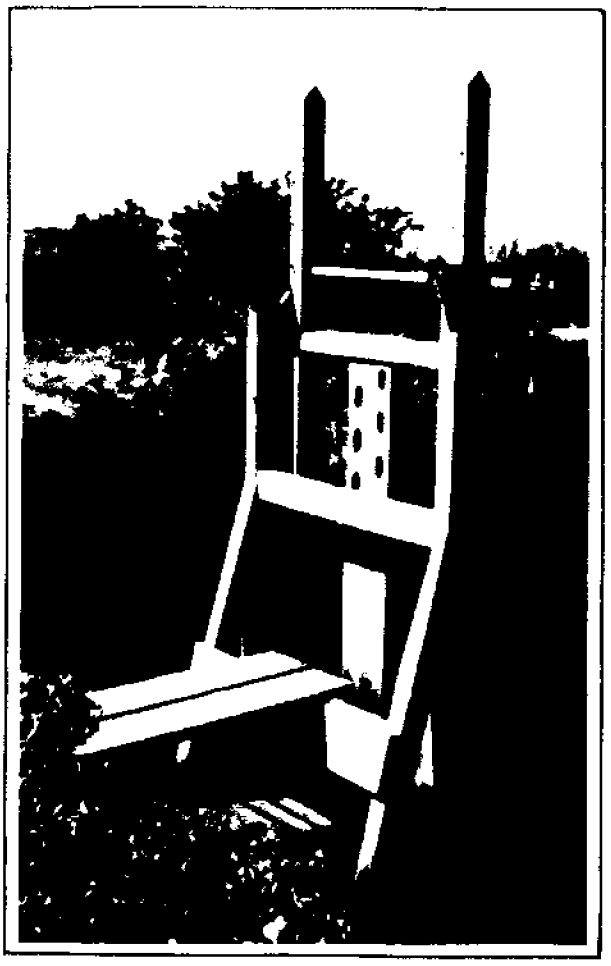
South Carolina
Sea Grant Consortium

SOUTH CAROLINA COASTAL WETLAND IMPOUNDMENTS:

Ecological Characterization, Management, Status, and Use

Volume I: Executive Summary



Edited by
M. Richard DeVoe
Douglas S. Baughman

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COASTAL WETLAND IMPOUNDMENTS: ECOLOGICAL CHARACTERIZATION, MANAGEMENT, STATUS AND USE

VOLUME 1: EXECUTIVE SUMMARY

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1 August 1987

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PREFACE

Coastal wetland impoundments, remnants of a once-flourishing rice culture industry, are the focus of a wetlands management controversy in the State of South Carolina. At one time, impoundments comprised approximately 29% of the State's 504,000 acres of tidal wetlands. Approximately 15% of these wetlands are currently impounded and are managed primarily for waterfowl habitat. Recent interest in reimpounding formerly impounded wetlands for additional waterfowl habitat and aquaculture has raised a number of ecological, policy and management questions. The controversy has focused on the question of how the state should regulate and monitor activities proposed for wetland areas which had been or are now impounded.

The Coastal Wetland Impoundment Project (CWIP) was designed to generate the first comprehensive characterization of a coastal impoundment system in South Carolina. The purpose of this investigation was to develop an information base which could be used by policy-makers and regulatory agencies to address the complex questions surrounding this valuable state resource.

The CWIP, a multi-institutional effort, was conducted at the Tom Yawkey Wildlife Center, near Georgetown, S.C., from summer 1982 to spring 1985. Each element of this four-year effort was reviewed by a peer group of scientists in each area to maintain scientific quality. The results of the CWIP are presented in three volumes: Volume I - Executive Summary; Volume II - Technical Synthesis; and Volume III - Technical Appendix. Volume I provides a concise statement of the research findings, along with a summary of research, management, and policy recommendations. Volume II contains the detailed results of the CWIP and has been organized into nine sections. Volume III provides supplemental technical data and information which support the results presented in Volume II. As a whole, the three-volume synthesis represents the efforts of a variety of individuals involved in the CWIP during the last four years.

Due to the number of perspectives represented in the CWIP synthesis, the terms "coastal wetland impoundments," "impounded wetlands," "impoundments," "former rice fields," "diked wetlands," and "managed wetlands" have been used interchangeably.

ACKNOWLEDGEMENTS

In a large research project such as the CWIP the list of individuals that deserve acknowledgement can be very long. During the four years of this study, the assistance of many persons was critical to the success and completion of this project; we would like to thank each person for his/her assistance. Additionally, each chapter in Volume II acknowledges the individuals associated with the research task. The acknowledgements cited here are those of the editors and the South Carolina Sea Grant Consortium.

We would like to thank the Trustees of the Yawkey Foundation and the South Carolina Wildlife and Marine Resources Department for allowing the research to be conducted on the Cat Island impoundments. Special thanks are extended to Mr. B. L. Joyner, Resident Biologist and Project Leader, Tom Yawkey Wildlife Center, for his cooperation throughout the four years of the study.

We are indebted to S. Olsen, J. Kraeuter, L. Barclay, W. Kitchens, R. E. Turner and R. Hodson for critical review and comment on the scope and direction of the project. Additionally, a number of scientists assisted in reviewing the individual chapters in Volume II. Their efforts are greatly appreciated. Phil Wilkinson, G. Reeves and K. Williams are acknowledged for providing technical assistance on impoundment management.

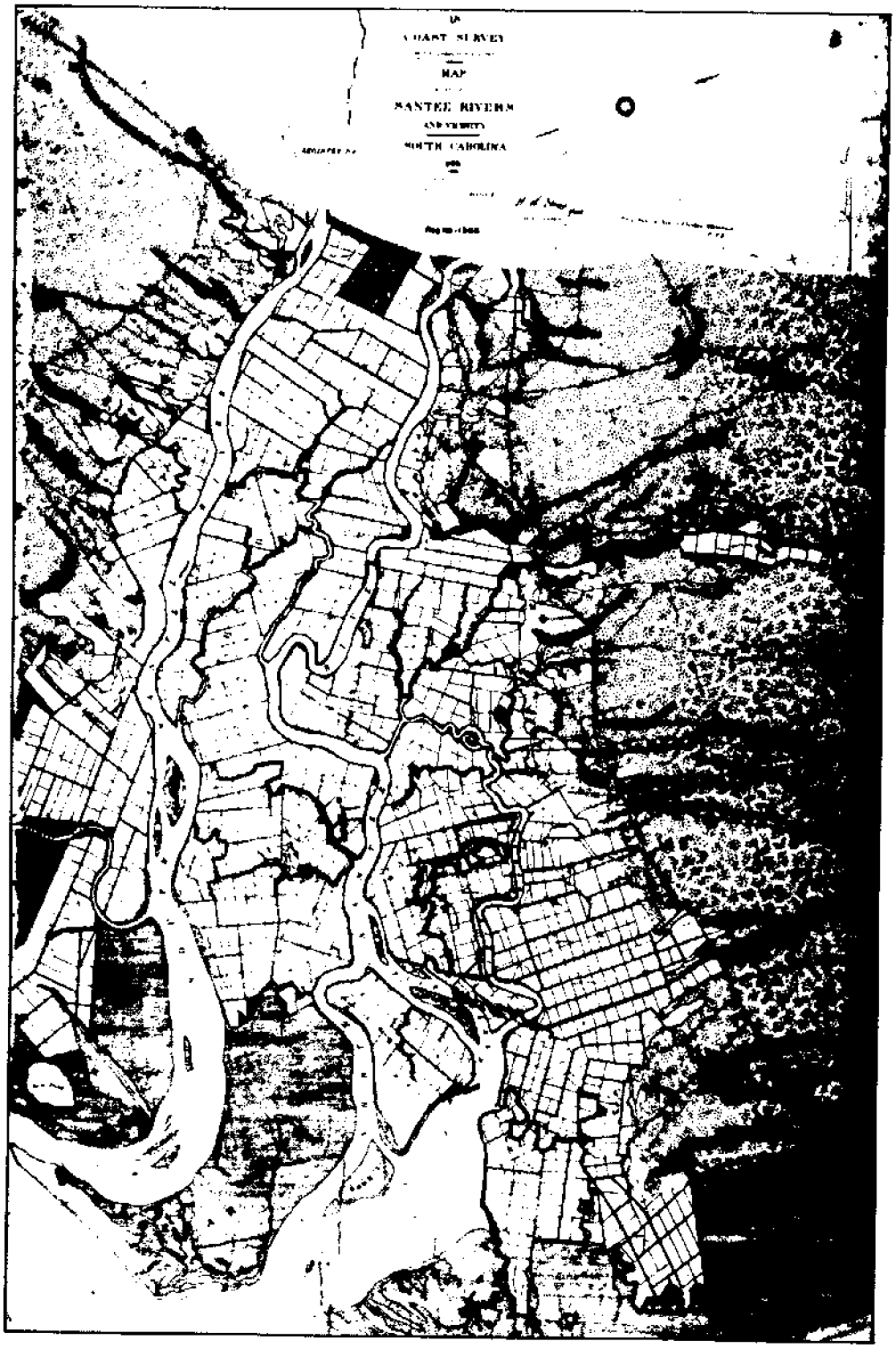
Special thanks are due to Carole Olmi for her assistance in the synthesis and preparation of Volume I and II. Andrew Mount also assisted in the preparation of the three-volume document, while Anne Hill and Frances Rogers provided writing, editorial and production assistance. Their efforts are gratefully acknowledged.

We are especially appreciative of the efforts of Annette Wilson and Monica Mulvey, who spent many hours and exhibited extreme patience in typing and word processing the document.

This project was funded by the National Sea Grant College Program and the South Carolina Sea Grant Consortium. We would like to thank Ms. Margaret A. Davidson, Consortium Executive Director, and Dr. David Duane, Sea Grant College Program Monitor, for their support and encouragement throughout the four years of the study.

SECTION I

INTRODUCTION AND BACKGROUND



1873 Coastal Survey map of the Santee Rivers and vicinity showing the extent of impoundments in the Santee delta.

Rice was cultivated in systems called impoundments along the Atlantic coast from the Cape Fear River in North Carolina to the Ogeechee River in Georgia; but activity and productivity were greatest in South Carolina, particularly in Georgetown County.

Many impoundments were constructed by clearing trees from freshwater swamps and by diking off wetlands intersected by tidal creeks. In some many instances, entire marsh-creek complexes were completely enclosed by dikes. The most common practice was to close off the open end of a marsh slough bounded by highlands. Water levels and salinity (in some cases) in impoundments were controlled with water control structures called trunks.

The demise of the rice culture industry in the early 1900s did not put an end to impoundment use. Many old rice fields became winter feeding and resting habitats for migratory waterfowl. These fields were used either as private hunting grounds or wildlife preserves and, as a result, provided habitat for many species of waterbirds and wildlife.

In other cases, rice field impoundments were considered vast wastelands unsuitable for cultivation and subsequently were abandoned and fell into disrepair.

Problem Identification

There is growing interest today in managing impoundments for waterfowl hunting, for conservation, for aquaculture, and as wildlife preserves. However, until recently, very little has been known about the status of impoundments and their effects on natural wetland processes. How much of the state's wetland acreage qualifies as impounded land? Which fields require reimpoundment and which need only minor repairs? Would restoring them to functional use jeopardize marine life and estuarine functions?

