MARYLAND

Research, Education, Outreach *Volume 19, Number 3*

MARINE NOTES

SPOTLIGHT ON NATURAL HISTORY

American Eel

Biology, Mystery, Management

BY WENDY MORRISON

Wendy Morrison

Eels have intrigued people since the time of Aristotle, who hypothesized that they were created from mud due to their appearance in lakes that were previously dry. Such misconceptions carried into the 1880s when a reward was offered to anyone who could produce an eel with eggs present in the body cavity. Unscrupulous fishermen were found stuffing eels with cod eggs to try to win the reward. Research on eels has solved many of the mysteries surrounding these unique fish, but important issues, including their exact spawning area, remain unknown. The economic importance of this animal has soared in recent years, but most people are still unfamiliar with its biology or its history in the Chesapeake Bay.

Denizens of the Chesapeake

Historically in the Chesapeake Bay, there have been two reasons for catching eels: bait for the crab fishery which targeted eels 10-14 inches long, or the live eel trade which targeted eels greater than 13 inches. The use of eels for crab bait has declined over the years as fishermen have changed to cheaper sources. The crab fishery current-

"If God had wanted us to be beneath the surface of the ocean, He would never have put eels down there."

— Dave Barry, humor columnist

This sentiment is probably shared by many, who think of eels as more snake than fish and who would prefer not to encounter one. If appreciated at all, it is most likely as bait for catching blue crabs. Yet the American eel (*Anguilla rostrata*), which supports a one-to-three million dollar fishery annually in the Bay, is an abundant resident of all tributaries to the Chesapeake. The Bay's commercial catch reached a high of 700,000 pounds in 1981, and though it has since declined, it remains an important fishery. The American eel is also found along the Atlantic coast of North America, throughout the Gulf of Mexico and the Caribbean to Venezuela, and inland to the St. Lawrence Seaway and the Great Lakes. Most eels caught in the Chesapeake are exported live to Europe and east Asia, where they are considered a delicacy and command a high price.

A creature whose method and place of reproduction were unknown until the 20th century, the eel has long fascinated scientists and fishermen alike. While we now know that the eel begins and ends its life in the waters of the Sargasso Sea, in the middle of the North Atlantic, unraveling the mystery of its reproduction still awaits discovery. Researchers in the Chesapeake are studying the eel to better understand its migration patterns and life cycle after reproduction and also perhaps to uncover the reasons for its declining numbers over the last twenty years.

Wendy Morrison, a graduate student in the University of Maryland's Marine-Estuarine-Environmental Sciences program who studies eels, wrote this issue's spotlight article. When people find out she's studying eels, says Morrison, they respond with disgust and wonder. "Why eels?" To Morrison, however, they are fascinating animals.

Scientists looking for eel eggs and newly hatched larvae can tell the approximate area where the eels must spawn, but no adult eels have ever been caught there.

ly accounts for only about seven percent of eel landings. Conversely, the live eel fishery has increased because of greater demand in Europe and Asia, as well as the development of better harvest technology.

