SCSGC-T-88-002 C2

South Carolina
Sea Grant Consortium

LOAN COPY ONLY

Working
Paper
Series

NATIONAL SEA GRANT DEPOSITORY
PELL LIBRARY BUILDING
URI, NARRAGANSETT BAY CAMPUS
NARRAGANSETT, RI 02882

CIRCULATING COPY
Sea Grant Depository

An activity of the South Carolina Sea Grant Consortium. This work is sponsored by the state of South Carolina and the NOAA National Sea Grant College Program Office, Department of Commerce, under Grant No. NA85AA-D-SG121.

The South Carolina Sea Grant Consortium
287 Meeting Street
Charleston, South Carolina 29401

SC-SG-TR-88-01

MANAGEMENT OF EXISTING COASTAL IMPOUNDMENTS IN SOUTH CAROLINA FOR SHRIMP CULTURE: PRODUCTION, WATER QUALITY, AND INCIDENTAL CATCH IN TWO IMPOUNDMENTS DURING 1985[1]

By

Eugene J. Olmi & Paul A. Sandifer
S.C. Wildlife & Marine Resources Department

Jack M. Whetstone, Clemson Univ. and South Carolina Sea Grant Extension Program

[1] Contribution Number 223 From The South Carolina Marine Resources Center

ABSTRACT

South Carolina possesses 204,300 ha of coastal marsh of which approximately fourteen percent is impounded, primarily for waterfowl management. In recent years, many impoundment owners have expressed interest in shrimp culture as an adjunct or alternative use of their impoundments. During 1985 two privately-owned impoundments (2.9 and 7.0 ha) in coastal South Carolina were managed to demonstrate proper management techniques and to document biological, physical, and chemical characteristics of impoundments managed for penaeid shrimp.

Impoundments were drained and treated with rotenone to eradicate potential predators and competitors of shrimp and then were flooded when postlarval white shrimp (*Penaeus setiferus*) were expected to be present in the adjacent estuary. Water quality parameters in each impoundment were monitored weekly until harvest. Also, during diurnal cycles in July and September, detailed changes in water quality were monitored every four hours. Seine samples were collected monthly, and impoundments were harvested by draining in October.

Natural tidal flushing was sufficient to maintain water quality parameters (temperature, salinity, dissolved oxygen, and pH) within acceptable limits for survival and growth of penaeid shrimp. Although initial densities of shrimp in impoundments were low, daily tidal flushing allowed recruitment of shrimp throughout the season (June–October). Extremely low yield of shrimp (0.64 kg/ha, mean weight 10.9 g) from one impoundment was attributed to a breach in the impoundment dike which allowed escapement of shrimp. The second

impoundment produced 56.8 kg/ha of shrimp (mean weight 22.6 g). Pink shrimp (P. duorarum) was most numerous (37.9 % of total), but white and brown (P. aztecus) shrimp each had greater biomass (41.7 and 49.9 % of total weight, respectively) than pink shrimp. Fishes were also recruited into impoundments during tidal flushing, and a minimum of thirty species of fish were collected from each impoundment. Fish biomass exceeded shrimp biomass by at least 3:1 at harvest and predation of shrimp by fishes may have been significant in reducing shrimp biomass.

Yields >100 kg/ha can not be expected regularly from impoundments because of natural fluctuations in shrimp abundance and predation within impoundments, but thousands of hectares of existing impoundments may be managed for shrimp production with little investment and only modest effort. Extensive management practices for shrimp need not preempt waterfowl management.

ACKNOWLEDGEMENTS

We thank the impoundment owners for their cooperation, assistance, and hospitality during this project, and we extend our appreciation to those people who assisted us during harvest operations, especially A. D. Stokes and K. F. Page. The assistance of M. H. Jones and K. R. Swanson in the preparation of this report is gratefully acknowledged. This project was supported by the South Carolina Sea Grant Consortium.

INTRODUCTION

South Carolina possesses approximately 204,300 ha of coastal marshes of which approximately 14 percent is currently impounded (Tiner, 1977). The primary management objective for nearly all of the impounded areas is improved waterfowl habitat; however, in recent years considerable interest has emerged for using those areas for aquaculture as an alternative to, or in conjunction with, waterfowl management. Several species offer potential for culture in coastal impoundments, but the most attractive species for brackish water impoundments are the penaeid shrimps (*Penaeus* sp.).

Extensive shrimp culture in the United States was pioneered by Lunz (1951, 1956, 1958 and 1968) with his work in impoundments in South Carolina. More recently, saltwater impoundments in the state have yielded up to 112 kg/ha of shrimp from extensive management (no supplemental stocking or feeding) (Whetstone et al., in press). Few owners of coastal impoundments, however, are cognizant of management techniques to improve penaeid shrimp production. Therefore, during 1985 we undertook a project to demonstrate proper management techniques for shrimp production in coastal impoundments and to assess the potential of such practices.

One criticism of waterfowl management practices in this state has been the degradation of water quality in impoundments which results in kills of all but the hardiest species. A recent study by McKellar (in press) has documented changes in water chemistry associated with certain waterfowl management practices. A secondary objective of our study was to document some of the biological, physical and chemical characteristics of impoundments managed for shrimp production.

METHODS AND MATERIALS

Two coastal brackish-water impoundments were selected for demonstration of extensive culture of penaeid shrimp. Impoundment A was located in Georgetown

County, South Carolina and had been initially constructed for rice cultivation. This 7.0 ha (17.3 acre) impoundment was rectangular with a central flat area surrounded by perimeter ditches. These ditches were less than 10 cm to approximately 150 cm lower than the central bed with a mean depth of 41 cm below the bed. Vegetation in impoundment A consisted of big cord grass (Spartina cynosuroides), which grew on the inner side of the containment dikes and along a shallow central ridge, and a sparse growth of widgeon grass (Ruppia maritima) on the central bed. Tidal exchange of water between the impoundment and the open estuarine system was through a wooden water control structure (86.4 x 91.4 cm opening) which regulated flow by opposite swing gates. A 1.25 cm mesh wire screen was placed over the outside opening. Minimum water level in the impoundment was regulated by a flashboard riser system. Water to flood impoundment A reached the site from the North Santee Bay via Minim Creek and the intracoastal waterway.

Impoundment B was located on Edisto Island in Charleston County, South Carolina. This impoundment had been created by the construction of an earthen dike across the upper reaches of an intertidal creek with its contiguous saltmarsh and was surrounded by existing high ground on three sides. The wetland area impounded was 2.9 ha (7.2 acres) of which 1.5 ha (3.7 acres) were Spartina alterniflora marsh. The bottom of the pond was irregular and was occasionally punctuated by clumps of live and dead oysters (Crassostrea virginica). Tidal exchange of water between impoundment B and the open estuary was through a 90 cm diameter culvert. The source of water for this impoundment was the South Edisto River via St. Pierre Creek and the lower reaches of the tertiary creek which extended to the site. Minimum water level in the impoundment was controlled by a flashboard riser system, and a 1.25 cm mesh screen at the top of the flash board riser filtered all inflowing and outflowing water.

Each impoundment was drained and the remaining water was treated with rotenone approximately one to two weeks prior to controlled flooding. A sample of the affected animals was collected by dipnets from each site for analysis of species composition.

