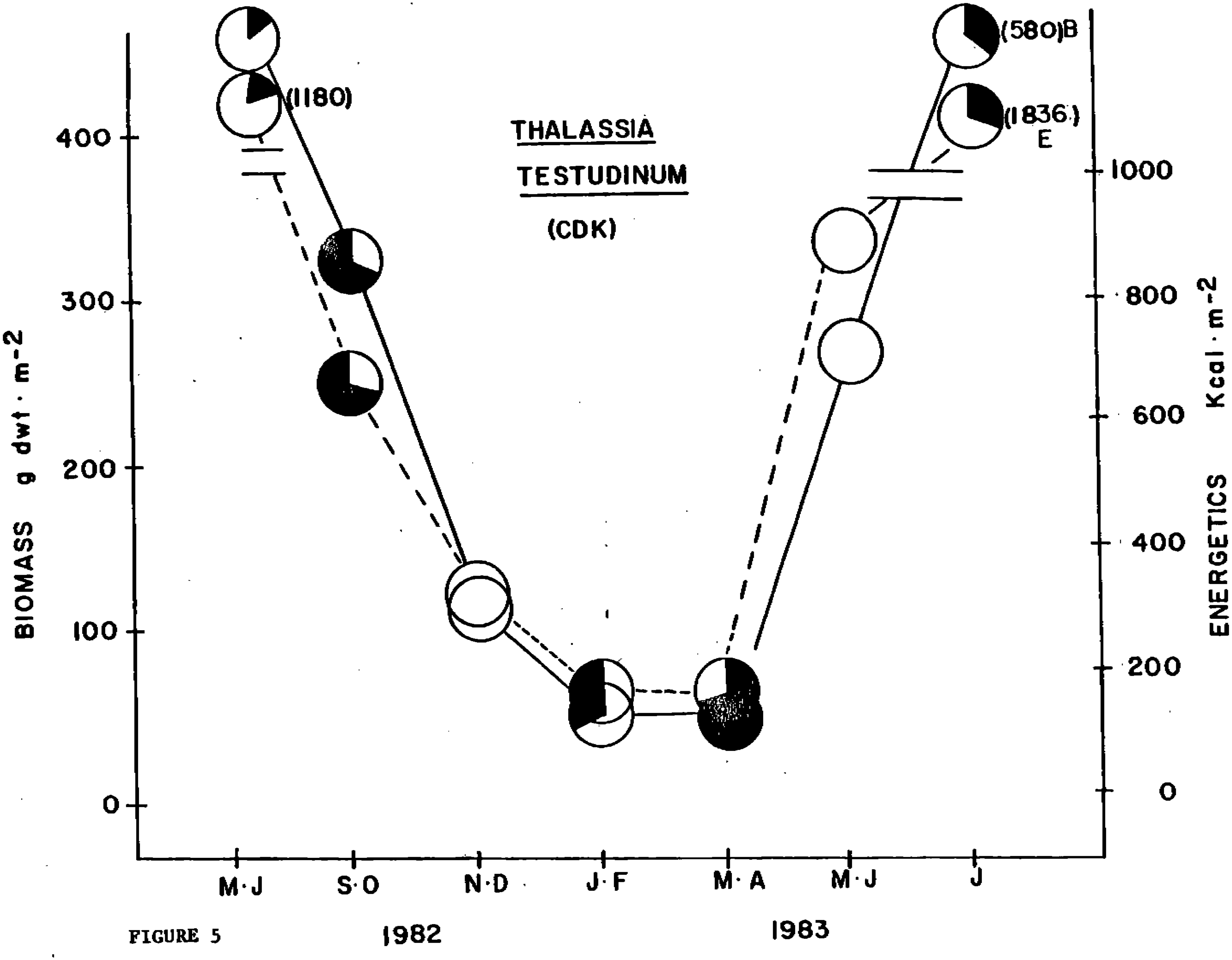

THALASSIA
TESTUDINUM
(CDK)
(1180)
(580)B
(1836)
E
BIOMASS g dwt · m-2
ENERGETICS Kcal · m-2
400
300
200
100
0
1000
800
600
400
200
0
M·J
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 5