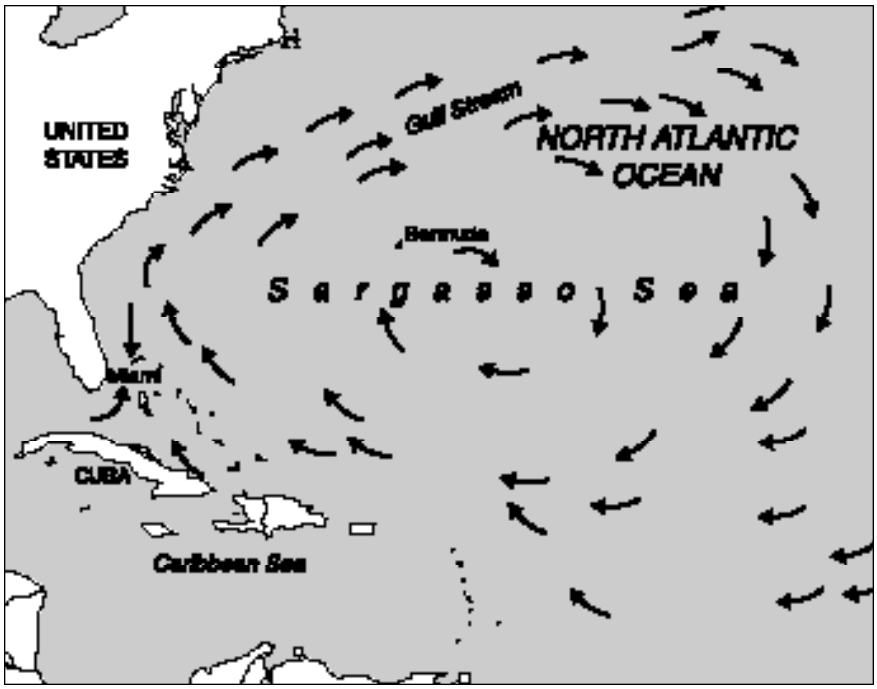
Until 1991, when "The Chesapeake Bay American Eel Fisheries Management Plan" was adopted, there was no regulation of the fishery. Scientists contributing to the plan noted that little data existed for eels, making an evaluation of the fishery close to impossible. In 1995, the Mid-Atlantic States Marine Fisheries Council called for fishery independent research aimed at monitoring population abundance, size structure, maturity, growth and sex structure of eels in the Chesapeake Bay. The Maryland Department of Natural Resources responded by establishing an eel monitoring program aimed at assessing recent changes in numbers, age and size. Studies first conducted in the Susquehanna and Sassafras Rivers in 1982 and again in 1997 suggested that the average size of eels as well as population abundance had declined over the ten-year period.

An Eel's Life

The life history of the American eel differs significantly from almost all other fish found in the United States. Eels are among the few catadromous species, meaning that they live in fresh water but reproduce in salt water. They range from Venezuela to Greenland and, surprisingly, all come from the same genetic stock (the term for this is "panmictic"). They come together in the Sargasso Sea to spawn.

After spawning, eggs hatch into leptocephali — long, flat, leaf-like larvae — that float like plankton. They

The Mysterious Seaweed Sea



The Sargasso Sea, where the mystery of eel spawning takes place, is something of a mystery itself. A vast area (some two million square miles) in the middle of the Atlantic, it was rumored throughout history to be filled with abandoned ships that were trapped on its nearly windless surface. The excerpt below from the November 1998 issue of *Smithsonian Magazine* (www.smithsonianmag.si.edu/smithsonian/issues98/nov98/ sargasso.html) shows just how unique it is.

> Out in the Atlantic, strange creatures make their home among seaweed in a floating lens of warm water. When Columbus reached the deep blue waters of the central North Atlantic, he thought he was very close to shore. After all, there was suddenly an abundance of plant life in the form of a floating algae, which he called, simply, "weed." His sailors, meanwhile, feared that their ships would become irretrievably entangled in the stuff.
>
> Their fears were misplaced — as were Columbus's hopes. The weed — which scientists ultimately dubbed *sargassum*, after a Portuguese word for it — is neither sturdy nor abundant enough to ensnare a ship of any size. And even the westernmost boundaries of the Sargasso Sea — a two-million-square-mile ellipse of deep-blue water adrift in the North Atlantic — lie many hundreds of miles from the North American shore.
>
> Defined by a floating lens of warm, exceptionally clear water, the Sargasso Sea drifts, its location determined by the changing ocean currents that, flowing in a clockwise promenade, form its perimeter. The algae that riddles its surface is actually a deceptively lush veneer to a stretch of ocean that is relatively devoid of life at deeper levels. But even in this ocean desert, there is an intricate web of life that has adapted to existence among the weed.

Wendy Morrison

Eels are caught using long, narrow mesh pots, shown above at right, held in place by square anchors, shown above at left.

Wendy Morrison

Anaesthetized eel about to be injected with Passive Identification Tag (PIT). Each tag contains a 10-digit number that can later be read with an electronic scanner.

drift with the currents for about a year before metamorphosing into "glass eels" and moving into coastal areas. It is this period of drift that distributes the eels through their wide geographic range. Glass eels are transparent and two to three inches in length — they travel into fresh water streams and migrate up-river, gaining their yellow/green pigmentation as they grow. Most of the eel's life is spent in this stage (called the "yellow eel") in fresh or brackish waters where it feeds on an assortment of foods, including crustaceans, fish, insect larvae, plankton, mice and almost anything else.

