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Increasing the Probability of Success in the Construction of Marshes in Coastal Virginia

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Introduction

The expansion of human populations and the anthropogenic impact on sensitive natural systems, such as wetlands, has spurred increased use of created marshes to offset the loss of developed natural marshes. Mitigation of the loss of valuable marshes has become increasingly important to regulatory agencies and consequently to the development community. The construction of marshes to compensate for permitted impacts to natural marshes is becoming pandemic. Emphasis on the successful construction of marshes has gained increased scrutiny with the recent passage of the Federal Guidance for the Establishment, Use and Operation of Mitigation Banks (CFR Vol. 60, No. 228, 1995) which allows the construction of marshes and the sale of credits to compensate for the destruction of natural marshes. Information on design criteria for the successful construction of marshes is vitally important for mitigation bank creation. Marsh construction, however, is a relatively young science, and the “successful” establishment of a constructed marsh is fraught with many difficulties, variables, and unknowns (Mitch and Wilson 1996). The question of if, and how long does it take, a constructed marsh to achieve the same level of function as similar natural marshes remains unanswered. In addition, the ability of constructed marshes to withstand invasion by non-native or aggressive, undesirable plants is questionable (Havens et al 1997).

This study involves the comparison of ecological conditions in a twelve year old artificially created tidal marsh excavated from upland and two nearby natural reference tidal marshes. These marshes were extensively studied in 1992 and baseline data is available for comparison (Havens et al 1995, Varnell and Havens 1995, Varnell et al 1995). The 1992 study was among the first to use the reference wetland concept and to use replicate sampling methods appropriate for robust parametric statistical analyses in the comparison of natural versus constructed marshes. This study builds on the extensive database of the previous study in order to compare over time the habitat function of a constructed marsh with reference natural marshes.

Methods

The study site is located in Sarah’s Creek, a tributary to the York River near Gloucester Point, Virginia, USA (37°16’30"N 76°29’40"W) approximately 10 km from the Chesapeake Bay and 40 km from the Atlantic Ocean. The tidal amplitude is 0.75 m.

The same methods and equipment used in the 1992 study were duplicated (Havens et al. 1995).

Physical characteristics of the marshes were determined from low altitude aerial photographs of a scale of 1:4200. The vertical aerial imagery was digitized using the vector-based GIS software ARC/INFO. Topcon infrared surveying equipment was used to survey elevations within each marsh. Each marsh was surveyed at transects of 10-m intervals with survey points along each transect every 10 m and at distinct elevation transition zones such as vegetation community margins and channel edges. At least five survey points were included in marsh channels for each transect. The gridded elevation topographies were overlaid with calculated mean high water to determine volume using LI Contour V+ software.

The total area of the constructed marsh is 0.65 ha. An adjacent marsh to the west is 0.58 ha and is located just upstream of the constructed marsh but is separated by a 15-m wide wooded peninsula. The other natural marsh is located approximately 150 m downstream (east) of the constructed marsh and is 0.42 ha in size. It is separated from the constructed marsh by approximately 16 ha of wooded upland. The constructed marsh is bordered on the north side by a shopping center complex and receives drainage from the shopping center parking lot via a sediment detention pond. There is additional freshwater input through a drainage ditch along the northeast border. The west marsh receives only incidental freshwater input while the east marsh receives freshwater input through a drainage ditch along the north border. A multiplex theater has been constructed within 15 m of the west marsh since the original 1992 study (Fig. 1, page 5).

The constructed marsh was created in 1987 by excavating an upland area and grading it to intertidal elevations. One-year-old greenhouse-grown *Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata* were planted on 50- to 90-cm centers on the graded land. The channel was excavated to a depth of 1 m below mean low water.

An intensive, two-season sampling strategy was chosen that followed a similar lunar cycle and time frame as the previous 1992 study (Fig. 2, below). Spring sampling occurred from 25 to 27 May 1999 and summer sampling occurred from 9 to 11 August 1999. By sampling each marsh for three consecutive days during two seasons (spring and summer), we could account for the short-term variability associated with assessing mobile aquatic fauna abundance in estuarine wetlands (Varnell et al. 1995).