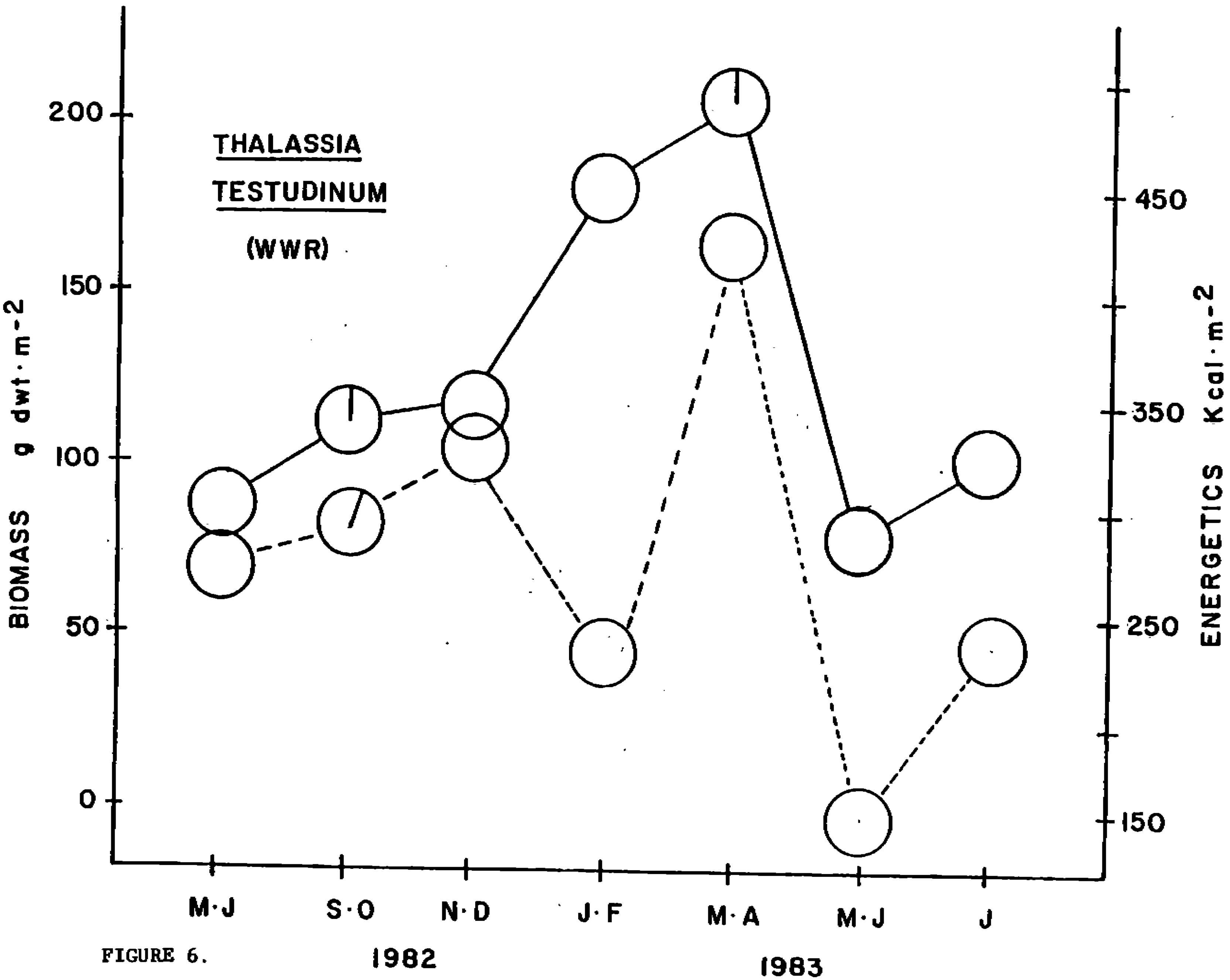

THALASSIA
TESTUDINUM
(WWR)
BIOMASS g dwt · m-2
200
150
100
50
0
ENERGETICS Kcal · m-2
450
350
250
150
M·J
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 6.

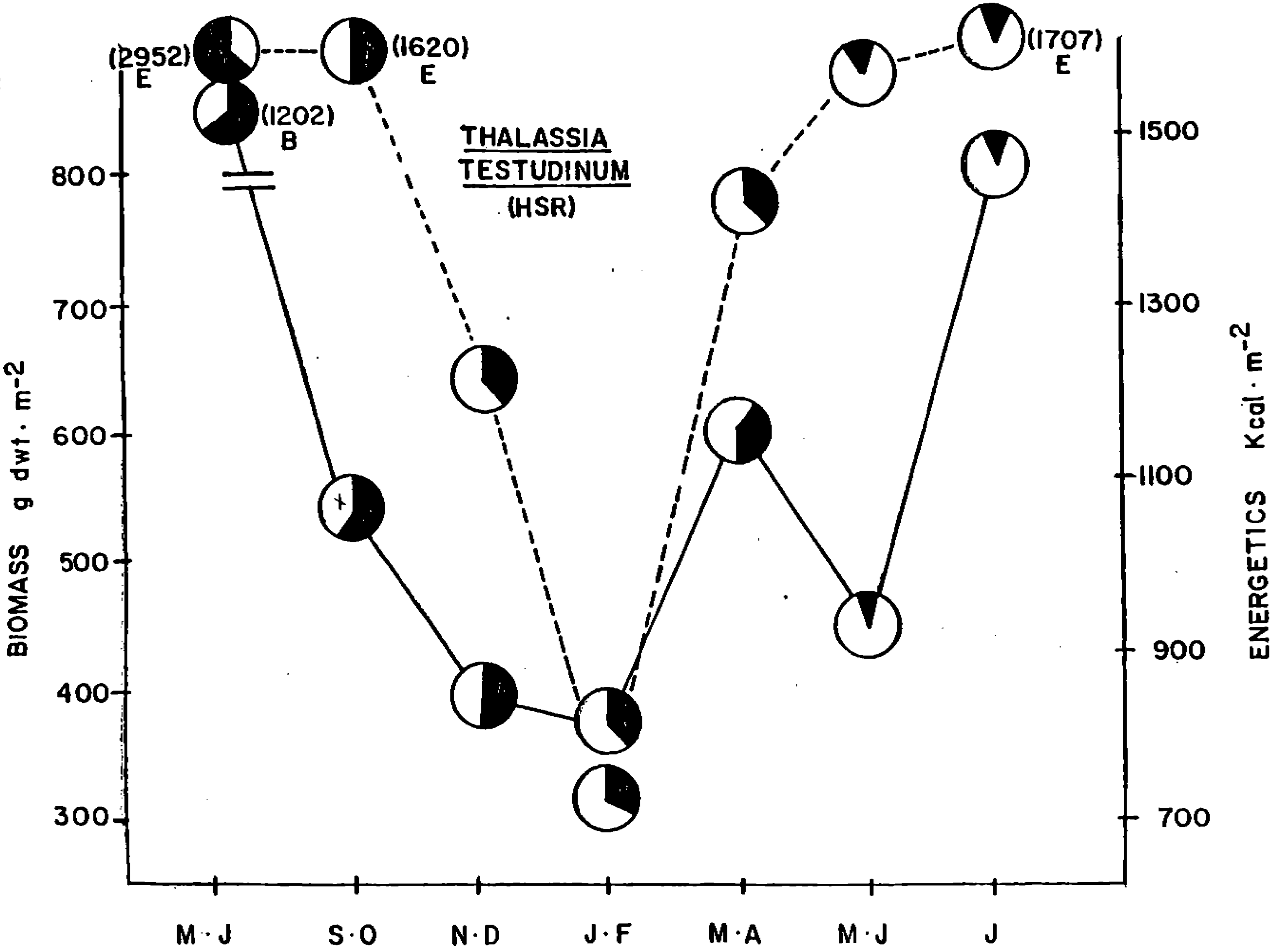

THALASSIA
TESTUDINUM
(HSR)
(2952)
E
(1620)
E
(1202)
B
(1707)
E
BIOMASS g dwt · m-2
ENERGETICS Kcal · m-2
800
700
600
500
400
300
1500
1300
1100
900
700
M · J
S · O
N · D
J · F
M · A
M · J
J
1982
1983

FIGURE 7.

