Toward Developing an Inventory of U.S. Coastal Wetlands

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Introduction

Despite a growing awareness of the importance of coastal wetlands, there is no data base to document their current distribution and abundance. Existing coastal wetlands inventories have been conducted for the most part at state and local levels, and they lack a unified system of classification and quantification. Recognizing this gap in wetlands information, the National Marine Fisheries Service (NMFS) and the Strategic Assessment Branch (SAB) (Ocean Assessments Division, Office of Oceanography and Marine Assessment, National Ocean Service) undertook a cooperative effort to compile existing coastal wetlands information by individual coastal county for the 22 coastal states in the contiguous United States, excluding the Great Lakes.

Development of this information is an integral part of NOAA's strategic assessments of the nation's coastal and oceanic regions (Ehler and Basta, 1984) and it's national program to determine the status and trends of coastal fisheries habitat (Lindall and Thayer, 1982; Thayer et al., 1985). The initial objectives were to: 1) Compile available coastal wetlands information by county and state, 2) evaluate their adequacy for strategic planning and assessment, and 3) provide an initial data base on wetlands for the assessment of available fisheries habitat. Plans for further use of the information and its improvement are also discussed.

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What Is a Wetland?

Wetlands are typically transitional areas between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by <6 feet of water (Cowardin et al., 1979; Frayer et al., 1983). Many different types of wetlands occur in a wide variety of settings. These include salt marshes along the ocean coastline, bottomland hardwood forests in the southern states, and prairie potholes in the midwest.

Because the reasons for defining wetlands are as diverse as the wetlands themselves, there is no single, indisputable definition for wetlands. To identify and delineate wetlands accurately for resource management, the U.S. Fish and Wildlife Service (FWS) developed a detailed classification system in 1979 that broadly defines wetlands as follows: ". . .wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes; 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season each year" (Cowardin et al., 1979).

The definition, and the classification system, are based on 5 years of field testing and review. Both are now widely accepted as national and international standards for wetlands management (Tiner, 1985). Even so, they do not suit the needs of all wetlands investigators. For example, a more restrictive definition has been developed by the U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) for regulatory purposes. In this case, wetlands are defined as: ". . .those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (Fed. Regist., 19 July 1977; 22 July 1982). As a result, EPA and the COE estimate their regulatory jurisdiction extends to over 64 million wetland acres in the contiguous United States (OTA, 1984). In contrast, the FWS reports the presence of 99 million acres of freshwater and estuarine wetlands for this same area based on the Cowardin system.

Differences in how wetlands are defined have caused considerable controversy and debate. This problem is compounded when compiling a comprehensive national data base because regional and state wetland inventories, representing much of the available data, have often used different definitions and inventory techniques to describe wetland boundaries.

Why Is This Data Base Needed?

Coastal wetlands are an important national resource. From Maine to Florida, across the Gulf of Mexico to Texas, and intermittently along the West Coast, a thin belt of wetlands provides critical habitat for fish, shellfish, and wildlife (Shaw and Fredine, 1956; McHugh, 1966; Turner, 1977; Flake, 1979; Lindall and Thayer, 1982; Sather and Smith, 1984). They filter and process agricultural and industrial waste (Kadlec and Kadlec, 1979; Tchobanoglous and Culp, 1980; Benner et al., 1982) and buffer coastal areas against storm and wave

damage (Knutson and Selig, 1982). They also are key factors in generating large revenues from a wide variety of recreational activities such as fishing and hunting (NMFS, 1981; FWS, 1982).

However, wetlands are rapidly disappearing in many areas. Urbanization, agriculture, hydrocarbon exploration, and other activities have contributed to the loss of more than 11 million acres of wetlands over the past 25 years (Frayer et al., 1983). Although most of these losses have occurred in inland areas, coastal wetlands have reportedly been depleted at an average rate of about 20,000 acres (31 square miles) per year during this period. Studies indicate, however, that the recent loss rate may be much higher. For example, in coastal Louisiana, Gagliano et al. (1981) estimated wetland losses of nearly 25,000 acres (40 square miles) per year. Furthermore, the U.S. Census Bureau predicts that by 1990, 75 percent of the U.S. population will live within 50 miles of the coastline (including the Great Lakes), indicating even greater competition in coastal areas for limited space and resources in the near future (CEQ, 1984). Despite these facts, no comprehensive information base on the nation's coastal wetlands is available. Therefore, we are really not in a position to judge accurately the current acreage, characteristics, and rate of loss (or gain) of the nation's coastal wetlands resource base.