Impoundment B was flooded on one tide from 1800h 3 June until 0115h 4 June. During flooding, four samples were collected with a 0.50 mm mesh plankton net to determine the initial density of penaeid shrimp. Initial flooding raised the impoundment water level to 86 cm above the mean level of the bottom. The sill level (top of the flashboard riser) was set such that, at the minimum water level, water exchanged with nearly every tide and depths in the impoundment ranged from 10 to approximately 200 cm with a mean depth of approximately 31.5 cm.

Impoundment A was flooded during four consecutive high tides on 20-22 June 1985. During the four flood periods a total of 10 samples were collected with a 0.50 mm mesh plankton net to determine the density of penaeid shrimps in the flood waters. Impingement of fish, crabs, and Spartina on the screen considerably slowed the rate of flooding the impoundment, especially during the two night periods, so that by the end of the four flood tides the water level had reached only 13.5 cm above the mean bed level. The sill level was set at 43.5 cm above mean bed level and the remainder of the flooding was not monitored. The sill level was lowered to 29 cm above mean bed level in August to drain off rainwater and increase circulation.

Following the initial flooding, water temperature, salinity, dissolved oxygen, and pH in each impoundment were monitored weekly. In impoundment A readings were taken at the surface and bottom next to the water control structure. In impoundment B readings were taken between 0800-1230h at the surface and bottom next to the culvert and in the shallows at the corner of the impoundment. Water temperature was measured with a stem thermometer; salinity was measured with a hand held refractometer; dissolved oxygen was measured with a YSI Scientific model 57 portable dissolved oxygen meter (impoundment B) or by the Winkler titration method (impoundment A); and pH was estimated with a bicolor pH test kit.

Once in July and September water temperature, salinity and dissolved oxygen were measured every four hours over a 24 hour period in both impoundments. These readings were collected 18-19 July and 16-17 September in impoundment A and 22-23 July and 17-18 September in impoundment B. In addition to the weekly sampling stations, water quality in the shallow perimeter ditch opposite the water control structure of impoundment A was monitored during diurnal sampling. A Ryan model H-30 automatic recording thermograph was placed in the back ditch of impoundment A following the initial filling of this impoundment.

Three plankton (0.50 mm mesh) samples were collected during night flood waters at impoundment A on 18-19 July and at impoundment B 22-23 July to determine if penaeid shrimp recruitment into the impoundments was continuing.

Shrimp populations in each impoundment were sampled monthly July through September. During sampling a nine mm bag seine was pulled through a section of a perimeter ditch in each impoundment, and a five foot diameter cast net was used to sample areas of the impoundments outside the ditches. Captured penaeid shrimp were identified to species, counted, measured for total length and returned to the impoundment. Other organisms collected in seine hauls were also identified and enumerated.

Impoundment A was harvested 15-19 October during seven low tide periods. Water was drained out of the impoundment through a 4.4-cm (1.75-in.) mesh tri-net with 3.75-cm (1.5-in.) mesh bag. The bag was emptied at least once during each outflow period. Because of a breach in the dike the impoundment could not be drained completely, and one pull of the nine-mm mesh bag seine was made to assess the remaining shrimp population. All organisms were identified and the total weight of each species was recorded. Captured penaeid shrimps were identified to species, enumerated and measured for total length.

Impoundment B was harvested 24 October 1985, 142 days after flooding. During one low tide, water from the impoundment was drained through a 12.5-mm mesh trawl with a 6.6-mm mesh bag. A nine-mm mesh bag seine was pulled repeatedly through two large scour depressions in the impoundment that did not completely drain. Total weights of shrimp, crabs, and fish were recorded. A subsample (9.4% by weight) of penaeid shrimps was returned to the laboratory where the shrimps were identified to species, enumerated, measured for total length, and weighed to the nearest 0.1 g. A list of organisms in the harvest was prepared from on-site observations (supported by lab identification of some individuals); however, the list may not reflect all of the species present in the impoundment.

For samples in which only shrimp total lengths were recorded, individual weights were estimated from length-weight regressions equations provided by Fontaine and Neal (1971).

RESULTS

Rotenone Samples

Dipnet collections from impoundment A following its draining and the application of rotenone were numerically dominated by Atlantic menhaden (*Brevoortia tyrannus*), spot (*Leiostomus xanthurus*), rainwater killifish (*Lucania parva*) and silversides (*Menidia* sp., probably *M. beryllina*) (Table 1). A small percentage (<1%) of the total number of affected animals were collected, and on-site observation indicated that menhaden and striped mullet (*Mugil cephalus*) were underrepresented in the sample. Several of the species collected are known to prey upon juvenile penaeid shrimp (e.g. pinfish [*Lagodon rhomboides*], weakfish [*Cynoscion regalis*], ladyfish [*Elops saurus*] and southern flounder [*Paralichthys lethostigma*]). The presence of juvenile brown shrimp (*Penaeus* aztecus, N=13) in the dipnet collections indicated previous recruitment of this species.

Approximately 30-40 percent of the affected animals observed in impoundment B following the application of rotenone were collected. This sample was dominated by spot and the mummichog (Fundulus heteroclitus) (Table 2). Potential shrimp predators in this sample included pinfish, ladyfish, mummichog and southern flounder. Juvenile brown shrimp were also present (N=45) in the rotenone sample from impoundment B.

Shrimp Recruitment

Nine plankton samples collected during the flooding of impoundment A, were used for estimates of initial shrimp densities. Volumes filtered per sample ranged from 30.0 m^3 to 127.8 m^3, and a total of 576.0 m^3 was filtered during the nine sets of the net. A total of eight penaeid shrimp were collected in the nine samples. The number of individuals and mean density (shrimp per 1000 m^3 of water) of each species were: six Penaeus duorarum, 10.1/1000 m^3; one Penaeus setiferus, 2.6/1000 m^3; and one Trachypenaeus constrictus, 0.9/1000 m^3. Except for one juvenile (20.1 mm TL) T. constrictus, these shrimps were postlarval stages (7.7-11.2 mm TL). Assuming the impoundment filled to the initial sill level (43.5 cm average depth), the estimated initial density (shrimp per m^2 of bottom area) of shrimps in the impoundment were: P. duorarum, $4.8 \times 10^{-3}/m^2$; P. setiferus, $1.2 \times 10^{-3}/m^2$; T. constrictus, $0.41 \times 10^{-3}/m^2$.

Four plankton samples collected during the initial flooding of impoundment B filtered a total of 857.7 m^3 of water (159.4-245.3 m^3 per set) and caught 12 penaeid shrimp. The number of individuals and mean density of each species were: five P. aztecus, 5.7/1000 m^3; five P. duorarum, 6.2/1000 m^3; one P. setiferus, 1.6/1000 m^3; and one T. constrictus, 1.0/1000 m^3. Three of the five P. aztecus and the one T. constrictus were juveniles and the rest of the shrimp were postlarval stages (6.5-15.1 mm TL). The impoundment initially filled to a mean depth of 86 cm resulting in initial shrimp densities (shrimp per m^2 of impoundment bottom) of P. aztecus, $6.6 \times 10^{-3}/m^2$; P. duorarum, $7.3 \times 10^{-3}/m^2$; and T. constrictus, $1.2 \times 10^{-3}/m^2$.

