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The Biology of Spaeroma Terebrans in Lake Pontchartrain, Louisiana with Emphasis on Burrowing

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THE BIOLOGY OF *SPHAEROMA TEREBRANS* IN
LAKE PONTCHARTRAIN, LOUISIANA WITH EMPHASIS ON BURROWING.

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ABSTRACT

Sphaeroma terebrans (Bate 1866) is an economically and ecologically important cosmopolitan species because this isopod is found burrowed in wood and marine structures of fresh to saline water. Existing literature on *S. terebrans* focuses on the destruction of red mangrove (*Rhizophora mangle*) in India, Pakistan, and Florida. This study concentrates on *S. terebrans* habitat and boring preferences in bald cypress (*Taxodium distichum*) in Lake Pontchartrain near the Bonnet Carre Spillway, Louisiana. In addition laboratory experiments for water column distribution and substrate preferences were conducted using cypress, Styrofoam, and balsa. Results indicate that this population may be parthenogenic and that wood or material hardness determines whether *S. terebrans* burrow when given a choice of substrates. The lake shoreline near the Bonnet Carre Spillway is retreating and the presence of *S. terebrans* contributes to shoreline erosion by weakening and destroying cypress. This has implications for restoration projects in coastal Louisiana.

INTRODUCTION

Why study *Sphaeroma*?

The genus *Sphaeroma* is of economic and ecological importance, both in the United States and other countries because of their inhabitation of wooden marine structures. *Sphaeroma terebrans* (Bate 1866) is known to burrow into and destroy red mangrove (*Rhizophora mangle*) in India, Kenya, Pakistan and Florida. This impact has generated both alarm and a multitude of biological studies of the effects of *S. terebrans* on red mangroves (Rehm and Humm1973; Estevez and Simon 1974; Howey 1977; Estevez 1978, Jones and Icely 1981; Perry 1988; Kensley and Schotte 1999; Theil 1999, and 2000). They colonize the prop roots and trunks of mangroves, thereby undermining the structural integrity and stability. This may lead to shoreline erosion (Rehm and Humm 1973). *Sphaeroma terebrans* is also responsible for damage to woody vegetation, boats, and marine structures such as pilings (Gareth Jones and Eltringham 1968; John 1968, and 1969; Rehm and Humm1973; Estevez and Simon 1974; International Symposium on Biology and Management of Mangroves (ISBMM) 1974). Many studies (Zachary and Colwell 1979; Jones and Icely 1981; Sankaranarayana Iyer et al. 1987; Perry 1988; Barkati and Tirmizi 1990; Messana et al. 1994; Nair 1996; Wier et al. 1996; Hass and Knott 1998; and Cragg et al. 1999) concentrate on *Sphaeroma terebrans* and mangroves, however, there are no studies investigating their burrowing of bald cypress (*Taxodium distichum*), an economically important species in the southeastern United States, particularly Louisiana (see Figure 1).

Sphaeroma may also be an important trophic link in intertidal community dynamics. They are considered filter-feeders that utilize nutrients and phytoplankton in the water column (John 1968, 1969; ISBMM 1974; Howey 1977; Boyle and Mitchell 1978; Estevez 1978; Barkati and Tirmizi 1990; Santhakumari 1991; El-Shanshoury et al.1994; El-Nady and Atta 1996; Wier et al. 1996; Hass and Knott 1998; Benson et al. 1999; Theil 1999, 2000; and Talley et al. 2001). They also may consume algae from their burrows and substrate (John 1968, 1969; Kuhne 1972; Howey 1977; Estevez 1978; Zachary and Colwell 1979; Benson et al. 1999). In addition, vacant burrows may provide habitat for small fish and invertebrates such as crabs (Richards 1930; Howey 1977; Estevez 1978; Perry 1988; Hass and Knott 1998; Theil 1999, 2000; Brooks and Bell 2001; and Talley et al. 2001).

Figure 1. Bonnet Carre Spillway cypress stump burrowed by *Sphaeroma terebrans* at low water.

Four species of the genus *Sphaeroma* are commonly found in North America; *S. quadridentatum, S. quoyanum, S. peruvianum,* and *S. terebrans*. Pigments and color vary within populations and regions. In Louisiana, *S. terebrans* occurs in Lake Pontchartrain (Poirrier and Mulino 1975) and a poster titled "The occurrence of the wood-boring isopod *S. terebrans*, in littoral cypress of Lake Pontchartrain and Lake Maurepas" presented at the 1998 Basics of the Basin meeting by Poirrier, Franze, and Arthur. Their sampling during the spring and summer of 1996 found the density of *S. terebrans* in littoral cypress of Lake Pontchartrain and Lake Maurepas to be 500 individuals per cubic decimeter.

Objectives

This study seeks to document the occurrence of *S. terebrans* in bald cypress trees and to determine the distribution, population structure, and sex ratio of the species in specific regions of Lake Pontchartrain. I investigated whether *S. terebrans* is found throughout Lake Pontchartrain and what its habitat and burrowing preferences are in terms of substrate hardness and water depth. The goal of this study was to determine existence and distribution of *S. terebrans* in Lake Pontchartrain and describe its habitat by means of field and laboratory experiments.

Taxonomy

Sphaeroma terebrans Bate 1866 taxonomic classification according to the Integrated Taxonomic Information System (http://www.itis.usda.gov) is as follows:

Kingdom Animalia
Phylum Arthropoda
Superclass Crustacea
Class Malacostraca
Subclass Eumalacostraca
Superorder Pericarida
Order Isopoda
Suborder Flabellifera
Family Sphaeromatidae
Genus *Sphaeroma*
Species *terebrans*

Synonymy (Estevez and Simon 1974)

Sphaeroma terebrans, Bate. 1866. The Annals and Magazine of Natural History, ser. 3, vol. XVII, p. 28, pl. 2, fig. 5.

Sphaeroma vastator, Bate. 1866. The Annals and Magazine of Natural History, ser. 3, vol. XVII, p. 28, pl. 2, fig. 5.

Sphaeroma destructor, Richardson. 1897. Proceedings of the Biological Society of Washington, 11: 105-107.

According to Estevez and Simon (1974), the taxonomic status of this wood boring isopod has remained confused due to multiple synonymy. Estevez and Simon (1974), after careful investigation of specimens from the Gulf of Mexico, Florida, Georgia, South Carolina, Virginia, Trinidad, Venezuela, Brazil, Ecuador, Kenya, and New Washington, concluded that synonyms of *S. terebrans* include *S. destructor* (Richardson 1897) and *S. vastator* (Bate 1866). The Integrated Taxonomic Information System (ITIS) Report (http://www.itis.usda.gov) does not agree with either of these synonyms and recognizes *S. destructor* as a valid species. In this study I follow the taxonomy and synonomy proposed by Estevez and Simon (1974).

General habitat

Members of the subfamily Sphaeromatidae are found in nearshore environments such as tide pools, rocks, docks or trees. In the United States *Sphaeroma terebrans* is found from Georgia to Louisiana in intertidal and shallow water (Kensley and Schotte 1989), though much research is concentrated in Florida (Gareth Jones and Eltringham 1968; Shultz 1969; Rehm and Humm1973; Estevez and Simon 1974; ISBMM 1974; Howey 1977; Estevez 1978; Benson et al.1999; Cragg et al. 1999; Kensley and Schotte 1999; Theil 1999, 2000; Brooks and Bell 2001). *Sphaeroma terebrans* also occurs in coastal mangrove forests, salt marshes, and freshwater tidal marshes in other areas of the world such as India (Cheriyan 1973; John 1968,1969; Nair 1996; Radhakrishnan and Natarajan 1989; Sankaranarayana Iyer et al. 1987; Santhakumari 1991), Pakistan (Barkati and Tirmizi 1990), Kenya (Jones and Icely 1981; Messana et al. 1994), Belize (Ellison and Farnsworth 1990). *Sphaeroma terebrans* burrow into wooden pilings and are also found in burrows of the *Limnoria* species, another burrowing isopod (Gareth Jones and Eltringham 1968; Rehm and Humm 1973; Boyle and Mitchell 1978; Perry 1988; Radhakrishnan and Natarajan 1989; El-Shanshoury 1994; Messana et al. 1994; Wier 1996; Hass and Knott 1998; Benson et al. 1999; Cragg et al 1999; Theil 1999, 2000; Brooks and Bell 2001).

Physical characteristics and reproduction

The average adult female *S. terebrans* length is between 8 and 10 mm. Adult males are smaller, averaging between 6.5 and 8.5 mm. Subadults range in length between 3 and 6 mm, and juvenile *S. terebrans* range in length from 2 to 3 mm (Theil 1999). Females sampled in Florida can produce two broods, one in early fall and a second in late winter or early spring (Theil 1999). Barkati and Tirmizi (1990) found lengths in populations of *S. terebrans* to be 1-12 mm in mangrove samples collected from the northern Arabian Sea near Pakistan. They become sexually distinguishable when they reached about 3.5 mm (Sankaranarayana Iyer et al. 1987). Some species of Sphaeromatidae are obviously sexually dimorphic and can be distinguished by observing the pleotelson; for other species within this subfamily a microscopic inspection of the pleopods is necessary to distinguish sexes. Gravid females easily distinguished because of their large size and visible eggs or embryos. Embryos develop after fertilization and appear egg-shaped. After further development limb buds emerge, eyes become pigmented and visible when the egg membrane is shed. As the embryo elongates it becomes “comma-shaped”, appendages develop along with the eyes, and segmentation of the pereon becomes visible. Embryos resemble juveniles with a soft whitish exoskeleton (Theil 1999). After this stage embryos exit the brood pouch and become juveniles.

Rehm and Humm (1973) studied *S. terebrans* from Florida and found that reproduction occurred within 2-4 weeks in captivity when temperature was set at 24ºC. *Sphaeroma terebrans* are peracarid crustaceans that undergo direct development within the female brood pouch (Theil 1999). Theil's research also concluded that the number of embryos produced was strongly correlated with female body length. Gravid females contained an average of 35 embryos (Barkati and Tirmizi 1990). Sankaranarayana Iyer et al. (1987) completed a study of three major lakes in Kerala, India and found that breeding levels for two similar species *S. terebrans* and *S. annandalei* peaked at different seasons. The highest breeding levels for *S. terebrans* occurred during the northeast monsoon season when oxygen levels were high and rainfall, nutrients, and temperature were at intermediate levels. According to Santhakumari (1991) and Sankaranarayana Iyer et al. (1987), *S. terebrans* seems to be a continuous breeder because young and ovigerous females were sampled on the Kerala coast throughout the year. Estevez (1978) found the population structure of *S. terebrans* to be seasonal in Florida. In the spring, adults were dominant; in the summer, embryos and juveniles were abundant; in the fall, the adult and embryo/juvenile ratio was about equal; and the winter had a large population of young adults and only a few juveniles (Estevez 1978).

Food preference

Howey (1977) postulated that *S. terebrans* is probably either a detritivore or planktivore suspension feeder. Gut analysis yielded no evidence of fungi as a food source for *S. terebrans*. Gut examinations found green-brown gut contents but no wood particles so Howey (1977) concluded that *S. terebrans* does not eat wood. Estevez (1978) and Rotramel (1972) both agreed that wood particles displaced by burrowing were not ingested. John (1968) reported that *S. terebrans* can subsist on cellulose derived from filter paper and natural/manmade seawater. Benson et al (1999) through laboratory experiments gathered that juvenile *S. terebrans* lived longer, molted, and grew when fed Sigma Cell 20 (a cellulose substrate) than juvenile *S.*

terebrans given no food. Kuhne (1972) found that *S. terebrans* preferred algae to wood as a food source in food experiments in static dishes.

Salinity preference

John (1969) concluded from laboratory experiments that the optimum salinity conditions for *S. terebrans* growth and reproduction was salinity range of 4-28 parts per thousand (ppt). Howey (1977) found that burrowing rates increase with a salinity increase. Barkati and Tirmizi (1990) found that *S. terebrans* in the Northern Arabian Sea prefer to colonize peripheral areas of mangroves in salinities ranging from 32 to 39 ppt, most *S. terebrans* in the North Arabian Sea were found in the lower end of this range.

Charmantier et al. (1994) conducted a study of osmoregulation and salinity tolerance of the euryhaline *Sphaeroma serratum* at different life stages from the embryo to stage I to V juveniles and adults collected from the French Mediterranean coast in Thau Lagoon. Through laboratory experiments, they found a strong correlation between osmoregulatory ability and salinity tolerance. Early and late stage embryos have no or weak osmoregulatory capabilities. However, once individuals of *S. serratum* exit the brood pouch their osmoregulatory capacity increases. Stage I juveniles are the most sensitive to salinity fluctuations, but they have hyperregulating capabilities that enable them to tolerate short-term periods of fresher water (approximately 17 ppt). *Sphaeroma serratum's* osmoregulatory capability allows it survive in euryhaline environments. *Sphaeroma serratum* is physically similar to *S. terebrans*, except this species is found in Europe and has a smooth pleotelson.

Temperature preference

Sphaeroma terebrans is found in semi-tropical and tropical climates around the world (Kensley and Schotte 1989). There was a significant negative correlation between temperature and breeding for *S. terebrans* in Veli Lake, Kerala, India where the water temperature ranged from 27.4º C to 33.2º C. There was a significant positive correlation between nutrients and breeding activity for *S. terebrans* in Kerala **(**Sankaranarayana Iyer et al 1987). Colder climates and areas where freezing air temperatures last longer than a few days probably limit the global distribution of *S. terebrans* (Kensley and Schotte 1989). Consequently they inhabit regions with semi-tropical to tropical climates.

Burrowing

Sphaeroma terebrans are strongly thigmotaxic because they immediately seek substratum when dropped in water (Howey 1977 and Estevez 1978). Estevez (1978) discovered that *S. terebrans* must have the burrow open to water on only one end, or they will exit and start new burrows elsewhere if openings are created on the dead end of their burrow. This led him to believe that the burrow aided in respiration and feeding by filtering. *Sphaeroma terebrans* create burrows by moving their mandibles up and down, and the cephalon and the first two pereonites back and forth like a rake, then the pleotelson and the pleopods flap up and down to create a current to evacuate the wood fragments and any air bubbles. Activity within the burrow consists mainly of digging, ventilation, cleaning, and filtering particles (Messana et al. 1994). The burrow serves as shelter, not a food source (John 1969). "The size of the burrow does not exceed that of its inhabitant, and burrowing activity decreases after the burrow has been established" (John 1969).

<u>Substrate preference</u>

Studies have shown that various substrates found in the intertidal zone such as red mangrove, *Rhizophora mangle*, (John 1968; Gareth Jones and Eltringham 1968; Rehm and Humm 1973; ISBMM 1974; Howey 1977; Estevez 1978), cork (John 1969); other mangroves and mango (Radhakrishnan and Natarajan 1987 and 1989), cypress, cedar, palm, pine (Benson et al. 1999), marsh species (Estevez 1994, Rice et al. 1990), and Styrofoam are colonized by *S. terebrans*. *Sphaeroma terebrans* prefers to inhabit aerial roots of red mangroves within the intertidal zone (Rehm and Humm 1973). Estevez (1978) postulated that boring might shape mangrove islands or prune potential growth in the intertidal zone. Estevez (1994) described *S. terebrans* as occupying rhizomes, living and dead stems of *Juncus romerianus* (black needle rush) and other marsh species such as leather fern (*Acrostichum aureum*), cattail (*Typha* sp.), smooth cordgrass (*Spartina alterniflora*), bulrush (*Scirpus validus*), saw grass (*Cladium jamaicensis*). Rice et al. (1990) also found *S. terebrans* in black needle rush as well as *Acrostichum aureum*. Benson et al (1999) noted that *S. terebrans* could inhabit cypress, cedar, palm, and pine. Radhakrishnan and Natarajan (1989) used *Mangifera indica* (Mango) wood blocks to test colonization of several different species of *Sphaeroma*, and discovered that *S. terebrans* will colonize mango wood. Radhakrishnan and Natarajan (1987) also discovered different borer intensity levels for different mangrove species, *S. terebrans* was abundant or very commonly found burrowed in *Rhizophora mucronata*, *R. apetalla*, *Avicennia officinalis*, and *Suaeda maritima*, and rarely found in *A. marina* or *Exoecaria agallocha*. John (1969) used cork in laboratory experiments and found that *S. terebrans* would readily burrow into this substrate.

Important strength and hardness properties of substrates

Wood properties such as elasticity, hardness, moisture content, specific gravity, and density may affect colonization of different kinds of wood. Wood strength and hardness values vary among tree species. These properties are standardized at a 12% moisture content and sometimes completed when condition of the wood is "green". There are no published laboratory studies or literature that compared strength properties for "soft" manmade materials such as Styrofoam and natural materials such as cypress or mangrove wood all of which *S. terebrans* are known to use for burrows. There has not been any strength testing or comparisons made with burrowed, weathered or waterlogged wood. It has been assumed that wood attacked by insects, fungi, or burrowing crustaceans weakens strength values. Determining how long and which type of natural wood or manmade substrates can withstand burrowing or other strength degradation may help with building future marine structures. Currently some strength and hardness information is available through the Wood Products Laboratory and various internet websites.

Two common strength properties recorded by the Wood Products Laboratory are elasticity and hardness. Elasticity means that a substrate will deform under low stress and reform after the stress is released. Elasticity can be measured in lumber on different axes (tangential, longitudinal, and perpendicular) of the grain of the wood. Hardness is the resistance to deformation. Standard tests for lumber used to determine strength and hardness include hardness, modulus of elasticity, modulus of rupture, side hardness, maximum crushing strength, and bending strength (ASTM 1998 and Forest Products Laboratory 1999). The following table displays strength properties, testing methods were developed by the American Society for Testing Materials (ASTM 1998) (see Table 1). Standardized strength and hardness tests are conducted on lumber grade wood, not waterlogged, weathered, *S. terebrans* burrowed wood, and not on aerated tissue such as prop roots or pneumatophores. Strength and hardness data for burrowed or "soft" wood were unavailable, but these values would presumably be much lower.

Table 1. Strength properties of burrowed substrates
Methods for individual tests described in ASTM 1998. Data for Table 1 was collected from the Forest Products Laboratory 1999, www.epspackaging.org, http://www.precisecut.com/material/wood/balsa.htm, http://www2.fpl.fs.fed.us/TechSheets/Chudnoff/TropAmerican/htmlDocs_tropamerican/Rhizophoramangle.html. * = values unavailable, M.C. = moisture content , Lb = pounds of force, psi = pounds per square inch, pcf = pounds per cubic foot.