Data Sources

Information on the extent of coastal wetlands has been developed by a variety of sources including Federal and state governmental agencies, and public and private research organizations.

Federal Data

The National Wetlands Inventory program (NWI) of the FWS and the Land Use and Land Cover program (LU/LC) of the U.S. Geological Survey (USGS) are Federal programs that compile wetlands data at the national level. NWI data, classified according to Cowardin et al. (1979), are used as a source of wetland information for four states (Table 1). LU/LC data were not used because of problems noted below.

The NWI program was established by the FWS in 1974 to generate scientific information on the characteristics and extent of the nation's wetlands and to provide data for making quick and accurate resource decisions (Tiner, 1984). This information was to be developed in two stages: 1) The creation of detailed wetland maps and 2) research on historical status and trends. The maps, developed using aerial photography, generally are based on 1:24,000 scale USGS quadrangles and illustrate wetland habitats based on the Cowardin et al. (1979) wetland classification system. Most of the imagery used to develop these wetland maps was taken in the middle to late 1970's. However, in some areas where more recent photography was not available, imagery as old as 1972 had to be used. While maps have been completed for most coastal areas, only a fraction have been digitized. Therefore, very little actual wetlands acreage data are presently available. Since the quantification of mapped data necessary to successfully capture detailed wetland information is expensive and time consuming, a complete data base of NWI coastal maps is not anticipated in the near future.

A 1983 FWS report on national wetlands status and trends (Frayer et al., 1983) represents the only recent attempt to survey the U.S. coastal and noncoastal wetlands. However, Frayer et al. (1983) suggest that, because data for the report were compiled by random sampling rather than a comprehensive inventory, they are meaningful only at a national or regional level and are generally unreliable for smaller areas such as states, counties, or estuaries.

The LU/LC program at USGS compiles land-use data, including wetlands, based on aerial photography. Although it represents a complete national data base describing nine categories and 37 subcategories of land use and land cover aggregated by state, county, or even hydrologic unit, the wetlands component lacks the detail and accuracy required for strategic assessments. For example, the data base divides wetlands into only two categories, forested and nonforested, with no designation for salt marsh, fresh marsh, or tidal flats. There is also some question about the ability of the LU/LC program to distinguish accurately between forested uplands and forested wetlands. But, although LU/LC data are not the best available for this project, they remain a powerful tool for many other land-use planning and characterization applications.

State Data

Twenty-one of the 22 coastal states in the contiguous United States that were contacted and surveyed had completed some type of wetland inventory; New Hampshire used soil survey data to estimate the acreage of salt marsh. These inventories had generally been conducted by state natural resource agencies and often included estimates of inland, as well as coastal, wetlands. The level of detail, the date the inventories were conducted, and methodology all showed considerable variation among states. The information presented in this report relies heavily on these state level wetland inventories. Table 1 summarizes the salient characteristics of these state inventories.

Compiling Existing State Data

Federal, state, and local agencies, and educational research organizations were contacted by a three-member project team to locate and evaluate available coastal wetlands data for each of the 22 coastal states (Fig. 1). The project team reviewed the acreage estimates, maps, and descriptive materials for appropriate information and, when necessary, made follow-up inquiries by telephone. The review focused in particular on when, how, and why each inventory was conducted. According to vegetative associations described in various inventory materials, the team consolidated wetland acreage data under the general categories of: 1) Salt marsh, 2) fresh marsh, 3) tidal flats, and 4) swamp. For instance, any wetlands identified as including *Spartina* sp. marshes were classified as salt marsh since they represent typical salt-tolerant coastal wetland vegetation. The data were then summarized by county, state, and region. Four wetland categories do not provide a sufficient level of detail for

Table 1.—Time period, methods of determining acreage, wetlands classification system, and references for the reports covering the 22 coastal states.