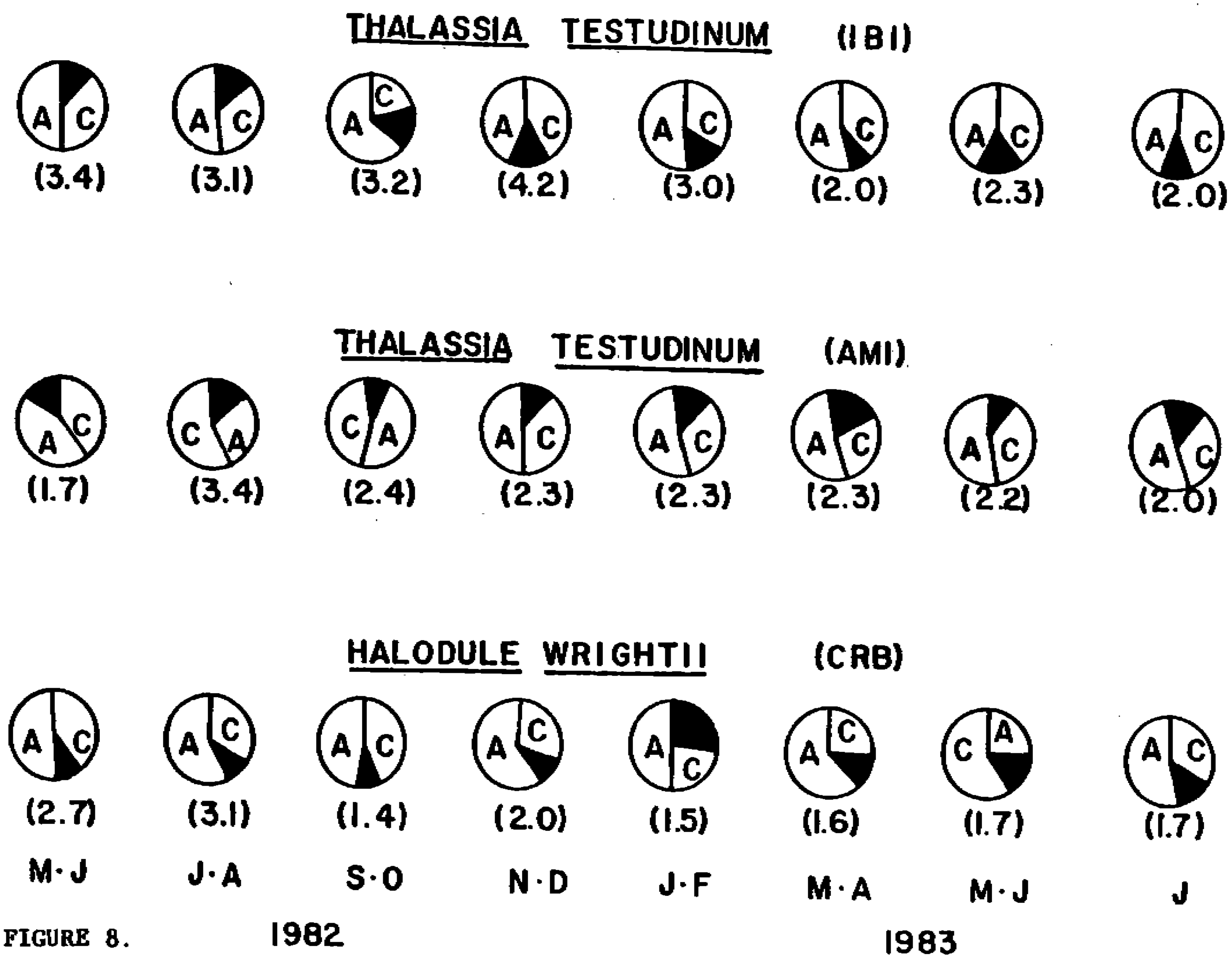

THALASSIA TESTUDINUM (IBI)
A C
(3.4) (3.1) (3.2) (4.2) (3.0) (2.0) (2.3) (2.0)
THALASSIA TESTUDINUM (AMI)
(1.7) (3.4) (2.4) (2.3) (2.3) (2.3) (2.2) (2.0)
HALODULE WRIGHTII (CRB)
(2.7) (3.1) (1.4) (2.0) (1.5) (1.6) (1.7) (1.7)
M·J J·A S·O N·D J·F M·A M·J J
1982
1983

FIGURE 8.

