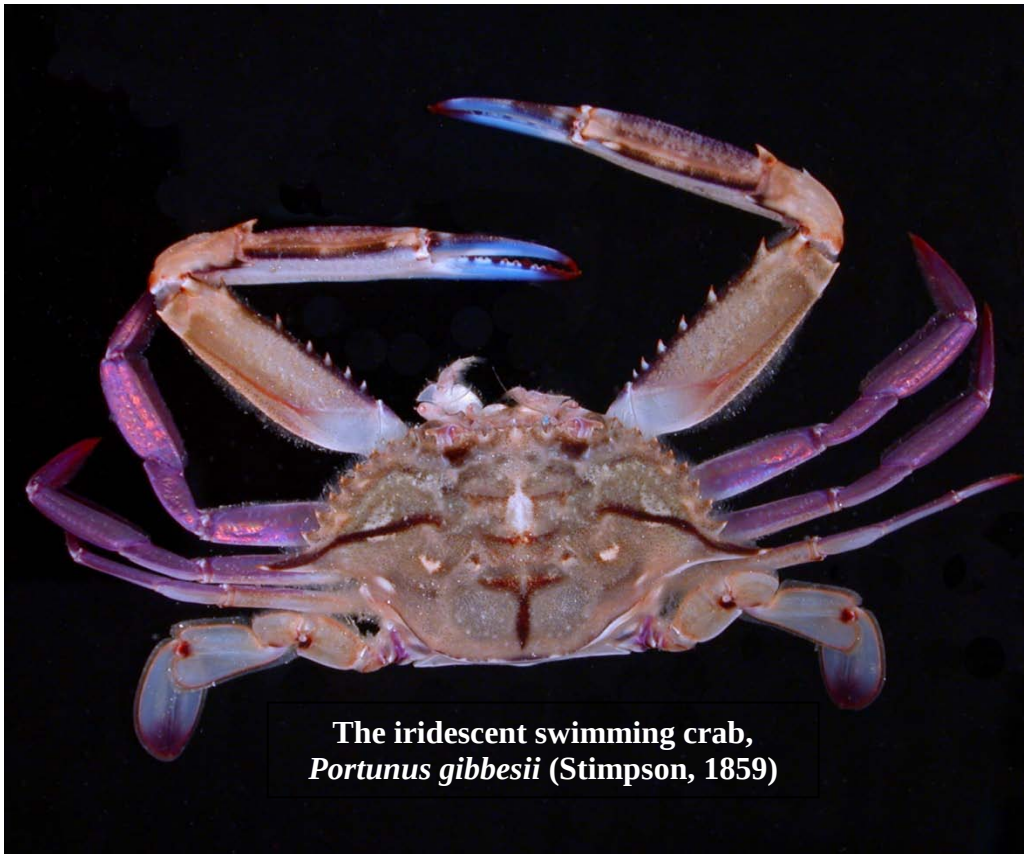
Southeastern Regional Taxonomic Center (SERTC)

Progress Report for the period 9/01/09 to 02/28/10

Award Number: **NA05NMF4721145 – no-cost extension**

Principal Investigator: **Dr. Elizabeth L. Wenner**
Marine Resources Research Institute (MRRI)
South Carolina Department of Natural Resources
Charleston, South Carolina



The iridescent swimming crab,
Portunus gibbesii **(Stimpson, 1859)**

SERTC Staff: David M. Knott, Susan T. DeVictor

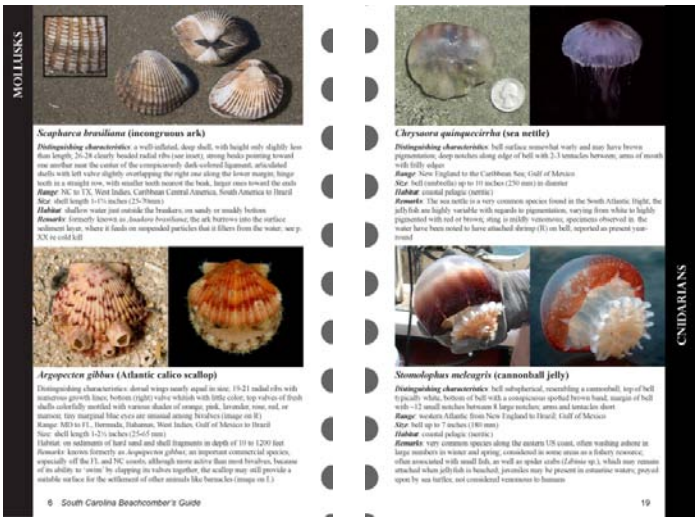
PROGRESS ON REMAINING SERTC JOBS

Although staff time dedicated to SERTC job tasks was more limited than previously, progress remains on track for their completion before termination of the grant at the end of August, 2010. During the past 6-mon reporting period, one biologist (STD) has been supported for 3.5 months, and others (DMK and ELW) have contributed unfunded time of more than 4 months towards such timely completion. As described in earlier progress reports, two of the four jobs delineated for completion during the current no-cost grant extension have been finished (Job 2 – prepare an online key to jellyfish of the South Atlantic Bight; Job 4 – Prepare an online key to echinoderms of the South Atlantic Bight). Progress on the remaining two job tasks and on ongoing SERTC objectives are reported here.

Prepare a brochure on beachcombing in South Carolina

Achievement: Steady progress has been made on the beachcomber's guide, which will be considerably more substantial than a brochure. Media specifications have been chosen for this professional-quality publication, which will be a 5.5 x 8.5" booklet with somewhere between 100 and 130 pages. Content pages will be printed on 100lb. coated paper, and the booklet will be bound with a plasticoil binding and a thick polyart cover. These are durable materials that are appropriate for outdoor use.

Using the graphic design software Adobe® InDesign® CS4, SERTC staff has produced a cover and a template for the content pages. To date, images and text have been completed for 16 items, with image layout of 22 additional items being completed. For the content pages, images include various combinations of *in situ* photographs of the item as it would likely appear on the beach, images of the items as they appear when living (taken in the lab under controlled lighting conditions), and inset images that show magnified detail of importance for identification. Completed draft portions of the guide have been extracted from the InDesign® file as a pdf document, which is attached as Appendix A of this report. When complete, the guide will include a Table of Contents, Introduction, Content Pages (major categories are cnidarians, bivalves, gastropods, crustaceans, echinoderms, worm-like animals, and a miscellaneous category), a Topical section with features appropriate to the interests of beachcombers (e.g. barrier islands and beach erosion, turtle nesting, horseshoe crab spawning, storm stranding, etc.), a Glossary, and an Index.



SERTC funding of $5-6K is expected to be available for production of ~1000 copies; however, at the present it is anticipated that additional non-grant funds in the amount of ~$4-5K will be available to increase production to well over 2500 copies. The most efficient method of distribution remains undecided, but considering the higher cost per item, compared to the SERTC posters, it will probably involve a more systematic method of delivery to teachers, with preference to those in coastal counties of South Carolina.

Prepare an online and printed guide to invasive marine species

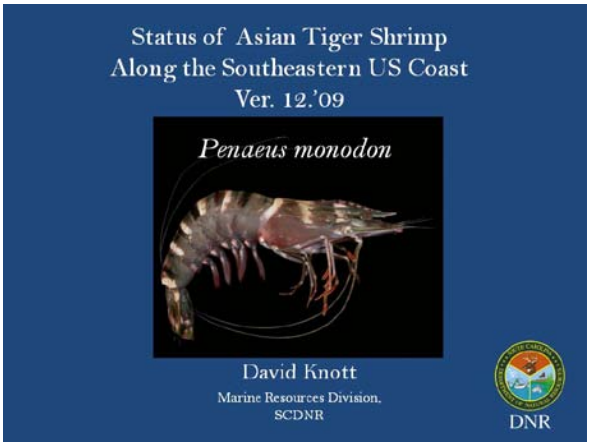
Achievement: Although construction of this webpage has not yet commenced, information, images, and perspective on important concepts related to the issue are being accumulated for production of content for both the webpage and the printed guide. In addition to profiles of conspicuous regional examples of invasive species and a listing of all known nonindigenous aquatic species reported from South Carolina, the web pages will include definitions and discussion of impacts, pathways of introduction, methods of prevention, approaches to control or eradication, and information about reducing the impacts and spread of nonindigenous species.

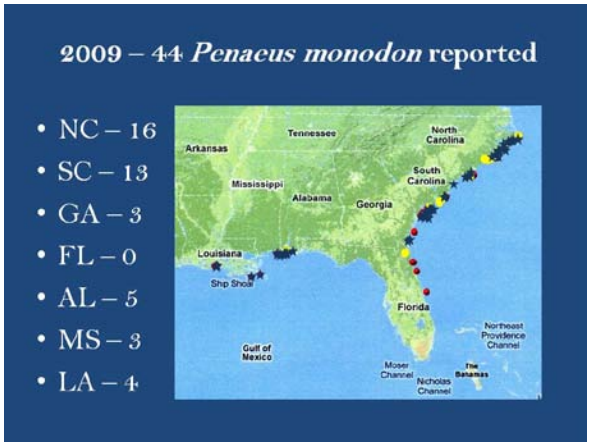
During the present reporting period, SERTC staff remained actively involved in issues regarding nonindigenous and invasive species. New observations were recorded throughout the SAB, and specimens were catalogued when they could be obtained. Among them were the Asian green mussel, *Perna viridis*, the tropical swimming crab *Callinectes bocourti*, and the Asian tiger shrimp, *Penaeus monodon*. Three lots of the Florida apple snail, *Pomacea paludosa*, were catalogued, documenting what appears to be a northern record for the occurrence of the only species of that genus that is native to North America. An assessment,conducted in the ACE Basin, of the occurrence and distribution of larvae of the invasive green porcelain crab, *Petrolisthes armatus*, will provide additional material for the SERTC specimen holdings, at no cost to the grant.

SERTC staff attended the two-day workshop ‘Controlling Invasives and Promoting Native Plants’. This event was part of the Coastal Training Program of the ACE Basin National Estuarine Research Reserve, and it was sponsored by the Southeast NERR and the SC Exotic Pest Plant Council. Two individuals on the SERTC staff were able to participate in this program at no cost to the SERTC grant. Conference attendees discussed the regulatory processes at federal, state and local levels, and how to work within that regulatory framework to encourage the landscape and ‘green’ industries to promote the use of native vegetation, rather than exotic plants, in landscaping projects.

Making the public aware of the impacts caused by invasive species is an important component of a comprehensive response to this growing problem. Mindful of that, SERTC staff presented a classroom lecture and participated in a field exercise with a biology class at a local high school. The classroom presentation included an explanation of the reasons for increasing concern about the impact of invasive species, as well as several local examples of introduced species. SERTC involvement in the field exercise consisted of assisting the teacher by pointing out and describing the nonindigenous species that settled on artificial substrates that the class placed in estuarine waters for several months.

One member of the SERTC staff currently serves on a regional panel of the federal Aquatic Nuisance Species Task Force. At the Gulf and South Atlantic Regional Panel (GSARP) meeting in Raleigh in November 2009, a summary of past and recent occurrences of the Asian tiger shrimp along the US coast was presented. The SERTC collection is a major repository for





specimens of *Penaeus monodon* that have been captured in the Northwest Atlantic. The SERTC staff maintains and updates a database of its occurrence there. An interview conducted at the SERTC lab, including footage of tiger shrimp specimens in the SERTC collection, was aired by the ABC affiliate in Atlanta as part of a daily news broadcast. GSARP members were also informed at this meeting of the continued fall occurrences in SC of two nonindigenous tropical/subtropical callinectid crabs; *Callinectes exasperatus* and *C. bocourti*. These occurrences were reported to the USGS and now appear in their searchable NAS database.

Callinectes exasperatus

Callinectes bocourti

ACCOMPLISHMENT OF ONGOING SERTC OBJECTIVES

Maintain and develop computerized and searchable reference collections of specimens (invertebrate and fish) housed in the collections of the MRRI and GML

During this reporting period, an additional 9 lots of invertebrates were accessioned and catalogued in the SERTC invertebrate collection (Table 1). Currently there are 3038 catalogued lots in the SPECIFY database, representing 784 different taxa in the collection. Among them are type specimens of four species: cotypes of *Comactinia echioptera* (crinoid), *Dardanus insignis* (hermit crab), *Luidia clathrata* (asteroid), and a paratype of *Chrysopathes micracantha* (antipatharian).

Table 1. Invertebrate lots catalogued into the SERTC collection during the reporting period.