Three plankton samples collected in the inflow of impoundment A on 18-19 July captured one subadult P. aztecus and one postlarval P. setiferus at a mean density for each of 5.06/1000 m^3. Three samples of the inflow water at impoundment B on 22-23 July contained a total of 14 postlarval P. duorarum at a mean density of 83.2/1000 m^3 of inflowing water.

Water Conditions

Weekly observations in impoundment A indicated that bottom water temperature increased from a low of 17.5 C the week after flooding to a maximum of 32.0 C in August (Fig. 1, App. 1), while surface water temperature reached a maximum of 35.5 C. Water salinity remained between 17 and 20 parts per thousand (ppt) during June and July, dropped to a low of 6 ppt following passage of a hurricane during August, and then increased to 14 ppt by October. Bottom dissolved oxygen (DO) levels recorded weekly varied between 3 and 7 mg/l with a mean of 4.7 mg/l, and surface readings varied from 5-16 mg/l (Fig 1, App. 1). There were only slight variations in pH levels throughout the study (7-9). During 24 hour monitoring at impoundment A in July and September, the variation in temperature and salinity was $\leq$4.6 C and <3 ppt respectively, at all sampling locations (Fig. 2, Appendix 2). Dissolved oxygen levels, however, ranged from 3.1 mg/l to greater than 20 mg/l in July and from 4.0 to 10.4 mg/l in September. At the base of the water control structure DO levels varied from 5.2 to 7.9 mg/l in July and 4.3 to 7.6 mg/l in September (Fig. 2). The minimum change in average depth over the beds was 8.0 cm in July and 10.5 cm in September which correspond to tidal exchange of approximately 16-19 percent of the impoundment volume per tidal cycle. The automatic recording thermograph that was placed in the ditch opposite the water control structure operated from 22 to 26 June and from 20 July to 2 August. Minimum and maximum temperatures recorded by the thermograph were 25.2 and 36.5 C. Daily temperature ranges during these 19 days were 0.9 to 7.7 C with a mean daily range of 3.7 C.

Readings of water temperature and salinity in impoundment B rarely varied more than 2 C or 1 ppt among the three sampling sites. Water temperature, recorded during weekly observations, reached a high of 33.1 C in August and a low of 20.1 C in early October (Fig. 1; Appendix 3). Water temperatures at the base of the culvert ranged from 21.8 to 31.6 C during the study with a mean of 27.0 C. Salinities in this impoundment were between 20.0 and 32.0 ppt, with the exception of a low reading of 13.0 ppt from the surface waters of the ditch after rainfall (Appendix 3). Weekly readings of dissolved oxygen were 3.3-10.3 mg/l with a mean DO reading of 5.7 mg/l at the base of the culvert. Only minor variations in pH (7.8-8.0) were detected in impoundment B during the study. Water conditions in impoundment B showed little change during 24-hour monitoring in July and September (Fig. 2, Appendix 4). The minimum dissolved oxygen readings were 3.2 mg/l at the base of the culvert in July and 4.4 mg/l at the edge of the ditch in September. The minimum changes in water level in impoundment B during the two 24-hour monitoring periods were 22 cm in July and 32 cm in September which correspond to water exchanges of approximately 55-63 percent of the impoundment volume.

Seine and Harvest

Impoundment A was harvested 15-19 October (grow-out duration, 118 days), and 4.5 kg (0.6 kg/ha) of shrimp, 159.6 kg (22.8 kg/ha) of fishes, and 25.7 kg (3.7 kg/ha) of blue crabs (*Callinectes sapidus*) were collected (Table 3). Pink shrimp (*P. duorarum*) comprised 52.9% of the total number of shrimp collected, but white shrimp (*P. setiferus*) accounted for 57.9% of the total shrimp weight. Only eight brown shrimp were collected representing 2.6% of the total number and

3.1% of the total weight. Mean sizes of white and pink shrimp at harvest were 120.6 mm TL (13.7 g) and 98.9 mm TL (8.7 g), respectively (Table 4). Twenty-five species of fishes were collected during monthly seine sampling and harvest (Table 5). Fish species with greatest biomass at harvest were spot (Leiostomus xanthurus, 86.3 kg), weakfish (Cynoscion regalis, 23.9 kg) ladyfish (Elops saurus, 19.3 kg) and croaker (Micropogonias undulatus, 13.27 kg).

Impoundment B was harvested 24 October (142 days after initial flooding) and 80.1 kg (56.8 kg/ha) of shrimps, 263.5 kg (186.9 kg/ha) of fishes and 3.4 kg (2.4 kg/ha) of blue crabs were collected (production estimates based on bottom area that was constantly flooded) (Table 3). The weight of the subsample of shrimp was 7.6 kg or 9.4% of the total. Of the three species, pink shrimp were the most numerous (37.9%), but contributed the least weight (8.5%) to the total. The mean size of pink shrimp at harvest was 81.9 mm TL and 5.0 g (Table 6). Brown shrimp comprised 34.0% by number and 49.9% by weight of the shrimp harvest. Mean size of brown shrimp increased each month of sampling and was 154.1 mm TL and 32.8 g at harvest (Table 6). White shrimp made up 28.1% of the total number and 41.7% of the total weight of the shrimp harvest. White shrimp achieved the greatest mean size (161.1 mm TL, 33.2 g) and exhibited the most uniform size structure at harvest (Table 6). The presence of small shrimp in monthly samples indicated that recruitment of all three species continued throughout the summer (Tables 4, 6).

Twenty-nine fish species and eight species of invertebrates were recorded at the harvest of impoundment B (Table 7). Penaeid shrimps were the dominant invertebrates. We estimated that the five most abundant fishes were silver perch (Bairdiella chrysura), mojarras (Eucinostomus sp.), mummichog (Fundulus heteroclitus), spot (Leiostomus xanthurus) and sailfin molly (Poecilia latipinna); and the five fish species which dominated by weight were silver perch, spotted sea trout (Cynoscion nebulosus), lady fish (Elops saurus), spot, and striped mullet (Mugil cephalus).

DISCUSSION

Our approach to maximize the shrimp harvest from two coastal impoundments involved the following procedures: 1) removing predators and competitors prior to controlled flooding, 2) flooding the impoundments during a period of high abundance of postlarval white shrimp in the estuary, 3) maintaining water levels in the impoundments which would allow daily tidal exchange (for water quality and additional shrimp recruitment), and 4) excluding predatory fishes while providing containment of shrimp by screening inflow and outflow.

The shrimp harvest from impoundment A was totally unsuccessful (4.5 kg; 0.64 kg/ha) and was far below the 64 kg/ha which had been harvested from this impoundment in 1983. The major factor influencing the poor harvest in impoundment A was a breach in the dike that was not noticed until the harvest operation. The breach was sufficiently large for shrimps and fishes to have moved out of the impoundment during the season. Also, the breach allowed water to enter and we were unable to completely drain the impoundment for harvesting. Having attempted to drain the pond during seven low tide periods, we pulled a seine through a section of the perimeter ditch and recovered only five shrimp. Because this impoundment was not easily seined and there appeared to be only a small population of shrimp, the harvest effort was abandoned. Thus, the 4.5 kg of shrimp recovered probably do not represent the actual shrimp production level which occurred during the growing season. Impoundment B produced 80.08 kg (56.8 kg/ha) of shrimp, slightly less than the 82.6 kg which were harvested the proceeding season. These harvests are within the range of values typically cited for such management (Lunz, 1958; Rose et al., 1975). Of the 80.08 kg of shrimp collected from impoundment B this season, 91% was comprised of large (mean weight 33g) brown and white shrimp, which command a high value.