Random sample plots within each marsh were selected for analysis of the vegetation, benthic fauna, and sediment carbon study components. The wetland boundaries for each marsh were delineated from aerial photographs and digitized. Each digitized image was computer overlaid by a grid of scaled 1-m^2 cells. Each square meter grid cell was numbered. For each marsh, square meter sample plots were identified by random number generation. Unique sample plots were generated for each study component requiring random sampling. Standard field flags from the previous study were located at 10-m intervals along the upland-wetland boundaries of each marsh from

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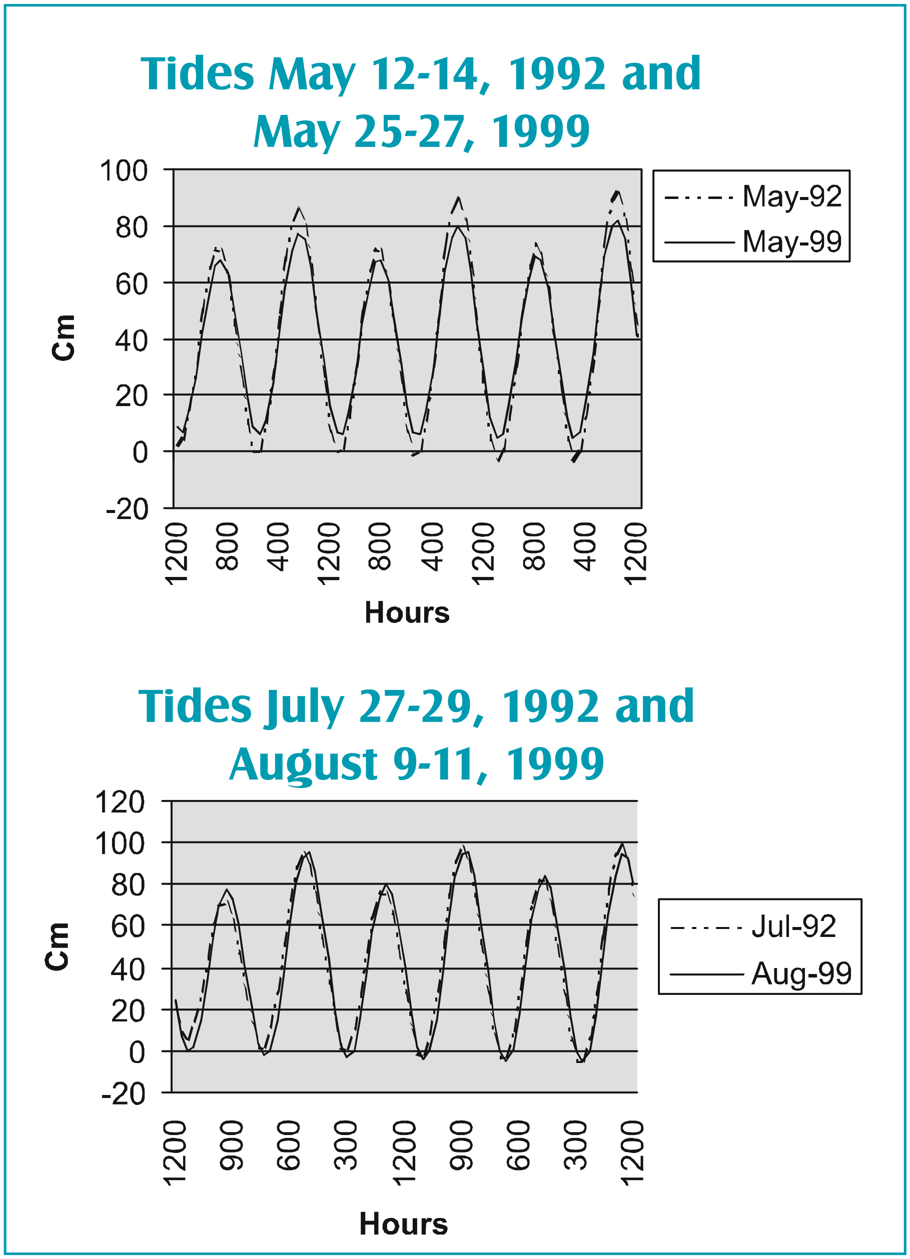

Figure 2. Tidal cycle comparison between 1992 and 1999 sample dates.