State	Time period	Methodology[1]								References
		Aerial photos	Ground survey	Wetland maps	Planimetry	Dot/grid	Digital	Cowardin	Other system	
Maine	1975-76	●	●		●				●	McCall, 1972; Maine Dep. Inland Fisheries, Augusta, ME (Unpubl. data); Maine State Planning, Augusta, ME (Unpubl. data).
New Hampshire	1970-74		●						●	Breeding et al. (1974); U.S. Soil Conservation Service, Durham, NH.
Massachusetts	1971-72 1977	●	●	●	●	●	●	●	●	Hankin et al. (1985); MacConnel (1975).
Connecticut	1968	●		●	●				●	Conn. Coastal Area Management Program, Hartford, CT (Unpubl. data).
Rhode Island	1970	●	●	●			●	●		FWS (1984c).
New York	1974	●	?	●	●				●	NYDEC (1974); N.Y. Dep. Environ. Conserv., Stony Brook, NY (Unpubl. data).
Pennsylvania	1970, 1972	●	●	●	?				●	Walton and Patrick (1973).
New Jersey	1976-77	●	●	●			●	●		Tiner (1985).
Delaware	1981-82	●	●	●			●	●		FWS (1984a).
Maryland	1976-77	●	●	●			●	●		McCormick and Somes (1982).
Virginia	Varied 1973-81	●			●				●	Series of tidal marsh inventories prepared by VIMS (i.e., Barnard, Doumlele, Harris, Moore, Priest, Silberhorn citations).
North Carolina	1954	●	●	●					+	Wilson (1962).
South Carolina	1971-77	●	●	●	●			●		Tiner (1977).
Georgia	1975-76	●	●			●			+	U.S. Soil Conservation Service, Athens, GA (Unpubl. data).
Florida	1972-76	●	●		●				●	Florida Dep. Environmental Regulation (1978).
Alabama	1979 & 1979-80	●	●	●	●				●	Stout and Long (1981); Stout et al. (1982).
Louisiana	1976-78 1969-75	● ●	● ●	● ●	●	 ●		●	 ●	Wicker (1980). Gosselink et al. (1979).
Texas	1950-54	●	●			●			●	Brown (1972-80); Keer et al. (1977).
California	Various dates, 1960's-1980's	?							●	Dennis and Marcus (1984).
Oregon	1972-73	?								Atkins (1973); Oregon Dep. Land Conservation and Development, Salem OR; Oregon Dep. of Fish and Wildlife, Salem, OR.
Washington	Various dates, 1975-82	?						●		Boule et al. (1983).

[1]Symbols: ? Methodology uncertain.
●Methodology as indicated.
+Wetland classification system based on FWS Circular 39 (Shaw and Fredine, 1956).

national and regional analysis of the most important coastal wetland habitats. However, with the variable wetland classification procedures used in the state inventories, a more refined breakdown of wetland types was not possible. Data on submergent wetlands (seagrasses) have been omitted. Submergent wetlands are major resources for fishery organisms as well as birds (Thayer et al., 1984) and should be included in any coastal wetlands data base. Unfortunately, most inventories used in this paper did not cover submergent wetlands.

Twenty-three different sources of coastal wetland data were consulted to compile acreage estimates for the 22 coastal states. Nineteen were independent inventories, compiled by individual states or state-affiliated research organizations. Data were compiled for 242 counties (Fig. 1). For some counties data were unavailable, while for others wetland areas were too few to consider.

Assessing the Estimates

The data compiled indicate the presence of over 11 million acres of wetlands along the Atlantic, Gulf of Mexico, and Pacific coastlines of the coterminous United States. This includes 4.4 million acres of salt marsh, 1.5 million acres of fresh marsh, 211,000 acres of tidal flats, and 5 million acres of swamp. The Gulf of Mexico has the most wetlands (5,184,000 acres) followed by the south-