When eels reach an appropriate size, and have enough stores of fat (this can take five to 25 years, depending on sex and location), they metamorphose into "silver eels" and begin the long migration back to the Sargasso Sea to complete their life cycle.

Understanding Biology

Researchers have been especially interested in determining the home range of the eel — does it have a territory, and, if so, how big is it? These are important questions for managers because they impact decisions on how to monitor and manage the fishery. Scientists have found that eels do have home ranges and that the size of these home ranges varies according to location in the river. Eels that inhabit small streams have very limited dispersal, while eels in larger rivers seem to move around more.

Steven Parker, a researcher in Maine, attached transmitters to eels before moving them 10 to 17 kilometers away from their home range into waters of different salinity. He found that the eels were not only able to survive this abrupt change in salinity, but were able to find their way back to where they were originally captured. It remains unclear what cues eels use to locate an area; olfaction is known to be important, but is not the only sense used. Scientists hypothesize that the eels' extraordinary sensory capabilities may have evolved to enable them to navigate to the Sargasso Sea and locate other eels to spawn.

Eel research has also centered on the differences between males and females. On average, mature female eels are larger than mature males. Males begin spawning migrations when they are 25 to 40 cm in length, while females begin when they reach 40 to 100+ cm. These patterns of size difference between males and females are prevalent in other fish species as well. Scientists hypothesize that males can migrate at smaller sizes because less energy is required to produce sperm. Females, on the other hand, invest more energy in egg production and therefore migrate later, when they are large enough to maximize their chances of reproductive success.

Researchers have also discovered gender differences related to population distribution. In some areas of the United States eels are almost exclusively female, while in other areas the population is mostly male. For example, Julie Weeder from Maryland DNR determined that 85 percent of eels caught are females. In general, males are found in more southern latitudes and closer to the mouths of estuaries, while females are usually found in more northern latitudes and in inland fresh water portions of rivers and streams. Many hypotheses exist to explain these distributions, including growth rate/predation trade-offs and hormonal influence through chemical contamination of water. Currently, the most accepted hypothesis relates to density dependent sex differentiation. Eels change into males if the population density is high and food competition strong. If densities are low and competition is minimal, they change into females.

The most intriguing research questions relate to spawning. Although researchers have studied these animals for years, none have found their exact spawning area. Scientists looking for eel eggs and newly hatched larvae can identify the approximate

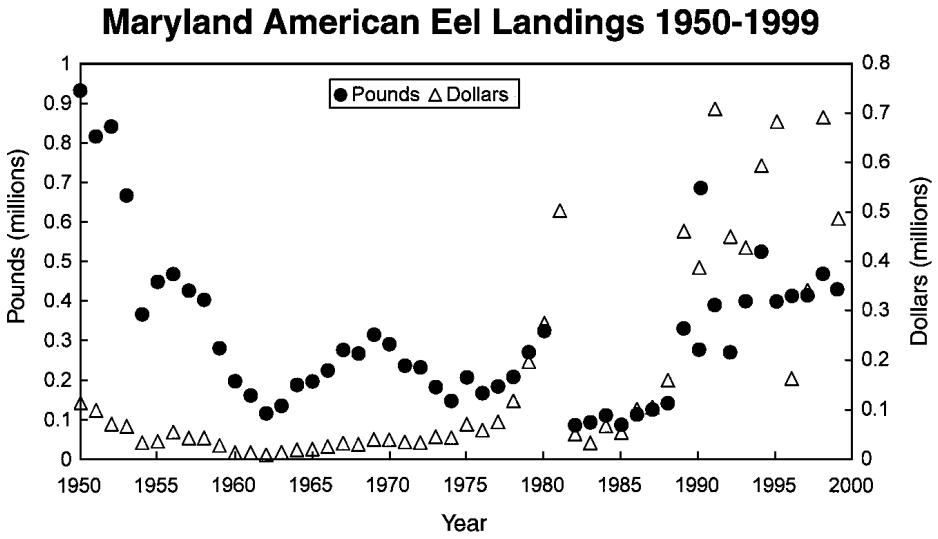
"In conducting my eel study, I got to see first hand what the eels ate for dinner due to an unsuspected side effect of the anaesthetic we used to calm them before tagging. The most interesting meal launched at me was a rabbit's foot, which made me wonder what happened to the rest of the rabbit."
— Wendy Morrison

