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Shorebirds in western Tennessee : migration ecology and evaluation of management effectiveness

Margaret Rohs Short

To the Graduate Council:

I am submitting herewith a thesis written by Margaret Rohs Short entitled "Shorebirds in western Tennessee : migration ecology and evaluation of management effectiveness." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

David A. Buehler, Major Professor

We have read this thesis and recommend its acceptance:

Craig Harper, Ralph Dimmick, Arnold Saxton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Arnold M Saxton

Craig A. Harper

Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

SHOREBIRDS IN WESTERN TENNESSEE: MIGRATION ECOLOGY AND EVALUATION OF MANAGEMENT EFFECTIVENESS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Margaret Rohs Short
December 1999

DEDICATION

This thesis is dedicated to all of the people who shared their excitement for the natural world and instilled in me a burning desire to explore and learn. This thesis is especially for my parents Thomas and Patricia Rohs, who supported my interests, put up with countless "orphan" animals, and drove me to all of my activities.

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Abstract

The loss of wetlands and shifting public interest towards the conservation of biological diversity and ecosystem management have encouraged wetland managers to consider managing more than just waterfowl. Because of the unique habitat requirements and the limited information available on migrant shorebirds in Tennessee, it has been challenging for wetland managers to formulate sound shorebird management plans. The goal of this project was to describe shorebird migration chronology in western Tennessee, document effects of management on three state wildlife management areas (WMAs) in western Tennessee, and discover which habitat variables influenced shorebird use of areas.

Data from 2 related studies were collected during peak spring and fall shorebird migrations. Two state Wildlife Management Areas were monitored in 1994 prior to active shorebird management, and five study areas were monitored along the Mississippi River in western Tennessee from spring 1996 through fall 1997. Three of these five areas were WMA's managed specifically for shorebirds, the others were known for abundant shorebird activity. Shorebird use and habitat conditions were recorded on study areas 2-5 times weekly.

A total of 29 species of shorebirds were recorded on study areas in 1994 -1997. The 7 most common species (descending order) were: pectoral sandpipers (*Calidris melanotos*), least sandpipers (*Calidris minutilla*), lesser yellowlegs (*Tringa flavipes*), semipalmated sandpipers (*Calidris pusilla*), American golden plovers (*Pluvialis dominica*), greater yellowlegs (*Tringa melanoleuca*), and solitary sandpipers (*Tringa *solitaria*). Management for shorebirds was effective, but shorebird use did not increase consecutively each year. Average water depth and percent of area in sparse vegetative cover were related to shorebird use. Waterfowl use of WMAs increased after shorebird management was enacted.

Based on the study results, careful management of water levels and vegetation density is necessary for maximizing shorebird use. Management of multiple units on WMAs will ensure that habitat is available throughout entire migration seasons. Smaller units with good water control capabilities can produce higher use per area than larger units with poor water control capabilities with habitat that is not as suitable.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction to Shorebird Migration Ecology and Study Area Description

Introduction

Shifting public interest towards the conservation of biological diversity and ecosystem management have encouraged wetlands managers to consider management for more than waterfowl. Manipulation of several different impoundments within a wetland system can attract many different groups of wildlife. For example, at Mingo National Wildlife Refuge in Missouri, waterfowl habitat was manipulated slightly to make the area suitable for migrating shorebirds (Fredrickson and Taylor 1982, Hands et al.1991).

The shift of interest from waterfowl management to broader based management of wetlands that includes shorebirds and other nongame species has come about for a variety of reasons. By the 1980's, the United States had lost roughly half of its wetlands, many which were located along the Mississippi River. Most loss occurred because wetlands were drained and converted to agriculture (Helmers 1993). At the same time, shorebird populations declined (Morrison et al.1994). Habitat loss and decreasing wetland wildlife populations have placed a greater emphasis on sound management of remaining wetlands to meet the needs of an increasing list of wildlife species of management concern. Wetlands along the Mississippi River, for example, are used by neotropical migrant songbirds during migration and for breeding, by waterfowl for breeding, migration, and wintering, and by shorebirds as migration stopover sites. All three groups of birds have been identified as needing management attention in the Lower Mississippi Valley Joint Venture plan because of declining populations (Loesch et al. 1994). Therefore, to meet the needs of the diversity of wildlife that is critically linked to wetlands, wetland managers must devise creative management approaches that meet the various habitat requirements of these species and conserve wetland habitats in general.

Information is limited concerning management of wetland species other than waterfowl (Hands et al. 1991). Relatively few studies have examined shorebird habitat use, especially at inland freshwater sites in North America (Colwell and Oring 1988). Recently, additional studies have been published on shorebird migration ecology, but the management techniques are new and scientifically untested (Helmers 1992). Additional research and evaluation of these techniques are needed to achieve multi-species management objectives in managed wetland settings. In light of the accelerated wetland acquisition by the Tennessee Wildlife Resources Agency and the agency's commitment to integrate shorebird management with wetland programs, data concerning shorebird ecology in western Tennessee are needed. The goals of this research are to document shorebird migration ecology, habitat use, and the response of shorebirds to management on state wildlife management areas in western Tennessee. These data then will be used to assist wetland managers in developing biologically sound management strategies for migrant shorebirds in western Tennessee.

Overview of Shorebird Migration Ecology and Management

Shorebird Migration Ecology

Forty-seven species of shorebirds (*Charadriiformes*) migrate through North America from their Arctic breeding grounds, to their wintering grounds in Central and South America (Myers 1983, Boland 1991, Helmers 1992, Skagen and Knopf 1993). Shorebirds use 3 major migration corridors: the Atlantic Coast, the Pacific Coast, and the

Great Plains through interior North America (Morrison 1984). During migration, shorebirds stop en route at staging areas to feed and restore energy reserves before continuing (Myers 1983). Staging areas vary in size from one to hundreds of hectares. The largest concentration of shorebirds occurs at Copper River Delta, Alaska on the Pacific Coast, Delaware Bay, Delaware and New Jersey on the Atlantic Coast, and Cheyenne Bottoms, Kansas in the North American interior (Myers 1983, Clark et al. 1995). Anywhere from 300,000 to 600,000-plus birds can be seen during peak migration on these sites. Staging areas on the Atlantic and Pacific coasts provide reliable food resources and many shorebirds use the same stop-over location year after year (Myers 1983). In interior North America, stop-over habitat tends to be ephemeral in nature, thus migrant shorebirds use habitat opportunistically (Skagen and Knopf 1993, 1994). Staging areas can be geographic bottlenecks causing large portions of shorebird populations to concentrate in a relatively small geographical area. Thus, shorebird populations within entire migration corridors can be affected by conditions at a single stop-over site (Myers 1983).

Different species of shorebirds as well as different individuals within a species have varied migration patterns (Boland 1990, O'Reilly and Wingfield 1995). Some species travel short distances (1-100 km) between stopover sites [e.g., black turnstone (see Table 1 for all scientific names)[1] and red phalarope], whereas other species travel intermediate distances (100-2,000 km; e.g., western sandpiper), or long distances (2,000-5,000 km; e.g., bristle-thighed curlew). Some species (e.g., semipalmated sandpipers and ruddy

[1] All tables and figures in Appendix

turnstones) show no apparent pattern with respect to distance traveled between stopover sites. Individuals within a species also vary in distance traveled between stop-over sites (O'Reilly and Wingfield 1995). Boland (1990) documented leapfrog migration occurring between shorebird species, in which smaller species bred farther north and wintered farther south than larger species. Similar sized species may migrate at different times and utilize different habitat which lessons competition for food (Recher 1966, Helmers 1991, 1992).

Some shorebird species exhibit different migration patterns for spring and fall (Recher 1966, Colwell and Oring 1988, Helmers 1992, O'Reilly and Wingfield 1995). In spring, peak migration occurs over a shorter time period [7 or fewer weeks (Memphis Chapter of Tennessee Ornithological Society; unpublished data)], with larger numbers of birds simultaneously using staging areas. During fall, migration is protracted [9 or more weeks (Memphis Chapter of Tennessee Ornithological Society; unpublished data)], with fewer birds using staging areas at once (Recher 1966, Colwell et al. 1988, Skagen and Knopf 1993). Spring migrants move northward as rapidly as possible which facilitates early arrival on the breeding grounds. Fall migrants move southward as food becomes unavailable or temperature becomes too low at staging areas (Recher 1966). Regardless of season, the rate and intensity of migration is affected by local/regional weather conditions (e.g., wind and rain), habitat conditions, and food availability (Recher 1966, Clark et al.1995, Butler et al. 1997).

Approximately forty shorebird species migrate though mid-western United States, including eighteen common species (Helmers 1992). To identify common species of the Lower Mississippi Valley, Hands et al. (1991) conducted a study at Ted Shanks Wildlife

Management Area located along the Mississippi River flood plain in eastern Missouri. The area was monitored for shorebird use during 3 shorebird migration seasons with 15 species observed. The 5 most common species were least sandpiper, semipalmated sandpiper, pectoral sandpiper, solitary sandpiper, and lesser yellowlegs (Hands et al.1991).

Migrant shorebird populations peak in the lower Mississippi Valley from April to mid-May, and from August through October (Helmers 1992). Some species are common during spring and fall (e.g., semipalmated sandpipers), while some species are common only during one season (e.g., American golden plovers in spring).

Semipalmated sandpipers are common migrants in interior North America during spring and fall (Gratto-Trevor 1992). During fall, semipalmated sandpipers migrating through the Mississippi Valley come from central and western Arctic breeding grounds. For example, 2 fall migrants documented in western Tennessee, were banded at Quill Lake, Saskatchewan (Gratto-Trevor and Dickson 1994). Other semipalmated sandpipers breeding in central Arctic, and all breeding in eastern Arctic migrate southward via the Atlantic Coast. During spring, semipalmated sandpipers that breed in the eastern Arctic region migrate north along the Atlantic Coast. Central and western Arctic breeders migrate northward through interior North America, including the Mississippi Valley (Gratto-Trevor 1992).

American golden plovers, in contrast, are common only during spring in the Mississippi Valley because of an elliptical migration pattern (Johnson and Connors 1996). During spring, the majority of all American golden plovers migrate northward through interior North America, with a major influx occurring during April over a broad region of the Mississippi, Missouri, and Ohio River valleys (Johnson and Connors 1996). American golden plovers are rare in the fall in the Mississippi Valley. Most fly southward offshore over the Atlantic to Central and South America, with small numbers of birds, particularly juveniles, traveling southward through the major interior river systems, along the inter-mountain West, and along the Pacific Coast (Johnson and Connors 1996).

Shorebird Management

The basic approach to shorebird management in North America has been described by Helmers (1992). He specifically addressed shorebird migration ecology, habitat needs, and management for interior, Atlantic, Gulf of Mexico, and Pacific regions. Many of the management techniques described in the manual are new and general in nature. Helmers (1992) recognized that the techniques he described needed to be tested and fine tuned by wildlife managers to accommodate their particular needs.

Appropriate staging areas for shorebirds usually consist of wetland areas with <10 cm of water and <25% vegetative cover (Helmers 1992). In the North American interior (including western Tennessee), natural wetland areas with these characteristics are temporally and spatially dynamic (Skagen and Knopf 1993). As a result, shorebirds migrating through the North American interior use habitat opportunistically (Skagen and Knopf 1994).

The number of shorebirds that stop at a particular staging area varies from year to year depending upon the quality and quantity of food resources available (Hicklin 1987, Iverson et al. 1996). Shorebirds stopping at staging areas in the North American interior feed on many different kinds of aquatic invertebrates, but a majority of their diet consists of Chironomid larvae (Eldridge 1990, Fredrickson and Batema 1992, Helmers 1992). Chironomids occur in open, shallow-water habitats with silty substrates, and feed on algae and decaying organic material. The presence of Chironomid larvae and other aquatic invertebrates is affected by vegetation, timing of flooding, depth of flooding, and duration of drawdown either naturally through evaporation or man-induced through the use of water control structures (Helmers 1993).

The density and type of wetland vegetation reflects the flooding regime. Sites managed for native wetland vegetation, as opposed to flooded agricultural crops, support a denser, more diverse invertebrate community (Hands et al. 1991). Regardless of vegetation type, units managed for shorebirds should have a vegetation density <50%, and most shorebirds prefer sites with a vegetation density <25% (Helmers 1992).

The timing of flooding is very important to create optimal conditions for shorebirds. The proper amount of water must be available for shorebird use during spring (March-May) and summer-fall (mid July-October) migrations. Units must be flooded prior to migration to allow adequate invertebrate populations to develop (Helmers 1992). To prepare units for spring migration, flooding should be conducted one month prior to the first heavy freeze of autumn (Helmers 1992). In western Tennessee, the fall-flooding target date might be October 1st, a time when most waterfowl managers are starting to flood moist-soil units for waterfowl. Flooding should be maintained throughout winter until the start of spring migration. This enables invertebrates to lay enough eggs to ensure the survival of larvae over winter.

To prepare units for fall migration, units flooded in spring should be allowed to dry out in June (Helmers 1992). Dry units intended for fall shorebird use should be reflooded two to three weeks prior to fall migration (flood date about July 15th). This allows sufficient time for invertebrates (Chironomids) to repopulate.

Water depth is a crucial component of shorebird habitat suitability. Different species of shorebirds utilize different water depths when foraging, but all shorebird species use <10 cm of water (Helmers 1992). Irregular topography within an impoundment is ideal because it creates a diversity of water depths that are compatible with the preferred feeding zones of a variety of shorebird species (Fredrickson and Taylor 1982, Hands et al. 1991, Helmers 1992). The ability to control water level is an essential ingredient of shorebird management, because of specific water depth requirements. To maintain site suitability for shorebirds, water manipulations of 2-8 cm are desirable. These requirements differ from typical waterfowl management where water levels are adjusted in large increments (e.g., 25-50 cm).

When managing wetlands for shorebirds, water levels are manipulated by pumping water into a unit to raise the water level and by drawing water down, or relying on natural evaporation, to lower the water level. To manage a unit that has been flooded for shorebird migration, a drawdown process is initiated. Gradual drawdowns are most effective for shorebirds because slow drawdowns provide a variety of water conditions that can be used by different shorebird species (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982). Also, a slow drawdown continuously exposes new substrate for foraging shorebirds, thereby ensuring a continuous supply of food.

In summary, the basic concepts of shorebird management have been well described by Helmers (1992). Site-specific management experience is needed in Tennessee and elsewhere along the Mississippi Alluvial Valley. Additional evaluation is needed to assess the effectiveness of these attempts to incorporate shorebird management concepts into integrated wetland management systems.

Each of the following chapters will address specific information needed to develop and use biologically sound shorebird management techniques in the Lower Mississippi Valley, particularly in western Tennessee. Chapter 2 describes shorebird migration chronology and evaluates the effect of shorebird management on shorebird use of wildlife management areas. Chapter 3 describes habitat characteristics associated with shorebird use of study areas and evaluates specifically how shorebird management affected habitat conditions. Chapter 4 discusses management implications of the data reported in Chapters 2-3. It is my goal that this information will provide wildlife managers in western Tennessee and the Lower Mississippi Valley with the knowledge needed to improve and better understand shorebird management.

Study Areas

Three different types of study areas were monitored for bird use during 1994, 1996, and 1997. All areas were located within 8 km of the Mississippi River (Figure 1). Eagle Lake, White Lake, and Black Bayou/Reelfoot Lake wildlife management areas (WMAs) are owned by the state of Tennessee, and managed for waterfowl. Each area consists of units with water control capability (i.e., the ability to hold water levels constant by pumping or draining water from units).

Phillippy Pits is privately owned agricultural land farmed in soybeans. It is considered "unmanaged" because it is not managed for shorebirds (or any other wildlife species), and lacks water control capability. Phillippy Pits lies low in the flood plain of the Mississippi River and floods naturally during spring and unusually high rain events. Phillippy Pits is known for abundant shorebird activity by local bird watchers.

The final study area type is a sewage treatment plant for the city of Memphis, known as the Earth Complex. The area is managed for sewage treatment and has water control capability, but is not managed specifically for shorebirds. Shallow water conditions, sparse vegetation, and high nutrient and invertebrate levels make this spot one of the best shorebird stopover sites in the entire Mississippi Valley.

Wildlife managers at Eagle Lake, White Lake, and Reelfoot/Black Bayou WMAs began incorporating shorebird management into their traditional waterfowl management plans in 1995. These WMAs were chosen for this study to document management effectiveness and fine tune shorebird management techniques on these areas. Phillippy Pits and the Memphis Earth Complex were chosen for study sites to further document the migration chronology of shorebirds stopping over in western Tennessee and to serve as controls for comparison of shorebird use with the WMAs.

Eagle Lake Wildlife Management Area

Eagle Lake, formerly known as Mustin Bottoms, was purchased in 1993 by the Tennessee Wildlife Resources Agency (TWRA). The 1,206-ha area is located in northern Shelby County and adjoins the southern and western portions of Meeman Shelby State

Forest and Wildlife Management Area. Eagle Lake is located 24 km north of Memphis, Tennessee and is adjacent to the Mississippi River.

Eagle Lake consists of 13 wetland compartments (ranging from 7.9 to 43.6 ha), each having water control capability. The area was monitored for water bird use during spring (April 1-May 15) and fall (August 1- October 1) in 1994, 1996, and 1997. In spring and fall of 1994, construction of individual impoundment units was not complete. Corn and soybeans were the predominant crops at Eagle Lake. Avian surveys were conducted on 5 areas that corresponded with future management units. Counts conducted during this time were considered part of the 1994 pilot study (Rohs et al. 1995) because shorebird management on Eagle Lake had not begun. By spring 1996, active shorebird management had begun. Most of the compartments contained water as a result of winter flooding for waterfowl. Throughout the spring, water was slowly drawn off the units to prepare for agricultural planting. All 13 units were monitored 2-5 times weekly while water was present. In fall 1996, most units were dry and planted in corn or soybeans except for 5 units, where water was being held and managed for shorebirds. During spring 1997, Eagle Lake WMA was unusually wet with severe flooding over most of the area. As a result, the area was inaccessible until April 15th. Counts were conducted on 13 units 5 times a week. Fall 1997 was similar to fall 1996, with water present on 5 units specifically managed for shorebirds.

White Lake Wildlife Management Area

White Lake is a 650-ha wildlife management area purchased in 1991 by TWRA. The area is located in Dyer County about 3 km north of Interstate 155 and 20 km west of

Dyersburg, Tennessee. The management area is situated between Reelfoot and Lake Isom National Wildlife Refuges to the north and Chickasaw National Wildlife Refuge to the south. It is adjacent to the Mississippi and Obion rivers.

White Lake consists of 9 compartments (ranging from 8.1 to 88.9 ha) with water control capability. Counts were conducted on this area during spring and fall shorebird migration seasons in 1994, 1996, and 1997. Counts conducted in 1994 were part of a pre-shorebird management pilot study (Rohs et al. 1995). All 9 compartments and 2 control areas were monitored for waterbird use in both seasons. In spring 1996, active shorebird management had begun. Spring 1996 was relatively dry until late in the migration season. Water was held on 2 units for shorebird use. During the last 2 weeks of the season, flooding of the Mississippi and Obion Rivers backed water onto White Lake and made the area inaccessible. In fall 1996, 4 units had water present. Data were collected at least 5 times weekly on the units until they were dry. In spring 1997, White Lake had unusually high water levels (up to 3 m of water over the entire area) because of rain events and rising backwaters of the Mississippi and Obion Rivers. Counts were conducted by boat once a week for the first 2 weeks of the season. Once the water receded and the area was accessible, surveys were conducted at least 4 times weekly on 3 units. During fall 1997, 2 units were managed for migrating shorebirds and monitored 1-4 times weekly.

Black Bayou/Reelfoot Lake Wildlife Management Area

The Black Bayou/Reelfoot Lake Wildlife Management Area is located approximately 10 km north of Tiptonville, Lake County, Tennessee. The area borders the west side of Reelfoot Lake and lies in the flood plain. Three units on the area were monitored for bird use from spring 1996 to fall 1997. Shorebird data were not collected in the 1994 pilot study because the site was developed already. The main unit, known as the goose pit (6 ha), had water control capability. Shorebird counts were conducted during all 4 migration seasons. Units "Far Pond" and "Mid Pond" were ponds (0.5 and 3.0 ha respectively) that flooded naturally during spring but were dry in fall. These units were monitored during spring 1996 and 1997, but not during fall because they were dry.

Phillippy Pits

Phillippy Pits is located in Lake County adjacent to the east side of the Mississippi River levee. It is approximately 9 km west of Black Bayou/Reelfoot Lake Wildlife Management Area. The pits consist of 5 privately-owned borrow pits that are farmed when dry. The borrow pits range in size from 4 to 51 ha. Elevation varies, so entire pits (ponds) may be dry especially during fall. Five units were monitored in 1996 and 1997. During spring, water levels often were too high to provide suitable stopover habitat for migrating shorebirds. During fall, many of the units had mud, shallow water, or were dry providing suitable stopover habitat. In spring 1997, some units were combined because flooding was so extensive that previously delineated boundaries were under water. Counts were conducted on all units while water was present.

The Memphis Earth Complex

The Memphis Earth Complex is approximately 63 ha and is located on the southwest side of Memphis, Shelby County, Tennessee, adjacent to the Mississippi River. The area contains sewage settling ponds, each of which has sludge-mud, flooded, and dry substrates present. Pond conditions change regularly as sewage is pumped in and settled and as water evaporates from the sites. The sewage ponds present ideal foraging habitat for shorebirds because of the habitat structure and because the nutrient-rich sewage provides ideal conditions for invertebrate populations to develop. This site has been known as a 'hot spot' for shorebirds and has been regularly censused by members of the Memphis chapter of the Tennessee Ornithological Society (TOS). The Earth Complex was included in the study because of its similarity to Eagle Lake in terms of position along the Mississippi River, because of the data already collected on shorebird use of the site by the TOS, and because of its reported high level of shorebird use. The Earth Complex serves as a good indicator of what species and abundances of shorebirds are moving through the area at any given time. Throughout the study anywhere from 6-12 ponds were monitored during the different seasons if suitable habitat was present.