Substrate	Hardness (Lb)		Modulus of Elasticity (psi)		Specific Gravity		Density (pcf)	
M.C.	**12%**	**green**	**12%**	**green**	**12%**	**green**	**12%**	**Green**
Balsa	*	*	490,000	*	*	0.16	14	*
Bald Cypress	510	390	1,440,000	1,180,000	0.46	0.42	32.2	57.7
Long leaf pine	870	590	1,980,000	1,590,000	0.59	0.54	41	43.5
Loblolly pine	690	450	1,790,000	1,400,000	0.51	0.47	35.6	38.7
Red Mangrove	2760	2240	2,950,000	15,200,000	0.71	0.89	67	*
Styrofoam	*	*	180 to 460	*	*	*	1.8	*

A number of papers describe *S. terebrans* colonizing *R. mangle* (Gareth Jones and Eltringham 1968; John 1968, 1969; Rehm and Humm1973; ISBMM 1974; Howey 1977; Estevez 1978; Messana et al. 1994; Nair 1996; Radhakrishnan and Natarajan 1989; Sankaranarayana Iyer et al. 1987; Barkati and Tirmizi 1990; Ellison and Farnsworth 1990; Barkati and Tirmizi 1991; Santhakumari 1991; Theil 1999 and 2000, Brooks and Bell 2001). Along the coast of Florida, mangrove prop roots are cut off at the mean high water level due to the burrowing of *S. terebrans* (Rehm and Humm 1973). Remaining prop roots are perforated with *S. terebrans* burrows on their shaded (concave) side. These prop roots are also subject to decomposition by bacteria and fungi. According to Messana et al. (1994), *S. terebrans* was not found in any fringing mangroves off the coast of Kenya, suggesting that it needs still water, not tidal influx to initiate burrows.

Estevez (1978) found that *S. terebrans* does not initiate burrows at random. If wounds are present on mangrove pneumatophores, a burrow can be established in 24 hours. Santhakumari (1991) described *S. terebrans* burrows that had a “cylindrical depth” (burrow length) of 20-30 mm and widths from 5-8 mm. He also noticed that the burrows were constructed at right angles to the root surface, and that *S. terebrans* prefer the soft parts or the prop roots of mangrove trees.

Fresh timber seemed to be only attacked by adults in a particular damaged or scarred spot, they also selected previously burrowed sites (Santhakumari 1991). Howey (1977) suggested that mangrove hardness related to nutrient uptake might be a limiting factor to burrow initiation. However, he found that softening of wood by fungal mycelia seemed to be unnecessary for burrow initiation. Howey (1977) discovered that *S. terebrans* numbers decreased as *R. mangle* root diameter increased, (0.6-1.4 cm had the highest density and 1.4-3.0 cm density started to decrease), suggesting that younger roots are more susceptible to *S. terebrans*' burrows. This population decrease may be due to increasing density of the prop root as the surface area of the red mangrove increases, which makes burrow initiation difficult for *S. terebrans*. A study of red mangroves along the Sind coast in Pakistan by Barkati and Tirmizi (1990) found no isopods in dead mangrove branches. However, *S. terebrans* populations in mangroves along the Kerala coast attacked both live and dead mangroves and prop roots at the mean high water level (Santhakumari 1991).

Competition

Perry (1988) researched nonherbivorous fauna within red mangroves in Pacific Costa Rica. She found competition of two species with overlapping niches. Perry (1988) discussed the effect of the isopod *S. peruvianum* and barnacles *Balanus spp*. on red mangrove root growth and productivity. The majority of the *Balanus spp.* (approximately 20% coverage) occupied low intertidal aerial red mangrove roots (0-75 cm from the substrate), instead of roots grounded in the substrate and lateral roots which grow parallel to and on the surface of the substrate. *Sphaeroma peruvianum* were present in aerial and lateral roots, but not grounded roots, with root initiation points greater that 100 cm above the substrate. However, isopod burrows were distributed along the entire intertidal range (20-200 cm). Estevez (1978) discovered a burrow community in mangrove pneumatophores in Florida that included annelids, *Hapliplanella* (cnidaria), *Corophium sp.* and *Hyale sp.* (crustacea), and *Sphaeroma quadridentatum* and *Iais sp*. (isopoda). Santhakumari (1991) found other fouling organisms in and among *S. terebrans* burrows such as the barnacle *Balanus amphitrite*, calcareous tube forming polychaetes, *Modiolus sp*., amphipods, hydroids, algae, free living polychaetes, bryozoans, copepods, diatoms, protozoans, oysters, and sea anemones. Some of these organisms may be competing for space or food resources.

Study area
The Lake Pontchartrain Basin encompasses several rivers, lakes, and estuaries (see Figure 2). Lake Pontchartrain itself has a mean salinity of 4 ppt, a mean depth of 3.7 m and a surface area of 1,630 km^2 (Sikora and Kjerfve 1985). Lake Pontchartrain is horizontally stratified; salinities are highest at the east end near the tidal passes and the southeast near the opening of the Inner Harbor Navigational Canal (IHNC) that is connected to the Mississippi River Gulf Outlet (MRGO), which opens into the Gulf of Mexico (see Figure 3). Salinity is lowest in the west because of minor Bonnet Carre Spillway (Spillway) leakage and other freshwater input from the Amite, Tickfaw, and Tangipahoa Rivers and small bayous (Swenson 1980). The major elements of circulation for Lake Pontchartrain are winds, tides, and river flow (Swenson 1980 and Signell and List 2001). Winds dominate tidal and riverine influence; however, periodic discharge from the Spillway can contribute the same amount of energy as wind (Gail 1980 and List and Signell 2001). The Spillway is located in the southwest portion of Lake Pontchartrain. The Spillway is periodically opened to divert Mississippi River water into Lake Pontchartrain for flood prevention. To date the Spillway has been opened 8 times (1937, 1945, 1950, 1973, 1975, 1979, 1983, and 1997). According to unpublished data of the United States Army Corps of Engineers (USACE), the Spillway structure can leak fresh water into Lake Pontchartrain when the Mississippi River rises to and above 15.3 ft (Spillway gage). The USACE monitors Lake Pontchartrain's water level at Frenier beach, which is approximately 4.5 km northwest of the shoreline where the Spillway connects with the lake (see Figure 3).

Lake Pontchartrain is an estuarine embayment with a restricted connection to Lake Borgne, through the Rigolets and Chef Menteur pass. The Lake Borgne estuary has a free connection to the Gulf of Mexico. Freshwater sources to Lake Pontchartrain originate from rivers such as the Amite, Tickfaw, Natalbany, Tangipahoa, and Tchefuncte, and bayous such as Lacombe and Bonfouca (Swenson 1980). Man-made salinity inflow to Lake Pontchartrain comes from the MRGO via the IHNC and the Intracoastal Waterway. Hurricanes and major storms also significantly alter the salinity and water quality of Lake Pontchartrain (Penland et al. 2001). The salinity levels in different areas of the lake rarely reach 12 ppt and often fall below 3 ppt, from 1986 to 1995 salinity monthly averages ranged from 1 to 7 ppt (Francis and Poirrier 1999) and from September 1996 to August 2002 monthly mean water salinities averaged 5.3 ppt (Cho

2003). The University of New Orleans (UNO) Nekton Laboratory and Chris Schieble provided some water quality data that helped to describe the most prevalent *S. terebrans* environment at the Bonnet Carre Spillway (see Figure 3). The UNO Nekton Laboratory measured salinity, temperature, and dissolved oxygen in Lake Pontchartrain near the Spillway from July 2000 through June 2003. These data showed an average salinity in this area of 4.6 ppt,with a range of 0.3 to 11.7 ppt (see Figure 4).

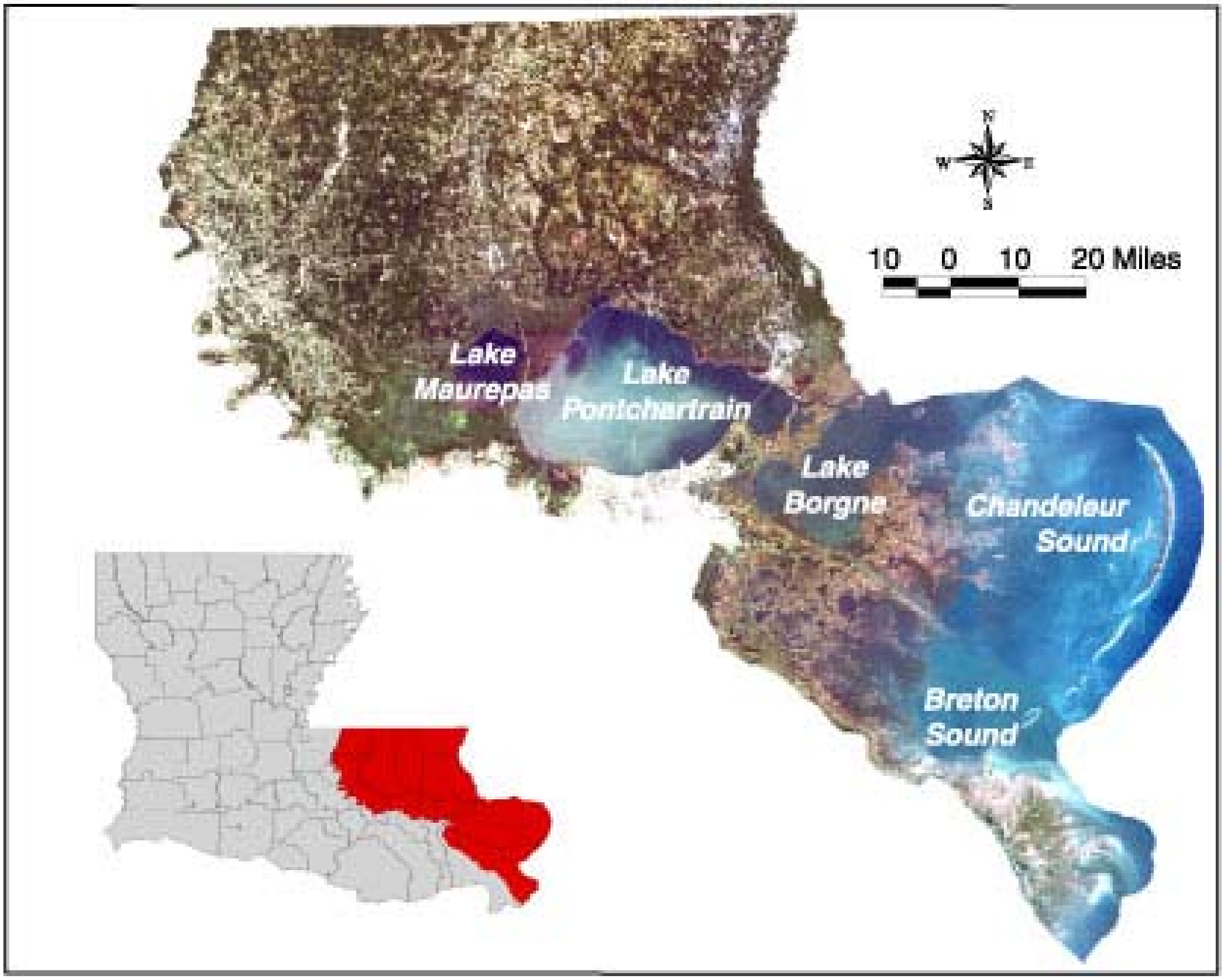


Figure 2. The Lake Pontchartrain Basin (Penland et al. 2001).

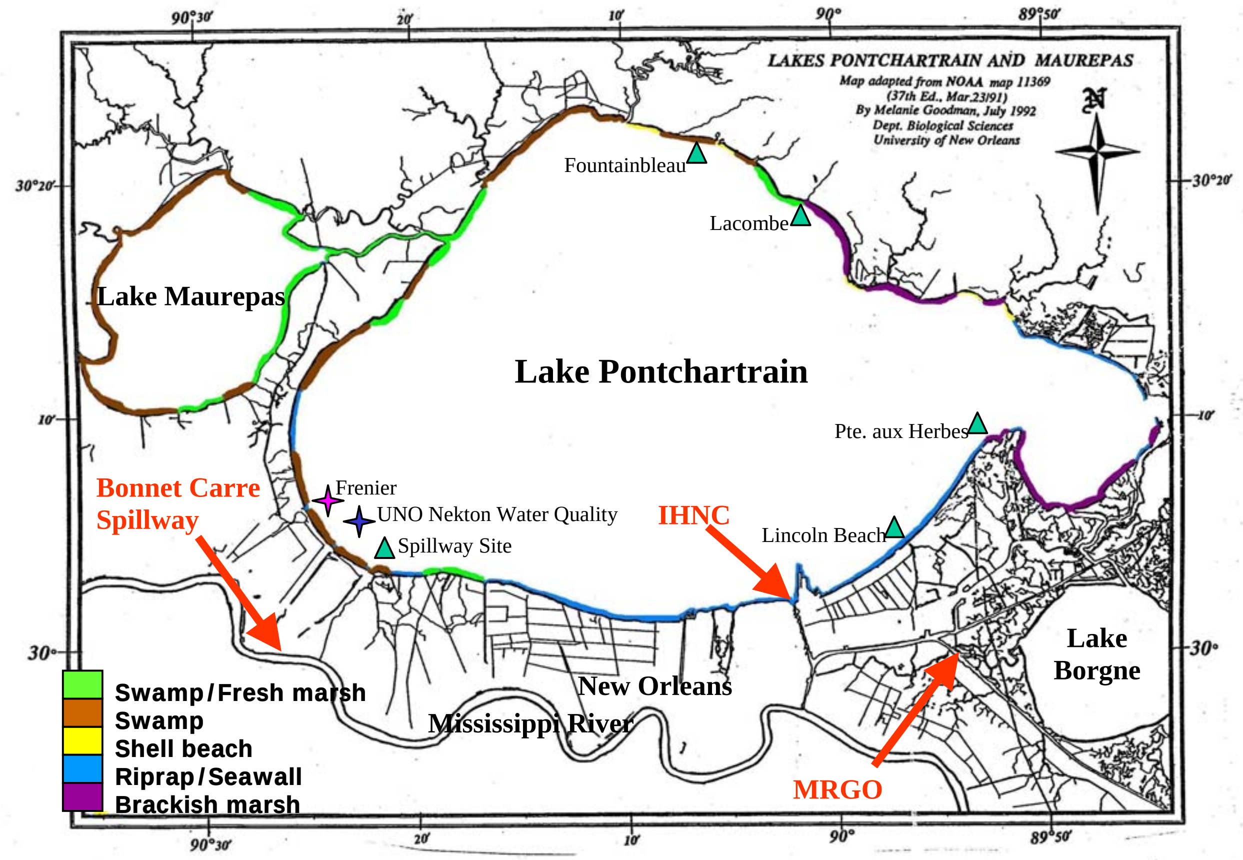


Figure 3. Lake Pontchartrain, fresh/saltwater influences, and shoreline type.

The woody shoreline of the Bonnet Carre Spillway and western Lake Pontchartrain is predominately a bald cypress-tupelogum swamp (*Taxodium distichum-Nyssa aquatica*) with some red maple (*Acer rubrum*), ashes (*Fraxinus spp*.), black willow (*Salix nigra*), Chinese tallow (*Sapium sebiferum*), eastern baccharis (*Baccharis halimifolia*), wax myrtle (*Myrica cerifera*), and palmetto (*Sabal minor*) (Montz 1985). Heavily eroded and burrowed stumps and dead trees in the intertidal zone of Lake Pontchartrain are composed of only *Taxodium distichum*.

The intertidal zone of Lake Pontchartrain is a diverse community. Among cypress stumps at the Spillway site there are numerous fish species (http://amazon.bio.uno.edu) as well as several invertebrates present such as crabs (*Callinectes sp*.), grass shrimp (*Palaeomonetes sp*.), mussels (*Ishadium recuurvum*, *Congeria leucophaeta*), barnacles (*Balanus sp*.), clams (*Rangia cuneata*), and larval insects (Poirrier 1984).

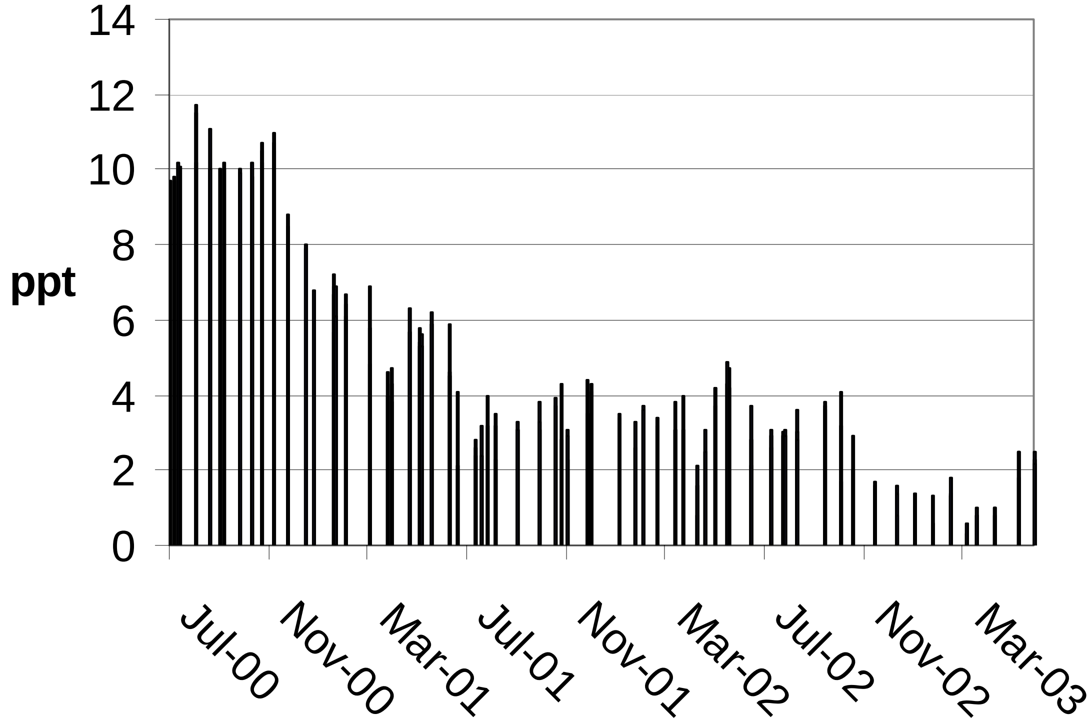


Figure 4. Salinity northwest of the Spillway site for July 2000 through June 2003. Exact location is Lat 30º 04.48 Long 90º 21.934 and Lat 30º 05.618 Long 90º 24.744. Data courtesy of Chris Schieble and UNO Nekton Laboratory.

