EVALUATION OF GREAT MARSH POND COMPLEX

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Department of Natural Resources and Environmental Control

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Acknowledgments

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INTRODUCTION

The Great Marsh, located in Lewes, Delaware (Fig. 1) is the site of a 5 year research project funded by Coastal Zone Management Act. The Division of Fish and Wildlife is studying the effects of Integrated Marsh Management (IMM) on waterbird utilization and production, invertebrate populations, submergent and emergent vegetation, water quality, fish populations, and mosquito reduction. Consisting of 2300 acres of tidal salt marsh, the Great Marsh was intensively grid-ditched for mosquito control in the 1930's and again in the mid-1960's. These ditches were indiscriminately placed at 150 ft. intervals, thus effectively draining many ponds which held permanent water (Fig. 2). After grid-ditching on the Great Marsh, non-tidal pond areas decreased from over 40 acres in 1926 to 10 acres in 1979. Many ponds were drained as a result on grid-ditching, however some may have been drained naturally (i.e. muskrat burrowing). These ponds, which one provided desirable habitat for wintering and breeding waterfowl and numerous waterbirds are now dewatered due to direct tidal connection. The Great Marsh once had many non-tidal ponds which provided important habitat for waterfowl and other waterbirds. These experimental ponds serve to reverse the detrimental effects of draining by putting permanent standing water back on the tidal marsh. Each pond provides habitat for feeding and resting waterbirds during various times of the year. The Great Marsh once was considered prime habitat for the declining black duck, providing good opportunities for hunting. In keeping with the nation's policy of "no net loss", it is

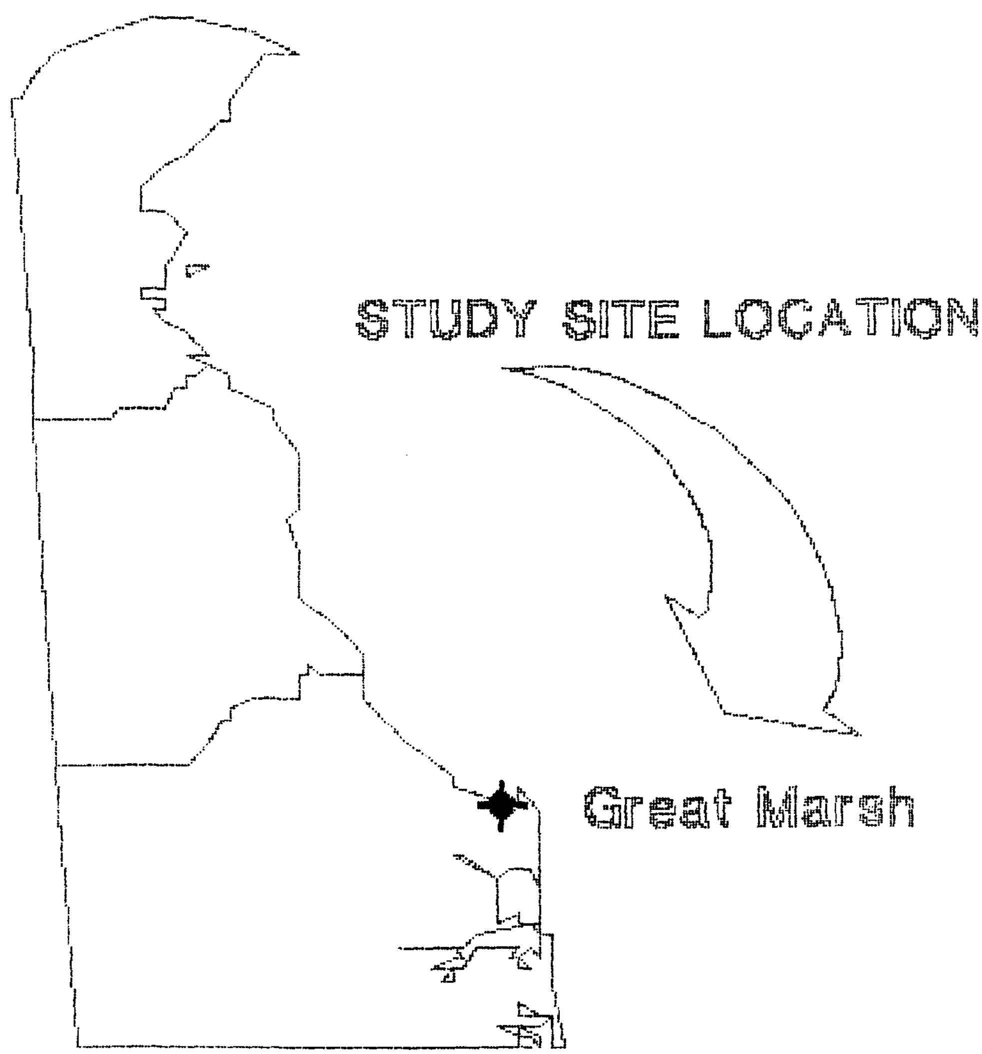


Figure 1. Great Marsh study site location

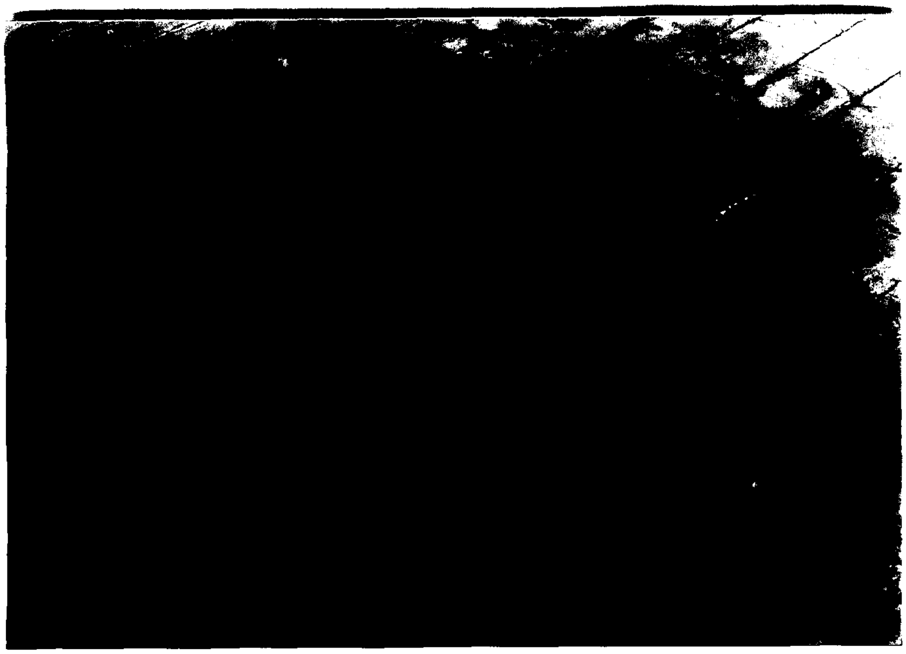


Figure 2. Ponds Affected by Grid Ditching

important to understand the function and value of restoration and creation of pond habitat to return a degraded marsh to its original values or to enhance a marsh lacking adequate available water habitat. These results will be used to determine the feasibility of routinely including similar ponds within OMWM (Open Marsh Water Management) projects to achieve integrated multiple use wetlands management.

One of the main objectives of the study is to enhance wildlife habitat through creation and restoration of ponds on degraded marshes. This maintains a stable habitat and provides feeding and refuge areas for numerous species (including waterfowl, shorebirds, wading birds, gulls and terns), both in quantity and quality important in terms of recreational hunting, bird watching and nature study.

In 1986, twelve experimental sites were selected for evaluation. *Spartina alterniflora* is the dominant emergent vegetation covering low-marsh areas and along tidal creeks and ditches. Salt hay consisting of *S. patens* and *Distichlis spicata* occurs in isolated areas of the open marsh, along the upland fringe, and in areas fringing wooded hummocks. Shrub species including *Iva frutescens* and *Baccharis halimifolia* occur on many of the ditch spoil mounds and upland areas. *Phragmites australis* occurs in small, isolated bands and patches along the upland edge. Stands of *Typha* and *Scripus* are found in scattered areas. Seven sites were chosen in areas of multi-depression, high density mosquito breeding habitats (salt hay habitat), three in non-mosquito breeding habitat (*S. alterniflora* habitat), and two ponds that were previously drained by grid ditches were restored by plugging the outlets. Another areas was treated with OMWM techniques. These techniques usually rely on small ponds (one-tenth of an acre or less) and ditches to eliminate breeding areas and allow small killifish access to mosquito larvae. However, in order to combine wildlife needs in conjunction with the objective of controlling mosquitoes, the ponds were enlarged to approximately one-half acre. The ponds were constructed with curvilinear sides for a natural appearance. The 12 installed ponds at Great Marsh account for approximately five acres, so there remains a let loss of 25 acres of non-tidal ponds when compared to pre-grid ditched. These ponds will help mitigate the loss of natural non-tidal ponds lost to grid-ditching.

A variety of equipment was used in construction including a crane, backhoe, bulldozer, and a rotary excavator. The ponds were dug to a depth of 4-18" with a 3 foot sump to serve as a fish reservoir during drought periods. This shallow depth also serves shorebirds and wading birds and allows enough light penetration to allow the growth of submerged aquatic vegetation (SAV). The resultant spoil is spread over the marsh surface with a final increase above original marsh elevation of approximately 2-4". The natural tidal ponds were plugged with spoil material to block direct tidal drainage and flooding. The controls included natural areas of marsh not affected by construction which contains flat pans which hold water during flood-over events and after heavy rain, and areas of contiguous marsh containing little or no water habitat. Two areas (C1 and C2) are completely vegetated with salt hay and _S_. _alterniflora_: C3A and C3B are areas of _S_. _alterniflora_ with numerous small flat pans and tidal ponds; and the last control area (C4) is dominated by _S_. _alterniflora_ with two small flat pans. Various experimental construction techniques were employed including semi-tidal systems in salt hay (ponds 5 and 7) and _S_. _alterniflora_ (pond 3), closed systems in salt hay (ponds 2, 6 and 8) and _S_. _alterniflora_ (ponds 4 and 12) and restored closed (pond 9) and restores sill (pond 10). Islands were constructed in ponds 2, 3, 4, 5, 6, 7, and 8 to promote nesting and reduce the amount of spoil deposited on the marsh surface.

In 1987 four 15-foot scaffolding towers were erected, positioned to have full view of 10 of the 12 ponds plus the OMWM site and the 5 control areas adjacent to the ponds (Fig. 3). The controls included areas which contain flat pans which hold water during flood-over events and after heavy rain, and areas of contiguous marsh containing little or no water habitat. Each pond and control area was measured and staked to provide equal area of viewing. There is a total of 16 observation areas - 10 ponds, 5 control areas and the OMWM site. The observation areas are observed for 2-hour periods on randomly selected days with equal dawn and dusk time frames. Every 15 minutes the observer would scan each area and record the species and the number of individuals utilizing the area within the staked boundaries and also its behavior and specific habitat being used. During the first year, 60 observation periods were scheduled from April through early December. Based on the first year of observations,

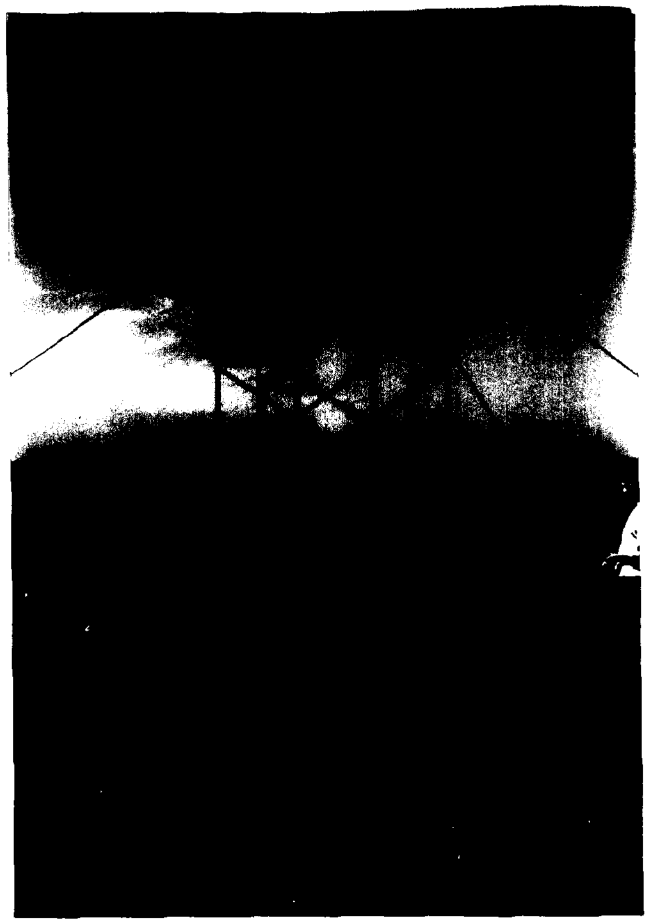


Figure 3. Observation Tower

the number of observation periods were decreased to 34 from mid-February through November for the remainder of the project. These dates concentrate on peak migratory periods for waterfowl and shorebirds.

During the four years of observation, a total of 54 species from four guilds have been recorded utilizing the areas: waterfowl - 15, shorebirds - 20, wading birds - 10, and gulls and terns - 9. Two miscellaneous species, kingfishers and osprey have also been observed using the ponds (Table 1). Although waterbird utilization was of primary concern, other important parameters assessed relating to pond quality and ability to attract waterbirds are invertebrate populations, emergent and submergent vegetation, fish populations, brood production, and water quality. In addition, the ability of the ponds and surrounding area to control mosquitoes was determined.

Table 1. **SPECIES LIST FOR GREAT MARSH BY SPECIES GUILD**

WATERFOWL

BLACK DUCK	HOODED MERGANSER
MALLARD	WOOD DUCK
GADWALL	RUDDY DUCK
BLUE-WINGED TEAL	PIED-BILLED GREBE
GREEN-WINGED TEAL	WIGEON
RED-BREASTED MERGANSER	BUFFLEHEAD
COMMON MERGANSER	DOUBLE-CRESTED CORMORANT
NORTHERN MERGANSER	

SHOREBIRDS

WILLET	DUNLIN
GREATER YELLOWLEGS	SOLITARY SANDPIPER
LESSER YELLOWLEGS	SPOTTED SANDPIPER
BLACK-BELLIED PLOVER	RUDDY TURNSTONE
SEMIPALMATED PLOVER	WILSON'S PHALAROPE
KILLDEER	MARBLED GODWIT
LEAST SANDPIPER	PECTORAL SANDPIPER
SEMIPALMATED SANDPIPER	NORTHERN PHALAROPE
SNIPE	STILT SANDPIPER
SHORT-BILLED DOWITCHER	BLACK-NECKED STILT

WADING BIRDS

GREAT BLUE HERON	GREAT EGRET
TRI-COLOR HERON	GLOSSY IBIS
LITTLE BLUE HERON	CLAPPER RAIL
GREEN-BACKED HERON	VIRGINIA RAIL
SNOWY EGRET	AMERICAN BITTERN

GULLS AND TERNS

GREATER BLACK-BACKED GULL	LEAST TERN
LAUGHING GULL	COMMON TERN
HERRING GULL	FORESTER'S TERN
RING-BILLED GULL	LITTLE TERN
BLACK-CROWNED NIGHT HERON	

MISCELLANEOUS

KINGFISHER	OSPREY

WATERBIRD UTILIZATION

Four scaffolding towers serving as observation blinds were erected in March 1987. Observations began on April 1 and continued through late-fall, early winter. Adjustments in rescheduling were made to concentrate on peak migratory periods to best utilize man-power. A total of 176 2-hour observations were scheduled from 1987-1990. A few had to be cancelled due to environmental factors such as flooded conditions on the marsh surface, heavy fog and lightning.

As one may expect, the data results are highly variable due to high and low pulses within the data caused by the mobile nature of the species being observed, weather factors, time of day, and migratory periods. Due to this high variability, the data will be assessed qualitatively via a relative use index. It was felt that just counting individuals was inadequate because utilization of the ponds over a period of time was most important. The relative use index is obtained by adding the number of birds seen during each scan for all observation periods (9 scans per observation period) for each season (spring, summer, fall) divided by the number of scans, divided by the total number of observation periods for a particular season (e.g. one bird seen during each of the 9 scans is the same as a flock of 9 birds observed for 1 scan - use index of 1.0).

Several approaches of analyzing the data were undertaken. First, for most comparisons, the yearly data was broken down into three seasons of observation (spring, summer and fall). The species observed were separated into 4 guilds - waterfowl, shorebirds, wading birds and gulls/terns (Table 1). An overall gross yearly comparison for each guild was initially reviewed. Because of the migratory nature of most of the species, and weather factors, particularly rainfall, seasonal use was judged to be most pertinent. Therefore, the ponds were compared to the controls in spring, summer and fall. Due to the variability of the controls, as described in the introduction, the control plots were separated into two distinct types - wet controls and dry controls.

Two basic types of construction exist when designing and creating pond systems - manmade (new construction) and restored ponds (plugging previously drained tidal ponds). Where possible, restored ponds are incorporated in a system design and the effective utilization of these ponds compared to a new "ideal" pond was addressed. Within the manmade ponds, two construction techniques within two vegetation types were employed and assessed-closed systems and sill systems in salt hay habitat, and closed systems and sill systems within S. alterniflora habitat.

Yearly Comparisons

Overall yearly comparisons of the four guilds are presented in figures 4-7. Waterfowl usage in the ponds and controls showed parallel increases from 1987-90 with the ponds having a larger use index than the control areas (Figure 4). The use index in the ponds for 1987-89 were approximately twice the value as the controls while 1990 ponds were approximately 25% greater. Shorebird utilization demonstrated steady decreases from initial installation through 1990 for both ponds and controls. When ponds are first constructed, expanses of thin spoil remains and is attractive to shorebirds for feeding on invertebrates. As the spoil areas revegetate, there is less habitat for the shorebirds and utilization becomes diminished as indicated in figure 5 when the use index in 1987 was approximately 7.5 and diminished to approximately 2.0 in 1990. The control areas were similar in usage to the ponds for 1988-1990, whereas in 1987 the ponds were greater - 7.5 compared to 4.4. The use index of wading birds was generally low throughout the year with value of 2.5 or less. Between year comparisons of ponds and controls were similar for each year except 1989 when readings were 2.2 in the ponds and 0.2 in the controls (Figure 6). Gull and tern usage ranged from 0.6 to 1.8 in the ponds and 0-0.3 in the controls due to the lack of deep water in the control areas (Figure 7). The preceding data is a gross overall comparison of ponds and controls. The following data attempts to show distinct important differences and similarities among created ponds, natural and degraded marshes.

Seasonal Use of Ponds and Controls

Waterfowl

Waterfowl pond use indices were higher for each year in the spring with 1987 and 1988 twice the values as the control areas. Overall usage increased from 1987 with maximum utilization in 1990 for both ponds (7.0) and controls (5.2) (Figure 8). Waterfowl use was greatest in the spring - black ducks in mid-February and March and green-winged teal in mid-April. Indices in summer and fall fell considerably to below 0.7 in summer and below 1.4 in fall (Figures 9 & 10). Although variable between years, the ponds were utilized more than control areas due to their capability of holding permanent water.

Shorebirds

Considerable use of the ponds and controls was realized in the spring of 1987 and 1988 with use indices of 6.6 and 8.2 in the ponds and 6.7 and 7.1 in the controls (Figure 11). Marked decreases for both areas occurred in 1989 and 1990 to a low of 1.8 for both ponds and controls. This reduction is due in part to vegetation recovery around the ponds perimeter which reduces available feeding habitat. One pond whose vegetation recovery was only 50%, shorebird usage was higher than ponds of 90-100% recovery. During the wet period of the year the ponds and controls were almost identical in usage. Major species include willet, greater and lesser yellowlegs and peep species. Shorebird use in ponds was very high in the summer of 1987 with a use index of 10.7 as compared to 4.6 for the controls (Figure 12). After 1987, the pond use index dropped to between 3.0-4.3 whereas the controls declined to 1.2 by 1990. During the fall season shorebird use was reduced for both ponds and controls. Again the ponds in 1987 had over twice use index as the controls with remaining years similar (Figure 13). As previously stated, fresh spoil from new pond construction creates feeding habitat for shorebirds. The control plots were often similar in utilization during the three seasons. However, the utilization of the control areas are subject to adequate rainfall or flooding tidal events whereas the ponds are permanent water habitat. Many times, particularly during mid to late summer certain control area pans would evaporate.

Wading Birds

Wading bird activity was minimal in spring for all years with a use index of less than 1.4 for ponds and controls (Figure 14). During the summer, activity increased slightly during 1987, 1989-90 within the ponds, while during 1988, the use index reached a high of 7.9. The controls were low for all four years with an index of 0.2-0.6 (Figure 15). The fall period was again low utilization similar to the spring with a use index of 0.4-1.2. The control areas reached 2.8 in 1988 while remaining years were 0.04-0.2 (Figure 16). Wading birds need water habitat deep enough and of a long duration to sustain fish population which the ponds provide year-round. Ten species of wading birds were observed with the major species being snowy and great egrets and great blue herons.

Gulls and Terns

Gull and tern activity was very low during spring and fall with a use index of less than 0.2 (Figures 17 and 19). The summer, however, had a peak use in 1987 of 3.9 and 2.8 in 1990 (Figure 18). The major utilization during the summer were gulls resting on exposed spoil areas. The control areas had only two periods of use during all seasons for all years - spring and fall of 1987. The largest use index was 0.05.

Wet and Dry Control Comparison

Due to the differences in the physical characteristics of the controls area and subjective observations in the field, the controls were separated into two categories - wet and dry controls. The wet controls contain flat pan areas capable of holding water after a tidal flooding event or rain and small tidal ponds. The dry controls are natural marsh areas of salt hay and *S. alterniflora* containing little or no water habitat.

Waterfowl

Springtime was the most utilized period of the year for all areas concerned as seen in figures 20-22. The ponds and wet controls were similar except in 1987 when the use index in the ponds was almost 5 times greater than the wet controls. The use index was as high at 7.0 in the ponds and 8.7 in the wet control by 1990 (Figure 20). An obvious but drastic difference was in the dry control when the use index was 0.13 or less for all years. Waterfowl utilization was considerably reduced during the summer and fall for all years (Figures 21 and 22) with indices of less than 0.7 in the summer and less than 1.3 in the fall. In each case the ponds were greater than the controls. The dry control areas had no waterfowl use during the summer and fall for all years.

Shorebirds

Spring shorebird utilization had similar use index patterns in 1987-90 with 1988 the peak year of usage for both ponds and wet controls. In every year the wet controls had larger use indices than the ponds ranging from 31-45% above the ponds indicating a preference for the shallower, temporary pans (Figure 23). As indicated by the declining trend towards 1990, the ponds perimeter vegetation caused a loss of ideal shorebird habitat but restoration of the ponds original condition is obtained. The fact that the wet controls followed the ponds similar yearly pattern may indicate an attraction to the Great Marsh ponds, and once they become vegetated usage becomes stable but less than newly exposed spoil. The dry controls had very little utilization during all years due to the lack of suitable habitat with indices of 0.75 or less for 1987-90.

The summer use indices were highest in 1987 for the ponds and wet controls with a pond index of 10.7 and 7.5 for the wet controls (Figure 24). The use index for 1988-90 dropped to a stable, but lower 4.3, 3.0, and 4.1 for the ponds while the wet controls had a more gradual but similar decline of 6.8, 3.1 and 2.0. The dry control areas were used even less in the summer with indices of 0.4 and 0.3 in 1987-88 and 0.0 in 1989-90 (Figure 24).

Fall utilization was considerably reduced for all areas concerned in 1987-90. The largest index was 3.1 in the ponds in 1987 (Figure 25). The remaining comparisons were similarly low for the remaining years in ponds and wet controls. Only 1988 had any usage however meager (0.09) in the dry controls (Figure 25).

Wading Birds

Spring wading bird activity was minimal in the ponds and controls for all years with the highest use index of 2.1 in the wet controls in 1990 (Figure 26). The remaining indices were 1.3 or less. Two years, 1988 and 1990, recorded 0.0 in the dry controls.

Wading birds showed a preference for the ponds during the summer for all years (Figure 27). In particular, 1989 had the largest index of 7.0. In 1987, 1988 and 1990, the index was similar ranging from 1.6-2.2. The wet control areas use index ranged from 0.2-0.9 probably caused by loss of water habitat for fish survival. The dry controls were similar but slightly lower than wet controls ranging from 0.3-0.6. The fall period indices for the ponds were similar but variable between years ranging from 0.4-1.2 (Figure 28). The wet controls were slightly lower except for 1988 when the use index reached 4.7 followed by 0.0 in 1989. In 1987 and 1990 the dry controls were lower, recording 0.0 in 1987 and 1990, while 1988 and 1989 were 0.06 and 0.09.

Gull and tern activity was most prevalent in the summer in the ponds for all years with 1987 and 1990 the largest indices of 3.9 and 2.8 (Figure 29). The wet controls in 1987 and 1988 had very low indices of 0.01 and 0.04 while the dry controls had no recorded utilization for all years.

Manmade and Restored Ponds

Manmade and restored ponds are the two basic options for pond construction when designing OMWM systems. Manmade ponds are shallow (up to 18") with tapered sides. Many species of waterfowl, wading birds and shorebirds are able to utilize these shallow depths. Restored ponds were once non-tidal but grid-ditching converted them to tidal ponds. They are generally deeper probably due to scouring, and the two ponds surveyed did not contain widgeon grass. However, they provide valuable permanent water habitat attractive to waterfowl, including bay species such as bufflehead and mergansers, wading birds and long-legged shorbirds. The following series of figures (30-39) illustrate comparisons between these two methods of construction.

The man-made pond indices during spring were variable between years with 1990 recording the largest index of 7.2 (Figure 30). Restored pond indices were low in 1987 and 1988 (1.0 and 1.2) however 1989 restored pond use index exceeded the manmade pond index 5.7 to 1.6 while 1990 was similar. During the summer, use indices fell to 0.7 or lower for both manmade and restored ponds for all years (Figure 31). In 1989 and 1990 restored use indices were 0.0. Manmade pond indices were again low in the fall having a maximum in 1989 of 1.6. The restored pond only had one year, 1987, with any utilization which was twice as high, 3.2, as the manmade pond (Figure 32).

During the spring shorebird period, utilization of the ponds was extreme in the manmade ponds during 1987 and 1988 with use indices of 6.9 and 9.2 (Figure 33). As previously stated, as the pond perimeter revegetates shorebird use habitat and usage diminishes as was the case in 1989 and 1990 when indices were reduced to 3.4 and 1.7 respectively. The restored ponds followed similar patterns with each year lower except for 1990 when values were similar, than manmade ponds with a maximum index of 5.1. A similar pattern for the summer was observed in the manmade ponds.

After a high index of 12.8 in 1987, shorebird utilization fell to between 3.4 and 5.0 in 1988-90 (Figure 34). The restored ponds were low in 1987, 1988 and 1990 with indices of 0.1-1.1 while 1988 had the highest index of 2.6. The fall period again demonstrated a declining trend towards 1990 in the manmade ponds from an index of 3.8 in 1987 to 0.2 in 1990 (Figure 35). The restored pond indices were low in 1987-89 considerably less than manmade ponds, ranging from 0.0-0.2 followed by 1.8 in 1990.

Wading bird activity during the spring was generally low during all years in manmade and restored ponds. The peak index for manmade ponds was 1.6 in 1988 and 1.7 in 1989 in restored ponds (Figure 36). The major difference between years was in 1988 when manmade ponds exceeded the restored ponds 1.6 to 0.03. The summer period had marked increased utilization in the manmade ponds while a slight increase was observed in the restored ponds. In 1987, indices for both manmade and restored ponds were similar, however the manmade ponds exceeded the restored ponds in 1988-1990 with a peak index in 1989 of 8.4 whereas the peak in restored ponds was 1.5 in 1987 (Figure 37). The fall indices between years were similarly low in both manmade and restored ponds with a maximum index less than 1.4 (Figure 38). During 1990 the restored ponds recorded 0.0 usage while the manmade pond index was 0.8 noting the biggest difference during fall.

As indicated in previous text and graphs the majority of gull and term activity occurs during the summer. Spring and fall utilization was below 0.25 for all years. Gulls and terns showed a definite preference for the manmade ponds during all years. A majority of this usage were gulls using the spoil and mudflat areas as resting zones. 1987 and 1990 were peak years with use indices of 4.8 and 3.5 (Figure 39).