CHAPTER 2

Shorebird Migration Ecology and Management Effectiveness

Introduction

More than 30 of the almost 50 species of shorebirds breeding in North America, have been recorded migrating through western Tennessee en route to their wintering grounds in Central and South America (Morrison 1984). The number of shorebirds stopping over in western Tennessee differ between seasons and years for a variety of reasons. Abiotic factors such as temperature and rainfall, the ephemeral nature of wetlands in interior North America (western Tennessee), and differing migration routes used in spring and fall by certain species, all influence the number of shorebirds using stop-over sites (Skagen and Knopf 1993, Recher 1966).

This chapter describes shorebird abundance, migration chronology, and species occurrences, as well as management effectiveness at Eagle Lake, White Lake, and Black Bayou/Reelfoot Lake WMAs. The specific objectives of this chapter are to:

1) document waterbird use on all study areas during peak spring and fall shorebird migration;

2) evaluate effects of shorebird management on state wildlife management areas by comparing relative shorebird use (birds/count/100ha) between site, season, and year on study areas;

3) describe migration chronology for the most abundant shorebird species stopping in western Tennessee during spring and fall; and

4) estimate the number of shorebird-use days at each study area during spring and fall migration.

Methods

Wildlife Monitoring

To assess the effectiveness of shorebird management, Howe and Collazo (1989) suggested daily monitoring of study areas during spring and fall migrations. In western Tennessee, peak spring migration occurs between 1 April-15 May, although birds actually move through the area from March through June. Peak fall migration occurs between 1 August-1 October, with the entire migration period occurring from July - November (Memphis Chapter of the Tennessee Ornithological Society, unpublished data).

All study areas, except the Memphis Earth Complex, were monitored by observers with binoculars and a 25 or 15-45x spotting scope at least 5 days per week for the duration of peak spring and fall migrations. The Earth Complex was monitored 1-2 times weekly during peak periods. Total counts were conducted on foot at Black Bayou/Reelfoot Lake WMA, Eagle Lake WMA, and Phillippy Pits. At White Lake, counts were conducted on four-wheeler and foot. At Eagle Lake and White Lake WMAs, a boat was used when extensive flooding occurred. Counts began at sunrise and ended 2 hours before sunset. Each compartment on each study area was visited for a fixed time period each day. Surveys lasted as long as necessary in order to record all waterbirds in suitable habitat. Suitable habitat had soil moisture ranging from saturated to flooded, with water depth □10 cm. Censuses were conducted during either morning or afternoon sampling periods in spring and fall. To randomize time-of-day effects, the order that the compartments were surveyed at each study site changed from day to day.

New birds that flew into a compartment and birds that left during the survey were recorded in the total count. Birds flying over the surveyed unit were not counted. Each site was approached carefully and large wading birds were recorded first as they flushed from the area. The remaining bird species were recorded while driving or walking around the compartment and stopping periodically. Data collected on terrestrial birds were incomplete and not used in the analysis.

For each management unit observed the following data were collected: species, count, bird activity, habitat use of each bird, time of day, and weather conditions. Bird activity was described as loafing, foraging, perching, or flushed. Weather conditions recorded included temperature, rainfall, percent clouds, and wind.

Statistics

<u>Total Counts and Waterbird Use on Study Areas</u>

The number of counts conducted at each study area in 1994, 1996, and 1997 were totaled. For each study area, waterbird use was described by species for each season and year. Species counts were summarized across groups that consisted of waterfowl, waders, gulls and terns, rails, and shorebirds.

<u>Migration Chronology</u>

Shorebird chronology was determined for the 7 most common species recorded on all study areas in 1994, 1996, and 1997. These species made up 79% of all shorebirds observed during the study. Breeding species such as killdeer and black-necked stilts (15% of observed shorebirds), and unidentified shorebirds (2% of observed shorebirds) were not included in the calculations.

To graph the migration chronology for each species during spring and fall, each season was divided into weeks. Spring season lasted 8 weeks from 25 March-19 May. Fall season lasted 9 weeks from 1 August-2 October. For each of the seven species, a weekly total from all study areas was calculated for spring and fall during each year of the study. The number of counts conducted varied weekly, so weekly bird totals were divided by the number of counts taken that week to calculate an average count for each week. Weekly average counts were graphed for each season and year to show duration and peak migration for each of the 7 species.

Evaluation of Shorebird Management

Shorebird management was evaluated on Eagle Lake, White Lake, and Black Bayou/Reelfoot Lake WMAs in 2 ways. For both methods, an index of shorebird use was created to take into account the difference in size (ha) and number of counts conducted on different study areas. For each area and week, the index consisted of total shorebirds seen divided by counts conducted, divided by area surveyed and multiplied by 100 ha; thus the index was an average count per 100 ha.

First, weekly indices were graphed comparing shorebird use on all 5 study areas by season and year. Analysis of variance was used to test how year (1996 and 1997), season (spring and fall), and area (Eagle Lake WMA, White Lake WMA, Black Bayou/Reelfoot Lake WMA, Phillippy Pits, and the Memphis Earth Complex) related to shorebird use. The model was:

Index (birds/count/100 hectare) = area year season area*season area*year*season.

The 1994 data were analyzed separately because data were only collected at 3 out of the 5 study areas. The same analysis of variance model was run on 1994 data as above, but year was not a variable. Additionally, a contrast statement was included in the model to compare shorebird use on Eagle Lake and White Lake WMAs with the Memphis Earth Complex.

Secondly, the weekly indexes were graphed for individual WMAs by season (spring and fall) and year (1994, 1996, and 1997), to determine whether management led to increasing shorebird use in successive years. An analysis of variance model was run to compare weekly average indices between years, by season, on WMAs.

Shorebird Use Days

Total shorebird use days provided by each study area were calculated by season and year by totaling the shorebirds counted each day during a season, including zero counts. On days when no counts were taken, an average was calculated of the counts taken immediately before and immediately after the unknown period. Shorebird use was summed over 45 days for spring and 61 days for fall. The analysis assumed that each individual shorebird observed spent the entire day on that particular area. More information on daily movements is needed to better understand the validity of this assumption.

Results

Waterbird Use

There were 2,569 counts completed in 1994, 1996, and 1997 (Table 2). Twenty one species of waterfowl, 11 species of waders, 8 species of gulls and terns, 2 species of rails, and 29 species of shorebirds were observed (Tables 3-7). Species composition and abundance varied on the study areas between season and year. Waterfowl species were more abundant in spring because they were still migrating through from their wintering grounds. Generally, more waders were seen in the fall, and the occurrence of gulls, terns, and rails did not seem to fit any seasonal pattern.

Waterfowl species made up 43% and 29% of all birds observed in spring and fall 1996-1997, respectively (Tables 3-7). Waterfowl use on Eagle Lake and White Lake WMAs increased once shorebird management was enacted. The highest percentage of waterfowl use occurred at White Lake WMA during spring 1996-1997.

Eagle Lake WMA

At Eagle Lake WMA, waterfowl numbers were greatest in 1996 and 1997, with blue-winged teal accounting for most of the abundance; waterfowl use ranged from 2 in fall 1994 to 3,920 in spring 1996 (Table 3). Wader species were most common in fall, with great egrets most frequently counted. Gull, tern, and rail abundance was limited to only a few species and relatively low abundance. The shorebird community was dominated by different species assemblages in spring and fall. For all springs combined, pectoral sandpipers, lesser yellowlegs, and American golden plovers were most common. Killdeer, black-necked stilts, and pectoral sandpipers were most abundant during autumn.

White Lake WMA

White Lake WMA received heavy use of waterfowl during the study, ranging from 989 ducks seen in fall 1994 to 6,616 ducks seen in spring 1997 (Table 4). Overall, blue-winged teal, mallard, and northern shoveler were most abundant; American coots were also common in spring. In general, waders were most common in fall, with great egrets most abundant. Six gull and tern species were seen, but none were commonly encountered. Least terns were observed in fall 1996 and 1997. The shorebird community was dominated by pectoral sandpipers, greater yellowlegs, and lesser yellowlegs in spring. In fall, killdeer, pectoral sandpipers, and least sandpipers were most common.

Black Bayou\Reelfoot Lake WMA

We observed 3,521 waterfowl in spring, 1997, with blue-winged teal most common (Table 5). Wader numbers varied between years and seasons with great blue and little blue herons most abundant. Bonaparte's and ring-billed gulls were seen only in spring 1996, whereas least terns were seen only in fall 1996. Black Bayou was the only area in this study with known nesting king rails present; only one was observed during the study. Lesser yellowlegs, pectoral sandpipers, and least sandpipers were the most common shorebirds species seen in spring; killdeer, pectoral sandpipers, and least sandpipers were the most common species in fall.

Phillippy Pits

Waterfowl counts ranged from 198 birds in fall 1997 to 3,852 birds in spring 1997, with blue-winged teal, mallard, and northern shoveler most abundant (Table 6). Waders were more abundant at this site than at other study sites, especially in fall. Great egrets and snowy egrets were the most abundant wader species. Four gull and tern species were observed at Phillippy Pits, although none were common. Least terns were observed each fall. Shorebirds were more abundant in fall than spring. Pectoral sandpipers, least sandpipers, and killdeer were most common, whereas in spring, pectoral sandpipers, lesser yellowlegs, and least sandpipers were most abundant.

The Memphis Earth Complex

The Memphis Earth Complex had highly variable waterfowl use, ranging from 51 birds in spring 1994, to 1,017 birds in spring 1997 (Table 7). Blue-winged teal and mallards were most common. The complex received very little wader use, with no more than 29 birds observed in any season. No gull, tern, or rail species were observed. Shorebird use of this site was extremely high, ranging from 851 birds observed in spring 1996 to 18,170 birds seen in fall 1997. Least sandpipers, pectoral sandpipers, and lesser yellowlegs were most abundant during spring. Pectoral sandpipers, least sandpipers, and killdeer were most common in fall.

Evaluation of Shorebird Management

Shorebird Use on Study Areas

In 1994, count indices at the Memphis Earth Complex were greater than indices at Eagle Lake and White Lake WMAs ($P = 0.0001$) (Figures 2-3, and Table 8). In spring 1994, the mean count index for Eagle and White Lake WMAs was <4 birds/count/100 ha, whereas the mean index for Memphis Earth Complex was 300.27 birds/count/100 ha (Table 8). In fall 1994, the mean count index for the Memphis Earth Complex was 249.65, whereas mean count indices for Eagle Lake and White Lake WMAs were <1 bird/count/100 ha.

Based on the analysis of variance model of shorebird use in 1996 and 1997, 4 components affected shorebird use (Table 8): study area, season, study area by season, and study area by year by season (P = 0.0001, P = 0.0008, P = 0.0004, and P = 0.0001 respectively). Shorebird use did not differ between years (P = 0.068).

In spring 1996, shorebird use index was highest at Black Bayou WMA (85.12 birds per count per 100 ha) and did not differ among the other 4 areas ($P < 0.05$) (Figure 4, Table 8). In fall 1996, shorebird use index was highest at Black Bayou WMA (1,268.29 birds per count per 100 ha) and did not differ among the other 4 areas ($P < 0.05$) (Figure 5, Table 8). In spring 1997, shorebird use index was again highest at Black Bayou WMA (327.63 birds per count per 100 ha) and did not differ among the other 4 areas ($P < 0.05$) (Figure 6, Table 8). In fall 1997, shorebird use index was highest at the Memphis Earth Complex (461.38 birds per count per 100 ha) and did not differ among the other 4 areas ($P < 0.05$) (Figure 7, Table 8).

Effects of Shorebird Management on WMAs

Shorebird use on WMAs differed by area and season (Tables 8 and 9). Shorebird use increased after 1994 (pre-shorebird management period) at Eagle Lake and White Lake WMAs (Table 9 and Figures 8-11). Shorebird use also increased consecutively by year during spring at Eagle Lake WMA and Black Bayou/Reelfoot Lake WMA (Figures 12-13), and during fall at White Lake WMA.

Shorebirds showed a positive response to management during spring at Eagle Lake WMA (Figure 8, Table 9). During spring 1994 and 1996, mean indexes were 3.54 and 4.25, respectively, and did not differ. Peak shorebird use on both areas was 10. In spring 1997, the mean index increased to 20 and the peak index rose to over 50. Fall seasons fluctuated at Eagle Lake (Figure 9, Table 9). In fall 1994, the average index was 0.95 and the peak index was 4. In fall 1996, the mean index increased significantly to 23.52, and the peak index reached 40. In fall 1997, the mean index was 7.33, the peak index was 15, and did not differ from 1994 levels.

The shorebird index did not differ at White Lake WMA in spring from 1994 to 1997 (Table 9). In spring 1994, the mean index was 1.82 and the peak index was 4 (Figure 10). The average indices in spring 1996 and 1997 were 23.48 and 13.95, the indices peaked at 44 and 34, respectively. During fall at White Lake, shorebird use showed a steady, yearly increase (Figure 11, Table 9), from an average index of 0.56 in fall 1994 to 73.81 in fall 1997. The peak index rose from 0 in 1994, to 70 in 1996, and 133 in 1997.

Shorebird use increased yearly during spring at Black Bayou/Reelfoot Lake WMA (Figure 12, Table 9). In spring 1996, the average index was 85.12 and the peak index was 170. In spring 1997, the average index was 327.63 and the peak index was over 560. Fall shorebird use decreased from 1996 to 1997 (Figure 13). The index averaged 1,268.29 and peaked at 2,100 in fall 1996. The average index for fall 1997 was 133.30, the index peaked around 320.

Migration Chronology

In descending order, the seven most abundant shorebird species observed on all study areas in western Tennessee in 1994, 1996, and 1997 were: pectoral sandpipers, least sandpipers, lesser yellowlegs, semipalmated sandpipers, American golden plovers, greater yellowlegs, and solitary sandpipers. Not including killdeer, common snipe, and unknowns, the aforementioned species made up 79% of all shorebirds observed. The migration intensity and peak varied among season and year for all species.

Pectoral Sandpiper

Pectoral sandpipers were the most common shorebird species migrating through western Tennessee study sites. In spring, migration of pectoral sandpipers was consistently low across all study areas at 1-4 birds per count in 1994 and 1996 (Figure 14). In spring 1997, pectorals showed a distinct peak in migration around 15–21 April, at 38 birds/count. In fall, peak migration was more pronounced for all years, occurring from 22 August - 4 September (Figure 14).

Least Sandpiper

Least sandpipers showed very consistent migration pattern for spring and fall across all study areas (Figure 15). In spring, birds came through relatively late in the season from 29 April - 19 May. The most birds were seen in spring 1997, averaging 20 birds/count during 6-12 May. In fall 1996 and 1997, when least sandpipers were most abundant, migration lasted about 5 weeks and was bi-modal with 2 distinct peaks from 29 August - 4 September and 12-18 September.

Lesser Yellowlegs

During each spring of the study, peak migration of lesser yellowlegs occurred 8-29 April (Figure 16). In spring 1996 and 1997, peak counts were relatively low with only 3-5 birds/count. In spring 1997, peak migration was more prominent, rising sharply at 17 birds/count during 8-14 April, then tapering off to 7 birds/count from 6-12 May. Peak migration was more consistent during fall for all years across all areas, occurring between

22 August - 19 September (Figure 16). The peak week of migration in 1996 and 1997 was 5-12 September.

Semipalmated Sandpiper

Semipalmated sandpipers migrate through western Tennessee in late spring, from 22 April past 19 May (Figure 17). In spring, semipalmated sandpipers were most common in 1997, at about 8 birds/count from 13-19 May. During fall 1994, only 1-2 birds/count were seen throughout the whole season (Figure 17). In fall 1996 and 1997, peak migration of semipalmated sandpipers appeared to be bi-modal, peaking first in early August and again in late August.

American Golden Plover

American golden plovers were most common in spring and were only recorded on study areas in 1996 and 1997 (Figure 18). In spring, plovers came through early, and were seen throughout April. The highest peak occurred in 1997 when 19 birds/count were observed from 15-21 April. In fall, 17 birds were seen in 1996, averaging <1 bird/count.

Greater Yellowlegs

Spring migration for greater yellowlegs occurred from 8-21 April (Figure 19). In fall, greater yellowlegs were less common, as only 3 birds were observed in 1994, <0.5 birds/count (Figure 19). In fall 1996, greater yellowlegs peaked at only 3 birds/count. In fall 1997, there were two peaks of 1-2 birds/count, occurring the week of 29 August and 19 September.

Solitary Sandpiper

Solitary sandpipers were most common in spring 1996 and 1997 (Figure 20). Peak migration occurred from 8-21 April. Fall migration appeared bi-modal (Figure 20). No more than 1 bird/count was observed in any year.

Shorebird Use Days

The Memphis Earth Complex and Eagle Lake WMA (Tables 10 and 11) provided the greatest shorebird use days for all 3 years. In 1994, the Memphis Earth Complex provided over 70,000 more use days compared to Eagle Lake and White Lake WMAs. In spring and fall 1996, Eagle Lake WMA (4,753 use days) and Phillippy Pits (15,547 use days) had the next highest use, respectively, compared to the Memphis Earth Complex (6,390 use days and 47,763, respectively). In spring 1997, Eagle Lake WMA received the highest use at 19,225 use days, followed by the Memphis Earth Complex. In fall 1997, the Memphis Earth Complex received the highest use at 148,301 use days followed by White Lake WMA at 6,848 use days.

Discussion

Importance of Shorebird Management to Waterfowl

Units managed for shorebirds can mean increased numbers of waterfowl. . Waterfowl use increased on Eagle Lake and White Lake WMAs after shorebird management was enacted in 1996-1997. Water manipulations for shorebirds in spring and fall coincide with blue-winged teal and wood duck needs, so the manager can accomplish both shorebird and waterfowl management simultaneously. Shorebird management provides wetland habitat to all bird groups, especially in fall, when areas would be normally be dry.

Importance of Western Tennessee for Migrant Shorebirds

Few studies have documented the abundance of shorebirds migrating through the Mississippi Alluvial Valley (MAV). To date, there have been only two published studies (Rundle and Fredrickson 1981, Hands et al. 1991), two Masters theses (Hands 1988, Helmers 1991), and one unpublished report (Rettig and Aycock 1994) documenting shorebird stopover abundance in the region. Based on these data and discussion with shorebird experts, Loesch et al. (In Press) estimated that 500,000 shorebirds migrate through the MAV each spring and fall. If these numbers are accurate, the MAV represents a significant portion of the shorebird migration, although important areas on the Atlantic and Pacific coasts receive more shorebird use. For example, the Copper River Delta in Alaska may host up to 20 million birds and the Bay of Fundy supports 800,000-1,400,000 birds seasonally (Hicklin 1987). Shorebird use of Cheyenne Bottoms in the Great Plains can reach 500,000 birds (Helmers 1991).

It is difficult to evaluate the significance of shorebird use in western Tennessee to the MAV when few comparative data exist in the region. Loesh et al. (In Press) assumed that the 500,000 shorebirds migrating through the MAV spent 10 days each in the region, thus accounting for 5 million use days. Rundle and Fredrickson (1981) estimated there were over 25,000 shorebird use days at Mingo National Wildlife Refuge in southeastern Missouri along the Mississippi River. Hands (1988) estimated there were 4000-8000 shorebird use days provided at Ted Shanks Wildlife Management Area in eastern Missouri along the Mississippi River. Extrapolation of Rettig and Aycock's (1994) counts to shorebird use days, yielded estimates ranging from <1000 to >40,000 use days for 9 state and federal WMAs in the lower Mississippi Valley. Shorebird use of these various management areas in the MAV fall within the range of values observed on individual wildlife management areas in western Tennessee. In fall 1997, the Memphis Earth Complex, however, had almost 150,000 shorebird use days. This suggests a significant portion of the shorebird migration through the MAV may stop over at Memphis. More birds may stop over at other sites in western Tennessee as shorebird management becomes more prevalent in the fall. In addition, a relatively large number of birds probably stop over in western Tennessee on private agricultural lands during wet springs and on shallow flats of the Mississippi River.

Species-specific migration data are required across North America to evaluate the significance of the MAV as a migration pathway for any individual species. In most cases, these data are incomplete but some trends may be apparent. For example, in both seasons during this study, pectoral sandpipers were the most common shorebird species, comprising 32% of all shorebirds seen. Pectoral sandpipers were also one of the most abundant species at 2 management areas in Missouri (Rundle and Fredrickson 1981, Hands et al. 1991) and at 9 management areas in Arkansas, Mississippi, and Louisiana (Rettig and Aycock 1994). This species is not commonly encountered during migration on the Atlantic Coast (Hicklin 1987, Clark et al. 1993), occur in low numbers through the Great Plains (Helmers 1991, Skagen and Knopf 1994, Davis and Smith 1998), and are rare on the Pacific Coast (Colwell 1995, Shuford et al. 1998). Hence, the MAV may provide critical migration habitat for pectoral sandpipers.

American golden plovers are more common in the MAV during spring than fall because of their elliptical migration pattern (Johnson and Conners 1996). They were the fifth most common bird seen during the study and all but a few birds were observed during fall. They were not commonly recorded in other studies conducted in the MAV, but one of these studies only occurred during fall (Hands 1988, Rettig and Aycock 1994). American Golden Plovers are common during fall on the East Coast, but not in spring (Hicklin 1987). They are rare in the Great Plains and the Pacific Coast (Skagen and Knopf 1994, Davis and Smith 1998, Shuford 1998). Apparently, the MAV is important to American golden plovers during spring migration.

Least sandpipers are common across the continent from the Atlantic to the Pacific Coast (Cooper 1994). Semipalmated sandpipers, lesser yellowlegs and greater yellowlegs are common on the Atlantic Coast, the MAV, and the Great Plains, but rare on the Pacific Coast (Hicklin 1987, Hands 1988, Helmers 1991, Davis and Smith 1998, Shuford 1998). Undoubtedly, the MAV is an important link in the migration corridors of many species.

Solitary sandpipers are fairly common in the MAV (Rundle and Fredrickson 1981, Hands 1991). They were among the top 5 species observed at Ted Shanks Wildlife Management Area in northeastern Missouri (Hands 1991), and were the seventh most common shorebird species in this study. Solitary sandpipers are uncommon in the Great Plains and on the east and west coasts (Hicklin 1987, Helmers 1991, Davis and Smith

1998, Shuford 1998). Therefore, the MAV may provide important stopover habitat for this species.