Without the proper scientific data, regulatory authorities have been hard pressed to determine which acreage, and under what circumstances, should be maintained or reclaimed as working impoundments. Nowhere is this controversy more evident than in the permitting process. Between 1967 and 1981, roughly 20 permit applications for repair and reconstruction of over 3,000 formerly impounded acres were filed in S.C. In each case, these applications were either denied or withdrawn. Yet since 1981, another dozen or so applications for reimpoundment or repair activities have been submitted to the state for consideration.

The absence of state and federal impoundment policies has also hindered informed decision-making. Most S.C. impoundments are managed for waterfowl habitat, but what about other promising uses, such as aquaculture? At the private level, the quality of management is also a concern; indeed, it is estimated that less than half of all functional impoundments are effectively managed. Given the impact impoundments may have on adjacent wetlands, should more intensive management be encouraged? Again, without a clear picture of impoundment management practices, these questions have been difficult to answer.

Clearly, there has been substantial private initiative to maintain impoundments as productive systems, but always in the face of a serious information gap. In an effort to close that gap, the South Carolina Sea Grant Consortium undertook the Coastal Wetland Impoundment Project (CWIP) in 1982.

The Coastal Wetland Impoundment Project

Purpose and Scope -- The goal of the project was to provide an initial comprehensive characterization of coastal impoundment ecology, distribution, management, and use. The project cut across academic disciplines and institutions to draw upon the expertise of researchers at many of the State's colleges, universities, and research institutions.

The ecological study components of the CWIP were intended to identify the degree to which the impoundment of intertidal wetlands

alters wetland processes and use by estuarine-dependent species. Research also addressed the distribution and condition of impoundments in South Carolina, and how they are managed. Finally, the project monitored state and federal policies regarding impoundment construction and repair. It should be stressed that this study represents the initial stage of investigation into these systems and, consequently, the findings can not be extrapolated to all other impoundments. The study does, however, yield information relevant to the resolution of the complex questions surrounding brackish impoundments.

General Objectives -- After a thorough review of the available information on coastal impoundments and detailed discussions with representatives of natural resource and regulatory agencies, impoundment managers, and environmental organizations, the CWIP identified the following objectives for study:

1. To determine stratigraphy, characterize hydrology, and identify the major floral and faunal components of the impoundments under study

2. To determine the flow of nutrients and biomass between the study impoundments and the adjacent open wetland area

3. To characterize the floral communities and determine primary productivity of the study impoundments and the adjacent open wetlands

4. To determine and compare the recruitment, growth rates, and standing crop biomass of commercially important species in impoundments with those in adjacent open wetland areas

5. To determine the current structural status of South Carolina impoundments; ownership, current and proposed uses, management techniques, and federal and state policy.

These five general objectives formed the basis for the identification and organization of 12 research tasks. These tasks were undertaken by a team of 14 researchers from five of the Consortium member institutions (Table 1). Project coordination was provided by the South Carolina Sea Grant Consortium.

Photo: Marc Epstein

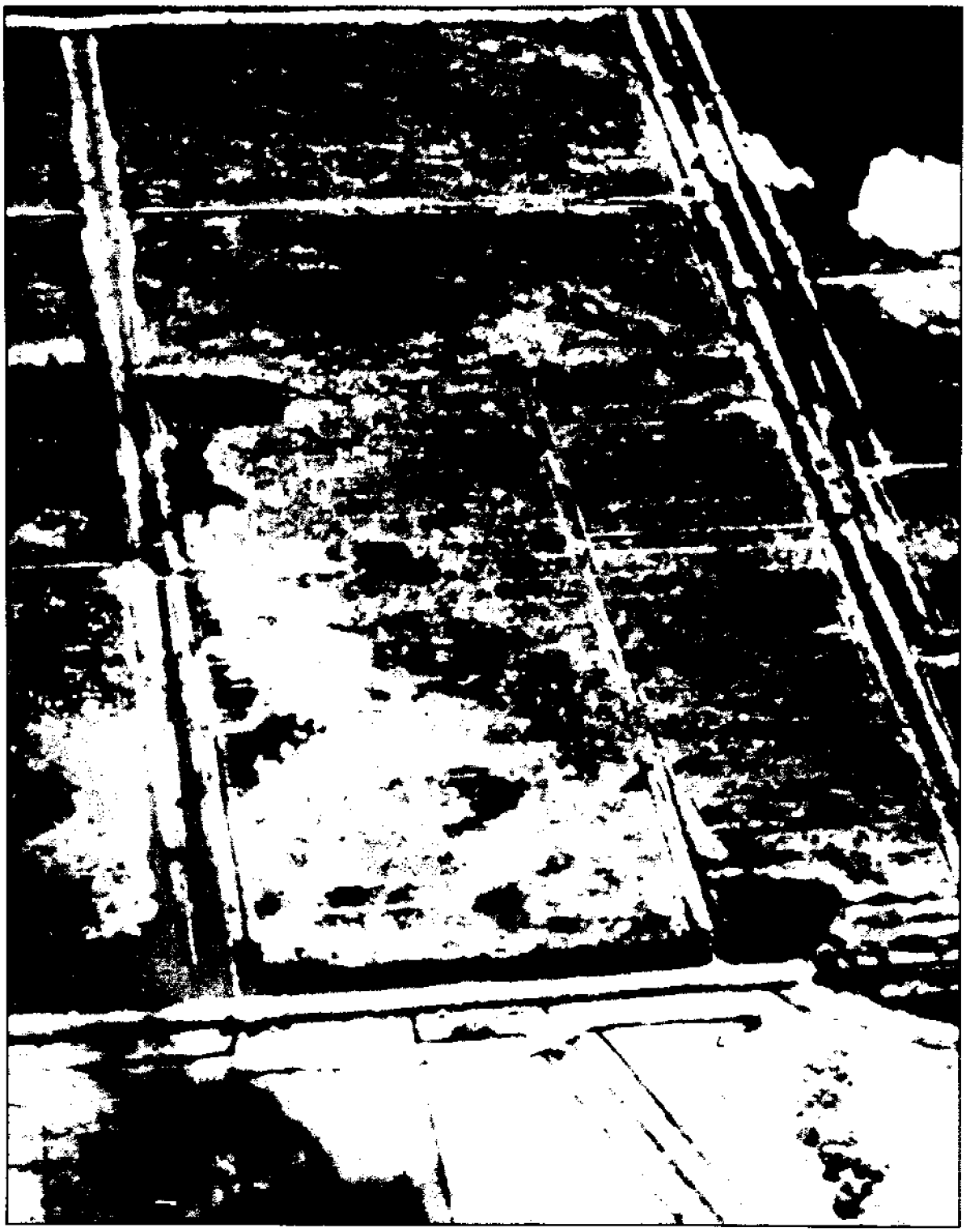
Table 1

The Coastal Wetland Impoundment Project: Team Members and Research Tasks

1. **Mark E. Tompkins**, University of South Carolina	1. Identify and conduct analyses of impoundment policy concurrent to the ecological studies, and determine the current status (extent, management, use) of impoundment systems in S.C.
2. **James P. May**, The Citadel **Paul Zielinski**, Clemson University	2. Characterize impoundment and wetland sediments and determine hydrologic and hydraulic attributes of the study system.
3. **Hank N. McKellar**, University of South Carolina	3. Determine hydrography, nutrient budgets and submerged aquatic productivity of the study system.
4. **B. Joseph Kelley**, The Citadel **Richard D. Porcher**, The Citadel	4. Determine distribution and primary productivity of macrophyte vegetation in the study area.
5. **Richard G. Zingmark**, University of South Carolina	5. Determine seasonal abundance and productivity of benthic microalgae in the study area.
6. **A. Keith Taniguchi**, University of South Carolina	6. Determine micro- and meso-zooplankton abundances, seasonal cycles, and dynamics of the study system.
7. **Bruce Coull**, University of South Carolina	7. Characterize the meiofauna population of the study impoundments.
8. **Elizabeth L. Wenner**, S. C. Wildlife and Marine Resources Dept. **Paul A. Sandifer**, SCWMRD **Robert Van Dolah**, SCWMRD	8. Determine the composition, structure, and population dynamics of macrobenthic invertebrates and decapod crustacean communities of the study area.
9. **Charles A. Wenner**, S. C. Wildlife and Marine Resources Dept.	9. Determine the composition, structure, and trophic dynamics of fishes at the study area.
10. **John Mark Dean**, University of South Carolina	10. Estimate and compare individual growth rates of ecologically important fishes.
11. **Robert L. Joyner**, Tom Yawkey Wildlife Center, SCWMRD **Marc Epstein**, Tom Yawkey Wildlife Center, SCWMRD	11. Determine the utilization of the managed and unmanaged areas by waterbirds and alligators.
12. **Jack M. Whetstone**, Clemson/Sea Grant Marine Extension Program	12. Disseminate project results through the Clemson/Sea Grant Marine Extension Program and assist nonprofit organizations in developing sound management strategies.

SECTION II

SURVEY OF COASTAL WETLAND IMPOUNDMENTS IN SOUTH CAROLINA



Introduction

The Coastal Wetland Impoundment Project (CWIP) included an in-depth survey of impoundment owners and managers. The mail survey was designed to determine the current structural status, ownership, management, and use of coastal impoundments in South Carolina. Some 1,500 individual impoundment sites were identified through the tax offices of the eight coastal counties: Beaufort, Berkeley, Charleston, Colleton, Dorchester, Georgetown, Horry, and Jasper. Of the 1,294 individuals subsequently surveyed, 659 responded to the request for information; in each county at least 40 percent of those surveyed responded. Additionally, nine of the 14 national corporations and all state and federal agencies that manage or own impoundment sites responded to similar survey requests. Over 65 percent of the estimated 144,000 acres of intact and former impoundments in South Carolina are represented by the survey results.

Status of Impounded Wetlands

Survey results indicated that impoundment fields varied dramatically in size, ranging from one to 1168 acres. Many relatively small fields were identified. Yet, much of the managed acreage identified occurred in relatively large fields. Experienced managers believe that small fields (<50 acres) are more easily controlled and more responsive to intensive management than large fields (>50 acres).

The CWIP survey found that of the 36,661 acres of intact diked wetlands covered in the survey, 34,265 acres were reported to be in working order, permitting manipulation of water levels, salinities and tidal exchange. The remaining acreage (2,396 acres) was reported to be fully enclosed with no tidal exchange permitted. In addition, 14,759 acres were reported to need repairs to the dike and/or water control structures even though the systems are enclosed and the water controlled (although 11,161 acres were located at one public site). Furthermore, in 1,626 acres either the water control structures were broken, or there was a break in the dike reported. An additional 387 acres were reported where the dikes were washed over. Finally, 41,611 acres of what are termed "formerly-impounded" sites were reported. These sites have deteriorated to such an extent that water levels and tidal exchange can no longer be controlled.

Thus, if only the sites claimed by private parties are considered, two major categories (representing 83 percent of the total acreage) can be identified: currently impounded and formerly impounded wetlands. In addition, a much smaller group of fields exists needing some form of repair to be restored to functional, manageable units. Findings of the survey indicate, therefore, that about 17 percent of the sites reported could be repaired and restored to functional units, under ideal conditions. In other words, a relatively small percentage of former ricefields are potential candidates for repair and restoration.