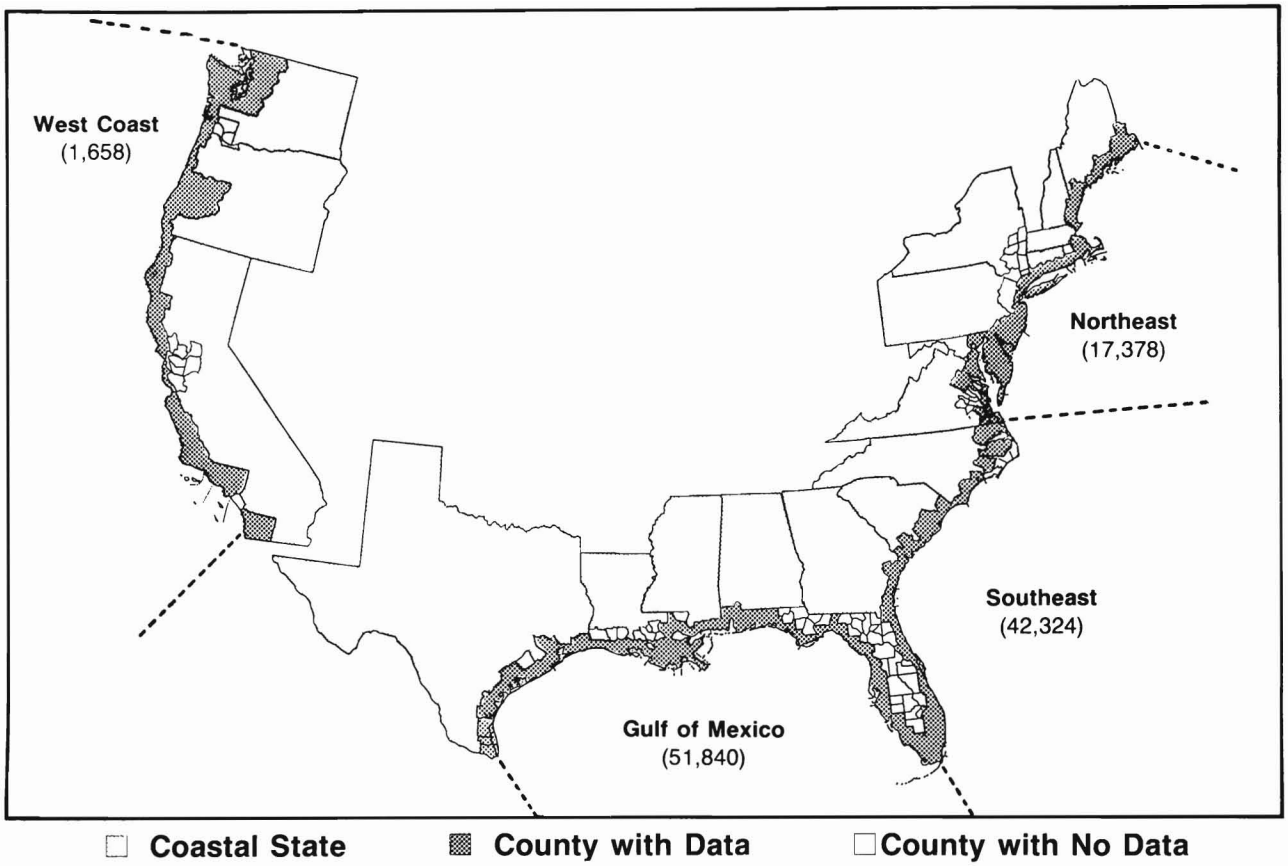

Figure 1.—U.S. coastal regions and wetlands totals (acres × 100).

east (4,232,400 acres), the northeast (1,737,800 acres), and the west coast (165,800 acres) (Fig. 1). Salt marsh and fresh marsh occurred most frequently in the Gulf of Mexico (2,648,900 acres and 859,600 acres, respectively). Swamp areas were most abundant in the southeast (2,652,500 acres), while tidal flats occurred most often in the northeast (161,500 acres).

Table 2 summarizes these estimates by state. More than 60 percent of the wetlands inventoried are concentrated in North Carolina, Florida, and Louisiana while the entire west coast (California, Oregon, and Washington combined) has less than 2 percent. About 40 percent of the coastal wetlands measured have been designated as salt marsh, 14 percent as fresh marsh, 2 percent as tidal flats, and 45 percent as swamp. Lacustrine wetlands, or wetlands associated with lakes and ponds, were excluded where possible, because they are typically inland and not influenced by coastal processes. While this is also true for some swamp areas, noncoastal swamps could not be discriminated from coastal swamps. Salt marsh inventoried for this project totaled 4,446,000 acres compared to the FWS estimate of 3,900,000 acres (Frayer et al., 1983). Other comparisons with FWS data cannot be made since most FWS estimates at the national or regional level include coastal and noncoastal wetlands.

Most of the data originally were developed using aerial photography combined with some ground-truth surveys. Typically, once wetlands were located on maps or photographs, their extent was quantified using either planimetric, dot/grid sampling, or digital techniques (Table 1). For more detailed information on how the wetland types were aggregated see Alexander et al. (1986).