Evaluation of Shorebird Management

Shorebird use was greater on managed areas in 1996 and 1997 after shorebird management was implemented than shorebird use in 1994 prior to management. This suggests that management for shorebirds was effective. Use of management areas also approached or exceeded shorebird use on two well-known stopover spots, Memphis Earth Complex and Phillippy Pits. This further demonstrates the potential for management to create suitable stopover habitat. Shorebird use did not increase with each consecutive year of management experience on all areas. This suggests that in spite of the increased experience of the managers, other factors must influence shorebird use. At Eagle Lake in fall, 1997 for example, shorebird use was similar to pre-management levels because of dry conditions. At Black Bayou in fall, 1997, shorebird use decreased from 1996 levels. This might have occurred because the vegetation became too dense for shorebird use after Japanese millet was planted in the management unit in August. These changes in shorebird use cannot be explained by regional differences in shorebirds migrating through the MAV because use of the Memphis Earth Complex during this period (fall, 1997) was very high.

It seems clear that a variety of factors can affect shorebird use. Landscape effects, management area characteristics, seasonal and annual variation in precipitation and habitat conditions, and the time and willingness of the respective manager to manage for shorebirds all affect use. The position and amount of wetland habitat around the region is seasonally dynamic and therefore quality habitat varies. This also affects shorebird use on management areas (Skagen and Knopf 1993, Farmer and Parent 1997, Davis and Smith 1998). Managers cannot control regional landscape effects or precipitation levels, but can affect habitat characteristics and time spent managing shorebirds on wildlife management areas.

Management area characteristics, such as unit size and topography can affect shorebird use as well. Topography plays a role in certain habitat characteristics that influence bird use such as amount of flooded and mud habitat, water levels, and vegetation height and density (Rundle and Fredrickson 1981, Hands 1988, Skagen and Knopf 1994, Rottenburg 1996). Areas that have just one or two small units can still provide important habitat for migrating shorebirds. In 1996-1997, regardless of season and year, Black Bayou/Reelfoot Lake WMA received the greatest amount of use per unit area. Most of the use occurred in unit 1, which was relatively small (6 ha) and flat. Water was easily pumped into, or drained out of the unit. When managed well, even small wildlife management areas, can provide quality habitat for a relatively large number of birds.

Seasonal and yearly variation in precipitation, water levels, and overall weather conditions affect shorebird use (Shuford 1998). Regardless of area or year, fall showed more shorebird use than spring, possibly because in fall juveniles are also migrating and fall migration lasts slightly longer than spring (Recher 1966, Colwell et al. 1988). In some instances, there was too much water on study areas during spring, resulting in less shorebird use. Regardless of rainfall and regional water levels, water levels within management units affect vegetative cover and invertebrate densities, ultimately affecting shorebird use. The ability to control water levels is paramount for effective shorebird management. Careful water level management and planning contributed to high shorebird use of unit one at Black Bayou/Reelfoot Lake WMA, during fall 1996. Temperature can also affect shorebird use. Spring temperatures can effect prey availability, therefore reducing shorebird use (Skagen and Knopf 1994).

The wetland portions of wildlife management areas in western Tennessee were managed primarily for waterfowl; shorebird management was not the top priority. Managers had a limited amount of time and space to devote to shorebird management. Maintaining the recommended habitat conditions for shorebird use is very time intensive. This undoubtedly played a role in shorebird use of management areas.

Shorebird Use Days

Loesch et al. (In Press) estimated that 500,000 shorebirds move through MAV during late summer and fall, each foraging an average of 10 days. Thus, the MAV needs to support 5 million shorebird use days. Each bird requires 4 m^2 of habitat per day or 40 m^2 for the 10 days they are passing through the MAV. So, assuming each bird requires 40 m^2 of habitat and 500,000 birds pass through, 2000 ha of habitat is required to support shorebird migration through the MAV. Loesch et al. (In Press) allocated 185 ha of this need to western Tennessee to support 462,500 shorebird use days. In fall, 1997, Memphis Earth Complex provided an estimated 148,000 shorebird use days on a 73 ha area, or about 2000 use days per ha. Fall 1997 shorebird use was one of the top seasons of use since Tennessee Ornithological Society started monitoring the Earth Complex in 1980. This observed use was comparable to the assumed use of 2500 use days/ha by Loesch et al. (In Press). The other 4 stopover areas monitored in this study, provided only 15,533 shorebird use days on 289 ha of managed habitat in fall 1997, or only 53 use days/ha. In fall 1996, when management was more successful in attracting birds, the areas supported an estimated 30,772 use days or 106 use days/ha. This observed use was more than an order of magnitude below the assumed use for these areas in the conservation plan (2500 use days/ha). Assuming the results for fall 1996 are representative of average management effectiveness in the region, Tennessee would need 4,363 ha of wetland habitat for shorebirds in order to meet the stated goal. The MAV would need 47,170 ha of wetland habitat to meet the regional goal.

There are 2 possible solutions to this apparent shortfall in shorebird habitat in Tennessee and the MAV. First, increased effort could be expended on management areas to improve habitat suitability/quality, therefore increasing shorebird use. Conditions on the management areas during fall 1996 and 1997 were not optimal because of varying water levels (especially lack of water) and dense vegetation on certain shorebird management units. Second, if habitat quality is not improved, allocating additional area for shorebird management would increase habitat availability and therefore shorebird use days. A combination of increased shorebird management effort and additional management areas may be needed to meet the goals set for Tennessee and the MAV region.

CHAPTER 3

Effects of Habitat on Shorebird Use

Introduction

During migration across interior regions of North America, shorebirds require shallowly flooded wetland habitats (<10 cm deep) sparsely vegetated containing an ample supply of macroinvertebrates for food (Helmers 1992). Different shorebird species partition available wetland habitats based on foraging technique, bill size and body size (Helmers 1992). Habitat suitability for shorebirds, in general, may be defined by structural conditions of seasonally flooded wetlands, including substrate characteristics (flooded, mud, dry), the amount and height of vegetation, and water depth in flooded areas. Habitat quality, however, is ultimately defined by the availability of invertebrates where suitable habitat structure is present.

Colwell and Oring (1988) reported limited research on shorebird use at inland sites in North America. Since 1988, shorebird use has been documented at inland sites (e.g., Hands et al. 1991, Helmers 1992 and 1993, Skagen and Knopf 1994, Davis and Smith 1998) and coastal sites similar in habitat type to inland sites such as man-made impoundments and agricultural fields (e.g., Rottenburg 1996, Weber and Haig 1996). In some of these studies, attempts were made to relate habitat variables, such as substrate and water depth, to shorebird use. Skagen and Knopf (1994), documented a relationship between the amount of wet-mud/shallow-water habitat and shorebird abundance in the Great Plains. Davis and Smith (1998) showed that 7 of 8 shorebird species using playas during migration through Texas did not use water depths in proportion to availability but instead were selective in their use. More research is needed, however, to determine how habitat conditions in managed wetlands are related to shorebird use. This understanding is vital to determine which management strategies are most likely to be successful for this group of species. The objectives of this chapter were to:

1) describe habitat available to migrating shorebirds on study areas;
2) determine which habitat variables are related to shorebird use on study areas; and
3) describe micro-habitat use of the most common shorebird species.

Methods

Collection of Habitat Variables on Study Areas

Habitat conditions were recorded daily for each compartment after the avian census was completed. Ocular estimates of percent cover were made in each unit for flooded, mud, or dry substrate conditions. Percent vegetation cover was estimated visually using 5 different cover classes (0%, 1-25%, 26-50%, 51-75%, and 76-100%). Minimum, maximum, and average water depth (cm) were recorded for each unit. Height of vegetation was estimated visually using 5 categories [no vegetation, short vegetation (1-10cm), medium vegetation (11-20cm), tall vegetation (>20cm), and flooded habitat without vegetation].

Collection of Micro-habitat Use Data

Four habitat variables were used to describe micro-habitat use by the most common shorebird species. The variables collected were substrate (dry, mud, flood, and edge - an additional substrate category used when a bird was foraging back and forth between mud and flooded habitat), vegetation height (0, 1-10cm, 11-20cm, >20 cm), vegetation density (0%, 1-25%, 26-50%, 51-75%, and 76-100%), and water depth (cm).

Individual characteristics of the different habitat variables were described for individual birds by visually evaluating a 20-cm radius around each bird.

Statistics

Description of Available Habitat on Study Areas

Data from one unit of each study area is presented to show typical habitat conditions during spring and fall, 1994, 1996, and 1997. Unit construction had not been completed at Eagle Lake WMA in 1994, so habitat was described on area 3, which included future unit 2M. No water depth measurements were taken and only frequencies, not amount of mud and flood substrate, were recorded. During spring of 1996, the Goose Pit was not counted at Black Bayou/Reelfoot Lake WMA, so habitat conditions were described from the Far Pond (FP). During spring 1997, flooding was so extensive at Phillippy Pits that ponds 1 & 2 merged, so conditions were described considering both ponds as one. Data from the Memphis Earth Complex are not presented in chapter 3 because habitat conditions that resulted from sewage management were not comparable to the other study areas. Average water depth (cm), percent of mud and flood substrate, percent cover of vegetation 0-10 cm in height, and percent cover with a vegetation density of 0-25% were graphed weekly for each season and year of the study (Figures 21-42).

To evaluate how often suitable conditions were present on a given management unit, suitable habitat was loosely defined as >25% of the management unit covered in water, <25 cm average water depth in the unit, and <50% vegetation cover. The number of weeks for each season of each year that met these conditions on the shorebird management units at Eagle Lake, White Lake, and Black Bayou were counted in 1996 and 1997.

Habitat Variable Effects on Shorebird Use

A regression model was created and run on 1996 and 1997 data to determine which habitat variables were most related to the shorebird count index (shorebirds seen/count/100 ha of habitat). The explanatory variables were average water depth (cm), percent of mud and flood substrate, percent cover with vegetation height of 0-10 cm, and percent cover with a vegetation density of 0-25%. Each of these variables were plotted individually against the shorebird count index to graphically illustrate any patterns of shorebird use of habitat variables.

Shorebird Micro-habitat Use

Micro-habitat use of pectoral sandpipers, least sandpipers, lesser yellowlegs, semipalmated sandpipers, American golden plovers, solitary sandpipers, and greater yellowlegs, were described because these species made up 79% of all shorebirds observed in 1994, 1996, and 1997 (see Chapter 2). Mean water depth use was calculated for each species during spring and fall, 1996 and 1997. No water depth measurements were taken in 1994. The frequency of substrate use, vegetation height, and vegetation density for each species was graphed for each season and year. A chi-square test was performed on each variable for all seven species individually, to determine if habitat use patterns differed by season and year. Fisher's exact test was run on variables that had a high percentage of cells with expected counts of less than 5, when possible.

Results

Description of Available Habitat on Study Areas

Eagle Lake WMA

Prior to management in spring 1994, Eagle Lake was covered with water that backed up from the Mississippi River after a wet spring. Although water depths were not measured systematically, >2 m of water was present on much of the area for several weeks. As a result, area 3 was inundated with no mud substrate present (Figure 21). In fall 1994, the entire area was dry and planted in soybeans (Figure 21). Little mud substrate was available in spring 1996 as 75-90% of the area was flooded with an average water depth of >50 cm (Figures 22 and 23). Because the area was row-cropped in summer 1995, there was sparse vegetation in spring 1996 with 0-25% vegetative cover over 60% of the area (Figure 24). In fall, 1996, frequent rains raised the average water depths to 15-25 cm; however, available mud substrate increased throughout the fall season as the flood water receded (Figures 22 and 23). Flood conditions in spring 1997 raised water depths to 10-20 cm. Available mud substrate varied between 20-40% during most of the season (Figures 22 and 25). Average water depths ranged between 10-15 cm and mud substrate averaged around 20% in fall 1997 (Figures 22 and 25).

Vegetative height and density, were suitable across most of the Eagle Lake unit for the entire study period (Figure 26). When water depths approached suitable conditions (spring and fall, 1997) and mud substrate was present (spring and fall, 1997), vegetation was generally sparse and vegetation heights were <10 cm. Eagle Lake had suitable habitat conditions in 0 of 7 weeks monitored in spring 1996, 0 of 9 weeks monitored in fall 1996, 5 of 7 weeks in spring 1997, and 2 of 9 weeks in fall 1997 (Table 12).

White Lake WMA

Before active shorebird management, White Lake was inundated with water backed up from the Obion River after a wet spring in 1994. Over 2 m of water was present on much of the area for most of the spring shorebird migration season (Figure 27). As a result, the White Lake unit was 80-100% flooded until the last 2 weeks of spring (Figure 28). In fall 1994, without management, White Lake unit had very little water present for migrating shorebirds (Figures 27-28). During spring 1996, White Lake had water levels <50 cm with 25-60% mud habitat until the last week of spring when water levels rose to almost 300 cm (Figures 27 and 29). Average water depths ranged between 5-10 cm for most of fall 1996 , and percent mud and flooded habitat ranged between 40-60% until the last 2 weeks of the season (Figures 27 and 29). Flood conditions prevailed in spring 1997, with average water depths up to 400 cm in early spring. Flood waters receeded to manageable levels in the last few weeks of the spring period (Figures 27 and 30).

Vegetation height and density were suitable across most of the White Lake unit except in 1996, when there was taller vegetation present (Figure 31). From 29 August - 18 September 1997, there was very little suitable habitat because the vegetation was to dense on White Lake (Figure 32). White Lake unit had suitable habitat conditions in 2 of the 7 weeks in spring 1996, 9 of 9 weeks in fall 1996, 3 of 7 weeks in spring 1997, and 7 of 9 weeks in fall 1997 (Table 12).

Black Bayou/Reelfoot Lake WMA

Average water depth in the Far Pond unit at Black Bayou ranged between 10-35 cm in spring 1996 providing over 80% flooded habitat (Figure 33 and 34). Average water depth in GP unit ranged between 2-15 cm in fall 1996(Figure 33). Mud substrate covered 10-42% of the area until the last 2 weeks of the season when over 90% of the area was flooded (Figure 34). Heavy rainfall raised water levels (12-32 cm) at the GP unit in spring 1997, flooding 45-80% of the area (Figures 33 and 35). Average water depths ranged between 2-10 cm, and percent mud substrate was 50-90% in fall 1997 (Figures 33 and 35).

Vegetation parameters (height and density) were suitable in spring 1996 and 1997. There was only 0-20 % cover of vegetation 0-10 cm tall in FP unit in spring 1996, but over 80% of the cover on the unit remained at <25% density (Figures 36-37). In fall, 1997, the unit was suitable until 22 August - 18 September when Japanese millet planted on the unit germinated (Figures 36-37). Black Bayou had suitable habitat conditions in 0 of the 7 weeks in spring 1996, 9 of 9 weeks in fall 1996, 6 of 7 weeks in spring 1997, and 4 of 9 weeks in fall 1997 (Table 12).

Phillippy Pits

Average water depths on compartment 2 ranged between 10-40 cm in spring 1996 (Figure 38). During the entire season, compartment 2 remained over 80% flooded (Figure 39). In fall 1996, average water depth ranged from 5-20 cm (Figure 38). Mud substrate increased throughout the fall, until the last 2 weeks (Figure 39). Spring 1997 was extremely wet. Average water levels on combined compartments 1 and 2 were between

38-50 cm (Figure 38). Over 80% of the area remained flooded until the last 2 weeks of the season (Figure 40). In fall 1997, average water depths on compartment 2 dropped from 18 to 0 cm (Figure 38), while the available mud substrate ranged from 25-80% (Figure 40).

Vegetative parameters (height and density) were suitable across most of compartment 2 in Phillippy Pits in spring and fall 1996 and 1997 (Figures 41-42). During spring 1996, <20% of the vegetation was 0-10 cm in height, but during most of the season over 80% of the unit had a vegetation density <25% (Figure 42). Phillippy Pits had suitable habitat conditions in 2 of 7 weeks in spring 1996, 8 of 9 weeks in fall 1996, 0 of 7 weeks in spring 1997, and 7 of 9 weeks in fall 1997 (Table 12).

Habitat Variable Effects on Shorebird Use

Average water depth and percent of area covered with sparse vegetation (0-25% vegetated cover) were related to the shorebird index in 1996 and 1997 ($P = 0.0016$ and 0.0063, respectively), but only explained a small amount of the variation ($R^2 = 0.0511$) (Table 13). Based on the negative parameter estimate of average water depth (-1.597), increasing average water depth correlated with decreased shorebird use (Figure 43). Most shorebird use occurred on units with <20 cm average water depth. Increasing the percent of a unit sparsely vegetated also was related to increasing shorebird use (Figure 44). Shorebird use showed no relation to percentage of the area in mud or flood cover ($P =$ 0.3891 and 0.2687, respectively) (Figures 45 and 46). Shorebird use also showed no relationship to the percentage of the area with vegetation height of 0-10 cm ($P = 0.2625$) (Figure 47).

Shorebird Micro-habitat Use

The 7 most common species used mean water depths between 0.4 and 5.75 cm in spring and fall, 1996-1997 (Table 14). Use differed among species (P = 0.0001), as smaller species used the shallowest water and larger species used the deepest water (Table 14-15). For example, mean water depths used by least sandpipers and greater yellowlegs ranged from 0.42-1.22 cm and 4.89-5.75 cm, respectively. Water depths used also varied for a given species by season (P = 0.0079) and year (P = 0.0425) (Table 15). Water depth used in spring tended to be shallower for most of the species than water depth used in fall. Water depths used in 1996 tended to be deeper than water depths used in 1997.

All 7 shorebird species used mud or flooded substrate 80-100% of the time, except American golden plovers in spring 1996 (Figure 48). All 7 species did not use mud-flood habitat in the same manner by season and year. Species with longer legs used flooded substrate more often. Greater and lesser yellowlegs used flood substrate in 75-90% of all observations in 1996 and 1997, whereas least sandpipers were observed in mud substrate 50-90% of the time during 1994, 1996, and 1997. During spring and fall 1994, there appeared to be more use of mud substrate than during other seasons for most species, especially lesser yellowlegs, semipalmated sandpipers, and greater yellowlegs. For each species individually, use of substrate differed by season and year (P = 0.0001) (Table 16).

Seven shorebird species used areas with no vegetation or vegetation of limited height (≤10 cm) in ≥50 percent of the observations, with a few exceptions (Figure 49). There were seasonal and yearly differences in use of vegetation height categories by species (P = 0.0001)(Table 16). For example, in spring 1994, pectoral sandpipers were not recorded using areas without vegetation, whereas during the rest of the study, use of this habitat type ranged from 15-85%. When looking at habitat use patterns across species for this variable, there seemed to be roughly similar trends in vegetation height use.

Shorebird use of vegetation density showed similar trends to use of vegetation height. At least 50% of the use was recorded on habitat with no or little (<25%) vegetative cover, with the exception of all species in spring 1994 (Figure 50). There were seasonal and yearly differences in use of vegetation density categories by individual species ($P = 0.0001$). When looking at habitat use patterns across species, there seemed to be similar trends of vegetation densities used.

Discussion

Description of Available Habitat on Study Areas

Habitat conditions varied widely by season and year across the management areas, affecting the amount and distribution of suitable habitat for migrant shorebirds. Managers were faced with the challenge of managing for several habitat parameters simultaneously (water and vegetation). No two seasons, years, or study areas were alike, so what worked in one year or season, did not necessarily work the next year or season. Average water depths tended to be too deep on management units during spring because of natural flood events, and resulted in more flooded than mud substrate. Vegetative cover on the areas during spring was often sparse (suitable condition) but inconsequential because water depths were too deep. Managers' ability to control spring water levels was limited because management areas were typically at the low point in the flood plain. Shorebird use on management areas during spring was variable, however, alternative habitats higher in elevation across the region probably served as alternative habitat.

Habitat conditions varied widely during fall as well. Across all 3 management areas during fall 1996, 66% of the season had suitable habitat present. Across all 3 areas in fall 1997, <50% of the season had suitable habitat because water was generally available only by pumping. In general, when conditions were suitable, substantial shorebird use was possible (see Chapter 2).

Habitat Effects on Shorebird Use

Average water depth of unit and percentage of unit with low (0-25%) vegetation density were the 2 habitat parameters significantly related to shorebird use. These 2 parameters, however, explained only a small portion of the variance associated with shorebird numbers. The negative parameter estimate for average water depth indicated that when water depths were too high, few shorebirds were present. Hayes and Fox (1991) found similar results, showing a negative correlation of water depth and shorebird numbers. Skagen and Knopf (1994) found a significant relationship between the amount of area in wet/shallow water habitat and shorebird numbers. No significant relationships between shorebird numbers and the percent mud or flood cover were discovered in this study. Different use of substrate, however, was noted for certain species. Given the resource partitioning observed across species, in which some species prefer mud habitat and others prefer flooded habitat, these effects might have been canceled out when use by all species was analyzed.

Shorebird species may have specific preferences but in western Tennessee, they tolerate a relatively wide range of conditions (see Figures 48-50). Shorebird use was greatest in units with low average water depths, but some use occurred in units with average water depths of 80 cm, and in one instance, as high as 300 cm. Under these circumstances, use may have occurred primarily along the shallow edges. Shorebird use occurred across all combinations of percent mud and flood substrates, as long as vegetation was relatively sparse and water depth was relatively shallow. Nonetheless, there was variability concerning the number of shorebirds using a given site once it became suitable. Other factors, (landscape level effects, season, timing of migration, weather, and prey densities) undoubtedly contributed to the variability observed in shorebird counts (Hands 1988, Hayes and Fox 1991, Warnock and Takekawa 1995). With the exception of prey densities, these factors were all outside the control of wildlife managers.

Water depth preference for all species was comparable to the findings of others (Fredrickson and Taylor 1982, Colwell and Oring 1988, Hands et al. 1991, Helmers 1993, Cooper 1994). Average water depth use for all 7 species combined was less than 7 cm, which agrees with shorebird management recommendations of target water levels from 0-10 cm (Helmers 1992).

The use of vegetation different heights and densities by shorebird species seemed to be more related to availability than preference. Use of vegetation categories across migration seasons for all species differed significantly, indicating they used what was available. Also, all species used vegetation categories similarly during each year and season.