White shrimp were targeted as desired species for "stocking" because of its typical abundance in this area and its adaptability for pond culture. Unfortunately, the 1985 white shrimp season was little better than the 1984 season which was considered an economic disaster, and few postlarvae were recruited at the initial filling of either impoundment. Brown shrimp were present in both impoundments prior to controlled flooding, and probably most of the 39.9 kg of brown shrimp which were harvested from impoundment B were from this initial stock. (Although brown shrimp were collected in dip net samples following the application of rotenone, shrimp are generally less susceptible than fish to rotenone poisoning and it is likely that most survived the treatment.) Minimum shrimp sizes in monthly samples indicated that recruitment occurred throughout most of the season, and pink shrimp, which generally recruit later than its congeners (Williams 1955; Bearden, 1961; Olmi, 1986), numerically dominated the shrimp catch in both impoundments. Thus, it appears that by maintaining sufficient water exchange (>10%/day), "continuous recruitment" can be effected. Late recruits, however, have a shorter period for growth before harvest and probably face intense predation within the impoundment. Flooding of the impoundments earlier in the season (March or April) would facilitate recruitment of brown shrimp. Then later in the season, when white shrimp are abundant, the water level in the impoundment could be lowered to allow for increased inflow. Attempts to flood impoundments for shrimp should be concentrated during dusk and at night when shrimp are generally more available (Williams and Deubler, 1968; Olmi, 1986).

Tidal water exchange was sufficient to prevent degradation of water conditions, and water quality did not appear to be a factor limiting shrimp production in either impoundment. Temperature, salinity, dissolved oxygen and pH remained within acceptable levels for penaeid shrimp, although the decline in salinity to six ppt in impoundment A during August may have stressed subadults.

The high diversity of fishes present in both impoundments (including several intolerant of low D.O.) also indicates that water quality did not diminish to lethal levels during the study. If larger impoundments are used, however, a single source of water exchange may not be adequate.

Predation of shrimps by fishes may have been an important factor in reducing numbers of shrimp in the impoundments. Fish biomass exceeded shrimp biomass by at least 3:1, and many of the spotted sea trout, weakfish and ladyfish which were collected during harvest exceeded 200 cm in length and were capable of feeding on juvenile shrimp (during 1984 several spotted sea trout and lady fish from impoundment B contained juvenile pink shrimp; Olmi, personal observation). Screening of the inflow water apparently did little to exclude unwanted fishes. Lunz and Bearden (1963) noted that shrimp harvests were not appreciably different between ponds with or without screens. Most of the movement of fishes into impoundments appears to occur during postlarval and early juvenile stages (McGovern, 1986). Screens which would exclude these fishes would also exclude immigrating shrimp. Rose et al. (1975) collected 41 species of fishes from impoundments in Louisiana which were managed for shrimp and considered predation to be significant. Efforts to control predators and competitors by screening inflow and the use of fish poisons resulted in a more than three-fold increase in the shrimp harvest (48.2 kg/ha v. 141.2 kg/ha; Rose et al., 1975). Control of predaceous fishes may be necessary if harvests >100 kg/ha of shrimp are to be expected; however, we hesitate to encourage the widespread use of fish poisons in tidally flushed impoundments. Previous harvests from these two impoundments contained a greater proportion of shrimp than did the 1985 season. For example, 64 kg/ha of shrimp and 16 kg/ha of fish were harvested from impoundment A during 1983, and impoundment B yielded 52.3 kg/ha of shrimp and 58.5 kg/ha of fish during the 1984 season. Although blue crabs and fishes probably resulted in decreased shrimp yields, blue crabs were harvested (by trap) throughout the season and many of the spot, flounder, sea trouts and other fishes that were recovered at harvest were of marketable size.

Conclusions

Coastal impoundments in South Carolina offer potential for extensive shrimp culture, but yields >100 kg/ha can not be expected regularly because of natural fluctuations in shrimp abundance and predation within the impoundments. Methods of predator/competitor control may increase shrimp yields, but the widespread use of fish poisons in tidally flushed impoundments should not be encouraged. Although shrimp production from coastal impoundments is generally low, thousands of acres of existing impoundments may be managed for shrimp with little (if any) capital investment and only modest effort. Management for shrimp need not preempt waterfowl management and it is believed that impoundments can be managed to achieve both objectives. Increased management efforts for shrimp (e.g., supplemental stocking, feeding, and aeration) may enhance yields, but are not compatible with waterfowl management and are probably not cost-effective in large impoundments.

LITERATURE CITED

Bearden, C. M. 1961. Notes on postlarvae of commercial shrimp (Penaeus) in South Carolina. Contrib. Bears Bluff Lab., No.33.

Fontain, C. T. and R. A. Neal. 1971. Length-weight relations for three commercially important penaeid shrimp of the Gulf of Mexico. Trans. Amer. Fish. Soc. 100:584-586.

Lunz, G. R. 1951. A salt water fish pond. Contr. Bears Bluff Lab. No. 12.

Lunz, G. R. 1956. Harvest from an experimental one-acre saltwater pond at Bears Bluff Laboratories, South Carolina. Prog. Fish Culture. 18(2):92-94.

Lunz, G. R. 1958. Pond Cultivation of shrimp in South Carolina. Proc. Gulf Caribb. Fish. Inst. 10:44-48.

Lunz, G. R. 1968. Farming the saltwater marshes, pp.172-177, In J.D. Newsom, ed. Proceedings of the marsh and estuary management symposium. La. State Univ., Baton Rouge.

Lunz, G. R. and C. M. Bearden. 1963. Control of predaceous fishes in shrimp farming in South Carolina. Contr. Bears Bluff Lab. 36:1-8.

McGovern, J. C. 1986. Seasonal recruitment of larval and juvenile fishes into impounded and non-impounded marshes. M.S. Thesis. The College of Charleston, Charleston, SC.

McKellar, H. N. In press. Nutrient Exchanges. Chapter 6, In: DeVoe, M. R. and D. S. Baughman (eds), South Carolina Coastal Impoundments: Ecological Characterizations, Management, Status, and Use. Vol. II. Publ. No. SC-SG-TR-86-2. South Carolina Sea Grant Consortium, Charleston, S. C.

Olmi, E. J., III. 1986. Factors affecting the abundance of penaeid shrimps in macroplankton samples from open and impounded brackish marsh systems in South Carolina. M.S. Thesis. The College of Charleston, Charleston, S.C. 95 p.

Rose, C. D., A. H. Harris and B. Wilson. 1975. Extensive culture of penaeid shrimp in Louisiana saltmarsh impoundments. Trans. Amer. Fish. Soc. 104(2):296-307.

Williams, A. B. 1955. A contribution to the life histories of commercial shrimps (Penaeidae) in North Carolina. Bull. Mar. Sci. Gulf Caribb. 5:116-146.

Williams, A. B. and E. E. Deubler. 1968. A 10 year study of meroplankton in North Carolina estuaries: assessment of environmental factors and sampling success among bothid flounders and penaeid shrimps. Chesapeake Sci. 9:27-41.