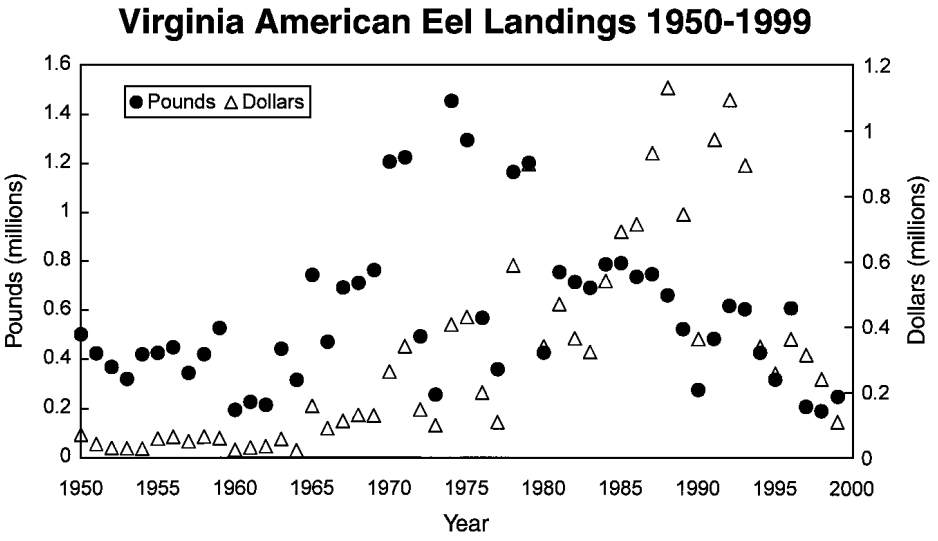
area where eels must spawn, but no adult eels have ever been captured there.

Exotic Invader

An exotic parasite from Asia, a nematode called *Anguillicola crassus*, has recently been discovered in American eels. The parasite, which infects the eel's swim bladder, is native to the Asian eel (*Anguilla japonica*), found in Japan, China, Taiwan and Korea. Before arriving in the United States, the nematode first invaded Europe, when infected Asian eels escaped from aquaculture facilities into surrounding waterways. The presence of the nematode was first discovered in European eels (*Anguilla anguilla*) in Germany in 1982, where documented effects include reduced swimming speed, reduced ability to change buoyancy, rupture of the swim bladder and occasionally death. European eels, without adaptations to stop the parasite, allowed for the quick propagation of the nematode, increasing introduction into distant waterways.

The nematode was discovered in American eels in an aquaculture operation in Texas in 1995, which prompted a search for the parasite in wild eels. It was first found in Winyah Bay in South Carolina and has subsequently been identified in eels in Maryland, New York and New Jersey. At this point, the distribution of the parasite has not been studied,





Commercial landings for American eels in the Chesapeake Bay have increased in value while the number of eels caught has declined. This generalization doesn't hold for both states: pounds in Maryland seem steady and value up. In Virginia, pounds and value are down in recent years.

nor has the effect of the parasite on the American eel. A paper by Anne Barse of Salisbury State University and David Secor at the UMCES Chesapeake Biological Laboratory alerted fisheries biologists to the parasite. They requested that all researchers studying eels inspect their fish for the presence of the nematode in order to better document its distribution and provide a means for monitoring its spread.

The Commercial Fishery

Even before discovery of the parasite, the future of the eel fishery had come into question due to declines in the yellow eel fishery and glass eel numbers. John M. Casselman, a Canadian eel researcher, has been monitoring the number of juvenile eels entering the St. Lawrence River since 1974. Stationing a camera inside the R.H. Saunders Hydroelectric Generating Station on a fish ladder specifically designed to allow eels to pass into water above the dam, he has found that in recent years there has been a significant and dramatic decrease in the number of juvenile eels entering the area. This key finding suggests that a decline in

American eels may occur in the near future.

One recent controversy concerning the American eel is the glass eel fishery, a lucrative industry that has only been feasible in the last few years. With technology now available to culture and transport glass eels, consumer demand has been rising, especially in Asia. Asian aquaculture facilities have found it more profitable to buy glass eels and culture them to adults than to purchase yellow and silver eels imported at a larger size. Only Maine and Connecticut currently have a glass eel fishery and some scientists and managers strongly criticize the practice. They would argue that removing such large numbers of glass eels could negatively impact yellow and silver eel fisheries as well as the population itself.