Date	CatNo	FullTaxonName	Preservation of specimen
29-Oct-09	3032	*Perotrochus quoyanus*	95 % ethanol
2-Nov-09	3033	*Perna viridis*	70 % ethanol
2-Nov-09	3034	*Pomacea paludosa*	95 % ethanol
3-Nov-09	3035	*Pomacea paludosa*	95 % ethanol
6-Nov-09	3036	*Chrysaora quinquecirrha*	70 % ethanol
12-Nov-09	3037	*Pomacea paludosa*	95 % ethanol
13-Nov-09	3038	*Callinectes bocourti*	95 % ethanol
13-Nov-09	3039	*Penaeus monodon*	70 % ethanol
13-Nov-09	3040	*Acasta cyathus*	95 % ethanol

Recently, information and links (e.g. http://data.gbif.org/datasets/resource/326) have been added to the SERTC website to facilitate online access to information about the holdings in the

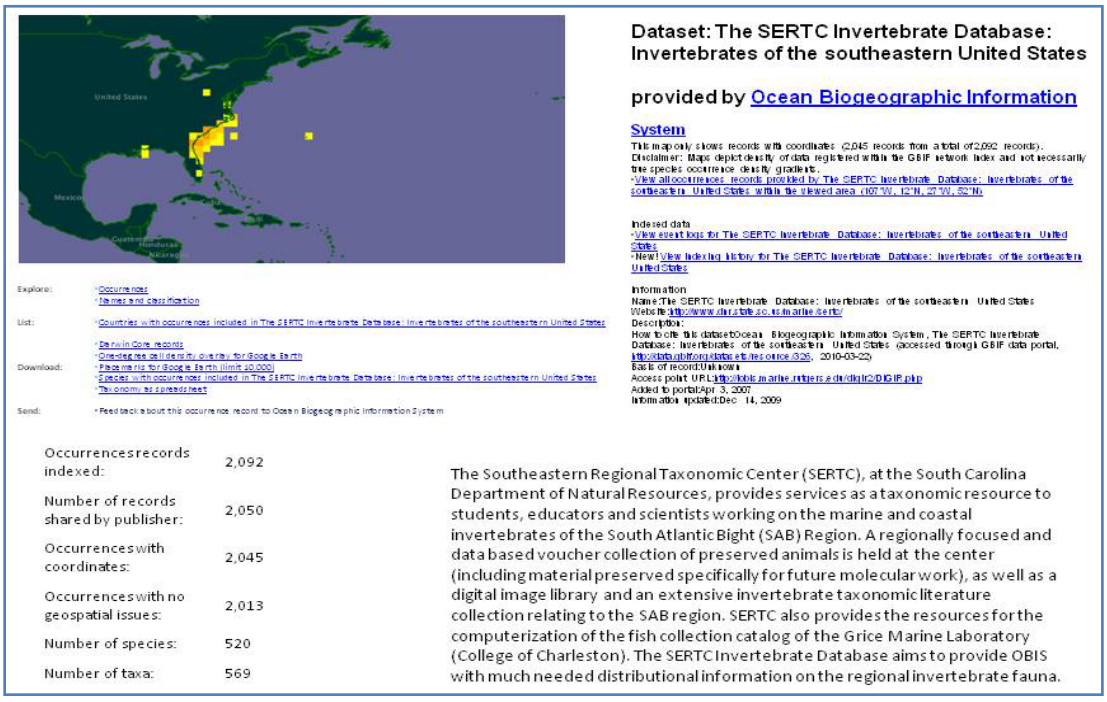


Figure 1. Display from a search for the SERTC database on the GBIF webpage.

SERTC invertebrate collection. Currently, most of the collection database is accessible by linking to a portal of the Global Biodiversity Information Facility (GBIF). Catalogue records at SERTC are periodically exported, reformatted and submitted to the GBIF through the OBIS node at the Institute of Marine and Coastal Sciences at Rutgers University (Figure 1). A variety of

search functions, including specific species searches, can be performed on the SERTC database, which currently contains 2050 records of occurrence, 520 species, and 49 additional taxa identified at a level higher than species. Information regarding each record of occurrence, such as that seen in Table 2, can be viewed at the GBIF website, and more detailed information and a location map for each record may be linked to via the 'View' button at that site.

Table 2. Example of search results returned at the GBIF website for 'SERTC Invertebrate Database'.

Scientific Name	Dataset	Institution Code	Collection Code	Catalogue Number	Basis of Record	Date	Coordinates	Country
Brasilomysis castroi	The SERTC Invertebrate Database:...	Marine Resources Research Institute,...	The SERTC Invertebrate Database:...	10	Observation	22/08/1978	33.5267°N, 79.0282°W	United States (inferred from coordinates) View
Bayerotrochus midas	The SERTC Invertebrate Database:...	Marine Resources Research Institute,...	The SERTC Invertebrate Database:...	1004-A	Observation	24/08/2004	31.3135°N, 78.8598°W	United States (inferred from coordinates) View
Calliostoma torrei	The SERTC Invertebrate Database:...	Marine Resources Research Institute,...	The SERTC Invertebrate Database:...	1005-A	Observation	30/08/2004	30.276°N, 79.3396°W	United States (inferred from coordinates) View
Hexapanopeus angustifrons	The SERTC Invertebrate Database:...	Marine Resources Research Institute,...	The SERTC Invertebrate Database:...	1018-A	Observation	11/05/2004	32.6025°N, 79.8093°W	United States (inferred from coordinates) View
Euceramus praelongus	The SERTC Invertebrate Database:...	Marine Resources Research Institute,...	The SERTC Invertebrate Database:...	1021-A	Observation	01/06/2004	32.8549°N, 79.4421°W	United States (inferred from coordinates) View

Validate identifications of provisionally identified specimens housed in the collections, continue to expand the scope of the SERTC invertebrate collection, and assist others with taxonomic identifications

SERTC staff routinely made themselves available to assist with identification of invertebrate animals for people with various interests (Table 3).

Table 3. Invertebrate identification assistance and information provided in response to inquiries.

Requestor and affiliation	Determination	ID based upon
Bob Thomas, Center for Environmental Communications, Loyola University	*Leptogorgia virgulata* (octocoral), bivalve shells (oysters, arks)	images
Lynne Matthews, Sanibel-Captiva Conservation Foundation Marine Laboratory	*Petrolisthes armatus* larva (green porcelain crab)	image
John Leffler, Marine Resources Research Inst., SCDNR	*Tabanus atratus* larva (black horsefly)	specimen
Kelly Sloan, College of Charleston student	*Aplidium* sp. (ascidian)	images
Linda Stehlik, NOAA Fisheries Lab, Sandy Hook, NJ	*Polyonyx gibbesi* larva (porcelain crab)	images
Sarah Goldman, Marine Resources Research Inst., SCDNR	Leucosiid crab larvae	specimens
Katie Dittloff, ABC News 4, Charleston, SC	*Luidia clathrata*, *Asterias forbesi* (sea stars)	images
Kevin Kolmos, Marine Resources Research Inst., SCDNR	*Themiste alutacea* (sipunculan worm)	images
J.D. Dubik, National Benthic Inventory, CCEHBR, NOAA	Various amphipods	specimens

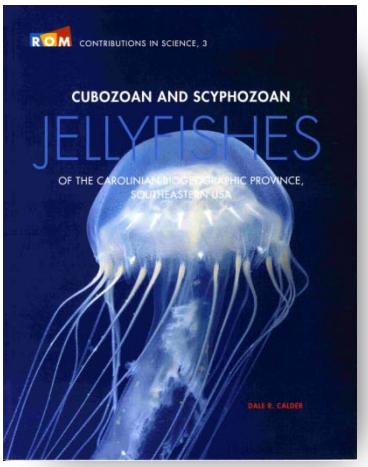
Private citizen	*Aplidium stellatum* (ascidian)	images
Keleigh Provost, Sanibel-Captiva Conservation Foundation Marine Laboratory	*Portunus gibbesi* (portunid crab)	image
Jamie Baldwin, Duke Univeristy	5 species of *Callinectes*	images

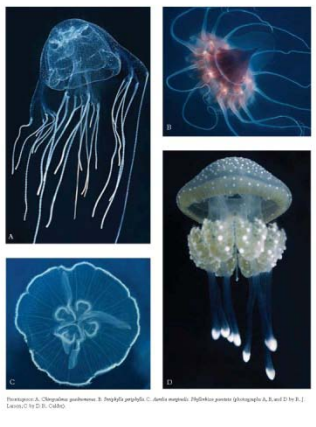
In addition to specimen identification, assistance has been provided to numerous parties requesting taxonomic or distributional information on a variety of invertebrates. Two undergraduate students from the College of Charleston were provided taxonomic literature, temporary laboratory space, and donation of staff time to facilitate projects on the occurrence of pteropod mollusks and decapod crustaceans on the continental shelf off South Carolina. It is anticipated that specimens from these projects will be provided to SERTC for inclusion in the specimen collection. Information and images were provided to the Director of the Sanibel-Captiva Conservation Foundation Marine Laboratory to assist in the identification of several species of penaeid shrimp. Results of SERTC staff examination and photography of organisms stranded on barrier beaches during a series of winter storms were provided to MRD management for their response to public inquiries about those events. An interview was also conducted with a news reporter from a local television station that was running a broadcast segment about the animals washed ashore. Finally, an inquiry from a private citizen via the SERTC website was answered by providing general information on the occurrence and seasonality of local jellyfish and the relative danger from their stings.

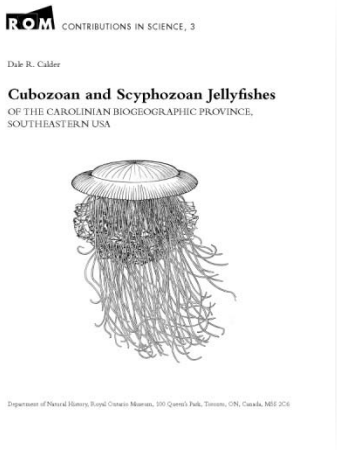
During the reporting period, taxonomic updates were made to 18 codes in the MRD/SCDNR species code list, and one additional species, previously not included in the list, was added. Since the inception of SERTC in 2001, 44 additions and 266 taxonomic updates or corrections have been made to the list of codes. These codes are used by the staff of the Marine Resources Research Institute (MRRI) as proxies for the scientific names of organisms included in most of the computerized databases generated by research at the Institute.

Prepare taxonomic resource materials such as guides to marine invertebrates from the SAB with illustrated keys and species lists (including taxonomic and distributional information)

The long awaited monograph on the jellyfish of the SAB was published by the Royal Ontario Museum, and copies have been placed into both the SERTC taxonomic reprint collection







and the Marine Resources Library at the SCNDR Marine Resources Research Institute. Delivery of an additional 100 copies for wider distribution is anticipated in the coming weeks. The monograph includes a key to all scyphozoan and cubozoan medusae known from the South Atlantic Bight, and provides illustrations and extensive information on synonymies, diagnostic morphological characters, the nematocyst complement and additional remarks on each of the 16 species covered (see Appendix B for an abbreviated view of the document that includes the table of contents, abstract, introduction, methods, systematic list and key to species, and an example of the systematic account of one of the species).

Maintain and update a library of taxonomic references and literature, maintain the bibliographic database of that collection, and maintain and expand the digital image library

Sixty-four reprints were entered into the ProCite literature catalogue this reporting period, and an additional 80 await entry. An up-to-date report from this literature database has been generated, and a pdf version with 3853 references has been prepared for the 'Searchable Databases' page during the next SERTC website update. This 233-page document is searchable via the standard search functions of Adobe Acrobat.

SERTC staff continued to take images of invertebrate specimens when new taxa became available. During the reporting period, approximately 240 digital images were taken of specimens belonging to 5 taxa: *Callinectes larvatus*, *Argonauta* sp., *Megabalanus coccopoma*, *Penaeus monodon*, and an unidentified parasite. The images listed in Table 4 were provided to researchers, students and educators for their use:

Table 4. Digital images from the SERTC archives that were provided to inquiring parties.

SERTC image usage (September 1, 2009 – February 28, 2010)		
DATE	IMAGE	USER
9/4/2009	*Megabalanus coccopoma*	Tucker Williamson, for use in a presentation at the College of Charleston Grad Student Colloquium
9/24/2009	*Donax variabilis*	Beth VanDusen, University of North Carolina at Chapel Hill, for use in power point presentation
11/2/2009	restricted use of website images	Dr. Richard Corner, Marine Biology, Institute of Aquaculture, University of Stirling, for use in introductory lecture about marine invertebrates
11/9/2009	Atlantic oyster drill	Heather A. Herrick, Department of Marine Science, The University of Texas at Austin, for use in a script in the program, *Science and the Sea*, a monthly article in Texas Saltwater Fishing (www.scienceandthesea.org)
11/11/2009	various polychaete images	Isaure duBuron, College of Charleston, for use in a presentation to graduate students
11/16/2009	*Callinectes sapidus*	Gabe Silver, Environmental Educator, James River Association, for use in interpretive signs and an educational guide and map for a water trail project in Virginia
11/20/2009	several SERTC website images	Martha Bademan, Florida Fish and Wildlife Conservation Commission, for use in a guidebook to Florida tropical/ornamental fish and invertebrates for FL law enforcement officers in the field

12/19/2009	*Bathypathes* sp.	Dennis Opresko (Oak Ridge National Laboratory), for a paper prepared for the Monterey Bay Aquarium Research Institute (Identification Guide to Deep-Water Genera of Antipatharians)
1/6/2010	*Bathypathes* sp. , bryozoan	Fabio Moretzsohn, for use in the book *Gulf of Mexico: Origin, Waters and Biota*. Volume 1, Biodiversity, p. 359. The images were modified to black and white illustrations
1/15/2010	*Panopeus* sp.	Ing. Pesq. Elmer Ordinola Zapata, Instituto del Mar del Perú, for use in mangrove crab studies
1/17/2020	oyster reef poster and barnacle images	Elizabeth Joyner, Karen Swanson, Nancy Hadley, (COSEE/Seagrant/SCORE), for online teacher resources

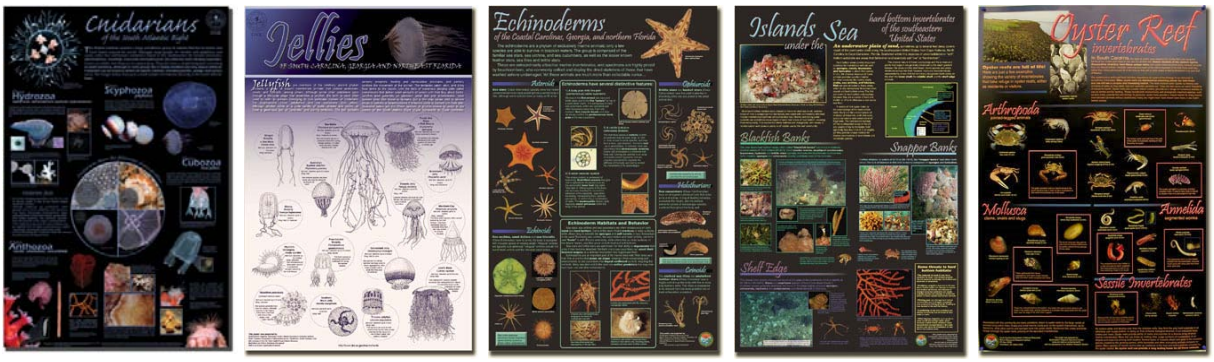
Develop a collection useful for genetic differentiation of species

With the exception of one lot of Cnidaria, one lot of mussels previously preserved in formalin, and a shrimp that had undergone tissue degradation, the specimens that were catalogued during this reporting period were placed directly into 95% ethanol. Since the introduction of PCR in the mid-1980s, the collection of fresh material that has not been fixed in formalin has led to the discovery of many cryptic or sibling species that were not previously recognized, because they were superficially indistinguishable based solely on morphological characteristics. As a benefit of the use of 95% ethanol as the fluid preservative for most SERTC specimens, we were able to provide tissue suitable for molecular analysis to Dr. Anja Schulze at Texas A&M, Galveston for her efforts to barcode the zooplankton of the Gulf of Mexico. Cirri from the nonindigenous barnacle *Megabalanus coccopoma*, which has been documented in the Gulf as well as along the southeastern Atlantic coast, were donated to assist in the completion of this project. Information on SERTC holdings of the genus *Macrobrachium* was provided to a Harvard University student who is examining the phylogeography of New World species of that genus.