Whetstone, J. M., E. J. Olmi III and P. A. Sandifer. In press. Extensive culture of penaeid shrimp in coastal impoundments in South Carolina (abstract). J. Shellfish Res.

Table 1. List of fish species collected by dip-net after draining and applying rotenone to impoundment A on 13 June 1985. Lagodon rhomboides and Anguilla rostrata were observed on site, but were not collected.

SPECIES	NUMBER	PERCENT BY NUMBER	WEIGHT (g)	PERCENT BY WEIGHT
Brevoortia tyrannus	93	20.7	1183	20.7
Leiostomus xanthurus	93	20.7	287	13.3
Lucania parva	86	19.2	24	1.1
Menidia sp.	81	18.0	32	1.5
Mugil cephalus	23	5.1	205	9.5
Micopogonias undulatus	23	5.1	94	4.4
Elops saurus	10	2.2	89	4.1
Fundulus heteroclitus	8	1.8	5	0.2
Poecilia latipinna	7	1.6	16	0.7
Gambusia affinis	6	1.3	1	0.1
Cyprinodon variegatus	6	1.3	7	0.3
Paralichthys lethostigma	4	0.9	179	8.3
Cynoscion regalis	3	0.7	2	0.1
Bairdiella chrysura	2	0.4	2	0.1
Eucinostomus sp.	2	0.4	1	0.1
Evorthodus lyricus	1	0.2	1	0.1
Dorosoma petenense	1	0.2	29	1.3
Lagodon rhomboides	--		--	
Anguilla rostrata	--		--	

Table 2. List of fish species collected with dip-net after draining and applying rotenone to impoundment B on 21 May 1985.

SPECIES	NUMBER	PERCENT BY NUMBER	WEIGHT (g)	PERCENT BY WEIGHT
Leiostomus xanthurus	879	78.6	1389	72.8
Fundulus heteroclitus	149	13.3	324	17.0
Brevoortia tyrannus	18	1.6	41	2.1
Mugil cephalus	18	1.6	62	3.3
Elops saurus	11	1.0	9	0.5
Gambusia affinis	11	1.0	6	0.3
Microgobius thalassinus	8	0.7	5	0.3
Menidia beryllina	6	0.5	8	0.4
Poecilia latipinna	5	0.4	7	0.4
Gobiosoma bosci	5	0.4	3	0.2
Symphurus plagiusa	2	0.2	3	0.2
Paralichthys lethostigma	2	0.2	31	1.6
Micropogonias undulatus	1	0.1	3	0.2
Lagodon rhomboides	1	0.1	3	0.2
Mugil curema	1	0.1	1	0.1
Paralichthys dentatus	1	0.1	12	0.6

Table 3. Total weight of penaeid shrimps, blue crab, and fishes harvested from impoundments A and B during October 1985.

Impoundment A	kg	kg/ha
Brown shrimp	0.1	< 0.1
Pink shrimp	1.8	0.2
White shrimp	2.6	0.4
Blue crab	25.7	3.7
Fishes	159.6	22.8

Impoundment B	kg	kg/ha
Brown shrimp	40.0	28.3
Pink shrimp	6.8	4.8
White shrimp	33.4	23.7
Blue crab	3.4	2.4
Fishes	263.5	186.9

Table 4. Number, mean length, and predicted mean weight of *Penaeus aztecus*, *Penaeus duorarum*, and *Penaeus setiferus* collected during monthly seine sampling (July, August, and September) and harvest (October) at impoundment A.

MONTH	SPECIES	N	TOTAL LENGTH (mm) MEAN	MIN	MAX	SD	WEIGHT* (g) MEAN	MIN	MAX	SD
July	*Penaeus aztecus*	3	112.0	110	115	2.7	11.0	10.5	11.9	0.8
July	*Penaeus duorarum*	1	32				0.3			
July	*Penaeus setiferus*	3	47.7	40	54	7.1	0.6	0.3	0.9	0.3
August	*Penaeus aztecus*	0								
August	*Penaeus duorarum*	6	74.0	63	79	5.7	3.6	2.2	4.3	0.7
August	*Penaeus setiferus*	14	99.4	68	119	13.2	7.0	1.9	11.8	2.6
September	*Penaeus aztecus*	1	62				1.9			
September	*Penaeus duorarum*	1	56				1.5			
September	*Penaeus setiferus*	21	117.6	69	142	21.0	12.6	2.0	21.0	5.6
October	*Penaeus aztecus*	8	103.0	82	119	11.2	8.9	4.4	13.2	2.7
October	*Penaeus duorarum*	162	98.9	68	123	9.0	8.7	2.7	16.5	2.4
October	*Penaeus setiferus*	138	120.6	65	171	20.7	13.7	1.7	38.5	7.0

*Mean weights were predicted from length - weight regression equations given by Fontain and Neal (1971).

Table 5. List of species collected from impoundment A during monthly seine sampling (July, August, and September) and harvest (October).

SPECIES NAME	JULY		AUGUST		SEPTEMBER		OCTOBER	
	TN	TW	TN	TW	TN	TW	TN	TW
Anchoa mitchilli	300+	--	858	--	p			
Anguilla rostrata			3	--				
Archosargus probatocephalus							3	0.51
Bairdiella chrysura			1	--			p	2.10
Brevoortia tyrannus							p	1.42
Callinectes sapidus			1	--			p	25.7
Citharichthys sp.							8	0.14
Cynoscion nebulosus	1	--			3	--	2	0.23
Cynoscion regalis	7	--	17	--	4	--	p	23.9
Elops saurus			1	--			p	19.3
Eucinostomus sp.					p	--	p	1.45
Gobionellus hastatus			4	--	p	--		
Gobiidae					p	--		
Lagodon rhomboides	5	--					p	4.79
Leiostomus xanthurus	10	--					p	86.3
Megalops atlanticus							4	0.82
Mendia cf. M. beryllina			21	--	p	--		
Micropogonias undulatus	7	--					p	13.3
Mugil cephalus							4	0.39
Palaemonetes sp.	p	--	p	--	p	--	p	--
Paralichthys lethostigma	1	--					8	3.49
Penaeus aztecus	3	--			1	--	8	0.14
Penaeus duorarum	1	--	6	--	1	--	164	1.76
Penaeus setiferus	3	--	14	--	21	--	130	2.61
Poecilia latipinna			2	--				
Pogonias cromis			1	--			3	1.02
Prionotus sp.							15	0.48
Selene vomer							1	0.03
Stellifer lanceolatus			1	--				
Symphurus plagiusa			2	--	p	--	1	0.03

TN total number collected of each species
TW total weight (kg) of each species
p species present, but number was not recorded
-- species present, but weight was not recorded

Table 6. Number, mean lengths, and mean weights of *Penaeus aztecus*, *P. duorarum*, and *P. setiferus* collected during monthly seine sampling (July, August and September) and harvest (October) at impoundment B.