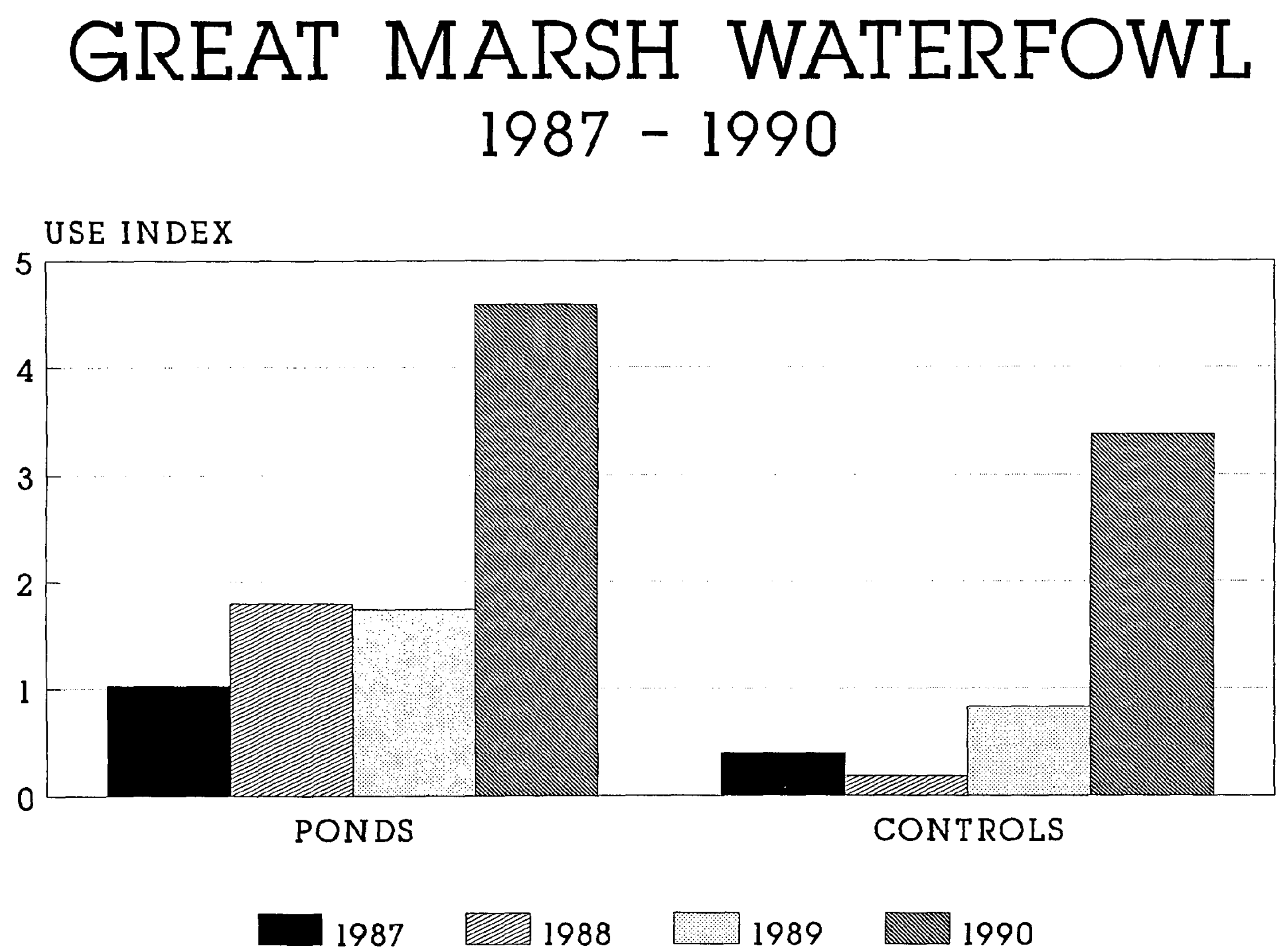


Figure 4. Yearly Waterfowl Indices for Ponds and Controls

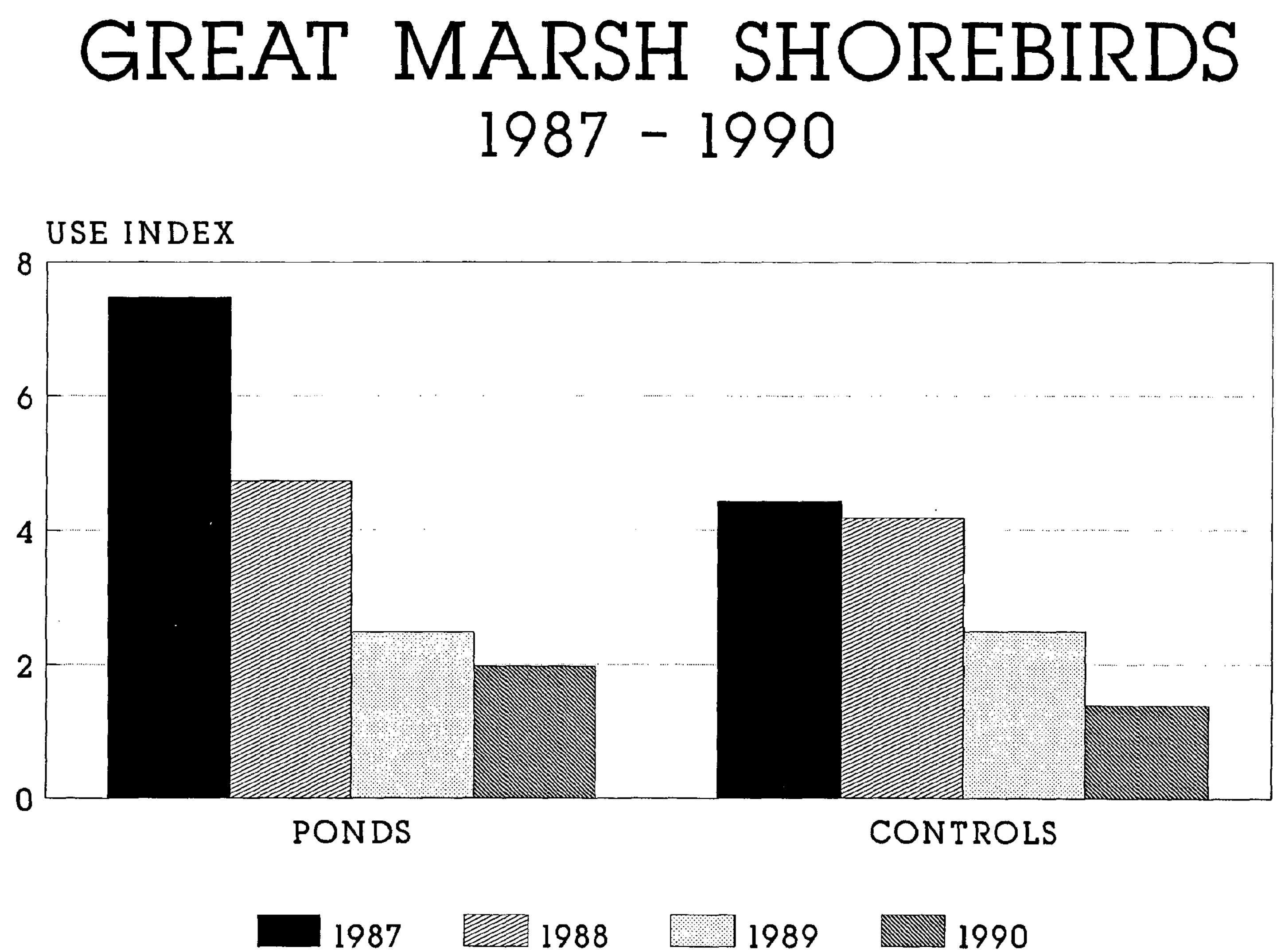


Figure 5. Yearly Shorebird Indices for Ponds and Controls

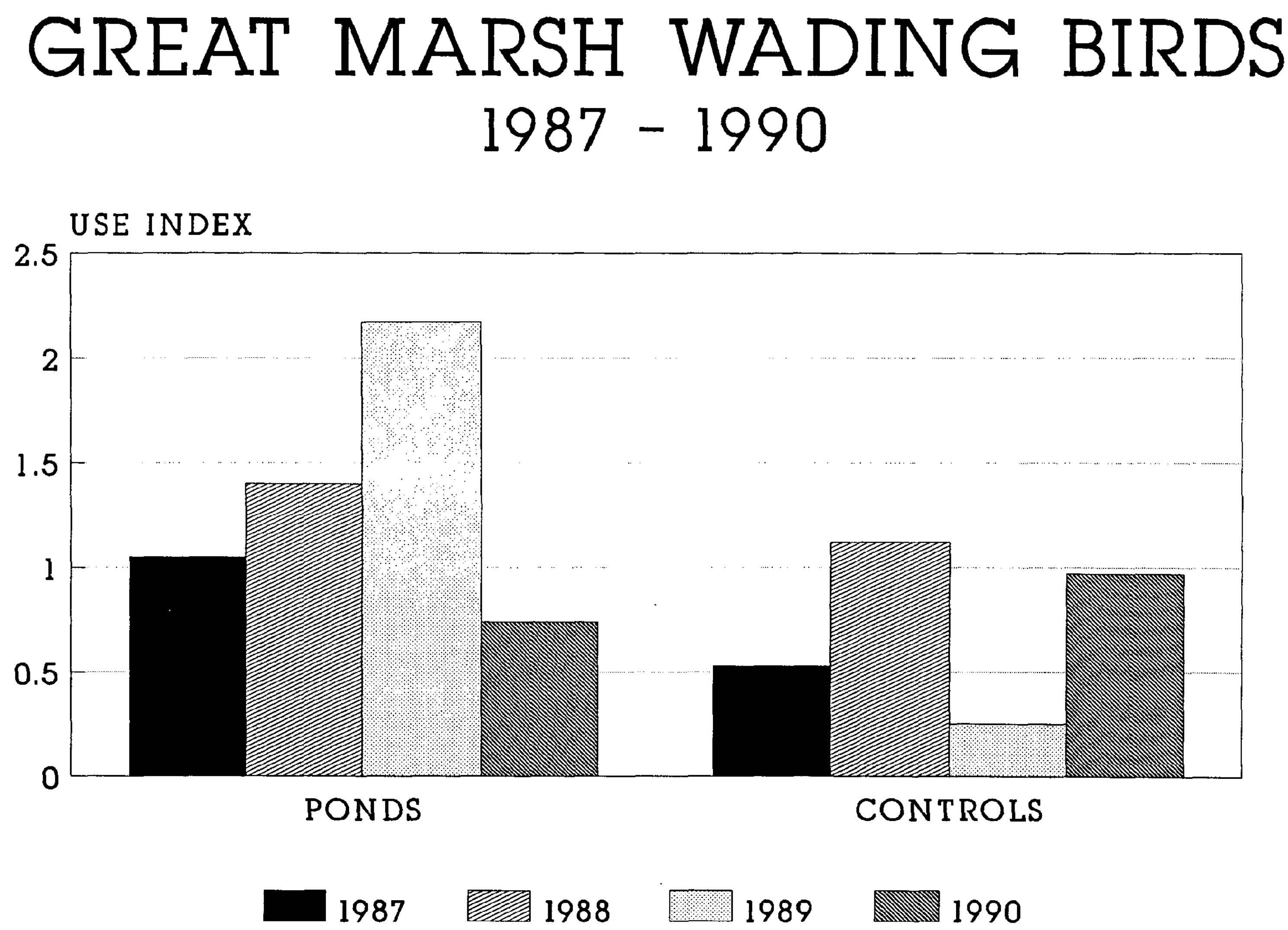


Figure 6. Yearly Wading Bird Indices for Ponds and Controls

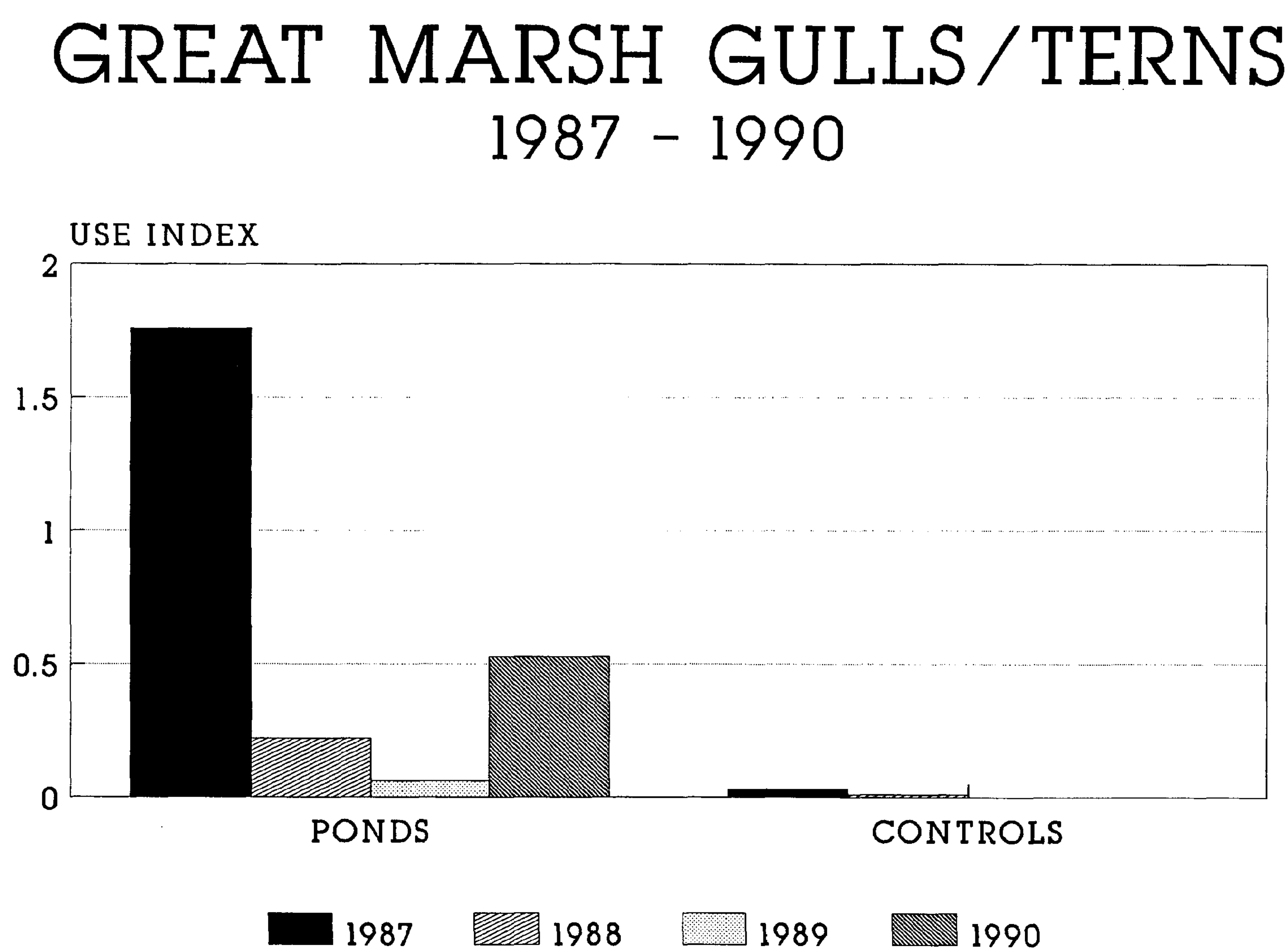


Figure 7. Yearly Gulls and Terns Indices for Ponds and Controls

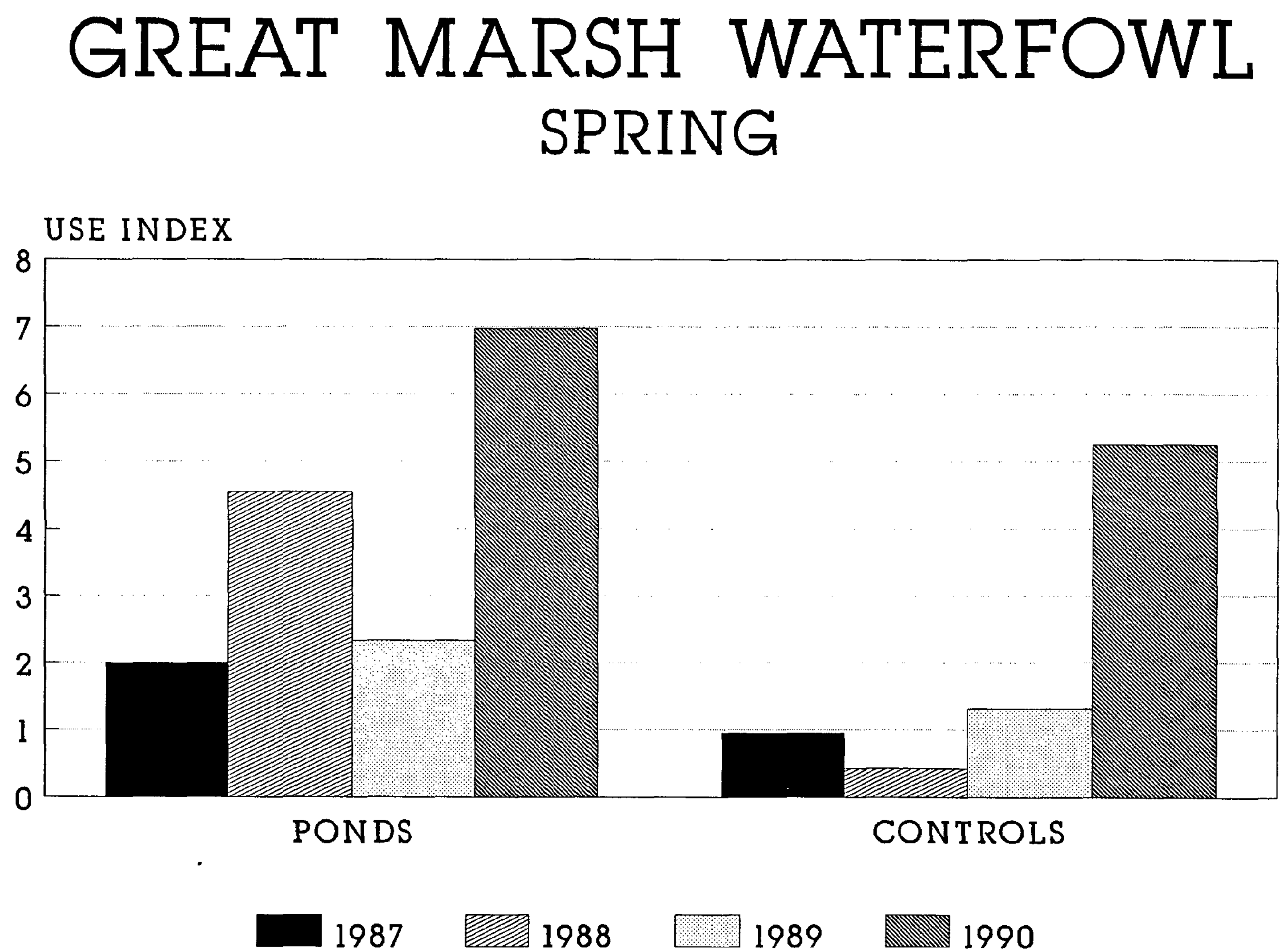


Figure 8. Waterfowl Use Indices in Spring 1987-90 for Ponds and Controls

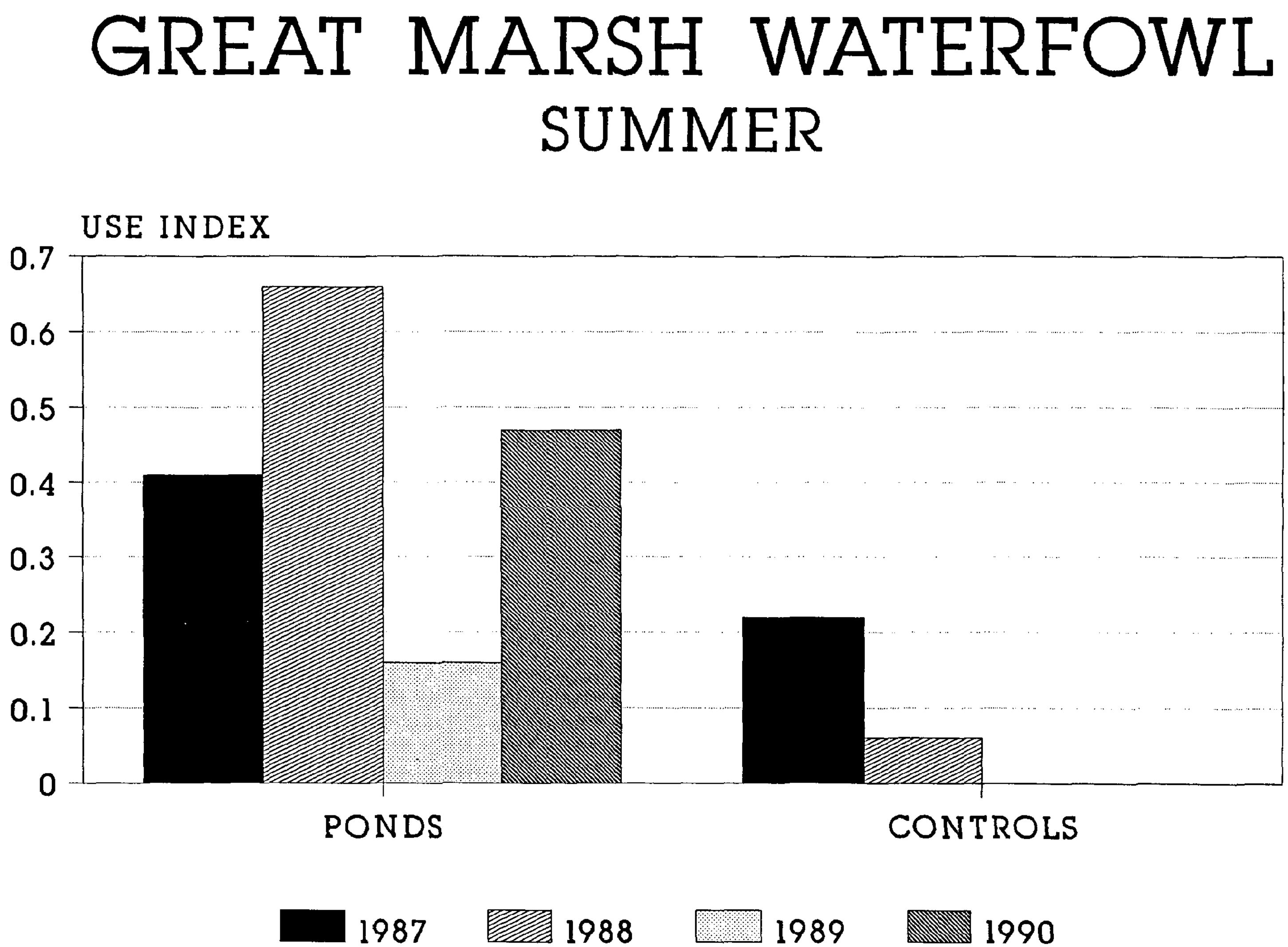


Figure 9. Waterfowl Use Indices in Summer 1987-90 for Ponds and Controls

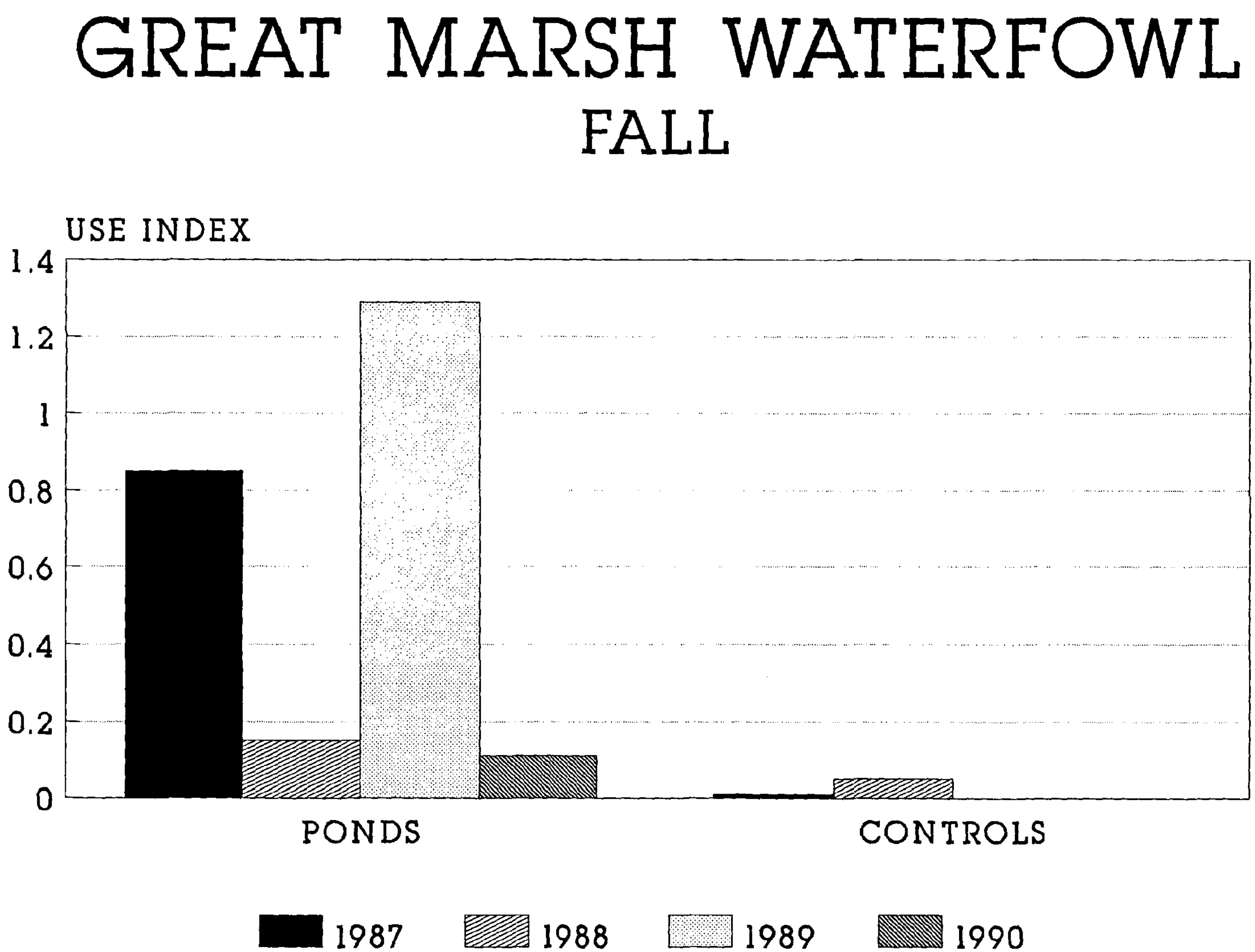


Figure 10. Waterfowl Use Indices in Fall 1987-90 for Ponds and Controls

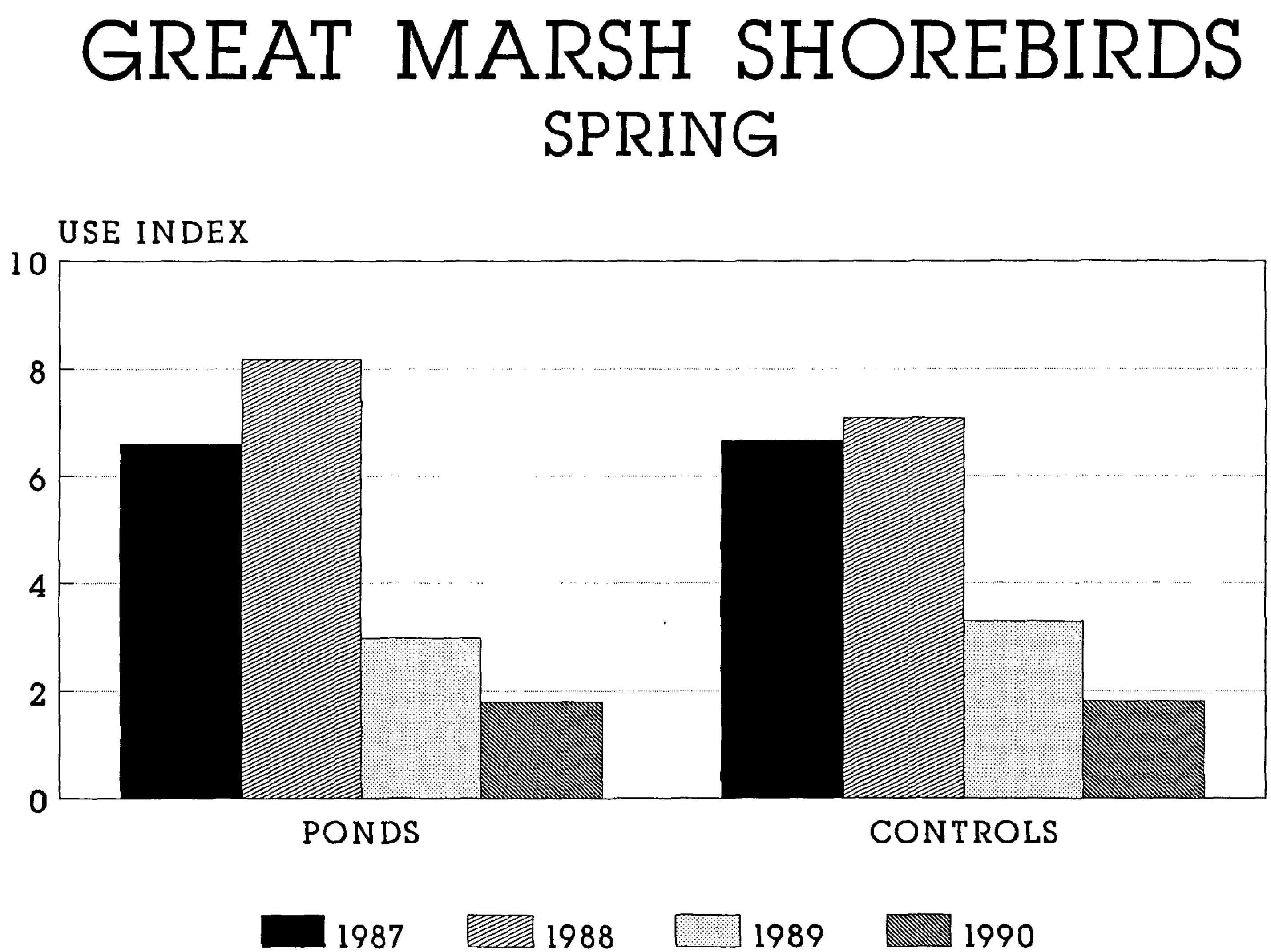


Figure 11. Shorebird Use Indices in Spring 1987-90 for Ponds and Controls