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Wetland Denizens

Fiddler Crab

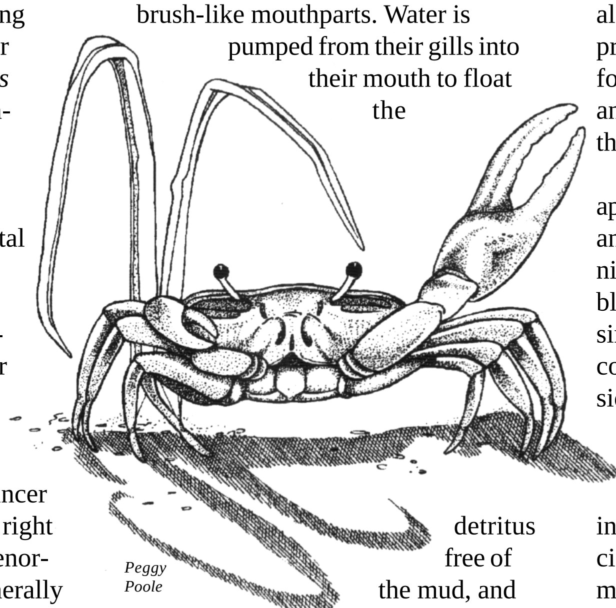
Uca species

by Walter I. Priest, III

One of the most frequently observed denizens of our east coast saltmarshes, particularly at the lower tide levels, is the fiddler crab. Once you have seen this small, but pugnacious crab, as he waves his single enormous claw (pincer) to warn you not to approach any further, you won't forget him. The fiddler crab is a burrowing crab, not a swimming crab like our well known blue crab, *Callinectes sapidus.* He also must not be confused with the small black marsh crab or the often present hermit crab. The fiddler crabs, like all crabs, are able to exploit the detrital portion of the saltmarsh food chain.

There are three species of fiddler crabs commonly found in our local marshes and all the marshes along the eastern seaboard. The males have the common characteristic of one large pincer which can be on either the left or right side. Male fiddler crabs use this enormous brightly colored pincer, generally 5 to 10 times larger than their opposing claw, for several things. Foremost, the claw is used by the crab to defend the territory around its borrow and ward off other intruders. Males also entice interested females into their bachelor burrows for mating. Male crabs can often be seen fighting over territory or females, but they are very careful in these skirmishes—a lost pincer spells disaster! While a lost pincer can be regenerated, it takes many months to accomplish and the new pincer is normally not as large nor as strong as the original. For this reason, most of these "fights" consist of pincer waving and posturing by the rival males. The two claws on females are quite small and are the same size. Only the male has the larger pincer. (See page 7 for illustrations of different pincers.)

Males and females use their smaller claws when feeding on mudflat surfaces or in the protection of the vegetated wetlands. They scoop mud into their mouths and filter out the entrapped detritus using specialized brush-like mouthparts. Water is pumped from their gills into their mouth to float the detritus free of the mud, and after swallowing the detritus, the mud is then redeposited on the marsh surface in the form of neat little mud balls. Fiddler crabs feed on the falling tide and are most active at low tide when the greatest area of exposed mudflats exists. As the tide rises, the fiddlers retreat to their burrows and seal the entrance with a mud ball plug. The everyday life of the fiddler crab is tied to the tidal cycle which influences its feeding habits and often induces color changes in the crabs' pincer and shell.



The Marsh or Black fiddler, *Uca pugnax,* the smallest of the fiddler crabs, is about 7/8 inch (22mm) wide and 5/8 inch (16mm) long and in the male is recognized by its dark olive or almost black carapace shell with a royal blue spot near the center. The female is similar in color except she does not have the royal blue spot. The males' large pincer has an oblique (sloping/angled) ridge on the inner surface and is brownish yellow at the base, becoming yellow on the hand section with almost white fingertips. This species prefers a muddy habitat and is often found along the banks of tidal marshes and often shares the same habitat with the next species.

The Sand fiddler, *Uca pugilator,* is approximately 1.5 inches (38mm) wide and 1.0 inch (25mm) long and is recognized by its purplish or grey-blue blotchy carapace shell. The female is similar in color but with more subdued colors. In males the large pincer is considerably larger than the opposing, smaller claw. It is smooth, *without* a rough oblique ridge, on the inner surface and bluish or reddish brown in color with white fingertips. This species is found higher on the marsh and more frequently in locations where there is more sand than mud.

The Red-jointed fiddler, *Uca minax,* is considered the largest of the three species, being just over 1.5 inches (38-42mm) wide and 1.0 inch (25mm) long. Males have a chestnut-brown carapace, grayish near the front with olive or grayish-brown walking legs. The extremely large male pincer has an oblique ridge with low, round projections on the inner surface of the hand, reddish areas at the moveable joints and white fingertips. This species is found in the muddy substrates of lower salinity marshes and seems to favor marshes that are nearly fresh water and less wet.