CHAPTER 4

Management Implications

Introduction

Wetland managers attempted to follow Helmer's (1992) guidelines for shorebird management on the state owned WMA's. Maintaining suitable habitat on areas through spring and fall migration proved challenging. Each area was different and managers faced various issues related to water and vegetation control. Shorebird management was a relatively new practice and goal on these WMA's. It is a learning process and can only be improved by experimentation and effort to yield optimal success. In the following section, recommendations learned from this study are provided that may prove useful for shorebird management.

Recommendations

- **Allocate more land for shorebird management in Tennessee and the entire MAV.**

Based on actual shorebird use of managed areas, the amount of area required to meet shorebird management goals in the MAV was greatly underestimated. Loesch et al. (In Press) allocated 185 ha of land for shorebird management in western Tennessee. Western Tennessee would actually need 4,363 ha of managed wetland habitat to support migrating shorebirds (See Chapter 2).

- **Regulate water levels in centimeters. Check levels regularly (daily if necessary), to ensure suitable habitat (1-10 cm) for migrant birds.**

Average water depth of a unit was one of the two key habitat parameters significantly related to shorebird use (Chapter 3). Units managed for shorebirds must have flooded habitat of 0-10 cm present in order to provide stopover habitat for migrant shorebirds.

- **Control vegetation density by disking, mowing, burning, or flooding. Vegetation density should be <25% to provide suitable habitat for migrant birds.**

Percentage of the unit with 0-25% vegetation density was a key habitat parameter related to shorebird use (Chapter 3). There are different ways to control vegetation. Managers must determine the appropriate control method for vegetation management. The existence of organic matter in the unit (vegetation), is an important food source for invertebrates.

- **Manage multiple units for migrating shorebirds, to ensure that some habitat will be present throughout the migration season.**

Different variables such as unit topography, vegetation, rainfall, and water control structures all affect shorebird habitat in a given management area. Planning should be an integral part of shorebird management to ensure that habitat will be present throughout shorebird migration.

- **Well managed small units (<10 ha) with good water control capabilities can produce higher use days per season than larger units that are not as well managed.**

The Goose Pit unit at Black Bayou/Reelfoot Lake WMA was only 6 ha in size, yet it provided some of the highest shorebird use in comparison to other areas in fall 1996. This unit was very flat and had good water control capability (i.e. pumping and draining). Managing smaller units intensively for shorebirds can produce high shorebird use areas.

- **Units managed for shorebirds can mean increased numbers of water fowl in both spring and fall.**

Managing wetlands for shorebirds provides wetland habitat, especially in fall, for a host of other species including waterfowl. Water manipulations on shorebird management units coincide with the habitat needs of migrating blue-winged teal and wood duck. Waterfowl use increased on 2 WMAs after shorebird management was enacted.

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APPENDIX

Table 1. Scientific names of species referred to in text and of waterbirds observed on five study areas in western Tennessee in spring and fall 1994, 1996, and 1997.

Species Common Name	Species Scientific Name
Waterfowl	
American Coot	*Fulicia americana*
American Wigeon	*Anas americana*
American Black Duck	*Anas rubripes*
Blue-winged Teal	*Anas discors*
Buffle Head	*Bucephala islandica*
Canada Goose	*Branta canadensis*
Common Merganser	*Mergus merganser*
Common Pintail	*Anas acuta*
Double-crested Cormorant	*Phalacrocorax auritus*
Gadwall	*Anas strepera*
Greater Scaup	*Aythya marila*
Green-winged Teal	*Anas crecca*
Hooded Merganser	*Lophodytes cucullatus*
Lesser Scaup	*Aythya affinis*
Mallard	*Anas platyrhynchos*
Northern Shoveler	*Anas clypeata*
Pied-billed Grebe	*Podilymbus podiceps*
Red-breasted Merganser	*Mergus serrator*
Ring-necked Duck	*Aythya collaris*
Rnddy Duck	*Oxyura jamaicensis*
Wood Duck	*Aix sponsa*

Table 1. Continued ...

Species Common Name	Species Scientific Name
Waders	
Black-crowned Night Heron	*Nycticorax nycticorax*
Cattle Egret	*Bubulcus ibis*
Glossy Ibis	*Plegadis falcinellus*
Great Blue Heron	*Ardea herodias*
Great Egret	*Casmerodius albus*
Green Heron	*Butorides striatus*
Little Blue Heron	*Florida caerulea*
Roseate Spoonbill	*Ajaia ajaja*
Snowy Egret	*Egretta thula*
Yellow-crowned Night Heron	*Nyctanassa violacea*
White Ibis	*Eudocimus albus*
Wood Stork	*Mycteria americana*
Gulls\Terns	
Black Tern	*Chlidonias niger*
Bonaparte's Gull	*Larus philadelphia*
Caspian Tern	*Sterna caspia*
Common Tern	*Sterna hirundo*
Forster's Tern	*Sterna forsteri*
Least Tern	*Sterna albifrons*
Ring-billed Gull	*Larus delawarensis*
Rails	
King Rail	*Rallus elegans*
Sora	*Porzana carolina*

Table 1. Continued ...

Species Common Name	Species Scientific Name
Shorebirds	
American Avocet	*Recurvirostra americana*
American Golden Plover	*Pluvialis dominca*
Baird's Sandpiper	*Calidris bairdii*
Black-bellied Plover	*Pluvialis squatarola*
Black-necked Stilt	*Himantopus mexicanus*
Black Turnstone	*Arenaria melanocephala*
Bristle-thighed Curlew	*Numenius tahitiensis*
Buff-breasted Sandpiper	*Tryngites subruficollis*
Common Snipe	*Capella gallinago*
Dowitcher Spp.	*Limnodromus spp.*
Dunlin	*Calidris alpina*
Greater Yellowlegs	*Tringa melanoleuca*
Killdeer	*Charadrius vociferus*
Least Sandpiper	*Calidris minutilla*
Lesser Yellowlegs	*Tringa flavipes*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Pectoral Sandpiper	*Calidris melanotos*
Red Knot	*Calidris canutus*
Red Phalarope	*Phalaropus fulicarius*
Ruddy Turnstone	*Arenia interpres*
Sanderling	*Calidris alba*
Semipalmated Plover	*Charadrius semipalmatus*
Semipalmated Sandpiper	*Calidris pusilla*

Table 1. Continued....

Species Common Name	Species Scientific Name
Short-billed Dowitcher	*Limnodromus gruseus*
Solitary Sandpiper	*Tringa solitaria*
Spotted Sandpiper	*Actitis macularia*
Stilt Sandpiper Upland Sandpiper	*Micropalama himantopu*
Upland Sandpiper	*Bartramia longicauda*
Western Sandpiper	*Calidris mauri*
White-rumped Sandpiper	*Calidris fuscicollis*
Willet	*Catoptrophorus semipalmatus*
Wilson's Phalarope	*Steganopus tricolor*

Table 2. Number of counts conducted at each western Tennessee study site in spring and fall, 1994, 1996, and 1997.

	—Before management—		————Active Shorebird Management————			
Study Areas	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Eagle Lake WMA	70	137	206	76	336	69
White Lake WMA	182	260	32	89	79	57
Black Bayou WMA	—	—	45	41	88	26
Memphis Earth Complex	6	42	33	86	136	62
Phillippy Pits	—	—	105	155	90	61
Totals	**258**	**439**	**421**	**447**	**729**	**275**

— Some units were not counted when area was dry or inaccessible due to flooding. In 1994 surveys were only conducted at White Lake WMA, Eagle Lake WMA, and the Memphis Earth Complex.

Table 3. Waterbirds observed at Eagle Lake Wildlife Management Area, Shelby County, Tennessee in spring and fall 1994, 1996, and 1997.

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Waterfowl						
American Coot	1	0	881	0	230	0
American Wigeon	0	0	51	4	0	0
Blue-winged Teal	9	0	1,131	1,130	1,158	260
Canada Goose	7	2	28	0	0	0
Common Merganser	0	0	0	0	38	0
Common Pintail	0	0	1	0	0	0
Double-crested Cormorant	57	0	161	0	0	0
Gadwall	0	0	558	0	5	0
Greater Scaup	0	0	6	0	0	0
Green-winged Teal	0	0	348	25	1	42
Hooded Merganser	0	0	8	0	13	0
Lesser Scaup	0	0	2	0	3	0
Mallard	26	0	74	70	29	20
Northern Shoveler	0	0	579	375	278	52
Pied-billed Grebe	0	0	70	15	11	8
Red-breasted Merganser	0	0	0	0	1	0
Ring-necked Duck	0	0	6	0	0	0
Wood Duck	37	0	16	21	2	40
Total Waterfowl	**137**	**2**	**3,920**	**1,640**	**1,769**	**422**
Waders						
Black-crowned Night Heron	0	0	1	14	0	0

Table 3. Continued.

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Cattle Egret	20	0	1	4	0	7
Great Blue Heron	175	24	35	64	246	114
Great Egret	36	2	43	846	329	648
Green Heron	26	3	4	96	6	0
Little Blue Heron	25	2	7	206	37	149
Snowy Egret	27	0	19	263	59	134
Yellow-crowned Night Heron	0	0	0	8	0	0
Wood Stork	0	0	0	170	0	0
Total Waders	**309**	**31**	**110**	**1,671**	**677**	**1,052**
Gulls\Terns						
Least Tern	0	0	0	5	0	14
Ring-billed Gull	0	0	0	0	223	0
Total Gulls\Terns	**0**	**0**	**0**	**5**	**223**	**14**
Rails						
Sora	0	0	10	0	1	0
Total Rails	**0**	**0**	**10**	**0**	**1**	**0**
Shorebirds						
American Golden Plover	0	0	384	0	3,000	0
Baird's Sandpiper	0	0	0	2	9	0
Black-bellied Plover	0	0	0	0	6	0
Black-necked Stilt	0	0	15	363	5	134
Common Snipe	0	0	530	7	6	3
Dowitcher Spp.	0	0	0	0	30	0

Table 3. Continued

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Dunlin	0	0	0	0	7	0
Greater Yellowlegs	3	0	106	25	2,422	3
Killdeer	63	205	250	811	78	144
Least Sandpiper	47	0	193	254	2,115	48
Lesser Yellowlegs	248	0	710	311	3,281	41
Pectoral Sandpiper	107	0	553	338	4,505	34
Semipalmated Plover	2	0	13	4	21	1
Semipalmated Sandpiper	0	98	384	19	381	14
Short-billed Dowitcher	0	0	0	0	1	0
Solitary Sandpiper	25	2	15	46	92	9
Spotted Sandpiper	5	0	24	58	66	6
Stilt Sandpiper	0	0	1	6	13	0
Upland Sandpiper	0	0	1	1	0	0
Western Sandpiper	0	0	0	1	6	0
White-rumped Sandpiper	0	0	0	0	45	0
Wilson's Phalarope	0	0	2	0	19	0
Total Shorebirds	**503**	**305**	**3,145**	**2,246**	**16,102**	**437**

Table 4. Waterbirds observed at White Lake Wildlife Management Area, Dyer County, Tennessee in spring and fall 1994, 1996, and 1997.

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Waterfowl						
American Coot	593	0	2,216	0	4,154	0
American Wigeon	2	0	40	2	0	1
Black Duck	0	0	0	9	0	0
Blue-winged Teal	315	543	990	1,222	797	1258
Buffle Head	0	0	0	0	9	0
Canada Goose	2	0	3	0	1	3
Common Merganser	1	0	0	0	0	0
Double-crested Cormorant	541	1	0	0	740	0
Gadwall	1	0	10	0	23	0
Green-winged Teal	0	0	148	19	0	157
Hooded Merganser	6	0	0	0	0	0
Lesser Scaup	6	0	0	0	8	0
Mallard	90	280	73	865	60	479
Northern Pintail	0	0	0	0	0	32
Northern Shoveler	8	1	658	32	415	250
Pied-billed Grebe	23	20	9	7	27	0
Red-breasted Merganser	0	0	0	0	6	0
Ruddy Duck	0	0	5	0	376	0
Wood Duck	50	144	0	105	0	102
Total Waterfowl	**1,638**	**989**	**4,152**	**2,261**	**6,616**	**2,182**
Waders						
Black-crowned Night Heron	15	26	0	2	0	7

Table 4. Continued

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Cattle Egret	393	0	1	49	0	1
Glossy Ibis	0	0	0	1	0	0
Great Blue Heron	289	89	49	382	100	122
Great Egret	484	295	60	871	82	1,525
Green Heron	0	9	0	4	0	0
Little Blue Heron	1,999	14	13	906	160	265
Snowy Egret	539	161	359	792	141	316
White Ibis	0	0	0	14	0	0
Total Waders	**3,719**	**594**	**482**	**3,021**	**483**	**2,236**
Rails						
Sora	0	0	0	0	0	1
Total Rails	**0**	**0**	**0**	**0**	**0**	**1**
Gulls\Terns						
Black Tern	0	0	0	1	0	0
Caspian Tern	3	0	0	0	1	0
Common Tern	2	0	0	0	0	0
Forster's Tern	0	0	0	0	8	0
Least Tern	0	0	0	47	0	44
Ring-billed Gull	42	0	0	0	1	0
Total Gulls\Terns	**47**	**0**	**0**	**48**	**10**	**44**
Shorebirds						
American Avocet	0	0	0	6	0	0
American Golden Plover	0	0	0	0	442	0
Black-bellied Plover	12	0	0	14	11	1

Table 4. Continued

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Black-necked Stilt	0	0	0	55	0	51
Buff-breasted Sandpiper	0	0	0	4	0	0
Common Snipe	0	0	181	3	11	15
Dowitcher Spp.	0	0	0	2	45	57
Dunlin	2	0	0	0	2	0
Greater Yellowlegs	26	1	216	22	325	107
Killdeer	86	282	58	1,387	2	2,241
Least Sandpiper	121	8	40	964	37	406
Lesser Yellowlegs	13	16	108	629	363	239
Long-billed Dowitcher	0	0	0	6	0	0
Pectoral Sandpiper	5	3	515	1,360	420	313
Semipalmated Plover	28	5	66	25	1	39
Semipalmated Sandpiper	36	0	1	358	0	245
Short-billed Dowitcher	2	0	4	22	27	0
Solitary Sandpiper	59	5	36	67	6	64
Spotted Sandpiper	47	2	5	8	18	19
Stilt Sandpiper	1	0	0	46	0	13
Western Sandpiper	0	0	0	32	0	3
Willet	0	0	0	3	0	0
Wilson's Phalarope	0	0	0	9	4	0
Total Shorebirds	**438**	**322**	**1,230**	**5,022**	**1,714**	**3,761**

Table 5. Waterbirds observed at Black Bayou Wildlife Management Area, Lake County, Tennessee in spring and fall 1996 and 1997.

Species	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Waterfowl				
American Coot	153	0	1,255	0
American Wigeon	47	0	3	0
Blue-winged Teal	38	600	1,287	100
Buffle Head	0	0	5	0
Gadwall	0	0	166	0
Green-winged Teal	18	2	441	9
Lesser Scaup	0	0	3	0
Mallard	20	133	33	0
Northern Shoveler	182	5	323	0
Pied-billed Grebe	1	1	5	0
Total Waterfowl	**459**	**741**	**3,521**	**109**
Waders				
Cattle Egret	0	2	0	1
Great Blue Heron	8	15	81	0
Great Egret	9	47	10	0
Little Blue Heron	0	87	1	3
Snowy Egret	4	37	1	0
Total Waders	**21**	**188**	**93**	**4**
Gulls\Terns				
Bonaparte's Gull	48	0	0	0

Table 5. Continued

Species	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Least Tern	0	287	0	0
Ring-billed Gull	56	0	0	0
Total Gulls\Terns	**104**	**287**	**0**	**0**
Rails				
King Rail	0	1	0	0
Sora	0	0	1	0
Total Rails	**0**	**1**	**1**	**0**
Shorebirds				
American Golden Plover	39	0	22	0
Black-necked Stilt	0	84	0	0
Buff-breasted Sandpiper	0	1	0	0
Common Snipe	8	6	2	0
Dowitcher Spp.	0	0	78	0
Dunlin	0	0	10	0
Greater Yellowlegs	13	10	115	0
Killdeer	11	1,112	17	181
Least Sandpiper	32	532	137	5
Lesser Yellowlegs	57	264	1,150	3
Pectoral Sandpiper	132	870	1,054	45
Ruddy Turnstone	0	1	0	0
Semipalmated Plover	0	7	5	0
Semipalmated Sandpiper	0	41	0	1
Short-billed Dowitcher	0	7	34	0
Solitary Sandpiper	8	11	4	0

Table 5. Continued

Species	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Spotted Sandpiper	10	5	0	0
Stilt Sandpiper	0	29	7	0
Wilson's Phalarope	0	0	150	0
Total Shorebirds	**310**	**2,980**	**2,785**	**246**

Table 6. Waterbirds observed at Phillippy Pits, Lake County, Tennessee in spring and fall 1996 and 1997.

Species	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Waterfowl				
American Coot	0	0	1,577	0
American Wigeon	70	0	141	0
Black Duck	0	2	0	0
Blue-winged Teal	576	2,326	659	106
Buffle Head	0	0	1	0
Canada Goose	0	67	12	0
Double-crested Cormorant	0	0	34	0
Gadwall	0	0	38	0
Greater Scaup	1	0	0	0
Green-winged Teal	242	7	98	0
Hooded Merganser	17	0	7	0
Mallard	416	801	150	87
Northern Shoveler	173	52	884	0
Pied-billed Grebe	1	5	246	0
Red-breasted Merganser	10	0	5	0
Ring-necked Duck	10	0	0	0
Ruddy Duck	0	0	0	2
Wood Duck	10	533	0	3
Total Waterfowl	**1,526**	**3,793**	**3,852**	**198**
Waders				
Cattle Egret	5	9	0	0
Great Blue Heron	87	566	177	328
Great Egret	40	3,278	83	3,569

Table 6. Continued

Species	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Green Heron	0	1	0	0
Little Blue Heron	0	336	0	954
Roseate Spoonbill	0	1	0	0
Snowy Egret	261	539	0	1,447
White Ibis	0	0	0	5
Total Waders	**393**	**4,730**	**260**	**6,293**
Gulls\Terns				
Bonaparte's Gull	2	0	0	0
Forster's Tern	0	0	1	0
Least Tern	0	9	0	69
Ring-billed Gull	23	0	0	0
Total Gulls\Terns	**25**	**9**	**1**	**69**
Shorebirds				
American Avocet	62	1	0	0
American Golden Plover	0	0	20	0
Baird's Sandpiper	0	3	0	1
Black-bellied Plover	0	24	1	0
Black-necked Stilt	0	28	2	0
Buff-breasted Sandpiper	0	16	0	0
Common Snipe	6	4	0	0
Dowitcher Spp.	0	1	0	1
Dunlin	11	0	0	0
Greater Yellowlegs	62	7	45	60
Killdeer	24	2,102	9	498
Least Sandpiper	89	2,243	21	721

Table 7. Waterbirds observed at the Memphis Earth Complex, Shelby County, Tennessee in spring and fall, 1994, 1996, and 1997.

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Waterfowl						
American Coot	0	0	0	2	22	0
American Wigeon	0	0	3	0	0	0
Blue-winged Teal	2	82	218	60	655	135
Canada Goose	16	0	4	17	32	62
Double-crested Cormorant	0	0	0	19	1	0
Gadwall	0	0	2	0	0	0
Green-winged Teal	1	0	3	0	0	3
Lesser Scaup	0	0	0	0	3	0
Mallard	29	13	24	503	63	42
Northern Shoveler	0	0	102	19	241	44
Pied-billed Grebe	0	0	0	4	0	0
Ring-necked Duck	0	1	0	0	0	0
Wood Duck	3	52	0	1	0	6
Total Waterfowl	**51**	**148**	**356**	**625**	**1,017**	**292**
Waders						
Cattle Egret	0	0	0	2	0	0
Great Blue Heron	0	5	0	12	0	0
Great Egret	0	0	0	13	0	1
Green Heron	0	3	0	1	0	0
Snowy Egret	0	0	0	1	0	0
Total Waders	**0**	**8**	**0**	**29**	**0**	**1**

Table 7. Continued

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Shorebirds						
American Golden Plover	0	0	0	17	0	0
Baird's Sandpiper	0	3	1	4	6	10
Black-bellied Plover	0	0	0	3	0	0
Black-necked Stilt	80	186	67	176	57	143
Buff-breasted Sandpiper	0	0	0	26	0	0
Common Snipe	0	0	46	0	2	0
Dowitcher Spp.	0	0	0	0	35	3
Dunlin	0	0	0	0	1	0
Greater Yellowlegs	1	2	1	2	47	11
Killdeer	80	457	53	2,048	58	2,454
Least Sandpiper	124	494	219	5,635	1,565	7,589
Lesser Yellowlegs	100	306	218	501	580	832
Long-billed Dowitcher	0	1	0	0	0	0
Pectoral Sandpiper	115	5,583	106	2,652	747	6,779
Sanderling	0	1	0	1	0	0
Semipalmated Plover	11	14	0	71	8	41
Semipalmated Sandpiper	0	270	88	283	759	1,982
Short-billed Dowitcher	3	4	0	3	0	0
Solitary Sandpiper	570	27	35	22	181	43
Spotted Sandpiper	9	1	15	7	16	1
Stilt Sandpiper	0	21	0	245	25	247
Western Sandpiper	3	34	0	33	60	116
Willet	0	0	0	1	4	0

Table 7. Continued

Species	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
White-rumped Sandpiper	0	0	0	0	25	1
Wilson's Phalarope	0	1	2	8	66	0
Total Shorebirds	**1,096**	**7,404**	**851**	**11,738**	**4,242**	**18,170**

Table 8. Mean shorebirds per count, per 100 hectares, by area, year, and season in 1994, 1996, and 1997, in western Tennessee.