Ownership of Impoundments

The subject of wetland ownership in South Carolina is controversial. The State now claims all lands below the mean high water mark. However, Kings Grants distributed during colonial times authorized ownership to the low water mark. Therefore, only property owners possessing a Kings Grant have the legal right, according to the state, to claim ownership of intertidal areas.

Interestingly enough, the state does not exercise its claim over those rice field impoundments that remain intact, nor do property owners attempt to exercise any claim over wetlands that are below the mean high water mark. The controversy is focused upon those former rice fields that have deteriorated to some extent; dikes have breached or been washed over, or water control structures are damaged or non-existent. In such cases, the State maintains that these fields, whether the deterioration is major or minor, have reverted to their original condition as tidal wetlands and, as such, constitute a public resource under the jurisdiction of the State.

By contrast, property owners have attempted to maintain their rights to these rice fields and to repair, or re-impound, them for private use. In such instances, they claim that the existence of rice fields, in any condition, constitutes an acknowledgement of the owner's right to this property; even when it falls below the mean high water mark. The affected property owners regard the state's claim to these former rice fields as governmental infringement upon the rights of the individual. The ensuing controversy has revolved around questions of ownership and the attendant use of what is currently accepted as a publicly and privately valuable resource.

Present ownership of the 41,224 acres of formerly impounded wetlands has been categorized by the survey (Table 2). Almost 50 percent of these areas are claimed by private owners and corporations. On the other hand, of the 58,408 acres of currently impounded wetlands covered in the survey, 40.7 percent are publicly owned.

Management of Impoundments

Intensive management of diked wetlands allows owners to enhance the productivity of their fields. Management practices are generally aimed at improving the production of desirable plants consumed by waterfowl and restricting the growth of undesirable plants. These strategies usually involve the manipulation of salinity (seeking fresh-to-brackish-water environments in most cases), the regulation of water levels (including draining and flooding cycles), and, in some cases, the manipulation of impoundment beds (primarily through cultivation and/or burning).

Six major types of management strategies were identified through the survey. These regimes are characterized by the management of water levels and manipulation of impoundment beds as (1) flooded, no exchange; (2) flooded, continuous exchange, (3) one-pulse drawdown and re-flood, no manipulation of the impoundment beds;

Table 2

Current Ownership of Diked Wetlands

Type of Respondent *	Diked Land (acres)	Formerly Diked Land (acres)
Traditional Owner	3,884	4,474
New Owner	10,410	10,098
Owner Not Classified		
Uncertain	5,534	5,032
Third Party Manager	10,141	2,052
Group Ownership	3,923	2,777
Corporate Owner	716	9,525
Public Ownership	23,800	7,266
Totals	58,408	41,224

* A traditional owner is a respondent who reported inheriting the property or having it transferred to her or him by a living relative. Thus these cases include all second generation owners. New owners are those who purchased the property during their lifetime. Many owners could not be classified for a variety of reasons; if an ownership group or a third party manager could be identified, those cases are noted. The remaining cases are classified as uncertain. Corporate owners include only those cases in which a multi-state enterprise is identified as the owner of the field; many of these cases involve timber companies.

Photo: Marc Epstein

(4) one-pulse drawdown and re-flood, with manipulation of the beds; (5) multiple-pulse drawdown and re-flood, no manipulation; and (6) multiple-pulse drawdown and re-flood, with manipulation (see Table 3).

Of the 48,785 acres of managed impoundments reported, 7.0 percent are managed without exchange, and 1.7 percent are managed with continuous exchange. Of the fields managed with a single draw-down and reflooding cycle, 12.8 percent are drained without further disturbance of the beds, while 22.9 percent are drawn down, followed by the burning or periodic cultivation of the beds. Of those fields managed with several cycles of flushing and flooding, 0.8 percent are managed without further disturbance, while 54.9 percent also include burning or cultivation as part of the strategy.

The intensity of management varies with the category of managers. Typically, managers working for public organizations manage impoundments more intensively. Third-party managers (non-owners managing the site for another party) often manage intensively, but a substantial number resort to less-demanding management practices.

Finally, impoundment managers indicated some continuing problems with management techniques. Fifteen percent of the respondents reported problems with fish kills, 23 percent reported algal blooms, 28 percent reported problems with water control, 22 percent reported problems with undesirable animals, and 22 percent of the respondents reported problems with cat clays (acidic marsh soils). Seventy-five percent of the respondents reported problems with "undesirable plants"; suggesting that this is the most prevalent problem facing managers today.

Another consequence of certain impoundment management strategies may be increased mosquito production. Local managers report some success with mosquito control through active management of the impoundment beds. Though many fields are drained and then subsequently flooded under typical management schemes, permitting a

Table 3

Major Types of Management Strategies Identified in the Survey

Strategy Category	Manipulations Involved
Flooded, no exchange	Impoundment beds remain flooded year-round, trunks set for no tidal exchange
Flooded, continuous exchange	Impoundment beds remain flooded year-round, trunks set for continuous tidal exchange
One-pulse drawdown and re-flood	Impoundment is drained and re-flooded once each year
One-pulse drawdown and re-flood with manipulation of the bed	Impoundment is drained and re-flooded once each year and the bed is burned or cultivated
Multiple-pulse drawdown and re-flood	Impoundment is drained and re-flooded more than once
Multiple-pulse drawdown and re-flood with manipulation of the bed	Impounded is drained and re-flooded more than once, and the bed is burned or cultivated

flushing type drawdown-reflood event could result in a significant reduction in the number of salt marsh mosquitoes hatched during the flooding cycle.

Use of Impounded Wetlands

The management objectives of impoundment systems throughout the state have changed little in recent years. Results of the survey indicate that waterfowl were the primary objective for 78 percent of the managed impoundments. Only 3 percent of the acreage covered in the survey was reportedly used for aquaculture.

Generally, some observers suggest that managed wetland fields can make an important contribution to intensive conservation efforts. More intensive management improves the habitat for birds and threatened and endangered species, provides sanctuaries for wildlife, and enhances areas suitable for hiking, bird watching and other related forms of recreation. Analyses of natural resource utilization sometimes distinguish between "consumptive" uses such as hunting, fishing, and shellfishing, and "non-consumptive" uses, such as hiking, bird watching, and wildlife preservation. Survey results suggest that 80 percent of the impounded wetlands surveyed are managed for "consumptive" uses, 12 percent for "non-consumptive" uses, and the remaining eight percent are managed equally for both.

Interest in coastal wetlands has raised the question of public access to these resources. According to the survey, the percentage of impoundment fields accessible to the public was reported as follows: corporate-owned = 0.0 percent; group (private)-owned = 15.6 percent; individual (private)-owned = 5.9 percent; third party-owned = 61.6 percent; and publicly-owned = 100 percent. An extrapolation of these responses to the total acreage of impoundments along the coast suggests that the public has access to 30,000 to 35,000 acres of impounded lands. Other fields are accessible, particularly for waterfowl hunting, through the payment of substantial lease fees.

Summary

The survey results suggest several implications for public policy:

- Regulatory policies focusing on 'repairs' to impoundments will affect a modest amount of wetland acreage, while policies affecting 'reimpoundment' involve much more substantial wetland areas.

- The controversy over ownership will likely continue. It should be noted that nearly half the survey respondents had completed ownership studies (i.e., title searches) though there was no immediate need to do so (e.g., to support litigation).

- Private managers have not been as prompt as public managers to update their management schemes. Further, even though management practices have improved, a substantial number of respondents continue to report a variety of problems in their fields.

The reasons for and solutions to these problems clearly need further assessment.

SECTION III

PHYSICAL CHARACTERIZATION OF THE CAT ISLAND IMPOUNDMENTS

Study Site Description

The ecological studies were conducted at the Cat Island Patty Field complex of the Tom Yawkey Wildlife Center in Georgetown, South Carolina (Fig. 1). The Yawkey Center includes a system of multiple coastal wetland impoundments close to an open marsh and estuarine waters. The compact experimental ponds of the Paddy Field complex were well suited for comparative ecological studies of impoundment and marsh processes. In addition, the site is owned and managed by the state and, with the approval of the Yawkey Foundation Trustees, was committed for the duration of the project. The Tom Yawkey Wildlife Center also committed the services of a resident biologist and research technician, experienced in the management of impoundments for waterfowl.

The study site (Fig. 2) consisted of a series of five impoundments ranging from 8.6 to 19.3 acres in size (average size was 13.6 acres); one unmanaged or breached tidal impoundment (19.5 acres); one larger managed impoundment (Cooperfield - 34.0 acres) adjacent to impoundment No. 1; Chainey Creek, the major water source for the impoundments; and the open marsh, located east of the impoundment complex. The South Carolina Wildlife and Marine Resources Department and former owner Tom Yawkey re-constructed these brackish water impoundments from previously impounded marsh in 1967. The impoundments have been managed for waterfowl habitat since 1970.

Impoundments 1 to 5 and Cooperfield were equipped with double flap-gate water control structures with interior flashboard risers, commonly referred to as "trunks" (Fig. 3). Managers can control both the flow of water into and out of impounded systems and the level of water on the impoundment beds by manipulating the flap-gates and flashboard risers.

Water Management -- The on-site water management scheme was designed to encourage the production of widgeon grass, *Ruppia maritima*, and other desirable waterfowl food plants in the impoundments.

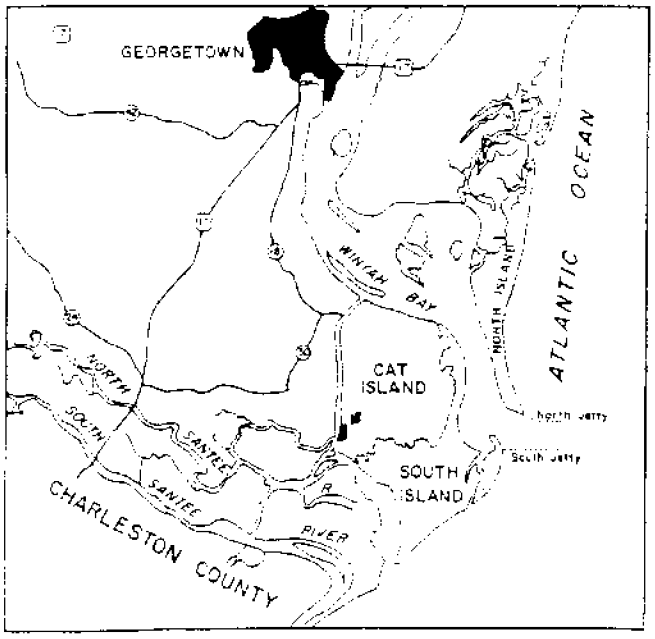


Figure 1. Map of the Georgetown, SC area showing the general location of the study site