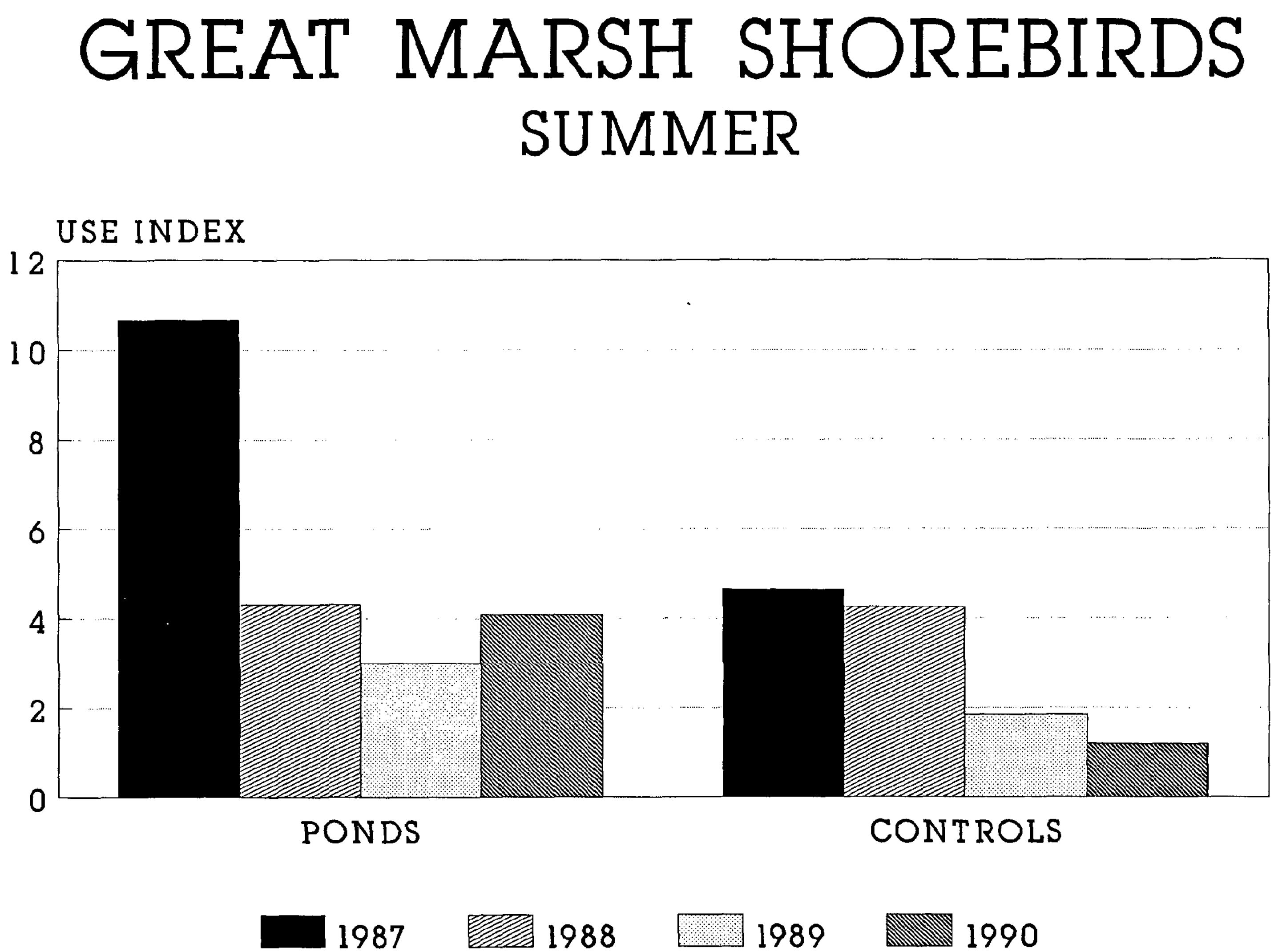


Figure 12. Shorebird Use Indices in Summer 1987-90 for Ponds and Controls

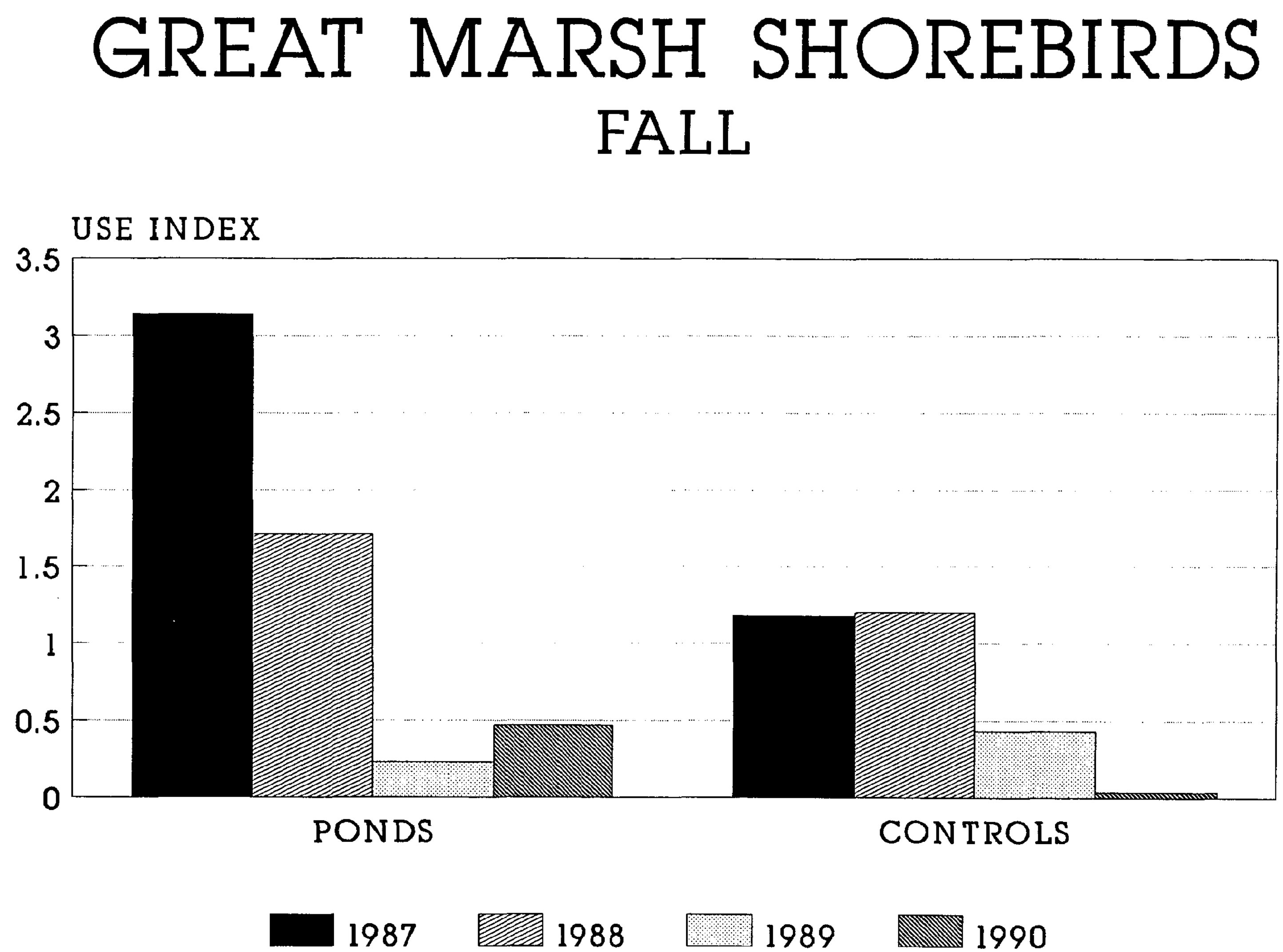


Figure 13. Shorebird Use Indices in Fall 1987-90 for Ponds and Controls

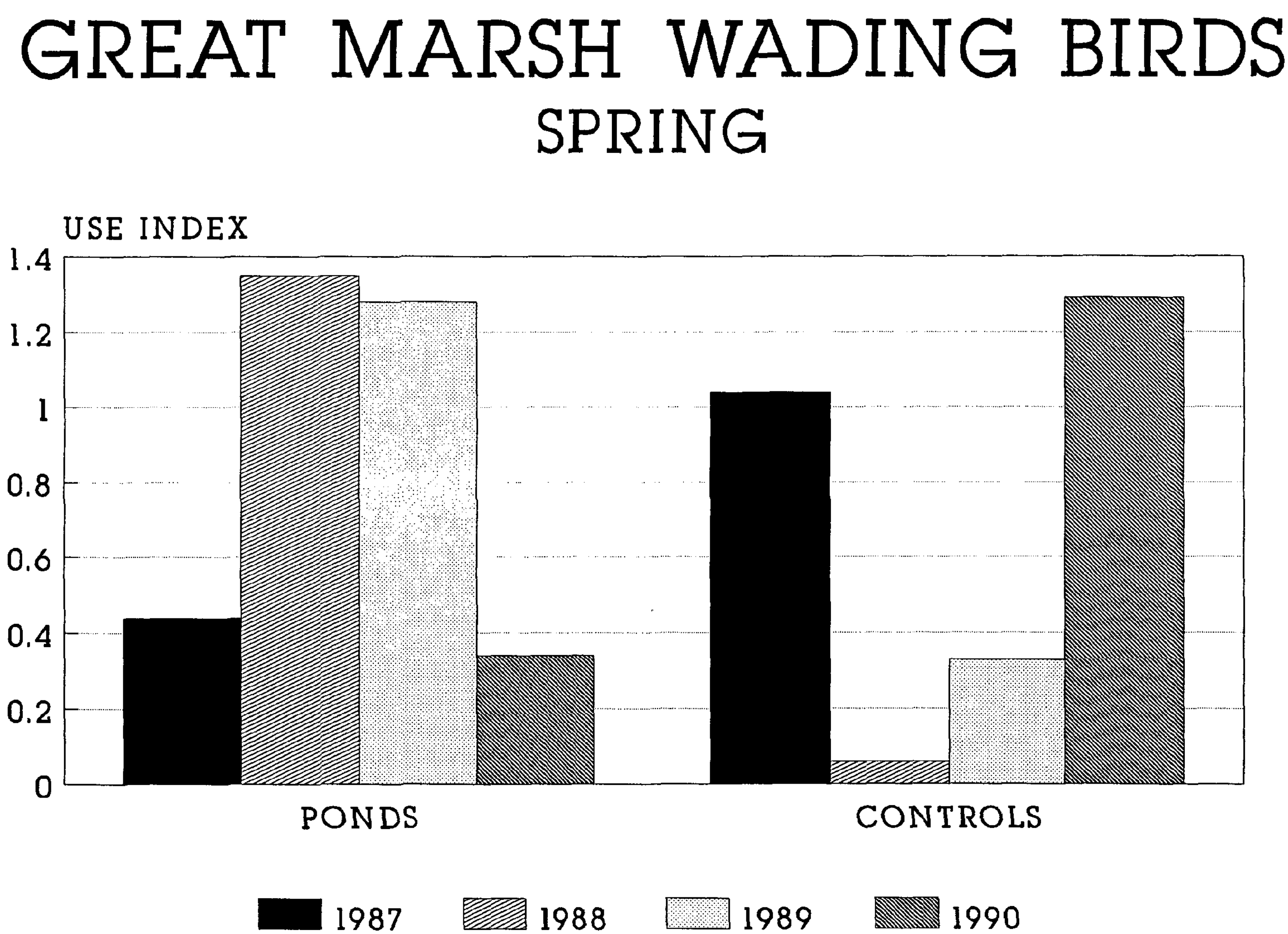


Figure 14. Wading Bird Use Indices in Spring 1987-90 for Ponds and Controls

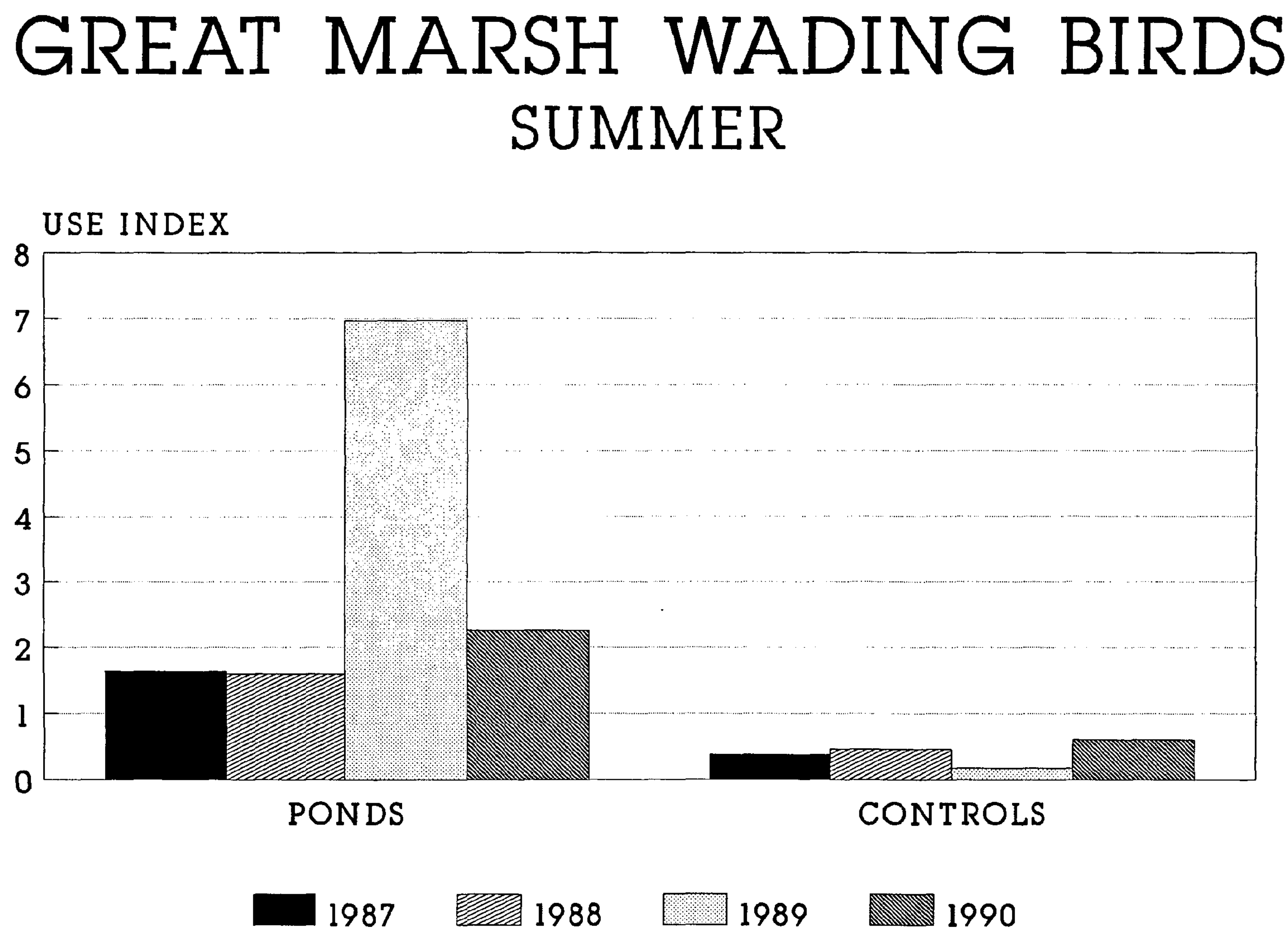


Figure 15. Wading Bird Use Indices in Summer 1987-90 for Ponds and Controls

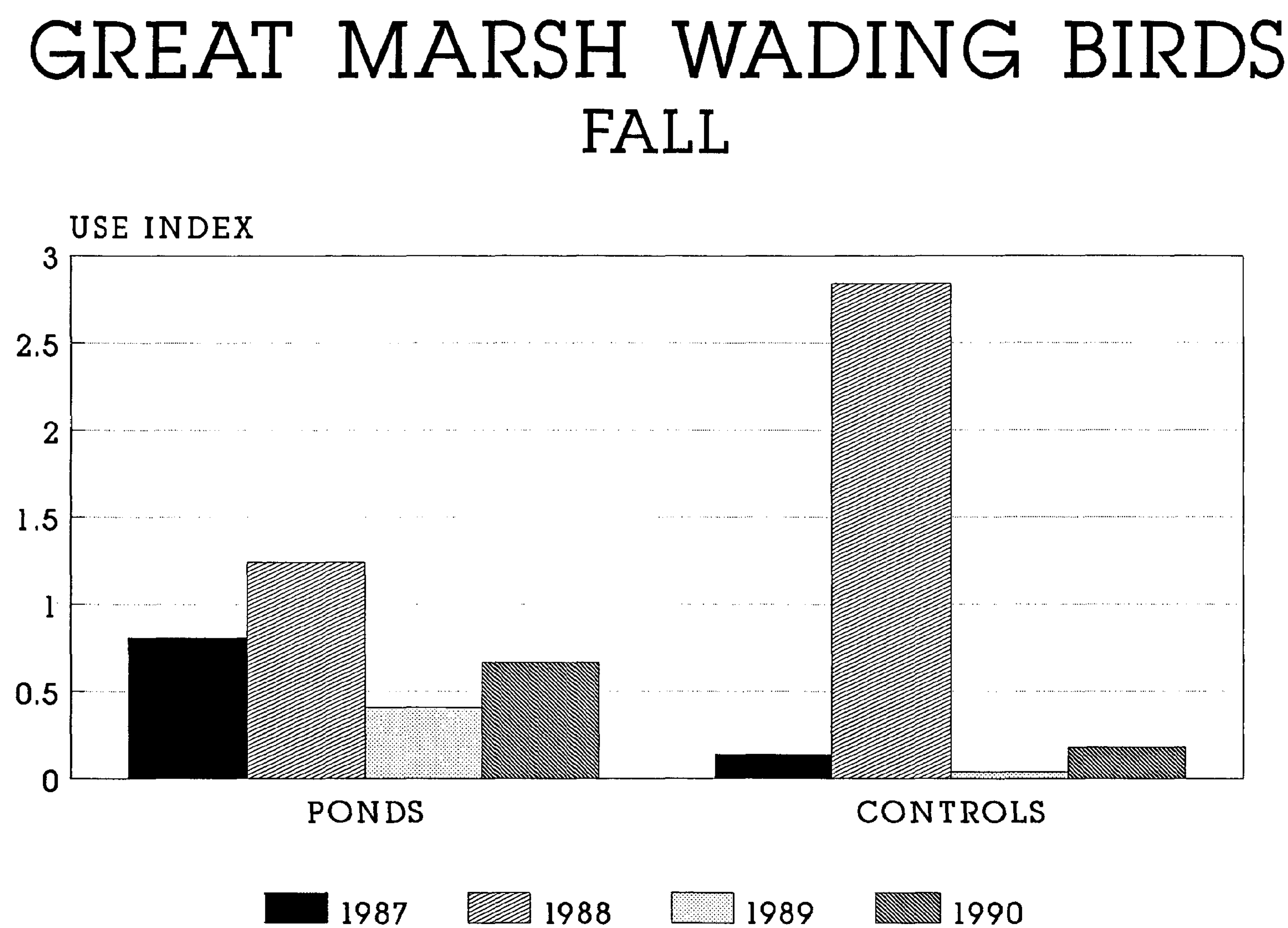


Figure 16. Wading Bird Use Indices in Fall 1987-90 for Ponds and Controls

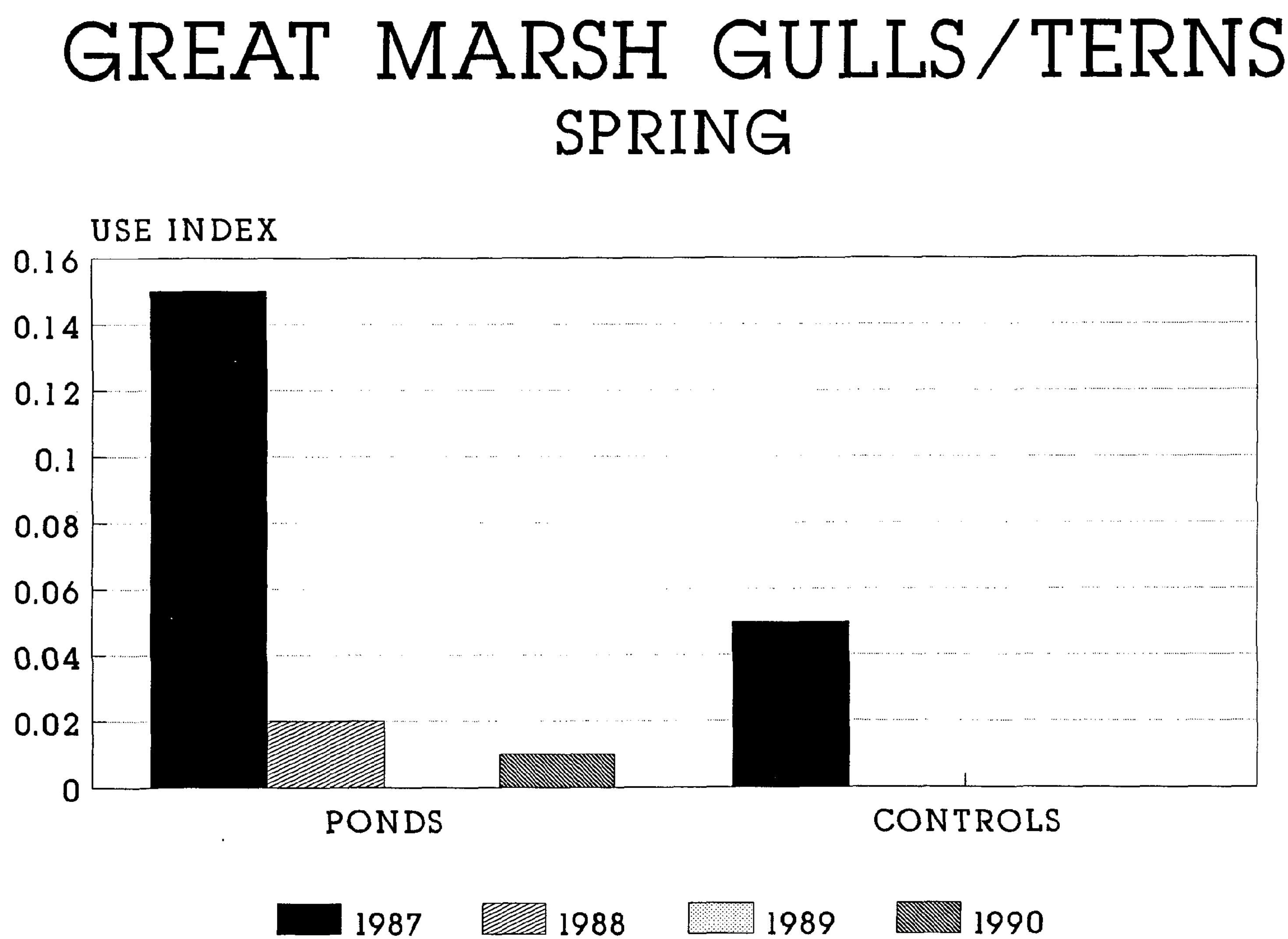


Figure 17. Gull and Tern Use Indices in Spring 1987-90 for Ponds and Controls

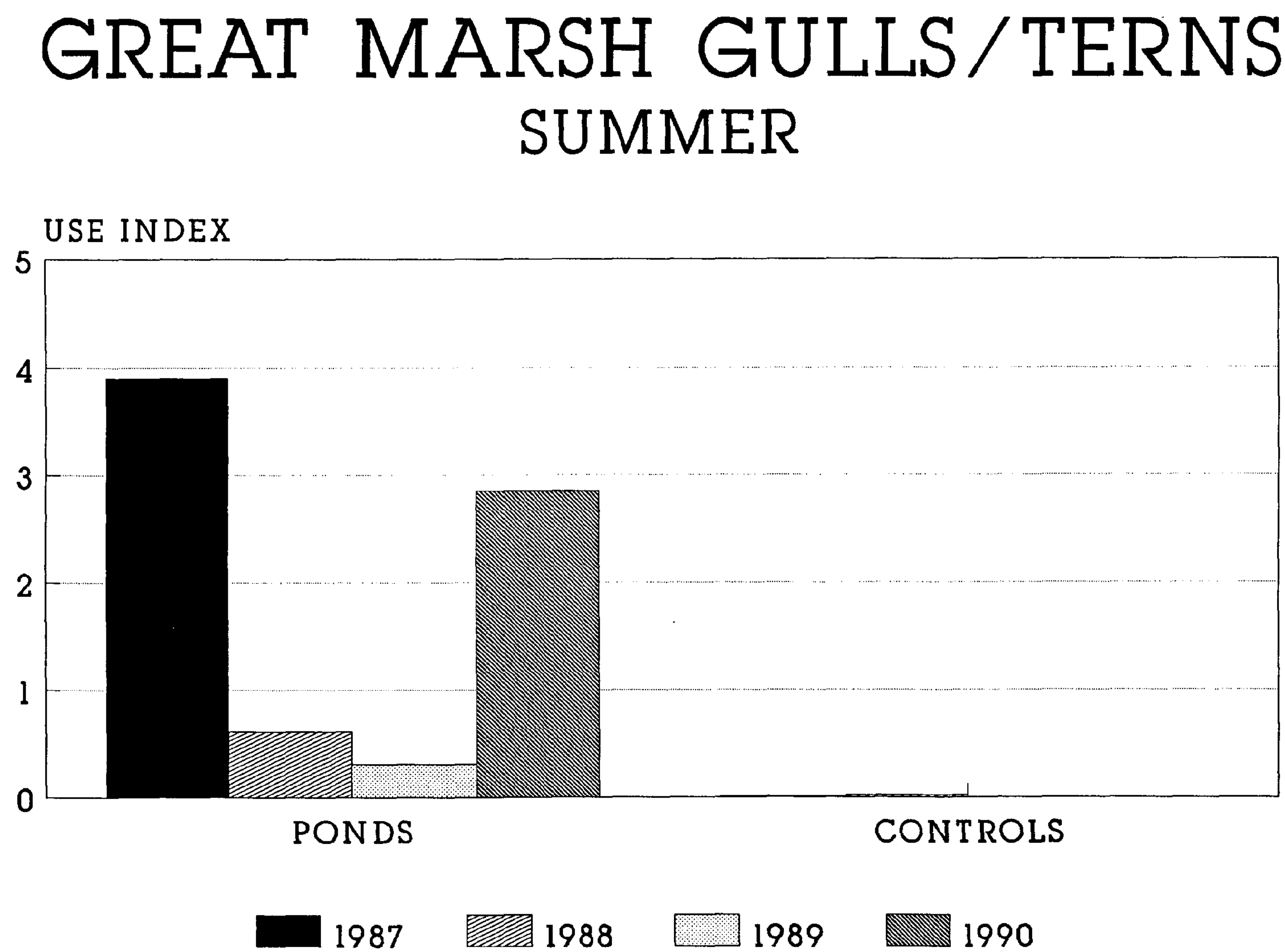


Figure 18. Gull and Tern Use Indices in Summer 1987-90 for Ponds and Controls

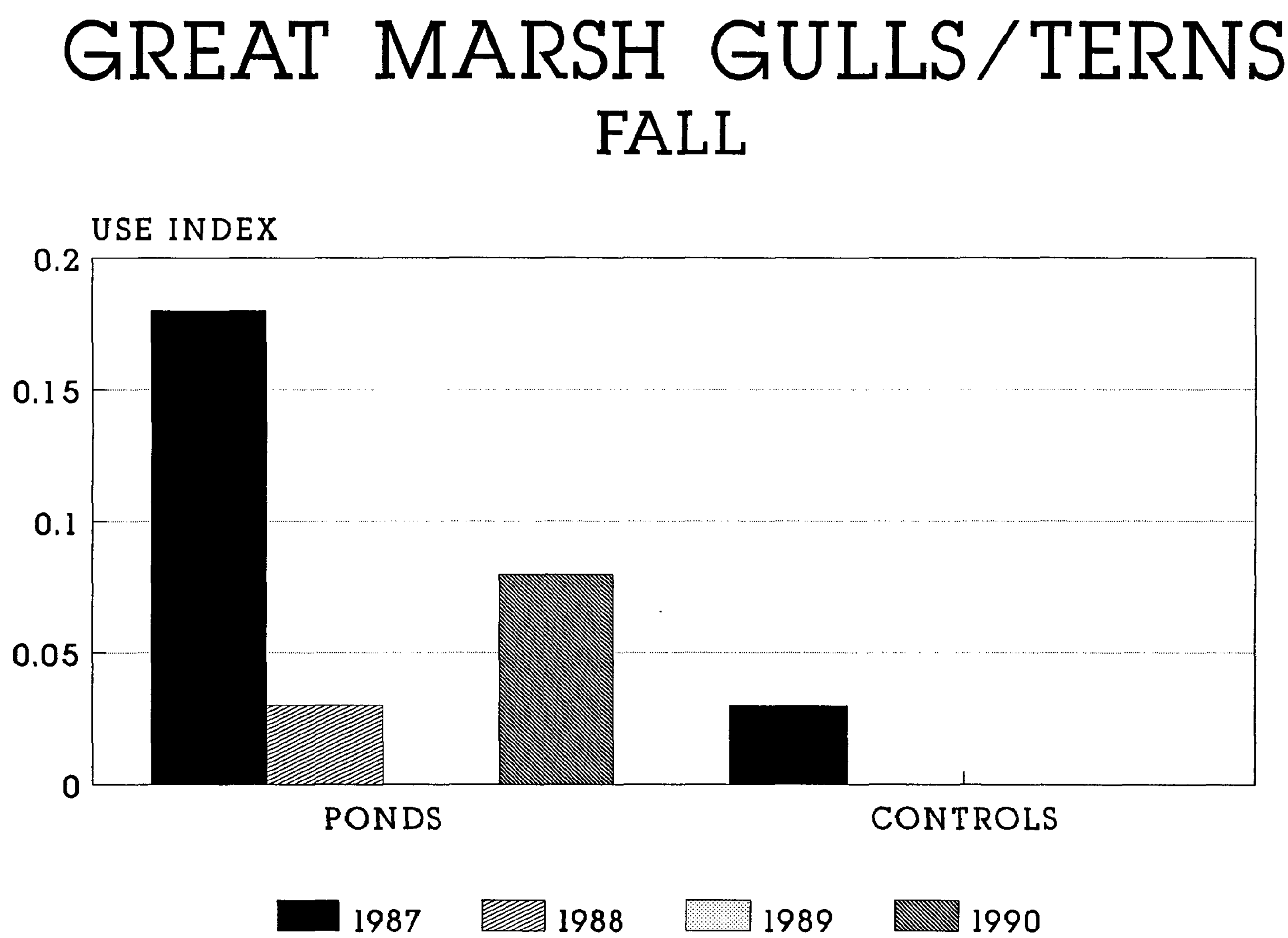


Figure 19. Gull and Tern Use Indices in Fall 1987-90 for Ponds and Controls