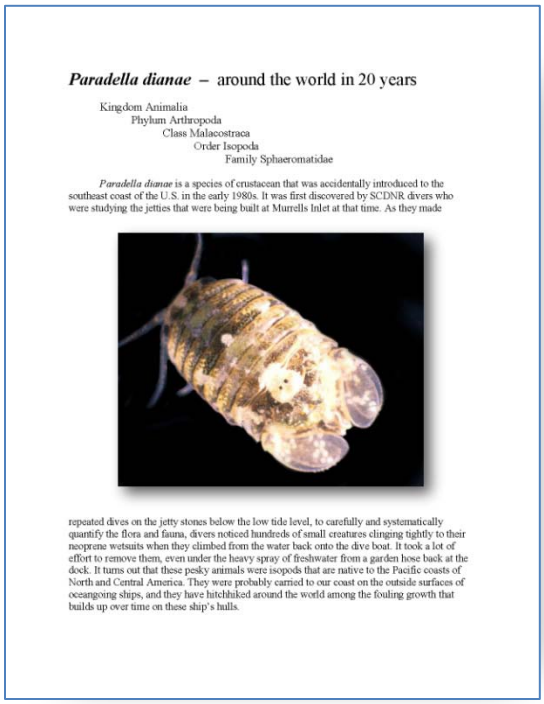
Unlike most freshly collected invertebrates for the SERTC collection, cnidarian specimens are generally fixed and preserved in formalin, in order to preserve the integrity of morphological characters of interest to taxonomists. Two such formalin-preserved specimens were provided to Dr. Allen Collins, Curator at the National Systematics Laboratory, NOAA Fisheries Service at the Smithsonian Institution. The well-preserved SERTC specimens of the cubozoan *Tamoya haplonema* were provided for inspection during a systematic revision of that species in that genus.

Promote, encourage and provide training in systematics through various activities such as presenting workshops, and producing educational material such as pamphlets and posters

Production of the 5th in a series of 24x36" educational posters was completed previously;however, approximately 100 additional copies in the series were distributed during the present reporting period, to teachers in instructional classrooms and at a meeting of the SC Marine Educators Association. An image of each poster is included on the 'Educational Resources' page of the SERTC website, with an email link for submission of requests for hard copies.



Updates to the SERTC website during the current reporting period included posting of a new "Featured Species" item. This addition provided informative facts about the sphaeromatid family of isopods, featuring the nonindigenous species *Paradella dianae*. A link from the

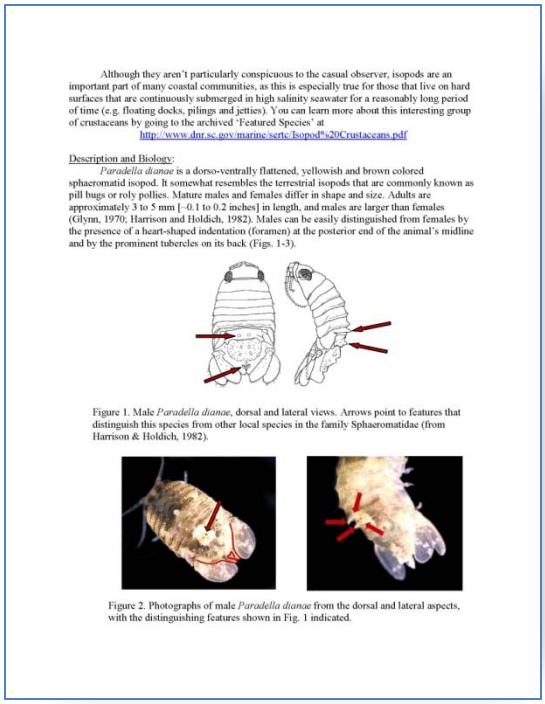


Paradella dianae **–** around the world in 20 years

Kingdom Animalia
Phylum Arthropoda
Class Malacostraca
Order Isopoda
Family Sphaeromatidae

Paradella dianae is a species of crustacean that was accidentally introduced to the southeast coast of the U.S. in the early 1980s. It was first discovered by SCDNR divers who were studying the jetties that were being built at Murrells Inlet at that time. As they made

repeated dives on the jetty stones below the low tide level, to carefully and systematically quantify the flora and fauna, divers noticed hundreds of small creatures clinging tightly to their neoprene wetsuits when they climbed from the water back onto the dive boat. It took a lot of effort to remove them, even under the heavy spray of freshwater from a garden hose back at the dock. It turns out that these pesky animals were isopods that are native to the Pacific coasts of North and Central America. They were probably carried to our coast on the outside surfaces of oceangoing ships, and they have hitchhiked around the world among the fouling growth that builds up over time on these ship's hulls.



Although they aren't particularly conspicuous to the casual observer, isopods are an important part of many coastal communities, as this is especially true for those that live on hard surfaces that are continuously submerged in high salinity seawater for a reasonably long period of time (e.g. floating docks, pilings and jetties). You can learn more about this interesting group of crustaceans by going to the archived 'Featured Species' at
http://www.dnr.sc.gov/marine/sertc/Isopod%20Crustaceans.pdf

Description and Biology:
Paradella dianae is a dorso-ventrally flattened, yellowish and brown colored sphaeromatid isopod. It somewhat resembles the terrestrial isopods that are commonly known as pill bugs or roly pollies. Mature males and females differ in shape and size. Adults are approximately 3 to 5 mm [~0.1 to 0.2 inches] in length, and males are larger than females (Glynn, 1970; Harrison and Holdich, 1982). Males can be easily distinguished from females by the presence of a heart-shaped indentation (foramen) at the posterior end of the animal's midline and by the prominent tubercles on its back (Figs. 1-3).

Figure 1. Male *Paradella dianae*, dorsal and lateral views. Arrows point to features that distinguish this species from other local species in the family Sphaeromatidae (from Harrison & Holdich, 1982).

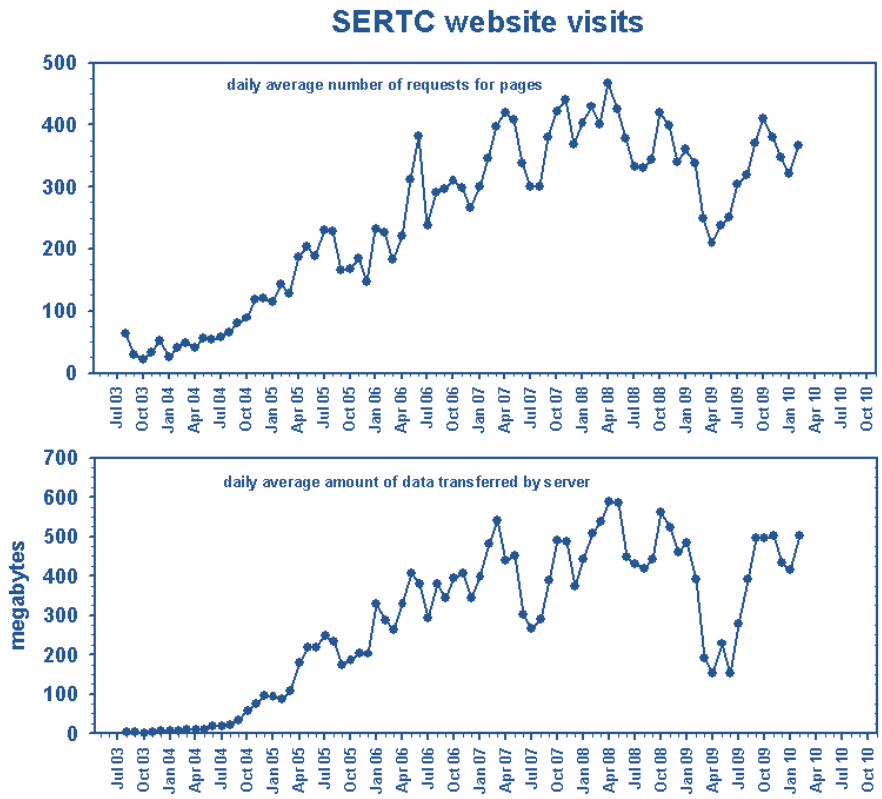
Figure 2. Photographs of male *Paradella dianae* from the dorsal and lateral aspects, with the distinguishing features shown in Fig. 1 indicated.

website to a pdf document (in its entirety in Appendix C) was provided to allow the information to be conveniently downloaded. With content similar to that contained in the species profile prepared for the SERTC Invasive Species webpage, this item contains additional detailed descriptions of the unique morphological features of *P. dianae* and provides detailed illustrations of six native sphaeromatids for comparison.

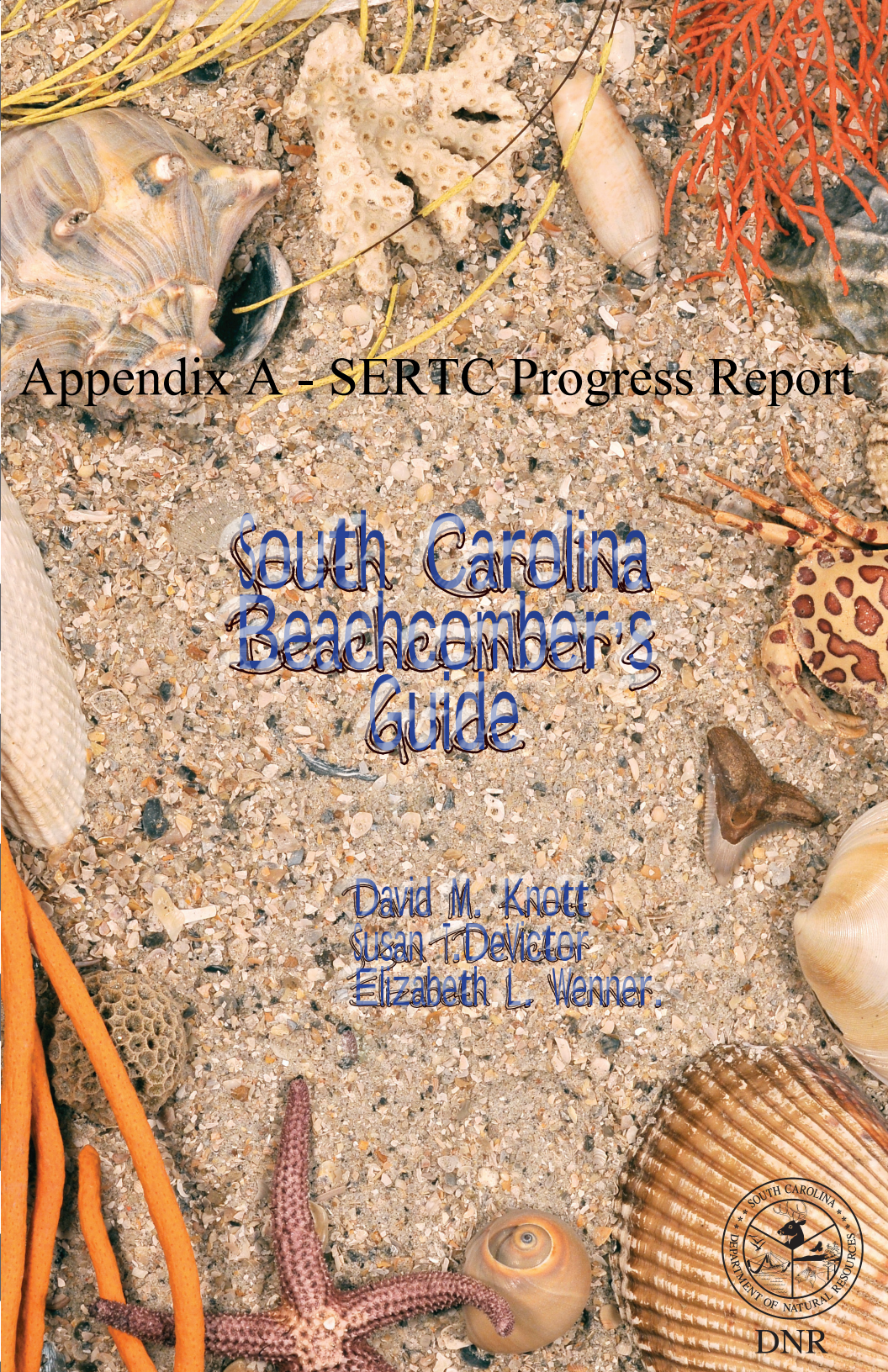
SERTC provided assistance to educators during their development of curriculum material for natural science classes. A list of about a dozen common beach-dwelling species, along with brief comments on the habitat and behavior of each, was provided to a teacher at Sullivans Island Elementary School for a guide to be used by students during field trips to the beach. In addition to images of oyster reef fauna that were provided to COSEE SouthEast staff for development of online teacher resources (see Table 4), SERTC staff reviewed and edited text to accompany

those images. SERTC was also contacted by the education section of SCDNR's office of Outreach and Support Services, who requested our participation, for the third consecutive year, in presentation of an educational program on the marine fouling community for high school students. The program will be conducted by SERTC staff during the coming summer.

Despite a slight temporary decline in use during December and January, the average monthly number of visits to the SERTC website and the amount of data transferred remained typical of levels recorded over the past two years.