Unfortunately, when confronted by

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GIS Geographic Information System

CCI Develops New Online GIS Resources

Marcia Berman

OSCAR

(Oil Spill Clean-up and Response Tool)

The Comprehensive Coastal Inventory Program with the Chesapeake Bay Program, announce the online mapping tool OSCAR. OSCAR is an interactive online tool designed to assist oil spill responders identify environmentally sensitive resources within the Chesapeake Bay. Minimizing impacts to natural resources is always a principal concern when an oil spill occurs. OSCAR is designed to rapidly display a collection of geographic data themes which designate sensitive areas within the Bay. Using software technology developed by the Environmental Systems Research Institute (ESRI®), OSCAR is an interactive map application which allows a user to select and display data at any location within the Bay. More than 50 themes are available. Simple menus instruct users to select desired themes, define the geographic extent, and display the results. The geographic boundaries can easily be shifted with zoom in and zoom out keys. This allows resources to follow the flow trajectory of a moving spill. Among the themes, OSCAR identifies a host of coastal habitat types and prioritizes these habitats based on clean-up response. All data themes include a description and/or a proper metadata record. Data contributions to this project were made by the Maryland Department of Natural Resources, the Chesapeake Bay Program, the National Oceanic and Atmospheric Administration, the Virginia Institute of Marine Science, and others. Due to the comprehensive nature of the data themes, the utility of OSCAR is unlimited. The site is available to the public, and access is through the Chesapeake Bay Program's Homepage at http://www.chesapeakebay.net. Users should look for this icon in the lower left corner of the page to enter the site. OSCAR was developed by the Comprehensive Coastal Inventory Program with funding through the Chesapeake Bay Program.

Watershed Map Gallery

(James and York River Watersheds)

Final preparations are being made to publish the online Watershed Map Gallery for the James and York River Watersheds. The gallery is a collection of map compositions which have been developed over the last several years to support resource management activities within these watersheds. These maps were originally components of the larger hardcopy versions of the York River Watershed, and James River Watershed Map Portfolios. Numerous requests for these products indicated a need for a wider distribution. Funding provided by the Environmental Protection Agency allowed the compositions to be converted to jpeg files and published to a VIMS hosted website. The website includes documentation and metadata, where available, about the development of each composition. The documentation is intended to provide users with source information and potential uses. At the site, a user can scroll through a list of maps available from several different primary categories. When a theme is selected, the map can be viewed at two different scales. A post script file can be downloaded to save the file locally. The Watershed Map Gallery will be accessed at http://www.vims.edu/ccrm/cci.html.

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mouth to head and specific sample sites were extrapolated from the flagged locations.

Salinity, dissolved oxygen, and temperature were measured each morning of the sampling period immediately after setting the block nets using a YSI 85 Temperature, Conductivity, Salinity, and Dissolved Oxygen meter.

Sediment was sampled in three habitat types within each marsh: high marsh, low marsh, and nonvegetated intertidal. Three sediment cores were randomly collected within each habitat type and divided into two fractions: 0-2 cm and 14-16 cm. Total organic matter and organic carbon were calculated for each habitat type and by depth. Organic matter was measured by loss on ignition at 450^{o}C and converted into organic carbon by multiplying by 0.45 (Craft et al. 1988).

Vegetation in each marsh was divided into community types: saltmarsh cordgrass (dominated by *Spartina alterniflora*), saltmeadow hay (dominated by *Spartina patens*), and saltbushes (dominated by *Iva frutescens* and *Baccharis halimifolia*). The saltmarsh cordgrass community was randomly sampled using a square meter quadrat. The saltmeadow hay community was randomly sampled using a 1/4 square meter quadrat. The saltbush community was randomly sampled using a 2-m radius plot. Percent cover and stem density data were collected for each sample within each community.

Benthic invertebrates were sampled using a 232.25-cm^2 benthic grab. Seven samples (with duplicates) were collected from each marsh in June. The samples were sieved through a 0.5-mm mesh, stained with rose bengal, and preserved in 10% formalin. Taxonomic

Continued on next page

Figure 1. Marsh site.

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identification to species level was determined where possible. The data were analyzed for community structure parameters such as species richness, diversity, and equitability using Shannon-Weaver analysis. Total sampled populations were tested for differences by nonparametric methods.