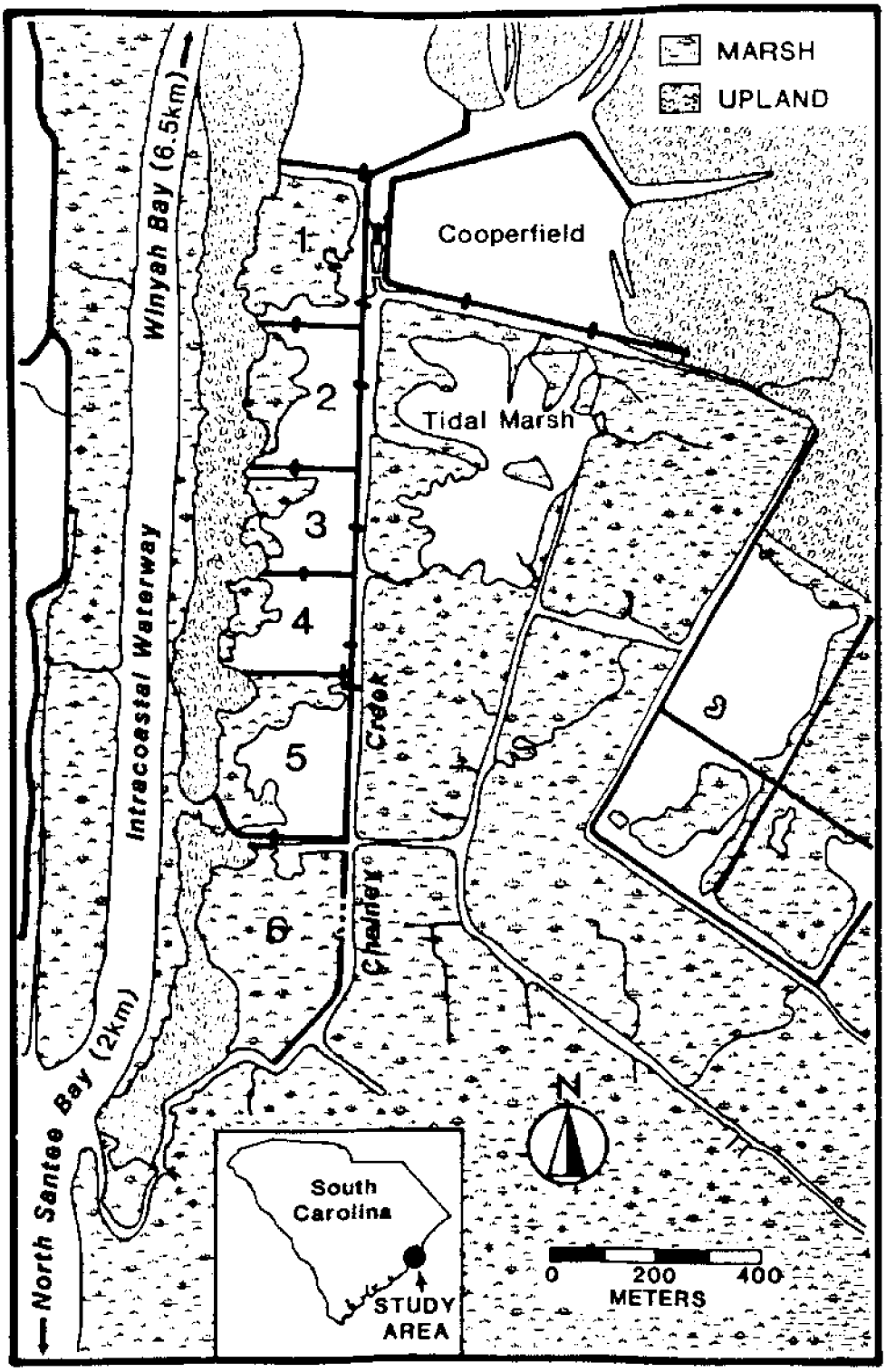


Figure 2. Schematic diagram of the study site at the Tom Yawkey Wildlife Center, Georgetown, SC.

The annual water management regime employed the following manipulations. Beginning in October, 1982, water levels were lowered by 10 cm each month to expose widgeon grass and its seeds for waterfowl grazing. The spring, 1983 drawdown and reflooding of the impoundments then took place in March and April; the impoundment beds were kept moist during drawdown to promote germination and growth of desired aquatic plants.

To offset mosquito production during the drawdown-reflood process in spring, the impoundments were flooded, quickly drained to remove mosquito larvae, and then quickly reflooded before new eggs were deposited. After reflooding, the water levels were maintained at a depth of 10 to 20 cm over the impoundment beds to prevent egg-laying by mosquitoes.

The impoundment trunks were then set to allow moderate tidal exchange, and each month from May to September, 1983 the water levels were gradually increased by 10 cm increments to allow growing space for the widgeon grass. By September, 1983 the water levels reached between 50-70 cm on the impoundment beds; the gradual drawdown process was begun again in October. Water levels were reduced in 10 cm increments each month until the drawdown-reflood process was repeated.

In 1984, impoundment manipulations were generally the same except for the length of the drawdown process and the overall management of impoundment 2. This unit was not allowed to drain below 20 cm for reasons of scientific protocol; the trunk was set to permit moderate tidal flushing. However, when the water levels in impoundments 1, 3, 4, and 5 reached that of unit 2, all impoundment water levels were gradually increased as was done in 1983.

In both years, the tidal or partially breached impoundment (impoundment 6) and the open marsh were influenced by normal tidal inundation, as expected.

It should be noted that spillways located between the study impoundments to facilitate additional circulation were left closed throughout CWIP, so that each unit could be

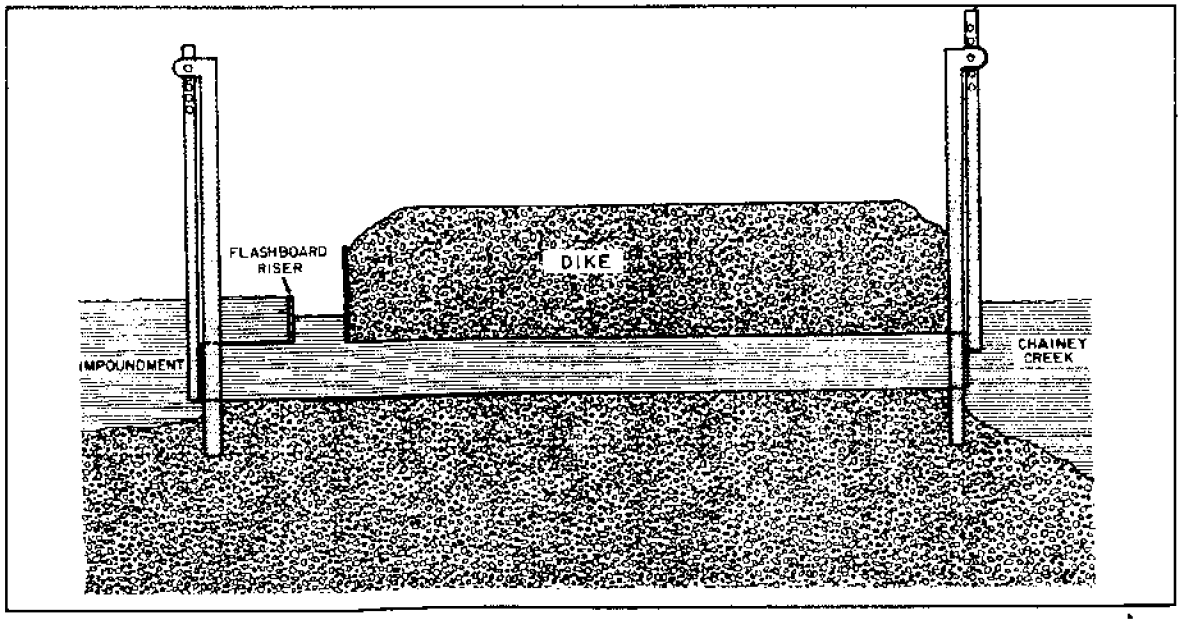


Figure 3. Cross-section schematic of a water control structure (ebb tide). *courtesy* Geno Olmi

studied individually. Water level was controlled only through the main trunk on Chainey Creek. As a result, the five study impoundments were managed without the benefit of their full potential for water circulation.

Climactic and Environmental Factors -- During the study, salinity ranged from one to 30 parts per thousand (ppt) in the impoundments and from zero to 32 ppt in the adjacent wetland area and tidal impoundment. In summer, high temperatures and salinities and low early morning dissolved oxygen (DO) levels in the impoundments produced stressful conditions for some species of aquatic animals and plants. These conditions were compounded by reduced water circulation; spillways located between the study impoundments were closed during the investigation. Under optimal management conditions, with greater water circulation, this situation may not have posed as severe a problem.

Freshwater for the impoundment complex was supplied by two sources: rainfall and the North Santee River. Total rainfall for the Cat Island site was 1.4 m in 1983 and 1.1 m through August of 1984. The average rainfall for the region is 1.3 m annually. Freshwater discharges from the North Santee River fluctuate and depend on the amount of rainfall and the volume of water released from the Santee-Cooper hydroelectric facilities. During the study, river discharge peaked in March and April of each year, and coincided with periods of peak rainfall.

The DO concentrations in the study impoundments were measured to compute gross community productivity and assess the quality of the impoundment environment as habitat for macro-invertebrates and fishes. Highest DO values were observed at dusk in March, May, and June, with lowest values recorded for dawn periods in July and August of both years.

Due to low DO conditions most of the impoundment "core" fishes were adapted to utilize the oxygen-rich waters at the air-water interface. When populations of these organisms were observed at the water surface, they experienced heavy predation from concentrations of waterbirds and alligators. Sub-lethal oxygen stress may have been the cause of this surface swimming behavior.

Sedimentology and Hydrology

Sediments that characterize marsh systems play an important role in determining plant and animal communities, in addition to influencing the degree of water movement between groundwater and surface water systems.

The study characterized the nature of the sediments and determined the degree of interchange between the waters in the study impoundments and the area's shallow water aquifer. The substrate of the impoundments was found to be primarily a layer of organic material over a relatively impermeable clay-silt layer. Water analysis indicated that groundwater recharge was not flushing the impoundment system due to the existence of this impermeable layer.

Impoundment dikes were constructed by excavating marsh bottoms and depositing the material on the adjacent marsh surface. It is possible that a potentially porous layer was formed between marsh substrates and dike structures. Thus, minor water exchange may occur between the impoundment and adjacent tidal creeks. Any appreciable water exchange through the dike could contribute to the exchange of nutrients and other materials between the impoundment and the adjacent marsh.

Analysis of dike structures indicates that there is a negligible flow of water through the porous organic layer. These results suggest that the exchange of water between the impoundments and the adjacent creek was primarily through the water control structures. It appeared that significant exchanges of nutrients and other materials did not occur through the impoundment beds and dikes.

Tidal Nutrient Exchanges

Wetlands productivity is attributed, in part, to the abundance and rapid turnover of nutrients. During the CWIP, the flow of nutrients between the impoundments and open marsh was monitored to compare the seasonal patterns in nutrient concentrations and net tidal flux.

Results of the CWIP demonstrate that tidal movements of major nutrient fractions in the study impoundments were considerably different from those observed in the adjacent tidal wetland. On an annual basis, the tidal wetland exhibited a net export of ammonium and ortho-phosphate with higher export rates occurring during summer. There were periods of net monthly import of these fractions, particularly from March to May, but the high export rates in summer offset this pattern. The annual net export of these inorganic fractions has been documented in other marsh systems, and has been proposed as a means of stimulating primary productivity in estuarine ecosystems during summer periods of high productivity.