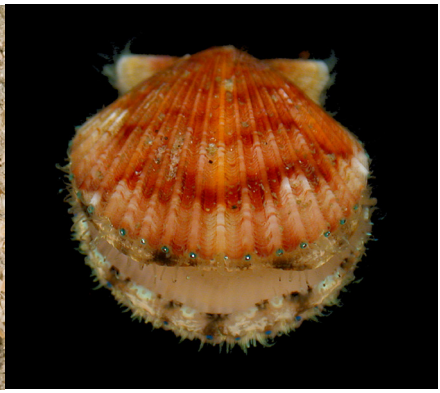


Appendix A - SERTC Progress Report



Scapharca brasiliana (incongruous ark)

Distinguishing characteristics: a well-inflated, deep shell, with height only slightly less than length; 26-28 clearly beaded radial ribs (see inset); strong beaks pointing toward one another near the center of the conspicuously dark-colored ligament; articulated shells with left valve slightly overlapping the right one along the lower margin; hinge teeth in a straight row, with smaller teeth nearest the beak, larger ones toward the ends
Range: NC to TX, West Indies, Caribbean Central America, South America to Brazil
Size: shell length 1-1¾ inches (25-70mm)
Habitat: shallow water just outside the breakers; on sandy or muddy bottom
Remarks: formerly known as *Anadara brasiliana*; the ark burrows into the surface sediment layer, where it feeds on suspended particles that it filters from the water; see p. XX re cold kill

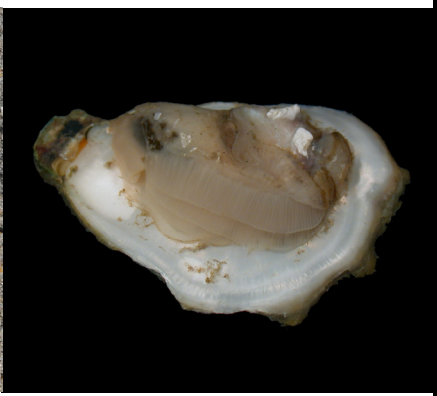


Argopecten gibbus (Atlantic calico scallop)

Distinguishing characteristics: dorsal wings nearly equal in size; 19-21 radial ribs with numerous growth lines; bottom (right) valve whitish with little color; top valves of fresh shells colorfully mottled with various shades of orange, pink, lavender, rose, red, or maroon; tiny marginal blue eyes are unusual among bivalves (image on R)
Range: MD to FL, Bermuda, Bahamas, West Indies, Gulf of Mexico to Brazil
Size: shell length 1-2½ inches (25-65 mm)
Habitat: on sediments of hard sand and shell fragments in depth of 10 to 1200 feet
Remarks: known formerly as *Aequipecten gibbus*; an important commercial species, especially off the FL and NC coasts; although more active than most bivalves, because of its ability to 'swim' by clapping its valves together, the scallop may still provide a suitable surface for the settlement of other animals like barnacles (image on L)

Arcinella cornuta (Florida spiny jewelbox)

Distinguishing characteristics: plump shell with 7-9 pleated radial ribs that are covered along their length with slender tubular spines; spines may be worn down in specimens that have washed ashore (L image); beaks curving forward with a prominent heart-shaped depression (lunule) in front; interior finely scalloped along the margins; shell with whitish exterior; interior creamy white with hints of yellow, pink or reddish tints
Range: NC to FL, Gulf of Mexico, Caribbean Central and South America to Venezuela
Size: shell length 1¼-1½ inches (~ 30-40 mm)
Habitat: on rubble bottom in shallow water (10 to 70 feet), but occasionally deeper
Remarks: older shell books may list this as Echinochama cornuta; the young of this genus are found attached to hard surfaces (e.g. rock, coral, shell), but as they age they detach and become free-living, unlike the other jewelboxes, which remain attached



Crassostrea virginica (eastern oyster)

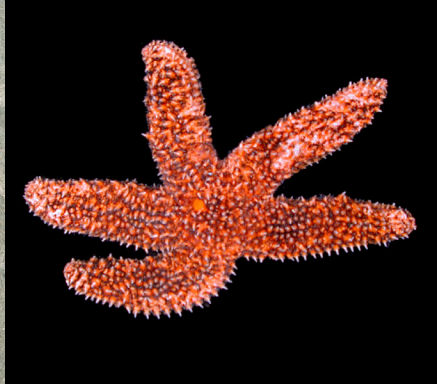
Distinguishing characteristics: shape quite variable, narrow at the hinge, gradually widening to a rounded or irregularly elongated oval; top valve flatter than bottom; grayish white exterior; interior glossy white with a purple muscle scar (top L image)
Range: along the eastern coasts of North and South America, from Canada to Brazil
Size: shell 2-6 inches in length (50-150 mm), occasionally larger
Habitat: ubiquitous estuarine inhabitant; firmly attached to hard surfaces, especially other oysters (lower L image); in SC, many oysters live in dense beds along creek banks and on intertidal mud flats, where they are commercially harvested
Remarks: shells found on ocean beaches are usually heavily weathered; they may be very abundant in some places where they have been concentrated by current and wave action (lower R image) after washing out of estuaries and tidal creeks

Echinolittorina placida (zebra snail)

Distinguishing characteristics: 5-7 whorls apparent; background color white, with narrow oblique wavy or zigzag brown to black lines
Range: Wilmington, NC through the Gulf of Mexico to northern Yucatan
Size: shell length ~ ⅛-¾ inches (3-20 mm)
Habitat: the high intertidal zone on jetty rock, limestone and other natural hard surfaces, where it grazes on algae
Remarks: because of the similarity of markings on their shells, this species has been frequently misidentified as *Littorina ziczac* in the South Atlantic Bight; it has only recently been described as a new species; close examination of crevices and sheltered faces of beach jetty rocks will often turn up these snails, often in the higher level of the intertidal zone where the barnacle *Chthamalus fragilis* is abundant (L image)

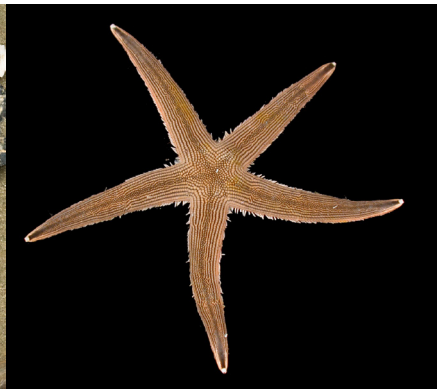
Neverita duplicata (shark eye)

Distinguishing characteristics: smooth globose shell with 4-5 whorls; slate gray to tan, with bluish tinges; apex coiled, resembling an eye (R image); dark callous near aperture
Range: MA to FL; eastern Gulf of Mexico through TX
Size: shell height 2-2½ inches (~ 50-60 mm); shell width ~ 3-3½ inches (~ 75-85 mm)
Habitat: on sand in shallow water at the low tide line and below; rarely to 80 feet
Remarks: referred to previously as *Polinices duplicatus*; a carnivorous snail, often responsible for the minute holes drilled into bivalve shells found on the beach; females produce 'sand collars' (L image, inset), which are actually a mix of sand and mucus, on which she attaches her light tan egg capsules; empty shells are popular homes for hermit crabs in the surf zone, and they also provide suitable hard surfaces for attachment of animals like slippersnails and barnacles (L image)



Asterias forbesi (Forbes' common sea star)

Distinguishing characteristics: 5-armed sea star with blunt arm tips; reddish- brown or purple, to brownish; distinct orange dot (madreporite) found off-center on the top (aboral) surface of the disc, ~ ⅛ inch (4 mm) across; spines generally scattered on disc and arms, rather than in regular rows
Range: ME to TX
Size: 7-10 inches (~ 180-250 mm) from tip of arm to tip of one of the two opposite arms
Habitat: shallow subtidal on jetties to 160 feet;
Remarks: the madreporite is the external opening of the water vascular system, which serves to control movement of the animal; a carnivorous species with a preference for mollusks, this species is often a pest on commercial oyster and clam beds; on jetty rocks it typically feeds on small mussels that it opens by slowly pulling the valves apart



Luidia clathrata (striped or lined sea star)

Distinguishing characteristics: small central disc with 5 flattened arms; top (aboral) surface bluish-grayish, but sometimes with brownish or pinkish tint; dark, narrow strip down the center of each arm is flanked by finer dark wavy lines (the less common *L. alternata* has a dark disc and distinct light/dark banding along each arm); underside (oral) usually cream colored (more yellow in *L. alternata*)
Range: NJ to FL, Bermuda, Gulf of Mexico, Caribbean, South America to Brazil
Size: 8-11 inches (~ 200-280 mm) from tip of arm to tip of one of the two opposite arms
Habitat: in protected and offshore waters on mud, sand or shell hash; from 0-130 feet, but rarely to more than 550 feet
Remarks: often stranded on beaches following winter storms; arms are easily broken; 'pinched' tips may indicate regeneration of damaged arms; see p. XX re cold kill

Chiropsalmus quadrumanus (fourhanded boxjelly)

Distinguishing characteristics: clear bell (umbrella) with four distinct, hand shaped arms (pedalia), each with 5-9 tentacles attached
Range: western Atlantic from NC to Brazil; Gulf of Mexico
Size: bell diameter up to 4 inches (100 mm); height, up to 5.5 inches (140 mm)
Habitat: coastal pelagic (neritic), washing ashore with storm activity and tides
Remarks: This species is a member of the Class Cubozoa; as the name implies it appears to have four distinct sides to its bell, although this feature may not be apparent when the jellyfish is not in the water; boxjellies are well known for the intensity of their sting, which is highly venomous when compared to other local jellyfish; the fourhanded boxjelly is observed on beaches from June through November.

Tamoya haplonema (glassy boxjelly)

Distinguishing characteristics: clear bell (umbrella), taller than wide, with four simple, lobe-shaped pedalia (arms), each with a single tentacle
Range: western Atlantic, from NY to Argentina; Gulf of Mexico
Size: bell diameter up to 2 inches (55 cm); height, up to 3.5 inches (90 mm)
Habitat: coastal pelagic (neritic)
Remarks: As with *Chiropsalmus* (above), this cubozoan has a 'boxy' (cuboidal) shape and four arms; the tentacles may be withdrawn (such as R, see arm tips) or broken off. This species is highly venomous when compared to other local jellyfish; the glassy boxjelly is typically observed on beaches from May though December

Chrysaora quinquecirrha (sea nettle)

Distinguishing characteristics: bell surface somewhat warty and may have brown pigmentation; deep notches along edge of bell with 2-3 tentacles between; arms of mouth with frilly edges
Range: New England to the Caribbean Sea; Gulf of Mexico
Size: bell (umbrella) up to 10 inches (250 mm) in diamter
Habitat: coastal pelagic (neritic)
Remarks: The sea nettle is a very common species found in the South Atlantic Bight; the jellyfish are highly variable with regards to pigmentation, varying from white to highly pigmented with red or brown; sting is mildly venomous; specimens observed in the water have been noted to have attached shrimp (R) on bell; reported as present year-round

Stomolophus meleagris (cannonball jelly)

Distinguishing characteristics: bell subspherical, resembling a cannonball; top of bell typically white, bottom of bell with a conspicuous spotted brown band; margin of bell with ~12 small notches between 8 large notches; arms and tentacles short
Range: western Atlantic from New England to Brazil; Gulf of Mexico
Size: bell up to 7 inches (180 mm)
Habitat: coastal pelagic (neritic)
Remarks: very common species along the eastern US coast, often washing ashore in large numbers in winter and spring; considered in some areas as a fishery resource; often associated with small fish, as well as spider crabs (*Libinia* sp.), which may remain attached when jellyfish is beached; juveniles may be present in estuarine waters; preyed upon by sea turtles; not considered venomous to humans

*Leptogorgia hebes (*regal sea fan)

Distinguishing characteristics: highly branched, with dome-like polyp mounds with slit-like pores on slightly flattened stems; deep red, purple, orange, dark yellow
Range: western Atlantic from VA to north FL; Gulf of Mexico; Aruba; Brazil
Size: height up to 18 inches (450 mm); stems up to ¼ inch (6 mm) in diameter
Habitat: attached to hardbottom; benthic
Remarks: This octocoral lives attached to hard substratum by a holdfast, which is typically visible below the branches; the woody axis is covered with polyps within colorful tissue while alive; often only bare or partially bare axes may be remaining on beached specimens; live tissue is comprised of numerous microscopic calcareous spicules, and may have gall barnacles or brittlestars attached; previously named *Lophogorgia hebes*

Leptogorgia virgulata (colorful sea whip)

Distinguishing characteristics: moderately branched with small pores through which polyps emerge; cycindrical stems; whip- or thrush-like; may be deep red, purple, orange, yellow, white or variations in between
Range: NY; Chesapeake Bay to FL; Gulf of Mexico; Brazil
Size: height up to 36 inches (~1 meter); stems up to 1/5 inch (2-5 mm) in diameter
Habitat: attached to hardbottom, as well as dock pilings, floating docks, etc.; benthic
Remarks: This octocoral may be attached to a hard surface by a holdfast or occasionally attached to bivalve shell or other object; the woody axis is covered with polyps within colorful tissue while alive; often only bare or partially bare axes may be remaining on beached specimens; live tissue is comprised of numerous microscopic calcareous spicules; lives in marine and estuarine environments; possible fouling organism

Callichirus major (Carolinian ghost shrimp)

Distinguishing characteristics: the elongated, membranous body is flattened top to bottom; head with small, smooth rostrum; claws unequal in size; abdomen long; transparent gray, except for porcelain white claws and hardened part of shell
Range: from NC into the Gulf of Mexico and to southern Brazil
Size: total length to ~ 4 inches (~100 mm)
Habitat: on sandy shores near the open ocean, often deeply buried; found from about mid-tide level to below low tide level
Remarks: forms a series of tunnels that may extend as much as 6 feet; it is rare to find this animal on the beach, and it normally goes undetected by beach visitors; the best clue to its presence is a small ¼ inch (6 mm) diameter hole in the sand near the low tide line, surrounded by a ring of small dark fecal pellets

Callinectes sapidus (blue crab)