Others argue that allowing the harvest in only a few states encourages illegal poaching in nearby states. Fishermen need only transport their catches across state borders to sell them legally. No studies have yet assessed the impact of the glass eel fishery or of the yellow and silver fisheries on eel populations. In Maryland, a minimum size requirement of six inches is enforced, effectively preventing the harvest of glass eels, while Virginia bans the harvest outright. In 2000, the market for glass eels dropped dramatically, decreasing the economic incentive and effectively eliminating most harvest — for the time being. More information on the survival of glass eels is necessary to discover whether or not this fishery has a deleterious impact on populations if it becomes profitable again.

Declines in eel populations, whether related to the glass fishery or not, will likely have significant consequences difficult to address. Regulating the fishery will require cooperation among different states as well as other countries. What researchers are learning will lead to a more thorough understanding of the biology of the species and will help managers decide the best course to take to halt declines.

For More Information

Web

Chesapeake Bay Program
Office, page on the American eel.
www.chesapeakebay.net/info/american_eel.cfm

NOAA Chesapeake Bay Office, page on the American eel.
noaa.chesapeakebay.net/spc/eel.htm

Bay Journal, July/August 1996, article titled, "Take the Bait: Get to Know the American Eel."
www.bayjournal.com/96-08/natural.htm

Maryland Biological Stream Survey Newsletter, March 1999, article titled "American Eel: Past, Present and Future." Maryland Department of Natural Resources.
www.dnr.state.md.us/streams/news/march99/eel.htm

Rutgers University, Institute of Marine and Coastal Sciences, page on American and European eels.
www.ecoscope.com/eelbase.htm

Earth and Sky Radio Program on the American eel, online transcript.
www.earthsky.com/1999/esmi990513.html

Southern Division of the American Fisheries Society, page on the swim bladder nematode *Anguillicola crassus*, among Chesapeake Bay American eels.
www.sdafs.org/meetings/99sdafs/physio/barse1.htm

Print

Working the Chesapeake: Watermen on the Bay, by Mark Jacoby. Maryland Sea Grant. This book chronicles a day in the lives of thirteen watermen throughout the four seasons as they harvest oysters, crabs, clams, finfish and eels. Illustrated with drawings by Neil Harpe.

Working with her advisor David Secor at the Chesapeake Biological Laboratory, Wendy Morrison has focused her work on understanding the biology of American eels with an emphasis on an unfished population in the Hudson River, New York. The river has been closed to commercial eel fishing since 1976 due to PCB contamination, so it offers a unique opportunity, says Morrison, to study eel populations without fishing pressure. The research aims to clarify population abundance, age structure, movement, and growth of the eels in fresh and brackish waters. This information will be helpful in determining the impact of eel fishing not only in the Hudson River when the fishery reopens, but also in other nearby areas.

Morrison was awarded a Sea Grant Knauss Fellowship for 2001 to work with NOAA's National Ocean Service, Center for Coastal Monitoring and Assessment Biogeography Program. She expects to complete her Masters degree in the University of Maryland MEES program this fall.

Managing Exotics in the Chesapeake

The Chesapeake 2000 Agreement set as a goal the control and management of invasive aquatic species that could harm the Bay. Signatories to the Bay Agreement are to identify and rank, by 2001, these potential non-native threats to the Bay's ecosystem. By 2003, they are to develop and implement management plans for those species.

According to Edith Thompson, the Exotic/Invasive Species Policy Coordinator for the Maryland Department of Natural Resources, each state in the Bay region — Maryland, Virginia, Pennsylvania and Delaware — is submitting a draft list of those species. The Maryland list currently singles out the following:

- Phragmites (*Phragmites australis*), the common reed, which creates a monoculture of plants, displacing native wetland vegetation. The common reed has little value for native wildlife and can raise the surface level of sediment, changing wetland to upland. Phragmites affects thousands of acres of wetland in Chesapeake Bay, from fresh to brackish marsh.

- Mute swan (*Cygnus olar*), which is beautiful but poses a threat to the Bay's struggling grass beds (SAV). Because the birds are here all year, the exploding Maryland population of mute swans poses a special threat to SAV, potentially affecting its growth during warmer months. The mute swans consume some 9-12 million pounds of SAV each year.