MONTH	SPECIES	N	TOTAL LENGTH (mm) MEAN	MIN	MAX	SD	WEIGHT[1] (g) MEAN	MIN	MAX	SD
July	*Penaeus aztecus*	63	112.2	70	158	26.0	13.5	2.7	35.4	8.8
July	*Penaeus duorarum*	13	75.0	48	94	14.6	4.1	1.0	7.3	2.1
July	*Penaeus setiferus*	1	74				2.5			
August	*Penaeus aztecus*	60	140.5	94	166	15.7	22.2	6.6	35.1	6.8
August	*Penaeus duorarum*	31	76.2	38	110	17.7	4.5	0.5	11.8	2.8
August	*Penaeus setiferus*	15	138.0	95	173	20.7	20.6	5.7	39.9	9.0
September	*Penaeus aztecus*	29	151.5	135	174	12.5	27.3	19.1	40.2	6.7
September	*Penaeus duorarum*	13	54.9	32	96	21.4	2.1	0.3	7.8	2.3
September	*Penaeus setiferus*	25	156.9	142	171	7.0	29.3	21.0	38.5	4.2
October	*Penaeus aztecus*[2]	115	154.1	88	182	19.2	32.8	5.5	54.5	11.9
October	*Penaeus duorarum*[2]	128	81.9	48	130	16.1	5.0	1.1	20.3	3.5
October	*Penaeus setiferus*[2]	95	161.1	71	185	13.9	33.2	2.2	47.5	7.0

[1]Weights of shrimp collected July-September were calculated from regression equations given by Fontain and Neal (1971).

[2]Subsample

Table 7. List of species collected during monthly seine sampling (July, August, and September) and harvest (October) from impoundment B. Some species may have been overlooked during harvest.

SPECIES NAME	JULY‡		AUGUST		SEPTEMBER		OCTOBER	
	TN	TW	TN	TW	TN	TW	TN	TW
Anchoa hepsetus			8	—	3	—	p	—
Anchoa mitchilli			52	—	48	—	p	—
Anguilla rostrata			1	—			p-M	—
Archosargus probatocephalus							p	—
Bairdiella chrysura			5	—	81	—	p-D	D
Brevoortia tyrannus							p-M	—
Callinectes sapidus			3	—			p	3.40
Callinectes similis							p-M	—
Caranx hippos							p-M	—
Chaetodipterus faber							p-M	—
Chasmodes bosquianus							p-M	—
Citharichthys sp.							p-M	—
Cynoscion nebulosus			1	—			p	D
Cynoscion regalis					6	—	p	—
Diapterus auritus							p-M	—
Elops saurus					1	—	p	D
Eucinostomus sp.			11	—	18	—	p-D	—
Fundulus heteroclitus					2	—	p-D	—
Gobionellus hastatus							p-M	—
Leiostomus xanthurus					4	—	p-D	D
Lolliguncula brevis			4	—			p	—
Lutjanus griseus							p-M	—
Megalops atlanticus							p-M	—
Mugil cephalus							p	D
Opsanus tau							p-M	—
Orthopristis chrysoptera							p	—
Palaemonetes sp.			p	—	p	—	p	—
Panopeus herbstii							p-M	—
Penaeus aztecus	63	0.85*	60	1.33*	29	0.79*	1218	39.9
Penaeus duorarum	13	0.05*	31	0.14*	13	0.03*	1356	6.8
Penaeus setiferus	1	<.01*	15	0.31*	25	0.73*	1006	33.4
Poecilia latipinna							p-D	—
Pogonias cromis							p-M	—
Squilla empusa							p-M	—
Syngnathus louisianae							p-M	—
Symphurus plagiusa					1	—	p-M	—
Synodus foetens							p-M	—

‡ penaeid shrimp only recorded from July sample
TN total number of each species collected
TW total weight (kg) of each species collected
p species present, but number was not recorded
— species present, but total weight was not recorded
M minor abundance; probably less than ten individuals in sample
D dominant;estimated to be one of top five fish species by number or weight
* total weight calculated from individual weights predicted by length-weight regression equations given by Fontain and Neal (1971).

Figure 1. Weekly water quality parameters for Impoundments A and B.