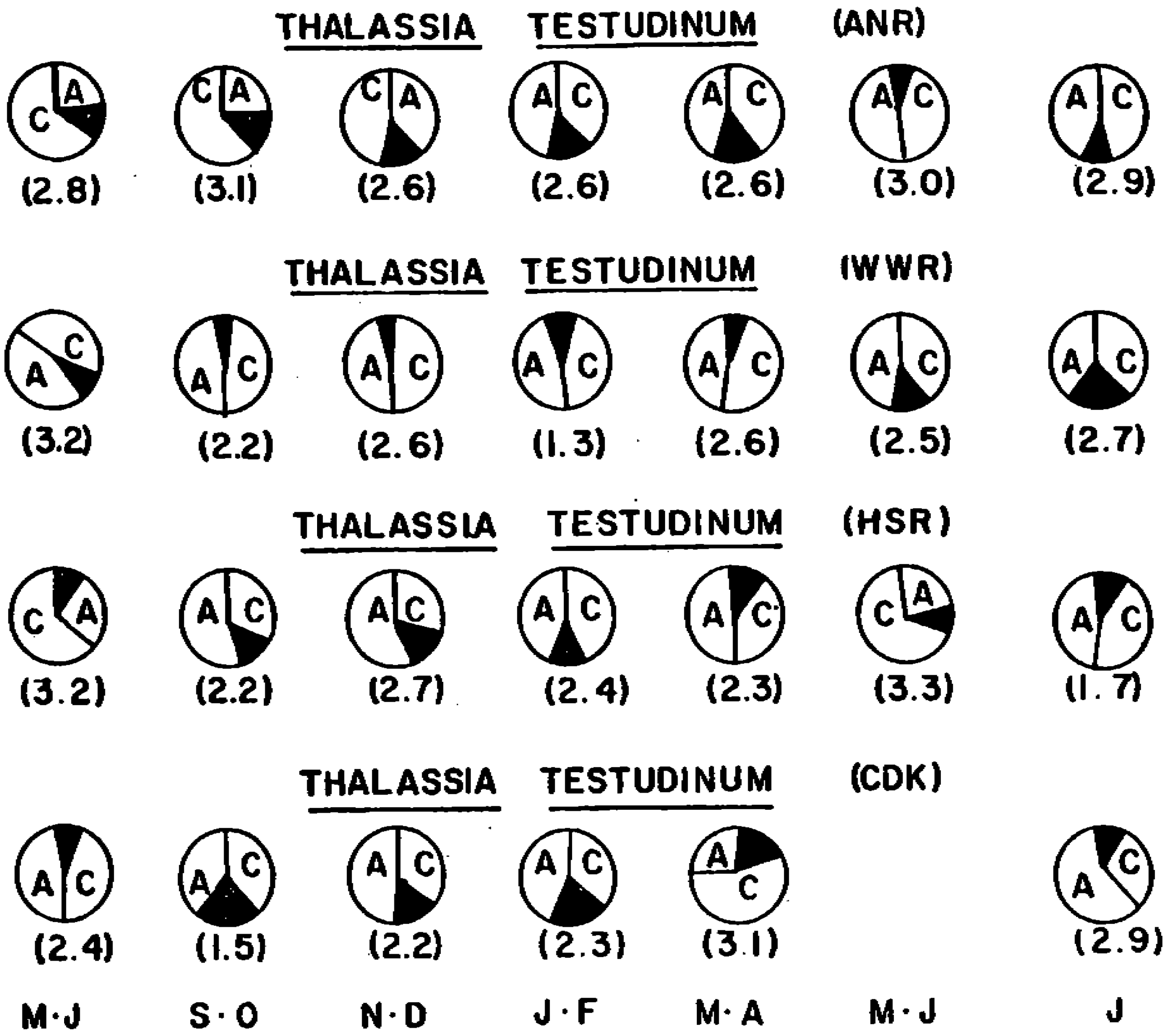


FIGURE 9. 1982 1983

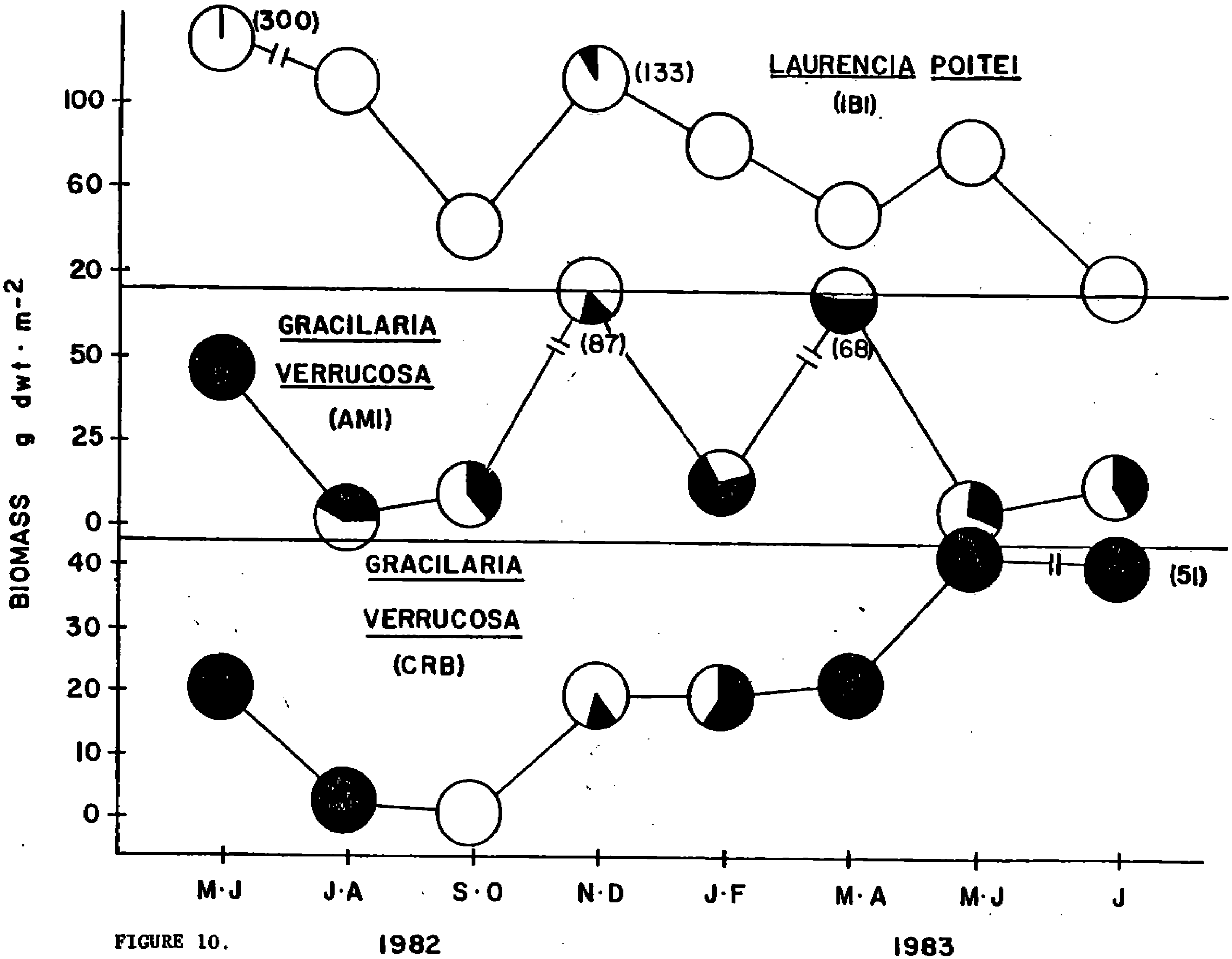

LAURENCIA POITEI
(IBI)
GRACILARIA
VERRUCOSA
(AMI)
GRACILARIA
VERRUCOSA
(CRB)
BIOMASS g dwt · m-2
(300)
(133)
(87)
(68)
(51)
100
60
20
50
25
0
40
30
20
10
0
M·J
J·A
S·O
N·D
J·F
M·A
M·J
J
1982
1983

FIGURE 10.