	---Before management---		-----------Active Shorebird Management-----------			
Study Areas	Spring 1994	Fall 1994	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Eagle Lake WMA	3.54 A	0.95 A	4.25 A	23.52 A	20.30 A	7.33 A
White Lake WMA	1.82 A	0.56 A	23.48 A	27.94 A	13.95 A	73.81 A
Black Bayou WMA	—	—	85.12 B	1,268.29 B	327.63 B	133.30 A
Phillippy Pits	—	—	21.93 A	157.70 A	14.40 A	85.51 A
Memphis Earth Complex	300.27 B	249.65 B	34.02 A	184.66 A	33.94 A	461.38 B

Variables	P-Value 1994	P-Values 1996-1997
area	0.0001	0.0001
year	—	0.0680
season	0.7052	0.0008
area*season	0.8910	0.0004
area*year*season	—	0.0001

— Year is not a variable in 1994 analysis.

Table 9. Mean shorebird count per 100 hectares by year, area, and season on three wildlife management areas in western Tennessee in 1994, 1996, and 1997.

Year	Eagle Lake Spring	Eagle Lake Fall	White Lake Spring	White Lake Fall	Black Bayou Spring	Black Bayou Fall
1994	3.54 A	0.95 A	1.82 A	0.56 A	—	—
1996	4.25 A	23.52 B	23.48 A	27.94 B	85.12 A	1,268.29 A
1997	20.30 B	7.33 A	13.95 A	73.81 C	327.63 B	133.30 B

Area	P-Values Spring	P-Values Fall
Eagle Lake WMA	0.0279	0.0001
White Lake WMA	0.0119	0.0001
Black Bayou/Reelfoot Lake WMA**	0.0298	0.0132

** Analysis for Black Bayou/Reelfoot Lake WMA does not include 1994 data because no data were taken in that year.

Table 10. Total shorebird use days provided on study areas in western Tennessee, 1994. (Before shorebird management).

Study Areas	Spring 1994	Fall 1994
Eagle Lake WMA		
Area 1	44	89
Area 2	64	65
Area 3	85	191
Area 4	53	204
Area 5	—	114
Control B	402	1
Total: Eagle Lake	**648**	**664**
White Lake WMA		
Unit A	1	119
Unit B	168	19
Unit C	64	—
Unit D	48	17
Unit EFG	310	78
Unit H	41	46
White Lake Unit	309	217
Control N	58	—
Control S	61	1
Total: White Lake	**1,060**	**497**
Total: Memphis Earth Complex	**8,235**	**64,538**

*** Construction on units at Eagle Lake WMA were not completed in 1994. The area was broken down into five survey areas. The areas equal a combination of units that were completed in 1995.

Table 11. Total shorebird use days provided on study areas in western Tennessee, 1996 and 1997.

Study Areas	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Eagle Lake WMA				
Unit 1M	429	—	8,194	495
Unit 2M	1,780	743	3,430	85
Ditch	—	10	—	—
Unit A	347	2	1,111	798
Unit B	184	—	2,193	25
Unit C	113	—	1,221	249
Unit D	181	—	292	—
Unit E	194	—	561	—
Unit F	22	—	—	—
Unit G	886	2,525	494	—
Unit H	38	—	13	—
Unit I	261	—	320	—
Unit J	22	—	401	—
Unit K	—	—	73	—
Unit L	296	—	145	—
Unit O	—	—	777	—
Total: Eagle Lake	**4,753**	**3,280**	**19,225**	**1,652**
White Lake WMA				
Unit A	—	—	—	—
Unit C/D	2,472	129	1,311	—
Unit E	—	1,100	187	1,393

** Due to flooding in spring 1997 some ponds were connected and therefore counted as one.—Some units were not counted when they were completely dry or inaccessible due to flooding.

Table 11. Continued...

Study Areas	Spring 1996	Fall 1996	Spring 1997	Fall 1997
White Lake	898	5,876	1,803	5,455
Corn Patch Pond	—	93	—	—
Total: White Lake	**3,370**	**7,105**	**3,394**	**6,848**
Black Bayou WMA				
Goose Pit	—	4,840	3,243	306
Mid Pond	166	—	65	—
Far Pond	642	—	834	—
Total: Black Bayou	**808**	**4,840**	**4,142**	**306**
Total: Memphis Earth Complex	**6,390**	**47,763**	**15,930**	**148,301**
Phillippy Pits				
Pond 1	51	68	—	11
Pond 2	378	13,680	—	5,768
Pond 3	214	145	—	52
Pond 4	455	1,081	—	—
Pond 5	1,160	573	332	896
Ponds 1&2**	—	—	197	—
Ponds 3&4**	—	—	349	—
Total: Phillippy Pits	**2,258**	**15,547**	**878**	**6,727**

** Due to flooding in spring 1997 some ponds were connected and therefore counted as one.
—Some units were not counted when they were completely dry or inaccessible due to flooding.

Table 12. Weeks with suitable habitat* conditions present on shorebird management units at four study areas in western Tennessee in 1996-1997.

Area	Spring 1996	Fall 1996	Spring 1997	Fall 1997
Eagle Lake Compartment 2M	0	0	5	2
White Lake Compartment WL	2	9	3	7
Black Bayou Goose Pit	0	9	6	4
Phillippy Pits Pond 2	2	8	0	7

* Suitable habitat defined when compartment has >25% flooded cover, average water depth <25 cm, and vegetation density <26%. Suitable habitat was possible for 7 weeks in spring and 9 weeks in fall.

Table 13. Relationship of habitat variables from five study areas in western Tennessee to shorebird use (birds/count/100 ha) for 1996-1997 data.

Variables**	Parameter Estimates	Standard Error	P-Values
Average Water Depth	-1.597	0.504	0.0016
Percent Cover Mud	0.829	0.962	0.3891
Percent Cover Flood	0.956	0.863	0.2687
Percent of Unit with 0-25% Vegetative Cover	2.272	0.828	0.0063
Percent of Unit with Vegetation Height 0-10 cm	0.835	0.744	0.2625

**For multiple regression model F Value = 5.196, P = 0.0001, DF = 5, and R^2 = 0.0511.

Table 14. Average water depth used by the 7 most common species on five study areas in western Tennessee for 1994, 1996, and 1997.

Species**	Spring 1996		Fall 1996		Spring 1997		Fall 1997	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Pectoral Sandpiper	1.68	0.20	2.09	0.14	1.43	0.17	1.87	0.22
Least Sandpiper	0.99	0.14	1.22	0.07	0.52	0.11	0.42	0.11
Lesser Yellowlegs	3.45	0.15	4.38	0.16	3.29	0.15	4.76	0.30
Semipalmated Sandpiper	0.91	0.26	1.55	0.12	0.50	0.19	1.07	0.11
American Golden Plover	0.59	0.14	1.80	0.46	0.40	0.13	—	—
Solitary Sandpiper	2.65	0.46	2.48	0.33	0.96	0.33	2.20	0.41
Greater Yellowlegs	5.22	0.25	5.44	0.45	4.89	0.19	5.75	0.45

**Water depth was not recorded for species in 1994.
— No American Golden Plovers were observed in fall 1997.

Table 15. Difference of water depth use by the seven most common species, by year, and season on five study areas in western Tennessee, 1996 and 1997.

Variable	F-Values	P-Values
species	159.18	0.0001
species*year	2.17	0.0425
species*season	2.90	0.0079
species*year*season	1.28	0.2678

Table 16. Results of Chi Square tests of seasonal and yearly differences in use of substrate, vegetation height, and vegetation density, for the 7 most common species recorded on five study areas in western Tennessee, 1994, 1996 and 1997.

Species	Habitat Variable *	X^2	D.F.	P-Value
Pectoral Sandpipers	Substrate	147.35	30	0.001
	Vegetation Height	404.56	48	0.001
	Vegetation Density	361.49	24	0.001
Least Sandpipers	Substrate	122.84	18	0.001
	Vegetation Height	214.85	42	0.001
	Vegetation Density	205.20	24	0.001
Lesser Yellowlegs	Substrate	134.13	18	0.001
	Vegetation Height	577.17	54	0.001
	Vegetation Density	346.34	30	0.001
Semipalmated Sandpipers	Substrate	157.53	18	0.001
	Vegetation Height	161.97	30	0.001
	Vegetation Density	126.96	24	0.001
American Golden Plovers	Substrate	26.93	6	0.001
	Vegetation Height	66.67	8	0.001
	Vegetation Density	40.97	8	0.001
Solitary Sandpipers	Substrate	82.11	30	0.001
	Vegetation Height	158.06	36	0.001
	Vegetation Density	108.64	24	0.001
Greater Yellowlegs	Substrate	105.36	18	0.001
	Vegetation Height	188.11	24	0.001
	Vegetation Density	169.26	24	0.001

* Number of categories were 4 for substrate, 5 for vegetation density, and 4 for vegetation height.

Figure 1. MAP OF FIVE STUDY AREAS IN WESTERN TENNESSEE

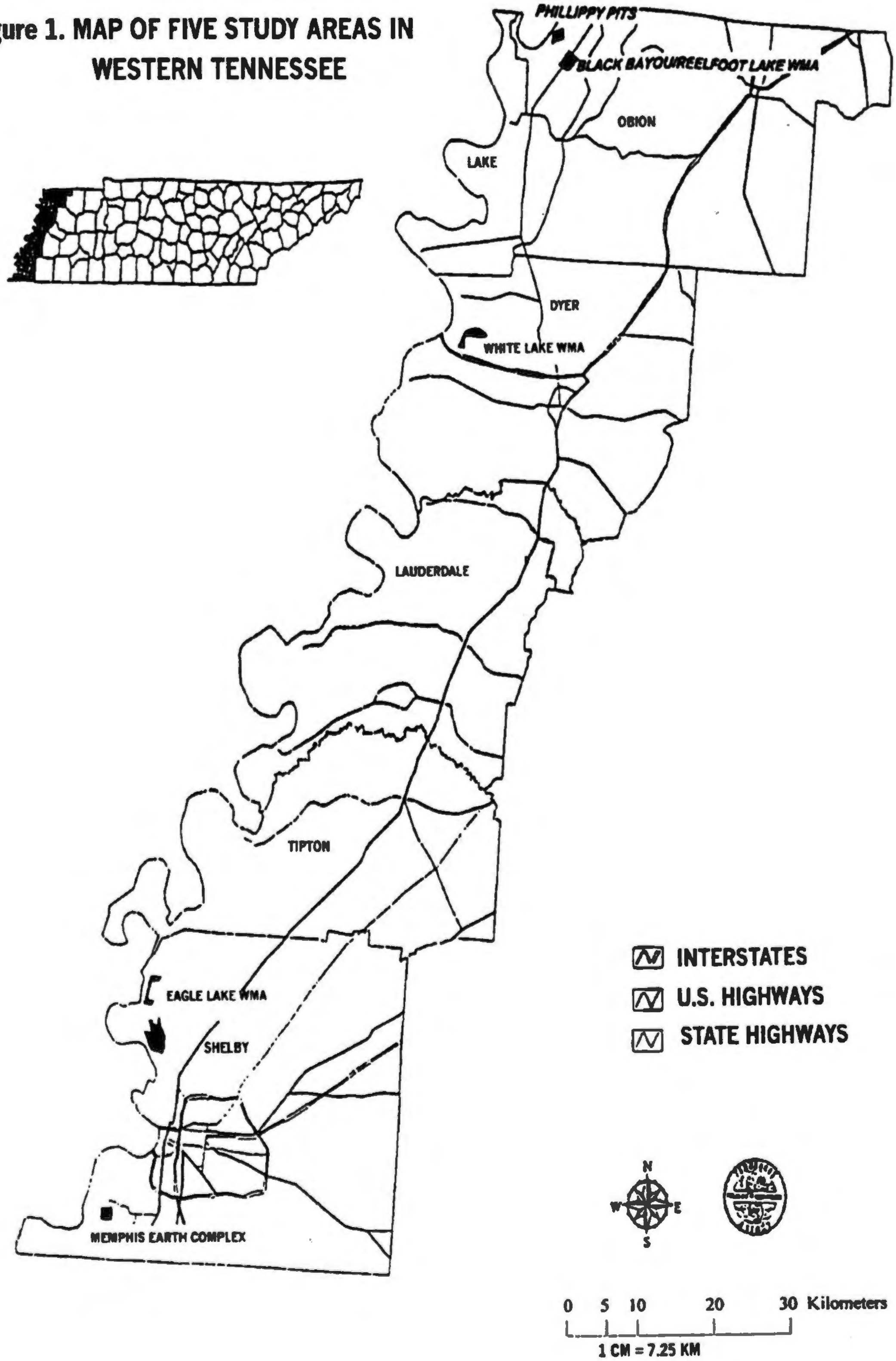


Figure 2. Weekly indices of shorebird use (birds/count/100 ha) on three study areas in western Tennessee in spring, 1994.

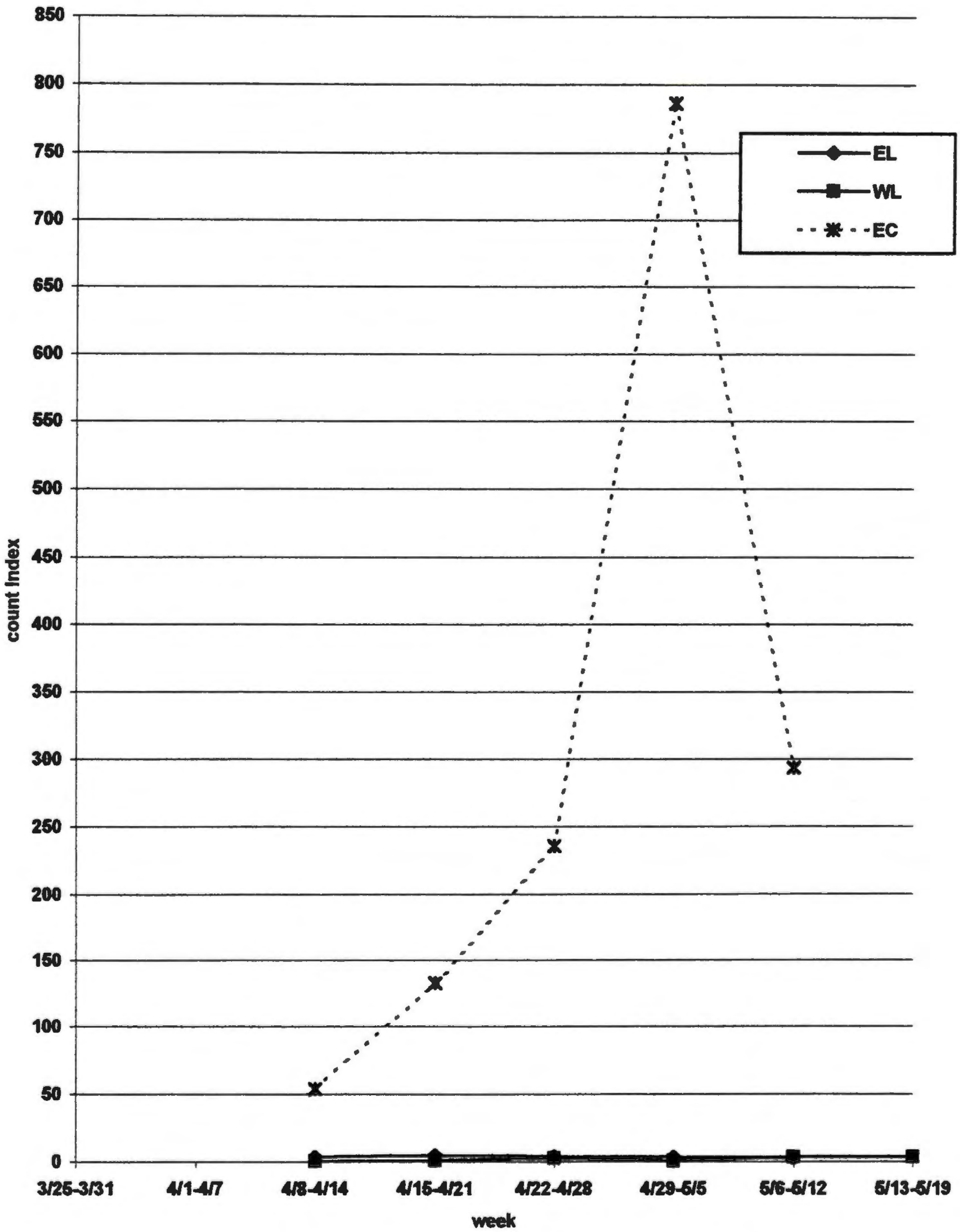


Figure 3. Weekly indices of shorebird use (birds/count/100 ha) on three study areas in western Tennessee in fall, 1994.

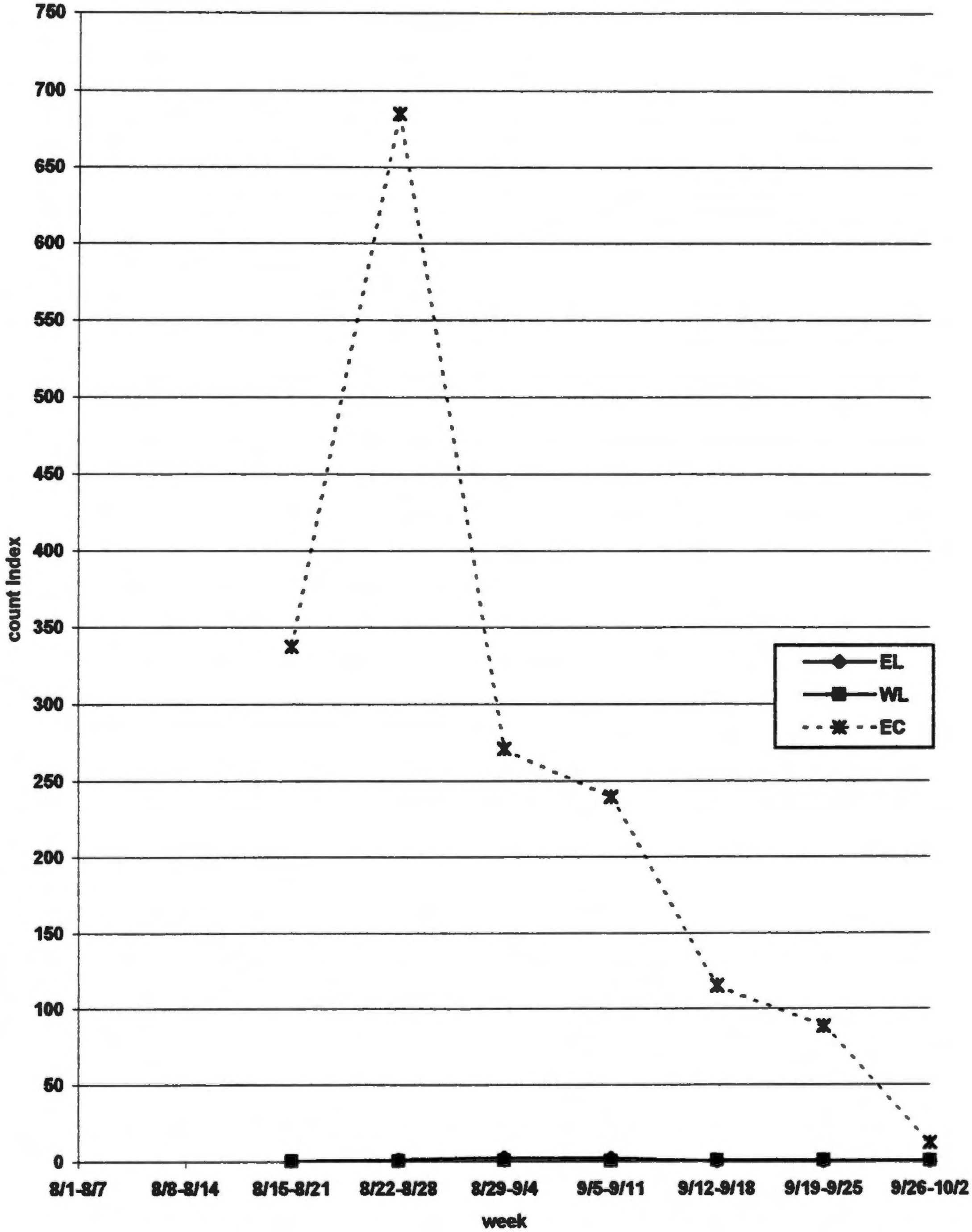


Figure 4. Weekly indices of shorebird use (birds/count/100 ha) on five study areas in western Tennessee in spring, 1996.

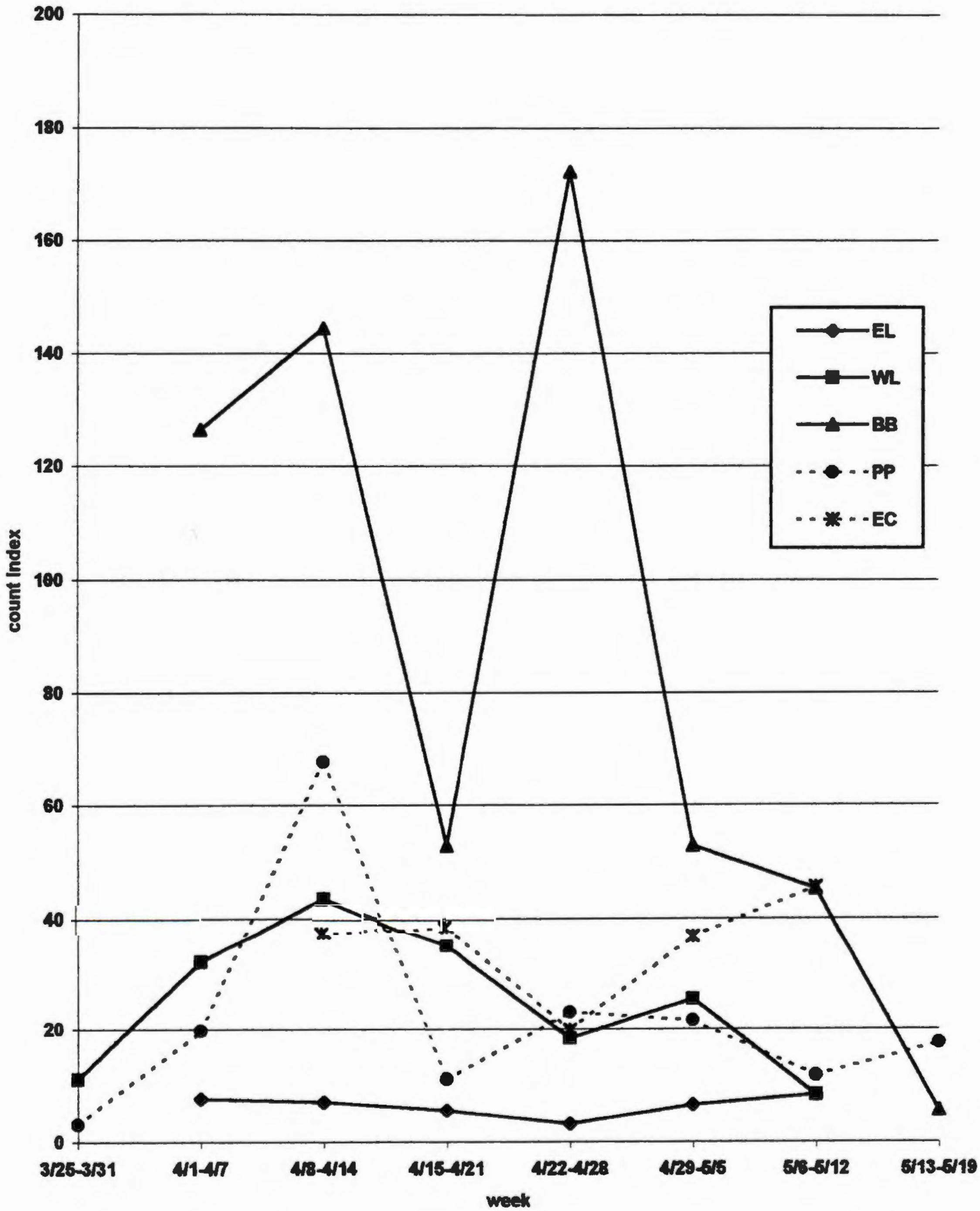


Figure 5. Weekly indices of shorebird use (birds/count/100 ha) on five study areas in western Tennessee in fall, 1996.