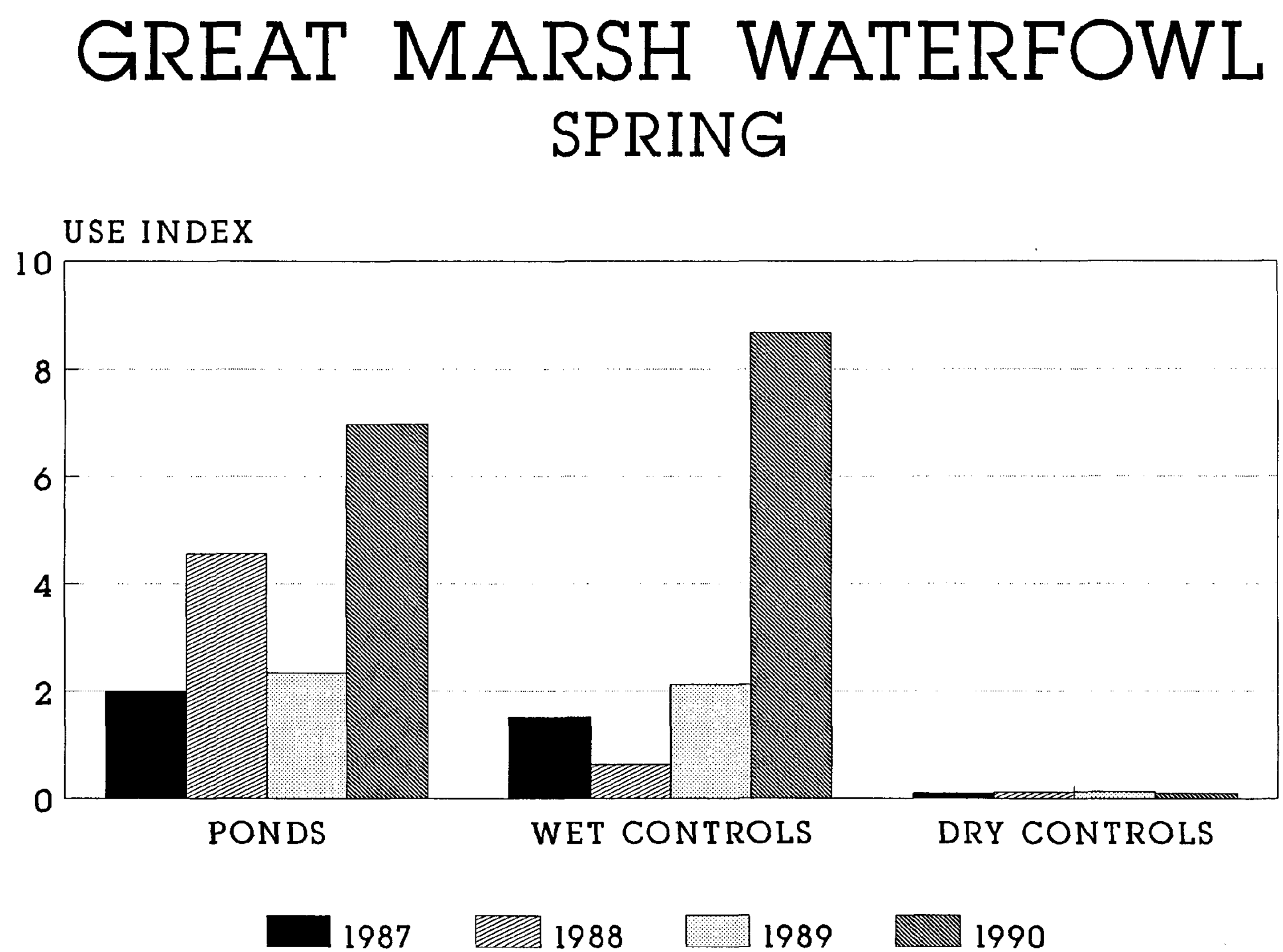


Figure 20. Waterfowl Use Indices in Spring 1987-90 for Ponds, Wet & Dry Controls

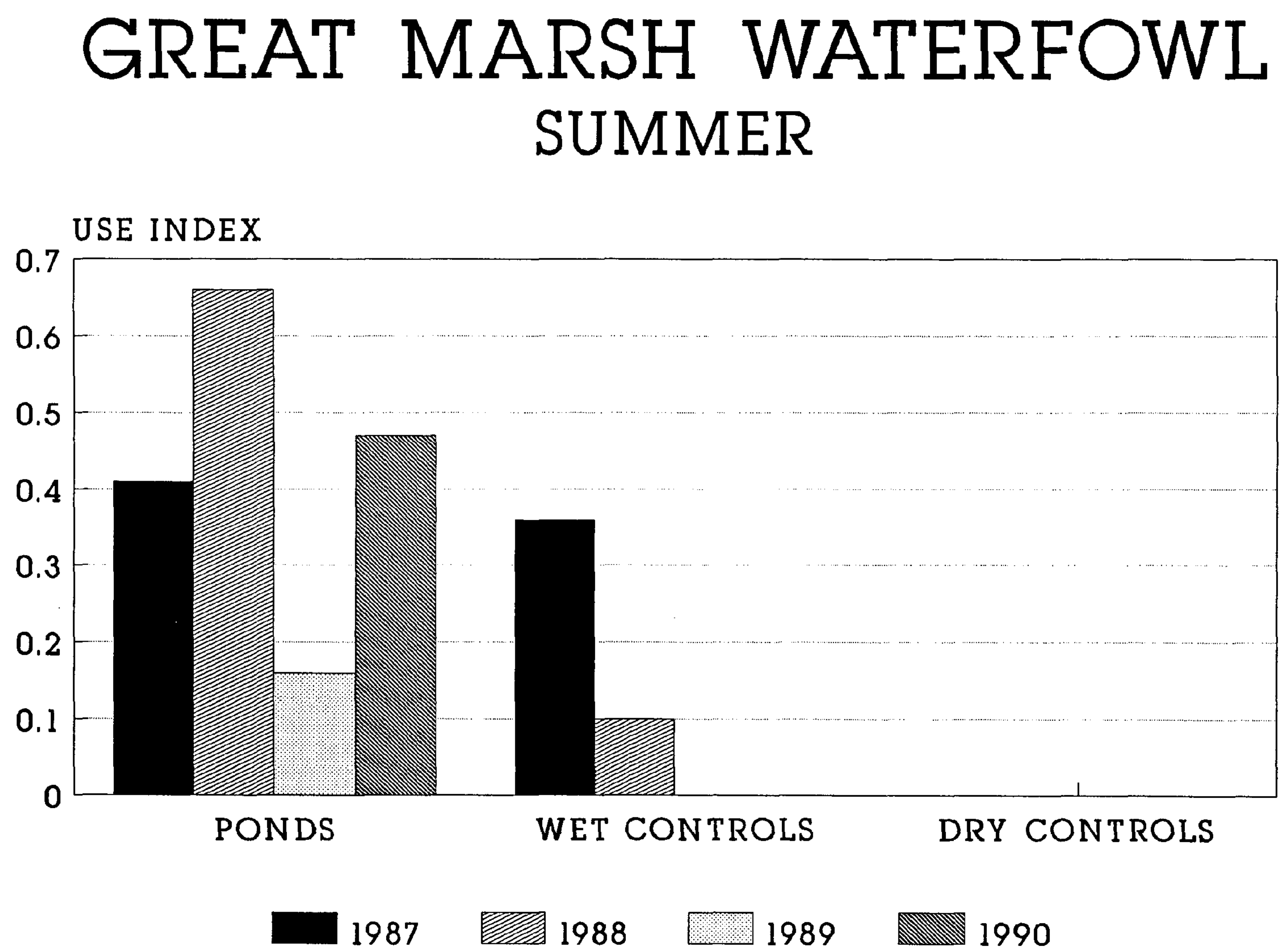


Figure 21. Waterfowl Use Indices in Summer 1987-90 for Ponds, Wet & Dry Controls

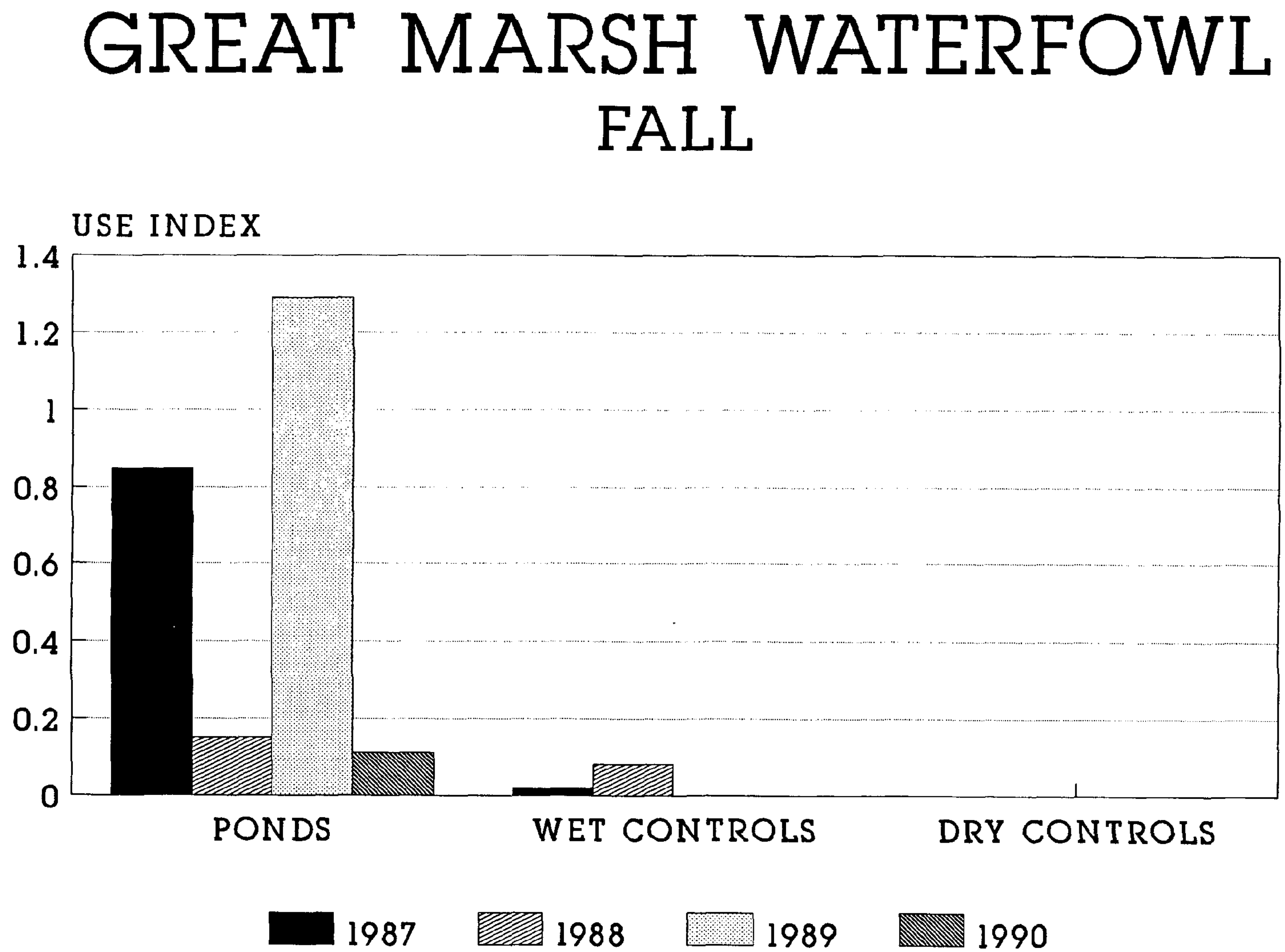


Figure 22. Waterfowl Use Indices in Fall 1987-90 for Ponds, Wet & Dry Controls

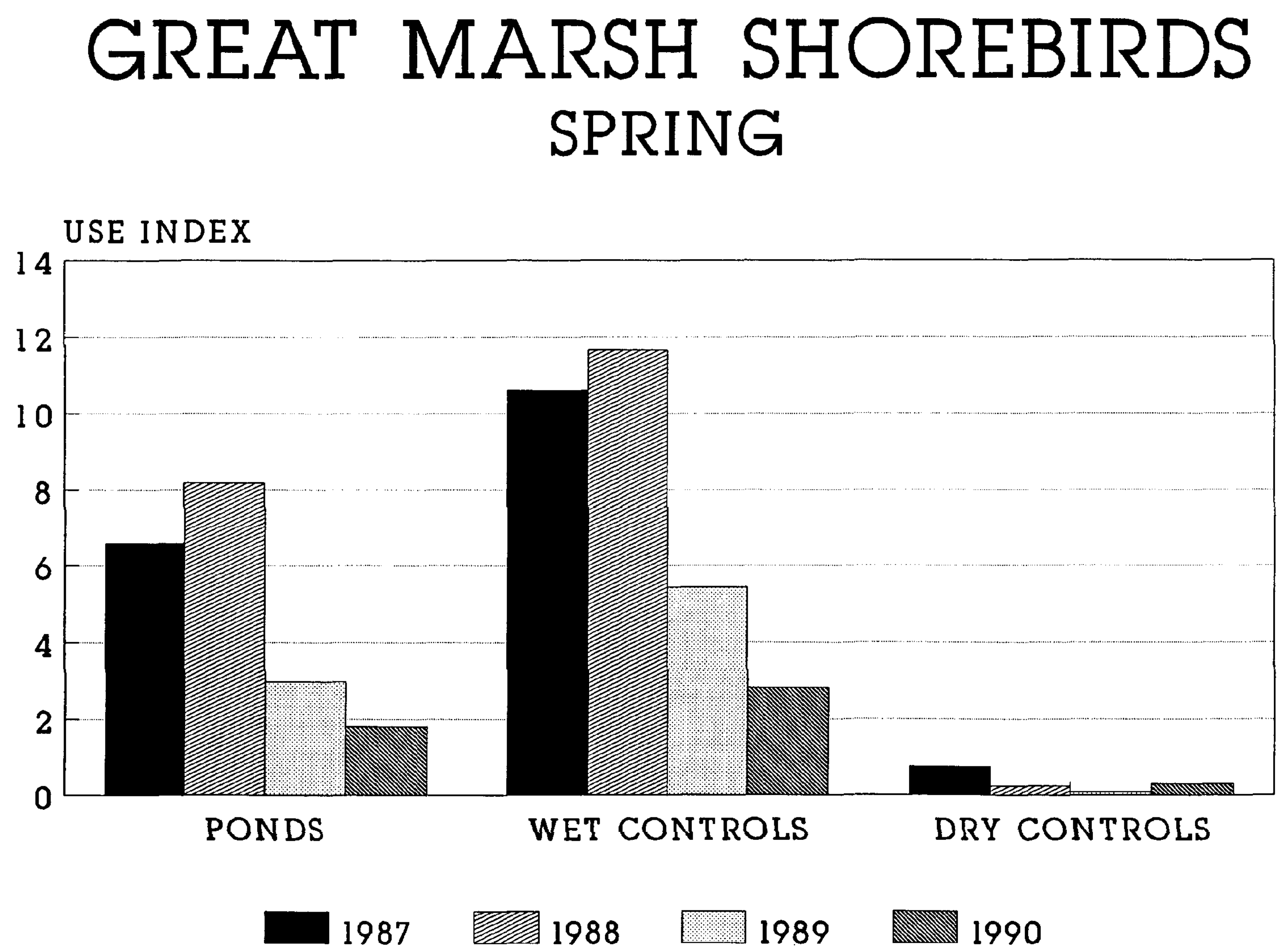


Figure 23. Shorebird Use Indices in Spring 1987-90 for Ponds, Wet & Dry Controls

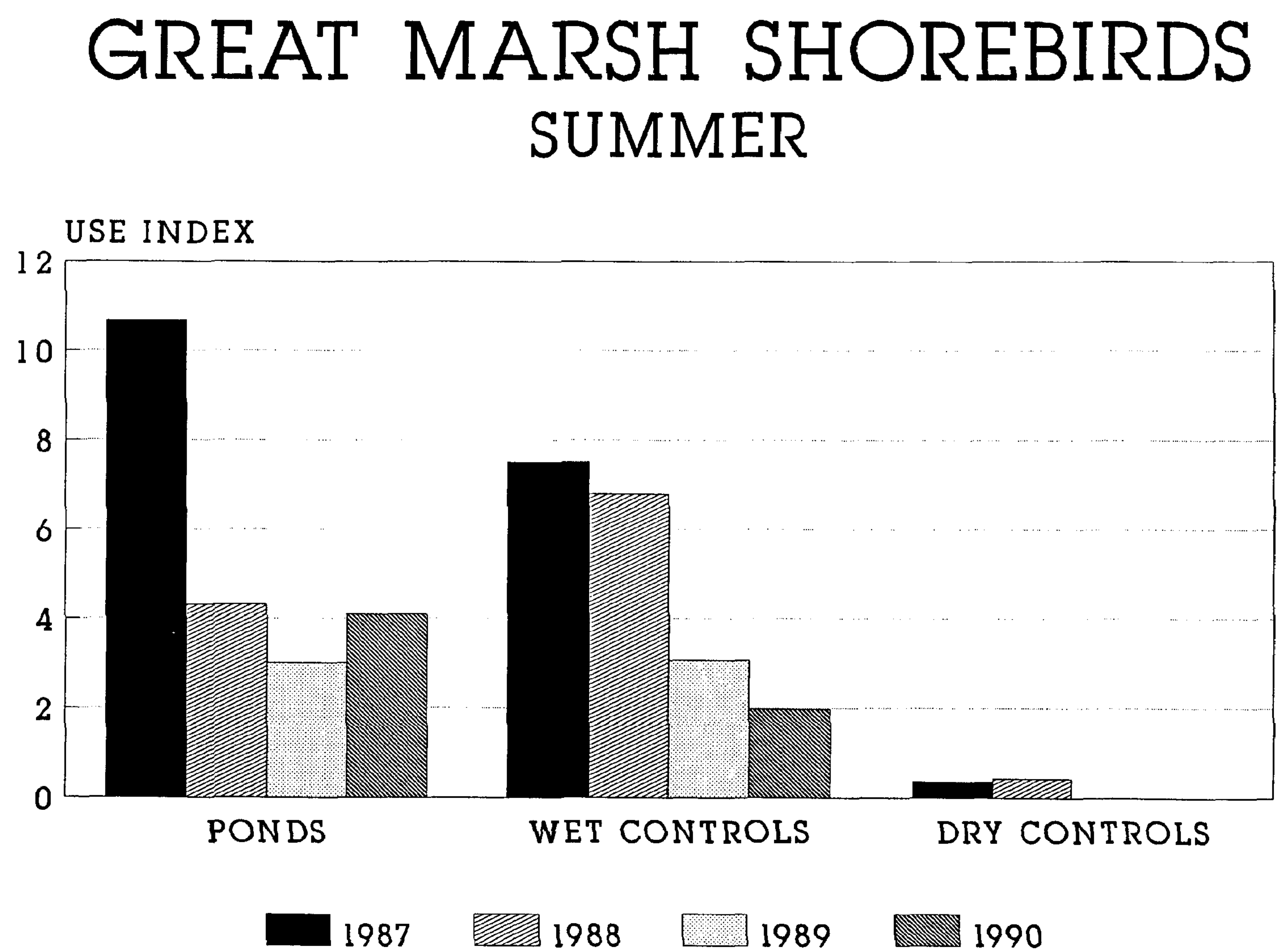


Figure 24. Shorebird Use Indices in Summer 1987-90 for Ponds, Wet & Dry Controls

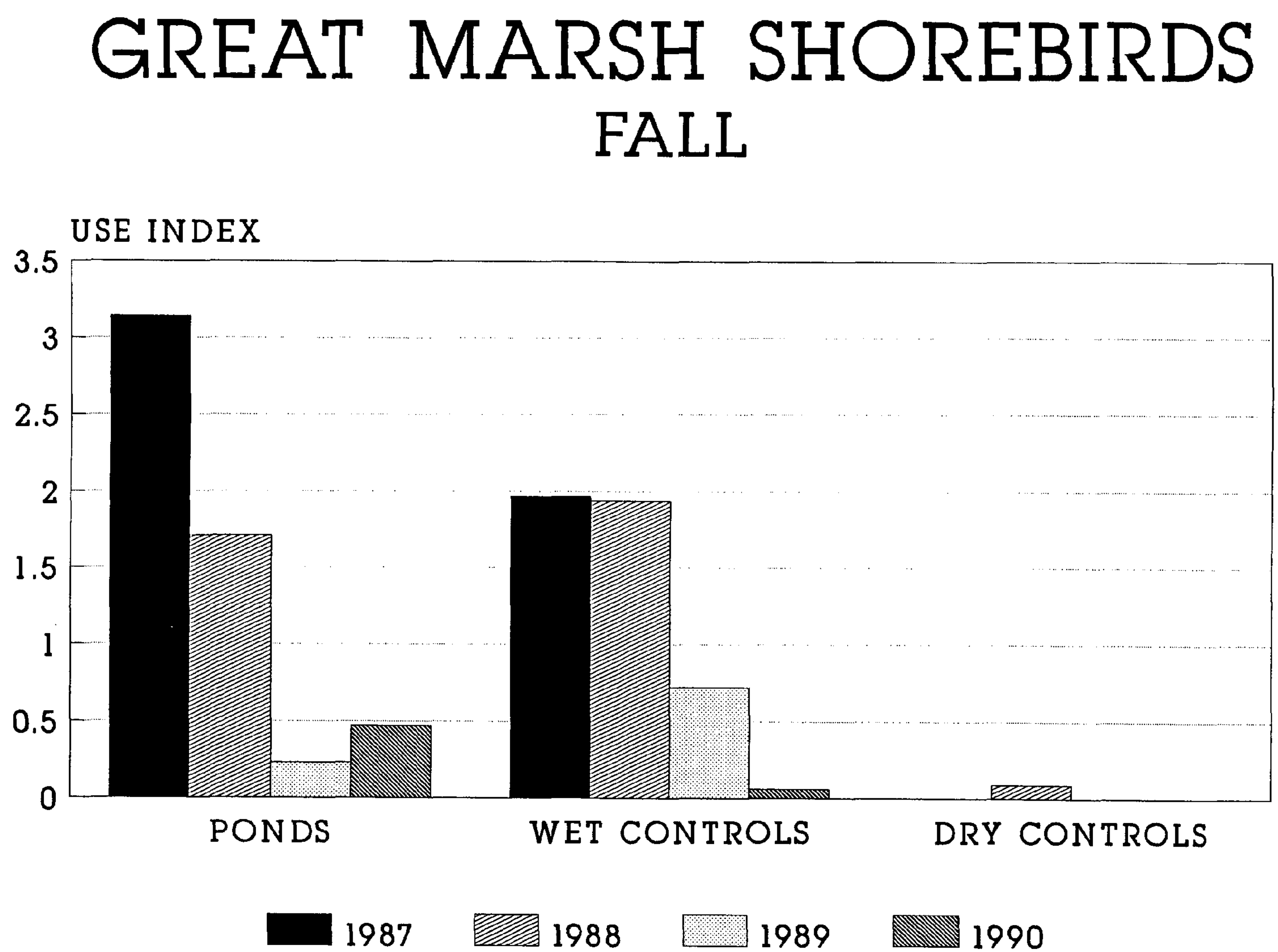


Figure 25. Shorebird Use Indices in Fall 1987-90 for Ponds, Wet & Dry Controls

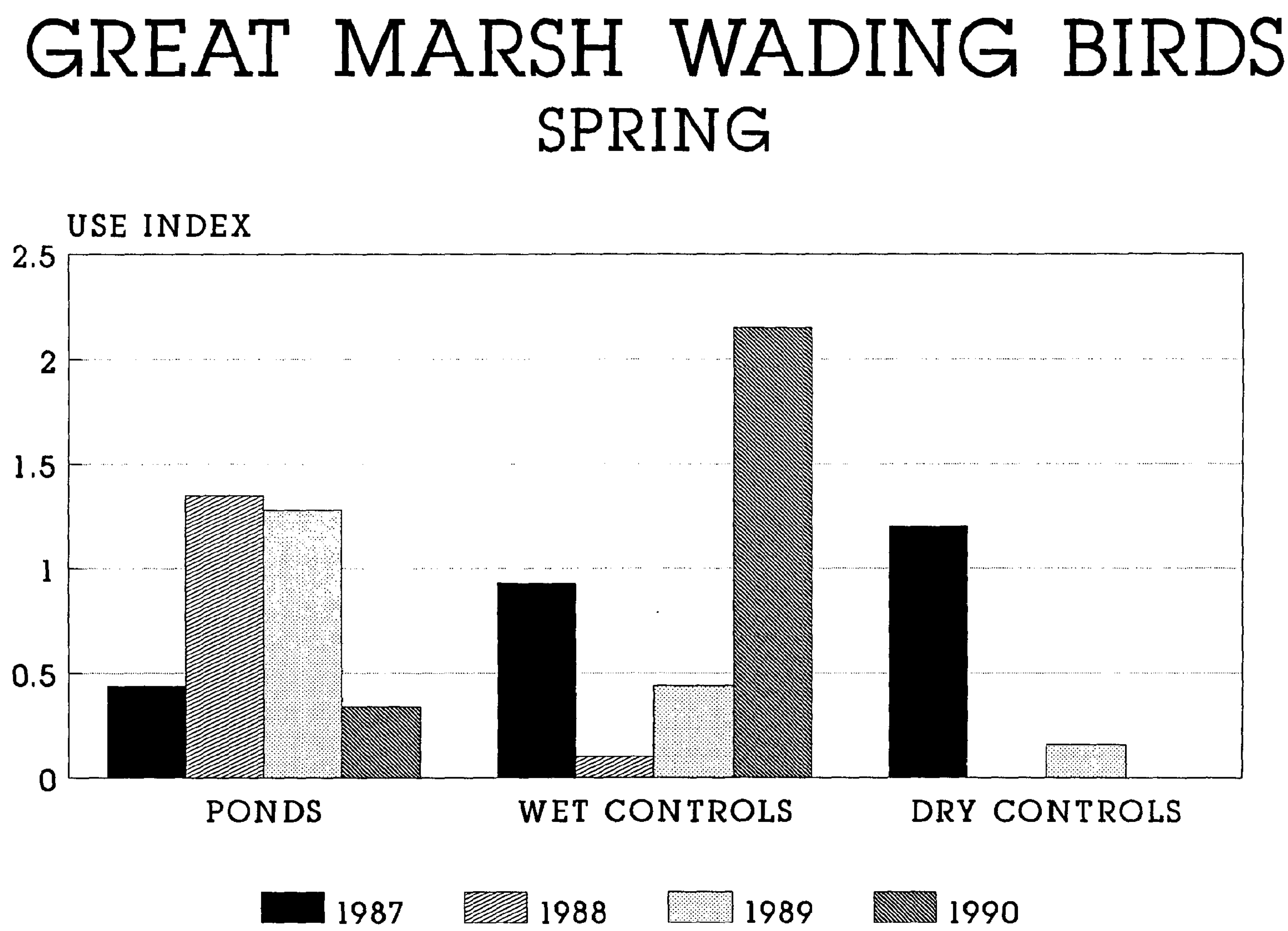


Figure 26. Wading Bird Use Indices in Spring 1987-90 for Ponds, Wet & Dry Controls