Distinguishing characteristics: body flattened; five pairs of legs, first pair pincer-like and last pair paddle-like at their end; edge of shell with 9 teeth on each side, rear pair longest and ending in sharp spines; two prominent triangular teeth at front between the eyes (compare with *C. similis*); body olive brown; bright blue on legs, along front and on pincers; female claw fingers red
Range: Canada to Uruguay, but most common from MA to TX
Size: to 9 inches (230 mm) from tip to tip of lateral spines
Habitat: bottom-dwellers in nearly every type of estuarine and near shore habitat
Remarks: one of the most important recreational and commercial species of the SC coast; living crabs less than 5 inches wide and those with a visible egg mass must be returned to the water if caught; tolerates nearly fresh to full-strength seawater

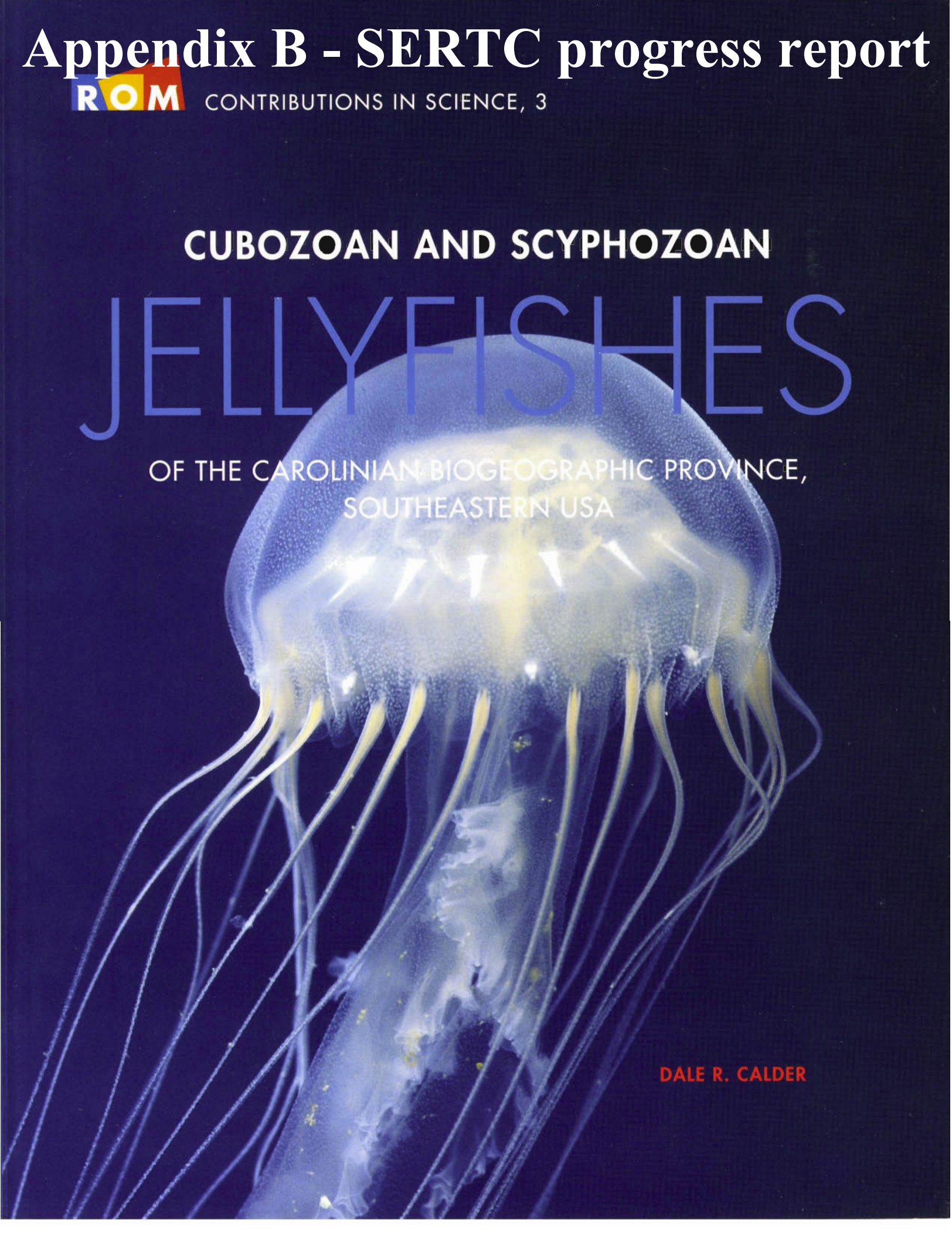
Appendix B - SERTC progress report

ROM CONTRIBUTIONS IN SCIENCE, 3

CUBOZOAN AND SCYPHOZOAN

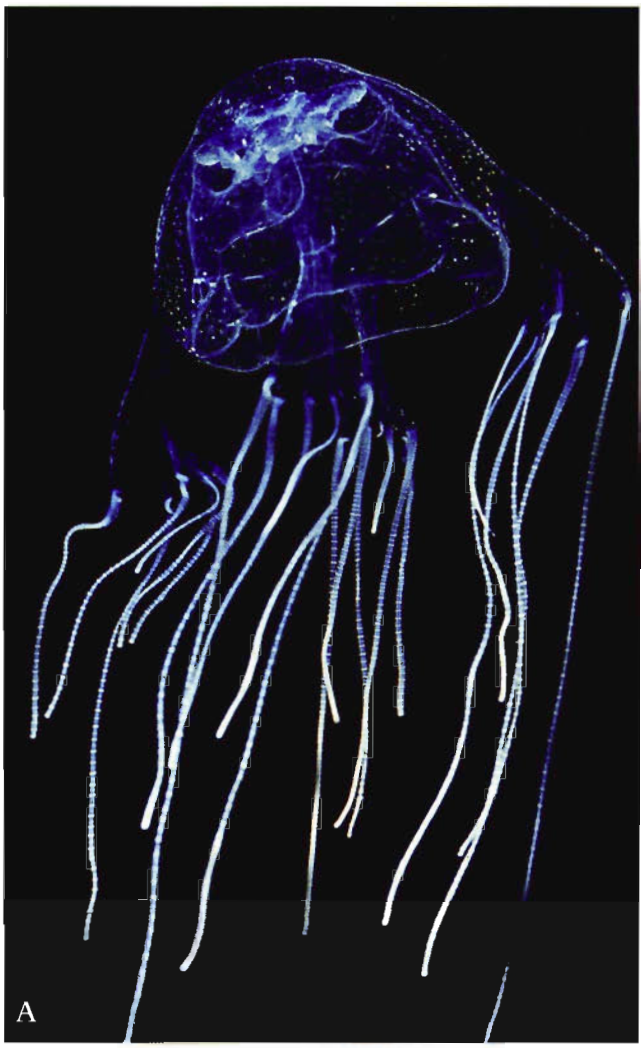
JELLYFISHES

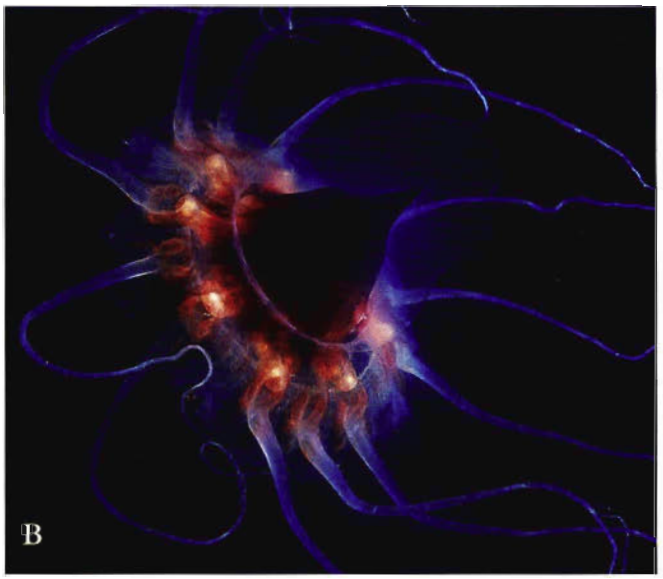
OF THE CAROLINIAN BIOGEOGRAPHIC PROVINCE, SOUTHEASTERN USA

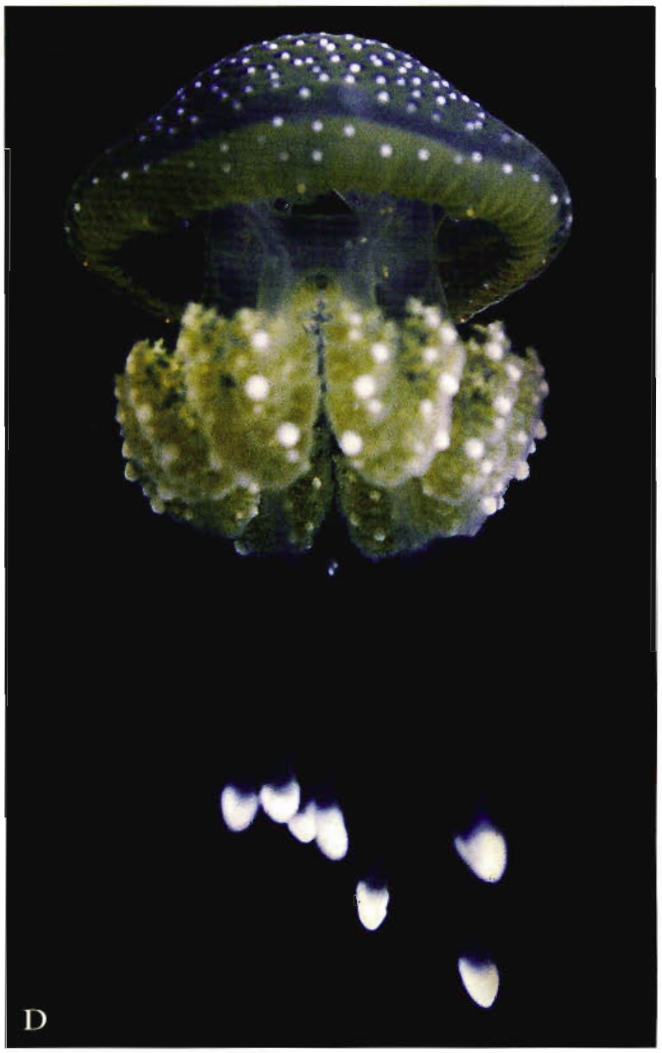


DALE R. CALDER

Published by the Royal Ontario Museum with the generous
support of the Louise Hawley Stone Charitable Trust







Frontispiece: A. *Chiropsalmus quadrumanus*. B. *Periphylla periphylla*. C. *Aurelia marginalis*. D. *Phyllorhiza punctata* (photographs A, B, and D by R. J. Larson; C by D. R. Calder).

CONTRIBUTIONS IN SCIENCE, 3

Dale R. Calder

Cubozoan and Scyphozoan Jellyfishes

OF THE CAROLINIAN BIOGEOGRAPHIC PROVINCE, SOUTHEASTERN USA

Department of Natural History, Royal Ontario Museum, 100 Queen's Park, Toronto, ON, Canada, M5S 2C6

Contents

Cubozoan and Scyphozoan Jellyfishes

Abstract

A synopsis is given of three species of cubomedusae (*Alatina alata*, *Tamoya haplonema*, and *Chiropsalmus quadrumanus*) and 13 species and subspecies of scyphomedusae (*Atolla wyvillei*, *Linuche unguiculata*, *Nausithoe punctata*, *Periphylla periphylla*, *Chrysaora quinquecirrha*, *Pelagia noctiluca*, *Cyanea capillata fulva*, *Cyanea capillata versicolor*, *Drymonema dalmatinum*, *Aurelia marginalis*, *Phyllorhiza punctata*, *Rhopilema verrilli*, and *Stomolophus meleagris*) reported from the Carolinian Biogeographic Province of the southeastern United States (Cape Hatteras, North Carolina to Cape Canaveral, Florida). Regional records of each species are documented by reference to literature reports and to museum specimens. Summaries are given of the biology, life cycle, abundance, nematocyst complement (where known), toxicity, and reported distribution of each species. Sampling undertaken each of the four seasons near Charleston, South Carolina, indicated that *Cyanea capillata versicolor* was the most prevalent species inshore during colder months, whereas *Stomolophus meleagris*, *Chrysaora quinquecirrha*, and *Chiropsalmus quadrumanus* were the most abundant medusae during warmer months. The invasive species *Phyllorhiza punctata* has now been reported from scattered locations across the study area. A new subclass, Coronamedusae, is established to accommodate the order Coronatae, representing a different clade from the existing nominal subclass Discomedusae (encompassing the orders Semaeostomeae and Rhizostomeae). The species of *Aurelia* indigenous to the region, usually identified as *A. aurita* Linnaeus, 1758 (type locality: Baltic Sea), is distinctly different from that boreal species and is assigned instead to *A. marginalis* L. Agassiz, 1862 (type locality: Florida). Nomenclatural matters considered here included authorship and dates of names, and type species of genera. The widely used generic name *Periphylla* F. Müller, 1861 is designated as both valid and a *nomen protectum*, while its virtually unused senior synonym *Cyclophylla* Brandt, 1837 is relegated to a *nomen oblitum*. No valid type species designation was found for the well-known genus *Cyanea* Péron and Lesueur, 1810; *Cyanea arctica* Péron and Lesueur, 1810 (a junior subjective synonym of *Medusa capillata* Linnaeus, 1758) is hereby so designated. Nomenclatural problems over the name *Phyllorhiza* L. Agassiz, 1862 exist due to a longstanding misconception about its type species. Current usage is maintained pending a submission to the International Commission on Zoological Nomenclature asking that the accepted concept of the genus be upheld.

Introduction

Scyphozoan and cubozoan medusae are an important component of the plankton in waters of the Carolinian Biogeographic Province along the southeast coast of the United States (defined here as Cape Hatteras, North Carolina, to Cape Canaveral, Florida) because of their typically large size, high frequency of occurrence, roles as both predators and prey, and associations with other taxa (especially fishes and crustaceans). During periods of abundance they may constitute a hindrance to commercial fishing in the region, and especially to shrimp trawling operations. Moreover, several species occurring in these waters are venomous to humans and of concern to public health. Meanwhile, a potential fishery exists for the seasonally abundant cannonball jellyfish (*Stomolophus meleagris*) given the considerable demand for jellyfishes as food in parts of East Asia (Omori and Nakano, 2001). These cnidarians have been little studied in the southeastern United States, however, and existing information on them is widely scattered.