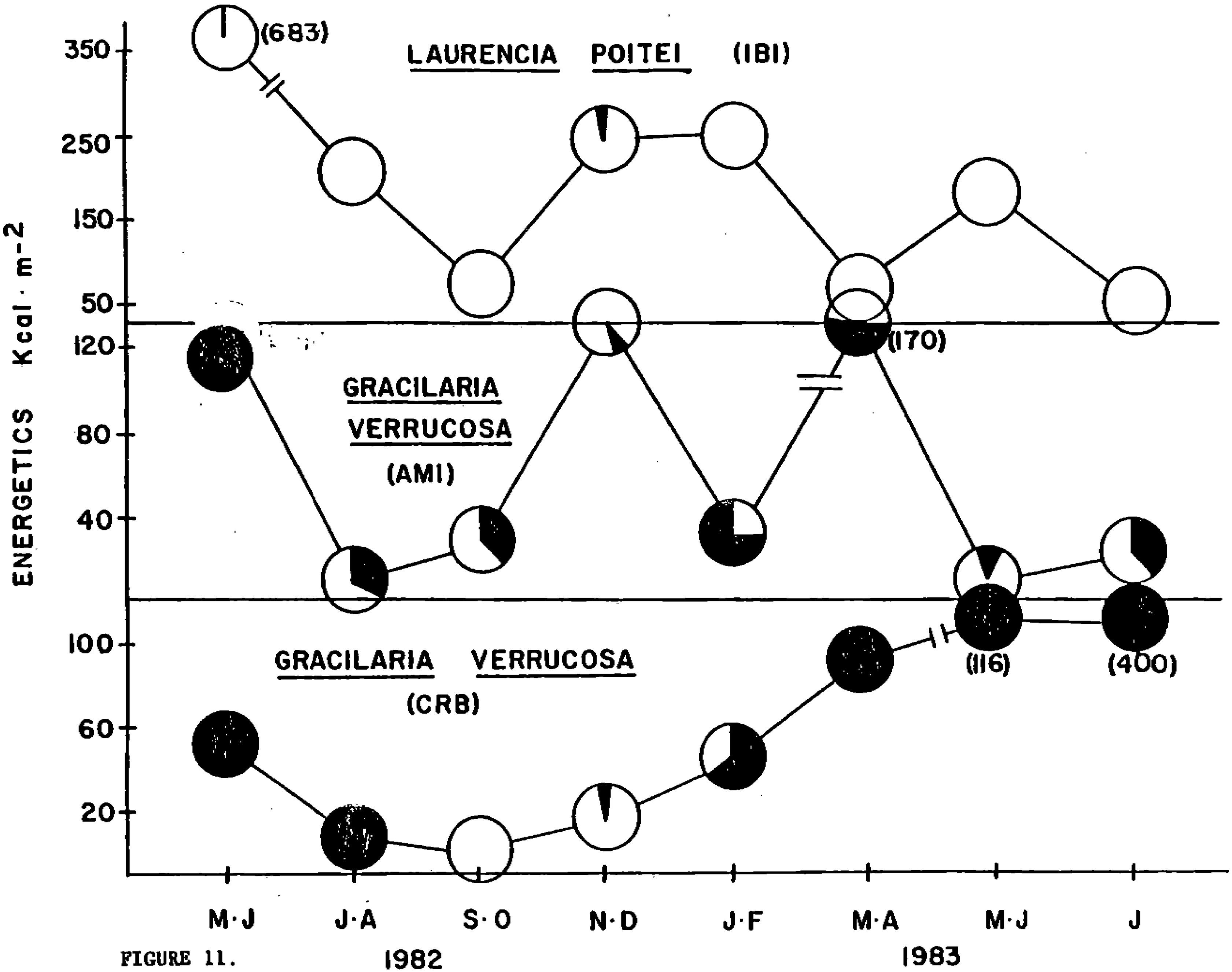


FIGURE 11.