- Nutria (*Myocastor coypus*), an imported rodent that resembles a large muskrat. Nutria eat marsh vegetation, especially three-square bulrush in lower Eastern shore salt marshes, but also fresh and brackish water marsh plants. Nutria have contributed to the loss of over 7,000 acres of salt marsh in the Blackwater National Wildlife Refuge alone.

- Green crab (*Carcinus maenas*), a European transplant that has made its way down the Atlantic coast. Green crabs eat young scallops, which is a special concern in Maryland's Coastal Bays.

- Water chestnut (*Trapa natans*), an invasive plant that can blanket the surface of ponds. Water chestnut creates a monoculture, preventing sunlight from reaching SAV and creating large, spiny seed pods that interfere with recreational use of waterways and beaches.

- Purple loosestrife (*Lythrum salicaria*), a pretty but persistently invasive plant. Like water chestnut, loosestrife creates a monoculture of plants in freshwater wetlands, excluding use of habitat by a diversity of native plants. It appears to have minimal value to native species.

Other top issues facing Maryland include: identifying foreign organisms entering the Chesapeake Bay via ballast water and implementing regulations that require ballast water reporting; controlling exotic/invasive plants in natural areas; mounting a rapid/emergency response to new invasions.

According to the DNR, resident Canada geese (those flocks that do not migrate) are a top priority, currently managed as a game species. Of course, West Nile Virus is also a top state priority, which is managed as a human health issue (by the state Department of Health, with DNR support), and not as an exotic species issue.

DNR also lists five nuisance species that have not yet caused known problems but which may have the potential to be harmful are:

- Zebra mussel (*Dreissena polymorpha*)
- Grass carp (*Ctenopharyngodon idella*)
- Japanese shore crab (*Hemigrapsus sanguineus*)
- Rapa whelk (*Rapana venosa*)
- Nuclear worm (*Namalycastis abiuma*)
- Suminoe oyster (*Crassostrea ariakensis*)

The Maryland DNR has had an Exotic/Invasive Species Policy Coordinator since Feb. 2001. The Coordinator notes that as DNR continues to develop its policy in concert with other agencies and states, the priority listing could evolve and change.

For More Information

Maryland Sea Grant web site on understanding species invasions. Download fact sheets online or order print versions by calling (301) 405-6376.
www.mdsg.umd.edu/exotics/index.html

Chesapeake Bay Program page on exotic species.
www.chesapeakebay.net/exotic.htm

Smithsonian Institution page on exotic species in the Chesapeake.
http://invasions.si.edu/species.htm

National Invasive Species Council final interagency plan
www.invasivespecies.giv/council/nmp.shtml

Students Participate in Summer Fellowship Program


Sandy Rodgers


Sandy Rodgers

This summer marks the thirteenth year for Maryland Sea Grant's summer Research Experiences for Undergraduates (REU) program. Fourteen students arrived in early June for orientation and to begin working with researchers at environmental laboratories. They will present the results of their summer's work at a seminar on August 17.

The REU fellowship, supported by a grant from the National Science Foundation, pairs fellows with a scientist-advisor to conduct an independent research project at one of three environmental laboratories in Maryland: Chesapeake Biological Laboratory, Horn Point Laboratory (both part of the University of Maryland Center for Environmental Science) or the Academy of Natural Sciences Estuarine Research Center.

This year's REU students were selected competitively from 88 applicants nationwide. Student fellows, their home colleges, research topics and advisors are listed below.

• **Christopher Chick** (Hendrix College). Nutrient burial in agriculturally impacted wetlands. Advisor: Jeff Cornwall.

• **Edward Galbavy** (Tufts University). Development and implementation of a precise mobile device measuring atmospheric ammonia and ammonium aerosols throughout southeast Maryland. Advisor: Ron Siefert.

• **Christopher Belnap** (Hartwick College). Bacterial mediation of dissolved organic matter and protein degradation in estuarine waters. Advisor: Rodger Harvey.

• **Amy Long** (University of Pittsburgh). What levels of turbulence affect *Pfiesteria piscicida's* ability to graze? Advisors: Diane Stoecker and Larry Sanford.

• **Zeb Schonernd** (Earlham College). Use of artificial substrates to predict habitat suitability for SAV restoration. Advisor: Laura Murray.