According to Beall et al. (2001), there are several different shoreline types surrounding Lake Pontchartrain. They include bulkhead, riprap, seawall, sand beach, shell beach, fresh marsh, intermediate marsh, brackish marsh, salt marsh, natural bank, and swamp, or any mixture of these types (see Figure 3). There are 81.9 km of swamp and wooded shoreline surrounding the lake (Beall et al. 2001). Most of the shoreline in the western part of Lake Pontchartrain consists of swamp and marsh. However, the southeastern side of Lake Pontchartrain that borders the city of New Orleans is armored with riprap and seawall. The northern and northeastern portion of the lake has a shoreline composed of marsh, swamp, shell, and riprap armoring (Beall et al. 2001).

Beall et al. (2001) calculated shoreline retreat for the Lake Pontchartrain Basin by comparing aerial photographs, maps, transects, and elapsed time between years 1850 and 1995. The south shoreline of Lake Pontchartrain has retreated an average of 0.74 m/year between 1850-1995, the north shoreline has retreated an average of 1.25 m/year for this same time period (Beall et al. 2001). Cypress swamp in the southwestern area of Lake Pontchartrain near the Spillway is experiencing greater retreat (1.1 m/year) than the fresh and intermediate marsh in the same area. The only areas of the lake that are somewhat protected are riprap and seawalled shorelines (Zganjar et al. 2001).

The wind and tidally determined water depth along the shoreline of Lake Pontchartrain may influence burrow placement of *S. terebrans*. Lake Pontchartrain is a wind-dominated system. Water level is influenced tidally by the Gulf of Mexico, and winds generated from the east (Stone 1980; List and Signell 2001). According to Cho (2003) for the time period of October 1996 to May 2001 winds originating in the east occurred more often than westerly winds. Winds from the northeast, east and southeast force more saline water into the Pontchartrain basin, and winds from the southwest, south and northwest drive water out of the basin. She found that north winds dominated the winter months (December to February), south and southeast winds dominated the spring (March to June), west winds dominated the peak summer months (July to August), and northeast winds dominated the fall (September to November). Water level in Lake Pontchartrain is lower during the fall and winter months. Wooden structures in deep water, not in the intertidal zone, do not experience drying from low water and may harbor large *S. terebrans* populations.

The clarity of lake water may also affect the distribution and suspension feeding of *S. terebrans*. Turbidity is influenced by salinity and wind (Francis et al. 1994). Because Lake Pontchartrain is a relatively shallow estuarine embayment it naturally has high turbidity levels because of wind driven re-suspension of bottom sediments (Francis et al. 1994). Wind speeds greater than 6.8 m/s are strong enough to stir up bottom sediments and increase turbidity within the Lake (Swenson 1980). Salinity and freshwater influx, wind driven circulation, and shallow water depth create a turbid estuary environment. Francis and Poirrier (1999) stated that there are strong correlations between water quality and salinity and wind speed in Lake Pontchartrain and that these factors vary with season. They found that salinity has a statistically significant positive effect on water transparency, and wind speed has a significant negative effect on water transparency. According to Francis and Poirrier (1999) 12 month moving averages of monthly secchi disk transparency varied from 55 cm to 1.7 m during the years 1986 to 1995. Chris Schieble and the UNO Nekton Laboratory reported secchi disk visibility from July 2000 through June 2003 varied from 0 m to 3.5 m (see Figure 5). The average visibility during this time period was 1 m near the Spillway site.

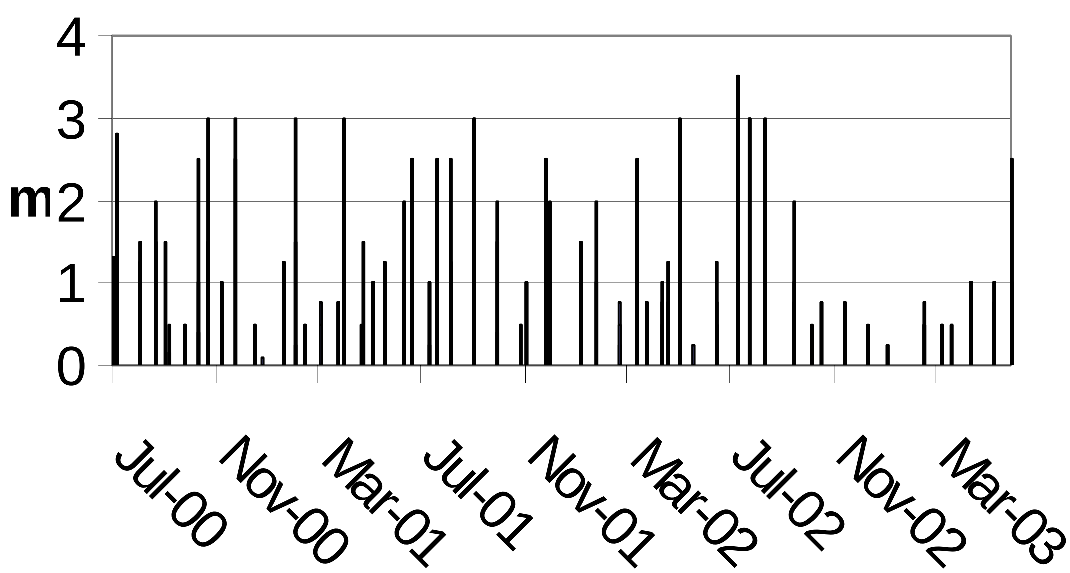


Figure 5. Water clarity northwest of the Spillway site for July 2000 through June 2003. Exact location is Lat 30º 04.48 Long 90º 21.934 and Lat 30º 05.618 Long 90º 24.744. Data courtesy of Chris Schieble and UNO Nekton Laboratory.

Water and air temperature in Lake Pontchartrain appear conducive to reproduction and growth of *S. terebrans*. Louisiana is considered subtropical, however on occasion short-term freezing events occur on the north and south shores. Freezing events in southern Louisiana are rare, when they do occur they last only a few days. These short-term freezing periods could also impact *S. terebrans* burrowed in littoral cypress. *Sphaeroma terebrans* can survive exposure for approximately 24 hours (Rehm and Humm 1973). This data was probably collected during episodes of non-freezing temperatures. Lake Pontchartrain's water temperature fluctuates seasonally. Cho (2003) found the mean water temperature of Lake Pontchartrain from September 1996 to August 2002 to be 23ºC. Peters and Beall (2001) reported the air temperature for Data Buoy 42007 in the Gulf of Mexico in approximately the same latitude as the center of Lake Pontchartrain for years 1981 to 1993, the month of July had a mean high of 28.3ºC and January had a mean low of 11.7ºC. According to Chris Schieble and the UNO Nekton Laboratory the average water temperature at the Spillway site was 22ºC, the highest temperature recorded was 32.9ºC and the lowest temperature was 7.8ºC (see Figure 6).

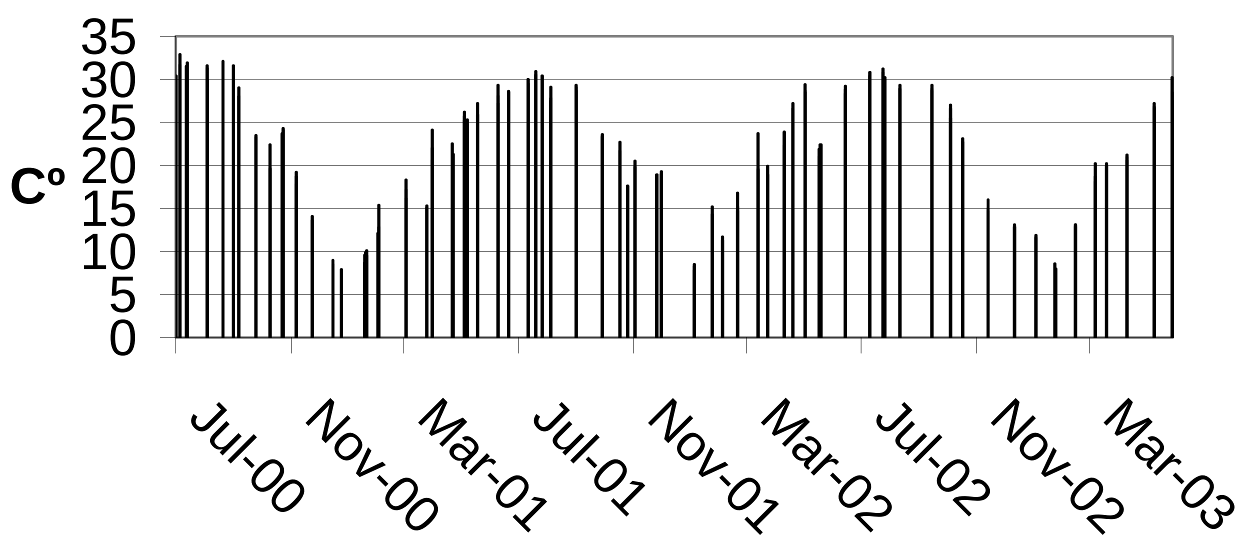


Figure 6. Water temperature northwest of the Spillway site for July 2000 through June 2003. Exact location is Lat 30º 04.48 Long 90º 21.934 and Lat 30º 05.618 Long 90º 24.744. Data courtesy of Chris Schieble and UNO Nekton Laboratory.

MATERIALS AND METHODS

Collection and identification

Observations, sampling, and collections of *S. terebrans* concentrated on the wooded shorelines of Lake Pontchartrain. Surveys of *S. terebrans* in the littoral zone of Lake Pontchartrain were conducted by wading out to cypress stumps a few days before laboratory burrowing experiments to collect *S. terebrans* and lake habitat water. Random pieces of cypress roots and trunks were also collected and sorted from the intertidal Spillway site (Latitude 30º 03. 54'N Longitude 90º 22.37'W) to determine population density. Wood samples from dead stumps and prop roots were collected by hand, hatchet, and saw. The wood was either dissected immediately in the field by prodding the isopods out of their burrows with a pocket knife, and placing them in plastic containers with frequently changed lake water or bringing the entire wood specimen back to the laboratory and dissecting it with the same methods. Ice was used to keep the water cool. As soon as they were transferred to the laboratory the *S. terebrans* were placed in new containers with fresh lake water, aeration, and a small piece of Styrofoam and allowed to acclimate for a two days. A sub-sample of the *S. terebrans* specimens collected was preserved in 70% ethyl alcohol for identification. *Sphaeroma terebrans* in the laboratory were also examined for sex and gravidity (i.e. presence of eggs or embryos). A detailed illustration of *S. terebrans* by Kensley and Schotte (1987), and the *appendix masculina* by Estevez and Simon (1974) are presented in Figure 7. Identifications were made in the laboratory using the original description (Bate 1866), other early descriptions (Richardson 1897, and Stebbing 1904), several keys and guides (Shultz 1969; Poirrier 1984; Kensley and Schotte 1989; http://www.itis.usda.gov), some taxonomic, and illustrative papers utilized include those written by Gareth Jones and Eltringham (1968), Rehm and Humm (1973), Estevez and Simon (1974), ISBMM (1974), Kensley and Schotte (1999), and Theil (1999). A sample of *S. terebrans* specimens was sent to Dr. Brian Kensley in the Department of Invertebrate Zoology at the Smithsonian Museum of Natural History and for verification.

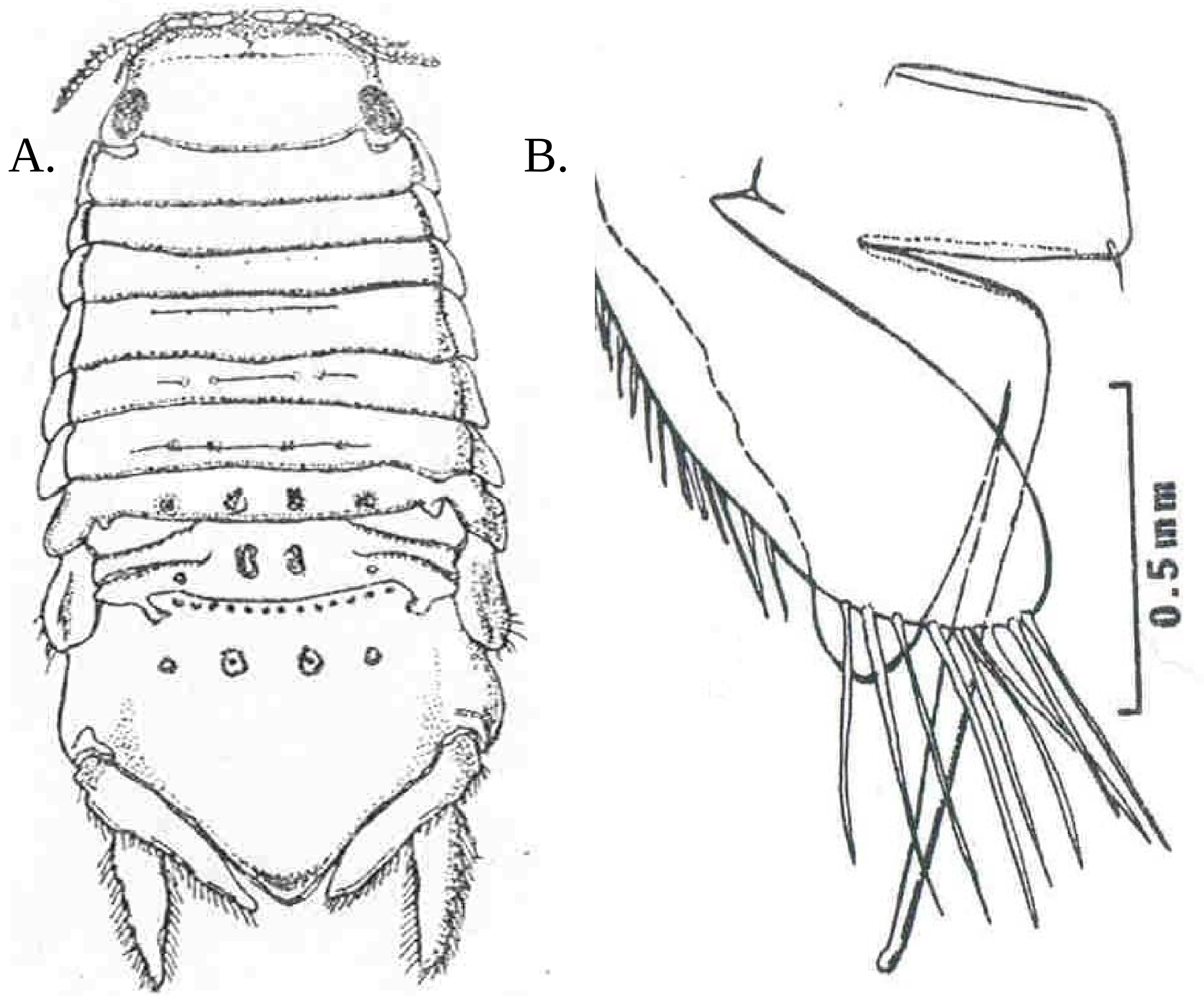


Figure 7. A. *Sphaeroma terebrans* Bate 1866 dorsal view from Kensley and Schotte (1989). B. *Sphaeroma terebrans* pleopod with *appendix masculina* from Estevez and Simon (1974).

Field experiments -- colonization

Blocks and field sampling

A total of ten Styrofoam blocks 10 cm length by 10 cm width by 2.5 cm height (10 X 10 X 2.5 cm) and 40 cypress blocks (10 X 10 X 2.5 cm) were placed in the field and observed once a month for *S. terebrans* colonization for one year starting July 2001 and ending July 2002. Observations included the number of blocks present, types of other colonizing invertebrates, and water conditions mainly salinity and water level. Blocks were anchored to the lake bottom by cinderblocks and attached to a permanent wooden structure either a piling or cypress tree in the intertidal zone of five representative sites in Lake Pontchartrain (see triangles on Figure 3). One to four Styrofoam blocks and eight cypress blocks were placed at each site. Blocks were placed on the north shore in Fountainbleau State Park (Latitude 30º20’14”N, Longitude 90º03’03”W) among burrowed dead cypress trees. Blocks were also placed among abandoned dock pilings at the end of Highway 434 south of Lacombe, Louisiana (Latitude 30º15’37”N, Longitude 89º57’23”W) located on the edge of Big Branch National Wildlife Refuge. Other blocks were placed on the southeast shore at Point aux Herbes (Latitude 30º09’14”N, Longitude 89º51’35”W). Another site was Lincoln Beach (Latitude 30º04’28”N, Longitude 89º57’00”W) on the south shore, among abandoned pilings. The last site was located among *S. terebrans* colonized cypress stumps at the Bonnet Carre Spillway (Latitude 30º03’54”N, Longitude 90º22’37”W). After one year the remaining blocks were collected from the representative sites and inspected for presence of *S. terebrans* and other invertebrate colonizers.

Stakes

Another experiment started at the end of May 2002 and ended at the end of May 2003 observed burrow placement height for *S. terebrans* in the water column. This experiment involved placing 10 stakes into the lake bottom parallel to the shoreline approximately 50 yards from the shoreline at a mean water depth of 1 m at the Spillway site. This experiment used four different types of wood, new pine (4 stakes) and weathered pine (2 stakes), Spanish cedar (2 stakes), and cypress (2 stakes). Different types of wood were used to determine if *S. terebrans* had a preference for density, hardness, or type. The stakes were hammered into the ground deep enough so that they would not be dislodged by heavy wave action. Approximately 1 meter remained exposed above the substrate. These 10 stakes were put in place 30 May 2002 and collected 29 May 2003. Once the stakes were collected, they were encased in fine mesh Nylon stockings so that the borers and other invertebrates would remain in place until sorted and preserved in 70 % isopropyl alcohol. I identified and counted macroinvertebrate species present. The stakes were subsampled in 10 cm increments where sessile barnacles and mussels were counted and their sizes averaged. All *S. terebrans* and burrows were measured for length, width, and placement height in the water column. Sex and gravidity were also determined.