Fish and blue crabs from each wetland were sampled by simultaneously setting a Priest Modified Hoop Net (Havens et al. 1995). The nets were set at the slack at high tide and emptied on the hour until low tide. The two natural marshes drain close to dry at low tide while the constructed marsh maintains less than 0.5-m depth in some places at mean low tide. At low tide the constructed marsh was seined to collect remaining fish and shellfish. Fish and crabs were identified, counted, measured and released. Sciaenids and other food fish (those commercially exploited) were separated and returned to the lab for further analysis.

The three marshes were surveyed to determine bird use during three seasons (winter, spring, summer) and at two tide stages (low and high tide). Marshes were surveyed between 0.5 and 3.0 h after sunrise and between 2 h before and 2 h after predicted low or high tide. Each of the 18 surveys (3 marshes x 3 seasons x 2 tide stages) was replicated three times within the same tide series. Each survey consisted of walking the perimeter of the marsh and recording all birds seen or heard within the marsh. Each marsh took approximately 20 minutes to survey. All three marshes were surveyed on each sampling day. This sampling effort was similar to that used by Burger et al. (1982) and identical to the method used in the previous study (Havens et al. 1995).

Discussion

As of the summer of 1999, the constructed marsh was 12 years old. The previous study revealed that organic carbon levels at depth were significantly lower in the constructed marsh when compared to the natural marshes. This is due, in part, to the excavation of the upland to create the marsh site. During the excavation process the organic top layer of soil is usually removed in order to reach a depth that will allow a tidal connection. It has been assumed that as the marsh matures organic matter will accumulate. This process is important to the overall function of the marsh since organic matter supplies the base for higher trophic levels. Organic matter levels at the surface of the marshes are similar, however the constructed marsh still contains significantly less organic matter at depth. This is similar to other studies which found that the accumulation of soil nutrients to levels similar to those of natural reference marshes may require more time (Craft et al. 1999). While some parameters such as the formation of microtopography within the constructed marsh may be affected by the significant lack of organic matter in the soil, the abundance of fish, blue crabs and benthic infauna appears not to be affected. Amending the site with organic substrate at the time of construction could have helped speed the development of a sediment profile similar to the natural marshes.

The existence of mature saltbush habitat in the natural marshes, and its low abundance in the constructed marsh continues to explain the variation in bird use between the constructed and natural marshes. Of the 162 obser-

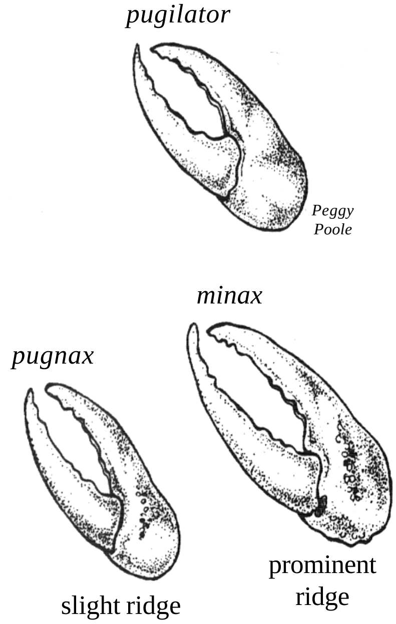
Table 1.
Differences observed between the constructed and natural marshes over time.

Parameters	**Differences observed 1992**	**1999**	
Organic carbon at depth	**Y**	**Y**	higher organic carbon in natural marshes
Salinity	**Y**	N	
Dissolved oxygen	**Y**	N	
Low marsh stem density	**Y**	N	
Saltbush stem density	**Y**	**Y**	higher stem densities in natural marshes
Saltbush percent cover	**Y**	**Y**	higher percent cover in natural marshes
Blue crab abundance	**Y**	N	
Blue crab size	**Y**	N	
Total fish abundance	**Y**	N	
Commercial fish abundance	**Y**	N	
Fish richness	**Y**	**Y**	higher richness value in constructed marsh
Fish diversity	**Y**	**Y**	higher diversity value in constructed marsh
Bird richness	**Y**	**Y**	higher richness value in natural marshes
Bird diversity	**Y**	**Y**	higher diversity value in natural marshes
Bird abundance	**Y**	**Y**	higher abundance in natural marshes

Hermit Crabs
continued from page 3

a moving, clicking, *muddy* hoard of fiddler crabs, it is very difficult to determine the minor subtleties in coloration needed for identification. Identification based on the coloration of the females is almost impossible. That leaves the population identification by means of the male pincer as the only viable option, provided you're able to catch one of the little denizens!