• **Leslie Brandt** (Gustavus Adolphus College). Epiphytic algae as UV filters on leaves of the seagrasses *Zostera marina* L. and *Ruppia maritima* L. Advisor: Eva Maria Koch.

• **Katharine Boyle** (San Francisco State University). The survivorship of *Mya arenaria* from predation as a function of SAV and SAV density. Advisor: Denise Breitburg.

• **Sarah Maurer** (Hofstra University). Predation and selectivity of *Neomysis americana* on *Eurytemora affinis* and rotifers. Advisor: Marie Bundy.

• **Elizabeth Kennedy** (Iowa State University). Sub-lethal effects of contaminants on *Leptocheirus plumulosis*. Advisor: Chris Rowe.

• **Adrian Kirby** (Saint Mary's College, Indiana). Carnivorous feeding preferences exhibited by adult copepods *Acartia tonsa* and *Eurytemora affinis*. Advisor: Mike Roman.

• **Tracy Jo Williams** (Florida Southern College). The effects of population densities and behavior of *Macoma balthica* on nutrient exchange and primary production in coastal sediments. Advisor: Roberta Marinelli.

• **Patrick Spain** (Suffolk University). The ability of various sized oyster spat to withstand increasing degrees of dessication. Advisor: Don Merritt.

• **Matthew Behum** (Colgate University). Effects of small-scale turbulence on the condition of larval fathead minnows, *Pimephales promelas*. Advisor: Tom Miller.

• **Cherie Jenkins** (Coastal Carolina University). Effect of salinity on growth rates and survival of juvenile Chesapeake Bay white perch, *Morone americana*. Advisor: David Secor.

Maryland Sea Grant's REU summer program is open to students who have completed at least two years of undergraduate work, will be enrolled as undergraduates in the fall and are U.S. citizens or permanent residents. For more information, visit the web at www.mdsg.umd.edu/Education/REU/index.html.

End Notes

On the Web

■ **Archive Publication.** www.mdsg. umd.edu/oysters/research/ mdoysters.html. *Maryland's Oysters: Research and Management*, published by Maryland Sea Grant in 1981 and now out of print, continues to serve as a valuable research reference. This critical review and synthesis of literature on the eastern oyster, *Crassostrea virginica*, is now available online in a searchable pdf form along with an annotated listing of selected literature.

■ **Rip Current Forecasts for North Carolina Beaches.** NOAA's National Weather Service and National Sea Grant College Program are teaming up to help educate the public about the dangers of rip currents which account for 80 percent of beach rescues annually — 36,000 rescues in 1997.

Using local area web sites, the NWS in North Carolina now provides rip current forecasts for most North Carolina beaches. Developed in cooperation with North Carolina Sea Grant, the sites provide twice daily updates from the Myrtle Beach, South Carolina, area north to Dare County, North Carolina. Easy-to-read maps alert the public if conditions along various strands pose a low threat, increased threat or dangerous threat for rip currents.

For forecasts for Pender, New Hanover and Brunswick counties in North Carolina and Myrtle Beach in South Carolina, go to http://nwsilm.wilmington.net; for Dare, Hyde, Carteret and Onslow counties, go to http://tgsv5.nws.noaa.gov/er/mhx/

Maryland Marine Notes
Volume 19, Number 3
May-June 2001

Maryland Marine Notes is published six times a year by the Maryland Sea Grant College for and about the marine research, education and outreach community around the state.

This newsletter is produced and funded by the Maryland Sea Grant College Program, which receives support from the National Oceanic and Atmospheric Administration. Managing Editor, Sandy Rodgers; Contributing Editors, Jack Greer and Merrill Leffler. Send items for the newsletter to:

Maryland Marine Notes
Maryland Sea Grant College
0112 Skinner Hall
University of Maryland
College Park, Maryland 20742
(301) 405-6376, fax (301) 314-9581
e-mail: mdsg@mdsg.umd.edu

For more information about Maryland Sea Grant, visit our web site:
www.mdsg.umd.edu/MDSG

Maryland Marine Notes **(current and back issues since 1995) is also available on the web at www.mdsg.umd.edu/MarineNotes**

Recycled Paper

PRINTED WITH SOY INK

Maryland Sea Grant College
0112 Skinner Hall
University of Maryland
College Park, Maryland 20742

Address Service Requested

Non-Profit Org.
U.S.Postage
PAID
Permit No. 10
College Park, MD