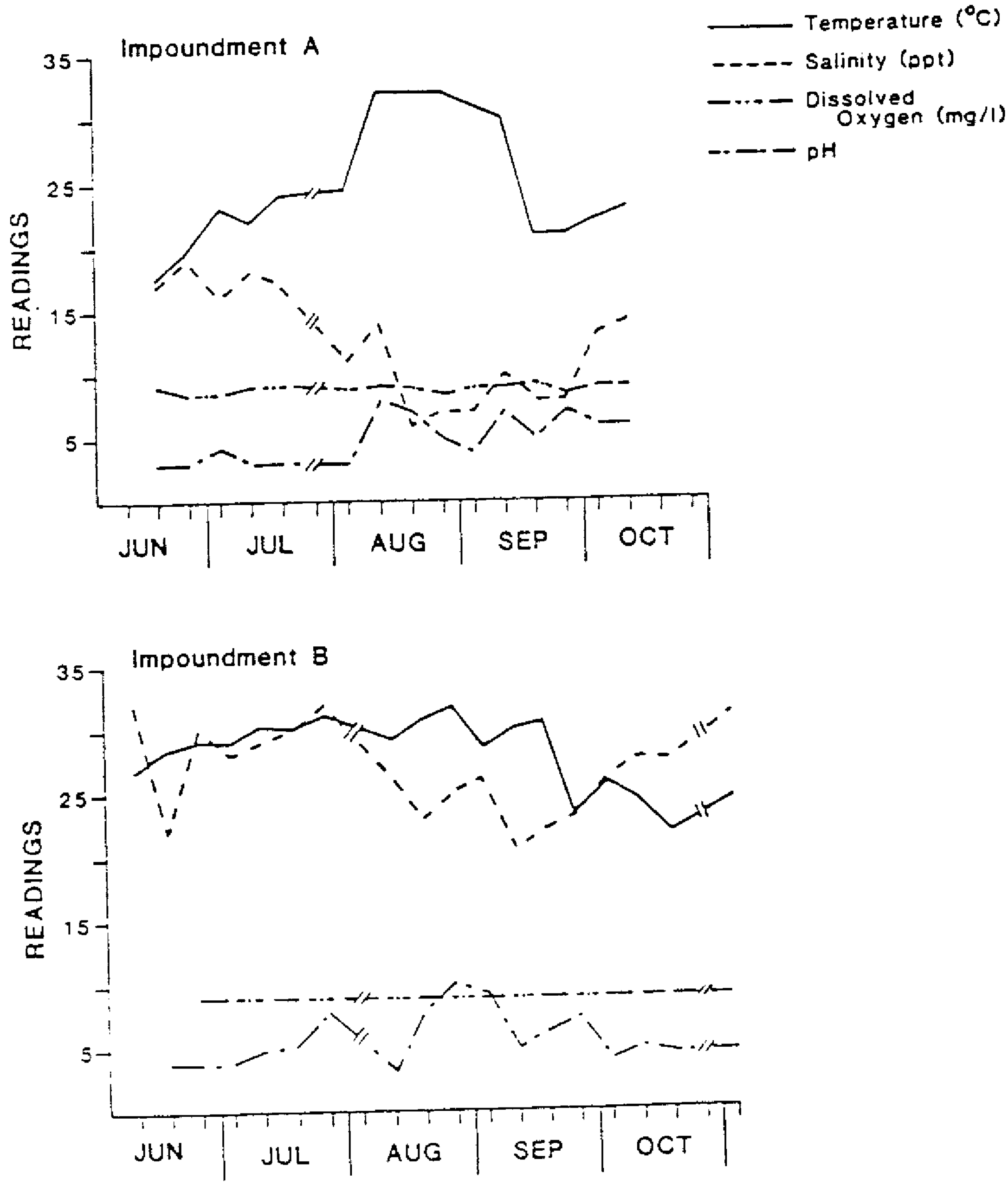
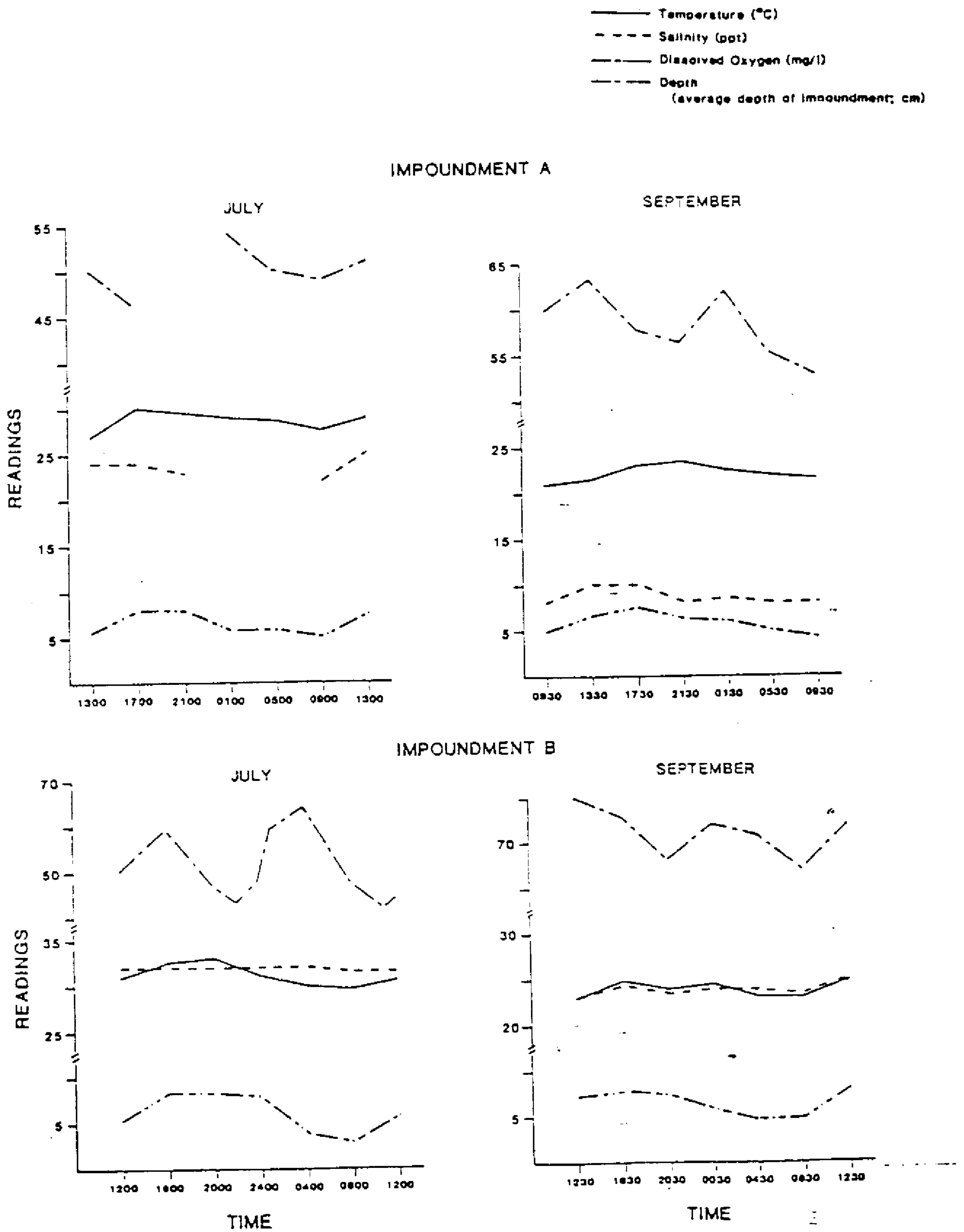


Figure 2. Impoundment depth, salinity, water temperature and dissolved oxygen readings at the bottom of the water control structures during 24 hour monitoring periods.



Appendix 1. Water conditions recorded weekly at impoundment A. Water samples collected from near the surface (S) and the bottom (B) next to the main trunk (water control structure). Depth is the average depth (cm) of water above the central bed.

DATE	TIME	DEPTH	TEMPERATURE (C)		SALINITY (ppt)		DIS. OX. (mg/l)		PH	
			S	B	S	B	S	B	S	B
06-26	1530	46	19	17.5	19	17	7	3	8.5	8
07-01	1500	48	20	19	20	19	8	3	8	7
07-11	1130	55	23	23	17	16	8	4	7	7
07-17	1500	51	22	22	18	18	5	3	9	8
07-25	1030	47	24		17		8	3	8	
NO READINGS										
08-09	1530	47	26	24.5	10	11	5	3	7.5	
08-14	1530	41	35.5	32	12	14	16		8	8
08-19	0900	46	33	32	6	6	8	7	8	8
08-31	1000	49	32	32	8	7	6	5	7	7
09-03	1600	56	33	31	6	7	5	4	8.5	8
09-11	1330	37	31.5	30	8	10	6	7	8	8
09-16	0900	60	21	21	8	8	7	5	8	8.3
09-26	0930	62	21	21	9	8	8	7	7.8	7
09-30	1000	35	23	22	13	13	7	6	8	8
10-07	1530	55	23		14		7	6	8	
MEAN		49.0	25.8	25.1	12.3	11.8	7.4	4.7	8.0	7.7
SD		7.8	5.6	5.5	4.9	4.6	2.6	1.6	0.5	0.5

Appendix 2. Water conditions of impoundment A during diurnal sampling in July and September. Water samples were collected from the surface (S) and bottom (B) next to the main trunk (M-TRK), at the surface next to a divider trunk (D-TRK) (July only), and in the ditch opposite the water control structure (DITCH). IMP DEP is the average depth (cm) of water above the central bed.

18-19 JULY DIURNAL

					TEMPERATURE (C)			SALINITY (PPT)			DIS. OX. (mg/1)		
MO-DA	TIME	TIDE	IMP DEP		M-TRK	D-TRK	DITCH	M-TRK	D-TRK	DITCH	M-TRK	D-TRK	DIT
07-18	1300	EBB	50	S	28.1	29.0	29.9	24.0	24.0	24.0	12.8	13.8	8.9
				B	27.0						5.7		
07-18	1700	EBB	46	S	31.3	32.1	32.4	24.0			16.0	19.1	20+
				B	30.0	30.4					7.8	10.9	
07-18	2100	FLD	--	S	29.4	31.0	30.7	23.0			8.7	13.8	16.3
				B	29.4	31.0					7.9	12.9	
07-19	0100	EBB	54	S	28.0	29.0	29.2				9.0	8.7	9.4
				B	28.9	29.0					5.8	4.1	
07-19	0500	EBB	50	S	27.1	28.3	27.8				8.4	7.2	7.2
				B	28.7	28.6					5.9	3.4	
07-19	0900	FLD	49	S	27.7	28.1	28.0	22.0			5.7	4.1	7.8
				B	27.6	28.1					5.2	3.1	
07-19	1300	EBB	51	S	29.1	30.7	30.3	25.0	24.0	24.0	12.2	19.2	14.2
				B	28.9	29.0					7.5	9.8	