Laboratory experiments

Sphaeroma terebrans was collected for laboratory burrow experiments from cypress stumps, driftwood, and prop roots at the Spillway site from July through October 2002. All laboratory experiments used a mixture of clear, aerated Lake Pontchartrain water and distilled water for habitat water. Salinity was maintained at 4.5 ppt with synthetic sea salts. Specimens used in these experiments were not fed, aside from any nutrition derived from the habitat water.

Block colonization (no choice)

This experiment tested whether *S. terebrans* would burrow into different substrates in "shoebox" aquariums in the laboratory. The different substrates included blocks of balsa, Styrofoam, or cypress that were glued to the bottom of the aquariums with non-toxic silicon aquarium adhesive, allowed to dry for two days, then leached with distilled water for two days to prevent tannins or chemicals from affecting the experiment. The water leachate was discarded, and the aquariums were flooded new habitat water. Habitat water was changed every 3 to 4 days. The experiment was run for 24 days; afterwards *S. terebrans* and blocks were preserved in 70% ethyl alcohol. The experiment utilized 12 (28.5 X 17 X 11.5 cm) aquaria filled with 1000 ml of habitat water. Ten *S. terebrans*, 1 stone aerator, and either 2 balsa blocks, 1 Styrofoam block, or 1 cypress block were placed in the 12 aquaria. Two smaller balsa blocks were used because larger balsa blocks were not available. Aquaria 1-4 contained balsa blocks (5 X 5 X 5 cm), aquaria 5-8 each contained a Styrofoam block (10 X 10 X 2.5 cm), and aquaria 9-12 contained a Cypress block (13 X 13 X 2.5 cm).

Once the experiment began, observations of *S. terebrans* outside burrows (swimming around in the aquaria), climbing on the blocks, and climbing on the aerator were made. Observations of the number of burrows, the number of *S. terebrans* in burrows, number of full molts (front end and back end), and deceased isopod lengths were made after the water was carefully drained. At the end of the experiment, measurements made included burrow length, width, and placement height in the water column. *Sphaeroma terebrans* were measured for length and width. Sex, gut contents, and gravidity were determined by observing each individual isopod with a dissecting microscope. The stomach and alimentary tract were opened and visible gut contents were inspected for wood particles. Final substrate choice was recorded in terms of where each isopod was at the end of the experiment.

Substrate preference (choice)

The second set of experiments tested if *S. terebrans* has a substrate preference if given a choice in the same shoebox aquaria in the laboratory. The aquaria were prepared and maintained with habitat water changes the same as in the block colonization no choice experiment except that they had a choice of two different substrates. This replicated experiment was also run for 24 days. The experiment utilized 20 (28.5 X 17 X 11.5 cm) aquaria filled with 1000 ml of habitat water. Each aquarium contained one stone aerator, 10-12 *S. terebrans*, and either: a choice of balsa or Styrofoam, Styrofoam or cypress, or balsa or cypress, or Styrofoam, or water only. The aquariums were set up in a grid on a long table (305 cm X 122 cm) in the laboratory with low light conditions. The experiment involved 6-9 observations of *S. terebrans* activities. They were observed every 3-4 days over the course of the experiment for burrowing, activity such as climbing on the substrate, wandering outside the substrate, or climbing on the aerator. Activity observations were made with water in the aquarium, but burrows were counted and recorded after water was slowly decanted to get an accurate count during the habitat water change. Water changes were completed within 30 seconds, so as not to expose the *S. terebrans* to drying periods longer than those experienced in the inter-tidal zone. Molted exoskeletons and dead specimens were also removed.

Once the experiment was finished, the isopods were preserved in 70% ethyl alcohol, burrows were measured for length, width, and placement height from base of aquarium. They were measured for length, and width. Sex, gut contents, and gravidity were determined by observing each individual isopod with a dissecting microscope. The stomach and alimentary tract were opened and visible gut contents were inspected for wood particles. Final measurements of the burrow placement height (mm) from the base of the aquarium and width (mm) were made with them inside the burrow by using a small ruler. Final substrate choice was recorded in terms of where each isopod was at the end of the experiment. Burrow depth measurements were made by carefully extracting them from burrows with forceps and placing a small, flat, flexible probe into the burrow, then removing it to measure the exact depth in millimeters. Once they were removed from the burrow, length, width, and sex was determined by using forceps, calipers, and a dissecting microscope. Length was assessed by unrolling the conglobate isopods and measuring the start of the first pleonal segment (the head) to the end of the telson (the tail). The width was measured at the widest pleonite in the middle section of the body.

Water depth preference

Water depth preference was determined using three aquariums constructed with polyvinyl chloride (PVC) pipe in the laboratory and meter long narrow Styrofoam blocks. For this experiment 15-25 *S. terebrans* were placed in individual PVC pipe aquarium with a Styrofoam block. This experiment was run four times for four days each (96 hours), the runs started on 11 July 2002, 19 July 2002, 30 July 2002, and 5 August 2002. Three 15.2 cm diameter PVC pipes with a height of 1 meter each were completely filled with Lake Pontchartrain water. A 4 X 2.5 X 122 cm Styrofoam block and a weighted aerator were placed in each PVC aquarium. The Styrofoam was secured in the center of the tube by a clamp and a weighted stand. Because Styrofoam is very buoyant the blocks were secured inside the PVC aquarium by either a plastic bag filled with rocks that was tied to the block or test tubes filled with small rocks and punched through a small section of the Styrofoam block. These extra weights were attached 5 cm from the bottom of the Styrofoam block.

Once the experiment was set up 15 or 25 *S. terebrans* with a length greater than 2 mm were placed in each PVC aquarium. Black plastic was wrapped around the top of the PVC aquarium with part of the Styrofoam block extending out of the top. This plastic was taped to the aquarium and the Styrofoam to exclude light. After 4 days, the Styrofoam blocks were carefully removed and measured, and the water in the PVC pipe was strained to catch any non-burrowing *S. terebrans*. *Sphaeroma terebrans* were carefully extracted from burrows with forceps to complete measurements. The 12 Styrofoam blocks were then measured for burrow placement height in the water column, burrow length, and whether the burrow was made on the smooth or rough side of the Styrofoam blocks. *Sphaeroma terebrans* utilized in the experiment were measured for length and width, and their sex and gravidity was determined with a dissecting microscope.

Strength and hardness properties of substrates

Hardness was measured on seven representative samples of burrowed cypress and two samples of drilled cypress lumber to see how it compared with the literature recorded hardness. The drilled cypress blocks were each drilled five times with a ¼ inch bit to create uniformity among samples. The *S. terebrans* burrowed cypress samples were very soft, heavily burrowed sections had a "sponge-like" consistency. The burrowed samples were compared with the non-burrowed wood and Styrofoam, which I had set out at the Spillway site. According to the American Society for Testing Materials hardness can be quantified by measuring the force required to imbed a Janka ball to one half its diameter. Hardness measurements were made on wet wood the natural habitat for *S. terebrans* within a day of collecting it from the field and oven dried wood with a moisture content of 12%, which is the standard procedure for the hardness test. Moisture content was determined by subtracting the weight of the cut wood by the weight of the oven dried wood, dividing this number by the oven dry weight and multiplying the result by 100. The first tests on 9 samples were completed on 10 June 2002, 6 burrowed cypress exposed roots, and 1 burrowed cypress stump that had been submerged in Lake Pontchartrain water, and 2 blocks of drilled lumberyard cypress.

A second hardness test was run on 20 June 2002 after the same samples had been dried for 10 days in a drying oven. Wet weights and dry weights were recorded before testing to calculate moisture content, and dimensions were measured to calculate density. The hardness modulus test followed the guidelines of ASTM D 1037 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Material (1999). However instead of testing particle panels of uniform shape and size, I tested samples of wet and dry cypress from a lumberyard and *S. terebrans* burrowed samples collected from the Spillway site. This procedure is applicable for materials greater in thickness than 1/8 inch (3 mm). The test procedure used a 0.444 inch (11.28 mm) diameter "Janka" ball which was then used to penetrate a 100 mm^2 area. The load is applied continuously throughout the test at a speed of 0.05 in./min. (1.3mm/min.). The maximum load (pounds of pressure applied to the wood) at which the Janka ball is embedded to one half of its diameter is used as the measure of "hardness modulus." The hardness modulus was measured and recorded by an electric circuit indicator and the results were graphed. The modulus is then equal to (load 2 – load 1)/(displacement 2-displacement 1) which is load of penetration in pounds per inch. The hardness modulus value was then converted to hardness by dividing by 5.4, the units for hardness are pounds (Lb).

Statistical analyses

The statistical analyses run on laboratory experiments included analysis of variance (ANOVA) and regression analysis. ANOVA and regression analysis were done using the SAS computer programs Jmp (1998-2002) and StatView (1996). Analysis of variance (ANOVA) was used to compare the means of multiple groups or replicates. Regressions were used to describe how the mean of the response value (y) changes according to the value of the explanatory variable (x). The regression summaries are representative of a best fit or prediction line when comparing two sets of data. The Mann-Whitney U test and the Bonferroni/Dunn post hoc tests were also run on laboratory experiments to determine which groups were significantly different. Other graphs were designed in Microsoft Excel. Replicate numbers were low for field experiments due to loss of blocks and stakes, therefore statistical analyses for these data could not be performed.

RESULTS

Identification

My identification of specimens as being *S. terebrans* agreed with Bate's (1866) original description and several keys and descriptive taxonomic papers cited in the materials and methods. Dr. Brian Kensley of the Department of Invertebrate Zoology at the Smithsonian National Museum of History and the verified that specimens collected from the Spillway site were *Sphaeroma terebrans* Bate.

Collections

<u>Total number, sizes, diet, and sex</u>

Over 2000 *S. terebrans* collected from January 2001 through October 2003 from the study site were examined. They were measured for individual sizes and dimensions and dissected to observe gut contents and determine sex. The *S. terebrans* specimens sampled ranged in length from 2 mm to 11 mm and width from 1 mm to 5 mm, however, embryos within the mother's brood pouch had lengths smaller than 2 mm. Gut contents were soft green-brown compact detritus-like substance and filled the alimentary canal. This substance broke apart easily and seemed to partially dissolve in water, but did not contain any woody fibers. *Sphaeroma terebrans* used in laboratory experiments did have small pieces of Styrofoam on their pleopods, but none was found in their guts. Keys and diagrams (Gareth Jones and Eltringham 1968; Shultz 1969; Rehm and Humm 1973; Estevez and Simon 1974; ISBMM 1974; Kensley and Schotte 1989, 1999; and Theil 1999) show that an *appendix masculina* should be present if male. It is difficult to sex the juveniles (2-3 mm in length), according to Dr. Martin Theil (personal communication 7/21/02) who has published papers on the reproductive biology of *S. terebrans* the size limit for subadults is 5 mm though some males can be clearly recognized at a smaller size. All of the isopods larger than 4 mm in length I sorted were female.

<u>*Sphaeroma terebrans* habitat</u>

Areas inhabited by *S. terebrans* are inundated wooded sections of the south and southwest shorelines of Lakes Pontchartrain and Maurepas. *Sphaeroma terebrans* in this area are found burrowed in tree stumps and exposed roots. Colonized submerged stumps are "honeycombed" with hundreds to thousands *S. terebrans* burrows. Wood strength and hardness properties are noticeably affected and much of the wood could be broken apart by hand. It was rare to find a colonized piece of wood with only one burrow. Evidence of *S. terebrans* on the south and southeastern shorelines included burrowed wood and Styrofoam samples collected from the rack line after storms. Burrows in collected driftwood and Styrofoam samples were investigated but they did not yield live *S. terebrans* specimens. In Lake Pontchartrain I have only found *S. terebrans* in fringing dead cypress, in water. Styrofoam floats have also been colonized by *Sphaeroma terebrans*. Styrofoam is an unnatural and manmade substrate present in Lakes Pontchartrain and Maurepas in the form of floats, boats, and garbage. I did not find any *S. terebrans* or burrows in *Spartina sp.* (smooth cordgrass) or *Juncus roemarianus* (black needle rush) marsh peat sampled at marshy shorelines around the Fountainbleau site, the Lacombe site, and the Point Aux Herbes site of the block field experiments in Lake Pontchartrain.

<u>Sex ratio – gravidity/population structure</u>

Sphaeroma terebrans sexed during burrowing experiments of this study yielded all females (some were reproductively active) and juveniles (see Table 2). I found that gravid females produced an average of 30.7 eggs or 20 embryos (where eyes were visible), the greatest number of eggs in a female was 127 and the least was 1 (see Figure 8). The greatest number of embryos in a female was 46. In all the substrate boring laboratory experiments, I sexed 800 *S. terebrans*. Of these, 82 were reproductively active (containing eggs or embryos) females. Therefore, ten percent of the adult population sampled in the months of July, August, September, and October 2002 was reproductively active. Nine different wood stakes placed in the field for 1 year had populations dominated by juveniles with lengths of 2 mm and widths of 1 mm. In this population of 549 *S. terebrans* collected on May 2003 there were 41 reproductively active females. The average number of embryos was 21.5 per female, but ranged from 5-41. Out of the 561 burrows in the field stakes, 9 were family burrows that housed juveniles and 1 adult, 13 burrows contained adult pairs, and 1 burrow had 3 adults in it. The average number of juveniles in these family burrows was 7, however the greatest number of juveniles excavated from one burrow was 16. This is similar to Theil (1999) who reported that parental females housed between 5 and 20 juveniles in their burrows.

Table 2. Population structure for all experiments.

Experiment	Total *S. terebrans*	# Female	# Gravid	# Juveniles
No Choice	120	120	4	0
First Choice	200	200	20	0
Second Choice	210	210	29	0
Water Depth	270	270	29	0
Field Stake	549	78	41	471
Totals	1349	878	123	471

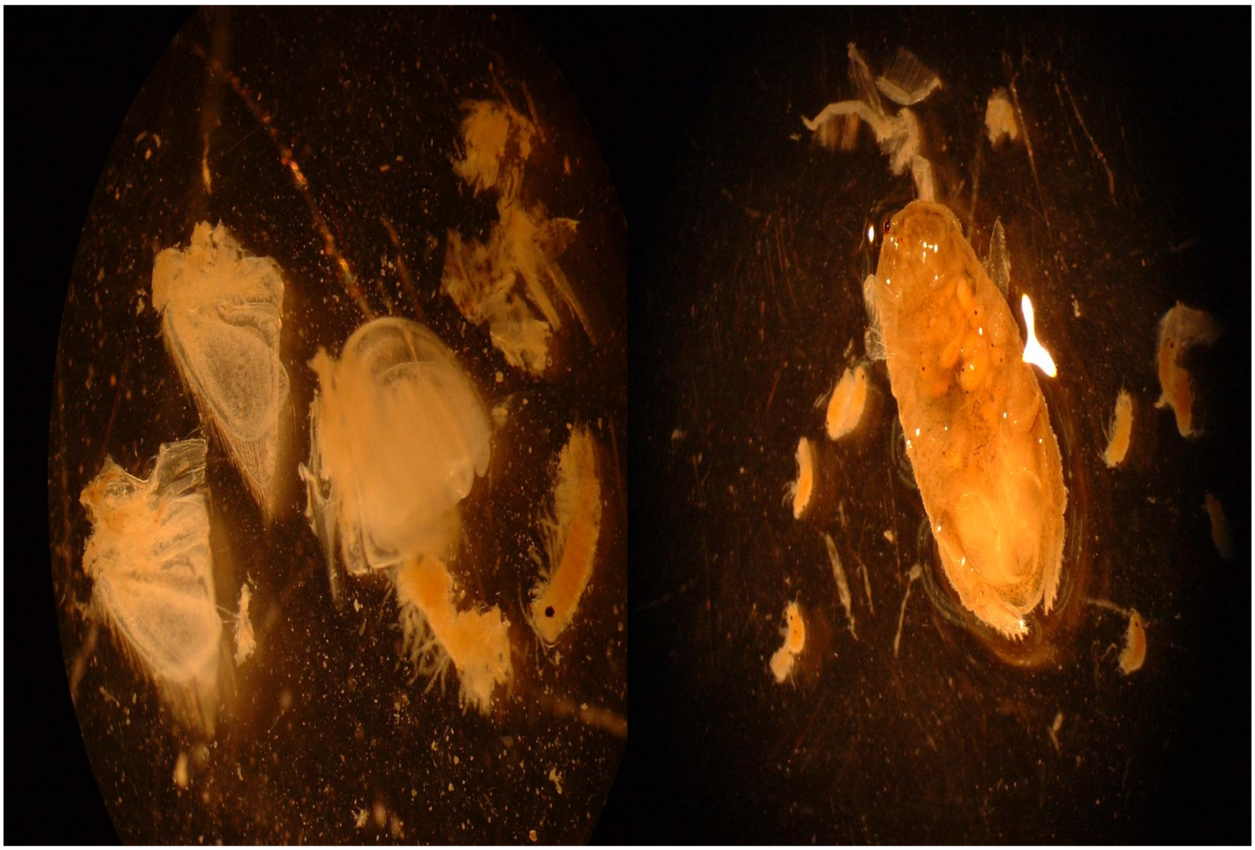


Figure 8. Photographs of enlarged pleopods and dissected female *Sphaeroma terebrans* with embryos.

Field experiments

<u>Blocks</u>

After approximately one year, 2 remaining cypress blocks at the Spillway were colonized, mostly by juvenile *S. terebrans* with dimensions of 2 X 1mm. The other cypress and Styrofoam blocks were lost over the course of the year. Where burrows were present, *S. terebrans* seemed to prefer the annual ringed portion of the blocks. However these two blocks did not constitute a representative sample size and statistical analysis could not be performed.

The main colonizers of cypress and Styrofoam blocks that were placed at the 5 representative sites around Lake Pontchartrain and monitored monthly were the green algae, *Cladophora* sp., and the macroinvertebrates *Corophium* sp. and *Grandidierella* sp. Submersed aquatic vegetation, *Ruppia maritima*, along with barnacles (*Balanus* sp.), and snails (*Texadina* sp.), could also be found on the blocks on the two northshore sites. Blocks at the Point Aux Herbes site, when present, were colonized by green algae such as *Cladophora*, *Enteromorpha*, and *Ulva*, along with macroinvertebrates such as *Grandidierella*, *Cerapus*, *Corophium*, and *Mucrogammarus*. Before the Lincoln Beach pilings were removed in February 2002, these blocks had similar colonization patterns as Point Aux Herbes, but also had gobies (*Gobiosoma bosc*), grass shrimp (*Paleomonetes* sp.), large blue crabs (*Callinectes* sp.), and the encrusting bryozoans (*Canopeum* sp.) on, attached to, or among the blocks. The Spillway site blocks were colonized by green algae (*Cladophora*), ectoprocta (*Victorella pavida* and *Conopeum* sp.), hydroids (*Garveia franciscana*), macroinvertebrates (*Grandidierella sp.*, *Corophium sp.*, *Cerapus sp.*), blood worms or chironomids (*Chironomus* sp.), mud crabs (*Rithropanopeus harisii*), barnacles (*Balanus* sp.), mussels (*Ishadium recurvum* and *Congeria leucophaeta*), gobies (*Gobiosoma bosc*), blue crabs (*Callinectes* sp.), and a few *Sphaeroma terebrans* (see Figure 9).