Despite generally good geographic coverage of the data presented, it is impossible to consolidate them into a national data base. Considerable variation exists in wetland definitions and classification schemes. While some states adopted the FWS system (Cowardin et al., 1979), others, in response to their own local or regional needs, developed independent classification systems based on slightly different criteria and boundary conditions. In some cases wetlands were classified into many distinct types, while in others wetland types have been consolidated into broad categories that cannot be disaggregated. Many state inventories were completed prior to 1979 and before the availability of a widely accepted national standard.

In addition, the time period when the

Table 2.—Coastal wetlands data by state.

Region and State	Wetlands acres (X 100) Salt marsh	Fresh marsh	Tidal flats	Swamp	Total	Percent of total
Northeast						
Maine	166	257	583	250	1,256	(1.1)
New Hampshire	75	N/A	N/A	N/A	75	(0.1)
Massachusetts	481	151	415	249	1,296	(1.1)
Rhode Island	79	0	0	571	650	(0.6)
Connecticut	166	N/A	N/A	N/A	166	(0.1)
New York	267	34	N/A	N/A	301	(0.3)
Pennsylvania	0	8	0	0	8	(<0.1)
New Jersey	2,174	217	486	4,723	7,600	(6.7)
Delaware	781	71	113	1,234	2,199	(1.9)
Maryland	1,636	256	18	194	2,104	(1.9)
Virginia	1,523	200	N/A	N/A	1,723	(1.5)
Subtotal	7,348	1,194	1,615	7,221	17,378	(15.3)
Southeast						
North Carolina	1,588	920	N/A	21,075	23,583	(20.8)
South Carolina	3,695	645	N/A	N/A	4,340	(3.8)
Georgia	3,743	315	95	2,860	7,013	(6.2)
Florida (Atlantic)	959	3,834	N/A	2,590	7,383	(6.5)
Subtotal	9,985	5,714	95	26,525	42,319	(37.3)
Gulf of Mexico						
Florida (Gulf)	4,313	755	N/A	9,707	14,775	(13.1)
Alabama	146	106	N/A	1,513	1,765	(1.6)
Mississippi	640	40	N/A	760	1,440	(1.3)
Louisiana	17,486	6,888	N/A	4,372	28,746	(25.4)
Texas	3,904	787	N/A	403	5,094	(4.5)
Subtotal	26,489	8,596	0	16,755	51,820	(45.9)
West						
California	216	44	134	34	428	(0.4)
Oregon	188	63	252	N/A	503	(0.4)
Washington	237	176	22	292	727	(0.6)
Subtotal	641	283	408	326	1,658	(1.4)
Grand total	44,463	15,787	2,118	50,820	113,175	(100.0)
(% of Total)	(39)	(14)	(2)	(45)	(100)	

Table 3.—Comparison of grid sampled and digital data for 16 1:24,000 NWI maps in coastal Louisiana and Texas.

Habitat	Acres Digital	Grid	Percent difference
Upland	109,227	108,495	−0.7
Open water	434,896	433,823	−0.2
Salt marsh	97,642	97,611	<0.1
Fresh marsh	17,584	17,885	+1.7
Tidal flat	8,013	7,861	−1.9
Swamp	1,225	1,016	−13.4
Total	668,587	664,420	−0.6

data were collected for each inventory varied. For example, the last statewide inventory of coastal wetland acreage in North Carolina was 1954, while for Delaware data are based on an inventory conducted in 1980-81. Since coastal wetlands have been subjected over the years to both environmental and developmental pressures, data collected at widely disparate times are often difficult to interpret. Some state inventories are based on detailed and comprehensive inventories, using state-of-the-art technology, while others have relied on incomplete data compiled from scattered projects in various locations.

Consequently, the state, regional, and national data summaries for wetland acreage and distribution compiled for this report, while not necessarily precise, represent order-of-magnitude estimates that can be useful as general indicators of coastal wetlands abundance. Much work remains to be done to develop a comprehensive nationwide assessment capability. Variability in the data quality and consistency of data between states, and lack of a unifying theme or purpose among states, makes the production of an accurate national picture of coastal wetland status and trends difficult.