Some 200 species of "true jellyfishes" or acraspedote medusae (Scyphozoa), and about 40 species of box jellies (Cubozoa), are currently recognized worldwide. Of these, 13 species and subspecies of Scyphozoa and three species of Cubozoa are known to occur from inshore waters seawards to the Gulf Stream between Capes Hatteras and Canaveral. Among these is the well-known invasive species *Phyllorhiza punctata*, originally described from Australia and recently identified from the study

area (Johnson and Allen, 2005; Lauren Hall, pers. comm., 2006; Justin Ellenberger, pers. comm., 2006; David Knott, pers. comm., 2007). *Drymonema dalmatinum*, another scyphomedusa initially thought to be recently invasive in the western North Atlantic (Larson, 1987a), is now known to have been present in waters off this coast more than 120 years ago. Three specimens of this medusa, taken off the coast of South Carolina in 1885, were recently discovered in collections at the National Museum of Natural History, Smithsonian Institution (Williams et al., 2001). Several other cubozoan and scyphozoan medusae generally limited to the eastern margins of the study area (*Alatina alata*, *Atolla wyvillei*, *Linuche unguiculata*, *Nausithoe punctata*, and *Periphylla periphylla*) are also included here. As for the number of species of Scyphozoa overall, Dawson (2004) postulated that diversity may be about two times the number currently recognized on the basis of morphology. The biodiversity of cubomedusae is also believed to be substantially higher than previously thought (Gershwin, 2005). These and other recent studies have provided evidence of extensive crypsis in scyphozoans and cubozoans, and the species-level taxonomy adopted herein seems likely to change in the near term. Thus, the conundrum taxonomists have faced in distinguishing species and in analyzing distributions of Hydrozoa (Calder, 1988:2) applies to the Scyphozoa and Cubozoa as well.

Scientific and public interest in jellyfishes has increased in recent decades. Their ecological importance, particularly as planktonic carnivores, has become more widely appreciated (Purcell, 1992; Mills, 1995; Arai, 1997). Large medusae are also now recognized as important prey of certain sea turtles, especially leatherbacks (*Dermochelys coriacea*) (Bleakney, 1965; Grant and Ferrell, 1993; Lutz and Musick, 1996; Frick et al., 1999). Concerns about venomous species have prompted research on these cnidarians in a number of countries, especially Australia, the United States, and Japan. An apparent increase in the incidence and severity of jellyfish blooms, and the negative impacts of such swarms on ecosystems and human activities in various parts of the world, has also been noted and investigated (Purcell, 2005; Purcell et al., 2001). In addition, invasive species such as *Phyllorhiza punctata*, noted above, are now the subject of numerous ongoing studies. Finally, jellyfish exhibits have become popular attractions at institutions such as the Monterey Bay Aquarium, the New England Aquarium, and the South Carolina Aquarium.

This study was undertaken to document the species composition, geographic distributions, seasonal occurrences, and historical records of scyphozoan and cubozoan medusae in the region, and to provide a key to their identification.

Materials and Methods

The geographic limits of this study extend from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, and from estuarine waters inshore to the Gulf Stream offshore. Known locally as the South Atlantic Bight, that confusing and inappropriate name is avoided here because it may be mistaken by some outside the immediate region for a location in the South Atlantic Ocean. The northern limit of the study area, as defined herein, includes Pamlico Sound, North Carolina, and the southern limit includes the Banana River, Florida. The region corresponds with what is commonly known by marine biogeographers as the Carolinian Province (Briggs, 1974). While the northern Gulf of Mexico is also generally considered part of the same biogeographic province, the medusae of that region were not considered here.

This account is limited largely to the medusa stages of Scyphozoa and Cubozoa; the polyp stages of these cnidarians (with the possible exception of those of *Rhopilema verrilli* and *Stomolophus meleagris*) are insufficiently known in the region to discuss in any detail at present. Data presented herein are based on literature records, on specimens in collections of various institutions (National Museum of Natural History, Washington, DC; Royal Ontario Museum, Toronto, ON; Marine Resources Research Institute, Charleston, SC; Grice Marine Laboratory, Charleston, SC), and on new material obtained as part of this investigation. Collecting was undertaken once each season in 2005 during the study (4–12 February, 9–20 May, 28 August–2 September, 30 October–4 November) in coastal South Carolina while working at the Southeastern Regional Taxonomic Center (SERTC) of the Marine Resources Research Institute, South Carolina Department of Natural Resources, in Charleston. Sampling was undertaken each quarter at stations in Inlet Creek, Charleston Harbor, and at the entrance of Charleston Harbor. At each site, qualitative collections were made using an otter trawl (10-minute tow), a half-metre bongo net (4–5 minute tow), and a one-metre-wide neuston net (4–5 minute tow). Surveys for stranded but recently live medusae were also undertaken each sampling period on Folly Beach, South Carolina. Abbreviations in the text are as follows: GMBL (Grice Marine Biological Laboratory [presently known as the

Grice Marine Laboratory], The College of Charleston, Charleston, South Carolina); ICZN (International Code of Zoological Nomenclature); ROMIZ (Invertebrate Zoology collections at the Royal Ontario Museum, Toronto, Ontario, Canada); SERTC (Southeastern Regional Taxonomic Center, Marine Resources Research Institute, South Carolina Department of Natural Resources, Charleston, South Carolina), USNM and NMNH (National Museum of Natural History, Smithsonian Institution, Washington, DC).

Synonymy lists are limited to the following works: (1) the original publication in which a given name was made available nomenclaturally, and (2) references to works which have provided original records of a given species in the study area. Matters of nomenclature were considered with reference to provisions of the ICZN (International Commission on Zoological Nomenclature, 1999). An attempt was made to trace and confirm authorship and dates of all nominal taxa used herein at the time they were made available under provisions of the code. A similar effort was made to determine the valid type species of each genus, the way in which it was so designated, and the author and date of that designation if it was fixed subsequent to establishment of the name. Scientific names above the family group have been attributed to the author who first used them, regardless of the level in the Linnaean hierarchy at which they were originally proposed. Thus, the phylum name "Cnidaria" is credited to Verrill (1865), even though he used the term at the rank of class.

Several recently proposed changes in the classification of Scyphozoa have been adopted here. Marques and Collins (2004) suggested, based on a detailed cladistic analysis of medusozoans, that the monophyletic clade comprising Coronatae, Rhizostomeae, and Semaeostomeae (Scyphozoa) is a sister group of another including the Cubozoa (together with the Stauromedusae and the fossil Conulatae). They proposed recognizing both the Cubozoa and Staurozoa as classes within the phylum Cnidaria, along with Hydrozoa, Scyphozoa, and Anthozoa. Moreover, they provided evidence that the scyphozoan orders Semaeostomeae and Rhizostomeae are more closely related to each other than to Coronatae. The name Discomedusae Haeckel, 1880 has been applied to this subclass (Marques and Collins, 2004; Dawson, 2004). The order Coronatae, excluded in that work from the Discomedusae, is herein assigned instead to an equivalent new subclass, Coronamedusae.

The classification and nomenclature of nematocysts both continue to evolve from the classic work by Weill (1934a, b). Stability of names of these organelles is desirable in order to minimize confusion, yet changes sometimes become necessary when knowledge of them advances. In this work, I have essentially followed the nematocyst terminology used earlier (Calder, 1974b; Mariscal, 1974), with some necessary modifications in light of more recent work. Data on nematocyst sizes given here are measurements of maximum length and width of undischarged capsules.

The terms bell, umbrella, and disk have been used interchangeably in the literature for the body of a jellyfish exclusive of the manubrium, oral arms, tentacles, and other parts that are suspended from it (Cornelius, 1997:116–117). The term umbrella has been used throughout in this work, even for the bell-shaped cubomedusae. This was done because the terms exumbrella for the upper and outer side of this structure, and subumbrella for the lower and inner side, are almost universally adopted.

Results

Classification

CLASS CUBOZOA Werner, 1973
ORDER CARYBDEIDA Lesson, 1843
Family Alatinidae Gershwin, 2005
Genus *Alatina* Gershwin, 2005
Alatina alata (Reynaud, 1830)
Family Tamoyidae Haeckel, 1880
Genus *Tamoya* F. Müller, 1859
Tamoya haplonema F. Müller, 1859
ORDER CHIRODROPIDA Haeckel, 1880
Family Chiropsalmidae Thiel, 1936
Genus *Chiropsalmus* L. Agassiz, 1862
Chiropsalmus quadrumanus (F. Müller, 1859)

CLASS SCYPHOZOA Goette, 1887
SUBCLASS CORONAMEDUSAE, subcl. nov.
ORDER CORONATAE Vanhöffen, 1892
Family Atollidae Hickson, 1906 (1880)
Genus *Atolla* Haeckel, 1880
Atolla wyvillei Haeckel, 1880
Family Linuchidae Haeckel, 1880
Genus *Linuche* Eschscholtz, 1829
Linuche unguiculata (Swartz, 1788)
Family Nausithoidae Haeckel, 1880
Genus *Nausithoe* Kölliker, 1853
Nausithoe punctata Kölliker, 1853

Family Periphyllidae Haeckel, 1880
Genus *Periphylla* F. Müller, 1861
Periphylla periphylla (Péron and Lesueur, 1810)

SUBCLASS DISCOMEDUSAE Haeckel, 1880
ORDER SEMAEOSTOMEAE L. Agassiz, 1862
Family Pelagiidae Gegenbaur, 1857
Genus *Chrysaora* Péron and Lesueur, 1810
Chrysaora quinquecirrha (Desor, 1848)
Genus *Pelagia* Péron and Lesueur, 1810
Pelagia noctiluca (Forsskål, 1775)
Family Cyaneidae L. Agassiz, 1862
Genus *Cyanea* Péron and Lesueur, 1810
Cyanea capillata fulva L. Agassiz, 1862
Cyanea capillata versicolor L. Agassiz, 1862
Genus *Drymonema* Haeckel, 1880
Drymonema dalmatinum Haeckel, 1880
Family Ulmaridae Haeckel, 1880
Genus *Aurelia* Lamarck, 1816
Aurelia marginalis L. Agassiz, 1862
ORDER RHIZOSTOMEAE Cuvier, 1799
SUBORDER KOLPOPHORAE Stiasny, 1921b
Family Mastigiidae Stiasny, 1921b
Genus *Phyllorhiza* L. Agassiz, 1862
Phyllorhiza punctata von Lendenfeld, 1884
SUBORDER DAKTYLIOPHORAE Stiasny, 1921b
Superfamily Rhizostomatoidea Cuvier, 1799
Family Rhizostomatidae Cuvier, 1799
Genus *Rhopilema* Haeckel, 1880
Rhopilema verrilli (Fewkes, 1887)
Family Stomolophidae Haeckel, 1880
Genus *Stomolophus* L. Agassiz, 1860
Stomolophus meleagris L. Agassiz, 1860

Key

1. Tentacles present on umbrella 4
— Tentacles lacking on umbrella 2

2. Umbrella almost spherical, with distinct brown band around margin; appendages lacking on mouth-arms ..... *Stomolophus meleagris*
— Umbrella flatter than a hemisphere, lacking brown band around margin; appendages or filaments on lower surface of mouth-arms 3

3. Mouth-arms with stout finger-like appendages; scapulets ("shoulder ruffles") present; exumbrella without prominent white spots ..... *Rhopilema verrilli*
— Mouth-arms with long and slender filaments basally; scapulets absent; exumbrella with numerous prominent white spots ..... *Phyllorhiza punctata*

4. Tentacles on underside of umbrella 5
— Tentacles on margin of umbrella 7

5. Tentacles in a wide band around underside of umbrella; medusae large (up to 1 m in diameter) ..... *Drymonema dalmatinum*
— Tentacles in eight U-shaped clusters on underside of umbrella; medusae smaller than above (up to about 20 cm in diameter) 6

6. Medusa purplish pink to deep red ..... *Cyanea capillata versicolor*
— Medusa yellow to yellow-brown, resembling a fried egg ..... *Cyanea capillata fulva*

7. Umbrella flat, plate-shaped, with numerous small tentacles around margin, with four horseshoe-shaped gonads centrally ..... *Aurelia marginalis*
— Umbrella, tentacles, and gonads not as above 8

8. Umbrella cuboidal; tentacles arising from each of four interradial corners 14
— Umbrella not cuboidal; tentacles not restricted to four interradial corners 9

9. Umbrella with distinct circular groove on upper surface 11
— Umbrella without distinct circular groove on upper surface 10

10. Umbrella with small wart-like clusters of stinging organelles; margin with 3–5 or more long tentacles in each of eight groups; most prevalent in estuarine and inshore waters ..... *Chrysaora quinquecirrha*
— Umbrella with distinctly elevated gelatinous mounds; margin with eight long tentacles; usually restricted to offshore waters..... *Pelagia noctiluca*

11. Umbrella higher than a hemisphere 12
— Umbrella decidedly flattened 13

12. Umbrella small (up to 2 cm high), thimble-shaped, brownish in colour; tentacles short, inconspicuous; in surface and near-surface waters offshore .... *Linuche unguiculata*
— Umbrella large (up to 25 cm high), cone- to dome-shaped, red in colour; tentacles long, conspicuous; in deep waters offshore ..... *Periphylla periphylla*

13. Umbrella very small (up to 1.5 cm wide); tentacles eight; gonads forming eight globular masses on undersurface of umbrella..... *Nausithoe punctata*
— Umbrella larger (up to 15 cm wide), with thick central lens; tentacles usually 22 (sometimes more)..... ..... *Atolla wyvillei*

14. Umbrella about as wide or more as high; tentacles about 7–9 on each of four hand-shaped pedalia..... ..... *Chiropsalmus quadrumanus*
— Umbrella distinctly higher than wide; tentacles one on each of four paddle-shaped pedalia... 15

15. Medusa with large, deep, cross-shaped stomach; rhopaliar niche opening a horizontal or crescent-shaped slit ..... *Tamoya haplonema*
— Medusa with shallow, flask-shaped stomach; rhopaliar niche opening T-shaped..... *Alatina alata*

Systematic Account

Phylum Cnidaria Verrill, 1865
Subphylum Medusozoa Petersen, 1979
Class Cubozoa Werner, 1973
Order Carybdeida Lesson, 1843

Remarks

The family name Carybdeidae, from which the name of this order is derived, has often been attributed to Gegenbaur (1857), but it was established prior to that by Lesson (1843) as Carybdeae. Louis Agassiz (1862:173) attributed the name to an even earlier work (Lesson, R. P. 1837. Prodrome d'une monographie des méduses. Rochefort. 62 pp.). However, only "a very small number of copies" of that document were issued (L. Agassiz, 1860:24), and in my opinion it does not meet criteria of publication under the code (ICZN Art. 8.1.3). Accordingly, Lesson (1843) is credited here as the author of the order name Carybdeida, and the taxon it refers to is understood in the sense of Werner (1984).