<u>Stakes</u>

The nine stakes of cypress, loblolly pine, weathered pine, and Spanish cedar placed at the Spillway site on May 30, 2002 and retrieved on May 29, 2003 were colonized by many species including *S. terebrans*. The most abundant inhabitant on all of the stakes were barnacles (*Balanus* sp.), approximately 20 of these barnacles were identified and found to be *Balanus subalbidus* (see Table 3). There was no significant effect when the total number of *Balanus* sp. was compared with the total number of *S. terebrans* in a repeated measures ANOVA ($F(1,40)=2.27$, $p=0.14$) on the colonized field stakes (see Figure 10). Mobile macroinvertebrates *Grandidierella*, *Cerapus*, *Corophium*, and *Chironomus* sp were also identified but were not counted. Also present on the stakes were green algae (*Cladophora* sp.), ectoprocta (*Victorella* *pavida* and *Conopeum* sp.), hydroids (*Garveia franciscana*), mud crabs (*Rithropanopeus harisii*), a few mussels (*Ishadium recurvum* and *Congeria leucophaeta*), and gobies (*Gobiosoma bosc*).

Figure 9. Cypress blocks at the Spillway site after 6 months in the field, not yet colonized by *S. terebrans*.

Table 3. Total numbers of *Balanus* sp. colonizing wood stakes.
Last row represents oven-dried weight of the *Balanus* sp. tests scraped from individual stakes.

***Balanus* sp.**	**Pine**	**Pine**	**Pine**	**Pine**	**Spanish Cedar**	**Spanish Cedar**	**Cypress**	**Cypress**	**Weathered Pine**
0-20 cm	74	100	173	211	214	192	297	205	110
21-40 cm	375	410	259	319	418	630	427	417	239
41-60 cm	401	539	386	416	563	453	301	319	200
61-80 cm	151	162	24	53	50	201	173	94	88
81-100 cm	14	0	0	0	0	22	38	20	144
dry weight	326.4 g	388.2 g	371.8 g	269.3 g	477.8 g	571.8 g	605.2 g	548.7 g	445.8 g

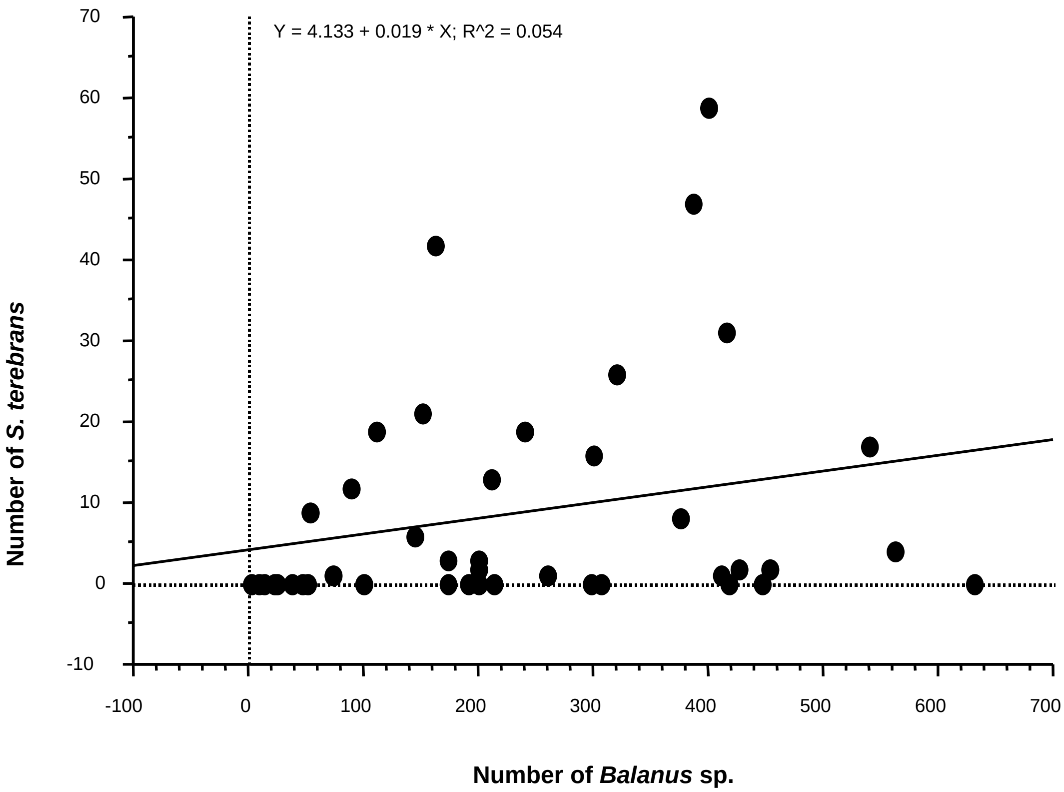


Figure 10. Comparison of colonization of *Balanus* sp. vs. *S. terebrans* on wood stakes.

The total number of burrows in the 9 stakes set at the Spillway site was 586 (see Table 4). The total number of *S. terebrans* removed from the stakes was 549 (471 juveniles (2 X 1 mm), 78 adult females (4-10 mm X 2-5 mm), and 41 of these adults females were gravid (7-10 mm X

3-5 mm). The weathered pine stake had the most *S. terebrans* burrows and one cypress stake had no *S. terebrans* burrows (see Table 4). Spanish cedar and cypress had the least amount of *S. terebrans* burrows. The average burrow height in the water column was 46.3 cm, but the maximum height was 89.1 cm and the minimum height was 1.9 cm. The majority (57%) of the *S. terebrans* burrows were in the 40 to 70 cm height of the wooden stakes, and only 10% of *S. terebrans* burrows were made in the first 10 cm (see Figure 11).

Table 4. Field stake experiment, distribution of *S. terebrans* burrows. Number of *S. terebrans* burrows in 10 cm height increments for each stake.

	Pine	Pine	Pine	Pine	Spanish Cedar	Spanish Cedar	Cypress	Cypress	Weathered Pine
0-10 cm	2	0	4	12	0	0	0	0	48
11-20 cm	1	2	0	4	0	0	0	0	32
21-30 cm	0	0	0	9	0	0	0	0	16
31-40 cm	10	1	3	18	0	0	0	0	3
41-50 cm	29	3	21	26	3	0	0	3	2
51-60 cm	31	19	66	18	0	2	0	5	2
61-70 cm	21	34	1	28	0	1	0	0	8
71-80 cm	6	3	0	0	0	0	0	0	50
81-90 cm	0	0	0	0	0	0	0	0	11
91-100 cm	0	0	0	0	0	0	0	0	3
Density g/cm^3	0.49	0.53	0.52	0.53	0.52	0.54	0.53	0.49	0.84

Burrows in cypress, pine, and cedar stakes collected from the Spillway site after one year were investigated. There was a significant correlation when the lengths of *S. terebrans* were compared with burrow lengths in a repeated measures ANOVA ($F(1,485)=1272.10$, $p<.0001$) in the colonized field stakes (see Figure 12). *Sphaeroma terebrans* found loose and not in a burrow were excluded from this comparison. The average burrow length was 3 mm; however, burrows ranged from 1 mm to 21 mm. The average burrow width was 1.5 mm, but widths ranged from 1 mm to 5 mm (see Table 5). Twenty-six *S. terebrans* were also discovered in pairs in the same burrow. Pine and cypress have similar wood densities (see Tables 1 and 4), however the burrowing was more abundant in the pine.

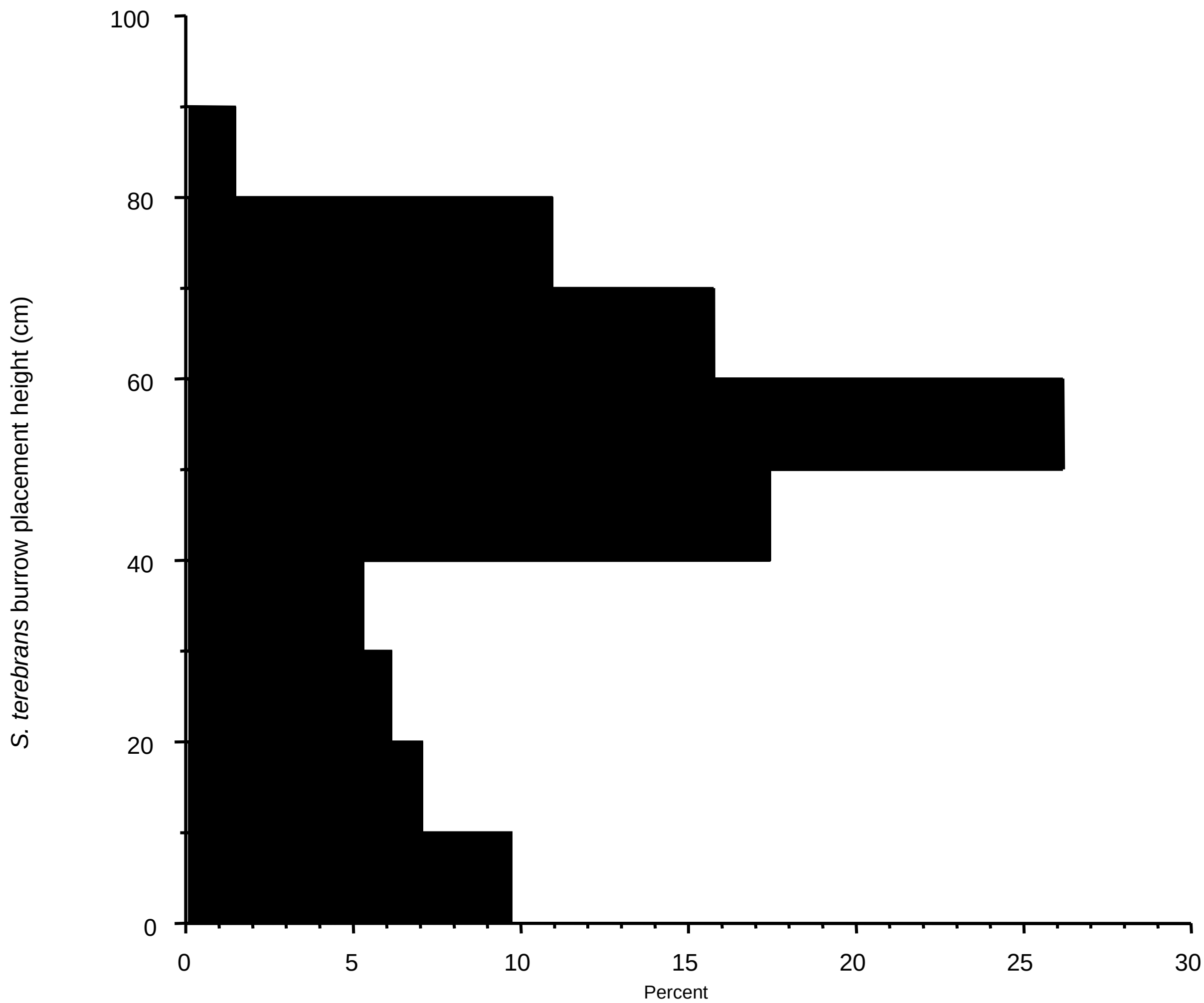


Figure 11. *Sphaeroma terebrans* burrow placement height on 9 wood stakes placed in the intertidal zone of the Spillway site for approximately one year.

Table 5. Field stake experiment, *Sphaeroma terebrans* burrow dimensions and population size and structure information.

	Wood stakes	Juveniles	Adults	Same burrow
# *S. terebrans*	549	471	78	91
Average burrow Placement height	46.3 cm	Maximum 89.1 cm	minimum 1.9 cm	
Average length	3 mm	2 mm	8 mm	
Average width	2 mm	1 mm	5 mm	
Gravid	41			
Burrows	561			23
Empty burrows	95			
Average burrow length	3 mm	Maximum 21 mm	minimum 1 mm	
Average burrow width	2 mm	Maximum 5 mm	minimum 1 mm	

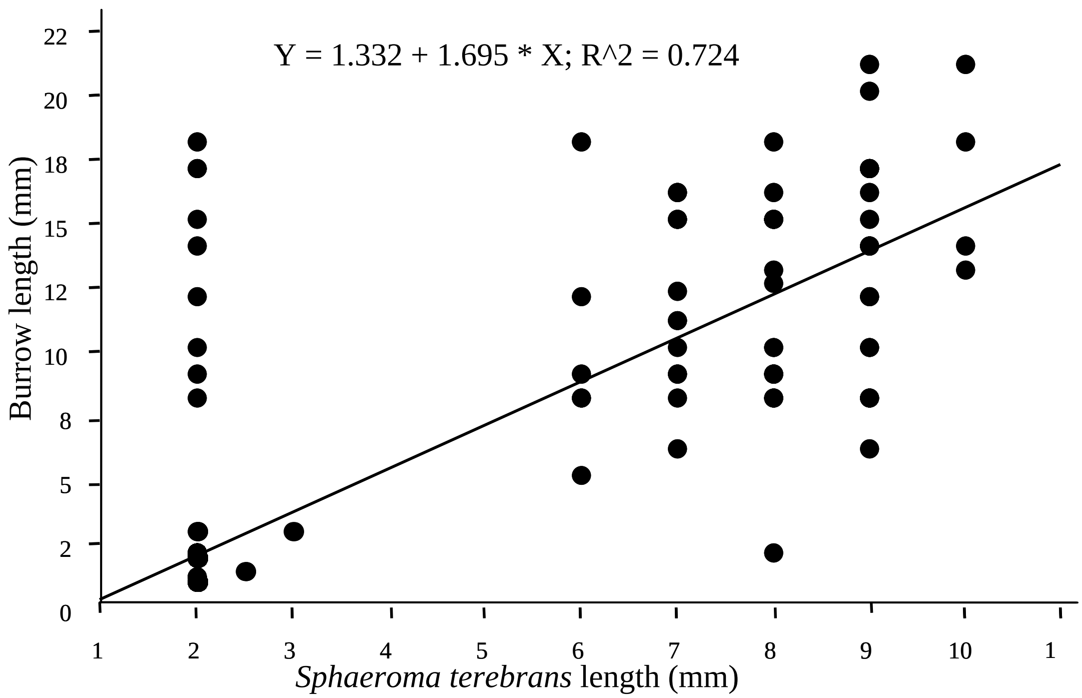


Figure 12. A comparison of *S. terebrans* body and burrow length for wood stake experiment. *Sphaeroma terebrans* not in burrows were excluded from analysis.

Laboratory experiments

<u>No choice experiment</u>

The No Choice experiment yielded a total of 58 burrows (12 balsa burrows and 46 Styrofoam burrows) (see Table 6). No burrows were made in the cypress blocks. There was a significant difference in substrates in which *S. terebrans* burrowed in the no choice substrate experiment when compared by a repeated measures ANOVA ($F(2,9)=30.47$, $p<.0001$) (see Figure 13). However, a Bonferroni/Dunn post hoc test set at a significance level of 5% found significant differences between cypress and Styrofoam ($p<.0001$) and balsa and Styrofoam ($p=.0002$), but did not find balsa and cypress to be significantly different ($p=.0383$). The total number of *S. terebrans* in this experiment was 120 (see Table 6). At the end of the experiment, there were 26 *S. terebrans* outside of burrows. There were 14 empty burrows. Forty-two *S. terebrans* died during the experiment. The percent survival of *S. terebrans* in the balsa, cypress, and Styrofoam was significantly different according to a repeated measures ANOVA, ($F(2,9)=7.70$, $p=.0112$) (see Figure 14). However, a Bonferroni/Dunn post hoc test revealed that only the cypress and Styrofoam substrates were significantly different ($p=.0044$) (see Figure 15). There were 44 molts. The average burrow dimensions (L X W) in the balsa were 5 X 3 mm and the burrow placement height was 9 mm, in the Styrofoam average burrow dimensions were 9 X 4 mm and the placement height was also 9 mm (see Table 6). There were 2 gravid females found in the balsa aquariums and 2 gravid females found in the Styrofoam aquariums. The average lengths of *S. terebrans* in this experiment were 6 mm in cypress, balsa, and Styrofoam. The lengths of *S. terebrans* varied from 4 to 10 mm.

Table 6. No choice burrowing experiment results after 24 days in the laboratory.