1209

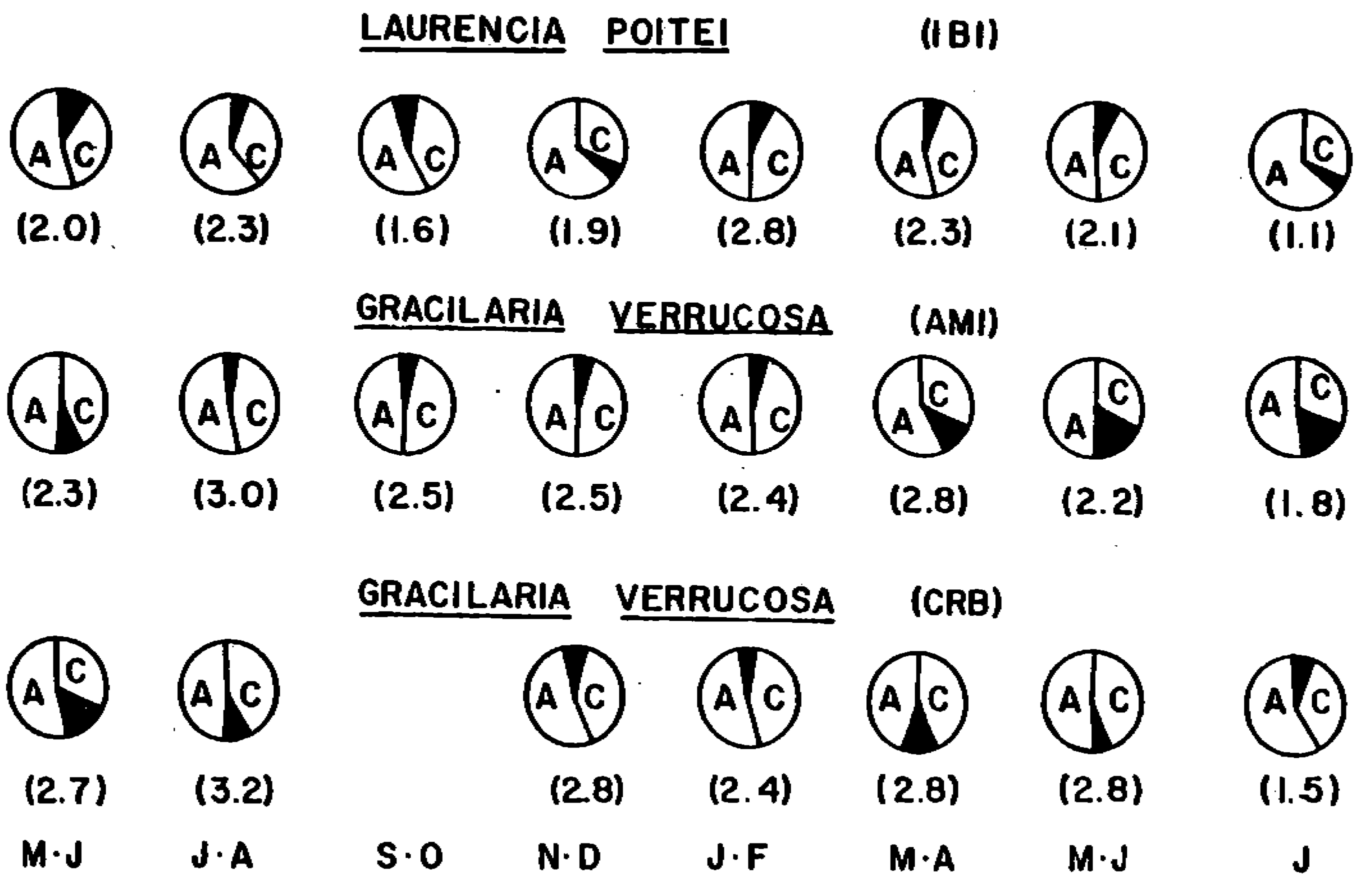


FIGURE 52 1982 1983

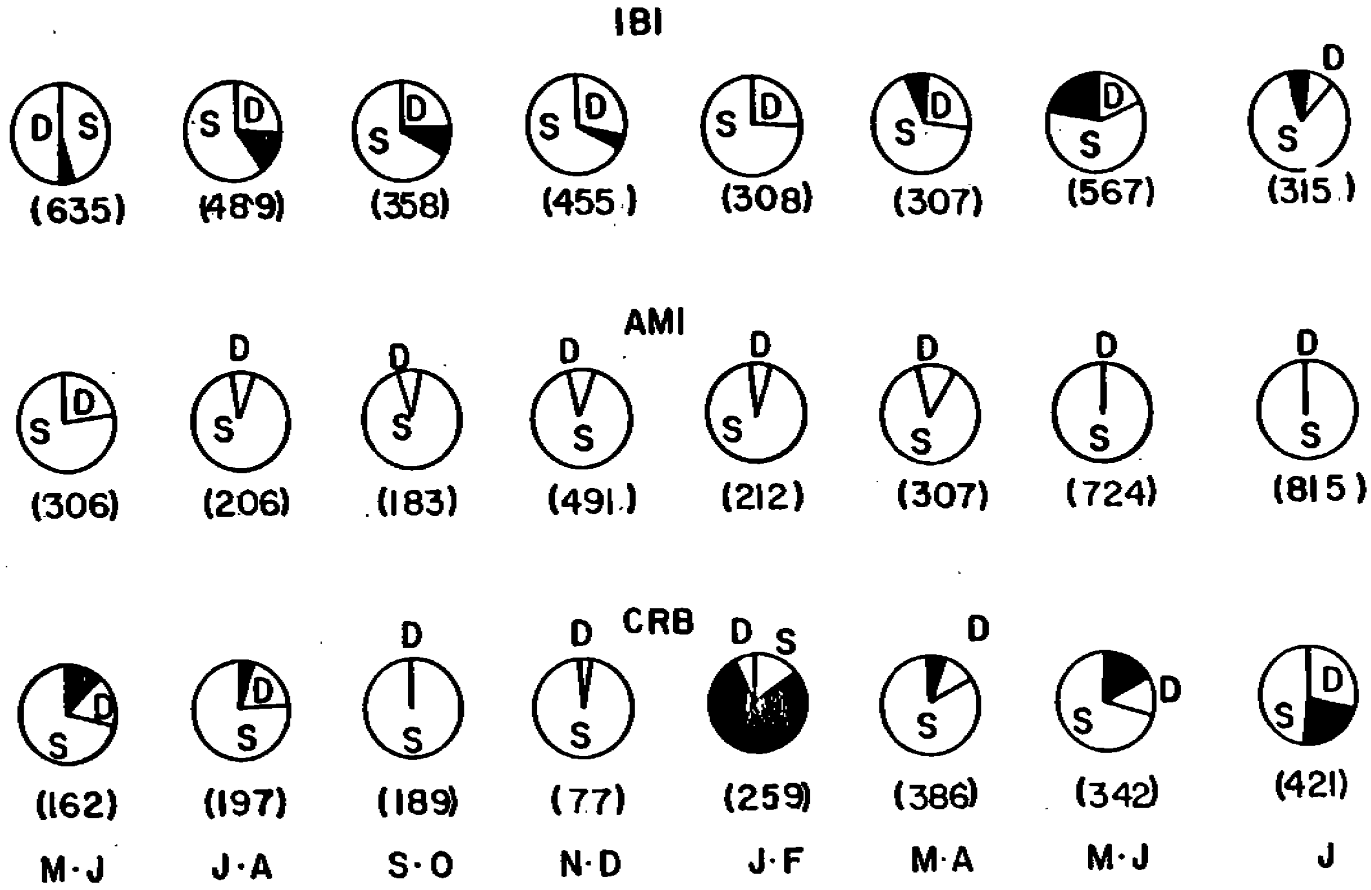


FIGURE 13 1982 1983