By comparison, the study impoundments, under this particular management strategy, generally showed opposite trends characterized by much lower annual rates of tidal exchange. Ammonium was exported, while ortho-phosphate was imported into the impoundments. However, the effect of wildlife utilization on nutrient dynamics was not considered during the study.

In contrast, the tidal exchange of phytoplankton biomass was similar between the study impoundments and the adjacent wetland system. However, biomass exchange differed considerably in direction of flow. The tidal wetlands imported phytoplankton biomass throughout the year, while impoundments exported phytoplankton biomass except during peaks of import in April and May.

Differences in mean concentration between ebb and flood tide were determined for total (TOC), dissolved (DOC), and particulate organic carbon (POC). The DOC fraction dominated TOC in both the tidal marsh and impoundment systems. DOC in the tidal marsh was consistently higher on ebb tides throughout the year, suggesting that DOC is exported from the marsh. In the impoundments, ebb tide and flood tide concentrations were similar during spring. However, DOC concentrations were as much as three times higher on ebb tide from late summer and throughout the fall, again suggesting that DOC was exported from the impoundments during this period.

POC exhibited similar seasonal trends in both the impoundments and tidal marsh. Mean POC concentrations in the tidal marsh on ebb tide were consistently higher than mean flood tide values, suggesting some export of POC during the year. On the other hand, POC values for the impoundments were variable, and no obvious pattern of import or export was observed.

Summary

Collectively, the annual tidal exchange of DOC, POC, and phytoplankton biomass between the two systems was comparable. Nevertheless, the quality and timing of the exchange of nutrients was observed to be clearly different. Some of these differences can be attributed to the quantities of water moving between the two systems. During summer months of restricted water flow, when high water levels were maintained in the study impoundments, tidal nutrient exchange was reduced. By contrast, maximum rates of nutrient export occurred during summer in the tidal wetlands and spring in the impoundments.

Although the water management strategy may account for some differences in the timing of nutrient exchange, dissimilarities in the form of nutrients exchanged at Cat Island may have been due to the biotic and geochemical characteristics of the two systems. For example, impoundments are often dominated by submerged benthic plant communities while open marshes are typically dominated by macrophyte plants; this difference in plant community structure will affect the mechanisms governing nutrient processing. These differences in nutrient exchange may effect estuarine productivity; however, additional data are required to fully evaluate these effects.

SECTION IV

ECOLOGICAL CHARACTERIZATION OF THE CAT ISLAND IMPOUNDMENTS

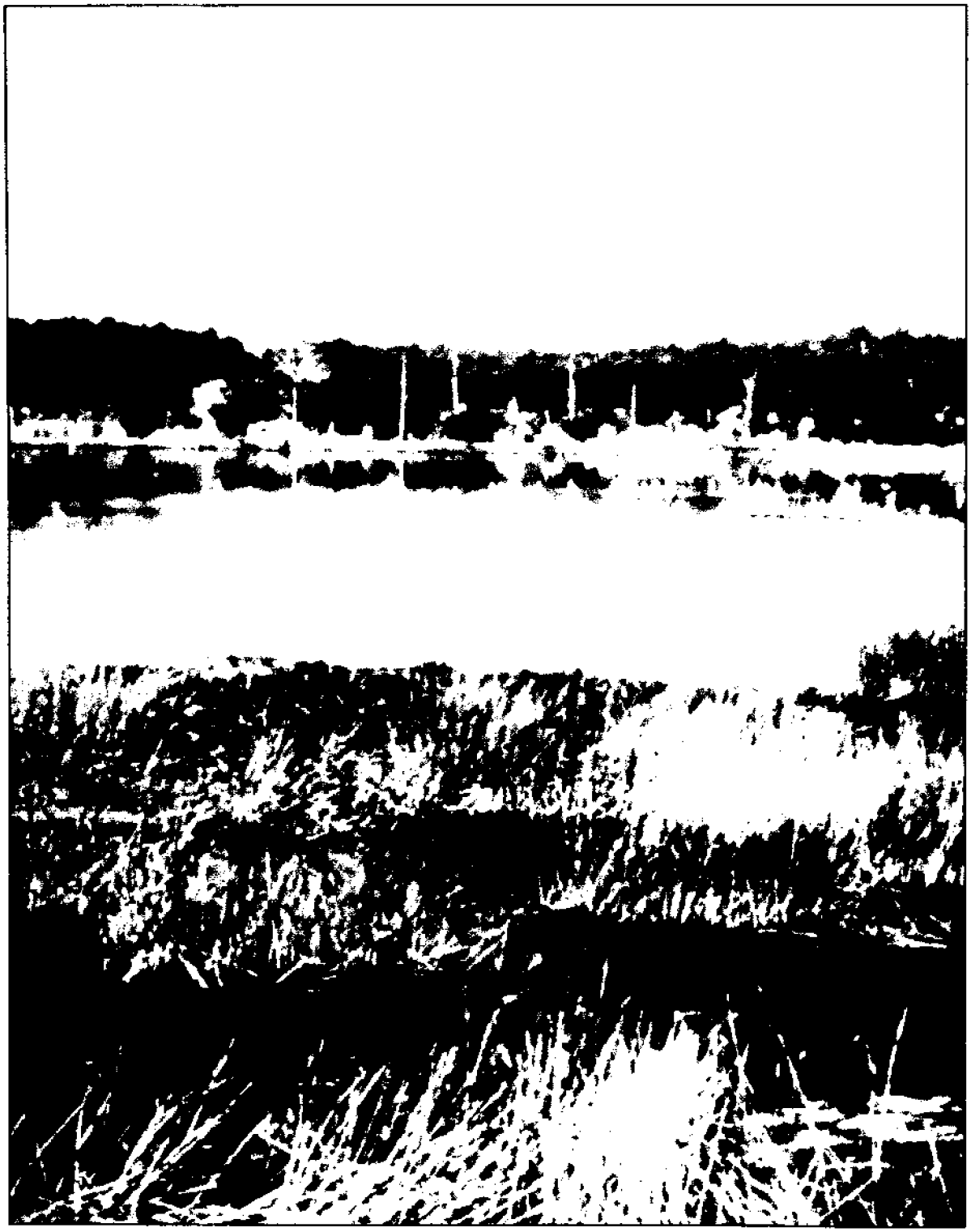


Photo: Marc Epstein

Primary Productivity and Systems Metabolism

Introduction

Primary production is the basis of the complex food web in all ecosystems. Total primary production in estuarine environments is comprised of three important floral assemblages: phytoplankton, benthic microalgae, and macrophytes. The relative contribution of each component to total primary production may vary between open tidal wetlands and coastal impoundments, depending on their respective biological and physical characteristics. The question CWIP sought to resolve was whether the impoundment of wetlands inhibited primary production.

Phytoplankton Production

Phytoplankton -- small diatoms, dinoflagellates and other single-celled algae -- is an important source of food for many small estuarine animals and is a major component of total primary production in estuarine environments.

The study impoundments supported high phytoplankton production, which dominated total aquatic production in these systems during late summer and fall. Indeed, high phytoplankton production was responsible for the large daily variations in DO levels observed during this time. The presence of large areas of standing water, high nutrient concentrations, and little water exchange in summer appear to be the major factors supporting high phytoplankton productivity. By contrast, the relative importance of phytoplankton production is usually low in open intertidal wetlands.

Benthic Microalgae

Benthic microalgae -- microscopic diatoms and photosynthetic bacteria that live on or in the surface sediments -- are a nutritious food source for micro- and meiofauna and for juvenile macrofauna. The extensive shallow mud flat areas in impoundments provide ample, well-exposed habitat for the light sensitive benthic microalgae. As a result, benthic microalgae may provide a substantial contribution to total primary productivity in impoundments.

Data derived from preliminary studies on the benthic microalgae of the study area were not conclusive but do suggest several patterns. The magnitude of biomass and the primary production of benthic microalgae in the study impoundments and the intertidal wetlands system generally agreed with literature values for various coastal environments. Based on these data and other studies that have found BMA to contribute up to three times the productivity of phytoplankton in coastal environments, it appears that benthic microalgae should be significant producers in impoundments.

Macrophyte Productivity

Macrophyte vegetation is a prominent feature of salt marshes along the South Atlantic coast. Both as live and dead plant (detritus) material, macrophytes provide habitat and food for numerous wildlife, fish and crustaceans. Total primary production is typically dominated by macrophyte production in southeastern coastal marshes. This high productivity has been partially attributed to the influence of tidal action which, in impoundments, is interrupted by dikes and water control structures. The CWIP compared macrophyte production in impoundments and open marshes to determine whether this alteration affected plant production.

Macrophyte plant communities were mapped and classified in both the study impoundments and the adjacent tidal wetland. Seven plant communities, including 19 species, were identified in the impoundments; the widgeon grass community accounted for the highest percent of coverage. By contrast, the tidal wetlands were characterized by three macrophyte communities, including 5 species; *Spartina alterniflora* and *S. cynosuroides* were the two dominant species.

Photo: Doug Baughman

This greater macrophyte diversity in impoundments is not unexpected since waterfowl management strategy is designed to promote a variety of vegetation.

To assess the contribution of macrophyte plant production to total aquatic productivity, net aerial primary productivity (NAPP) was estimated for each community in both wetland systems. NAPP estimates for each plant community in the study impoundments and the tidal wetland were not significantly different, and were consistent with estimates found in the literature for the same species in the southeast. It appears, then, that manipulating water levels in impoundments does not inhibit macrophyte productivity.

Because the management strategy for the study impoundments was designed to encourage the growth of widgeon grass, and other vegetation attractive to waterfowl, it was not surprising that this community dominated impoundment macrophytes in terms of percentage of cover. However, even though widgeon grass was the target species, its contribution to total NAPP was moderate compared to that of the other six impoundment macrophyte communities. The methods used did not account for losses due to grazing, seed dispersal or mortality and, as a result, production may have been underestimated.

It is interesting to note, however, that the standing crop of the widgeon grass community peaked in June of each year and was largely gone by the fall when the migratory waterfowl arrived. Widgeon grass seeds were still available, though, and provided an alternate food source.

Summary

Overall, the data suggest that total primary production in impoundments and open wetlands was similar and perhaps not affected by altered tidal action; but the relative contributions of phytoplankton, benthic algae and macrophytes differed between systems. In the tidal wetland, primary production was dominated by emergent vegetation, while submerged macrophytes, benthic algae, and phytoplankton were the significant primary producers in the study impoundments.