Once the male fiddler has attracted the attention of a female by his "pincer waving and clicking," they retire to his burrow to mate. The female extrudes her fertilized eggs - as many as a quarter million - onto her abdominal flap in one small spongy cluster. After several



months the eggs hatch and are released into the nearest tidal creek at high tide. After several moults the young fiddler crabs undergo metamorphosis and change into their final form, returning to the land for the rest of their lives.

Fiddler crabs are at the top of the menu for many other organisms. Wading birds like the great blue heron or the smaller green heron prize fiddler crabs. Many terrestrial animals like raccoons and foxes can make a meal from fiddler crabs. Even other crabs are fond of a fiddler crab meal. This, of course, is predicated on the fact that these predators can actually catch the elusive fiddler crab before he or she returns to the safety of their respective burrow.

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vations of bird activity in the west marsh, 60% were recorded in the saltbush habitat. In the east marsh, 37% of the observations of bird activity were in the saltbush habitat. In the constructed marsh, which has very little saltbush community, 24% of the observations were recorded in the saltbush or dead saltbush.

In the three marshes, all the neotropical migrant songbird activity was recorded in the saltbush community (dead saltbush community in the constructed marsh). Planting sections of the constructed marsh with mature saltbush species could have increased the attractiveness of the marsh to birds by providing nesting, perching and foraging sites for temperate and neotropical migrant species.

The constructed marsh has reached a general level of function similar to that of nearby natural marshes for the parameters measured (Table 1). Some morphological differences remain such as the differences in community type ratios. Significant differences in habitat function remain in three areas: sediment organic carbon at depth, mature saltbush density, and bird utilization (hypothesized to be related to saltbush density). Data from this study suggests that the addition of an organic soil amendment at the construction phase and the planting of a mature saltbush community would help increase the probability of a success in the construction of artificial marshes to replace the habitat functions of natural marshes.

The study was funded in part by the Virginia Coastal Resources Management Program (NOAA Grant # NA-87020253-01). The full report can be viewed on the VIMS Center for Coastal Resources publications website www.vims.edu/ccrm

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Calendar of Upcoming Events

December 14 - 15	**VIMS Winter Botany** For more information contact Bill Roberts at wlr@vims.edu.
January 8-11, 2001	**COASTAL GEOTOOLS, Coastal Resource Spacial Technology Tools Conference.** Charleston, S.C. Contact: Steve Meador or Mark Jensen, (843) 740-1200, GeoTools@noaa.gov
March 27-29, 2001	**National Hydric Soils Workshop**. Atlantic City, NJ. Sponsored by EPA. Abstracts due now. Contact Ralph Spagnolo at: spagnolo.ralph@epa.gov
July 15-19, 2001	**Coastal Zone 2001. Hands Across the Water-Linking Land, Lake and Sea.** Call for Papers. Abstracts due September 8, 2000. For more information, please call (843) 740-1279, or email Jan.Kucklick@noaa.gov

VIMS Shoreline Reports to be Updated and Go Online

Beginning sometime after the first of the new year, the Wetlands Advisory Program of the Center for Coastal Resources Management at VIMS will begin using an updated format for its Shoreline Permit Application Reports. These reports are presently utilized as environmental input to the decision-making process by local wetlands boards, VMRC, and DEQ, among others. VIMS will be taking advantage of new technology which will allow the incorporation of color photographs, site location maps and detailed vicinity maps to complement each specific permit application and the written environmental assessment for the proposed activity.

In addition, the Wetlands Program will begin putting the reports on the VIMS home page from which they will be downloaded by the regulatory agencies and will also be available to anyone interested in the VIMS assessment of a particular shoreline proposal. This operational procedure will make the VIMS report available sooner, will eliminate time lost in mailing and will allow full utilization of the color enhancements that are part of the new format.

The new report format will also present tidal wetland information on a watershed level, report cumulative tidal wetland impacts pertinent to the subject application over the previous five year period and will tie the wetlands data base to other existing GIS efforts in the Center.

The goal is to phase in the new report format and phase out the mailing of reports in January of 2001. Localities are being surveyed to make sure that all have the necessary access to, and ability to download the VIMS home page. Other steps will be in place to help insure a smooth transition to the strictly electronic distribution of the reports.

The Center's web page contains a myriad of other wetland and shoreline management information which may be useful to local officials and other users such as shoreline permit applicants, permit agents, contractors and waterfront property owners. Numerous technical reports, self-guided education units, newsletters and other features provide information on subjects dealing with all aspects of shoreline and wetlands management. The web page will be updated on a regular basis and will also contain information on wetland cumulative losses as derived from the Center's tidal wetland data base.