Ongoing Efforts

Since the existing data proved unsatisfactory for compiling a national data base, a search was undertaken for a cost effective method to quantify the current extent of coastal wetlands. Initial results indicated that using a grid sampling technique on NWI maps offered a reasonable alternative. To test this procedure, a grid sampling technique was used to quantify habitat types for 16 previously digitized 1:24,000 scale NWI maps. For the purposes of these preliminary tests, the numerous habitat types designated on the NWI maps were aggregated into six general categories: 1) Salt marsh, 2) fresh marsh, 3) tidal flats, 4) swamp, 5) open water, and 6) uplands. After some testing, a 45-acre grid cell size with about 900 sampling points per map was determined to be both efficient and accurate for estimating these six habitat types at this scale. Each map was sampled separately by mounting the grid over the map and systematically recording the habitat type at each sampling point. The information was recorded on data sheets and entered into a computer mapping and statistics program. Based on the results (Table 3), it appeared that grid sampling could provide a time and cost effective technique for compiling a reasonably accurate coastal wetlands data base.

Before establishing a full scale grid sampling effort, SAB and NMFS organized a workshop bringing together individuals with experience in wetlands mapping and management to discuss NOAA's efforts to compile a national coastal wetlands data base. Sixteen professionals from six Federal organizations participated. Specific objectives of the workshop were to review current information on the distribution and extent of coastal wetlands and to solicit comments and recommendations from the workshop participants on NOAA's proposed grid sampling project. In, general, workshop participants supported NOAA's proposal to grid sample NWI maps (Strategic Assessment Branch, 1986). Workshop participants recommended, however, that the number of habitat categories sampled

be expanded from six to the fifteen listed below:

1) High salt marsh
2) Low salt marsh
3) Brackish marsh
4) Nonfresh marsh (unspecified)
5) Tidal fresh marsh
6) Nontidal fresh marsh
7) Fresh marsh (unspecified)
8) Tidal flats
9) Estuarine forested-scrub/shrub
10) Tidal fresh forested-scrub/shrub
11) Nontidal fresh forested-scrub/shrub
12) Fresh forested-scrub/shrub (unspecified)
13) Upland
14) Open water-fresh
15) Open water-nonfresh

These categories were incorporated into the operational phase of the project and grid sampling was begun in June 1986. The program is expected to be completed in 1988.

Both NMFS and NOS have identified the status and trends of coastal wetlands as a priority research problem. Reliable baseline data on the current extent of coastal wetlands are needed not only to accurately monitor trends, but to implement appropriate management strategies and assess their impact. Without such data, a coordinated effort to manage coastal wetlands and their associated resources will be difficult to achieve. Data generated by the efforts outlined in this paper should be an important step to a better understanding of our coastal wetland resources.

Literature Cited

Alexander, C. E., M. A. Broutman, and D. W. Field. 1986. An Inventory of coastal wetlands of the USA. Strategic Assessment Branch, NOAA, 25 p. (mimeogr. rep.).

Atkins, F. 1973. Coastal wetlands of Oregon. Oreg. Coast. Conserv. Develop. Commiss., Oreg. Dep. Fish Wildl., Salem.

Barnard, T. A., Jr. 1975. City of Hampton tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 60.

_____ and D. G. Doumlele. 1979. City of Virginia Beach marsh inventory. Vol. 2, Lynhaven River, Lake Rudeek and their tributaries. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 217.

Benner, C. S., P. L. Knutson, R. A. Brochu, and A. K. Hurme. 1982. Vegetative erosion control in an obligohaline environment, Currituck Sound, North Carolina. *In* Third Annual Meeting of the Society of Wetland Scientists, Wrightsville Beach.

Boule, M. E., N. Olmsted, and T. Miller. 1983. Inventory of wetland resources and evaluation of wetland management in western Washington. Wash. State Dep. Ecol., Olympia.

Breeding, C. H. J., F. D. Richardson, and S. A. L. Pilgrim. 1974. Soil survey of New Hampshire tidal marshes (with maps). N.H. Agric. Exper. Sta., Univ. N.H., Durham.

Brown, L. F. 1972-80. Environmental geologic atlas of the Texas coastal zone. Bur. Econ. Geol. Univ. Tex., Austin.

CEQ. 1984. 15th Annual Report of the Council on Environmental Quality. President's Counc. Environ. Qual., Washington, D.C.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. Wash., D.C., Rep. FWS/OBS-79/31.

Dennis, N. B., and M. L. Marcus. 1984. Status and trends of California wetlands. Environ. Sci. Assoc. Inc., San Francisco.