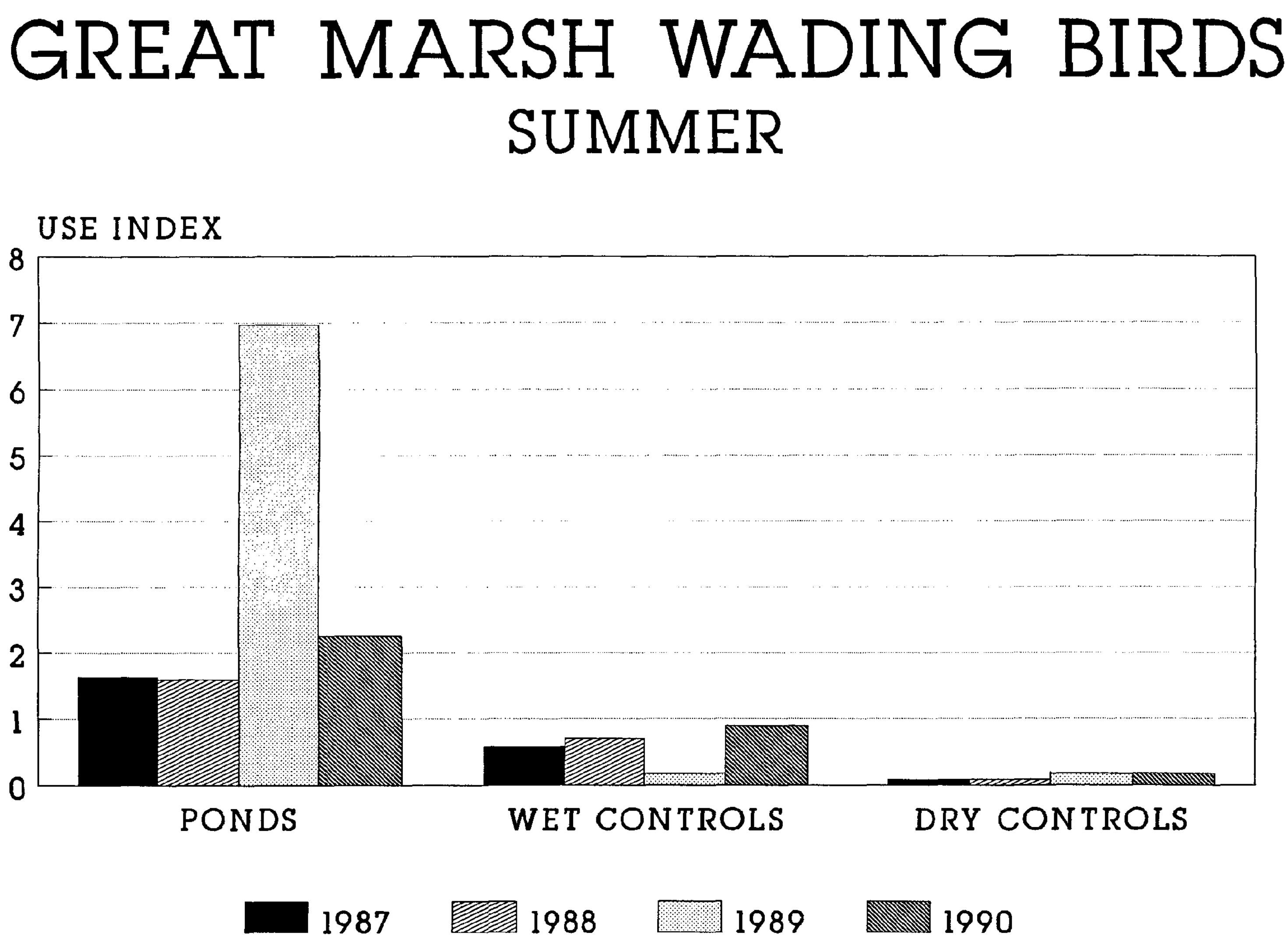


Figure 27. Wading Bird Use Indices in Summer 1987-90 for Ponds, Wet & Dry Controls

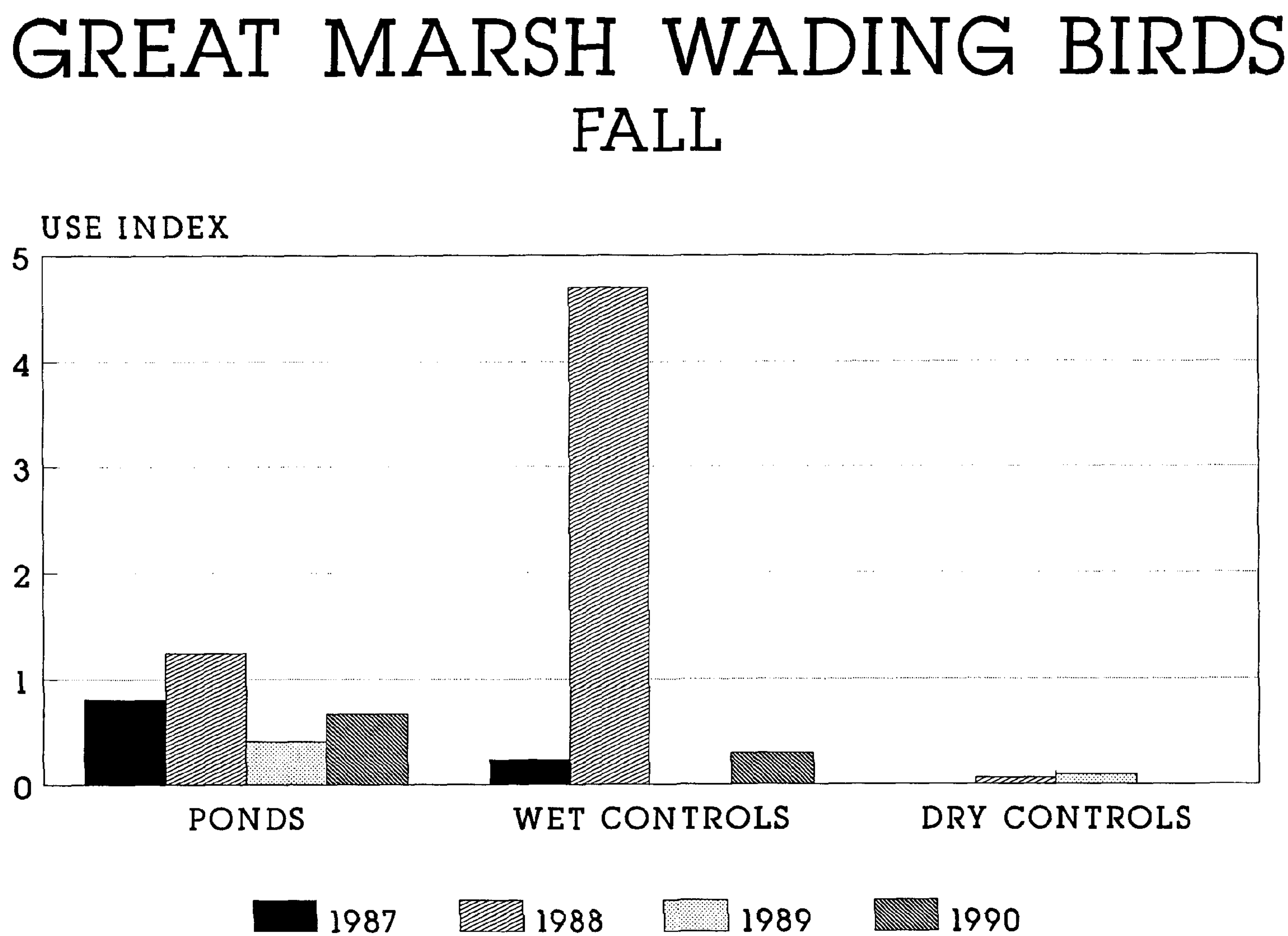


Figure 28. Wading Bird Use Indices in Fall 1987-90 for Ponds, Wet & Dry Controls

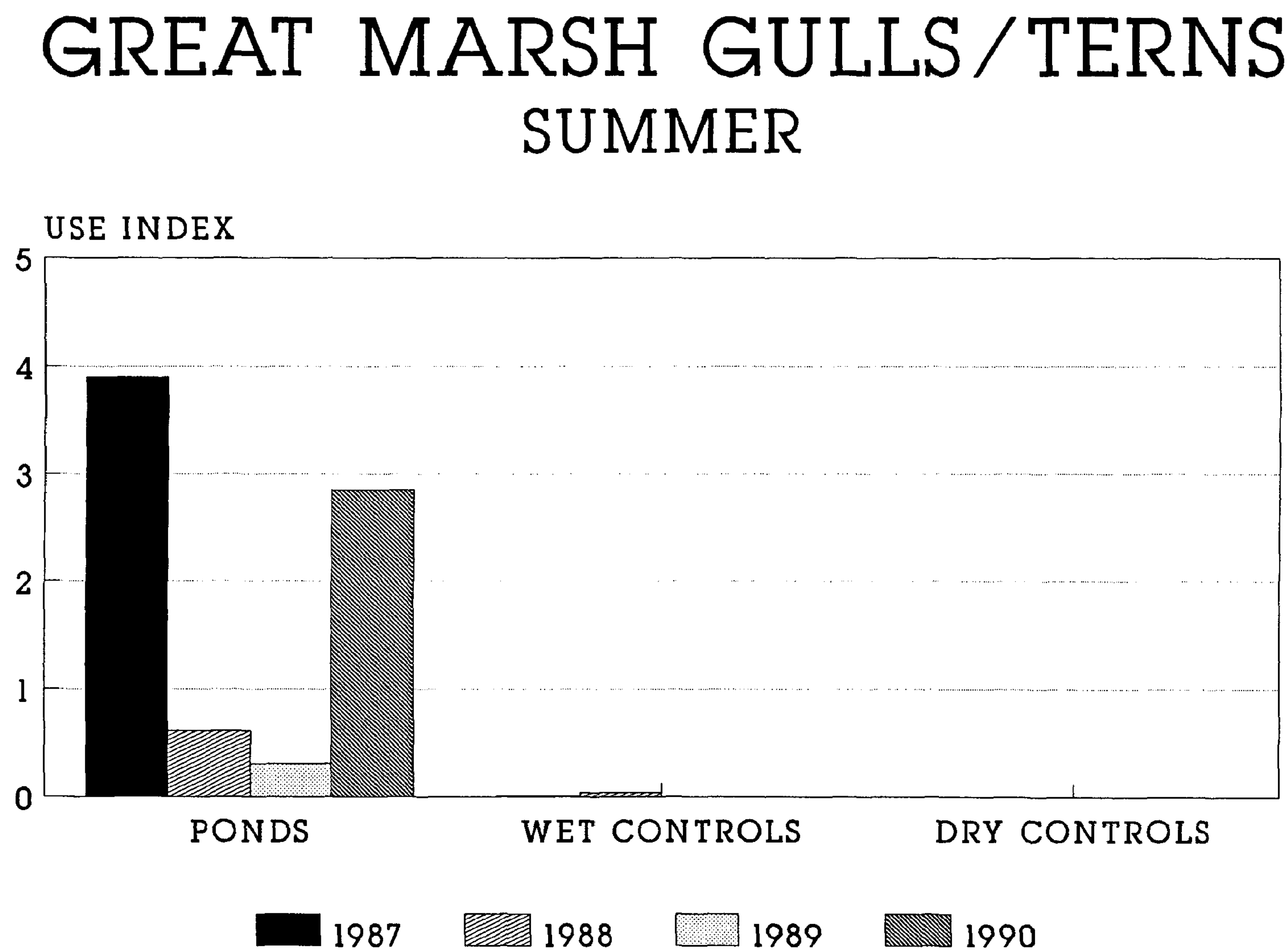


Figure 29. Gull and Tern Use Indices in Summer 1987-90 for Ponds, Wet & Dry Controls

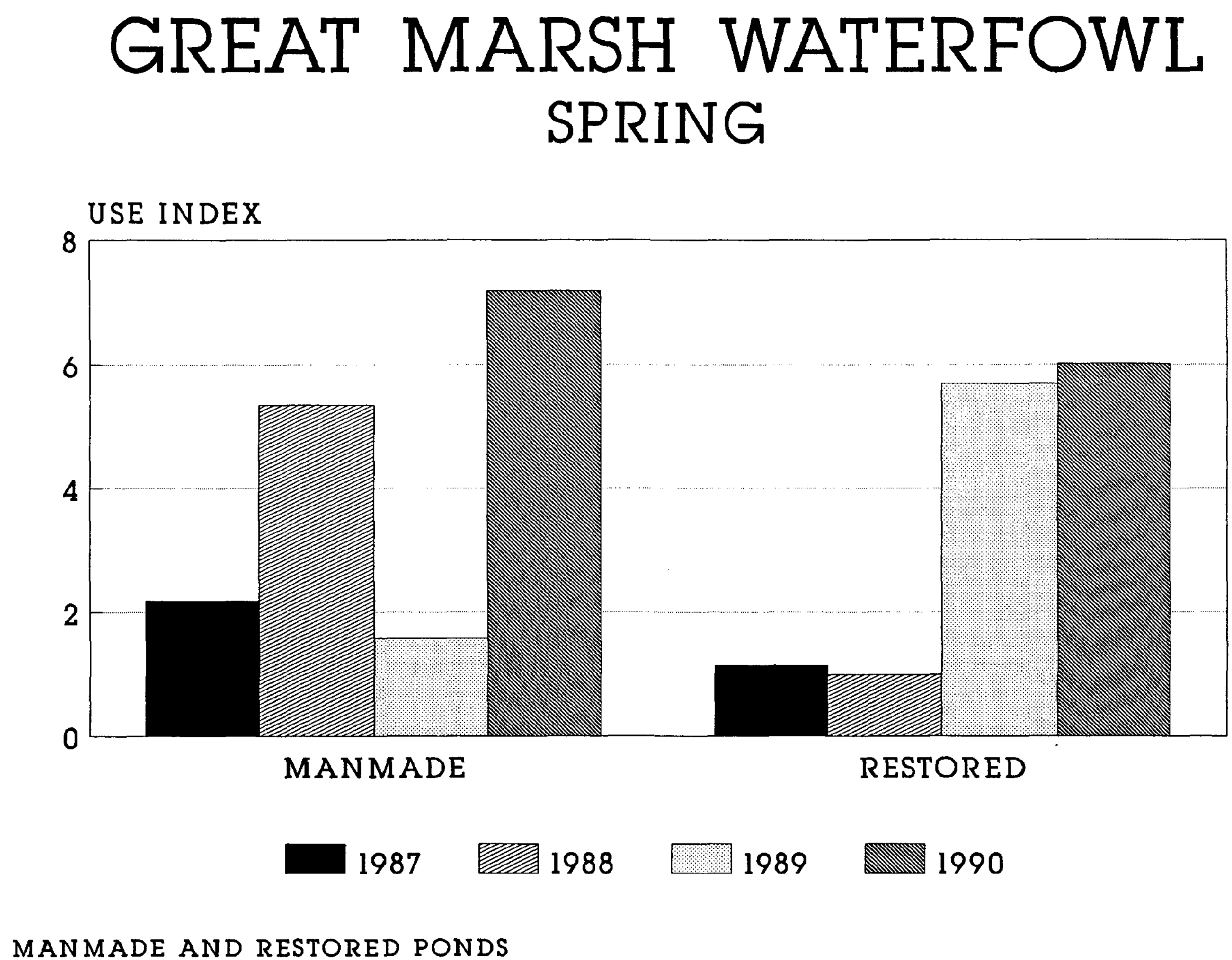


Figure 30. Waterfowl Use Indices in Spring 1987-90 for Manmade and Restored Ponds

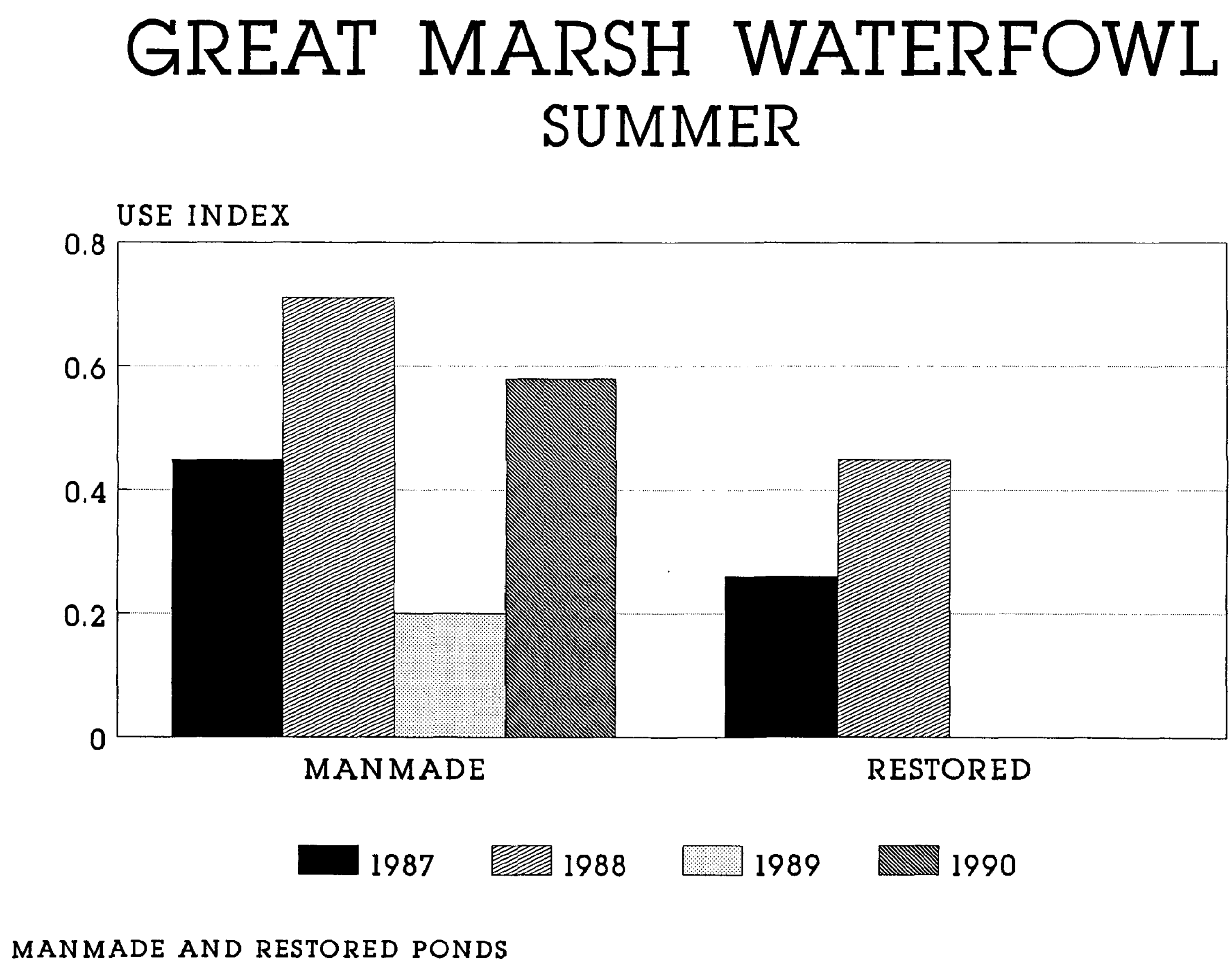


Figure 31. Waterfowl Use Indices in Summer 1987-90 for Manmade and Restored Ponds

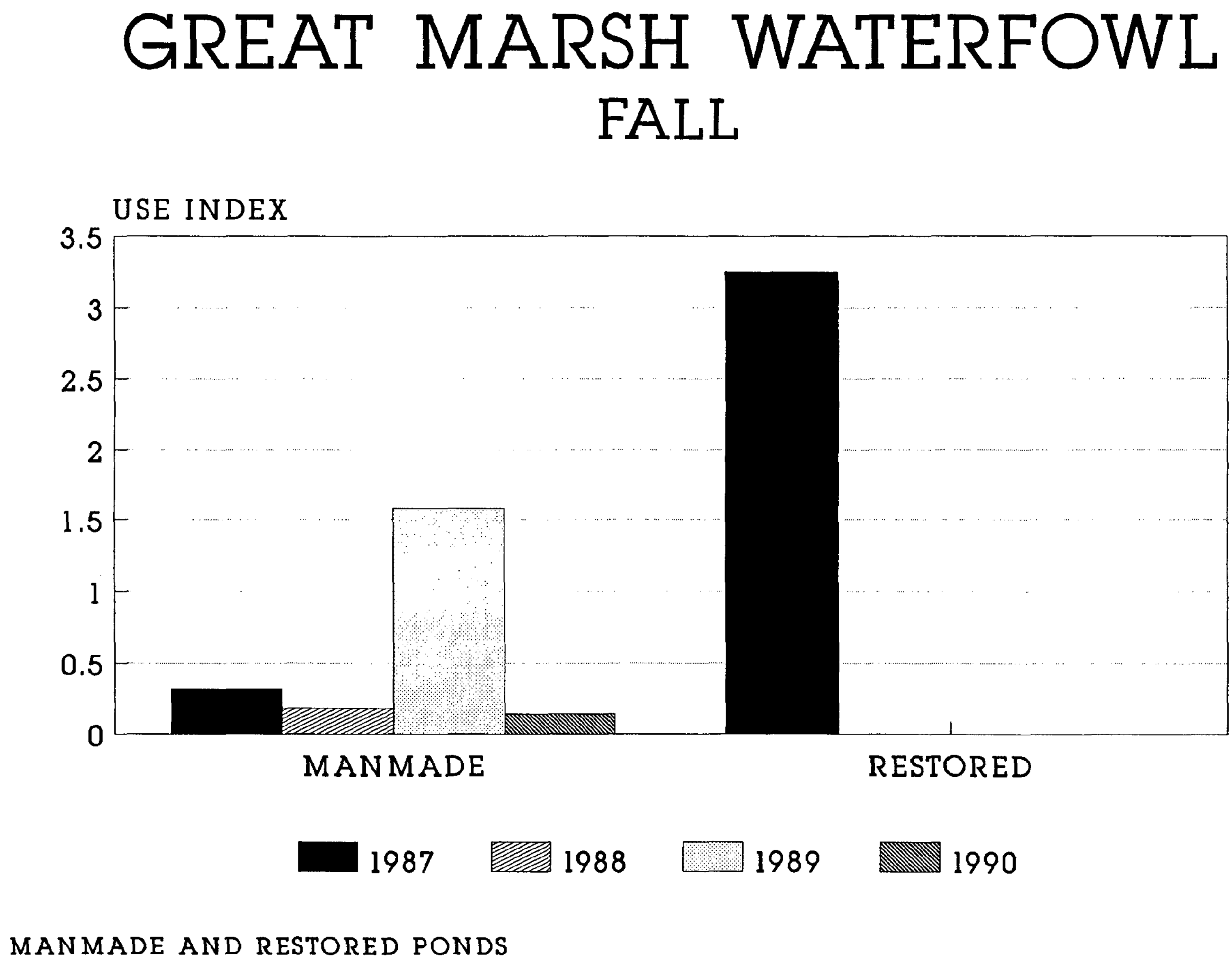


Figure 32. Waterfowl Use Indices in Fall 1987-90 for Manmade and Restored Ponds

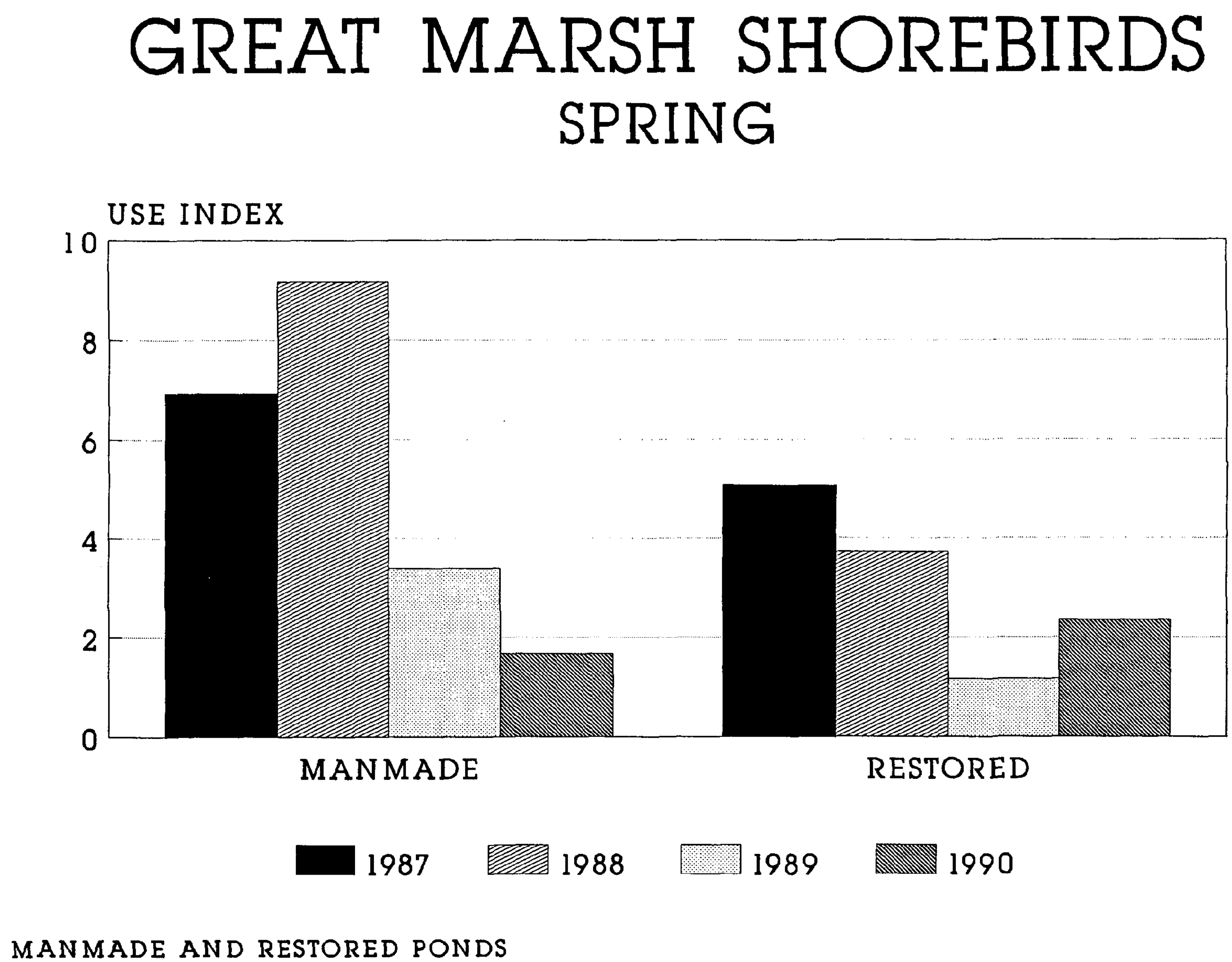


Figure 33. Shorebird Use Indices in Spring 1987-90 for Manmade and Restored Ponds

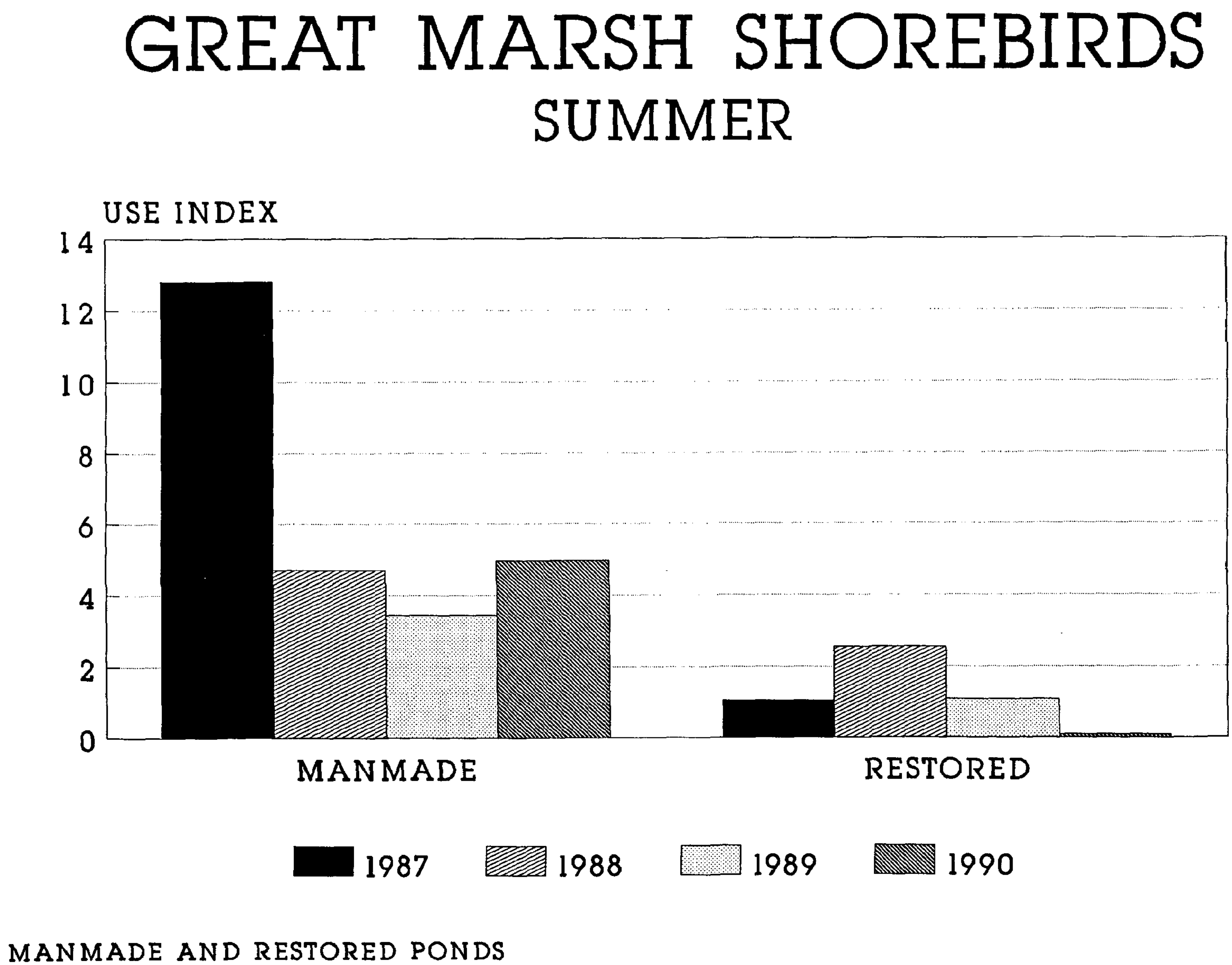


Figure 34. Shorebird Use Indices in Summer 1987-90 for Manmade and Restored Ponds