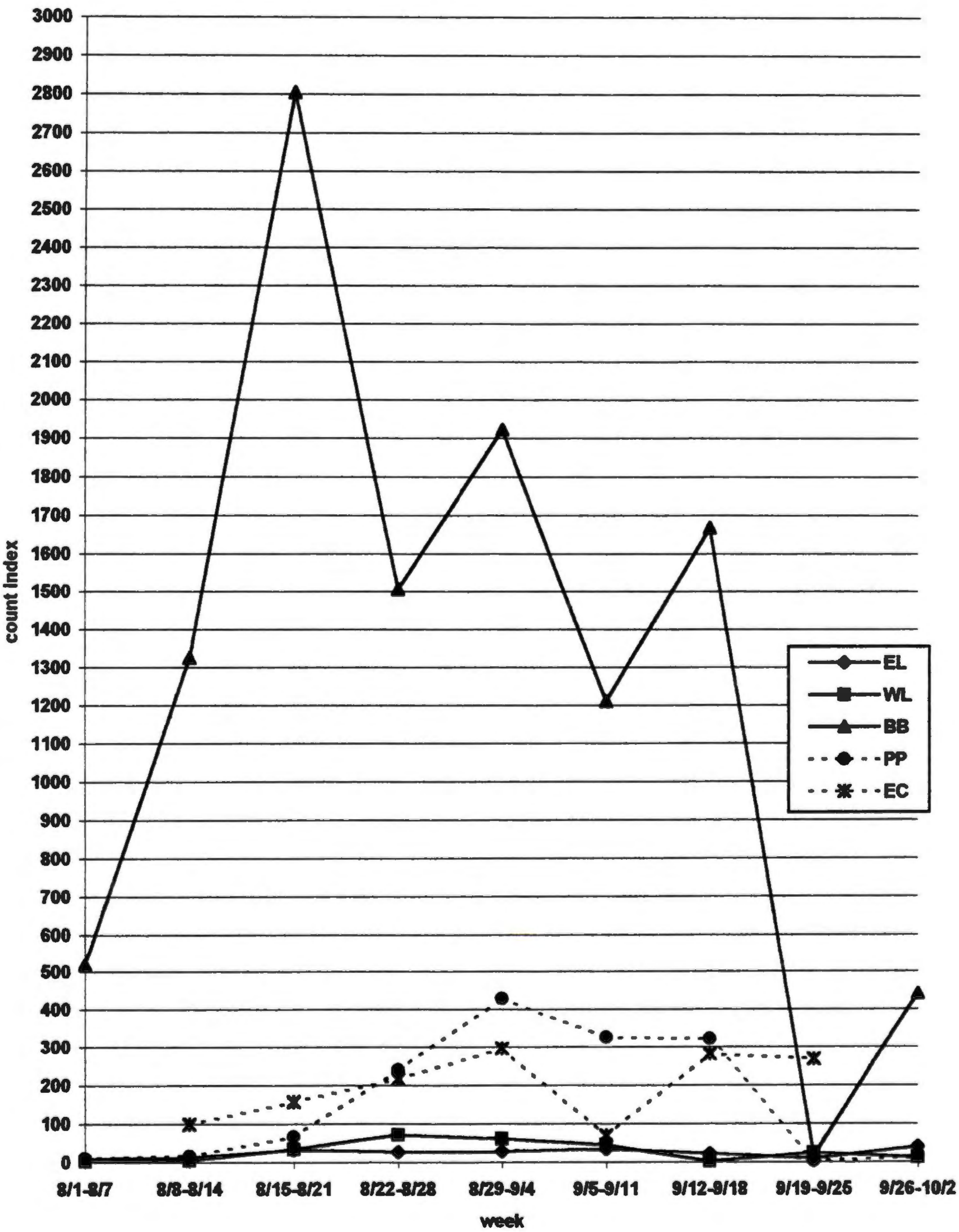


Figure 6. Weekly indices of shorebird use (birds/count/100 ha) on five study areas in western Tennessee in spring, 1997.

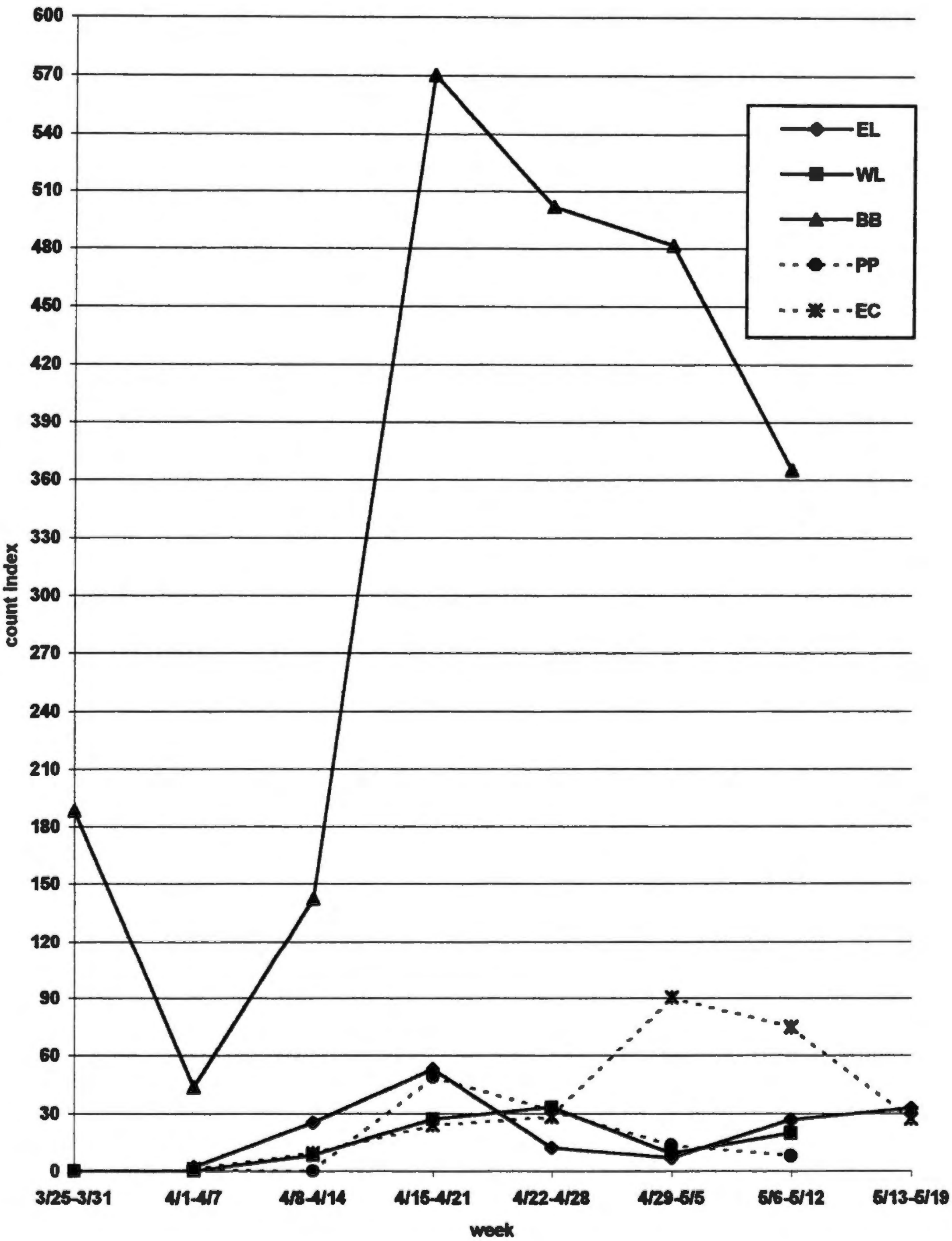


Figure 7. Weekly indices of shorebird use (birds/count/100 ha) on five study areas in western Tennessee in fall, 1997.

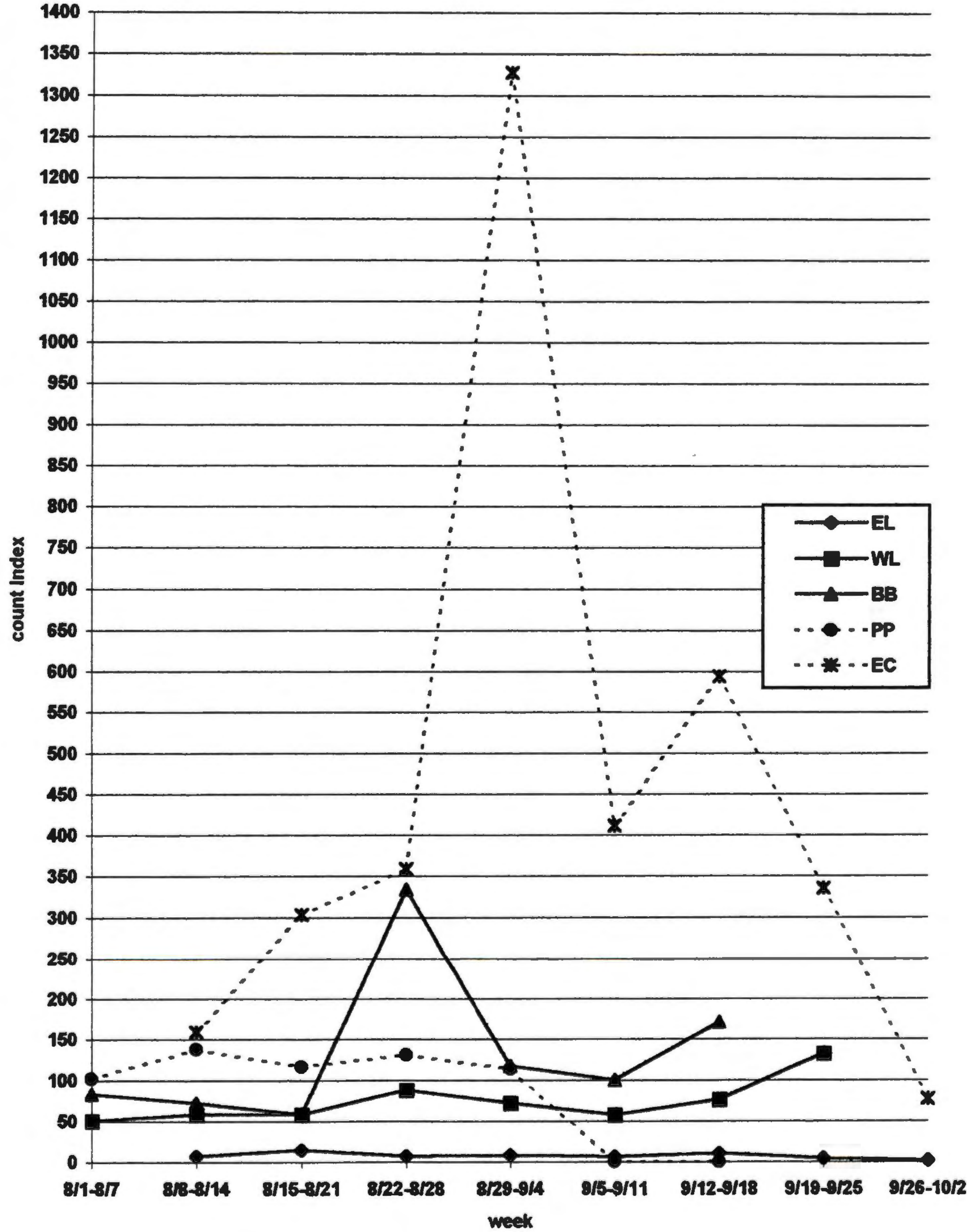


Figure 8. Weekly shorebird count indices on Eagle Lake Wildlife Management Area, Shelby County, Tennessee in spring 1994, 1996, and 1997. Counts in 1994 were prior to initiation of shorebird management practices on the area.

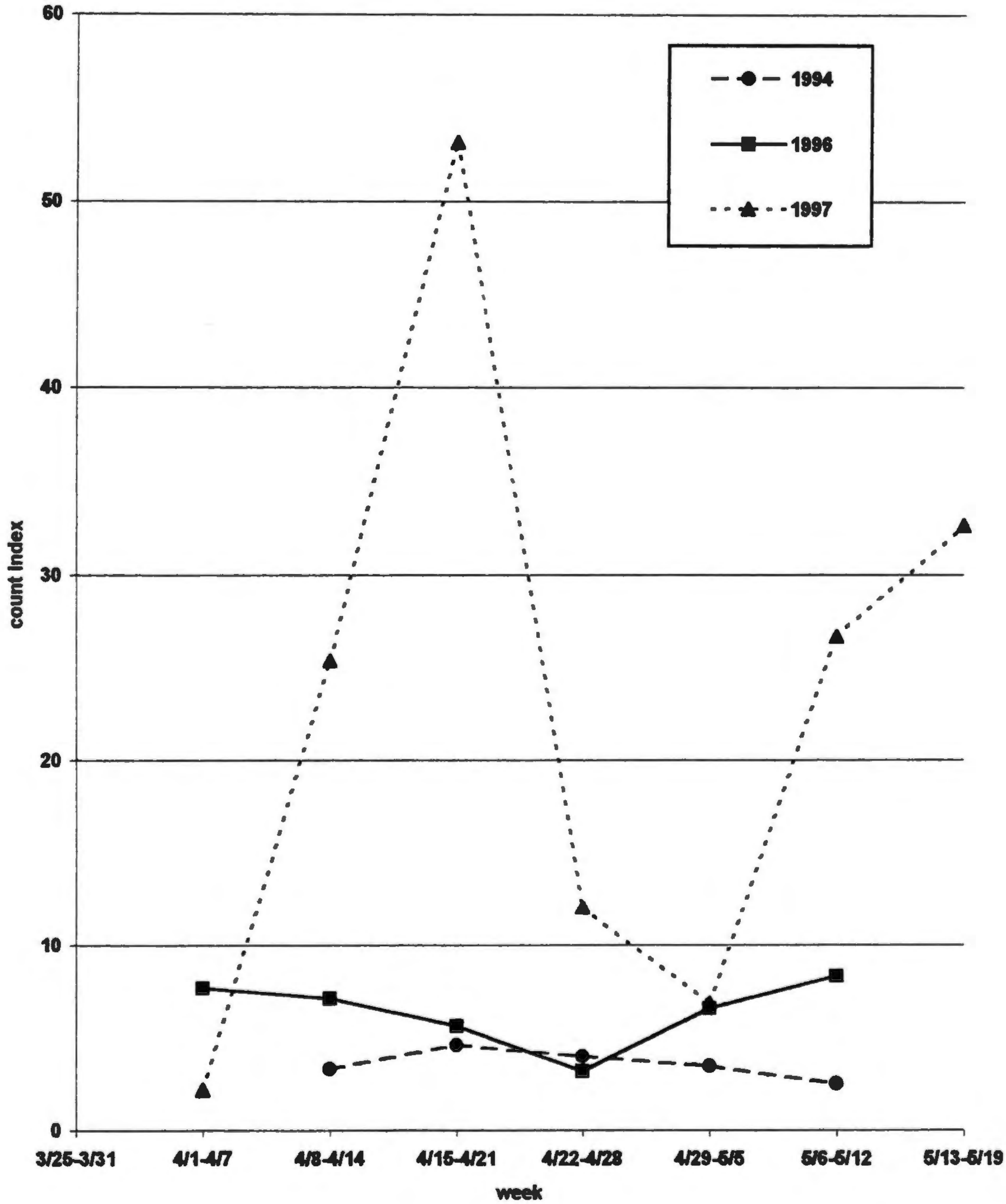


Figure 9. Weekly shorebird count indices on Eagle Lake Wildlife Management Area, Shelby County, Tennessee in fall 1994, 1996, and 1997. Counts in 1994 were prior to initiation of shorebird management practices on the area.

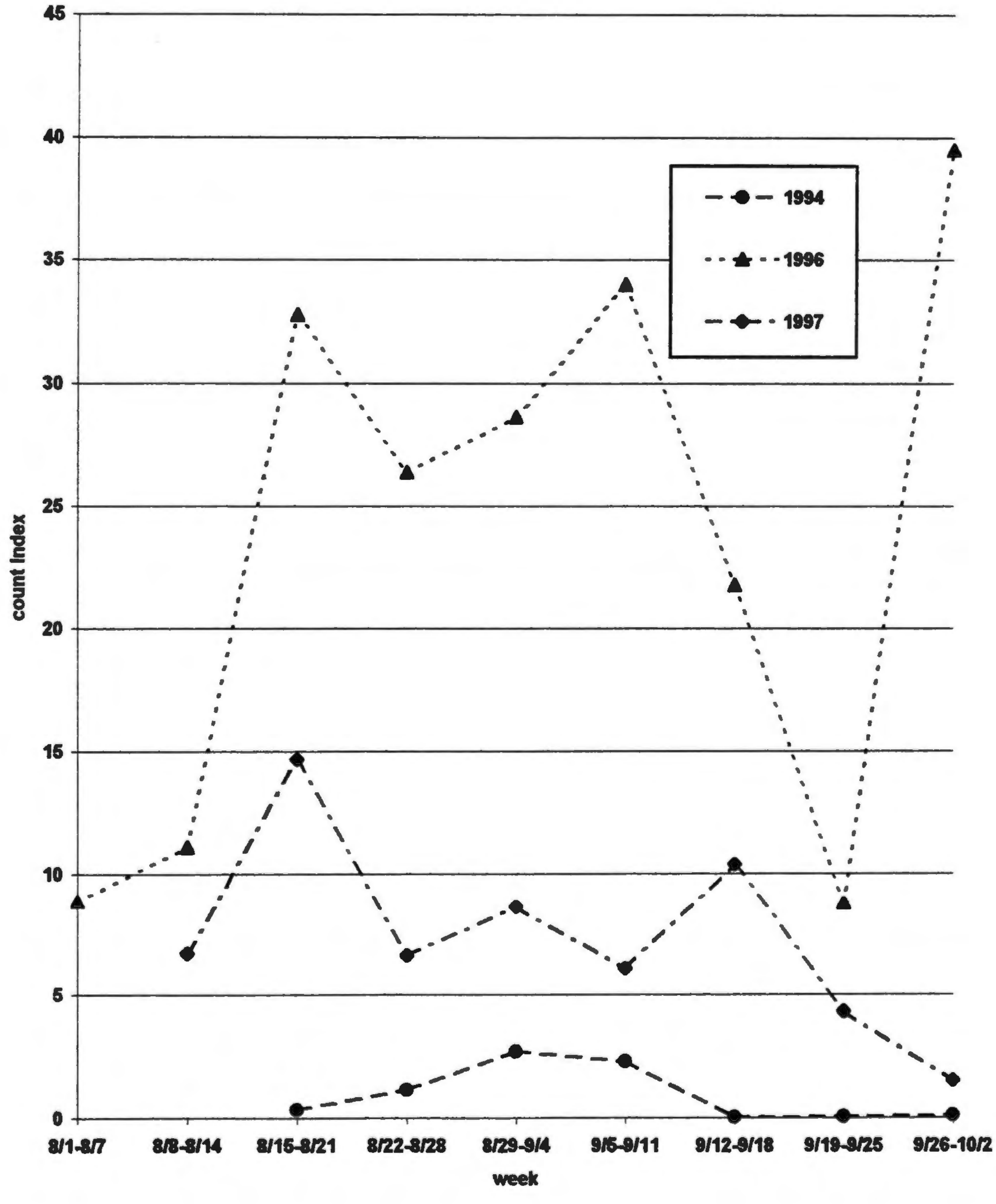


Figure 10. Weekly shorebird count indices on White Lake Wildlife Management Area, Dyer County, Tennessee in spring 1994, 1996, and 1997.