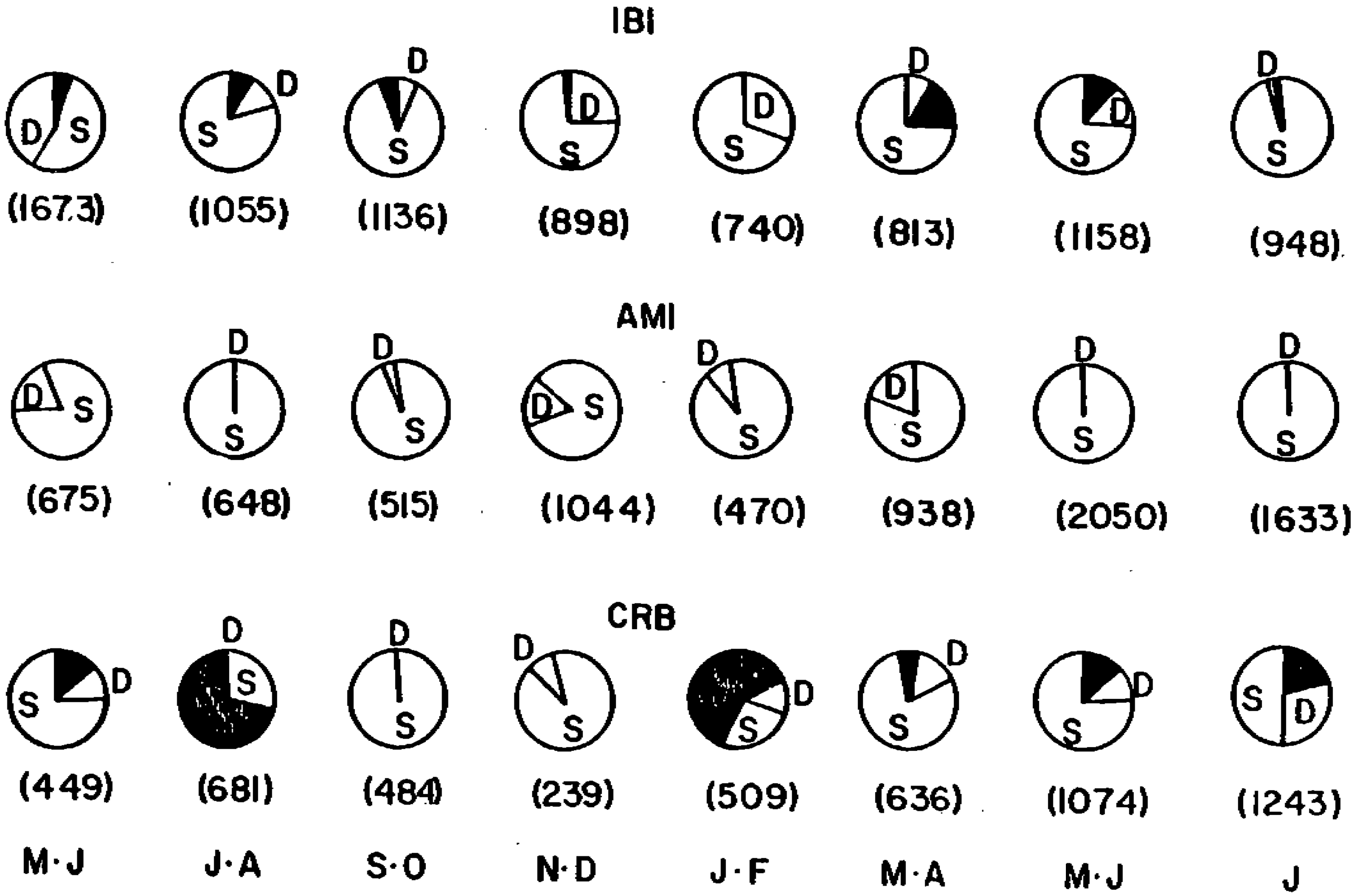


FIGURE 14 1982 1983

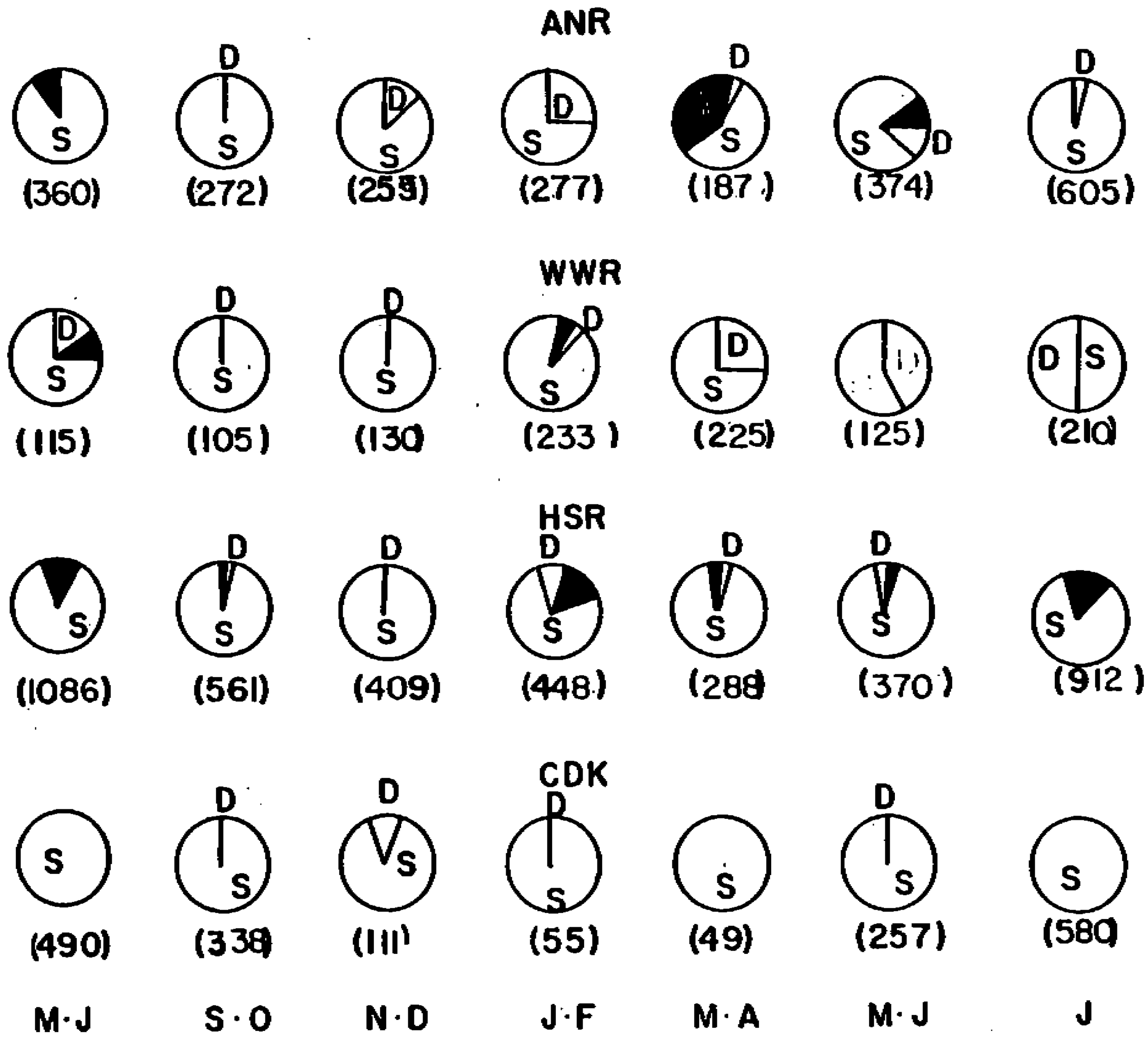


FIGURE 16 1982 1983