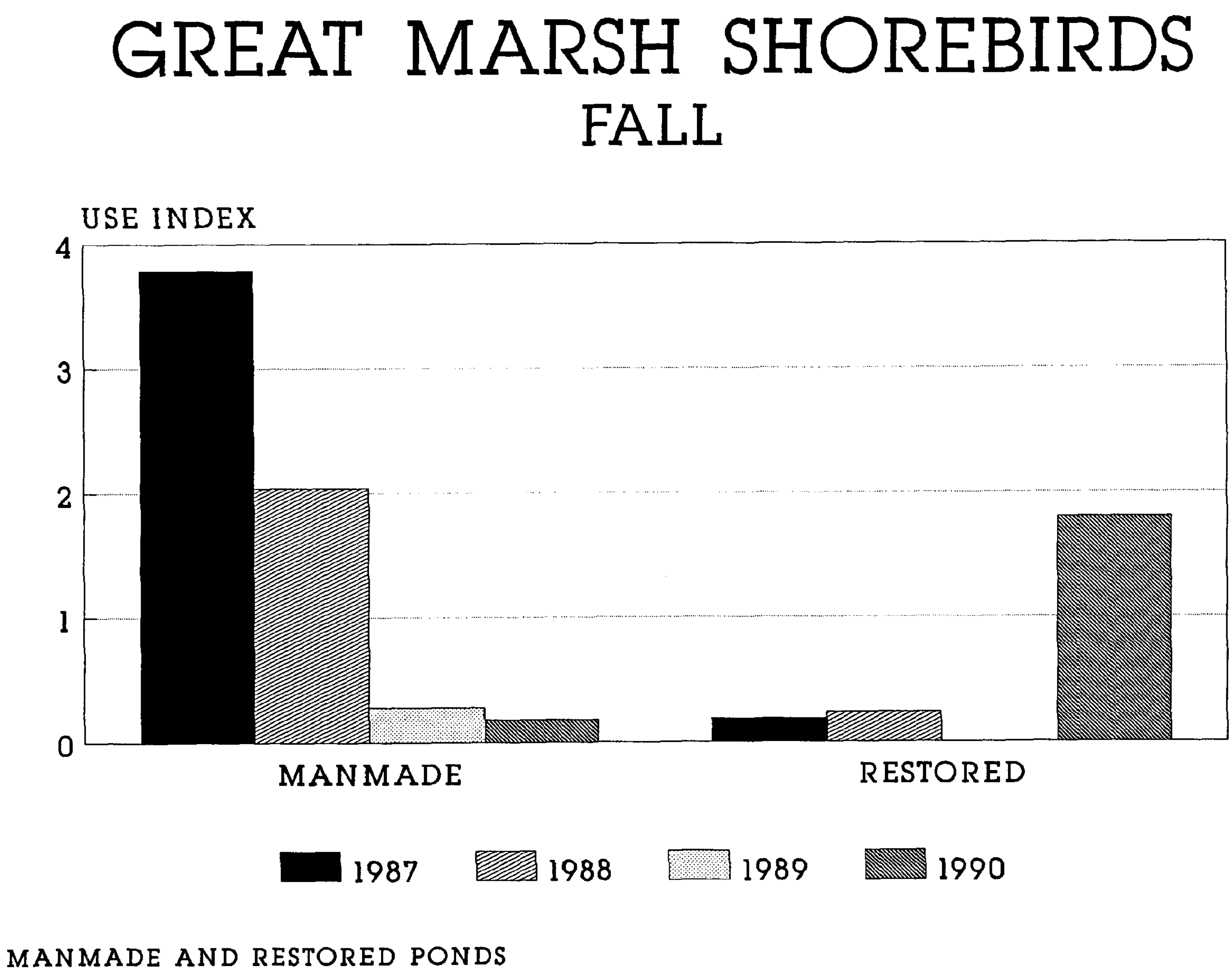


Figure 35. Shorebird Use Indices in Fall 1987-90 for Manmade Restored Ponds

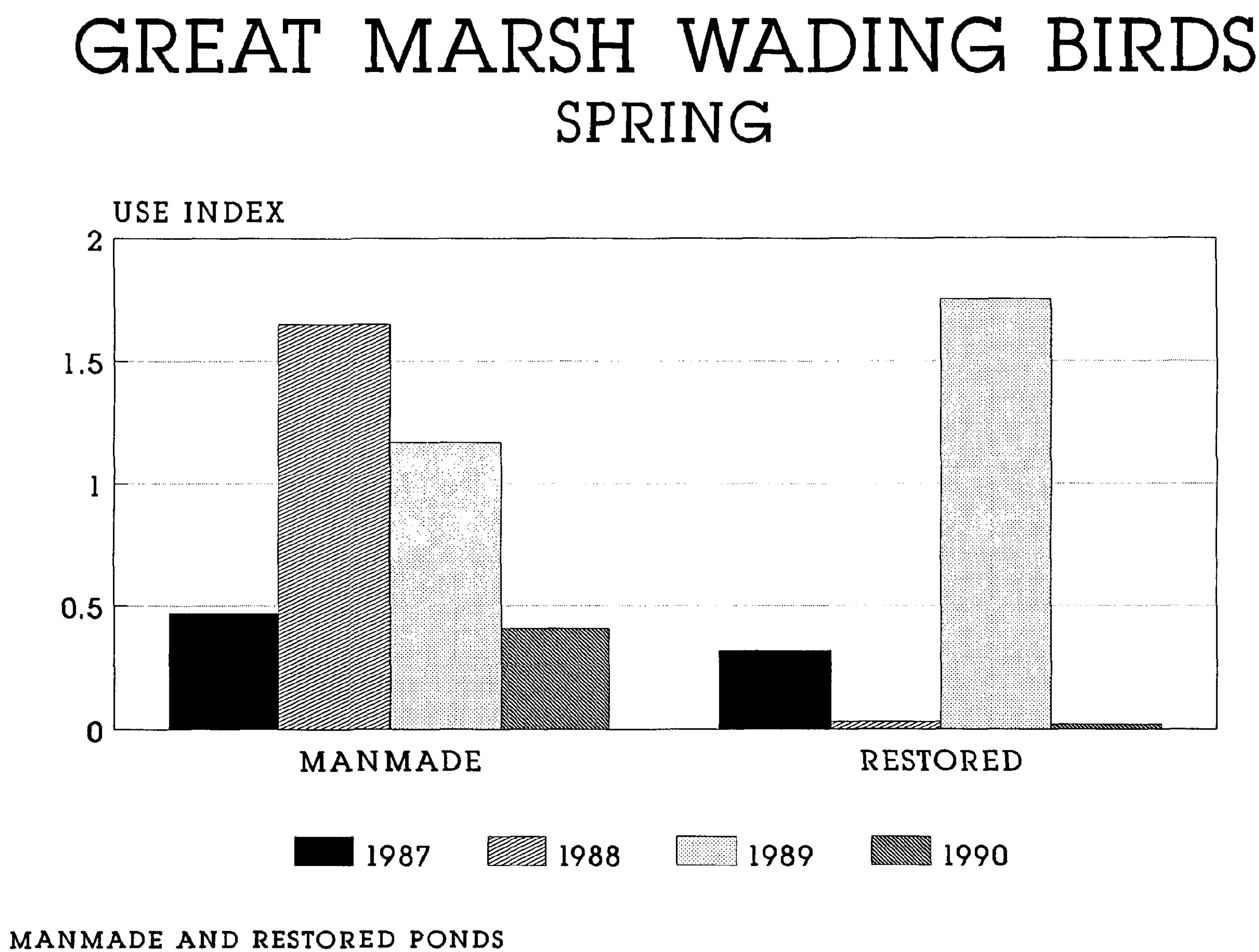


Figure 36. Wading Bird Use Indices in Spring 1987-90 for Manmade and Restored Ponds

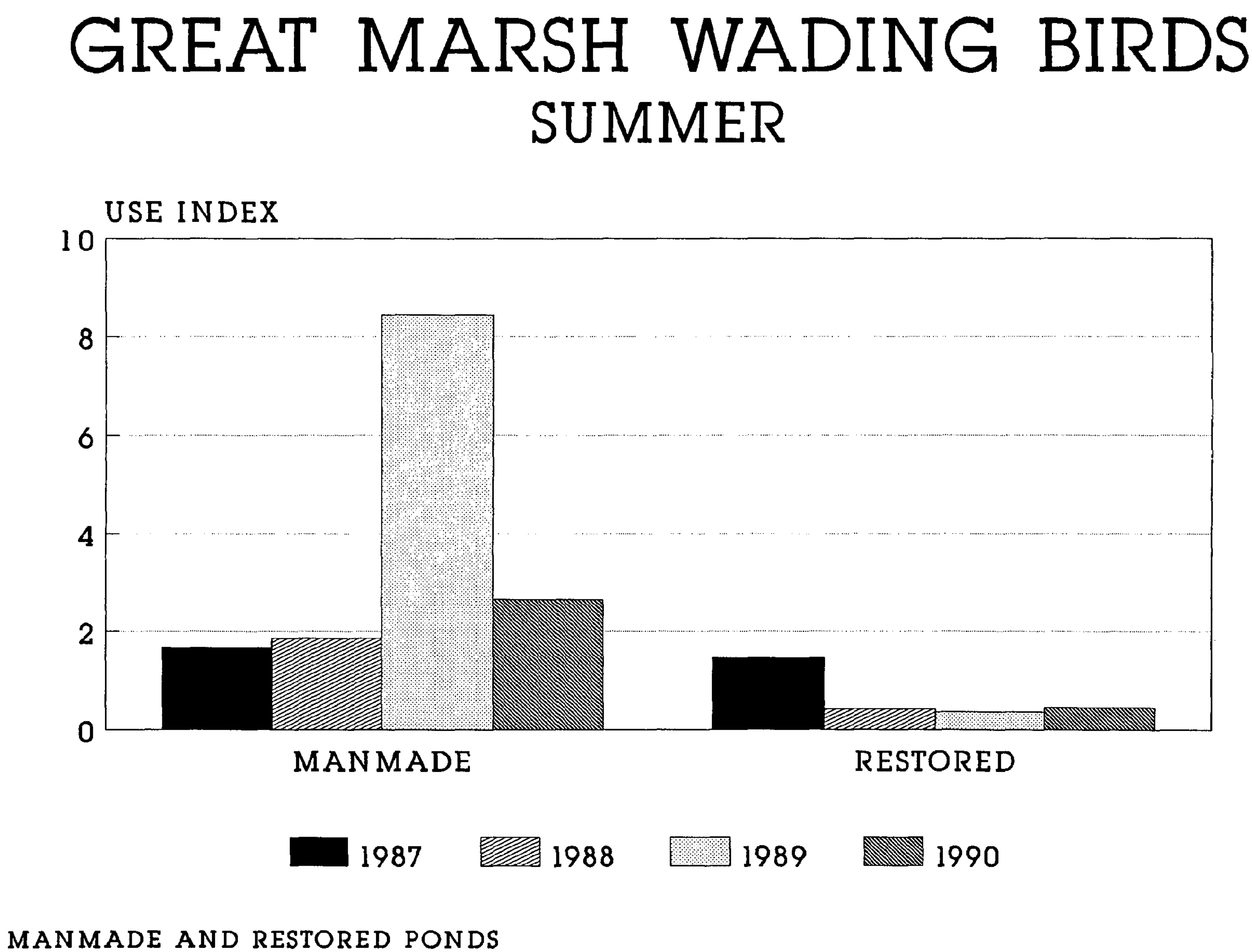


Figure 37. Wading Bird Use Indices in Summer 1987-90 for Manmade and Restored Ponds

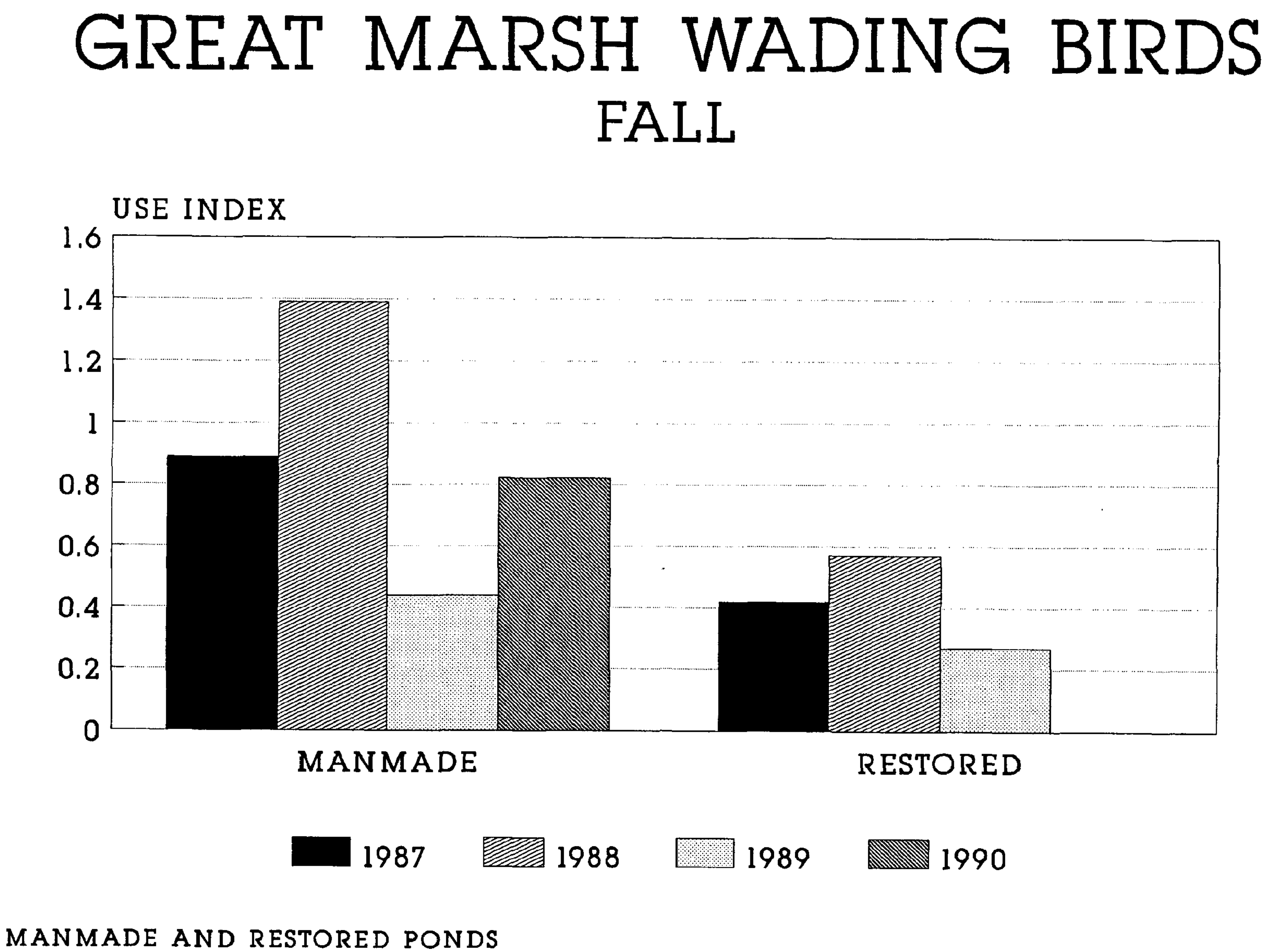


Figure 38. Wading Bird Use Indices in Fall 1987-90 for Manmade and Restored Ponds

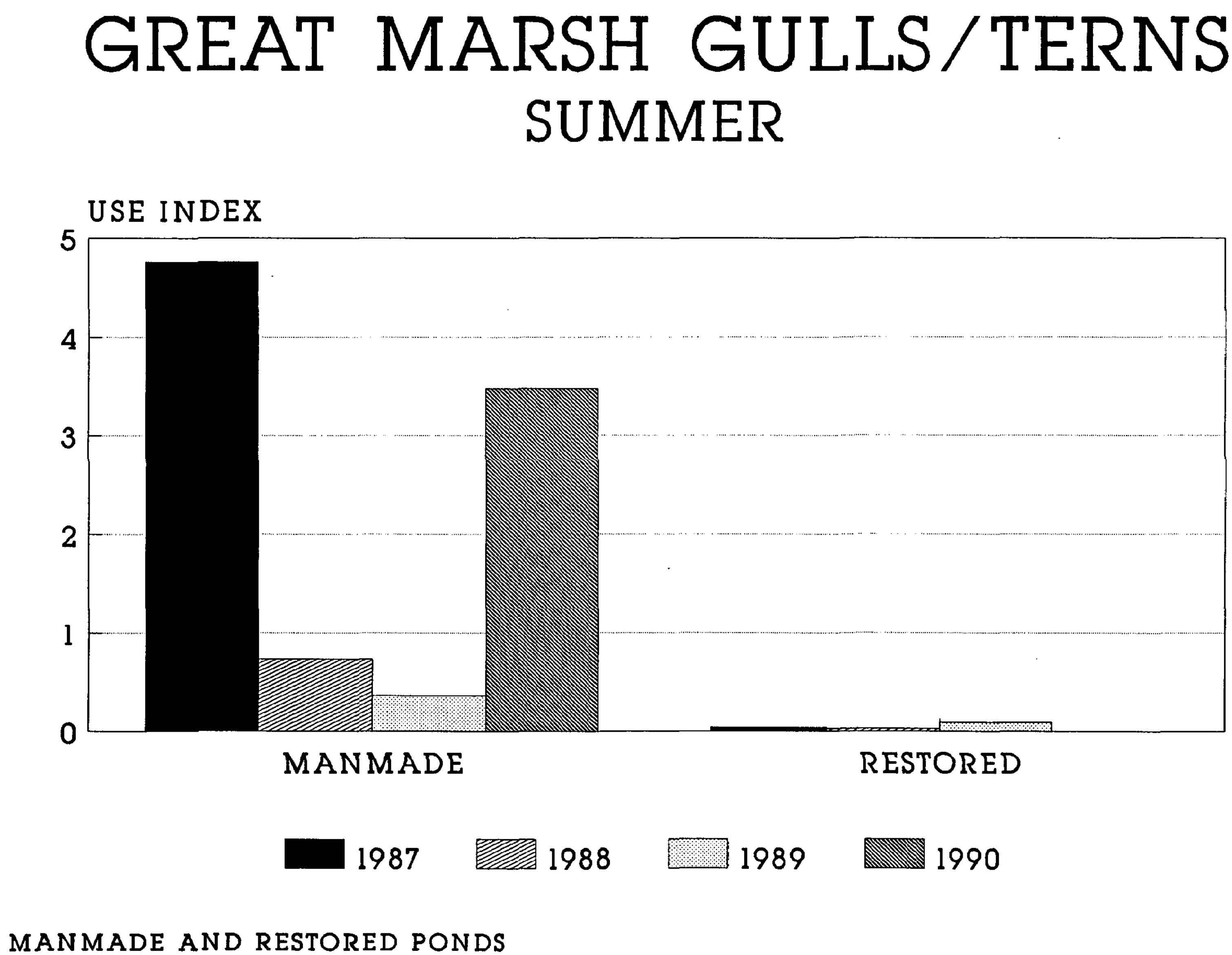


Figure 39. Gull and Tern Use Indices in Summer 1987-90 for Manmade and Restored Ponds

WATER QUALITY

Water quality data was collected from the 12 ponds during 1987-1990. Parameters sampled include: salinity, dissolved oxygen, pH, specific conductivity, carbon dioxide, ammonia, hardness, chloride, sodium, nitrate, nitrite, and ortho-phosphate (Fig. 40). Initially, the lab analysis was conducted by personnel at Delaware State College. However, as funds were reduced, these tests were completed using Hach test kits and meters.

Salinity

Salinity within the estuary is highly variable. The important factor in species composition, distribution and maintenance is the magnitude of seasonal and tidal fluctuations in salinity. The highest salinities occur during the summer due to lower rainfall and evaporation. Within the ponds salinities varied by as much as 18 ppt throughout the year with a range of 4-33 (Table 2). The organisms that reside in these ponds are able to withstand these variations through osmoregulation. There was little difference in salinity between salt hay constructed ponds or *S. alterniflora* constructed ponds. Each was variable throughout the year.

Dissolved Oxygen

Dissolved oxygen within the ponds can have extreme variations on a daily basis. Depending on the amount of aquatic vegetation, DO levels can be saturated during the day, and fall to 1 ppm or less overnight. This also occurs in natural marsh

Figure 40. Water Sampling at Great Marsh

ponds. Fish species are forced to "gulp" air during the night. The summer months tended to have the lowest DO readings due to increased biological activity. Samples were collected during mid-morning and were within biologically acceptable levels except for ~~two~~ instances during August when the DO fell below 2 ppm in two ponds (Table 3). No fish kills or other organism die offs were observed.

pH

The pH of the ponds remains fairly constant due in part to the usually monthly tidal inundation. Seawater is strongly buffered and remains a constant pH of 8-1 to 8-3 (Reid & Wood 1976). As table 4 indicates, pH values ranged from 6.53 to 9.4 with the majority of readings falling between 7.2 and 8.5. Voudoroff and Katy, 1950, state that the pH limit for the most resistant fish species is 4.0 to 10.1.

Carbon dioxide

Carbon dioxide is important in that it buffers the water against rapid changes in pH. CO_2 values for the ponds range from 45.2 ppm to 170ppm with the highest readings occurring during the summer (Table 5). The warm summer temperatures cause the highest rate of respiration and maximum rate of decomposition. Voudoroff and Katy (1950) state that concentrations of 100-200 ppm of CO_2 can be lethal to sensitive fish in the presence of adequate dissolved oxygen. Higher concentrations may be tolerated by hardier esturine organisms.

Ammonia

Excessive ammonia levels are harmful to aquatic species because it decreases the ability of the hemoglobin to combine with oxygen and can cause suffocation (Brockway 1950). There is no distinctive differences of ammonia levels between ponds, Values range form 0-2.4 ppm (Table 6). Samples collected during summer months (June and August) tended to have higher concentrations. According to Ellis (1937) concentrations of 2.5 ppm are considered harmful in the pH range of 7.4 - 8.5.

Sodium/Chloride/Specific Conductivity/Hardness

Specific conductivity is a measurement of the total ion concentration of water and is directly related to salinity. In seawater, sodium and chloride comprise the majority of the ions. In freshwater, calcium and magnesium make up the largest percentage. The brackish ponds average salinity is less than that of seawater so there is freshwater input. Tables 7, 8 and 9 depict the values for sodium, chloride and specific conductivity. Hardness is primarily attributable to calcium and magnesium ions. All values in the ponds ranged from 71-479 ppm (Table 10). Berger (1943) states that "good" quality freshwaters should not exceed 270 ppm hardness. Brackish waters have higher total ion concentrations hence hardness values can be considerably higher. Samples taken at a river mouth adjacent to the Great Marsh had values as high as 6800 ppm (Delaware 1980 State Water Quality Inventory, July, 1980). The results of the sodium, chloride, specific conductivity and hardness samples taken are considered normal values and not limiting to the biological health of the ponds.

Nitrate/Nitrite

Nitrate acts as a fertilizer for all types of plants. However, excessive nitrates can stimulate the growth of algae and aquatic weeds resulting in algae blooms. These blooms occur every year in varying degrees in all ponds from approximately 5% to 100% surface coverage. Nitrate values were generally higher in the spring and fall samples (Table 11).

Nitrites are quickly converted to nitrates and are generally found in small amounts. Ponds were sampled with Hach nitrite kits. No nitrite values were high enough to register.

Phosphate

Phosphates rarely produce toxic effects upon fish and other aquatic life (Vivier, 1935; Abegg, 1950; Fuller, 1949), but may contribute to increased algae production. Values were variable between 0 and 2.7 ppm with most readings below 1.0 ppm (Table 12). These values are similar than those recorded at the mouth of the Broadkill River near the Great Marsh in 1978-79 (Delaware State Water Quality Inventory, July 1980) which ranged from 0.25 to 2.75 ppm.

The ponds at Great Marsh are generally shallow in depth and provide a year round stable habitat designed to replace and improve the loss of permanent water habitat lost through grid ditching. The water quality parameters sampled pose no

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
APR 1987	24	22	20	14	18	11	16	16	22	17	22	17
AUG 1987	32	32	31	28	28	25	24	24	30	27	30	29
OCT 1987	18	16	11	12	14	7	18	16	24	20	22	13
MAR 1988	22	15	22	18	14	8	12	10	26	16	26	22
AUG 1988	31	31	30	19	21	21	26	21	31	25	27	29
JUN 1989	18	16	24	10	12	10	10	9	33	14	20	14
AUG 1989	16	10	28	14	8	5	7	6	26	12	18	22
MAY 1990	-	4	23	10	8	6	10	9	25	16	-	17
AUG 1990	-	20	27	14	16	16	16	15	26	-	-	16

Table 2. Pond Salinities in all Ponds for 1987-90

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
APR 1987	8.1	8	9.5	8.7	8.1	8.6	9.4	8.8	8.2	8.3	6.7	9.2
AUG 1987	6.2	6.4	5	4.1	5	6.8	6.9	8.7	8.3	7.1	6.5	2.3
OCT 1987	8.8	8.2	9.2	9.2	8.9	8.8	9.2	8.9	9.1	9.2	8.8	9
MAR 1988	8.4	8.5	8	7.8	8.2	8.6	8.4	8.2	8.8	8.4	7.7	8.5
AUG 1988	5.6	6.1	6.2	6.5	6.6	6.6	5.2	5.7	6	6	6.2	1
JUN 1989	8	5.7	9.5	6.5	10.5	4.4	5	5.2	5.2	7.1	6.2	10
AUG 1989	6.1	10.2	5.3	4.2	5.2	3.3	1.8	3.4	5.1	3.8	4.3	3.2
MAY 1990	-	20	12.1	11.9	11.2	13.9	13.3	11.7	17.8	9.6	-	11.7

Table 3. Dissolved Oxygen Levels in all Ponds for 1987-90.

DATE	POND 1	2	3	4	5	6	7	8	9	10	11	12
APR 1987	7.36	7.6	7.19	7.05	6.75	7.5	7.28	7.1	8.44	7.21	6.63	7.17
AUG 1987	7.46	7.78	6.81	6.57	6.53	7.32	7.32	7.81	7.48	7.24	7.05	6.57
OCT 1987	7.37	7.83	7.76	7.39	7.23	7.27	7.62	7.52	7.57	8.16	7.13	7.55
MAR 1988	8.29	8.25	8.48	8.1	7.81	8.41	8.03	8.6	8.5	8.76	7.67	7.92
AUG 1988	7.8	8.2	7.5	7.6	7.5	7.2	7.5	7.6	7.5	7.6	7.3	7.4
JUN 1989	8.3	8.3	7.5	7.5	7.7	8.5	8.4	8.4	7.9	7.9	7.7	8.2
AUG 1989	7.7	8.8	7.2	7.3	7.3	6.8	7.2	7.4	7.8	7.3	7.4	7.3
MAY 1990	-	9.4	8.1	8.2	7.7	9	9	9	9.4	8	-	8.3
AUG 1990	-	8.5	7.9	8.5	8.3	9.2	7.6	9	7.5	7.9	-	7.9

Table 4. pH Readings in all Ponds for 1987-90.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	91.5	89.3	119	74.2	74.9	81.4	61.9	64.1	107	64.7	77.2	73.5
AUG 1987	158	162	130	111	164	170	96.1	118	132	101	140	117
OCT 1987	77.8	72.3	48.1	52.2	75.9	47.4	118	89.1	103	105	96.3	61.6
FEB 1988	68.7	63.9	66.8	62.1	61.4	60.9	74.8	45.2	68.4	55.5	70.6	62.4
AUG 1988	40	-	30	25	30	50	30	35	25	20	40	35
JUN 1989	45	25	40	25	25	15	30	35	45	40	40	30
AUG 1989	45	20	40	25	35	30	30	25	35	20	25	25
MAY 1990	-	-	35	30	35	10	-	-	-	35	-	35
AUG 1990	-	25	70	35	65	-	60	-	90	80	-	45

Table 5. Carbon Dioxide Levels in all ponds for 1987-90.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	0.8	0.8	0.7	0.6	0.8	0.95	0.7	1.3	0.4	0.45	0.55	0.45
AUG 1987	0.9	0.65	0.95	0.45	0.65	1.95	0.5	0.7	0.65	0.65	0.65	0.75
OCT 1987	0.7	0.5	0.5	0	0.35	0.35	0.5	0.9	0.45	0.35	0.35	0.45
FEB 1988	0.55	0.55	0.6	0.6	0.55	0.6	0.65	0.7	0.45	0.55	0.45	0.35
AUG 1988	2.28	2.16	2.16	1.56	1.56	2.16	2.4	1.56	2.04	1.68	1.68	2.04
JUN 1989	2.4	1.56	1.68	1.56	1.8	1.8	2.04	2.04	2.4	2.04	-	2.4
AUG 1989	0.96	0.72	0.45	1.2	1.32	1.92	1.68	1.56	0.6	0.96	0.6	1.08

Table 6. Ammonia Levels in all Ponds for 1987-89.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	2100	1610	3620	1720	1490	1070	1140	1060	4040	1560	2870	2570
APR 1987	6050	5640	5380	3720	4390	2860	3630	3560	4980	4050	5400	4080
OCT 1987	4710	4390	3040	3510	3520	1830	4900	4070	6090	5070	6280	3160
FEB 1988	7530	5620	7410	6270	4520	3160	4070	3380	9000	5620	9140	7770

Table 7. Sodium Levels in all Ponds for 1987-89.