16-17 SEPTEMBER DIURNAL

					TEMPERATURE		SALINITY		DIS. OX.	
MO-DA	TIME	TIDE	DEPTH		M-TRK	DITCH	M-TRK	DITCH	M-TRK	DIT
09-16	0930	FLD	60	S	20.8	20.2	8.0	8.0	7.0	7.0
				B			8.0		5.0	
09-16	1330	EBB	63.5	S	23.3	23.5	10.0	10.0	8.9	7.4
				B	21.5				6.7	
09-16	1730	EBB	58.0	S	24.8	24.2	10.0	9.5	9.4	9.3
				B	23.1				7.6	
09-16	2130	FLD	56.5	S	23.5	23.7	8.0	8.0	7.5	7.4
				B	23.5				6.4	
09-17	0130	EBB	62.0	S	22.0	22.7	8.5	8.5	7.1	6.1
				B	22.5				6.2	
09-17	0530	EBB	55.5	S	21.0	22.5	8.0	8.0	5.4	5.0
				B	22.0				5.0	
09-17	0930	FLD	53.0	S	21.8	22.6	8.0	9.0	4.9	4.0
				B	21.6				4.3	

Appendix 3. Water conditions recorded weekly at impoundment B. Water samples collected from near the surface (SURF) and the bottom (BOTT) next to the water control structure and at the edge of the impoundment ditch (DITC). pH readings were from the bottom sample only.

			DEPTH (cm)		TEMPERATURE (C)			SALINITY (ppt)			DIS. OX. (mg/l)			pH
MO-DA	TIME	TIDE	OVER SILL	POND AVG	SURF	BOTT	DITC	SURF	BOTT	DITC	SURF	BOTT	DITC	
06-14	1100	EBB	12.0	43.0		26.9			32.0					
06-19	1100	EBB	6.0	37.5	28.4			22.0		22.0	8.9	3.9	8.9	
06-27	1015	EBB	15.5	48.0		29.2	29.3		30.0	30.0		3.8	4.6	8.0
07-03	1030	FLD	44.0	63.0		28.9	29.5		28.0	20.0		3.9	6.0	8.0
07-12	0900	EBB	9.5	41.5		30.2	30.5		29.0	29.0		4.8	3.9	8.0
07-17	1220	EBB	24.5	57.0		30.1	31.2		30.0	30.5		5.2	6.2	
07-22	1130	FLD	32.0	50.0		31.0	32.0		32.0	32.0		7.9	7.6	7.9
NO READINGS														
08-07	1050	EBB	23.5	55.0	29.0	29.2	30.0	26.5	26.5	26.0		3.3	4.5	8.0
08-13	1240	EBB	14.0	46.0	31.2	30.7	33.1	23.0	23.0	22.5	10.0	8.1	7.9	7.9
08-20	1140	FLD	53.0	64.0	31.0	31.6	31.2	25.0	25.0	24.0	10.3	10.0	10.0	8.0
08-27	0915	EBB	30.0	62.5	28.4	28.5	28.2	26.0	26.0	26.0	9.6	9.3	7.8	7.8
09-05	0900	EBB	7.5	38.5	30.1	30.0	29.5	20.5	20.5	13.0	5.6	5.1	6.8	8.0
09-10	1015	EBB	7.0	38.0	30.6	30.4	31.4	22.0	22.0	22.0	7.3	6.4	8.3	7.9
09-17	1230	FLD	-	90.0	23.6	23.1	25.6	23.0	23.0	23.0	7.9	7.3	8.5	8.0
09-24	0900	EBB	31.0	62.5	25.4	25.7	25.2	26.0	26.0	26.0	4.9	4.6	4.4	7.9
10-01	0825	FLD	38.0	49.5	24.3	24.3	23.9	28.0	27.5	27.5	-	5.0	5.0	7.9
10-06	0800	EBB	0.0	31.5	22.0	21.8	20.1	27.5	27.5	27.5	4.7	4.4	4.6	8.1
NO READINGS														
10-23	1030	EBB	25.0	57.5	24.3	28.0	24.5	31.5	31.0	31.0	4.7	4.7	5.6	7.8
MEAN			21.9	51.9	27.4	3.0	28.4	25.1	27.0	25.4	7.4	5.7	6.5	7.9
SD			14.8	13.8	3.3		3.6	3.1	3.5	4.8	2.3	2.0	1.9	0.1

Appendix 4. Water conditions in impoundment B during diurnal sampling in July and September. Water samples were collected from near the surface (SUR) and near the bottom (BOT) next to the water control structure and from the surface at the edge of the ditch (DITC). pH readings were from the bottom sample only.

22-23 JULY DIURNAL

			DEPTH (cm)		TEMPERATURE (C)			SALINITY (ppt)			DIS. OX. (mg/1)		
DATE	TIME	TIDE	OVER SILL	AVG. POND	SURF	BOTT	DITC	SURF	BOTT	DITC	SURF	BOTT	DITC
07-22	1130	FLD	32.0	50.0	31.0	31.0	32.0	31.0	32.0	32.0	6.2	5.3	7.6
07-22	1600	EBB	26.5	59.2	33.8	32.5	34.0	32.0	32.0	32.0	8.0	8.3	8.5
07-22	2000	EBB	14.0	47.0	31.5	33.0	31.6	31.0	32.0	31.5	7.0	8.1	8.1
07-22	2200	EBB	10.0	43.5									
07-22	2400	FLD	14.0	47.5	31.0	31.0	31.0		32.0		5.8	7.8	6.7
07-23	0110	FLD	42.0	59.0									
07-23	0400	EBB	30.0	64.0	30.1	29.9	30.0		32.0		4.0	3.9	4.6
07-23	0800	EBB	15.0	48.0	29.5	29.6	29.6		31.5	31.0	3.0	2.9	3.3
07-23	1100	EBB	9.5	42.0									
07-23	1200	FLD	28.0	44.0	30.8	30.5	31.1	31.5	31.5	32.0	5.3	5.7	7.4

17-18 SEPTEMBER DIURNAL

			DEPTH (cm)		TEMPERATURE (C)			SALINITY (ppt)			DIS. OX. (mg/1)		
DATE	TIME	TIDE	OVER SILL	AVG. POND	SURF	BOTT	DITC	SURF	BOTT	DITC	SURF	BOTT	DITC
09-17	1230	FLD		90.0	23.6	23.1	25.6	21.0	23.0	23.0	7.9	7.3	8.5
09-17	1630	EBB		81.5	24.9	24.9	24.5	24.5	24.5	24.5	8.4	7.8	9.4
09-17	2030	EBB		62.0	24.0	24.1	25.0	23.5	23.5	23.0	7.9	7.4	6.9
09-18	0030	FLD		78.0	24.3	24.6	24.1	24.0	24.0	24.0	6.2	5.9	5.9
09-18	0430	EBB		73.5	23.1	23.3	23.1	24.0	24.0	23.5	5.3	4.8	4.4
09-18	0830	EBB		58.0	22.9	23.2	22.3	23.5	23.5	24.0	5.2	4.9	4.9
09-18	1230	FLD		77.5	24.9	24.8	24.0	25.0	25.0	24.5	8.3	8.0	8.5