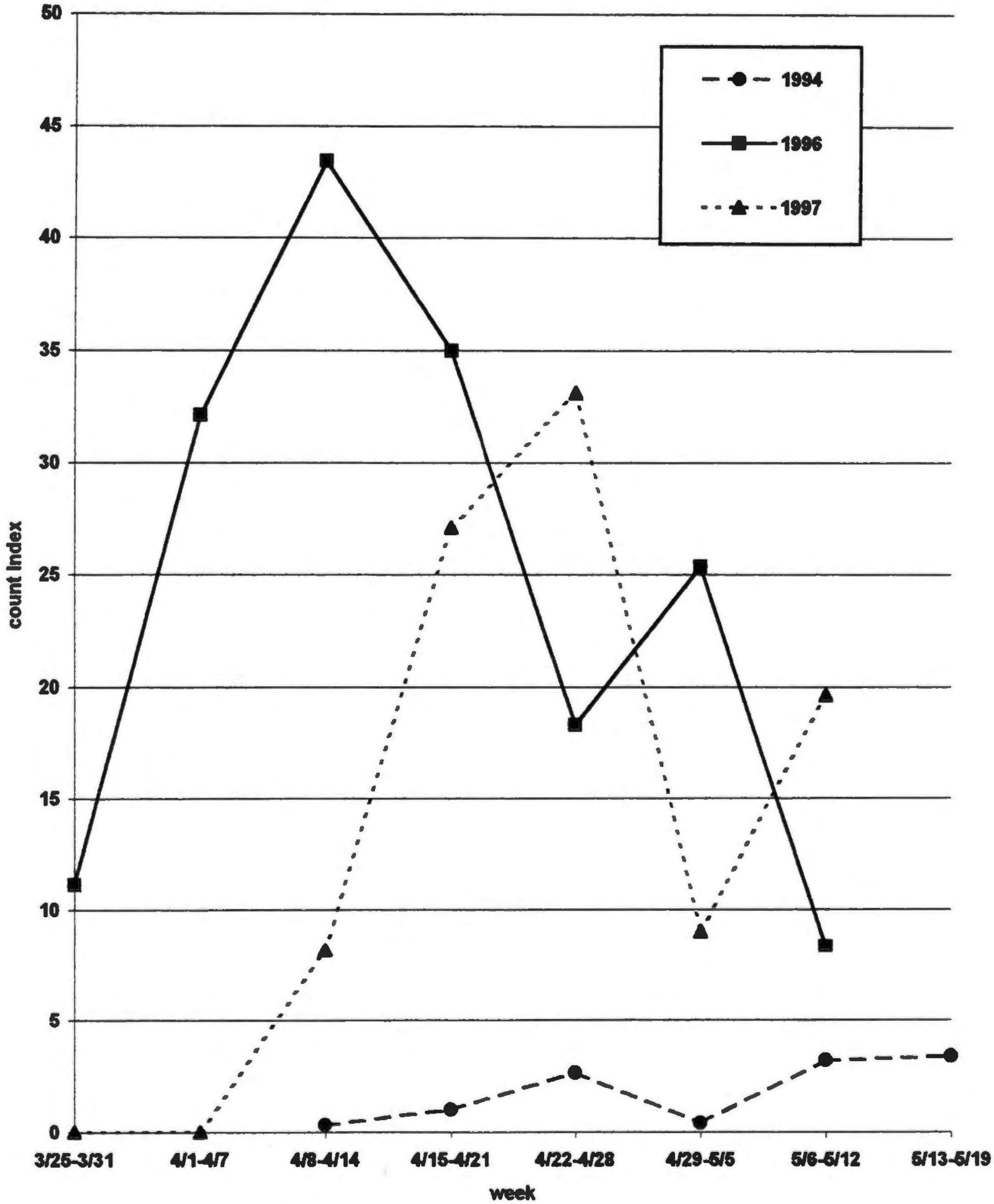


Figure 11. Weekly shorebird count indices on White Lake Wildlife Management Area, Dyer County, Tennessee in fall 1994, 1996, and 1997.

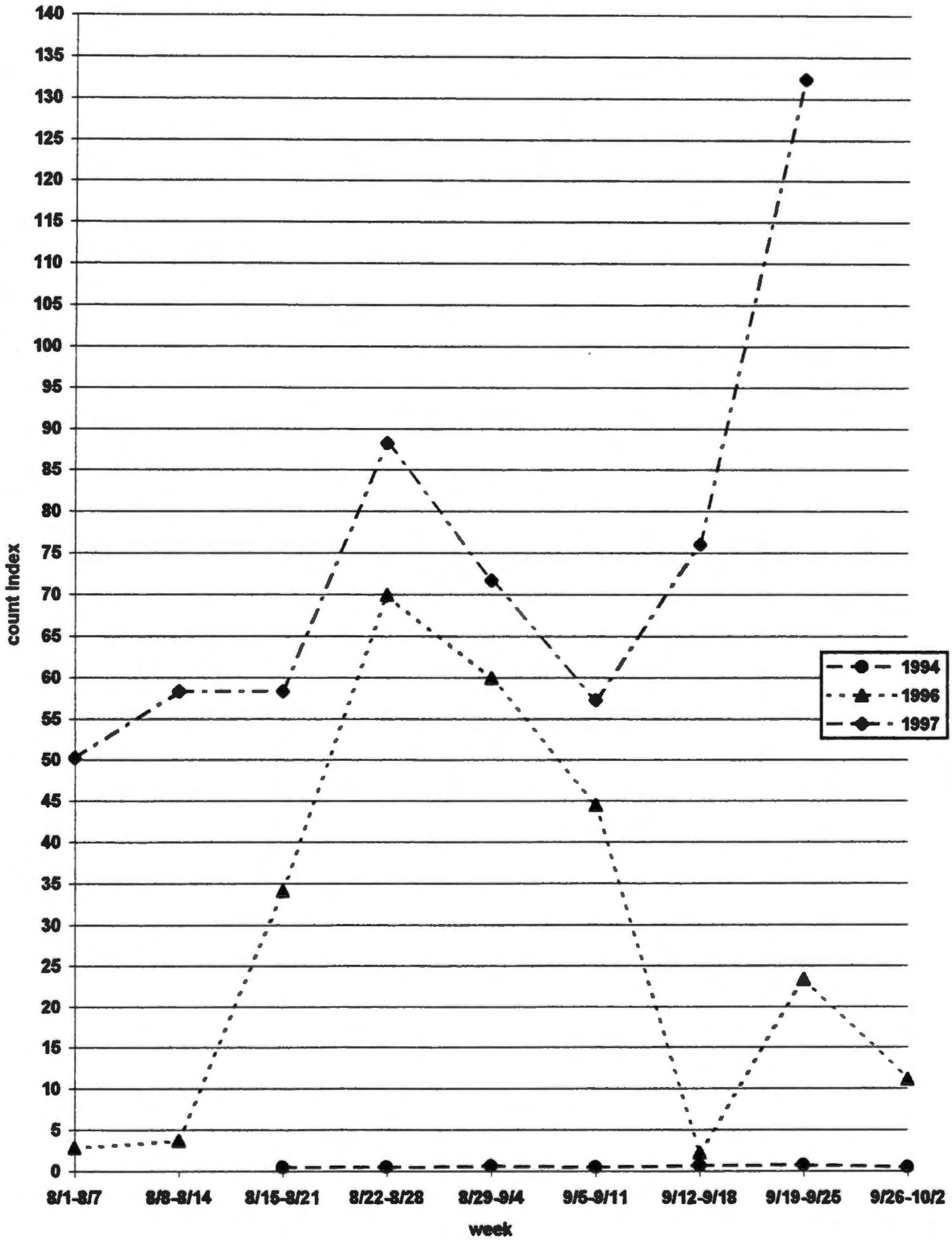


Figure 12. Weekly shorebird count indices on Black Bayou/Reelfoot Lake Wildlife Management Area, Lake County, Tennessee in spring 1996 and 1997.

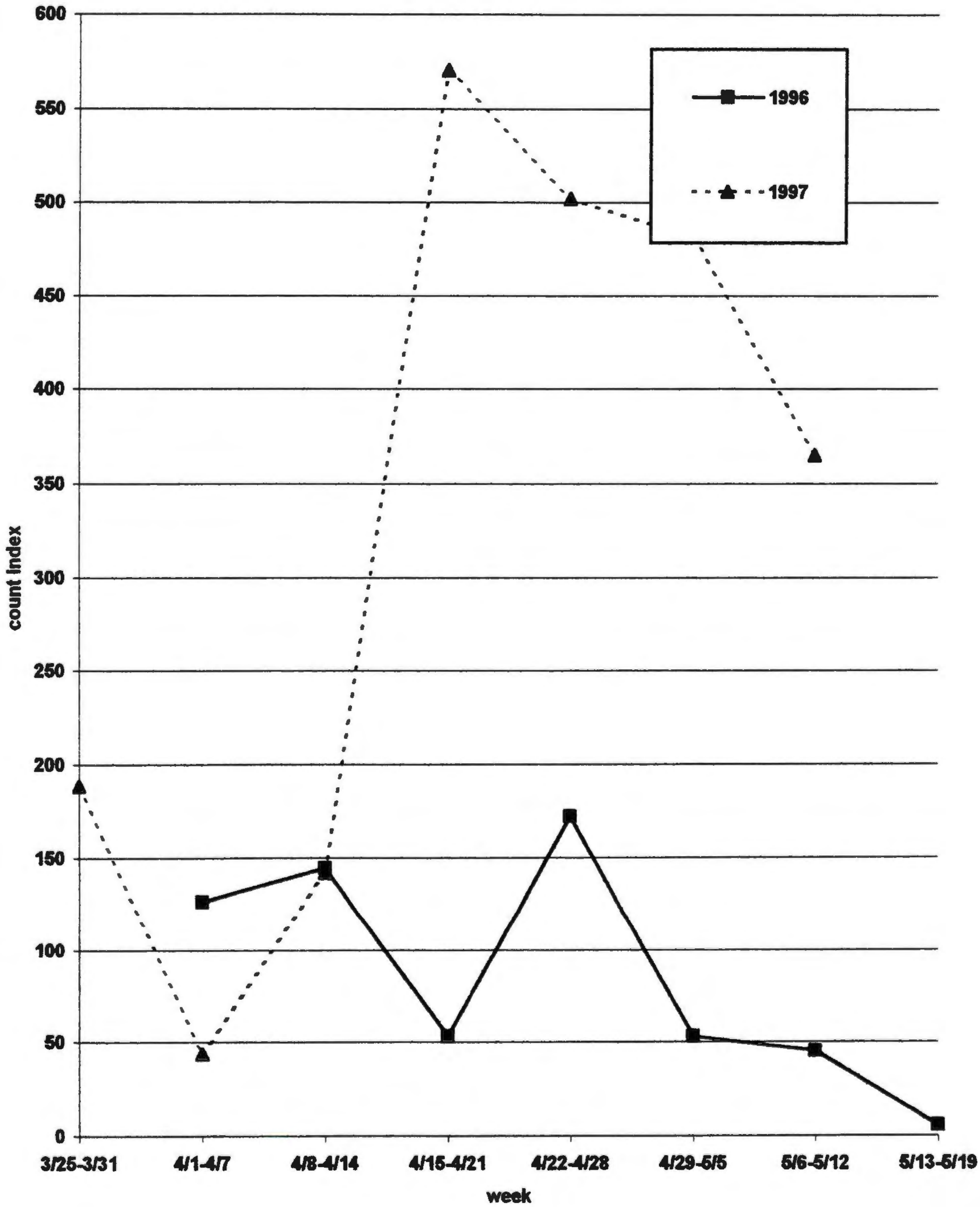


Figure 13. Weekly shorebird count indices on Black Bayou/Reelfoot Lake Wildlife Management Area, Lake County, Tennessee in fall 1996 and 1997.

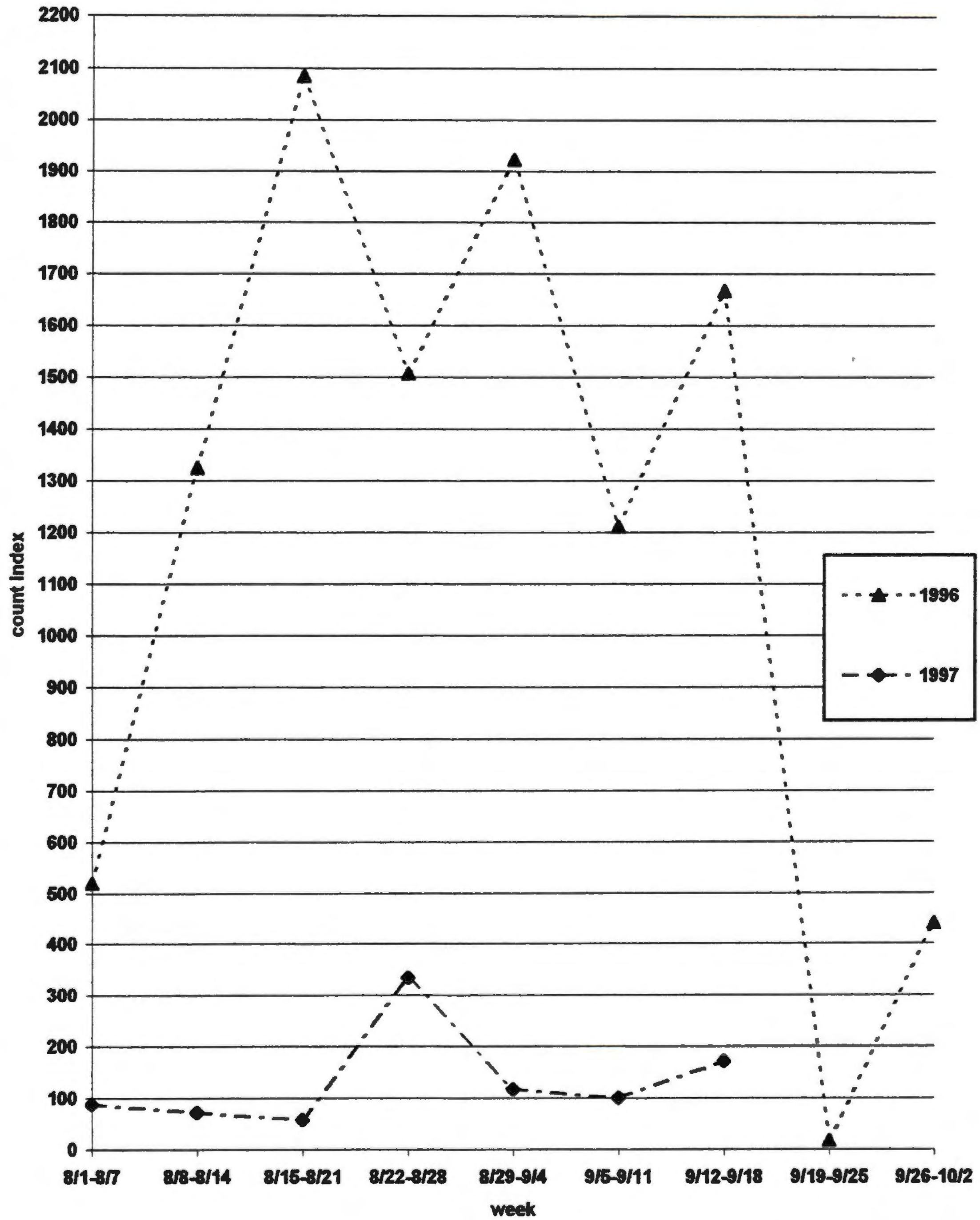
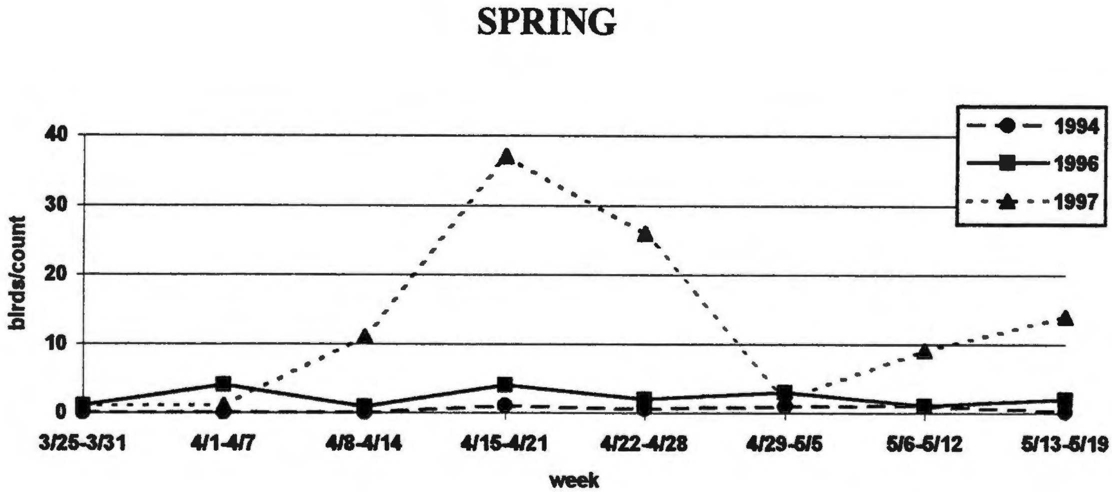


Figure 14. Weekly average counts of pectoral sandpipers on five study sites in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, and fall (1 August-1 October) 1994, 1996, and 1997.



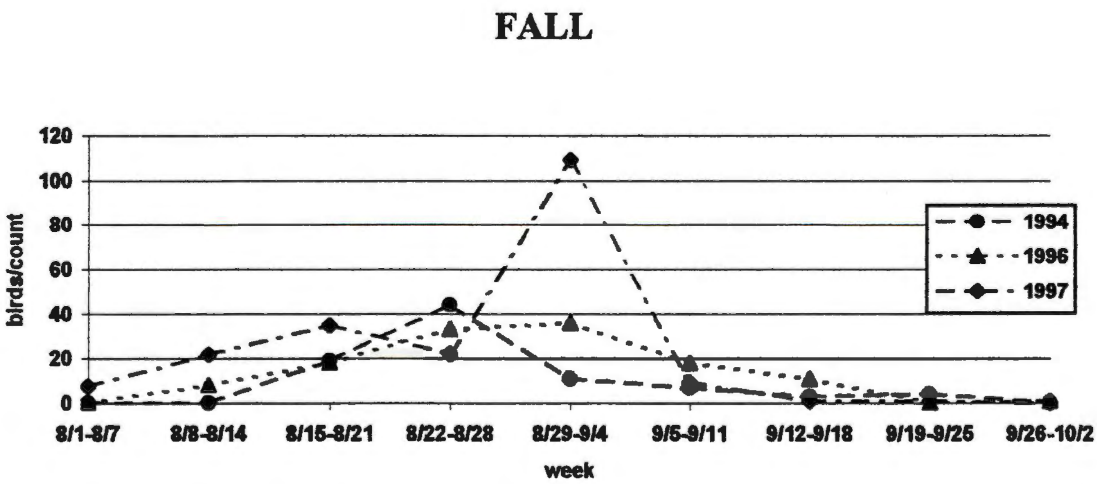
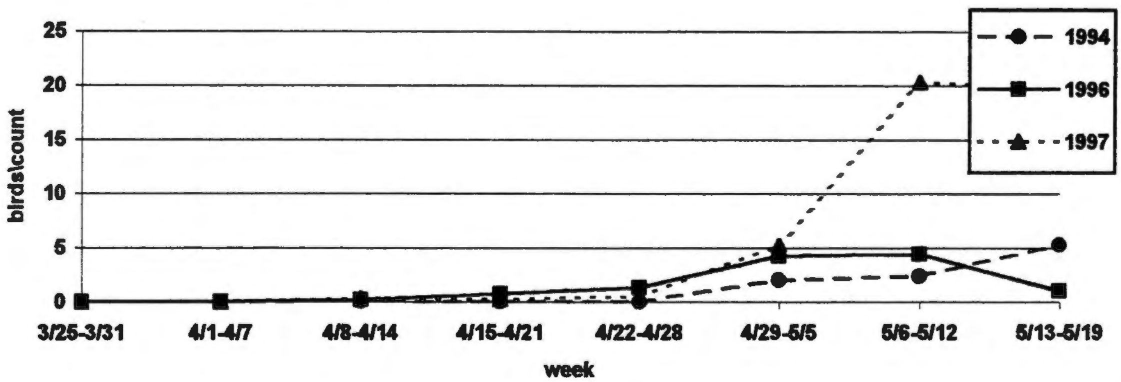


Figure 15. Weekly average counts of least sandpipers on five study sites in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, and fall (1 August-1 October) 1994, 1996, and 1997.

SPRING



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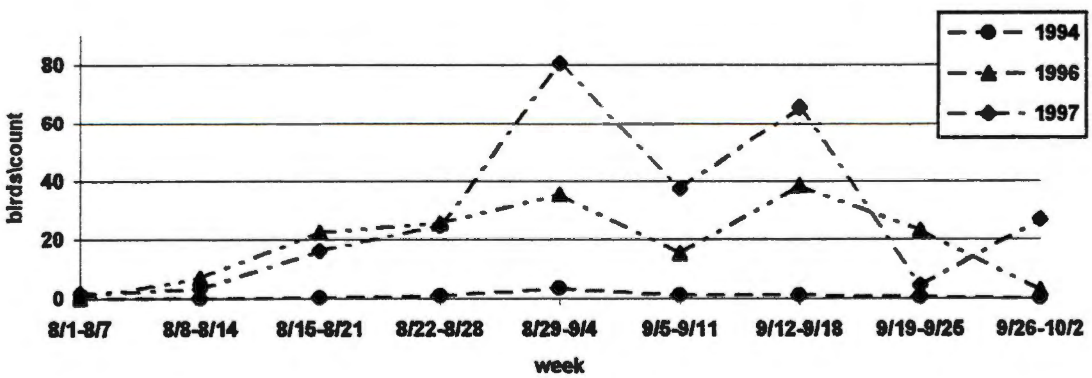
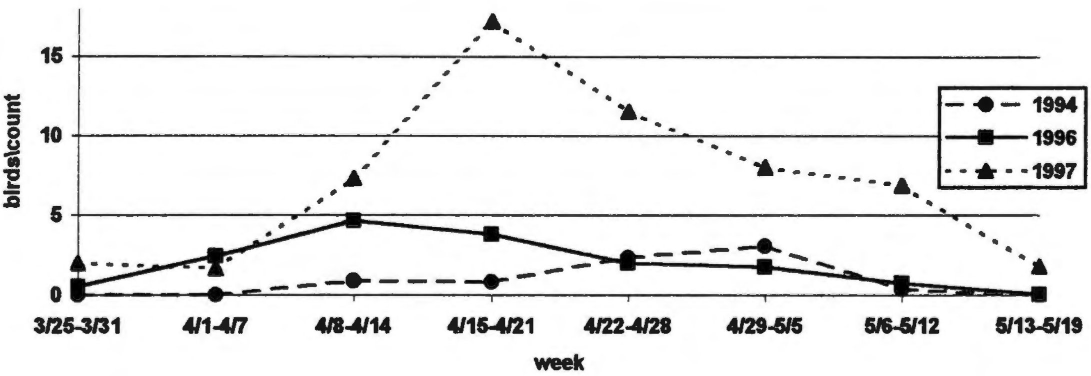


Figure 16. Weekly average counts of lesser yellowlegs on five study sites in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, and fall (1 August-1 October) 1994, 1996, and 1997.