	POND											
	1	2	3	4	5	6	7	8	9	10	11	12
DATE												
MAR 1987	11300	9380	18600	9840	8540	6530	6920	6600	20800	9240	15600	14200
APR 1987	8740	8360	9000	6040	5990	4230	5600	5810	7790	6520	8180	6520
OCT 1987	3710	3620	2670	2960	3330	2140	4120	3700	4740	4370	4700	3250
FEB 1988	4450	3920	4650	4240	3540	2850	3320	2800	4620	3500	4490	4060

Table 8. Chloride Levels in all Ponds for 1987-88

DATE	POND 1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	21800	18200	33000	18500	15900	12100	13000	12900	35200	17000	28200	25900
APR 1987	24000	24000	23200	17000	20500	14000	17900	18000	24000	20200	25400	20100
OCT 1987	23500	22200	15000	17000	18500	10900	25000	21500	30000	26500	29000	17900
FEB 1988	33000	25500	32900	28200	22500	16600	20200	16800	38200	36000	38800	34000
AUG 1989	24000	17200	39500	17800	12900	5800	10100	7800	37100	17700	25500	30400

Table 9. Conductivity Readings in all Ponds for 1987-89.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	268	179	429	147	110	73.7	92	76.8	479	110	279	223
APR 1987	229	219	200	122	156	83.6	107	113	175	134	183	137
OCT 1987	254	210	84.5	94.1	89.7	40.3	135	118	182	141	165	74.1
FEB 1988	164	123	155	135	101	71	94	80	184	119	190	165

Table 10. Hardness Readings in all Ponds for 1987-88.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
MAR 1987	19.1	17.3	26.5	15.7	14.5	13.3	12.2	12.4	29.1	15.3	21.8	21.3
APR 1987	32.6	22.8	22.4	18	24.2	17.1	19.3	19	26.4	22	26.8	23.6
OCT 1987	16.1	16.8	13.1	15.9	18	12.1	20.7	18.2	22.9	23.6	24.4	19.9
FEB 1988	14.3	11.7	13.6	12.6	9.94	8.09	9.71	8.81	15.9	11.8	16.7	16.1
AUG 1988	13.2	17.6	8.8	13.2	13.2	8.8	13.2	13.2	13.2	13.2	13.2	8.8
JUN 1989	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2

Table 11. Nitrate Levels in all Ponds for 1987-89.

	POND											
DATE	1	2	3	4	5	6	7	8	9	10	11	12
AUG 1988	0.5	0.7	0.5	0.4	0.5	1	0.3	0.5	0.2	0.3	0.4	0.7
JUN 1989	0.4	2	1	1.9	2.7	2.3	0.1	0.1	0.1	0.1	0.8	0.1
AUG 1989	0.1	0.2	0	0.3	0.1	0.2	0	0.5	0.1	0.4	0.2	0.1

Table 12. Ortho Phosphate Readings in all Ponds for 1988-89.

biological limiting factors to the health and productivity of the ponds and are similar to permanent natural marsh pools.

GREAT MARSH EMERGENT AND SUBMERGENT VEGETATION

Predominant vegetation typing was assessed prior to pond site selection and installation in 1986 in order to compare recovery rate and success of waterbird usage between different vegetative species and to assess submerged aquatic vegetation growth.

There are three dominant species - *Spartina patens* and *Distichilis spicata* collectively called salt hay, and *Spartina alteriflora*. Salt hay typically occurs around the perimeter of wooded hummocks and in small areas in the open marsh. *S. alterniflora* is the dominant vegetation occurring in areas more frequently flooded by tides. Species which occur along ditch edges, upland and old spoil mounds include the shrubs *Iva frutescens* and *Baccharis halimifolia* and a non-desirable grass *Phragmites australis*.

Pond excavation involves removing spoil from the proposed site and depositing it over the marsh surface. It is critical that spoil deposition be kept to a minimum because there is a small window of a few inches where vegetation changes will occur. Previous studies have shown that a change of just 2-3 inches, either by raising the marsh surface or lowering the water table, will cause areas of *S. alterniflora* to convert to salt hay and salt hay to convert to shrubs.

The objective of emergent vegetation recovery following pond excavation was to have the S. alterniflora ponds return to original or salt hay if spoil deposition proved to be higher than desirable. In the case of salt hay constructed ponds, spoil levels had to be kept to a minimum to avoid invasion by undesirable species such as shrubs or Phragmites.

The dominant species of submerged aquatic vegetation is widgeon grass (Ruppia maritima). It is well known as an important waterfowl food. It also harbors many aquatic invertebrates important for duck broods and feeding waterfowl and fish. An algae which occurs in abundance is Cladophora which may also be important as a food source, however excessive coverage can shade out widgeon grass.

Emergent vegetation patterns and recolonization of spoil areas around the IMM ponds was initially evaluated during 1988 using false-color IR aerial photographs taken in October, 1988 and by ground reconnaissance. Spoil areas around ponds located in high-marsh areas vegetated by Spartina patens and Distichlis spicata (salt hay) exhibited substantial regrowth (ca. 50-90%) of these original emergent vegetation species. The opportunistic plant species Pluchia which colonized fresh spoil areas around these ponds in 1987 was largely replaced by these original salt hay vegetation species during 1988. Additionally, a few clumps of S. alterniflora colonized spoil areas around these ponds. Some spoil areas around closed ponds located in high-marsh areas were unvegetated, apparently due to extended periods of inundation resulting from water overflow from these ponds. Spoil areas associated with semi-tidal high-marsh ponds exhibited more complete revegetation than high-marsh closed ponds. Upland edge spoil areas are largely revegetated by the original plant community consisting of *Iva*, *Baccharis*, and *Myrica* shrubs. Some ephemerally flooded high-marsh pond bottom and perimeter areas have been colonized by *S. alterniflora*.

Vegetation recovery around low-marsh ponds excavated in *S. alterniflora* areas progressed slower than around high-marsh ponds. Semi-tidal low-marsh ponds exhibited more complete revegetation than closed low-marsh ponds, apparently the result of excessively high water tables and marsh surface inundation around the closed ponds. Approximately 20 to 50 percent of the spoil around low-marsh ponds has been revegetated by *S. alterniflora*, resulting in a mix of vegetation and mudflat around each pond.

Ditch spoil plugs installed in tidal-grid ditches in order to stabilize pond water levels were vegetated by the surrounding grass species. A few higher spoil plugs were colonized by *Iva* and *Baccharis* shrubs.

The emergent vegetation was again assessed in 1990, four years after installation of the ponds. Gross recovery of existing vegetation was compared to original vegetation species and percent recovery of vegetated area to spoil was determined. The twelve ponds surveyed were equally divided among dominant species of salt hay and *S. alterniflora*. After four growing seasons, 10 of the 12 ponds have vegetation recovery ranging from 90-100%. Figure 41 shows a pond constructed in salt hay habitat with near 100% recovery. The remaining two ponds are 75 and 50

Figure 41. Near 100% Vegetation Recovery Around Perimeter of Pond Following Four Growing Seasons

percent recovered. These two ponds which have not fully revegetated were constructed in areas of low marsh S. alterniflora. During flooding events the water exceeds the banks of the ponds and remains on the marsh surface for extended periods of time inhibiting germination and growth of vegetation (Fig. 42). Although the original intent was for full recovery, there are some benefits associated with these mudflat/flatpan areas. Waterbird use, particularly shorebirds, has remained fairly constant in the pond with 50% recovery whereas the ponds whose recovery has progressed year to year towards full recovery, shorebird use has diminished.

Care must be taken to keep spoil deposition to a minimum, particularly in high marsh areas. Ponds with remaining recovery of 5-10% can be partly attributed to excess spoil. In areas where possible, spoil can be deposited in upland vegetation to reduce spoil deposition on the marsh surface. Figure 43 depicts a pond site soon after construction in February, 1987 and vegetation recovery in 1989.

The recovery of vegetation from original species to as it exists today demonstrated 75% of the ponds returning to pre-excavation conditions The six original S. alterniflora areas recovered to S. alterniflora as the dominant species. Two of the six salt hay areas recovered to predominantly salt hay with Baccharis halimiflora the secondary species ranging from 15-30 percent. Unexpectedly, three of the salt hay areas recovered to S. alterniflora ranging from 40-90 percent dominance probably caused by raising the water table in the immediate area and keeping

Figure 42. Approximately 50% Vegetation Recovery Around Perimeter of Pond Following Four Growing Seasons.

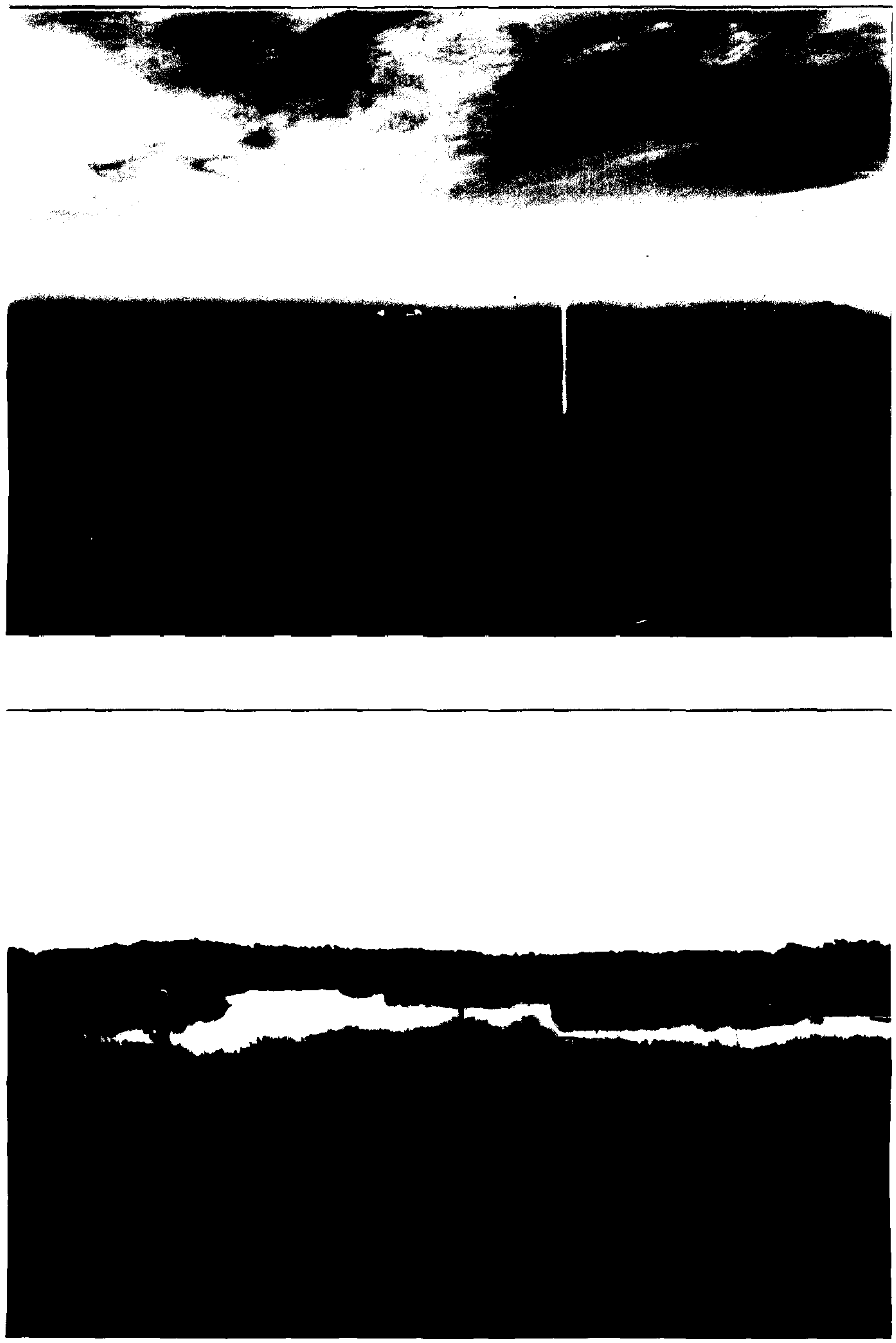


Figure 43. Pond Following Construction and Recovery

spoil height to a minimum. This is considered a positive result as S. alterniflora is more important in terms of nutrient exchange with the estuary.

The predominant submerged aquatic vegetation (SAV) in these salt marsh ponds is Ruppia martima. Ruppia normally first appears and is most abundant in early to mid-summer, May - July. SAV appeared during the first growing season, 1987, in three of the twelve ponds. The dominant emergent vegetation of these areas was salt hay. In 1988, Ruppia was present in six of the ponds but only three contained significant amounts (maximum of 45 to 97 percent) (Table 44). Of the additional three colonized ponds two were again in areas of salt hay vegetation. The 1990 survey showed there were seven ponds containing SAV, with percentages ranging from maximums of 40-90 percent, (Fig 44). Of the ponds surveyed only one S. alterniflora constructed pond contained Ruppia. Figure 45 compares percentage of Ruppia growth in the ponds of salt hay and S. alterniflora habitat. All of the ponds constructed in salt hay had Ruppia growth ranging from 75-90% maximum coverage. Only one pond constructed in S. alterniflora habitat contained Ruppia and was lower in total coverage (40%). An algae, predominantly Cladophora, was present in small amounts in four of the twelve ponds during 1987. In 1988, seven ponds contained Cladophora in slightly larger amounts ranging from 1-79 percent. By 1990, every pond had varying amounts of algae ranging from 1-75 percent. The ponds with the largest percentage of algae were ponds constructed in salt hay areas with percent coverage from 60-75% maximum while S.

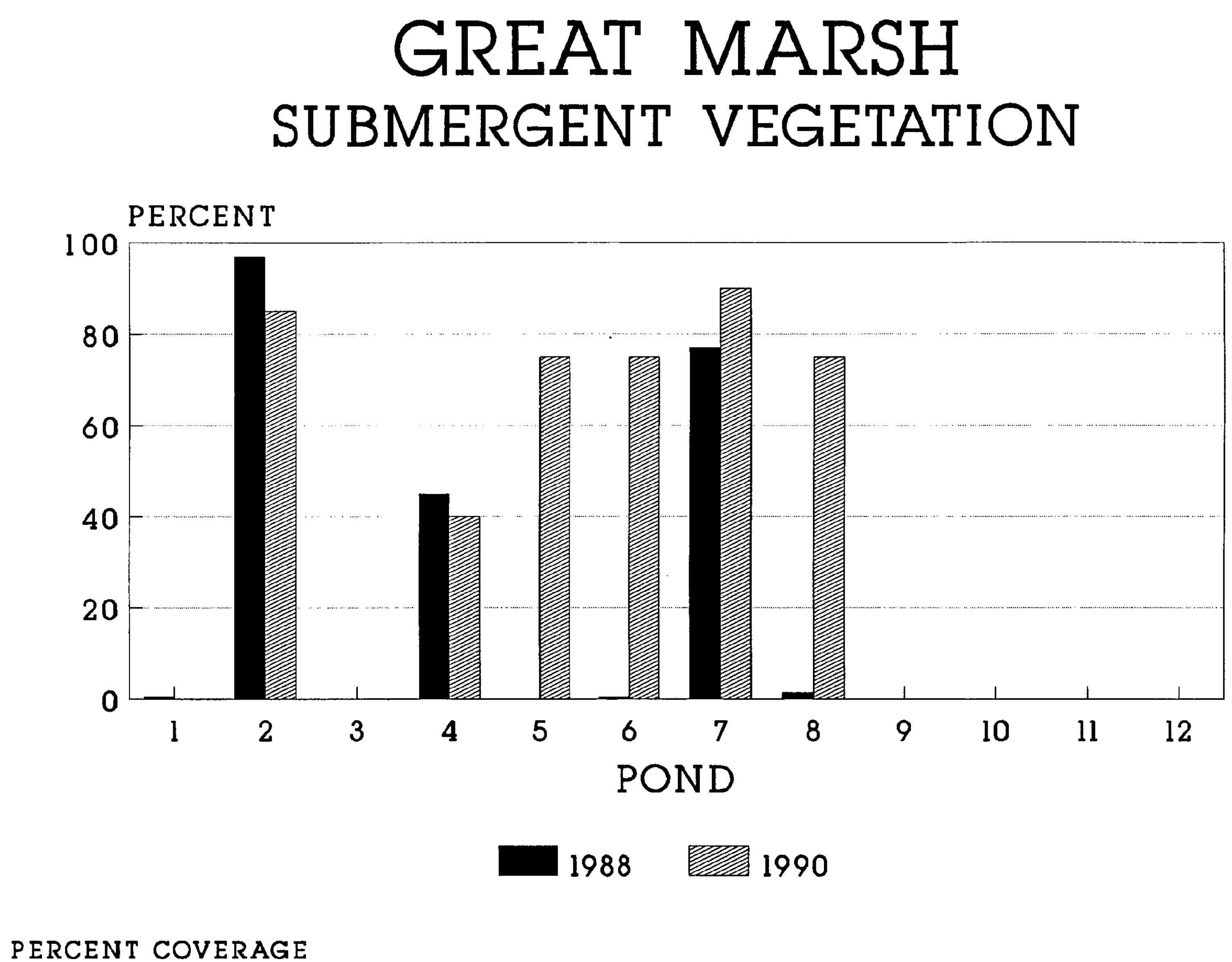
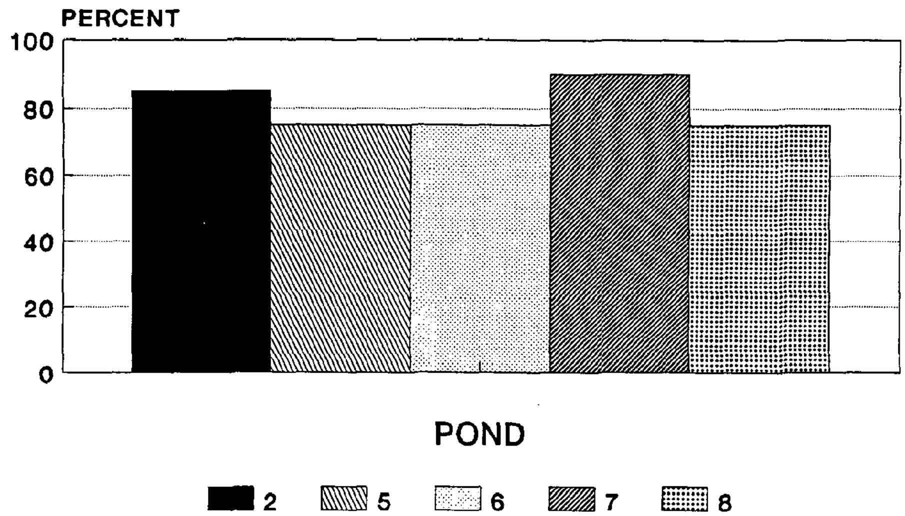
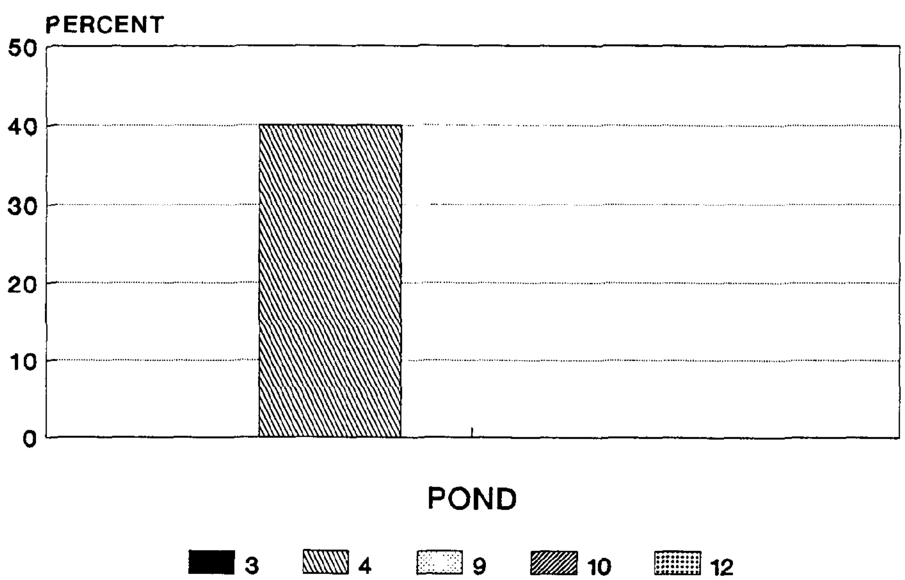


Figure 44. Percent Coverage of SAV (<u>Ruppia maritima</u>) in all Ponds for 1988-90

GREAT MARSH
SUBMERGENT VEGETATION

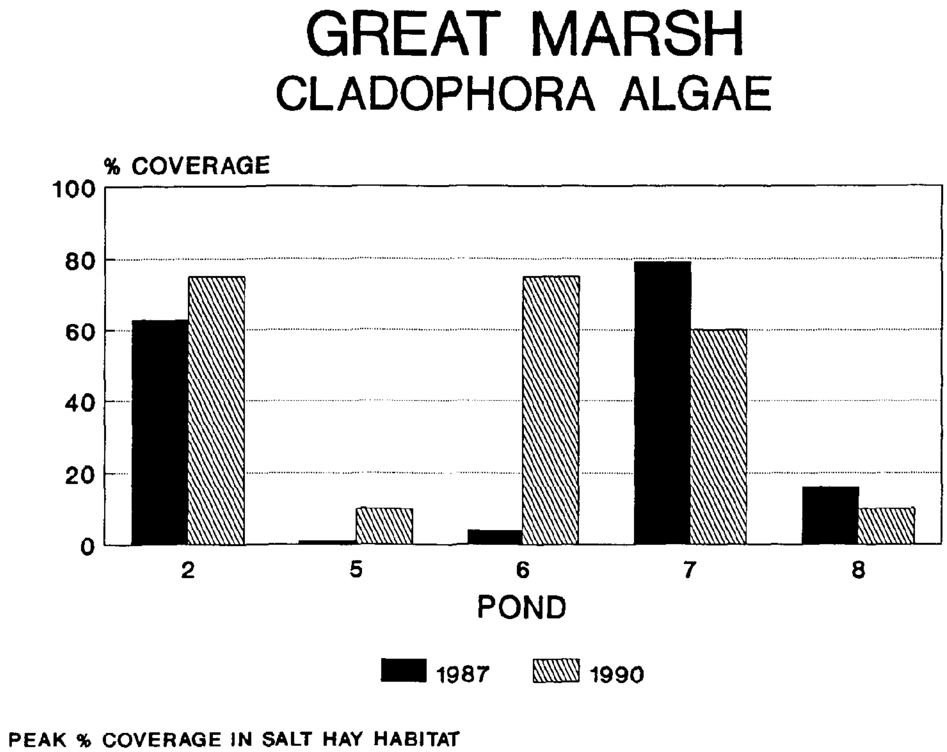


% COVERAGE BY EMERGENT VEGETATION TYPE-
SALY HAY



% COVERAGE BY EMERGENT VEGETATION TYPE-
SPARTINA ALTERNIFLORA

Figure 45. Percent Coverage SAV (Ruppia maritima) by two Vegetation Types in 1990



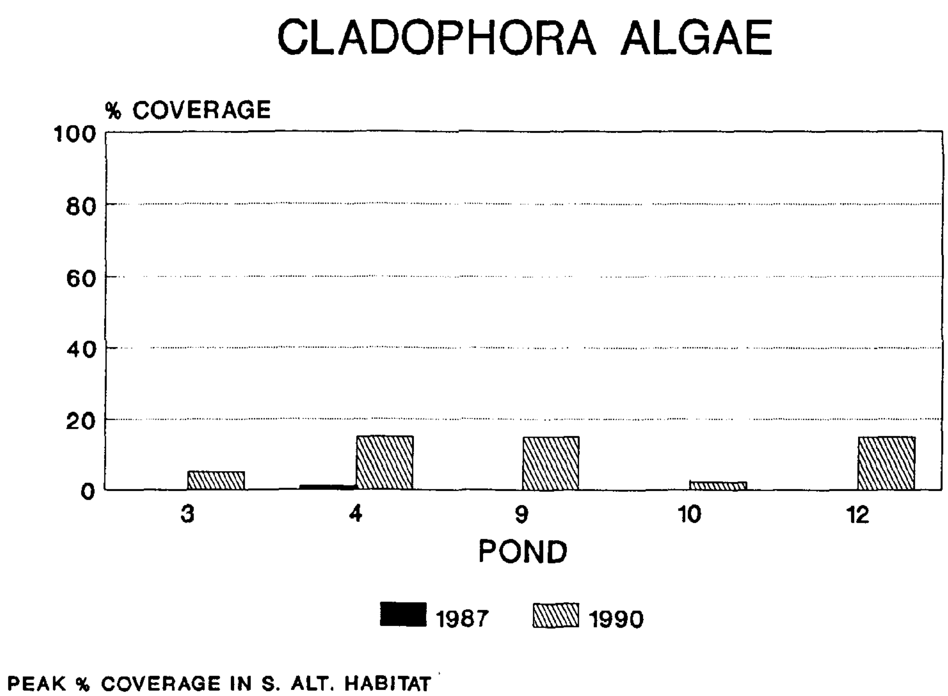


Figure 46. Percent Cladophora Algae by Two Vegetation Types in 1987 and 1990

alterniflora areas ranged from 2-15 percent (Fig. 46). There appears to be a correlation between percent coverage of Cladophora and Ruppia. The higher the percentage of surface coverage on the pond surface, Ruppia tends to be reduced.

The colonization of Ruppia appears to be correlated to pond depth and substrate. The ponds constructed in salt hay areas generally have a firmer bottom than S. alterniflora areas allowing a better "foothold" for rooting. Depth of pond, which affects light penetration, can also affect Ruppia colonization. Mahaffy (1987) has shown that ponds with a depth greater than 0.5m have little or no Ruppia growth. As shown in figure 45, restored ponds (9 and 10) are generally deeper and constructed in S. alterniflora habitat and contain no Ruppia growth.

GREAT MARSH INVERTEBRATES

Invertebrate sampling of the twelve ponds was conducted in 1987-1990. During the first two years, samples were collected by a graduate student from the University of Delaware working full time on this project. However, the student failed to pass the comprehensive exam and responsibility for data collection, analysis and writing the final report became the Division of Fish and Wildlife's. Although intensive data collection during 1989 and 1990 was not possible, invertebrates were sampled during times when availability of adequate populations of invertebrates would be utilized by any waterfowl broods which would be produced, as almost 100% of the broods diet is animal protein. These invertebrates are also important to spring and fall migrating shorebirds in addition to wintering black ducks and sustaining fish populations.

Sampling procedure involved sweeping a section of pond edge and aquatic vegetation with a D-shaped sweep net (Fig. 47). Collected samples were sorted, counted and identified to order. Two samples per pond were collected.

Data analysis of invertebrate populations involved consideration of various scenarios. Between pond comparisons of total invertebrates per pond per sample is shown in Figure 48. The most revealing differences depicted in this table is the overall increase of invertebrates from 1987-88 to 1989-90. This is attributed in part to establishment of populations over a period of time and an increase of emergent and submergent vegetation. Large numbers of gastropods and crustaceans, were captured among the dense SAV Ruppia. All ponds appear to harbor adequate populations of aquatic invertebrates to support any broods produced and sustain wintering waterfowl as certain species rely on gastropods as other food sources become scarce. Figure 49 combines all ponds and separates invertebrates by order. Six orders of aquatic invertebrates were collected including Coleptera, Diptera, Hemiptera, Odonata, Crustacea and Gastropoda. Within these six orders were 19 families of invertebrates. Catch per effort increased for each year during 1989-90 from the two previous years. The majority of the sample was from the order Crustacea, mainly amphipods, and gastropoda - snail species including Melampus, Nassarius, Physidae, and Littorina.

Before construction began, some obvious site specific

Figure 47. Invertebrate Sampling at Great Marsh.

differences among the ponds and adjacent areas existed. In order to ~~allow~~ provide useful management options for future construction based on invertebrate populations, the selected sites were separated into different categories. The basic and most obvious differences include man-made ponds and previously drained restored ponds and ponds constructed in salt hay (*Spartina patens* and *Distichilis spicata*) zones and *S. alterniflora* zones. Generally, the man-made ponds are more shallow with tapered sides then are restored ponds. Overall, number of invertebrates per sample was slightly higher in the man-made ponds for Coleoptera, Diptera, Hemiptera and Odonata whereas Crustacea was similar in abundance. The largest difference were Gastropods which are approximately five times more abundant in man-made ponds (Figure 50).