Family Alatinidae Gershwin, 2005

Remarks

Gershwin (2005) redefined the family Carybdeidae and established the family Alatinidae to accommodate her new genus *Alatina* and the earlier described *Manokia* Southcott, 1967. She assigned *Carybdea alata*, a poorly known but frequently reported species in the western Atlantic, to *Alatina*.

Genus *Alatina* Gershwin, 2005

Alatina Gershwin, 2005:504.

Diagnosis

Medusa with clear, cuboidal umbrella; with four simple pedalia and four tentacles; stomach shallow, with no mesenteries; rhopaliar niche ostia T-shaped, with one upper scale and two lower scales; velarial canals three per octant; gastric cirri long, mostly parallel and in a single plane, forming four crescent-shaped phacellae (modified from Gershwin, 2005).

Type Species

Alatina mordens Gershwin, 2005, by original designation.

Remarks

Gershwin (2005) founded *Alatina* as a new genus and assigned to it 11 nominal species, including *Carybdea alata* (Reynaud, 1830).

Alatina alata (Reynaud, 1830)

(Fig. 1)

Carybdea (*Medusa*) *alata* Reynaud, 1830:95, pl. 33, fig. 1.
Carybdea alata — Larson, 1976a:15.
Alatina alata — Gershwin, 2005:515.

Common Names

Winged boxjelly, sea wasp.

Type Locality

Atlantic Ocean ("...dans l'océan Atlantique") (Reynaud, 1830).

Museum Material

North Carolina, Atlantic Ocean east of Cape Hatteras, 35°03' N, 74°41' W, 204–228 m, R/V Sands Station 606-9-T1-C, D, 06 April 1967, one medusa, USNM 53694.

Specific Characters

Medusa with characters of the genus; umbrella up to 6–8 cm high, 5 cm or more wide (up to 23 cm high and 14 cm wide in *A. alata* forma *grandis*); exumbrellar surface without warts; sensory niches covered by one scale above and two below; stomach short, mouth surrounded by four simple lips; gastric filaments forming horizontal crescents at corners of stomach; pedalia spatula-shaped, interradial; tentacles four, simple (Mayer, 1910b; Kramp, 1961).

Nematocyst Complement

Medusa, newly metamorphosed from polyp (Puerto Rico; Arneson and Cutress, 1976):
Exumbrella—
  microbasic euryteles (20 μm long x 8 μm wide)
  holotrichs (spherical) (13 μm in diameter)
Tentacles—
  euryteles (30 μm long x 7 μm wide)
Gastric cirri—
  euryteles (small, no measurements given)

Remarks

The binomen *Carybdea alata* (recently renamed *Alatina alata* by Gershwin, 2005) has been applied to certain

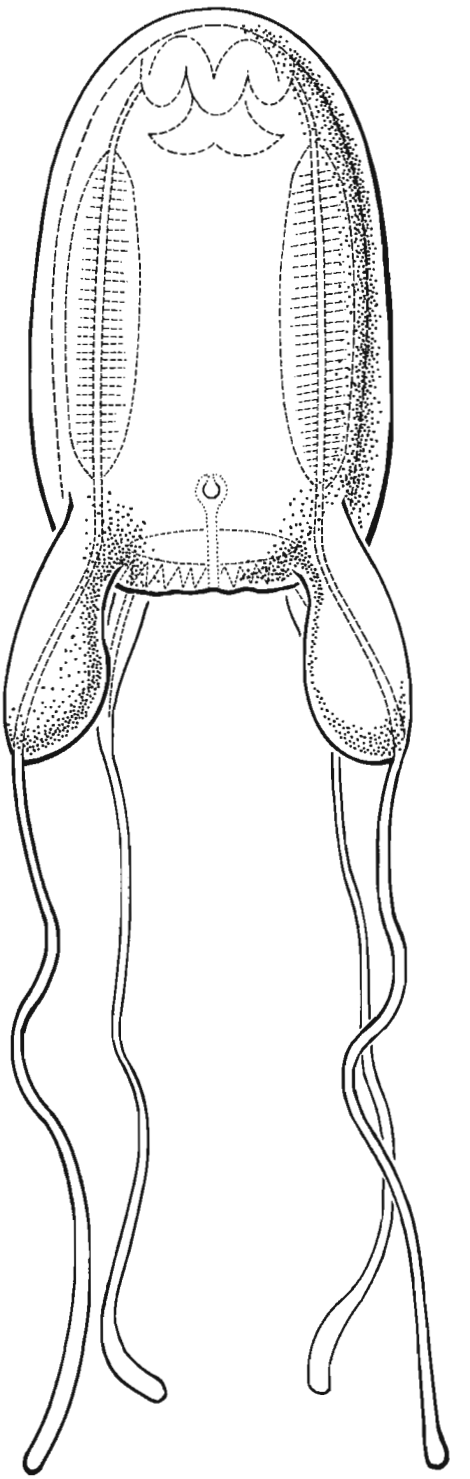


Fig. 1. *Alatina alata* (Reynaud, 1830), after Sterrer (1986) and Mianzan and Cornelius (1999).

boxjellies worldwide, but more than one species is now thought to exist under that name (Morandini, 2003; Gershwin, 2005). Uncertainty also exists over the identity of the species upon which Reynaud (1830) based the name, because the original description was so lacking in detail. No type material is known to exist. The type locality was reported by Kramp (1961) to have been somewhere in the South Atlantic Ocean. While the species of the genus from the warm western Atlantic may be the same as that called *C. alata* by Reynaud (1830), the nomenclature of the species needs to be stabilized by designation of a neotype. Gershwin (2005) expressed the intention to do this once a suitable specimen could be located.

Arneson and Cutress (1976) described the life cycle of a species identified as *Carybdea alata* based on cultures of specimens from Puerto Rico. Spawning of medusae was observed there during July (1973) and August (1974). Fertilization occurred within the ovary, and zygotes developed into blastulae before being shed into the water. These became free-swimming planulae after one day. Settlement of the planulae occurred about four days later, and four rudimentary tentacles were apparent after another couple of days. Some 54 days after fertilization, with polyps having 12 tentacles, asexual reproduction by budding began. Metamorphosis commenced two weeks later in polyps possessing 16 tentacles: this involved resorption of the tentacles and hypostome, and gradual transformation of the polyp into a medusa. A change in cnidome accompanied this process, with stenoteles occurring in the polyp but not the medusa, and spherical holotrichs occurring in the medusa but not the polyp. Medusae were liberated one week after metamorphosis began. A small fragment of the polyp adhering to the apex of the umbrella was absorbed within 10–13 hours. This general life cycle, with asexual reproduction by budding and with a single polyp metamorphosing entirely into a single medusa, is similar to that described in other species of cubozoans (Werner et al., 1971; Franc, 1995b; Stangl et al., 2002; Fischer and Hofmann, 2004).

According to Arneson and Cutress (1976), medusae of *Carybdea alata* (= *Alatina alata*) are strong swimmers, and while neritic are usually confined to cleaner offshore waters. They rise to the surface at night to feed. From studies in Puerto Rico, food items included polychaetes, mysids and crab megalopae (Larson, 1976b). Medusae of this species are thought to live for more than a year (Arneson and Cutress, 1975).

Larson (1976a) recorded the occurrence of *Alatina alata* (as *Carybdea alata*) in the study area based on a specimen at the NMNH (USNM 53694), as cited above. This species has also been collected immediately east of the region, in the Sargasso Sea, at 32°33' N, 72°14' W (USNM 42017).

The cubomedusa in the western North Atlantic known as *Carybdea alata* (now *Alatina alata*) is known to be venomous to humans (Humann, 2002). The nematocyst complement of medusae identified as *C. alata* from Hawaii incorporated various categories, including those identified as heterotrichous microbasic euryteles (Yanagihara et al., 2002).

Reported Range

Study area: Cape Hatteras (Larson, 1976a).

Overall: reported to be circumtropical, including Gulf of Mexico; neritic (Kramp, 1961, 1970a; Graham, 1998; Morandini, 2003).

Family Tamoyidae Haeckel, 1880
Genus *Tamoya* F. Müller, 1859

Tamoya F. Müller, 1859:1.

Diagnosis

Medusa with clear, cuboidal umbrella, with height exceeding width; four simple, scalpel-shaped pedalia and four flattened tentacles; stomach large, deep, cruciform, with four well-developed mesenteries extending to subumbrellar wall; rhopaliar niche ostium essentially a horizontal to crescent-shaped slit; stomach pouches four, lacking diverticula; gastric cirri in four vertical bands along interradial walls of stomach; velarial canals dendritic, numerous; eyes six per rhopalium (two median and four lateral) (Mayer, 1910b; Kramp, 1961; Cornelius, 1997; Mianzan and Cornelius, 1999; Gershwin and Alderslade, 2005).

Type Species

Tamoya haplonema F. Müller, 1859, by subsequent designation by Haeckel (1880).

Remarks

The generic name *Tamoya* was introduced by F. Müller (1859) for two new species of cubomedusae from the coast of Brazil, *T. haplonema* and *T. quadrumana*. L. Agassiz (1862) referred *T. quadrumana* to a new genus, *Chiropsalmus*, and restricted *Tamoya* to "...the species with simple tentacular lobes" (i.e. *T. haplonema*). Such elimination does not qualify as a valid type species designation (Art. 69.4, ICZN), however, and Haeckel (1880:443) is

Appendix B - SERTC progress report

ROYAL ONTARIO MUSEUM
100 QUEEN'S PARK
TORONTO, ON
M5S 2C6
www.rom.on.ca

ISBN 978-0-88854-471-1
ISSN 1710-7768

Appendix C - SERTC Progress Report

Paradella dianae **–** around the world in 20 years

Kingdom Animalia
Phylum Arthropoda
Class Malacostraca
Order Isopoda
Family Sphaeromatidae

Paradella dianae is a species of crustacean that was accidentally introduced to the southeast coast of the U.S. in the early 1980s. It was first discovered by SCDNR divers who were studying the jetties that were being built at Murrells Inlet at that time. As they made

repeated dives on the jetty stones below the low tide level, to carefully and systematically quantify the flora and fauna, divers noticed hundreds of small creatures clinging tightly to their neoprene wetsuits when they climbed from the water back onto the dive boat. It took a lot of effort to remove them, even under the heavy spray of freshwater from a garden hose back at the dock. It turns out that these pesky animals were isopods that are native to the Pacific coasts of North and Central America. They were probably carried to our coast on the outside surfaces of oceangoing ships, and they have hitchhiked around the world among the fouling growth that builds up over time on these ship's hulls.

Although they aren't particularly conspicuous to the casual observer, isopods are an important part of many coastal communities, as this is especially true for those that live on hard surfaces that are continuously submerged in high salinity seawater for a reasonably long period of time (e.g. floating docks, pilings and jetties). You can learn more about this interesting group of crustaceans by going to the archived 'Featured Species' at

http://www.dnr.sc.gov/marine/sertc/Isopod%20Crustaceans.pdf

Description and Biology:

Paradella dianae is a dorso-ventrally flattened, yellowish and brown colored sphaeromatid isopod. It somewhat resembles the terrestrial isopods that are commonly known as pill bugs or roly pollies. Mature males and females differ in shape and size. Adults are approximately 3 to 5 mm [~0.1 to 0.2 inches] in length, and males are larger than females (Glynn, 1970; Harrison and Holdich, 1982). Males can be easily distinguished from females by the presence of a heart-shaped indentation (foramen) at the posterior end of the animal's midline and by the prominent tubercles on its back (Figs. 1-3).

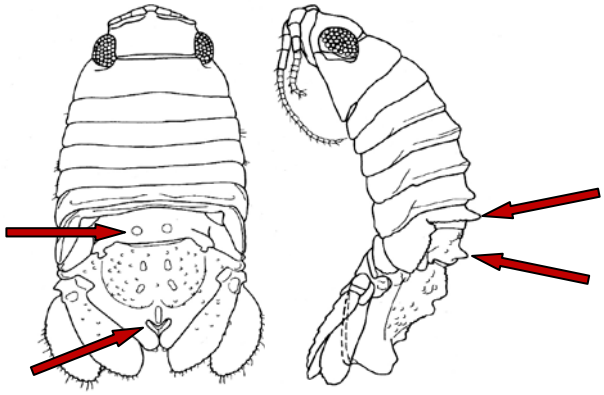


Figure 1. Male *Paradella dianae*, dorsal and lateral views. Arrows point to features that distinguish this species from other local species in the family Sphaeromatidae (from Harrison & Holdich, 1982).