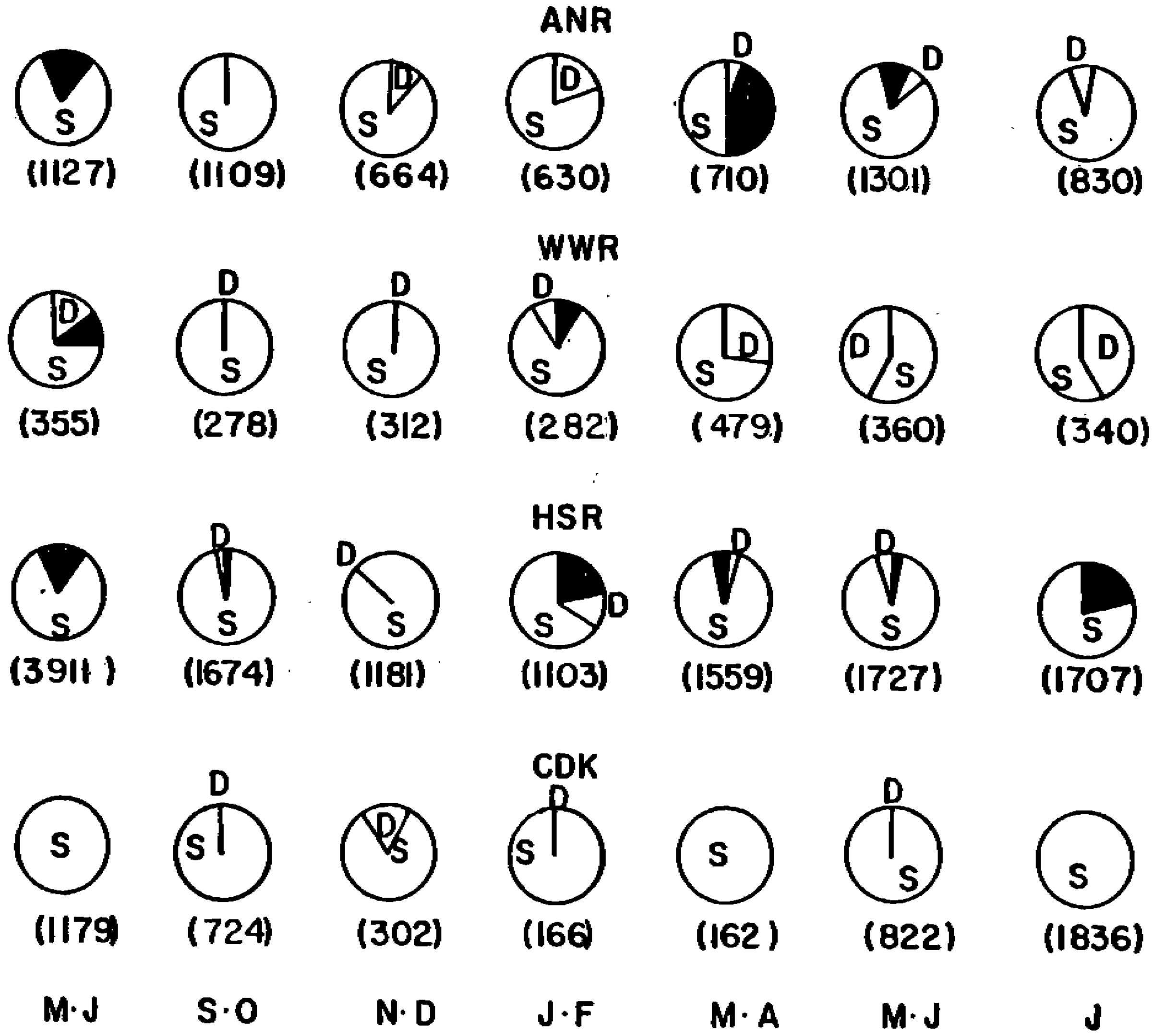


FIGURE 16. 1982 1983

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