Doumlele, D. G. 1976a. City of Virginia Beach marsh inventory. Vol. I, North Landing River and tributaries. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 118.

_____. 1976b. Fairfax County tidal marsh inventory (including City of Alexandria and Arlington County). *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 108.

_____. 1979a. Essex County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 207.

_____. 1979b. New Kent County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 208.

Ehler, C. N., and D. J. Basta. 1984. Strategic assessment of multiple resource-use conflicts in the U.S. Exclusive Economic Zone. *In* Exclusive Economic Zone Papers. Reprint from Proceedings of Oceans '84. Washington, D.C.

FWS. 1982. National survey of fishing, hunting, and wildlife-associated recreation. U.S. Dep. Int., Fish Wildl. Serv., Wash., D.C.

Flake, L. D. 1979. Wetland diversity and waterfowl. *In* P. E. Greeson, J. R. Clark, and J. E. Clark (editors),Wetland functions and values: The state of our understanding. Am. Water Resour. Assoc., Minneapolis.

Florida Department of Environmental Regulation. 1978. Statistical inventory of key biophysical elements in Florida's coastal zone. Div. Environ. Programs, Bur. Coastal Zone Planning, Tallahassee.

Frayer, W. E., T. J. Monahan, D. C. Bowden, and F. A. Graybill. 1983. Status and trends of wetlands and deepwater habitats in the coterminuous United States, 1950s to 1970s. Colo. State Univ., Dep. For. Wood Sci., Ft. Collins.

Gagliano, S. M., K. J. Meyer-Arendt, and K. M. Wicker. 1981. Land loss in the Mississippi River Deltaic Plain. Trans. Gulf Coastal Assoc. Geol. Soc. 31:295-299.

Gosselink, J. G., C. L. Cordes, and J. W. Parsons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystem of Louisiana and Texas. 3 vols. U.S. Fish Wildl. Serv. Off. Biol. Serv., Rep. FWS/OBS-78/9-78/11.

Hankin, A. L., L. Constantine, and S. Bliven. 1985. Barrier beaches, salt marshes, and tidal flats: An inventory of the coastal resources of the Commonwealth of Massachusetts. Massachusetts Coastal Zone Management Program, Boston.

Harris, A. F. Jr., and J. C. Mizell. 1979. Spotsylvania and Caroline County tidal marsh inventory (including the city of Fredericksburg). *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 167.

Kadlec, R. H., and J. A. Kadlec. 1979. Wetlands and water quality. *In* P. E. Greeson, J. R. Clark, and J. E. Clark (editors), Wetland functions and values: The state of our understanding. Am. Resour. Assoc., Minneapolis.

Keer, R. S., L. E. Garner, and L. F. Brown Jr. 1977. Land resources of Texas. Bur. Econ. Geol., Univ. Tex., Austin.

Knutson, P. L., and W. N. Selig. 1982. Wave damping in Spartina alterniflora marshes. *In* Third Annual Meeting of Wetland Scientists, Wrightsville Beach.

Lindall, W. N. Jr., and G. W. Thayer. 1982. Quantification of National Marine Fisheries Service habitat conservation efforts in the southeast region of the United States. Mar. Fish. Rev. 44:18-22.

MacConnell, W. P. 1975. Remote sensing 20 years of change in Massachusetts 1951/52-1971/72. Mass. Agric. Exper. Sta. Univ. Mass. Amherst.

McCall, C. A. 1972. Manual for Maine wetlands inventory. Maine Dep. Inland Fish. Game, Game Div. Augusta.

McCormick, J., and H. A. Somes, Jr. 1982. The coastal wetlands of Maryland. Md. Dep. Nat. Resour., Annapolis.

McHugh, J. L. 1966. Management of estuarine fisheries. *In* American Fisheries Society Symposium on estuarine fisheries. Am. Fish. Soc., Bethesda, Md.

Moore, K. A. 1975a. Prince William County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 78.

_____. 1975b. Stafford County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 62.

_____. 1976. Gloucester County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 64.

_____. 1977a. City of Newport News and Fort Eustis tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 137.

_____. 1977b. Northampton County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 139.

_____. 1980. James City County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 118.

_____. 1981a. King George County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 68.

_____. 1981b. Surrey County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 187.

NMFS. 1981. Fisheries of the United States, 1980. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Curr. Fish. Stat. 8100.