Planktonic Community

Zooplankton

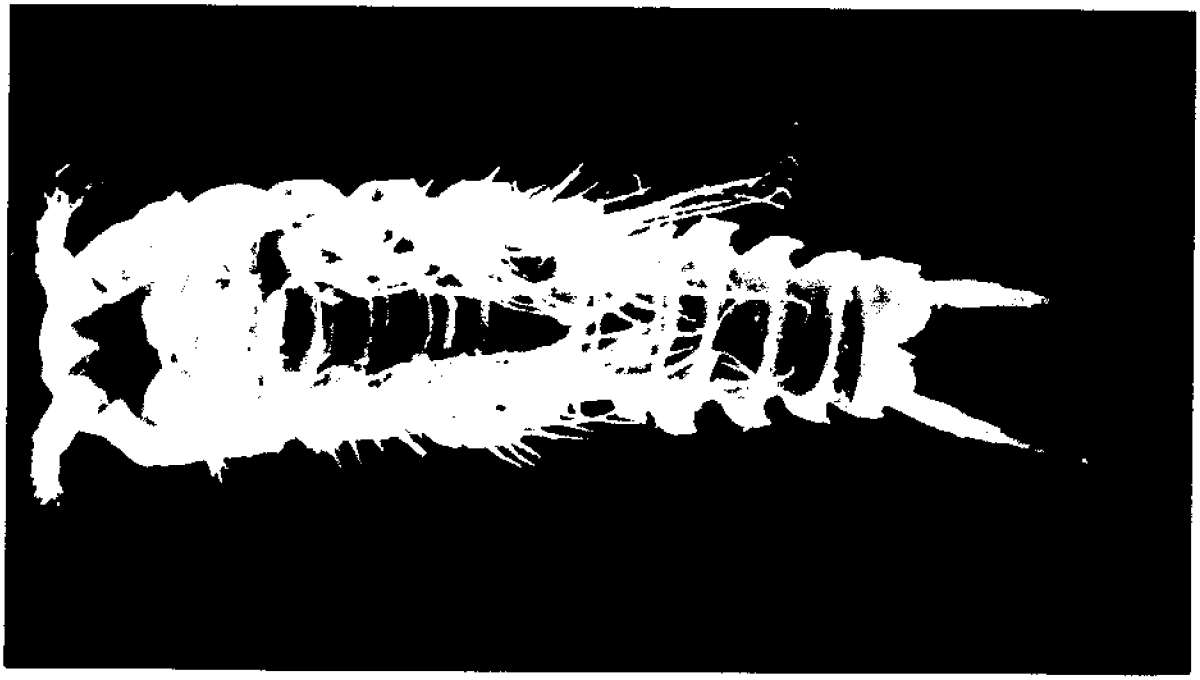
Zooplankton are an integral food source for many marine and estuarine fish larvae. In fact, the commercially and recreationally important fishes in wetlands have planktonic larvae that depend entirely on zooplankton. Consequently, the impoundments and the adjacent tidal creek were compared to determine which habitat supported higher densities of zooplankton.

Results indicated that the annual standing stock of zooplankton was generally higher in the study impoundments than in Chainey Creek. In addition, there was significant seasonal variability in the density of zooplankton in the impoundments. Impoundment zooplankton populations decreased to the low standing stock levels observed in Chainey Creek during periods of extensive impoundment flushing in the spring (March-April). Standing stock levels also decreased during periods of low impoundment water levels, when greater tidal exchange occurred with Chainey Creek.

Conversely, the standing crop of zooplankton was highest in impoundments during periods of reduced water exchange with Chainey Creek, primarily in August and September. The peak period of impoundment zooplankton biomass also corresponded with the highest values measured for phytoplankton production.

Summary

In general, the zooplankton densities measured during the study were comparable to densities reported in large estuaries and open coastal habitats. However, under certain conditions, the recorded zooplankton blooms from managed impoundments suggest that they are capable of producing higher densities than natural systems.



Enhydrosoma propinguum; 250x.
Photo: Bruce Coull

Benthic Community

Benthic Meiofauna

Meiofauna, small invertebrates (<0.5 mm) found within the upper 1-2 cm of sediment, are another important source of food for estuarine fish and macro-invertebrates. In a preliminary study, meiofaunal populations in the study impoundments and the open tidal marsh were sampled and compared.

Harpacticoid copepods and nematodes dominated meiofauna populations at all study sites. Tidal wetland sites (intertidal *Spartina* marsh and subtidal creek bottoms) contained more species than analogous sites within the study impoundments. Among the study impoundments, no two units contained similar abundances of meiofauna. The meiofauna populations appeared to exhibit a patchy distribution which could not be explained by differences in abundance values between the impoundment ditches and flats. Information from this study indicates that meiofauna occur patchily in impoundments, with abundance values approaching those shown for high intertidal *Spartina* marsh.

Benthic Macrofauna

Bottom-dwelling macro-invertebrates (crustaceans, polychaete worms, gastropods, insects, etc.) are a common source of food for adult fishes and birds in saltmarsh ecosystems. A comparison between the macrobenthic communities in the impoundments and the adjacent wetland was undertaken as a part of the CWIP.

Results showed that habitats within the study impoundments supported different and less diverse assemblages of macrofaunal invertebrates than analogous habitats in Chainey Creek and the adjacent wetland. Vegetated sites in the study impoundments accounted for 39 taxa (species groups), as opposed to the 65 taxa collected at sites in the open wetland. Similar, non-vegetated sites (i.e., perimeter ditches) in the impoundments contained 46 fewer taxa of benthic macrofauna than comparable sites in Chainey Creek.

Faunal assemblages in impoundments consisted primarily of hydrobiid snails, insects, oligochaetes and some polychaetes. In contrast, gammarid amphipods, isopods and polychaetes were more common in the tidal wetland.

Summary

Overall, the study impoundments supported fewer and less diverse benthic fauna than natural tidal wetlands, indicating an environment unsuitable for some species of benthic invertebrates. Furthermore, study data suggest that structural differences between habitats were important factors affecting distribution patterns. Such factors as sediment composition, availability of organic matter, DO concentrations, hydrogen sulfide accumulation and predation influence the spatial patterns of macrobenthos, and may have accounted for the observed differences between the impoundment and adjacent wetland systems.

Nektonic Community

Crustaceans and Fishes

Saltmarshes provide habitat, food, and protection from predators for numerous crustacean and fish species. Many of these animals, including over 75 percent of all commercially and recreationally important species, require access to this habitat to complete a portion of their life cycle. Some scientists suggest that impoundment dikes and water control structures alter the utilization of these nursery areas by estuarine dependent species. Two separate research components compared recruitment and community structure of fishes and crustaceans in impoundments and adjacent open marsh.

Among penaeid shrimp, post-larval brown shrimp (*Penaeus aztecus*) recruited to the study area almost exclusively during the May to June period of maximum water exchange between the two systems. As a result, they were relatively abundant in collections at the impoundment water control structures. Conversely, post-larval pink shrimp (*P. duorarum*) recruited into the study area in late summer and early fall during periods of minimal water exchange; therefore, few pink shrimp entered the impoundment although they were abundant in Chainey Creek.

Juvenile blue crabs (*Callinectes sapidus*) were almost always more abundant at impoundment stations, probably due to the greater efficiency of the impoundment trunk net. However, the immigrating post-larval stage (megalopa) were virtually precluded from entering the impoundments because their recruitment coincided with the late summer-early fall period of low water exchange.

Fishes which were abundant as larvae or juveniles in Chainey Creek during May, the period of maximum water exchange, were recruited into the impoundments. In June and July, larval ladyfish (*Elops saurus*), tarpon (*Tarpon atlanticus*), silver perch (*Bairdella chrysura*), and croaker (*Micropogon undulatus*) were recruited into impoundments during high tide when water flowed into the impoundments over the trunk spillways. Fishes that recruited into the study area during periods of little water exchange did not use the impoundments to any large extent. For example, spot (*Leostomus xanthurus*) -- the dominant larval fish collected from the tidal creek -- were not abundant in the impoundment samples because water control structures were closed during the period of maximum recruitment.

The data also suggest that water control structures and dikes prevented those fishes and decapod crustaceans that recruited into the impoundments from entering Chainey Creek during periods of natural emigration. For example, only 7.6 percent as many penaeid shrimp were collected emigrating from impoundments as were collected immigrating into these systems. Similarly, the greater abundance of mature female blue crabs within impoundments during months when they typically migrate offshore to spawn suggests that crabs were retained within impoundments. Transient estuarine fish species entering impoundments as larvae or juveniles during periods of maximum water exchange (in spring), were also denied access to Chainey Creek during periods of natural emigration from the estuarine environment. Judging from the study findings, this phenomenon affected the ability of these species to complete their respective life cycles.

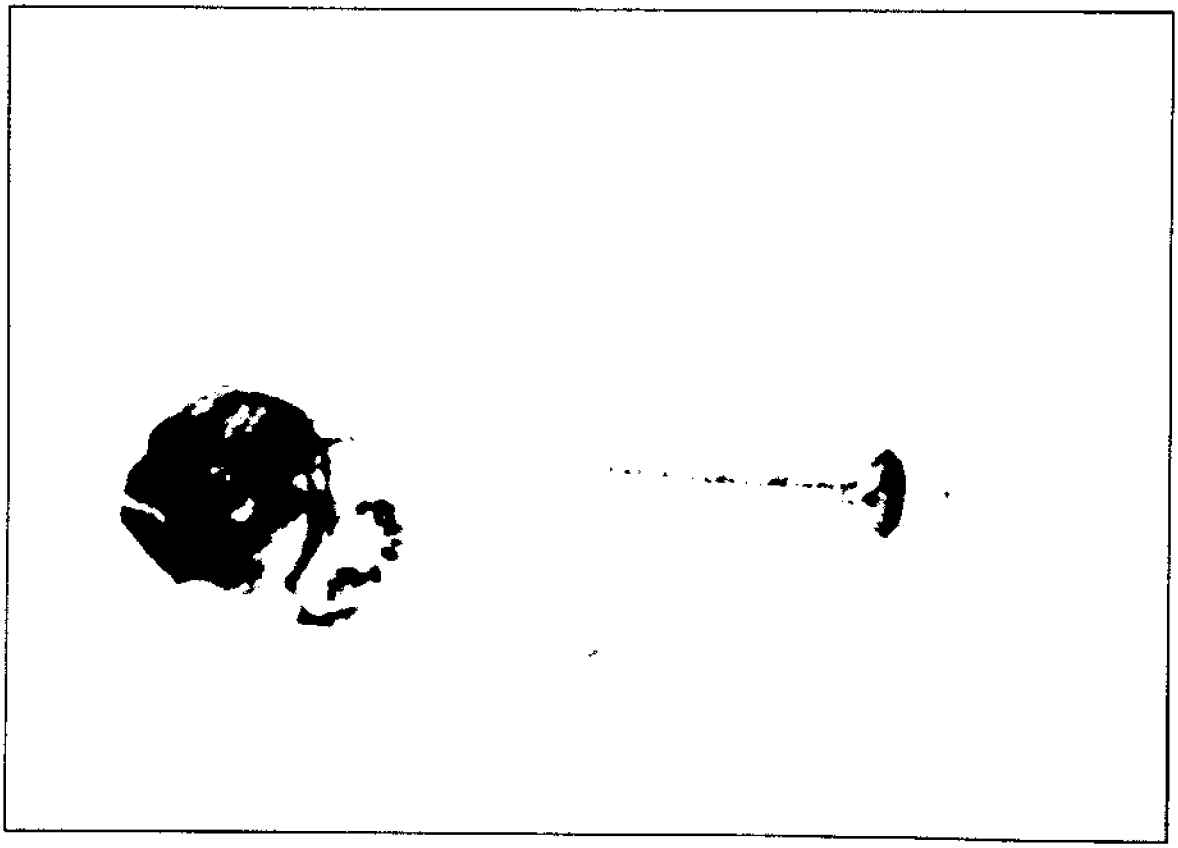
Diversity and abundance of fishes--and densities of decapod crustaceans--differed between the study impoundments and adjacent creek. The composition and number of decapod crustacean species collected by seine and trawl in the creek and impoundments were similar. The most dominant decapod crustaceans--grass shrimp, brown shrimp, white shrimp (*P. setiferus*), pink shrimp and blue crab--were essentially the same in both habitats. On the other hand, 16 more species of fishes were collected in the tidal creek system than inside impoundments. The dominant fish species collected from the creek was the mummichog

(*Fundulus heteroclitus*) whereas mosquitofish (*Gambusia affinis*) dominated the impoundment fish assemblage. These differences in community structure may be attributed to the barrier imposed by dikes and water control structures, predation by waterbirds and alligators and the stressful hydrographic conditions in the impoundments.