Figure 51 shows differences in invertebrate populations within salt hay and *S. alterniflora* constructed ponds. The major difference among the two vegetation types are within the orders Gastropoda and Crustacea. Large numbers of Gastropods were captured within the salt hay ponds particularly in 1989 and 1990, whereas *S. alterniflora* ponds were approximately 8 times less. Crustacean populations within *S. alterniflora* ponds for 1988-1990 were approximately twice as high as salt hay ponds. Number of Crustacea for 1987 were similar for both vegetation habitats. The orders Coleoptera, Diptera, Hemiptera and Odonata were slightly higher in salt hay ponds for all years. As described in the submergent aquatic vegetation section, SAV occurs more frequently in salt hay constructed ponds as *S. alterniflora*

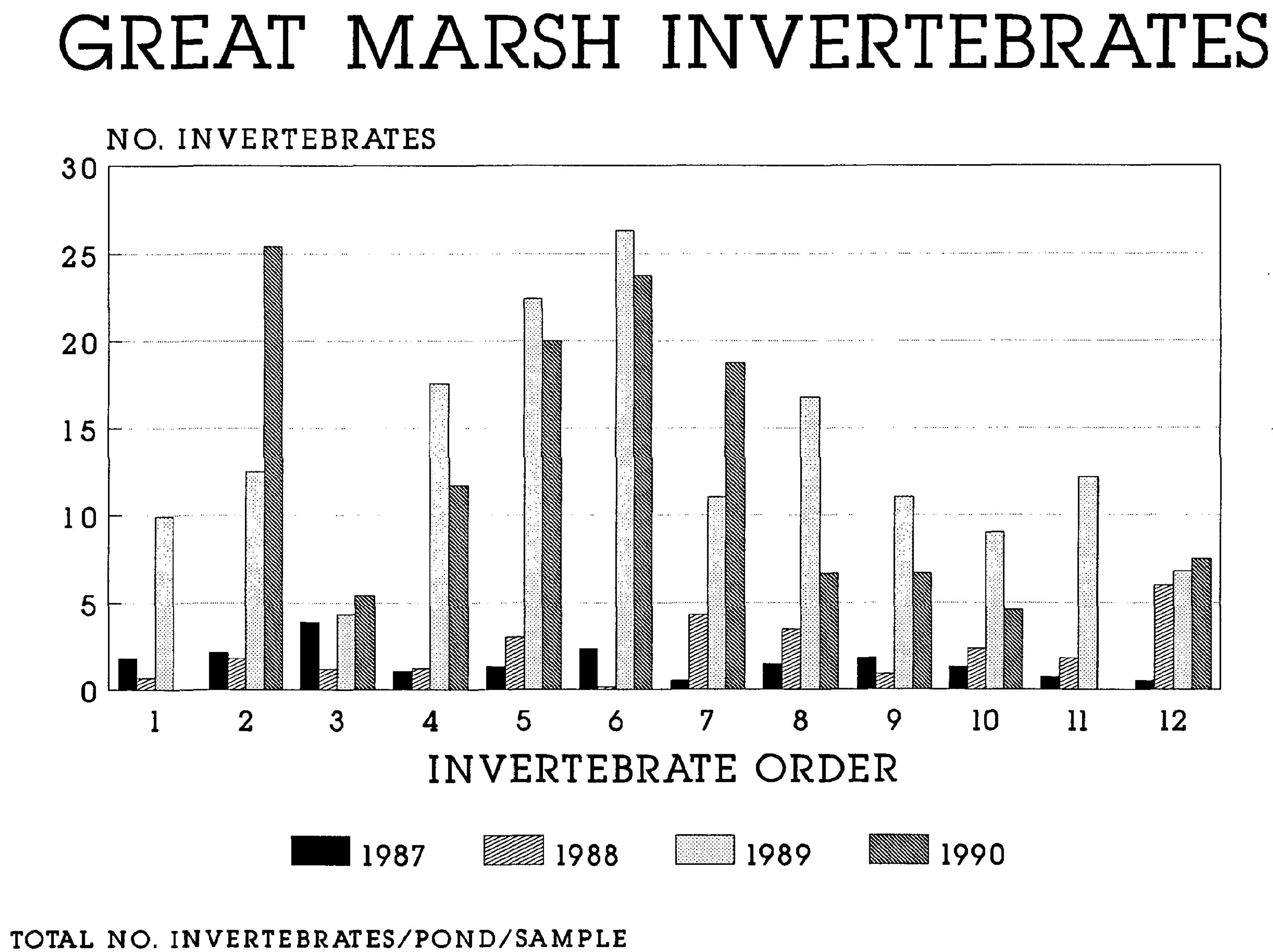


Figure 48. Number of Invertebrates Per Sample in all Ponds for 1987-90

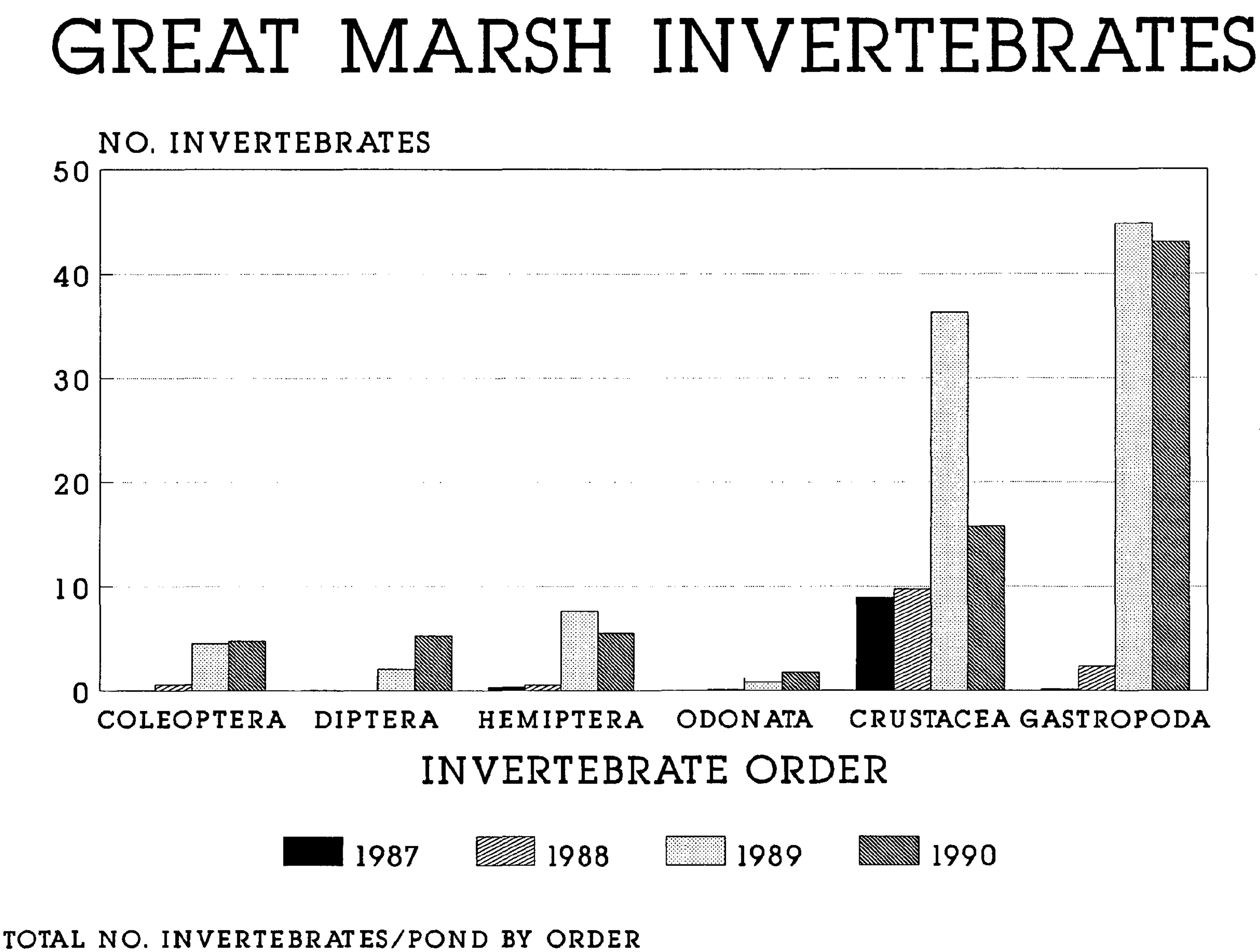
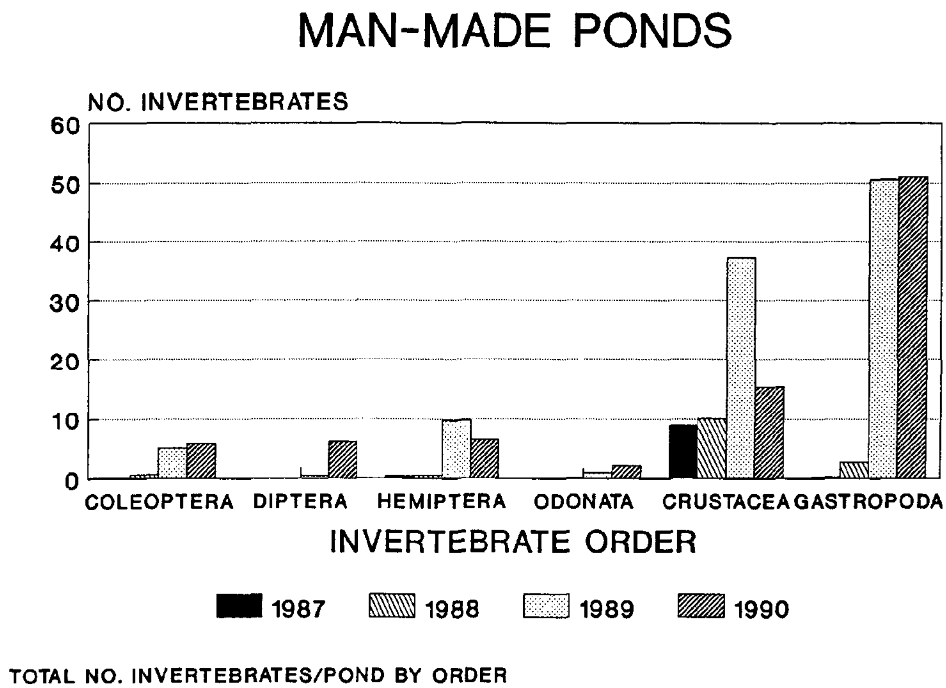


Figure 49. Number of Invertebrates per Pond by Order in 1987-90

GREAT MARSH INVERTEBRATES



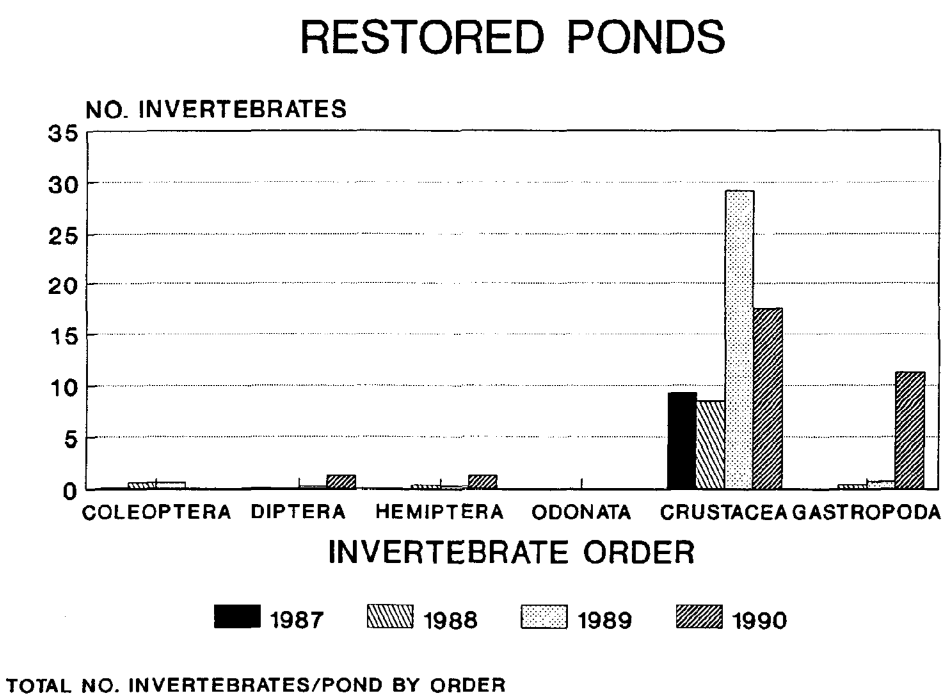
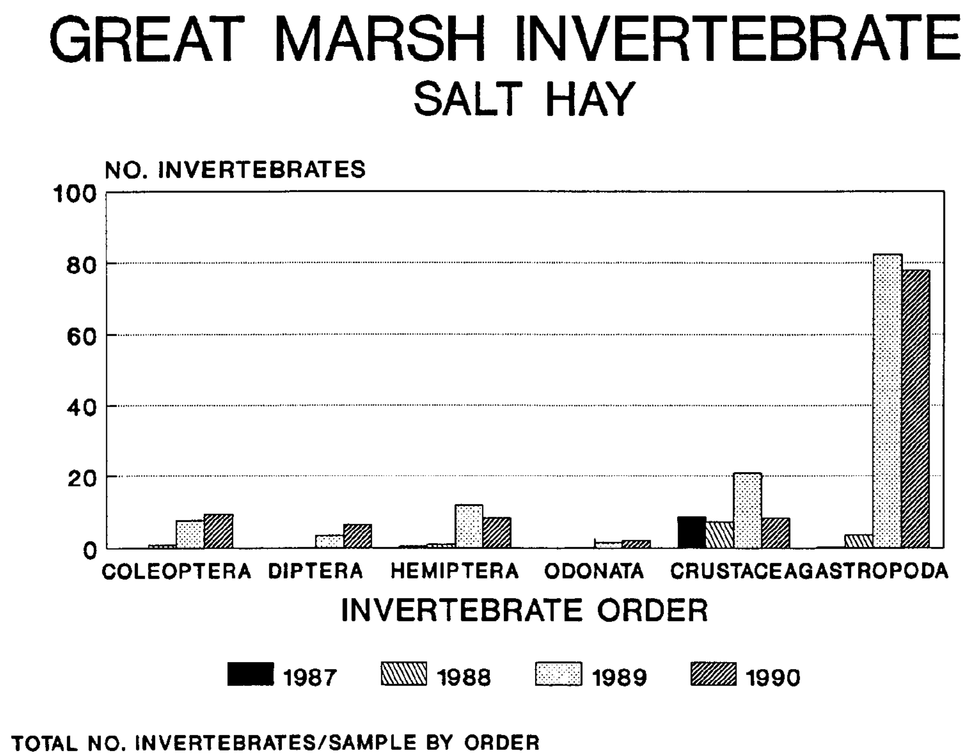


Figure 50. Number of Invertebrates per Pond by Order in Man-Made and Restored Ponds in 1987-90



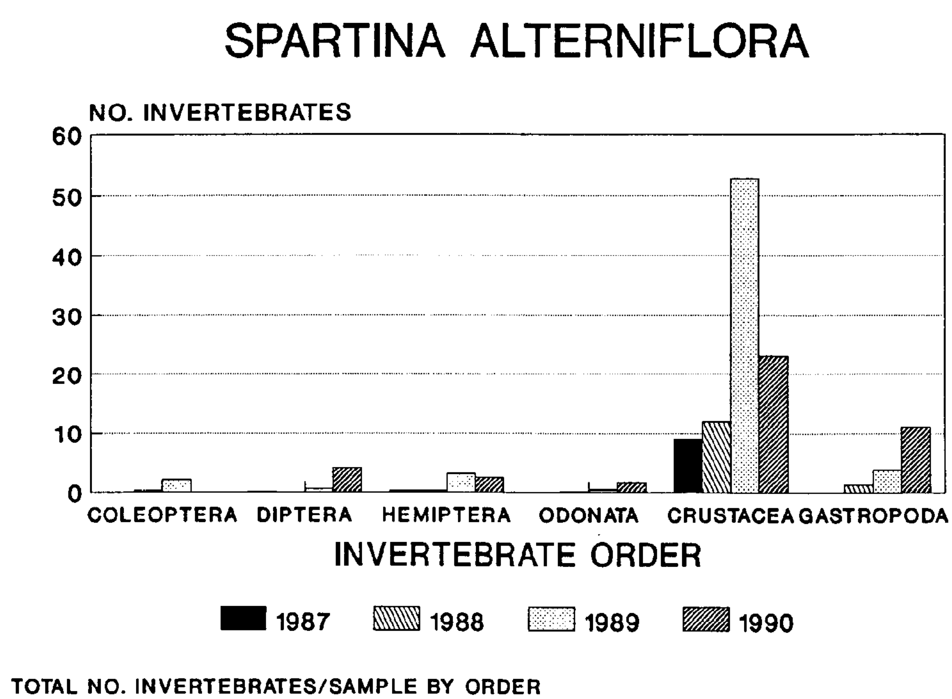


Figure 51. Number of Invertebrates per Pond by Order in Two Vegetation Types in 1987-90

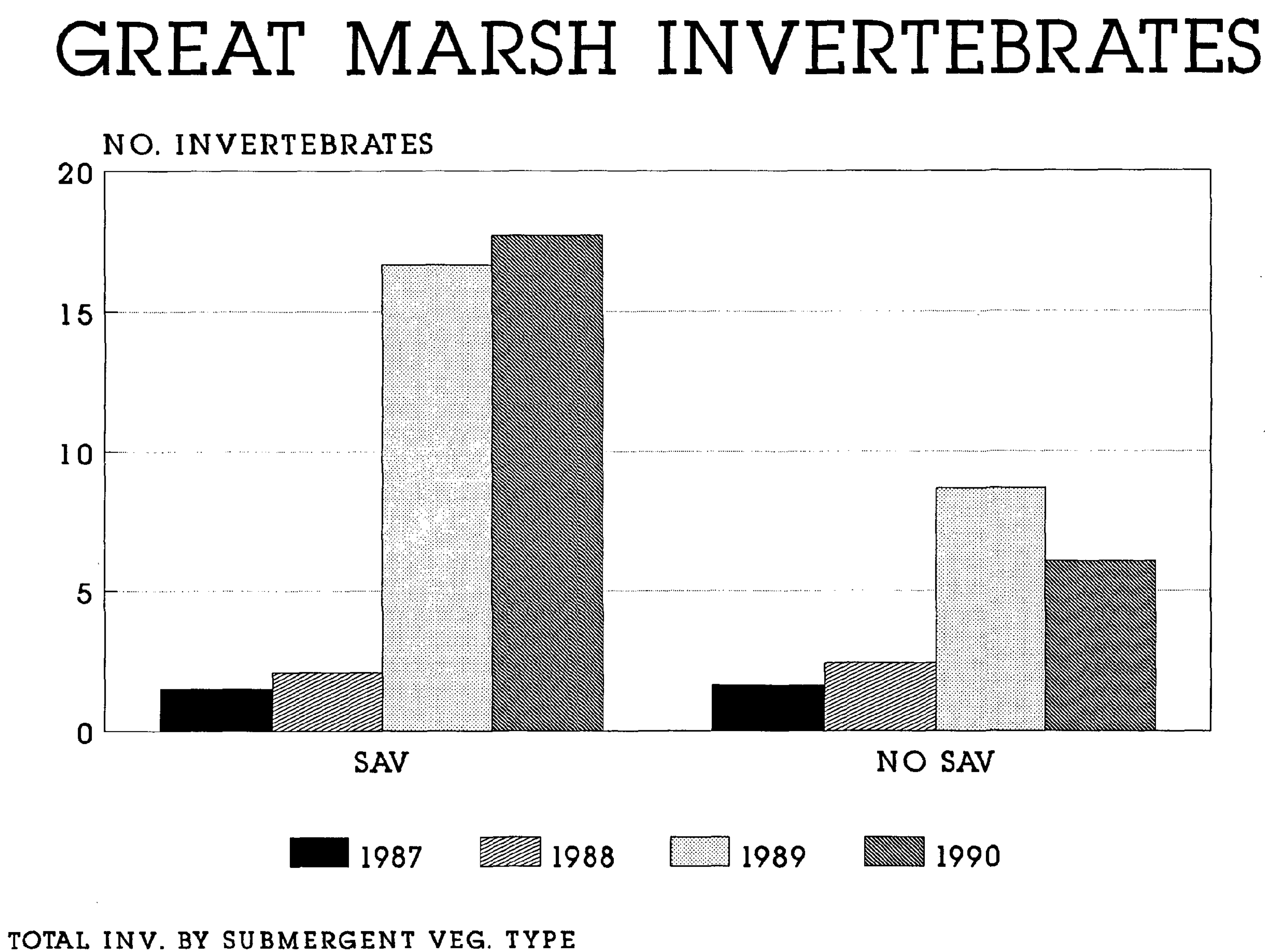


Figure 52. Number of Invertebrates in Ponds With or Without SAV

areas. It appears that invertebrate abundance may be related to SAV growth within the ponds as overall abundance is larger in ponds containing high percentages of SAV (Figure 52).

BROOD SURVEY

Brood surveys were conducted at Great Marsh via helicopter during 1986-88. Peak brood production periods of the year were selected in June and July. Transects were flown over the entire 2300 acres of Great Marsh, taking special note of the IMM areas both pre- and post-treatment. The flights were scheduled during the morning and averaged 1 hour and 10 minutes.

Table 13 shows the results of the aerial brood survey. Waterfowl production was very poor throughout the area. The black duck was the only brood species observed with a maximum of two broods per nesting season. There were no broods located within the ponds or IMM area during pre- or post-treatment. Nesting waterfowl and broods have been observed adjacent to and on the IMM ponds during scheduled waterfowl observation surveys. However, successful brood production is less than originally hoped for considering the new available habitat.

Predation is evidently high due to the large number of foxes and raccoons observed during waterfowl observations. Actual nest predation by a fox was observed on a gadwall nest.

GREAT MARSH BROOD SURVEY

	BLACK DUCK
12 JUNE 1986	4-IIA, 5-III
11 JULY 1986	0
2 JUNE 1987	0
7 JULY 1987	1-IB, 4-IIA
22 JUNE 1988	3-IIB
20 JULY 1988	6-III

* NO BROODS WERE LOCATED IN PRE- OR POST IMM STUDY AREAS.

Table 13. Great Marsh Brood Survey, 1986-88.

FISH POPULATIONS

Fish and select aquatic invertebrate populations were surveyed in the 12 ponds during the summer and fall of 1987. Two 15 meter sections of the pond were blocked and sampled using a 15 foot seine. Fish and invertebrates captured were identified to species and counted. Totals of each species were divided by number of seines to obtain catch per unit effort. The objective was to determine if fish populations were large enough to eliminate any mosquito brood that may be produced within the pond.

A total of six fish species and two invertebrate species were collected. Fish species collected in order of abundance include: *Cyprinodon variegatus*, *Fundulus heteroclitus*, *Lucania parva*, *F. luciae*, *Menidia beryllina*, and *F. majalis* (Table 14). Two species of crustaceans were captured including *Palaemonetes pugio* and *Callinectes sapidus* (Table 14). Catch per unit effort data indicates that during the summer there was a range of a low of 68 to a high of 469 fish per seine effort for all ponds. During the fall the range was 33 to 363 per seine effort. All ponds contain adequate numbers of fish to prey upon any mosquito larvae that would be produced in the ponds. *P. pugio* were most abundant in the fall and *C. sapidus* was found in low numbers during all these seasons. These fish species are not only important as mosquito larvae predators, the fish and crustaceans also serve as a food source for many waterbirds including herons, egrets, gulls, terns and kingfishers. Qualitative checks during various periods of the year from 1988 - 1990 indicated large fish populations in all ponds.

GREAT MARSH FISH SAMPLING
1987

POND	F. heteroclitus SUMMER	F. heteroclitus FALL	C. variegatus SUMMER	C. variegatus FALL	L. parva SUMMER	L. parva FALL	F. luciae SUMMER	F. luciae FALL	F. majalis SUMMER	F. majalis FALL	M. beryllina SUMMER	M. beryllina FALL	P. pugio SUMMER	P. pugio FALL	C. sapidus SUMMER	C. sapidus FALL
1	48	14	185	214	1	-	-	2	-	-	-	2	-	19	-	-
2	6	5	61	59	1	14	-	-	-	-	-	-	6	16	-	1
3	44	4	117	28	-	-	1	-	-	1	-	-	13	40	-	-
4	22	2	312	202	-	4	-	-	-	-	-	6	-	115	1	-
5	30	16	102	40	2	2	1	1	-	-	4	-	8	84	1	-
6	95	16	126	61	-	1	2	1	-	-	-	-	125	78	-	-
7	52	30	64	115	2	2	2	-	-	-	2	-	1	60	-	1
8	12	30	276	188	1	2	-	-	-	1	1	2	1	68	-	-
9	87	128	24	232	-	2	-	1	-	-	-	10	4	72	-	2
10	23	180	29	65	1	10	1	1	-	-	52	20	2	68	-	-
11	32	17	435	28	-	1	2	-	-	-	-	1	2	62	-	-
12	42	3	78	78	-	-	-	-	-	-	-	-	-	24	-	-

Table 14. Fish Sampling Results in all Ponds in 1987

MOSQUITO REDUCTION

Historical Mosquito breeding sites of *Aedes sollicitans* were eliminated by the construction of the 12 ponds and additional OMWM work. No mosquito breeding was observed in any of the ponds due to large resident fish populations and by destruction of mosquito breeding habitat. The limited number of mosquito producing depressions caused by equipment (ruts from heavy machinery) were eliminated by excavating radial ditches from the pond and ditches to the breeding areas. These ditches allow predatory fish access to mosquito producing locations. This 2300 acre area was once routinely aerial sprayed with larvacide. This practice has now been eliminated.

DISCUSSION AND RECOMMENDATIONS

When the Great Marsh project was undertaken in 1986, OMWM techniques were well established. OMWM ponds are generally small (one-tenth of an acre or less), but served their purpose of eliminating multi-depression mosquito breeding habitat while providing some permanent water for waterbirds. It was felt that large ponds (one-half acre or more) would provide a more attractive habitat for many species of waterbirds. A similar study conducted by Mike Erwin (Patuxent Research Center) found that larger ponds in fact are more desirable than standard OMWM ponds (results not published at time of this writing). The primary objective for the larger ponds was for waterfowl enhancement. However, due to construction techniques such as tapered sides and depths of 4-18", these ponds became quality habitat for various species including waterfowl, shorebirds, wading birds, gulls and terns and other species such as osprey and kingfishers. Additionally, these ponds are large enough to be effectively partitioned by creating islands to allow non-competitive utilization. Many marshes can benefit by creating and restoring ponds due to their degraded nature (i.e. grid ditched areas). In many cases, as with Great Marsh, these ponds are helping to restore marshes to their original condition. Even with the 12 created or restored ponds on Great Marsh, there remains a net loss of 25 acres of non-tidal pond habitat.

The following list summarizes major points and provides some potential management suggestions:

1) Overall, the ponds, both manmade and restored, were

utilized considerably more than typical natural marsh areas associated with Great Marsh. Areas of marsh containing little or no water habitat provide very little usable habitat for feeding and resting waterbirds. A large percentage of Delaware's marshes are degraded due to grid-ditching. As previously stated, installation of mew ponds and restoration of existing tidal ponds help mitigate the loss of permanent water. Routing installation and enlarging of ponds in multi-depression mosquito breeding habitat in degraded or non-degraded marshes will provide increased and enlarged habitat for all guilds of birds observed in this study and all parameters surveyed.

2) Natural flat pan areas, during certain periods of the year, particularly spring, are utilized similarly as the ponds for waterfowl and shorebirds. Green-winged teal and black ducks use these areas routinely when available. Wading birds and gulls and terns prefer the deeper habitat the ponds provide with the capability of supporting fish populations. If these flat pans are determined to be non-mosquito breeding habitat, it would be beneficial to leave untouched since no work or marsh disturbance is necessary and they provide certain benefits. As a subjective aside, flat pan areas were fortuitously created by a trac-vehicle in non-breeding S. alterniflora. These areas are now routinely utilized by shorebirds and waterfowl. These pans could be created, provided there is routine flooding to prohibit mosquito breeding, due to low cost of installation and minimal marsh surface disturbance.

3) As previously discussed, ponds were constructed in two

vegetation types, salt hay (S. patens and Distichilis spicata) and S. alterniflora. Salt hay ponds generally exhibited fuller recovery of vegetation. S. alterniflora created ponds sometimes have standing water around the pond perimeter retarding vegetation growth - however, shorebirds continued to utilize these areas whereas other ponds whose vegetation recovery was near 100%, shorebird use diminished.

Salt hay created ponds have a higher potential for unwanted species such as Iva, Baccharis and Phragmites. These are typically high marsh species and excess spoil can cause surface elevations around the perimeter of the pond to be raised. However, in two instances salt hay created ponds converted to S. alterniflora as the dominant species, possibly caused by raising the water table in the immediate area with permanent water and by keeping spoil height to a minimum.

4) Submergent aquatic vegetation (SAV) generally occurs in salt hay created ponds while S. alterniflora ponds typically contain little or no widgeon grass (Ruppia maritima). Of the ponds surveyed in the study, all of the salt hay created ponds contained Ruppia ranging from 75-90% by 1990. Only one pond created in S. alterniflora habitat contained Ruppia with a maximum of 40% coverage. In order for Ruppia to colonize salt marsh ponds, the substrate generally needs to be firm and depth no greater than 0.5m.

A species of algae, Cladophora occurs naturally in many salt marsh ponds. Ponds constructed in salt hay zones had larger percent coverage than did S. alterniflora zones ranging from 60-

75% and 2-15% inclusive. These mats of algae tend to shade out and kill *Ruppia*. However, *Cladophora* does harbor large quantities of invertebrates such as snails and amphipods as black ducks have been observed feeding among the algae seiving invertebrates. In addition, invertebrate abundance may be related to SAV growth as overall abundance was greater in ponds containing SAV.

Generally, invertebrates are more abundant in manmade ponds versus restored ponds. Salt hay constructed ponds contain larger numbers of Gastropods while larger numbers of Crustaceans were observed in *S. alterniflora* ponds. The remaining order of Coleoptera, Diptera, Hemiptera, and Odonata were higher in salt hay ponds.

5) Manmade ponds overall were utilized more frequently for all guilds, and on a year-round basis, than restored ponds. Shorebirds in particular benefit from the shallower design. Gulls and shorebirds utilize the exposed spoil for feeding and resting. However, bay species of waterfowl such as buffleheads and mergansers prefer restored ponds deeper habitats. Additionally, in some instances restored ponds are utilized by waterfowl during cold periods when the shallower ponds freeze over. Restored ponds are very worthwhile, incorporating into a system design, considering the minimal amount of work and perturbation on the marsh surface, usually requiring one or more plugs of ditches.

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