	Cypress	Balsa	Styrofoam
# *S. terebrans*	40	40	40
Average burrow placement height	0 mm	9 mm	9 mm
Average *S. terebrans* length	6 mm	6 mm	6 mm
Average *S. terebrans* width	*	*	*
Gravid	0	2	2
Non-burrowed *S. terebrans*	15	11	0
Molts	22	7	15
Mortalities	19	14	9
Burrows	0	12	46
Empty burrows	0	4	10
Average burrow length	0 mm	5 mm	9 mm
Average burrow width	0 mm	3 mm	4 mm

*** no data**

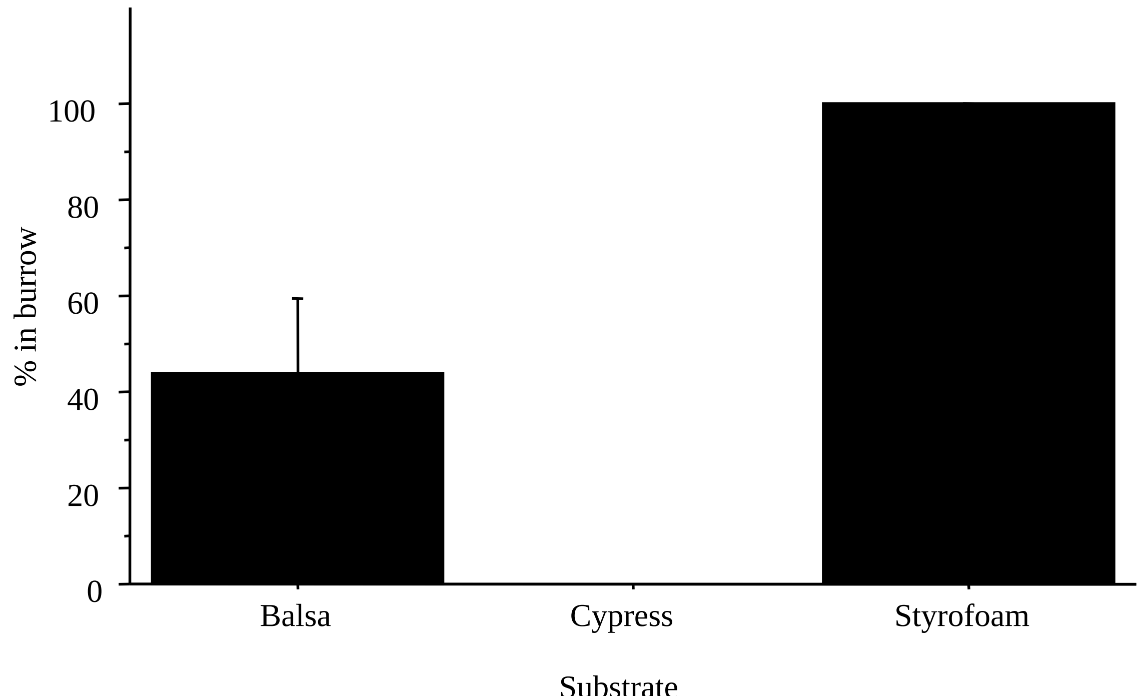


Figure 13. Mean (+1 standard error) percentage of *S. terebrans* in balsa, cypress, or Styrofoam burrows in the 24 day no choice substrate experiment.

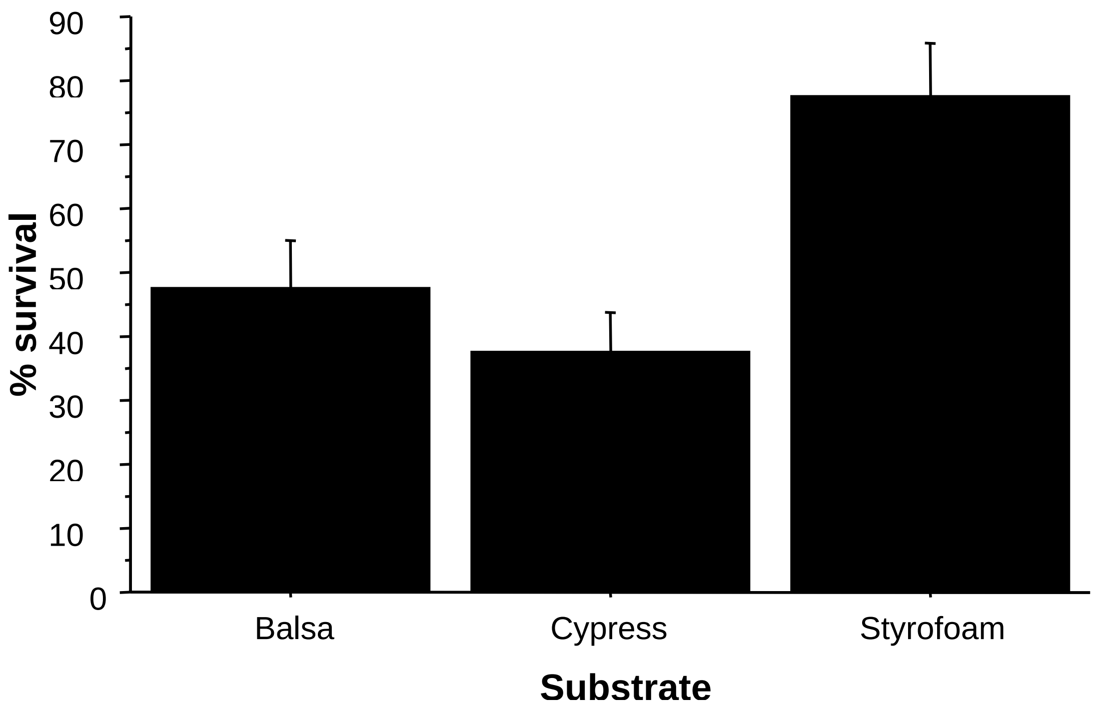


Figure 14. Mean (+1 standard error) percentage of *S. terebrans* surviving in either balsa, cypress or Styrofoam in the 24 day no choice substrate experiment.

<u>Substrate preference (choice experiment)</u>

In the laboratory, a substrate choice experiment was run twice each for 24 days to test substrate preferences of *S. terebrans*. It colonized Styrofoam and balsa, but not cypress. Styrofoam had the most burrows, balsa had a few burrows, and there were no burrows in the lumber quality cypress.

The first substrate choice experiment of the two choice experiments started August 2 and ended in August 27, 2002. A total of 200 *S. terebrans* were used in this experiment (see Table 7). The total number of burrows created was 146. Forty-two burrows were observed in the balsa/Styrofoam aquariums, 13 in the balsa/cypress aquariums, 39 in the Styrofoam/cypress aquariums, 49 in Styrofoam aquariums, and 0 in the water only aquariums (see Table 7). Considerably more *S. terebrans* burrowed into balsa than cypress (Mann-Whitney U test tied Z-value=-1.984, tied P-value=.0472) (see Figure 16). Significantly more *S. terebrans* burrowed into Styrofoam than balsa (Mann-Whitney U test tied Z-value=-2.428, tied P-value=.0152), and significantly more *S. terebrans* burrowed into Styrofoam than cypress (Mann-Whitney U test tied Z-value=-2.477, tied P-value=.0132) when given a choice (see Figure 15). There were 26 *S. terebrans* not in burrows or outside by the end of the experiment. There were 41 empty burrows. Sixty-eight *S. terebrans* died during the experiment (see Table 7). The average burrow dimensions (L X W) for each of the substrate choices were: balsa/Styrofoam, balsa/cypress, Styrofoam/cypress, Styrofoam are displayed in Table 7. The total number of gravid *S. terebrans* was 20. The average *S. terebrans* dimensions (L X W) in each of the aquaria were 6 X 3 mm at the end of the experiment. However, dimensions did vary from 5 X 3 mm to 9 X 4 mm.

Table 7. First substrate choice experiment results for burrow dimensions and *S. terebrans* population size, structure, and mortalities after 24 days.
( ) infers block type.

	Balsa (Styrofoam)	Balsa (Cypress)	Styrofoam (Cypress)	Styrofoam	Water
# *S. terebrans*	40	40	40	40	40
Average burrow placement height	25 mm (12 mm)	26 mm (0)	17 mm (0)	14 mm	0
Average *S. terebrans* length	6 mm (6 mm)	6 mm (0)	6 mm (0)	6 mm	6 mm
Average *S. terebrans* width	3 mm (3 mm)	3 mm (0)	3 mm (0)	3 mm	3 mm
Gravid	8	3	1	2	6
Non-burrowed *S. terebrans*	2	3	2	3	16
Molts	16.5	10	18.5	21.5	12
Mortalities	8	24	9	5	24
Burrows	2 (40)	16 (0)	39 (0)	49	0
Empty burrows	0 (12)	3 (0)	10 (0)	16	0
Average burrow length	8 mm (12 mm)	8 mm (0)	12 mm (0)	11 mm	0
Average burrow width	3 mm (3 mm)	4 mm (0)	4 mm (0)	3 mm	0

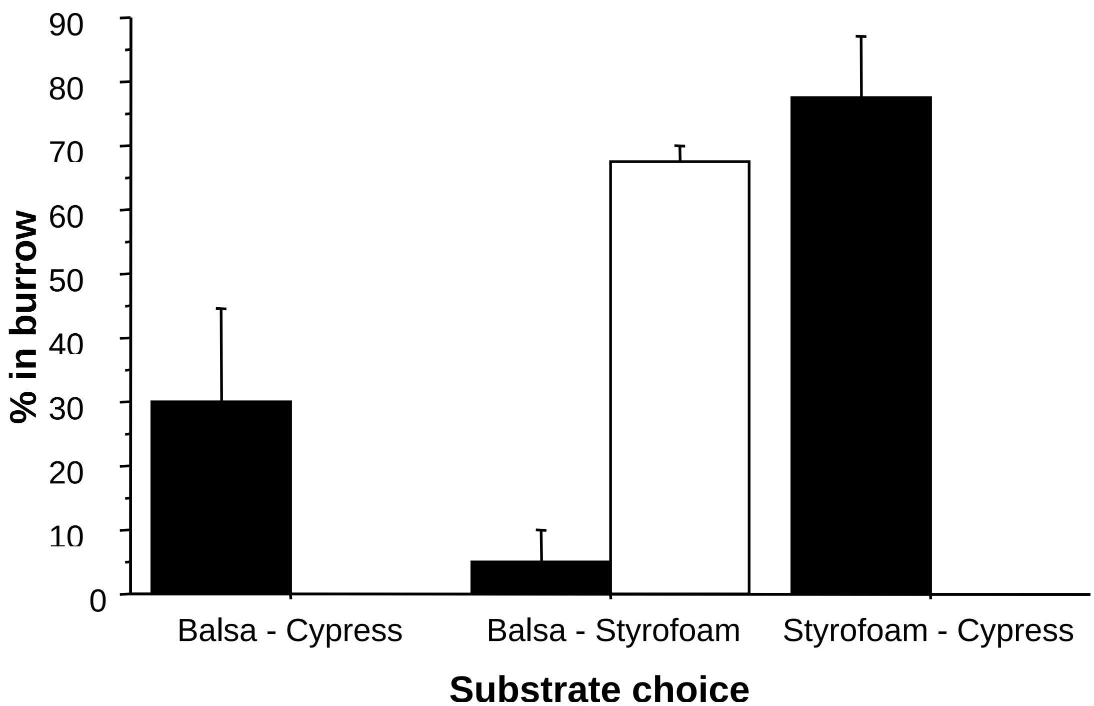


Figure 15. First substrate choice experiment, the mean (plus 1 standard error) percentage of *S. terebrans* in a burrow when given a choice between balsa and cypress, balsa and Styrofoam, and Styrofoam and cypress.

The second substrate choice experiment was also run for 24 days, it started October 28 and ended November 19, 2002. When offered a choice between balsa and cypress in the second experiment, considerably more *S. terebrans* burrowed into balsa than into cypress (Mann-Whitney U test Z-value=-2.477, tied P-value=.0132) (see Figure 16). Styrofoam was the preferred substrate to burrow into when *S. terebrans* were given a choice between it and balsa and Styrofoam and cypress (Mann-Whitney U test tied Z-value=-2.646, tied P-value=.0082) (see Figure 16). During this experiment 148 burrows were created by *S. terebrans* (41 in the balsa/Styrofoam aquariums, 19 in the balsa/cypress aquariums, 42 in the Styrofoam/cypress aquariums, 46 in Styrofoam aquariums, and 0 in the water only aquariums (see Table 8). Two hundred eleven *S. terebrans* were used in this choice experiment (see Table 8). There were 35 *S. terebrans* not in burrows or outside by the end of the experiment. There were 21 empty burrows (see Table 8). The survival of *S. terebrans* for each substrate choice was significantly different in a repeated measures ANOVA (F(4,15)=6.21, p=.004) (see Figure 17). Forty-eight *S. terebrans* died during this experiment (see Table 8).

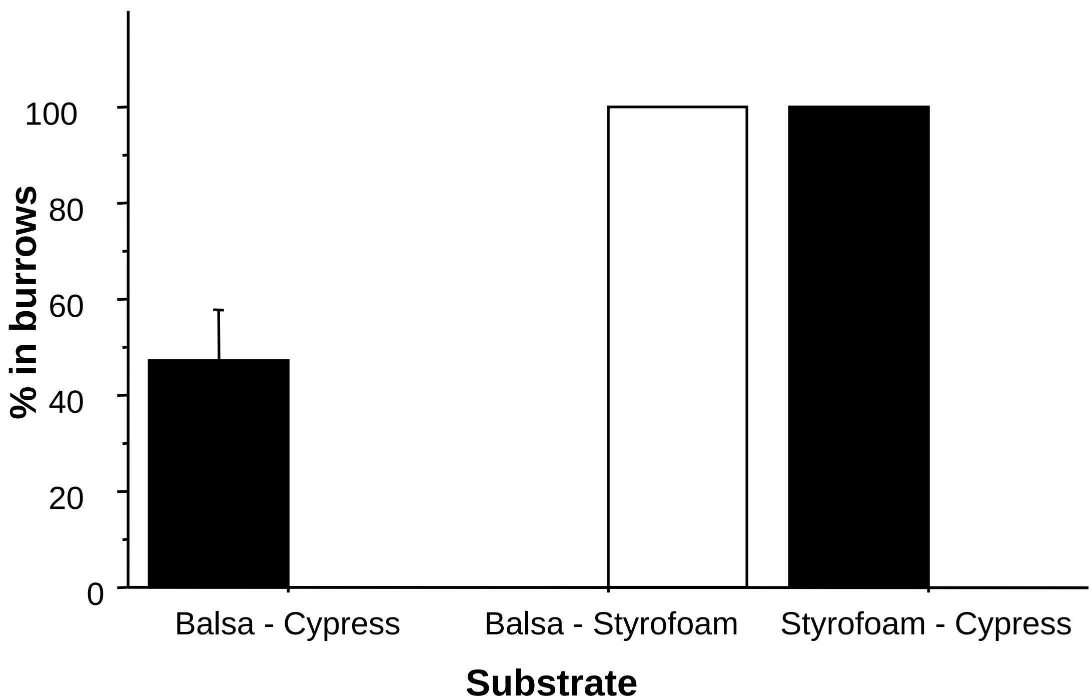


Figure 16. Second substrate choice experiment, mean (+1 standard error) percentage of *S. terebrans* in burrows when offered a choice between balsa and cypress, balsa and Styrofoam, or Styrofoam and cypress.

Table 8. Second substrate choice experiment results for burrow dimensions and *S. terebrans* population size, structure, and mortalities after 24 days.
( ) infers block type.

Substrate	Balsa (Styrofoam)	Balsa (Cypress)	Styrofoam (Cypress)	Styrofoam	Water
#S. terebrans	40	42	43	41	44
Average burrow placement height	0 (14 mm)	16 mm (0)	17 mm (0)	11 mm	0
Average *S. terebrans* length	0 (7 mm)	7 mm (0)	7 mm (0)	7 mm	7 mm
Average *S. terebrans* width	0 (4 mm)	4 mm (0)	4 mm (0)	4 mm	4 mm
Gravid	13	2	9	2	3
Non-burrowed *S. terebrans*	0	11	0	2	22
Molts	2.5	6	4.5	5.5	1
Mortalities	3	13	6	4	22
Burrows	0 (41)	19 (0)	42 (0)	46	0
Empty burrows	0 (7)	1 (0)	2 (0)	11	0
Average burrow length	0 (11 mm)	9 mm (0)	13 mm (0)	13 mm	0
Average burrow width	0 (4 mm)	4 mm (0)	4 mm (0)	4 mm	0

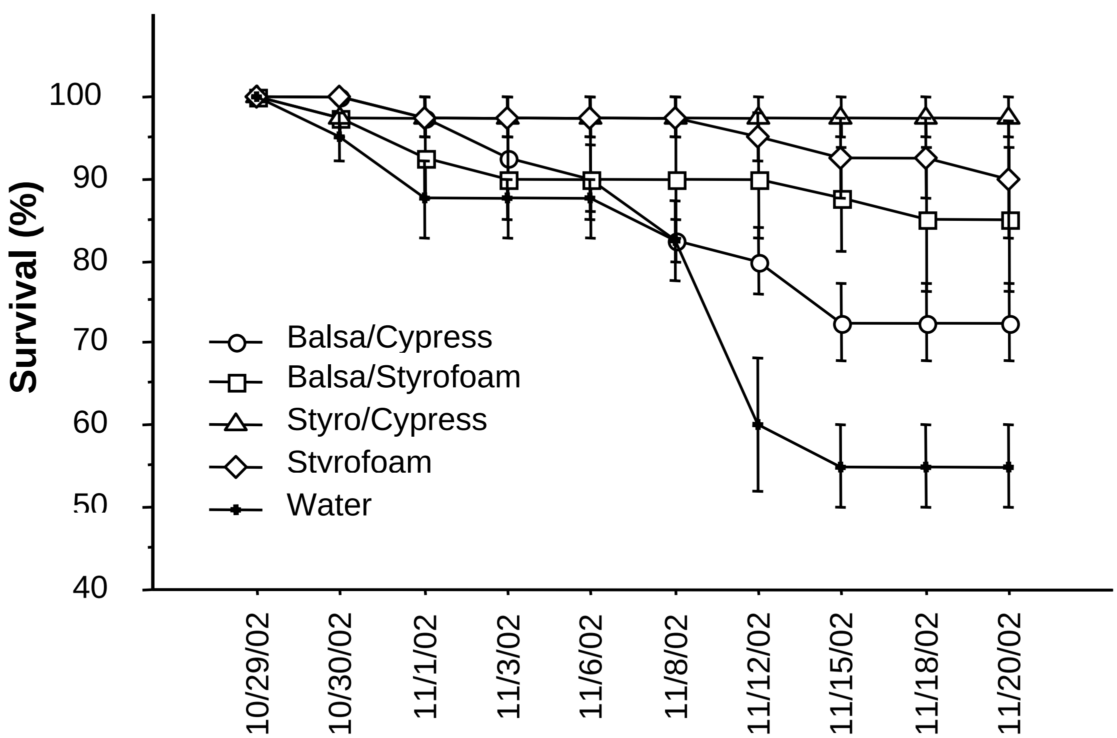


Figure 17. Survival (%) of *S. terebrans* in second 24 day substrate choice experiment.

Styrofoam was the preferred substrate for *S. terebrans* to burrow because it had the greatest percentage of burrows of all the substrate choices (see Figure 15 and 16). The average burrow dimensions (L X W) for each of the substrates were greater in the Styrofoam blocks than the balsa (see Table 8). Average burrow dimensions and burrow placement height for the balsa/Styrofoam aquaria (burrows were only constructed in the Styrofoam blocks), the balsa/cypress aquaria (burrows were only constructed in the balsa blocks), the Styrofoam/cypress aquaria (again burrows were only constructed in Styrofoam blocks), the aquaria with only Styrofoam are listed in Table 8. There were no burrows in the water only aquariums because there was no substrate option. There were 29 gravid *S. terebrans* in this experiment (see Table 8). The average *S. terebrans* dimensions (L X W) for each of the aquaria were 7 X 4 mm at the end of the experiment. Dimensions of *S. terebrans* in the second choice experiment did vary from 3 X 2 mm to 11 X 5 mm.