NYDEC. 1974. New York tidal wetlands inventory (with maps and acreage data). N.Y. Dep.

Environ. Conserv., Albany.
OTA. 1984. Wetlands: Their use and regulation. Off. Technol. Assessment, U.S. Congress. Rep. OTA-0-206, Wash., D.C.
Priest, W. I. III. 1981. Middlesex County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 218.
Sather, J. H., and R. D. Smith. 1984. An overview of major wetland values and functions. U.S. Fish Wildl. Serv., Washington, D.C. Rep. FWS/OBS-84/18.
Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States: Their extent and their value to waterfowl and other wildlife. U.S. Dep. Int., Fish Wildl. Serv. Circ. 39.
Silberhorn, G. M. 1973. Lancaster County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 45.
_____. 1975. Northumberland County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 58.
_____. 1977. Accomack County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 138.
_____. 1981a. Mathews County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 47.
_____. 1981b. York County and town of Poquoson tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 53.
_____ and A. E. Harris. 1981. Isle of Wight County tidal marsh inventory. *In* Applied marine science and ocean engineering. Va. Inst. Mar. Sci., Spec. Rep. 213.
Stout, J. P., and M. J. Long. 1981. Wetland habitats of the Alabama coastal area. Part 2, An inventory of wetland habitats south of the Battleship Parkway. Ala. Coast. Area Board, Tech. Pub. CAB-81-01.
Stout, J. P., M. J. Long, H. M. Dowling, and M. T. Powers. 1982. Wetland habitats of the Alabama coastal zone. Part 3, An inventory of wetland habitats of the Mobile-Tenesaw River Delta. Ala. Coast. Area Board, Tech. Rep. 81-49A.
Strategic Assessment Branch. 1986. Summary of proceedings: NOAA coastal wetland workshop. National Oceanic and Atmospheric Administration, Rockville, MD, 11 p. (mimeogr. rep.).
Tchobanoglous, G., and G. L. Culp. 1980. Wetland systems of wastewater treatment: An engineering assessment. Univ. Calif., Davis.
Thayer, G. W., W. J. Kenworthy, and M. S. Fonseca. 1984. The ecology of seagrass meadows of the Atlantic coast: A community profile. U.S. Fish Wildl. Serv. Rep. FWS/OBS-84/02, 147 p.
_____, M. S. Fonseca, and W. J. Kenworthy. 1985. Wetland mitigation and restoration in the southeast United States and two examples from sea grass utilization. Proc. Estuar. Manage. Symp.
Tiner, R. W. Jr. 1977. An inventory of South Carolina's coastal marshes. S.C. Wildl. Mar. Resour. Dep., Off. Conserv. Manag., Tech. Rep. 23, Charleston.
_____. 1984. Wetlands of the United States: Current status and recent trends. U.S. Dep. Int., U.S. Fish Wildl. Serv., Newton Corners.
_____. 1985. Wetlands of New Jersey. U.S. Fish Wildl. Serv., Natl. Wetlands Inventory, Newton Corner.
Turner, R. E. 1977. Intertidal vegetation and commercial yield of penaeid shrimp. Trans. Am. Fish. Soc. 106:411-416.
FWS. 1976. Existing state and local wetlands surveys (1965-1975). Off. Biol. Serv. U.S. Fish Wildl. Serv., Washington, D.C.
_____. 1984a. National wetlands inventory acreage summaries for Delaware. U.S. Fish Wildl. Serv., Newton Corner. Photocopy.
_____. 1984b. National wetlands inventory acreage summaries for New Jersey. U.S. Fish Wildl. Serv., Newton Corner. Photocopy.
_____. 1984c. National wetlands inventory acreage summaries for Rhode Island. U.S. Fish Wildl. Serv., Newton Corner. Photocopy.
Walton, T. E., Ill, and R. Patrick. 1973. The Delaware estuary system, environmental impact and socioeconomic effects (with maps). Delaware River estuarine marsh survey. Acad. Nat. Sci., Phila.
Wicker, K. M. 1980. Mississippi Deltaic Plain region ecological characterization: A habitat mapping study - A user's guide to the habitat maps. U.S. Fish Wildl. Serv., Off. Biol. Serv., Rep. FWS/OBS-79/07.
Wilson, K. A. 1962. North Carolina wetlands: Their distribution and management. N.C. Wildl. Resour. Dep., Raleigh.