In addition, fishes that normally prey on benthic or planktonic organisms had a wider range of food items in the creek environment than similar feeders in the impoundments, due to the greater diversity of macrofauna found in the open tidal system. As a result, the dominant fish species in the impoundments tended to be those noted as opportunistic feeders.

Summary

The nature and timing of water exchange between Chainey Creek and the impoundments directly influenced use of the study impoundments by pelagic organisms, especially decapod crustaceans and estuarine fishes. Data indicate that the impoundments, under CWIP management strategy, inhibit the normal migrations of certain species and, thus, the completion of their life cycles. The overall utilization of impoundments by the decapod crustacean and fish communities was influenced by predation, the stressful hydrographic conditions (DO, salinity, temperature, etc.) and the relationship between a species' life history pattern and the periods of maximum water exchange between impoundments and the adjacent tidal creeks.



Paralichthys dentatus
Photo: Jack McGovern

Wildlife Community

Waterbirds

The study impoundments hosted higher numbers of waterbirds and more diversified waterbird assemblages than the unmanaged areas. On an annual basis, the total number of shorebirds, waterfowl, and waders using impoundments greatly exceeded the numbers using the unmanaged sites. In addition, of 77 wetland bird groups that utilized the study area, 76 were observed in the impoundments, while only 56 were observed in the unmanaged sites. Though waterfowl were the primary target of the widgeon grass management regime, shorebirds dominated the average annual use of the managed units (53.0 percent), followed by waterfowl (27.0 percent) and waders (14.0 percent). Other waterbird assemblages (surface divers, aerial divers, and raptors and rails) comprised the remainder of the average annual use.

Distinct seasonal patterns of waterbird use of the tidal marsh and impoundments were observed. In summer and fall, waders dominated the waterbird assemblages. By winter, waterfowl populations accounted for 61.5 percent of all waterbird utilization, while in the spring, shorebirds accounted for almost 80 percent of avian usage. The seasonal differences observed during the two-year field investigation were directly related to the natural feeding and resting behaviors of these waterbird groups and the water level management of the impoundments.

Alligators

Alligators were observed in all months of the study except December, January, and February. Of the 502 alligator sightings, 61.2 percent were less than 1.5m in length. The greatest concentration of alligators was observed on the larger, managed impoundment, Cooperfield. This phenomenon was, to a degree, a function of that impoundment's proximity to a freshwater pond.

Summary

In conclusion, water-level manipulations that encourage both the growth of waterfowl food plants and waterfowl use provided favorable water level and habitat conditions to large influxes of other waterbirds. The high waterbird use of impoundments appears directly related to season, management of water levels, impoundment size, and resource availability. Coastal impoundments managed for brackish waterfowl food plants can provide desirable conditions for a variety of game and non-game wildlife.

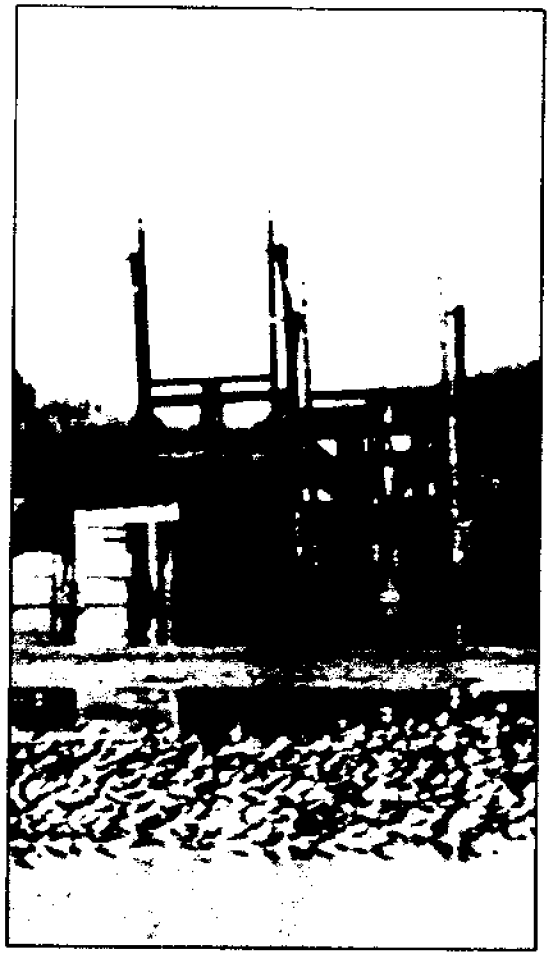


Photo: Marc Epstein

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SECTION V

IMPLICATIONS OF THE COASTAL WETLAND IMPOUNDMENT PROJECT

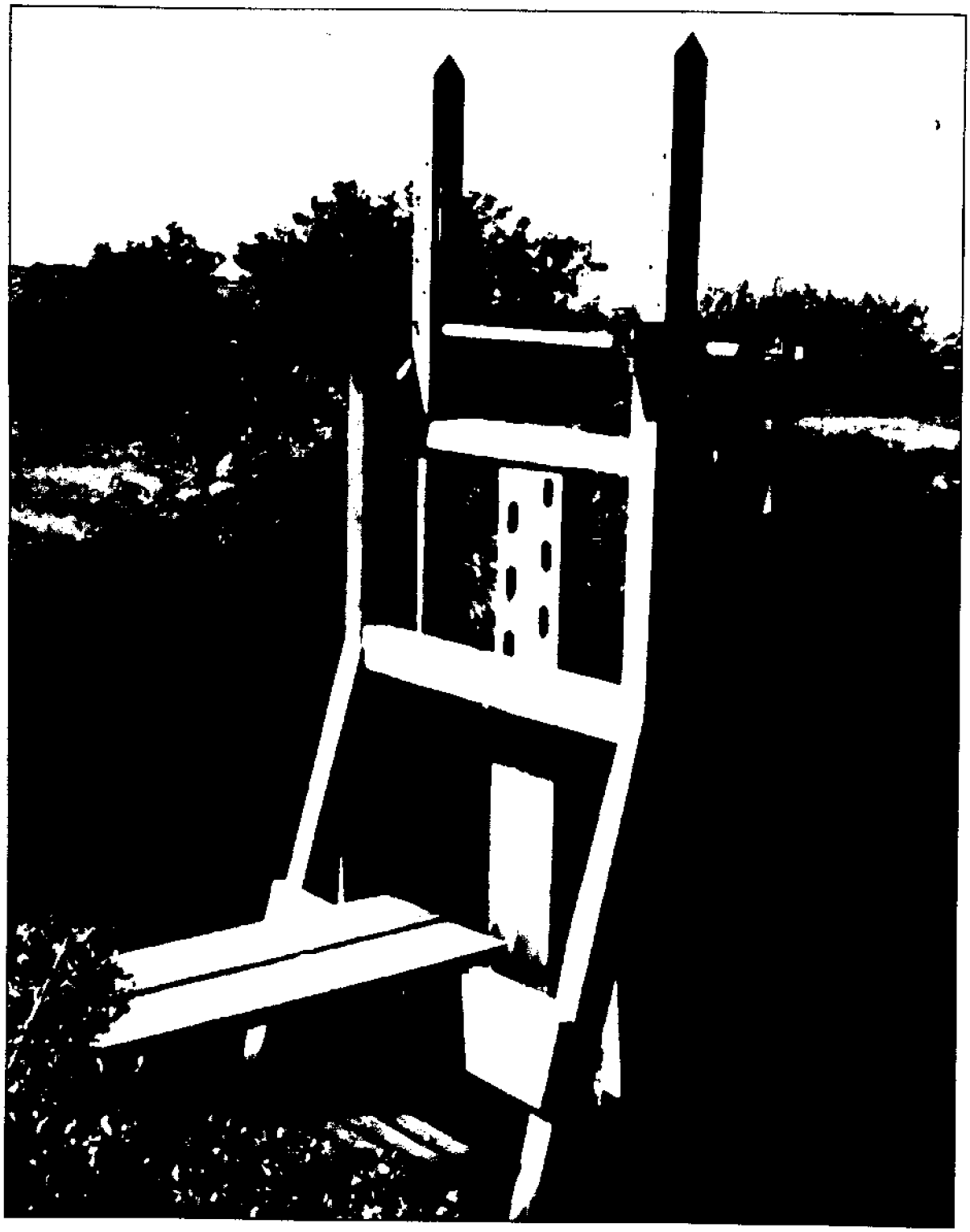

Photo: Rick DeVoe

Implications of Ecological Results

The CWIP examined the ecological characteristics of a set of brackish-water impoundments subjected to a single, but typical, waterfowl management strategy. The data derived from these studies are site specific, however, the general patterns observed may be applicable to a number of areas.

As a whole, the study area, comprising managed impoundments, tidal creeks, open wetlands, a remnant impoundment and small parcels of high ground, was documented to be an integrated and productive ecological system. The impoundments were important habitat areas for many species of waterbirds, reptiles, and other wildlife. The tidal creeks and wetlands served an equally important role, providing habitat for transient and resident species of crustaceans and fishes.

The two systems were different in regard to the overall community structure of several major biological components, but the basic ecological processes occurring in each were similar. However, certain species of macrobenthic invertebrates, crustaceans and fishes appear to be adversely impacted. The dikes and water control structures impeded the normal flow of tidal waters. This alteration interfered with migration patterns and produced undesirable hydrographic conditions for certain estuarine species.

It became apparent early in the study that the impoundment management strategy employed on-site played a significant role in the way the impoundment system functioned. From our data it is clear that the major differences observed in the two systems are, in fact, a function of water transfer effects. These effects are due primarily to tidal influences, water-level patterns, and the degree of water exchange between the two systems.

These general findings, although not unexpected, suggest that efforts to resolve the issues regarding impoundments in South Carolina should be focused, in the near-term, on the techniques and technology of management. It may be possible to minimize undesirable impacts and maximize favorable conditions in impoundments through calculated and tested management strategy manipulations.

Implications for Impoundment Management

Clearly, the management strategy is the primary influence on the functioning of impoundment systems. The general patterns illustrated by the ecological data, in combination with the results of the statewide impoundment survey, have provided a foundation for the several management improvements suggested below. It should be noted that these require field testing to assess their practical application and economic feasibility.

Enhancement of Impoundment Management for Target Species

The production of widgeon grass was the primary objective of the management program in the CWIP study impoundments. In 1983-84 the peak biomass of widgeon grass occurred in late summer. Although this peak in widgeon grass production may have been affected by the high temperatures and salinities, these results suggest that a better reflood process may yield the maximum production nearer to the migrating waterfowl season.