<u>Water depth preference using Styrofoam blocks</u>

In the laboratory water depth experiment, most burrowing occurred within the first 20 cm of the 100 cm Styrofoam blocks (see Figure 18). Three hundred four burrows were created in the 12 replicate blocks (see Table 9). There were 40 empty burrows at the end of the experiment. Sixteen *S. terebrans* did not burrow and were found at the bottom of the PVC aquaria at the end of the experiment. The average burrow placement height in the water column was 15.6 cm. The average burrow length was 9 mm. Average *S. terebrans* dimensions were 6 X 3 mm, however, lengths ranged from 2 to 10 mm and widths ranged from 2 to 5 mm. The greatest height of a burrow in the water column was 97.7 cm and the shortest height was 0 cm. The smallest burrow length was 0 mm and the greatest burrow length was 19 mm. In this experiment the lengths of *S. terebrans* was significantly correlated with burrow length when analyzed in a repeated measures ANOVA ($F(1, 242)=63.46$, $p<.0001$), (see Figure 19), empty burrows and the 16 *S. terebrans*, which did not burrow were excluded from this analysis. However, burrow lengths also seem to be dependent on *S. terebrans* population abundance according to a repeated measures ANOVA ($F(1, 244)=6.26$, $p=.013$) (see Figure 20). In the Styrofoam block laboratory experiment, at high population abundance (25 *Sphaeroma terebrans* per PVC aquarium) burrow lengths were shorter. When the experiment was run with a low population abundance (only 15 *S. terebrans* per PVC aquarium), burrow lengths were significantly longer. *Sphaeroma terebrans* population density was also significantly correlated with log of the burrow placement height in the water column according to a repeated measures ANOVA ($F(1,242)=6.54$, $p=.0112$) (see Figure 21). *Sphaeroma terebrans* in the high population (25 individuals) burrowed throughout the 100 cm Styrofoam block. *Sphaeroma terebrans* in the low population (15 individuals) preferred to burrow closer to the bottom of the PVC aquaria, less than 70 cm.

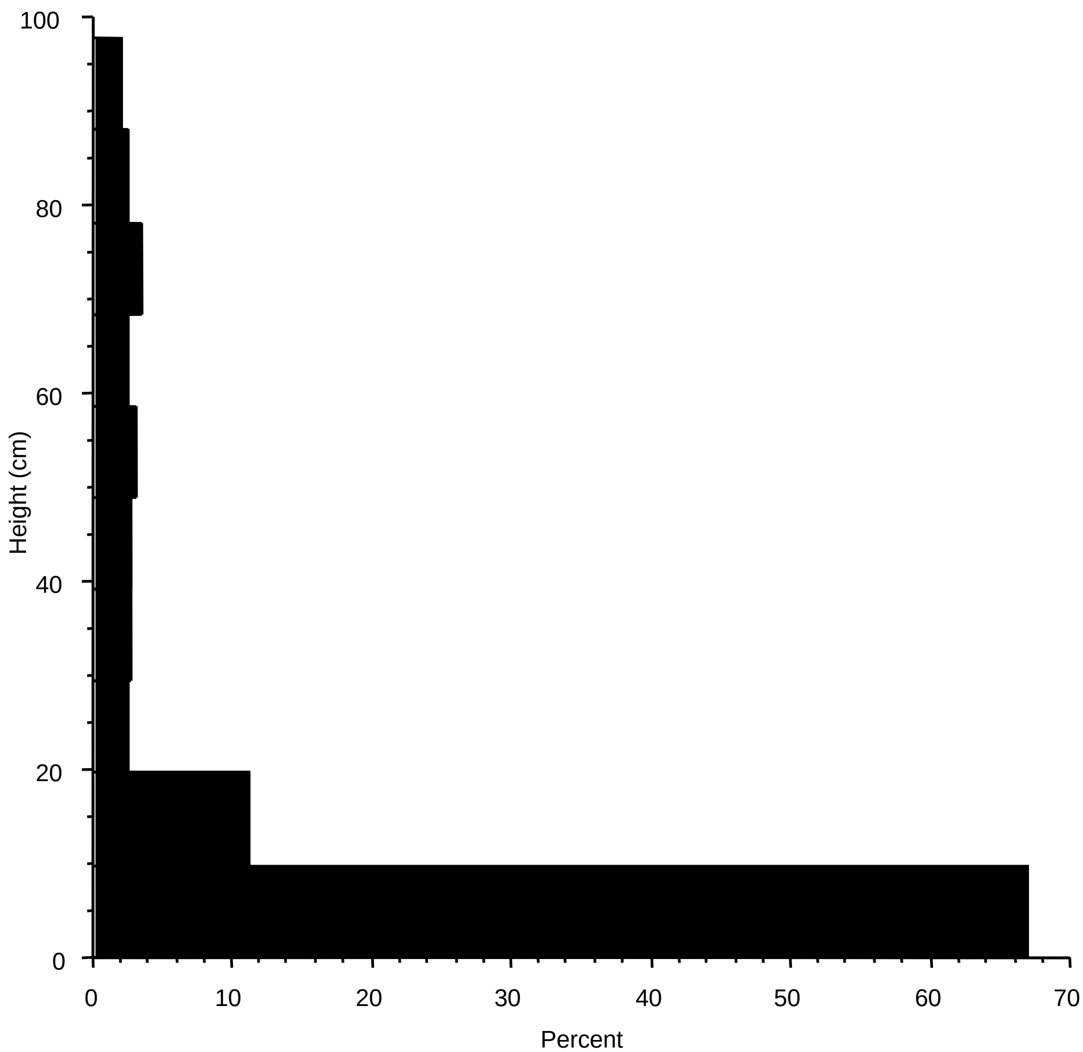


Figure 18. *Sphaeroma terebrans* burrow placement heights in 12 Styrofoam blocks placed in PVC aquaria after 4 days.

Table 9. Burrow placement height preference Styrofoam block 4 day experiment results of burrow dimensions and *S. terebrans* population size, structure, and mortalities in PVC aquaria with 12 Styrofoam blocks.

Substrate	Styrofoam blocks
# *S. terebrans*	270
Average burrow placement height	15.6 cm
Average *S. terebrans* length	6 mm
Average *S. terebrans* width	3 mm
Gravid	29
Non-burrowed *S. terebrans*	16
Molts	7
Mortalities	8
Burrows	304
Empty burrows	40
Average burrow length	9 mm
Average burrow width	3 mm

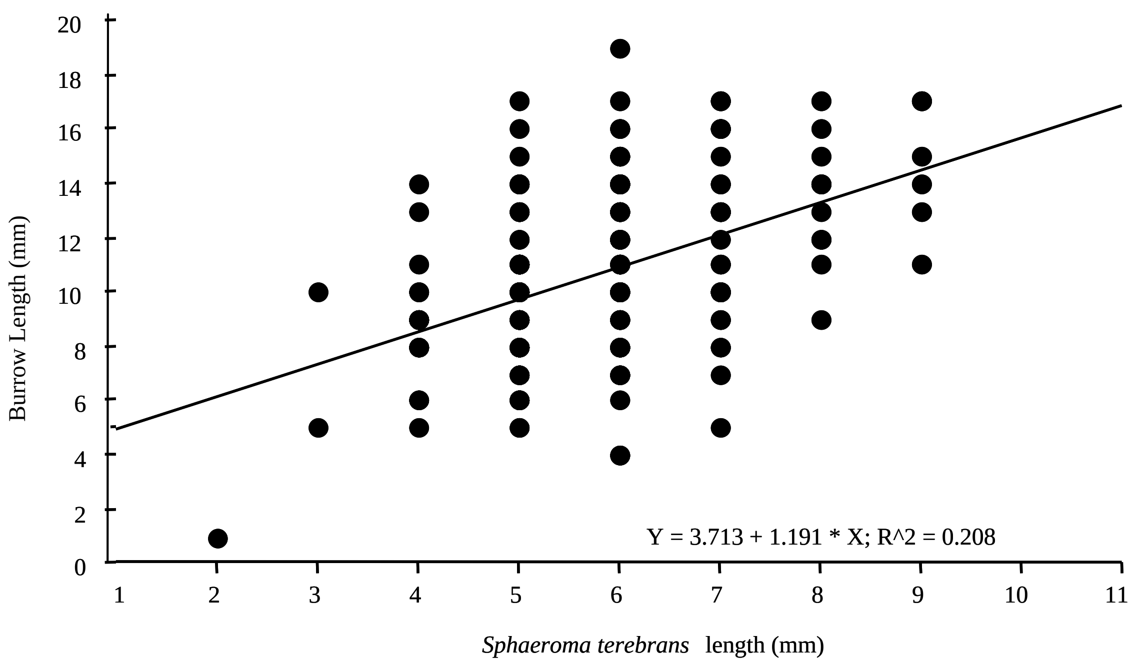


Figure 19. Comparison of *S. terebrans* body and burrow lengths for 12 Styrofoam blocks in PVC aquaria after 4 days.

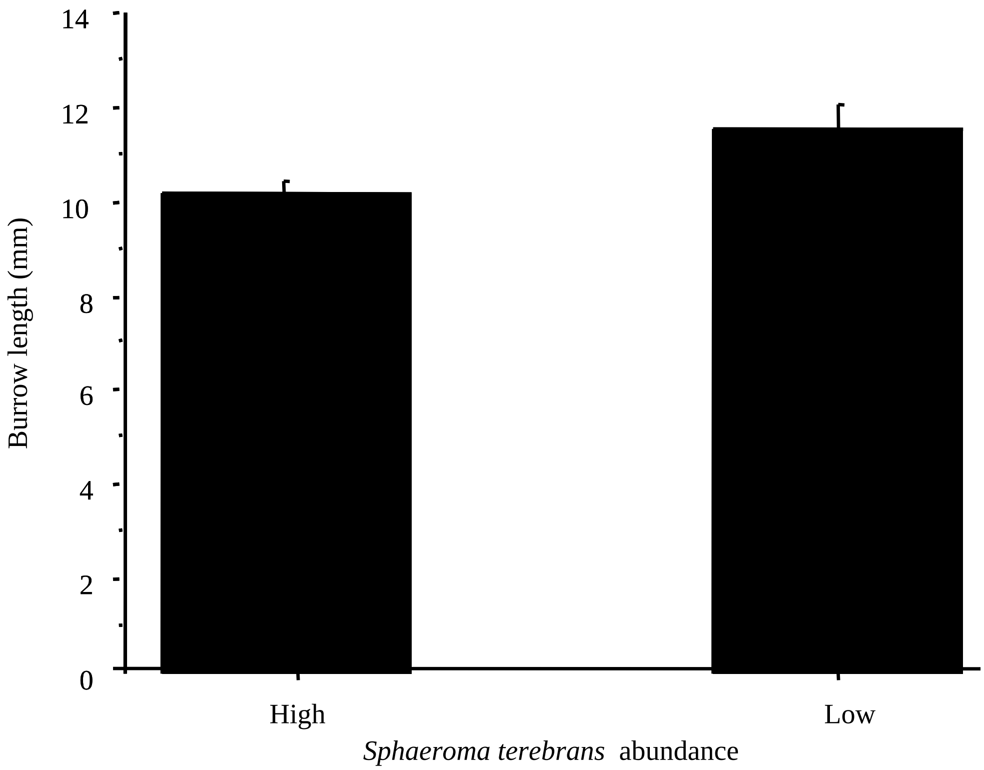


Figure 20. *Sphaeroma terebrans* population abundance vs. burrow lengths, high density has 25 *S. terebrans* per aquaria, low density has 15 *S. terebrans* per aquaria.

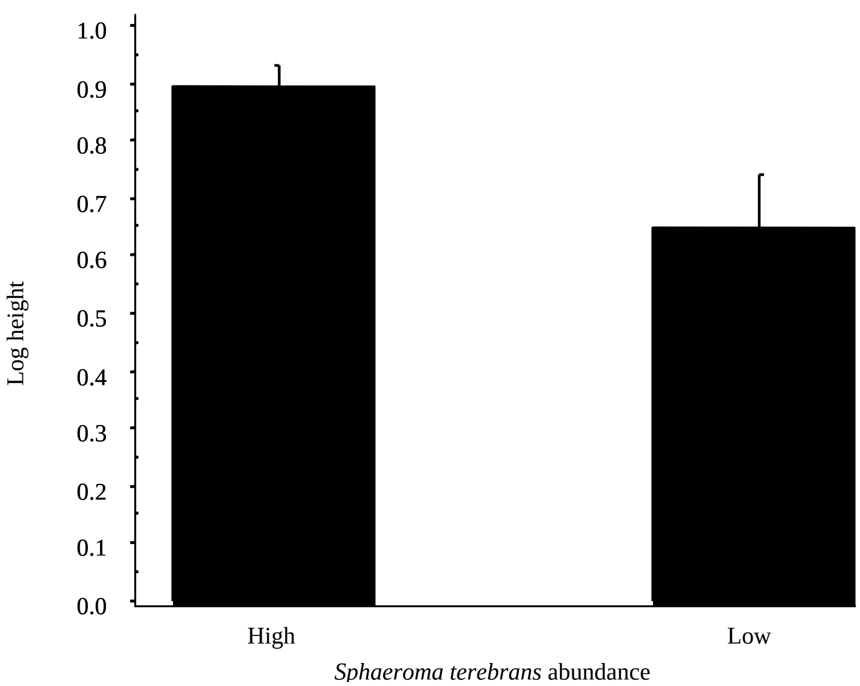


Figure 21. *Sphaeroma terebrans* population abundance vs. log burrow placement height, high density has 25 *S. terebrans*, low density had 15 *S. terebrans* per aquaria.

Cypress densities, hardness and *S. terebrans* abundance

During January through June 2002, 24 samples of cypress trunks and prop roots were collected from the Spillway site. Wood densities and *S. terebrans* abundance were compared to determine if there was a preference for a certain wood density (see Figure 22). There was no significant effect when comparing *S. terebrans* abundance and the density of colonized cypress according to a repeated measures ANOVA ($F(1,31)=.17$, $p=.69$). *Sphaeroma terebrans* abundance varied with cypress density. The greatest number of *S. terebrans* sorted was 433 in a cypress sample with a density of 6.87 pcf (0.11 g/cm^3). The least number of *S. terebrans* sorted was 0 in a cypress sample with a density of 13.11 pcf (0.21 g/cm^3). The average number of *S. terebrans* was 59. Cypress density ranged from 6.87 to 27.47 pcf (0.11 to 0.44 g/cm^3), but mean was 13.11 pcf (0.21 g/cm^3). Hardness of burrowed and lumber grade cypress was also compared for 9 samples. Lumber grade cypress blocks had hardness values of 844.0 Lb and 1172 Lb. The density of these blocks was 28.72 pcf and 28.10 pcf consecutively. An exposed root had the lowest hardness value of 69.2 Lb and a density of 14.35 pcf. Figure 23 graphs the hardness values of one cypress block, one exposed root, and part of a tree stump of those tested in their wet and dry conditions. Figure 23 also shows the density and number of burrows for these samples. The average hardness for all the colonized cypress tested was 498.3 Lb.

In the laboratory experiments involving substrate choice and no choice, balsa and Styrofoam were the preferred substrate in which *S. terebrans* burrowed. The density for balsa was 14 pcf and the density for Styrofoam was 1.8 pcf and no hardness data was available because the values were too small. For these experiments using 1062 *S. terebrans*, there were a total of 698 burrows constructed in either balsa or Styrofoam, and 0 in the densest, hardest substrate cypress (approximately 28 pcf, and 900 Lb).

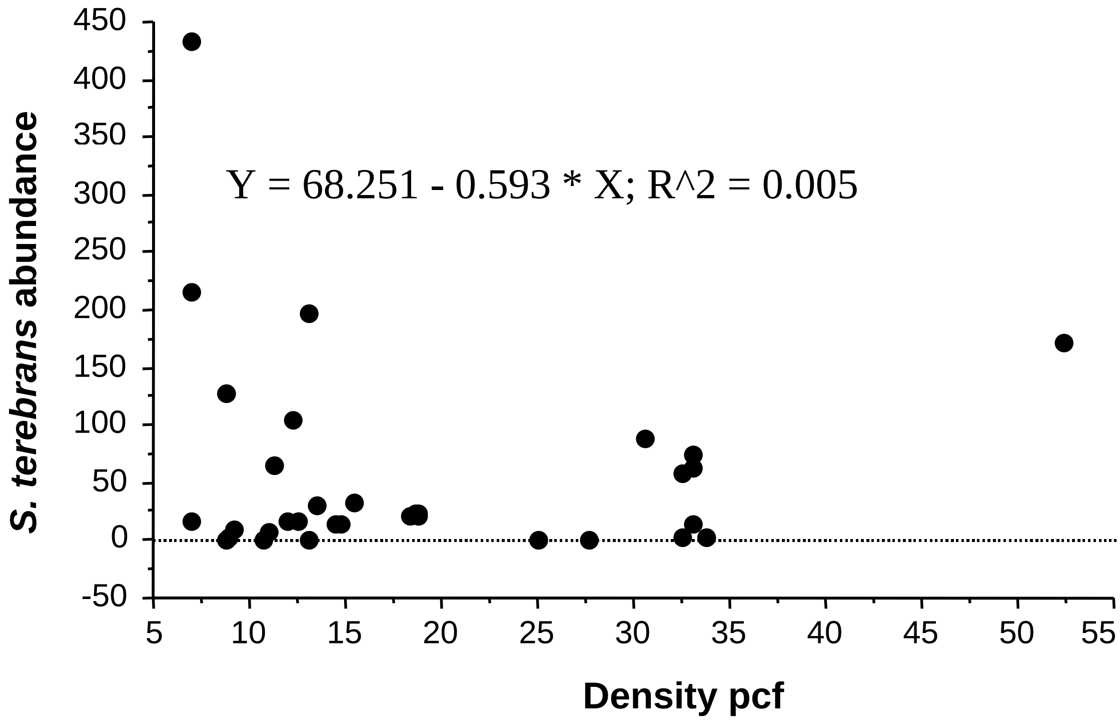
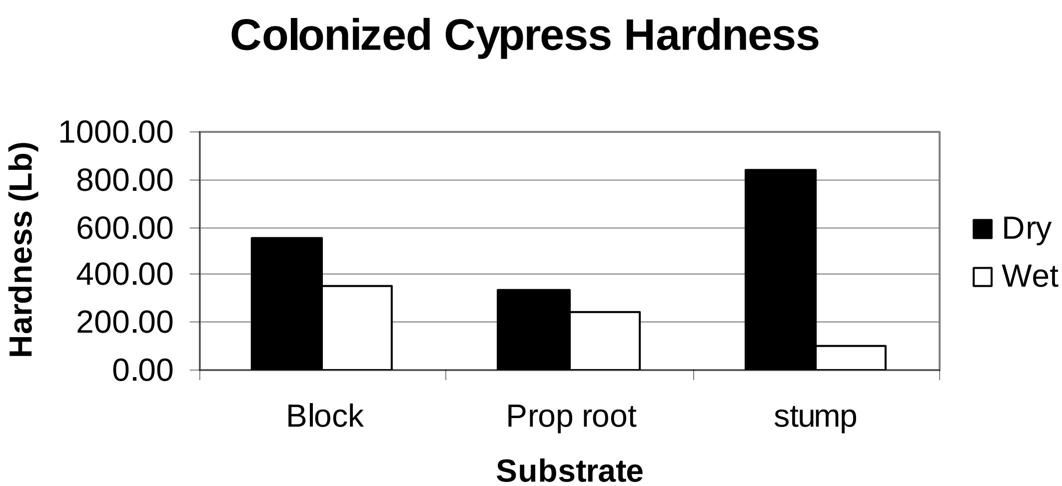


Figure 22. S*phaeroma terebrans* abundance vs. density of colonized cypress.