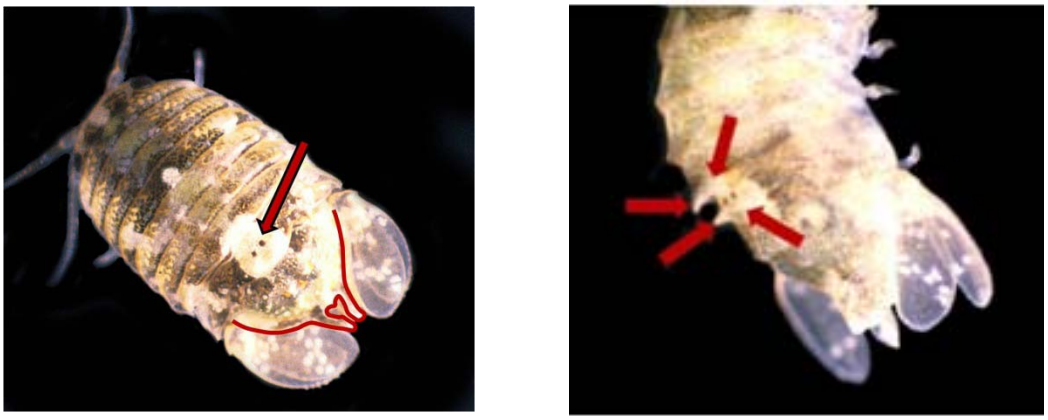


Figure 2. Photographs of male *Paradella dianae* from the dorsal and lateral aspects, with the distinguishing features shown in Fig. 1 indicated.

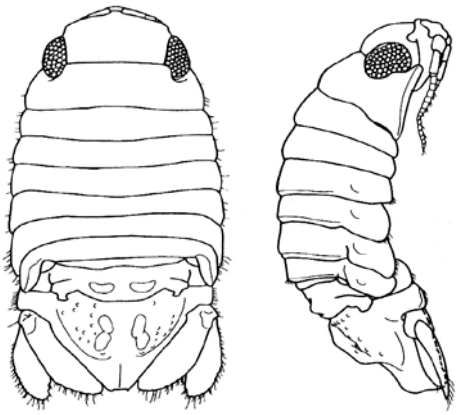


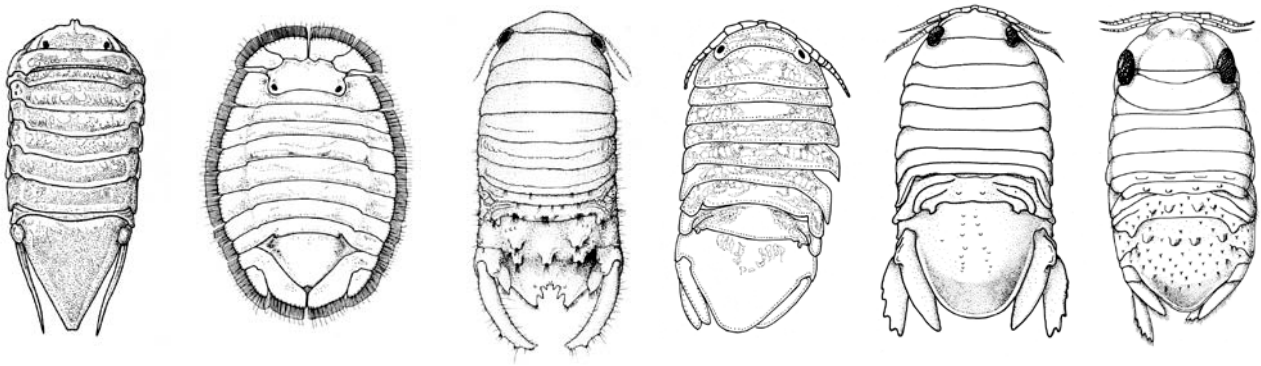
Figure 3. Female *Paradella dianae*, dorsal and lateral views. Note lack of heart-shaped foramen and dorsal tubercles seen in males, as shown in Figs. 1&2 (from Harrison & Holdich, 1982).

Paradella dianae is commonly found among intertidal algae on a variety of substrates, including rock, mud and man-made surfaces like jetties, buoys and piers. The species is often rather secretive, hiding among the heavy growth of marine invertebrates, under stones, or in the shells of dead barnacles or polychaete tubes, especially when the tide has gone down. For food, it grazes on the algae and bacterial film that is attached to the surface (Harrison and Holdich, 1982). *P. dianae* is known to survive at temperatures as low as 14°C [57.2°F] (Nelson and Demetriades, 1992), although its established range on the US Atlantic coast suggests that it tolerates temperatures lower than that. It can survive in a wide range of salinities, from full-strength ocean water to estuarine water diluted to less than half of that (Fulani, 1996; Rodriguez et al., 1992), and it is also known to withstand heavy pollution (Pires, 1980).

This species has a rather unusual life history, since it starts life as a female and changes some time later into a male. This unusual lifestyle, known to scientists as protogynous hermaphroditism, was discovered by Kensley and Schotte (1999). After a male and a female *P. dianae* copulate, eggs are deposited in a brood pouch on the female's underside. The number of eggs may range from 14 to 25 per brood (García-Guerrero and Hendrickx, 2005). When the eggs have reached the appropriate stage of development, small juvenile isopods are released into the surrounding environment. In Florida populations, *P. dianae* has two peaks in abundance during the year; one occurs in sometime from late winter to early spring, and the second happens in late summer to early autumn (Nelson and Demetriades, 1992). However, in its native range, females bearing eggs (gravid) were only collected during the summer, with peaks off egg production in the month of June (García-Guerrero and Hendrickx, 2005).

Similar Species:

Paradella dianae resembles several other species in the family Sphaeromatidae, which is represented in the SAB by the genera *Ancinus, Cassidinidea, Paracerceis*, *Sphaeroma* and *Exosphaeroma*. Kensley and Schotte (1989) provide keys to the four sphaeromatid subfamilies and to species in each of these genera.



A B C D E F

Figure 4. Male sphaeromatid isopods of South Carolina. A: *Ancinus* sp.; B: *Cassidinidea ovalis*; C: *Paracerceis caudate*; D: *Exosphaeroma diminutum*; E: *Sphaeroma quadridentaum*; F: *Sphaeroma terebrans* (also nonindigenous in South Carolina). Illustrations A-C, E, F are from Kensley & Schotte, 1989, Smithsonian Institution Press; D is from the Handbook on the common marine isopod Crustacea of Georgia by Robert J. Menzies & Dirk Frankenberg, copyright 1966 by the University of Georgia Press and reprinted by permission of the publisher.

Native Range:

Paradella dianae is a native of the Pacific coast of North America, from Ventura County, California to Michoacan, Mexico and along the west coast of the Gulf of California from Guaymas Sonora to Sayulita, Nayarit, Mexico (Espinosa-Pérez and Hendrickx, 2001; Iverson, 1974).

Introduced Range:

A real world traveler, *Paradella dianae* has been found in many locations around the globe. Unable to spread so far under its own power, the isopod has most likely been accidently introduced to new locations by hitchhiking on the hulls and other exterior surfaces of ships. The species is now known from such far-flung locations as the Marshall Islands (Glynn, 1970), both coasts of Australia (Harrison and Holdich, 1982), the Atlantic coast of Spain (Rodriguez et al., 1992), the Mediterranean Sea (Atta, 1991; Forniz & Maggiore, 1985), the Arabian Sea (Javed and Ahmed, 1987) and Hong Kong (Bruce, 1990). In the Western Atlantic Ocean, *P. dianae* is known from Brazil (Pires, 1980), Venezuela (Glynn, 1970), Texas (Clark and Robertson, 1982), and Florida, including Key West (Kensley and Schotte, 1989).

At the time of its earliest discovery in South Carolina on the jetty rocks at Murrells Inlet (reported by Van Dolah et al., 1984 as *Paradella quadripunctata*), it initially reached abundances as great as 1500 individuals in one square meter. Subsequent collections of *Paradella dianae* in South Carolina have been made at Charleston Harbor, Sullivans Island, North Inlet and Murrells Inlet (Fox and Ruppert, 1985; Knott, unpublished data).

History of Dispersal:

The first record of *Paradella dianae* outside of its native range was from the Marshall

Islands in 1967 (Glynn, 1970). Four years later the species was found in Townsville, Queensland, Australia, and then in 1980 Furlani (1996) observed it in Western Australia. On the other side of the Indian Ocean, *P. dianae* was found in the Arabian Sea in 1984 (Javed and Ahmed, 1987), then in the Mediterranean Sea (Forniz & Maggiore, 1985), Hong Kong in 1986 (Bruce, 1990) and along the Atlantic coast of Spain in 1988 (Rodriguez et al., 1992).

The first report of *P. dianae* in the Atlantic Ocean was from Mayagüez Bay, Puerto Rico in 1966 (Menzies and Glynn, 1968). Two years later it was discovered in Venezuela (Glynn, 1970), and in 1978 it was found in Brazil (Pires, 1980). Its first known appearance in the United States was along the coast of Texas (Clark and Robertson, 1982), about the same time it was found in South Carolina (Van Dolah, et al., 1984). *P. dianae* was then found in 1984 on the Atlantic coast of Florida (Nelson and Demetriades, 1992). Although no records exist of its presence along other portions of the Gulf coast, the Georgia coast or into North Carolina, its establishment in Texas, Florida and South Carolina suggest that it may also occur in those places.

Realized and Potential Adverse Impacts:

In Florida, *P. dianae* is one of the most abundant isopods, reaching densities of 53,000 individuals in one square meter (Nelson and Demetriades, 1992). Although the ecology of this species has not been studied in its new home in the South Atlantic Bight (Cape Canaveral to Cape Hatteras), given the high densities noted in Texas and Florida, it may be a significant competitor of other native grazing species for food or for space in the cryptic habitats that it occupies.

Cited Material:

Atta, M.M. 1991. The occurrence of *Paradella dianae* (Menzies, 1962) (Isopoda, Flabellifera, Sphaeromatidae) in Mediterranean waters of Alexandria. Crustaceana 60: 213-217.

Bruce, N.L. 1990. New records of isopod crustaceans (Flabellifera) from Hong Kong. pp. 549-554 *In*: Morton, B., ed. The marine flora and fauna of Hong Kong and Southern China II. Hong Kong University Press, Hong Kong.

Clark, T.S. and Robertson, P.B. 1982. Shallow water marine isopods of Texas. Contribution in Marine Science 25: 45-59.

Espinosa-Pérez, M.C. and Hendrickx, M.E. 2001. Checklist of isopods (Crustacea: Peracarida: Isopoda) from the Eastern Tropical Pacific. Belgian Journal of Zoology 131(1): 43-55.

Forniz, C. and Maggiore, F. 1985. New records of Sphaeromatidae from the Mediterranean Sea (Crustacea, Isopoda). Oebalia 11: 779-783.

Fox, R.S. and Ruppert, E.E. 1985. Shallow-water marine benthic macroinvertebrates of South Carolina. University of South Carolina Press, Columbia, SC.. 329 pp.

Furlani, D.M. 1996. A guide to the introduced marine species in Australian waters. Centre for Research on Introduced Marine Species Technical Report No. 5.

García-Guerrero, M. and Hendrickx, M.E. 2005. Fecundity and reproductive period of *Paradella dianae* and *Uromunna* sp. (Peracarida, Isopoda) associated with prop roots of *Rhizophora mangle* in a tropical coastal lagoon, SE Gulf of California, Mexico. Crustaceana 78(7): 769-780.

Glynn, P.W. 1970. A systematic study of the Sphaeromatidae (Crustacea: Isopoda) of Isla Margarita, Venezuela, with descriptions of three new species. Memoria de la Sociedad de Ciencias Naturales La Salle 85(30): 5-48.

Harrison, K. and Holdich, D.M. 1982. Revision of the genera *Dynamenella*, *Ischyromene*, *Dynamenopsis*, and *Cymodocella* (Crustacea: Isopoda), including a new genus and five new species of eurabranchiate sphaeromatids from Queensland waters. Journal of Crustacean Biology 2: 84-119.

Iverson, E.M. 1974. Range extensions for some California marine isopod crustaceans. Bulletin of the Southern California Academy of Sciences 73: 164-169.

Javed, W. and Ahmed, R. 1987. On the occurrence of *Paradella dianae* (Menzies, 1962) a genus and species of Sphaeromatidae (Isopoda, Flabellifera) in the Arabian Sea. Crustaceana 53: 215-220.

Kensley, B. and Schotte, M. 1989. Guide to the marine isopod crustaceans of the Caribbean. Smithsonian Institution Press, Washington, D.C. 308 pp.

Kensley, B., Schotte, M. 1999. New records of isopods from the Indian River Lagoon, Florida (Crustacea: Peracarida). Proceedings of the Biological Society of Washington 112(4): 695-713.

Menzies, F.J. and Frankenberg, D. 1966. Handbook on the common marine isopod Crustacea of Georgia. University of Georgia Press, Athens, Georgia. 93 pp.

Menzies, F.J. and Glynn, P. 1968. The common marine isopod Crustacea of Puerto Rico: a handbook for marine biologists. Studies on the Fauna of Curaçao and other Caribbean Islands 27(104): 1-133.

Nelson, W.G. and Demetriades, L. 1992. Peracarids associated with sabellariid worm rock (*Phragmatopoma lapidosa* Kinberg) at Sebastian Inlet, Florida, U.S.A. Journal of Crustacean Biology 12: 647-654.

Pires, A.M.S. 1980. New record of Sphaeromatidae (Isopoda) from the Brazilian southern coast: *Dynamenella dianae* (Menzies, 1962). Crustaceana 39(2): 133-140.

Rodriguez, A., Drake, P. and Arias, A.M. 1992. First records of *Paracerceis sculpta* (Holmes, 1904) and *Paradella dianae* (Menzies, 1962) (Isopoda, Sphaeromatidae) at the Atlantic coast of Europe. Crustaceana 63: 94-97.

Van Dolah, R.F., Knott, D.M. and Calder, D.R. 1984. Ecological effects of rubble weir jetty construction at Murrells Inlet, South Carolina – Vol. I: Colonization and community development on new jetties. Technical Report EL-84-4, prepared by Marine Resources Research Institute, Charleston, SC, for Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. 138pp.

Authors: David M. Knott & Susan T. DeVictor
Southeastern Regional Taxonomic Center
South Carolina Department of Natural Resources

Sam Crickenberger
Department of Biological Sciences
Clemson University