Managing impoundments for specific target species other than waterfowl has also been demonstrated. For example, penaeid shrimp can be selectively recruited into impoundments if flooding of the impoundment coincides with the period of maximum post-larval shrimp densities in the adjacent creek. To ensure shrimp survival, dissolved oxygen (DO) and temperature must be maintained above the minimum requirements. This can be accomplished by allowing for at least 10 percent water exchange per day. During good years, coastal brackish impoundments may produce between 50 and 100 kg/ha of naturally-occurring penaeid shrimp if there is successful recruitment of post-larval shrimp, and if adequate water exchange is maintained.

Additionally, slight modification to traditional waterfowl management programs -- staggered draining and flooding, different salinity situations, and varied cover conditions -- can provide favorable habitat to multiple non-game wildlife.

Enhancement of Water Quality Conditions

When water circulation is minimal in the summer, water quality conditions in impoundments may become stressful to many invertebrates and fishes, and widgeon grass. Low DO concentrations combined with high temperatures and salinities are the principle elements of this environmental stress. Results of the CWIP suggest that increased water circulation and exchange may reduce many of the adverse impacts. This may be accomplished in several ways: (1) a quick, partial drawdown and reflood process; (2) an adjustment of the flashboard riser and flapgates to permit daily tidal flushing; (3) an increase in bottom water circulation through the inside gate of the trunk; or, (4) a combination of all of the above.

Enhancement of Non-Target Organism Migration

Marine biologists are primarily concerned that impoundments present a barrier to normal recruitment and emigration of transient marine species that use wetland areas for a portion of their life cycle. The results of the CWIP suggest that this is indeed a valid concern. However, migrations may be improved by increasing bottom water circulation. This may be accomplished by allowing water exchange through the inside gate as opposed to the flashboard riser. Although this would not make impoundments as accessible to estuarine species as open tidal wetlands, proper intensive management of these impounded areas may provide adequate habitat for both wildlife and marine organisms.

Mosquito Production and Impoundment Management

Salt marsh mosquitoes lay their eggs on damp soil. The eggs hatch into larvae when the areas are flooded by heavy rains or tides. Consequently, conditions in brackish-water impoundments make them ideal for the production of large populations of mosquitoes.

Management of impoundments to minimize the production of mosquitoes should include two key practices. First, the impoundments must be set up to allow the beds to drain adequately into the perimeter ditches or canals. By doing so, waters containing mosquito larvae can be removed from the impoundment beds, making the larvae more accessible to predatory fish. In smaller impoundments this procedure may not be difficult; however, larger impoundments may require additional cross ditching and/or trunks to provide adequate drainage. Second, the management scheme should be designed to remove developing mosquito larvae during the reflood process. This procedure was employed during the CWIP, and involved a second flushing-reflood event soon after the major reflooding process to further reduce mosquito production in impoundments.

Topics Requiring Additional Research

The Coastal Wetland Impoundment Project has provided baseline information on the ecology of a brackish-water impoundment complex; an analysis of the current status of impoundment ownership, management, and use throughout the state; and an overview of suggested improvements for impoundment management. Nevertheless, a number of questions remain that require further exploration and study. The following suggestions for research were generated through numerous discussions with the CWIP investigators and technical advisors after a thorough review of CWIP results. These recommendations also include the issues that have surfaced since the initiation of the CWIP in 1982.

Hydrography

The results of the CWIP underscore the importance of impoundment hydrography (water movement) as a significant driving force in the system. However, since the majority of impoundments in South Carolina are larger than those studied, additional work is needed to determine how large systems are influenced by water circulation patterns. In addition, studies should examine the effects of water exchange and periodic flushing/ flooding events on water quality inside these larger systems and in adjacent water bodies. These studies should include an examination of the effects of periodic releases of large volumes of water from impoundments on water pH, nutrient levels, and DO concentrations.

Primary Production

Net aerial primary productivity (NAPP) of the emergent vegetation in the five impoundments examined under the CWIP was not significantly different from that of the adjacent open wetland area. Similarly, the total value of the three components of primary production (macrophyte vegetation, phytoplankton and microbenthic algae) in the impoundments was comparable to the adjacent open marsh. Further examinations of NAPP and total community primary production should be made for other impoundment systems to determine if they are similar to the Cat Island system. Additional studies of primary production might include the determination of underground biomass, turn-over rates, and detritus export. Addressing these questions would provide a better measure of how representative the results of the CWIP are to impoundment systems throughout South Carolina.

Evaluation of Other Management Strategies

The CWIP examined the ecological differences between open wetlands and brackish-water impoundments under one particular management scheme designed to attract waterfowl. Statewide, a variety of management schemes have been developed by managers to attract waterfowl and, more recently, for aquaculture purposes. Impact analyses of the more intensive schemes, especially those involving cultivation and/or burning, are lacking. The effects of these techniques may be significantly different from those observed during the CWIP. Their impacts on impoundment productivity and habitat utilization by aquatic species should be investigated.

Additional studies on the effects of management schemes to produce other target species, such as shrimp or crawfish, and multi-species management for both waterfowl and shrimp (and wildlife and fisheries resources), would also expand the existing base of knowledge.

Other management-related research should include studies to determine the feasibility of double-cropping widgeon grass; delaying the reflood process to produce a later crop of widgeon grass, or using multiple flushing to reduce mosquito production.

Water Exchange/Transfer Effects

Water circulation patterns appear to be the most significant factor responsible for the differences between the study impoundments and open wetlands. Results of the CWIP suggest that better water circulation between the two systems may reduce the differences observed and thus, create a more favorable habitat for certain aquatic species. Thus, future research should focus on investigations of methods for improving the amount and timing of water exchange. Studies should determine the optimal number, placement and design of impoundment water control structures to maintain adequate circulation and water quality. Additionally, the enhancement of circulation and drainage in larger impoundments may require crossditching and/or crossdiking. The costs and benefits of these modifications should also be established.

Above all, the investigation of management techniques to increase water exchange, both in volume (to maintain adequate water quality) and timing (to provide for the immigration and emigration of marine/aquatic species), is critical for the development of management protocols and the wise use of this valuable wetland resource.

Implications for Policy

The work of many scientists, lasting over the four years of the Coastal Wetland Impoundment Project (CWIP), has helped to clarify the problems and opportunities associated with wetland impoundments in South Carolina. As is often the case with carefully controlled scientific studies, this project answered some old questions, improved our understanding of some others, and identified new issues and areas of research. The CWIP confirms some common beliefs about the management of former ricefields, but it also raises new questions about current management practices.

As with any natural resource, the future of it depends as much on policy as scientific information. Until recently, the status of impoundment policy in S.C. was vague at best. However, a 1986 state Supreme Court ruling overturning a request for reimpoundment has deterred other impoundment owners from seeking permits to do the same. In this particular case, science was not a factor in the judgment. Nevertheless, based on that decision and the findings of the CWIP, it would seem that impoundment policy should focus on existing resources rather than on the restoration of formerly impounded lands.

A number of East and Gulf Coast states are faced with similar wetlands management issues. S.C. is well positioned to develop sound impoundment policy, not only for its own use, but for the benefit of other wetlands policy makers.

Water Transfer Effects

The ecological consequences of diking wetlands have been discussed in detail in the CWIP, and it appears that water transfer effects should shape the state's policies toward impoundments. The study clearly supports the need for intensive, on-site management to reduce these effects.

It would be desirable for the state of South Carolina to encourage impoundment managers to increase water exchange with the surrounding ecosystem. This exchange should improve water-quality conditions within impoundments, and thus reduce potential impacts on the estuarine environment. The state should not, however, concentrate on inflexible and detailed specification of management practices at this time.

The Practical World of Impoundments

The CWIP survey of the status of impounded wetlands along the coast reveals that many sites are being actively managed and used by those who claim them. The state of South Carolina has not challenged the continuation of current activities, nor does it appear likely to do so in the near future. On the other hand, other sites have fallen into disrepair and are now described by survey respondants as "formerly impounded." The costs of rediking, both economic and political, seem to rule out the reimpoundment of these sites any time soon. The number of sites needing only "repairs" to restore dikes and water-control structures to functional use appears relatively small.

Analysis of current management practices reveals an important opportunity for South Carolina. According to survey results, some impoundment owners managing for waterfowl habitat are using substandard techniques. Although precise management schemes for each site can not be confidently prescribed, general management principles for upgrading these systems have been identified. The best way to ensure consistent good management is to use the expertise of a wildlife manager. With the help of new scientific data, impoundment managers have an opportunity to improve their management practices, ultimately benefitting owners and the public at large.

The Information Problem

Although the CWIP is a comprehensive study, it can not be applied to all impoundments throughout the state. First, the study impoundments were much smaller than many that are operated along the coast, which may have made them easier to control and manage. Also, the study focused on only one style of waterfowl management, although other management strategies have been identified for waterfowl as well as aquaculture. Given the limitations of an expansive, comprehensive investigation, it seems clear that less-detailed "reconnaissance studies" are inadequate; relying on a few isolated observations of an otherwise unknown site cannot provide enough information about the ecological characterisitics of a particular site.

The CWIP did not concentrate on remnant impoundments; therefore, it's premature, without more informaton, to make policy recommendations about these systems. Understandably, those concerned with the impact diking has on water flow and exchange will want to know the effects of remnant dike structures on water circulation and natural processes. Such concerns may lead to state policies focusing not only on rediking, but also on "dediking", the removal of these remnant dikes. As it stands now, the impact of these structures is unknown.

Summary

The CWIP has increased understanding of the ecological characteristics of impoundments, but policy-makers must consider political elements as well.

The implications of this research for S.C.'s impoundment policy stems from the following conclusions:

1. Management of impoundments should focus on repair and maintenance of existing fields rather than on the reimpoundment of formerly impounded acres. This course of action seems only practical, considering the ramifications of a recent court decision overruling a request for reimpoundment.

2. According to survey results, only a small percentage of impoundments fall into the category needing repair and maintenance to function as productive units.

3. Given the scientific, economic and political issues surrounding impoundments, the state should focus on the management and repair of existing impoundments; however, a clearer definition of "repair" should be specified.

4. The state should encourage impoundment management practices which minimize water transfer effects. The CWIP studies show that better manipulation of water exchange between impoundments and adjacent natural wetlands will benefit the system, the owner, and the public.

Conclusions

How can the data and information generated by the CWIP be used in the decision-making process? First, these data will provide decision-makers with an idea of the trade-offs associated with a given decision. If the scientific community knows the specific questions being asked and is aware of the specific objectives, a fairly accurate response can be provided.

Second, CWIP information has broadened the existing data base available to agency staff, applicants, and other interested persons. For the first time, concurrent data exists on shrimp, crab, fish, waterbird, and alligator utilization of impoundments and adjacent open wetlands.

Third, information generated under the policy and management study should provide insight, for the first time, on the current distribution, condition, and ownership of impounded and formerly impounded wetlands throughout South Carolina. More importantly, it has provided information on how effectively impoundments are being managed.

Finally, information developed under the CWIP will provide a framework for at least partial resolution of the impoundment issue. Now that information has been synthesized, it can be used in the assessment of applications for re-impoundment and repair and maintenance activities in the future. Further, this same data can be used by Cooperative Extension and Marine Extension personnel, impoundment managers, and others to improve impoundment management techniques; to maximize the utilization of enclosed habitat; and to enhance migrations of fish and crustaceans while providing habitat for other game and non-game waterbirds.

Photo: Rick DeVoe