	Density (pcf)	Burrows
Block	28.10	25
Exposed root	14.35	197
Stump	8.74	433

Figure 23. Hardness, density, and number of *S. terebrans* burrows for three colonized cypress samples (ASTM 1037).

DISCUSSION

This study documents the presence of *S. terebrans* in Lake Pontchartrain. Dr. Brian Kensley positively identified preserved specimens I collected from the Spillway site. The earliest specimens of *S. terebrans* from Lake Pontchartrain in the Smithsonian National Museum of Natural History were collected August 24, 1953 from an area one mile west of Bayou Chinchuba. There is also an earlier reference that *S. destructor* has occurred in Pass Manchac since 1924 (Atwood and Johnson 1924). It is my opinion that *S. terebrans* is a native species to Lake Pontchartrain, because I have found no evidence that it is invasive.

The distribution of *S. terebrans* remains generally within the 1-meter intertidal zone of Lake Pontchartrain. *Sphaeroma terebrans* has colonized woody vegetation, mainly bald cypress, debris, and marine structures on the north, northwest, and southwest shorelines. I found a few references that *S. terebrans* inhabit cypress by Benson et al (1999) where she stated that it could burrow in cypress, and a poster presentation by Poirrier, Franze, and Arthur (1998) indicating that they occur in littoral cypress at densities of 500 individuals per cubic decimeter in Lake Pontchartrain.

The most interesting finding of my research regarding the population structure and sex ratio was that all the *S. terebrans*, large enough to sex, collected from the Spillway site were female; no males were present (see Table 2). Estevez and Simon (1974); Estevez (1978); and Messana et al. (1994) found the sex ratio to be nearly 1:1, however, these studies were all completed in red mangrove habitats of higher salinity 17.5 to 35 ppt. According to Shultz (1969) some isopods are parthenogenic and there are numerous references for other arthropods such as bees, aphids, and fruit flies being parthenogenic naturally or by disturbances in their environment. The fact that all of the *S. terebrans* sexed for this study were female and many were reproductively active leads me to believe that this population could be parthenogenic. Future research maintaining several generations of *S. terebrans* in the laboratory would verify that this population is indeed parthenogenic or whether this is a result of a low salinity habitat.

I would describe the habitat of *S. terebrans* in Lake Pontchartrain as constantly changing. Environmental conditions vary at the Spillway site in the intertidal zone because the area is exposed at low tide and inundated at high tide. Salinity, temperature, wind direction, water level, and water clarity change daily. Field experiments were initiated when Louisiana was ending a drought and salinity levels in Lake Pontchartrain were unusually high, almost 12 ppt in August 2000 (see Figure 4). The salinity in the lake for the year July 2000 - July 2001 averaged 6 ppt which was twice as high as the salinity for the block (July 2001-July 2002) and stake (June 2002-June 2003) experiments that had an average salinity of 3 ppt (see Figure 4). Much of the literature states that *S. terebrans* prefer higher salinity water 4-39 ppt, than the average 4 ppt of Lake Pontchartrain (John 1969, Barkati and Tirmizi 1990).

Water temperatures in Lake Pontchartrain are conducive for *S. terebrans* reproduction, and this was evident because many *S. terebrans* collected were either gravid females or juveniles. North and westerly winds can decrease water level and expose normally submerged cypress trunks to freezing temperatures and ice can form on the wood, killing *S. terebrans* and trapping them in their burrows. During sampling for this study cypress stumps were exposed for short periods of time, however, freezing events were not observed. If freezing events had occurred the *S. terebrans* population might have been negatively impacted in Lake Pontchartrain because *S. terebrans* trapped in frozen cypress stumps during infrequent freezes probably experience high mortality rates.

Wind speed and direction determine water level in Lake Pontchartrain. Strong winds from the north and west can push lake water offshore and expose areas of the shoreline and cypress stumps to air and drying periods. Low water levels make it difficult for *S. terebrans* to create a current with their pleopods and suspend food within their burrows. If this happens during extreme temperatures it would probably increase mortality. The majority of the wind for January 2001 – December 2003 came from the north, south, and east (Cho 2003). This increased the water level at the Spillway study site and pushed saltwater inshore to Lake Pontchartrain, which was probably beneficial to *S. terebrans*. Another factor which influences *S. terebrans* at the Spillway site is the periodic opening of the Bonnet Carre Spillway for flood control and leakage when the water level of the Mississippi River is high. Day et al (1999) found that diversion of

Mississippi River water in 1997 through the spillway had significant water quality impacts by increasing nutrients and freshening Lake Pontchartrain. Following the closure of the spillway an extensive blue-green algal bloom, of predominately *Anabaena circinalis* and *Microcystis aeruginosa* occurred and was linked to fish kills (Dortch et al. 1998; Poirrier and King 1998). Some leakage when the Mississippi River water is high also decreases the salinity at the Spillway site and this freshening probably negatively impacts and stresses *S. terebrans*. However, even with the Bonnet Carre Spillway openings and leakage there is not enough freshwater and sediment dispersed to create land or decrease the erosion rates in this area; this is evident by the shoreline retreat. The erosion in the southwest and western parts of Lake Pontchartrain is actually creating habitat for *S. terebrans*.

There is little in the literature on the burrowing preferences of *S. terebrans*, however John (1968) stated that they prefer to burrow in “presoftened” wood, Howey (1977) found that lignicolous fungal softening had a negligible effect on burrowing, and Estevez (1978) and Santhakumari (1991) discovered that *S. terebrans* seek out scars or wounds on red mangrove prop roots for burrow initiation. Rehm and Humm (1973) stated that *S. terebrans* bore into mangrove material within 24 hours and produce extensive hollowing within a few days. Nearly all burrows were about 5 mm in diameter indicating that the invasions were usually the work of adults (Rehm and Humm 1973). *Sphaeroma terebrans* do exhibit substrate and water depth preferences and these can be determined by means of field and laboratory experiments.

Field experiments in Lake Pontchartrain were run during this study to observe and describe the habitat, and to determine the presence and distribution of *S. terebrans*. Blocks of cypress and Styrofoam were placed in different areas of the lake where there was evidence of *S. terebrans* burrows. Weather, wave action, shoreline type, human influence, and the hardness and buoyancy of the block materials used were all factors in why colonization by *S. terebrans* was unsuccessful on all but two blocks. The Styrofoam blocks were lost within a month of placement in the field, if the Styrofoam had remained it probably would have been colonized first. The blocks were mostly colonized by *Cladophora* sp., *Corophium* sp., and *Grandidierella* sp. instead of *S. terebrans*. I did learn from this experiment that it takes approximately one year of submergence and exposure in Lake Pontchartrain for lumber grade cypress to “soften” and be burrowed by *S. terebrans*, and juveniles, not just adults, initiate those burrows.

The field stake experiment was conducted to determine the height distribution of *S. terebrans* burrows in the water column and substrate preferences at the Spillway site, where colonization had previously occurred. The main colonizers of these field stakes were *Balanus* sp. and *S. terebrans*. Both *Balanus* sp. and *S. terebrans* were present throughout the submerged 100 cm of the wood stakes (see Table 3 and Table 4). However, there was no correlation between the number of *Balanus* sp. and the number of *S. terebrans* colonizing the stakes (see Figure 10). Preliminary field tests indicate that in Lake Pontchartrain’s water column, *S. terebrans* prefer to place burrows at the 40-70 cm height (see Figure 11). In Costa Rica, Perry (1988) found that gastropods such as *Cerithium sp*., *Thais kiosquiformis*, and *Morula lugubris*, and the hermit crab *Clibanarius panamensis* were predators and control colonization by *S. peruvianum* and *Balanus* sp. in the 0-75 cm height of red mangrove roots. *Sphaeroma terebrans* in Lake Pontchartrain burrow into cypress stumps inhabited by many other invertebrates such as mussels and barnacles. All of these species probably compete for space on the stump and for nutrients. Wood hardness and fluctuating water level and to some extent predation, population density, and temperature may explain why the majority of *S. terebrans* burrows in the field stakes were in the 40-70 cm water depth (see Figure 11 and Table 4); and why old cypress stumps are thinner and heavily burrowed at approximately this same water depth. Numerous isopod burrows are clearly visible when the lake water level is low and stumps are exposed (see Figure 1).

Density and hardness of burrowed cypress is variable, and these values decrease as moisture content and burrows increase. We do know that as wood “weathers” its strength properties decrease. Wet or saturated cypress in Lake Pontchartrain can and will be colonized by *S. terebrans.* Results from this study show that *S. terebrans* can colonize wood with densities ranging from 6.9 to 52.4 pcf (see Figure 22). More samples need to be tested to determine the hardness level at which *S. terebrans* cannot burrow, however, we do know that they can burrow into wet wood with a hardness up to 234 Lb (see Figure 24). Future experiments could test colonization of *S. terebrans* with wood that has different densities or hardness at different depths in the water column in the laboratory and in the field.

Laboratory experiments conducted in this study were utilized to determine burrow preferences in terms of burrow placement, abundance, and dimensions, along with the dimensions of the burrowers. Results of laboratory experiments in this study indicate that *S. terebrans* prefers to burrow into the softest substrate when given a choice (see Figures 15 and 16). *Sphaeroma terebrans* ranging in size from juveniles to adults will burrow or attempt to burrow depending on the hardness or density of the substrate. In all laboratory experiments with Styrofoam as a burrow substrate, there were more burrows in this substrate than balsa or cypress (see Tables 6, 7, and 8). Judging by the number of burrows, the Styrofoam substrate was preferred. Styrofoam's low density and "softness" make it easier to initiate burrows than the other substrates. The balsa/cypress aquaria in the choice experiments had the least percentage of *S. terebrans* burrowed, most were swimming around in the aquarium actively seeking out a substrate to burrow or deceased. Burrows constructed in the balsa/cypress aquaria by *S. terebrans*, were only created in the balsa substrate. This is probably because the balsa was less dense or softer than the cypress substrate. Laboratory water column height experiments with Styrofoam blocks yielded results that the majority of *S. terebrans* burrow at water column distance from the bottom of 0-20 cm (see Figure 18); however, this seems to be influenced by population density (see Figure 21). At high abundance *S. terebrans* made burrows at greater heights presumably to space themselves out for filter feeding. Analysis of data also found a relationship between population abundance and burrow lengths, at high density significantly shorter burrows were constructed. This may also be for filter feeding purposes.

Sphaeroma terebrans prefer to be in a burrow for filter feeding and protection. Styrofoam had the greatest survival of all experiments (see Tables 6, 7, 8, 9). The water only aquaria had the lowest survival of all experiments. Most of the mortalities in the Styrofoam experiments occurred at the start of the experiments when the *S. terebrans* were first transferred into the aquaria. The water only aquaria had some mortality at the beginning of the experiment, but the greatest mortality was during the second week of the experiment, this was probably because they were not able to filter feed in a burrow. I think *S. terebrans* are stressed when not burrowed, this was evident by the higher mortality in the water only and cypress only aquaria where there were no burrows. Howey (1977) and Estevez (1978) both stated that *Sphaeroma terebrans* are strongly thigmotaxic; they immediately seek out a substrate to burrow. In the water only aquaria where there was no substrate *S. terebrans* attempted to burrow in the air stone or search for shelter by attempting to "bury" under other *S. terebrans*.

John (1968) commented that *S. terebrans* were negatively phototaxic, this behavior was consistent with my laboratory experiments, *S. terebrans* would locate themselves under objects to avoid light. Also, in the laboratory experiments, once a burrow was constructed individual *S. terebrans* remained in their burrows. I agree with Estevez (1978) that *S. terebrans* burrows help them to suspension feed. Dimensions of the burrow are not much larger than its inhabitant, if *S. terebrans* were digesting wood rather than filter feeding, we would probably find burrow dimensions to be much larger. *Sphaeroma terebrans* that were able to construct and remain in their burrows survived the experiment. I would estimate that with regular water changes *S. terebrans* could live in artificial substrates in the laboratory for several generations.

Burrow lengths significantly increased with the size of *S. terebrans* in laboratory Styrofoam blocks and wood field stakes. There was no correlation with *S. terebrans'* size and burrow placement in the water column for either the laboratory Styrofoam block or the field stake experiment. In all the laboratory experiments the greatest burrow lengths were constructed in the Styrofoam substrate. This was probably because it was the softest and least dense substrate available and therefore easiest for burrow construction. Perry (1988) studied burrow placement of *S. peruvianum* in red mangrove and found that roots not yet grounded in the substrate were susceptible to isopod attack. She also stated "isopods are probably excluded from older roots that have entered the substrate because they cannot burrow into the tough, woody tissues of these roots," (Perry 1988). This is not consistent with my laboratory and field data, where many cypress stumps and exposed roots were grounded and had different density and hardness values.

Other invertebrates in the intertidal zone may impact the colonization of *S. terebrans*. Theil (1999 and 2000) examined 1397 burrows of *S. terebrans* from September 1997 to August 1998 in the Indian River Lagoon, Florida. He noticed another isopod *Sphaeroma quadridentatum* inhabiting some of the same burrows as reproductive, gravid, and parental female *S. terebrans*. *Sphaeroma quadridentatum* is a high salinity species that does not create their own burrows, but seek out crevasses or burrows, empty barnacle shells, or root cracks to inhabit. Theil (1999) found that reproductive *S. terebrans* females couldn't distinguish between their own juvenile offspring and juvenile *Sphaeroma quadridentatum*. This probably has a negative effect on the survival of *S. terebrans'* offspring. I have not found any *S. quadridentatum* in any of the wood samples sorted from Lake Pontchartrain, but that does not mean that they are not present. This non-boring species may negatively impact the population of *S. terebrans* if present in Lake Pontchartrain. Ellison and Farnsworth (1990) demonstrated through experiments that common sponges (*Tedania ignis* or *Haliclona* sp.) and ascidian (*Perophora formosana* or *Didemnum conchyliatum*) species could prevent isopod attack if they colonize free-hanging mangrove roots before burrowing isopods (*S. terebrans* and *S. peruvianum*).

CONCLUSION

Past studies concentrated on *S. terebrans* colonizing small red mangrove prop roots in higher salinity environments. *Sphaeroma terebrans* also inhabit littoral bald cypress in Lakes Pontchartrain and Maurepas, a relatively low salinity environment 4 ppt and 0.5 ppt respectively (Beall et al 2001), however salinities range from fresh to 12 ppt. Other environmental variables influence the colonization of *S. terebrans*.

Population abundance, predators, wood or substrate hardness and density affect *S. terebrans*. *Sphaeroma terebrans* in Lake Pontchartrain colonize waterlogged cypress stumps up to 3 feet in diameter. The dimensions and density of the cypress stumps and exposed roots colonized in the lake are variable. *Sphaeroma terebrans* may utilize cypress in Lake Pontchartrain because the trees are already dead and not able to defend themselves with tannin production or sap. I have not found any *S. terebrans* burrowing into "live", healthy cypress in areas of predominately freshwater. I would conclude that "soft" and waterlogged substrates are the preference for *S. terebrans* burrow initiation. The density of this substrate can be as high as 52.4 pcf and as hard as 234 Lb, because these were the maximum values for density and hardness that I have found *S. terebrans* burrows. However, wood density and *S. terebrans* populations vary. If red mangrove was readily available for density and hardness comparison, we might find that its prop roots would be the preferred substrate. A choice experiment with red mangrove and cypress would answer this question, though red mangrove is not present in Lake Pontchartrain. More field experiments need to be conducted to determine if population abundance, predators, or wood hardness and density affect burrow placement height in littoral cypress in Lake Pontchartrain. Predators of *S. terebrans* in the intertidal community of Lake Pontchartrain also need to be investigated. Wood hardness and density measurements of colonized and non-colonized cypress need to be studied at different heights in the water column. To protect remaining cypress and the shoreline, controlling of the spread of *S. terebrans* needs to be considered.

Sphaeroma terebrans destruction of bald cypress contributes to shoreline retreat of Lake Pontchartrain. *Sphaeroma terebrans* "honeycombed" burrows weaken cypress stumps and prop roots in the littoral zone and exacerbate the erosion at the Bonnet Carre Spillway and other shorelines of Lake Pontchartrain. *Sphaeroma terebrans* damage cypress trees to the point that strong waves, can remove trunk sections or stabilizing roots with minimal effort. Loss of these trees increases erosion in areas where cypress roots and stumps once held sediment. The strategic placement and removal of Styrofoam or other soft materials may decrease the colonization of cypress and help slow erosion. Erosion and land loss are major concerns in Louisiana, because this isopod is probably found on wooded shorelines of other estuaries within this state. Further research is needed about *S. terebrans*, their habitat, and their impact on Lake Pontchartrain, and coastal erosion in the state of Louisiana.

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