SPRING



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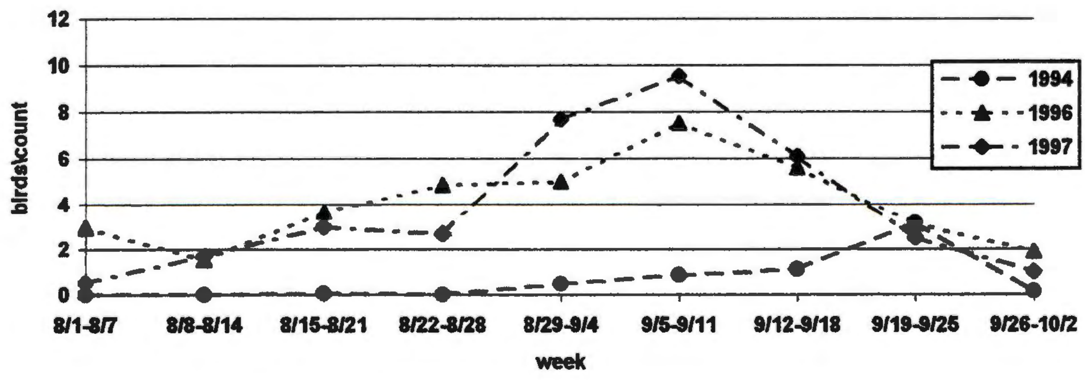

Figure 17. Weekly average counts of semipalmated sandpipers on five study areas in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, and (1 August-1 October) 1994, 1996, and 1997.

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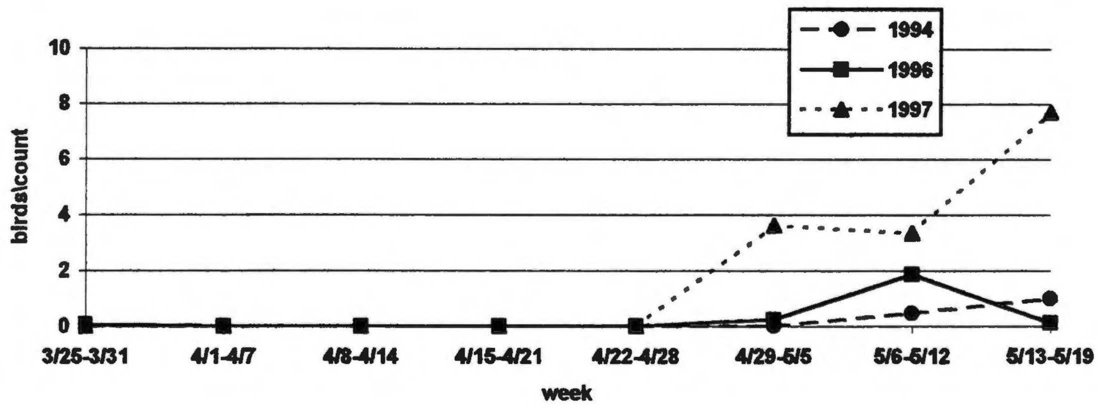

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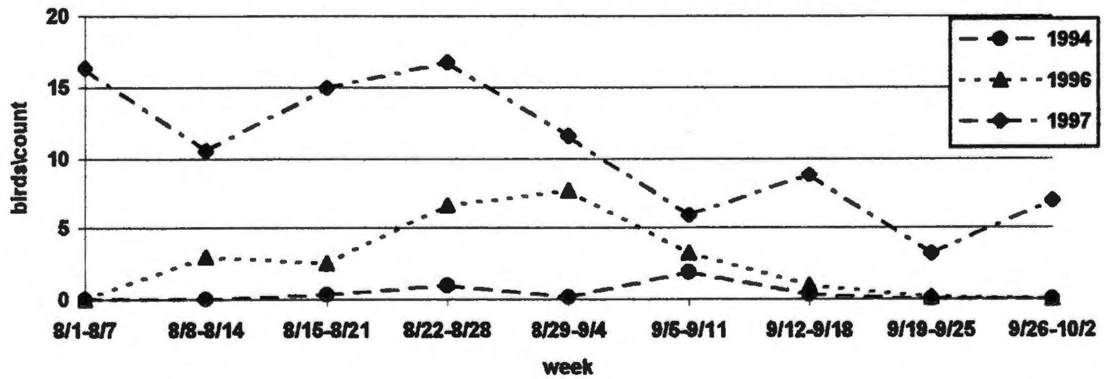
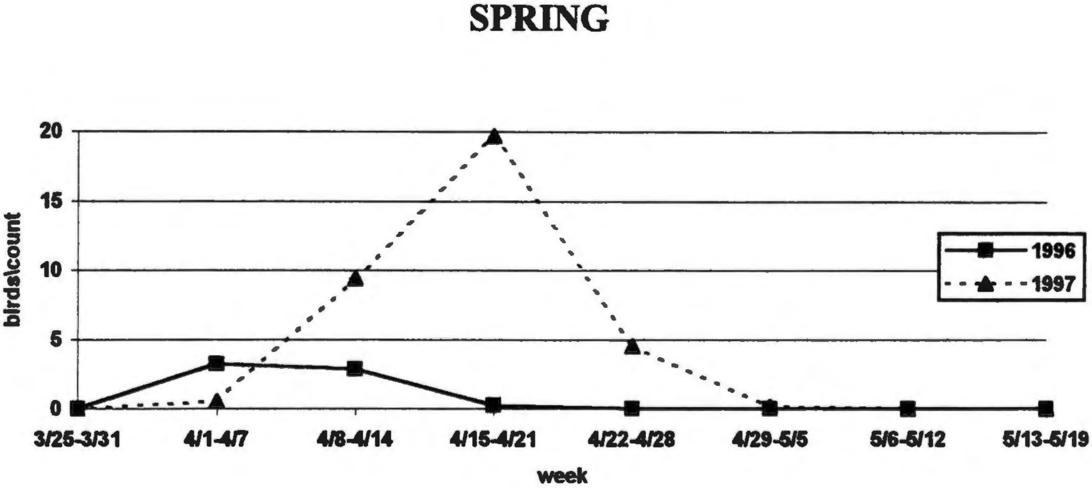
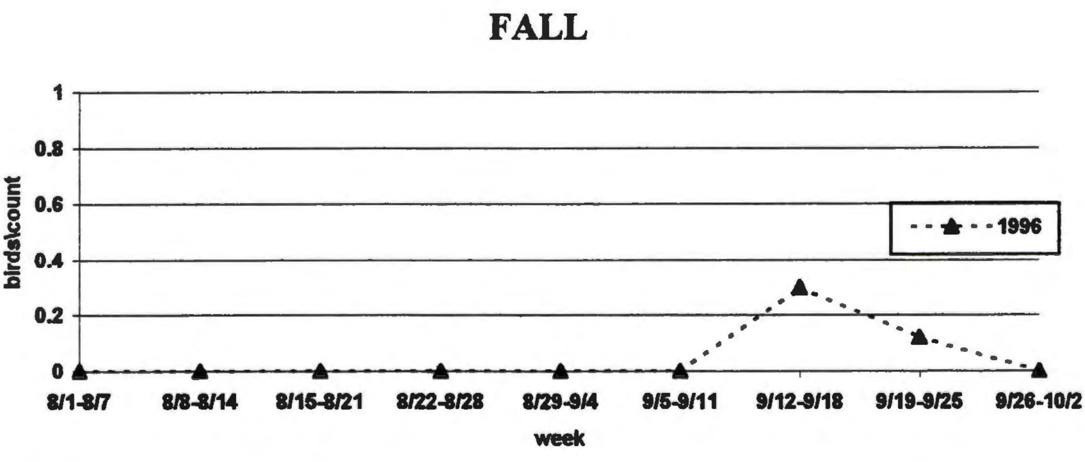


Figure 18. Weekly average counts of American golden plovers on five study areas in western Tennessee during spring migration (1 April-15 May) 1996 and 1997, and (1 August-1 October) 1996.

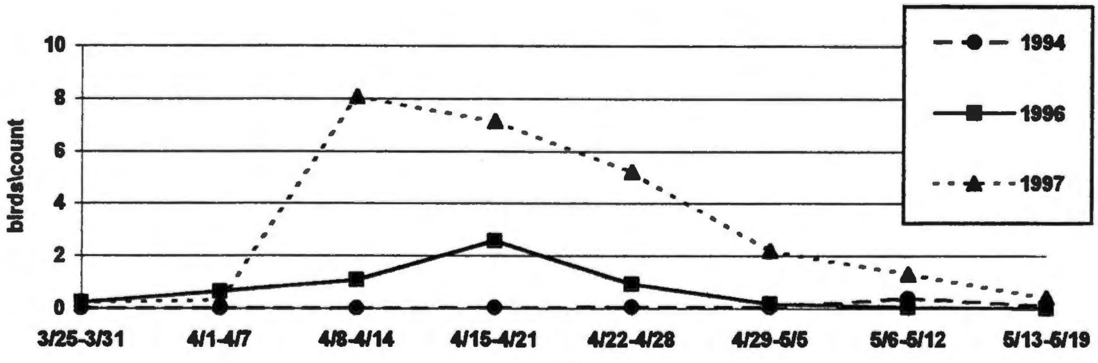




** No American golden plovers were observed during 1994 or 1997 fall seasons.

Figure 19. Weekly average counts of greater yellowlegs on five study sites in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, and fall (1 August-1 October) 1994, 1996, and 1997.

SPRING



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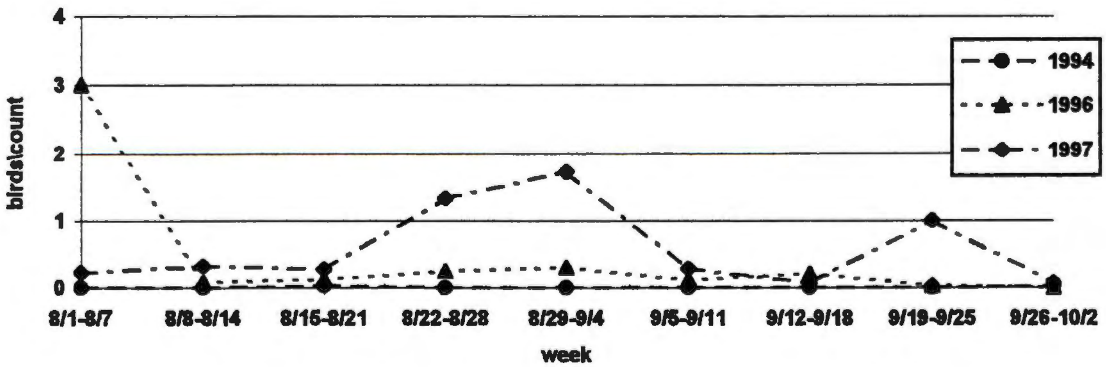
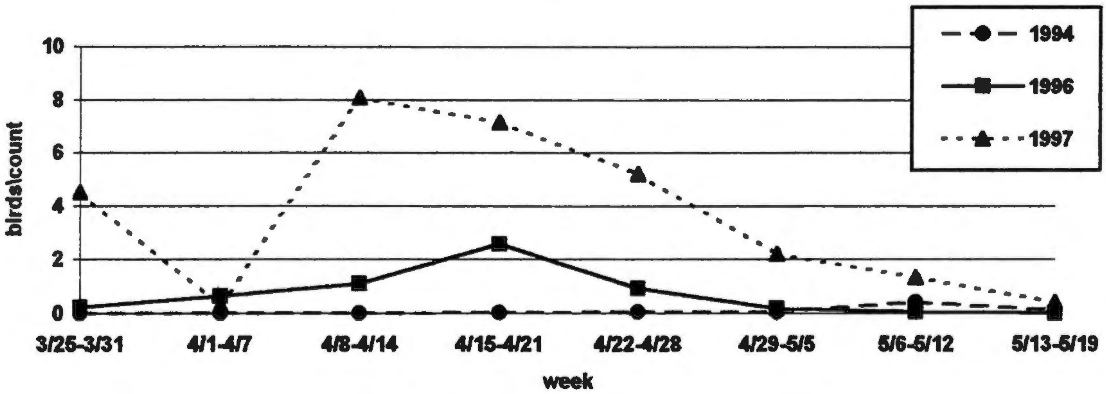


Figure 20. Weekly average counts of solitary sandpipers on five study sites in western Tennessee during spring (1 April-15 May) 1994, 1996, and 1997, (1 August-1 October) 1994, 1996, and 1997.

SPRING



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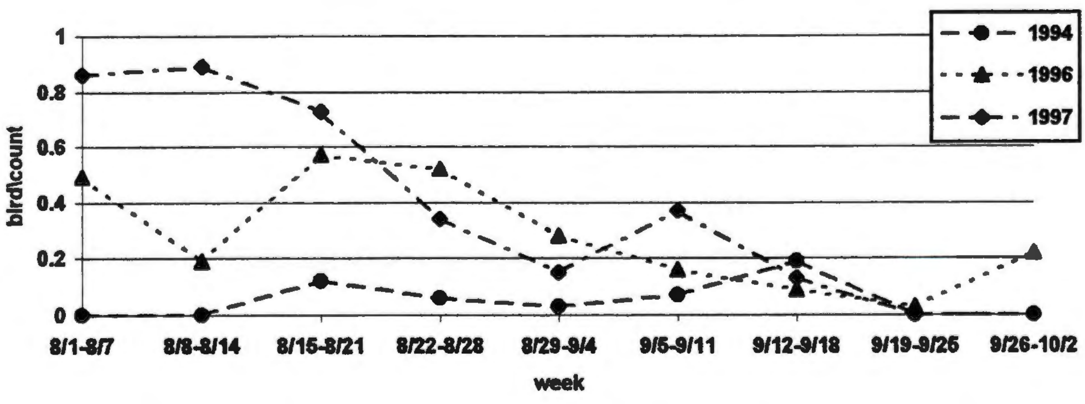
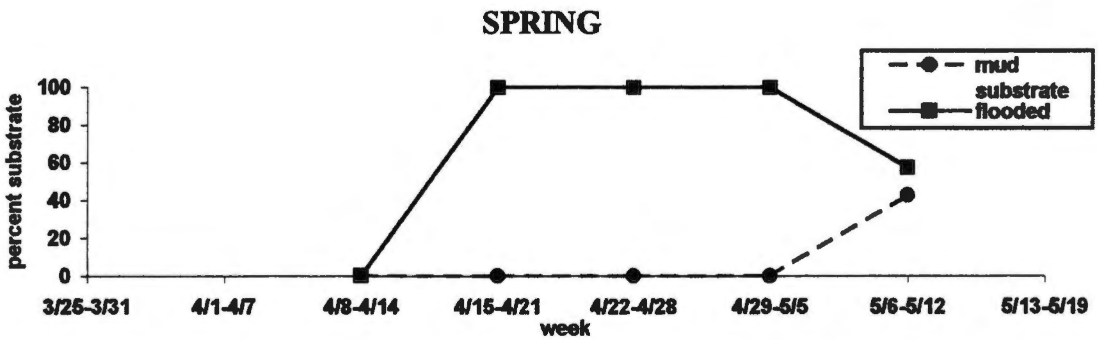
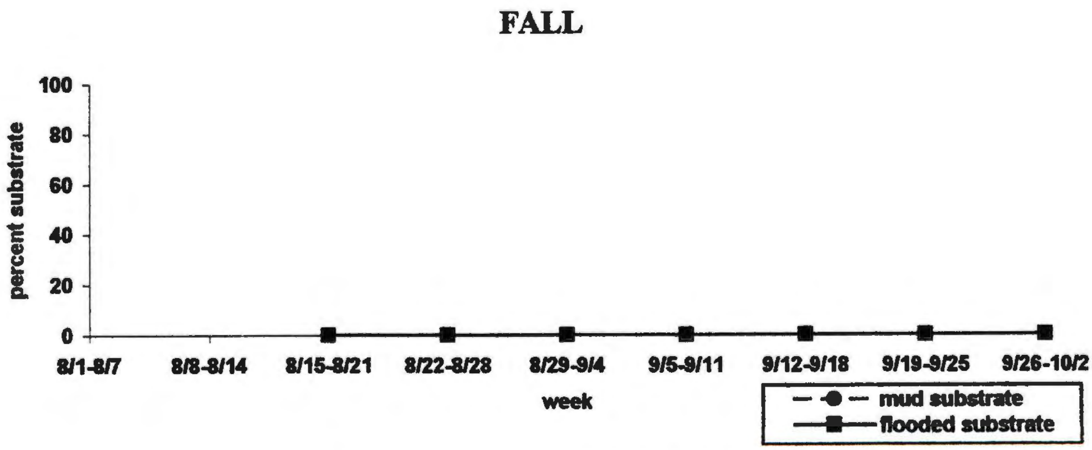


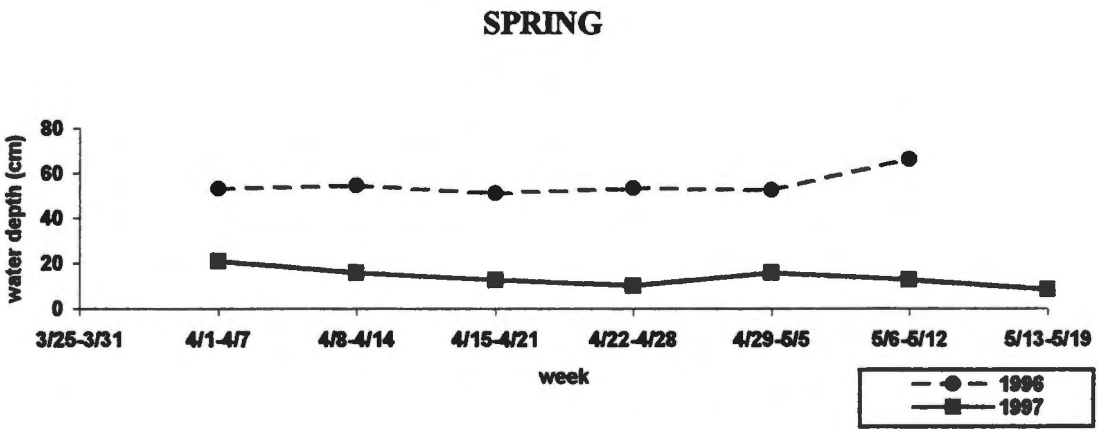
Figure 21. Percent frequency of mud and flood substrate available to migrant shorebirds at Eagle Lake, Shelby County, Tennessee area 3 (includes future compartment 2M) in 1994.





*** There was no flood or mud substrate in area 3 at Eagle Lake in fall 1994.

Figure 22. Average water depth of flooded substrate at Eagle Lake, Shelby County, Tennessee, compartment 2M in 1996 and 1997.



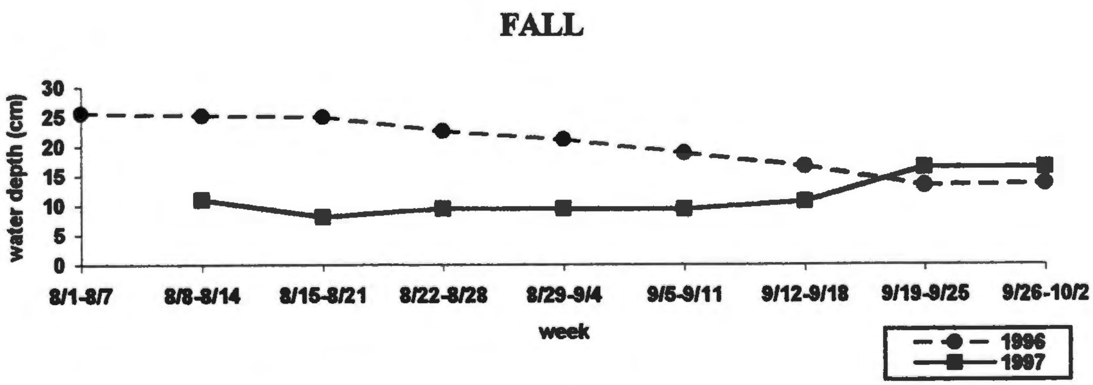
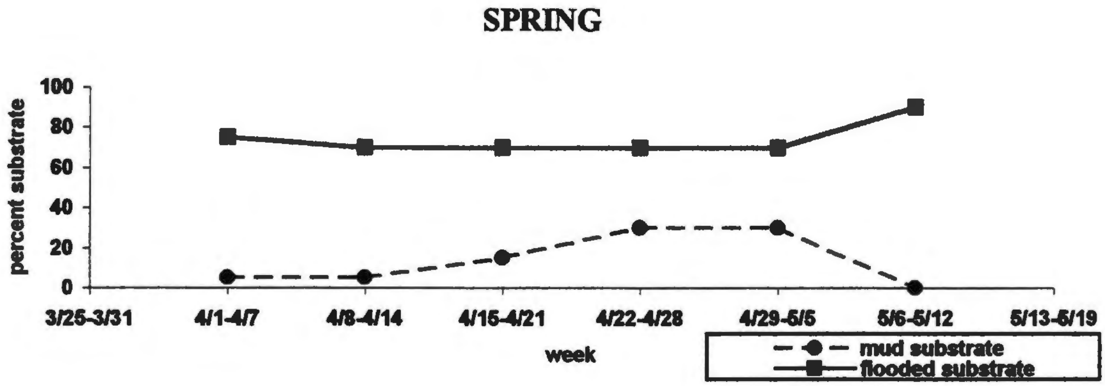


Figure 23. Percent mud and flood substrate available to migrant shorebirds at Eagle Lake, Shelby County, Tennessee, compartment 2M in 1996.



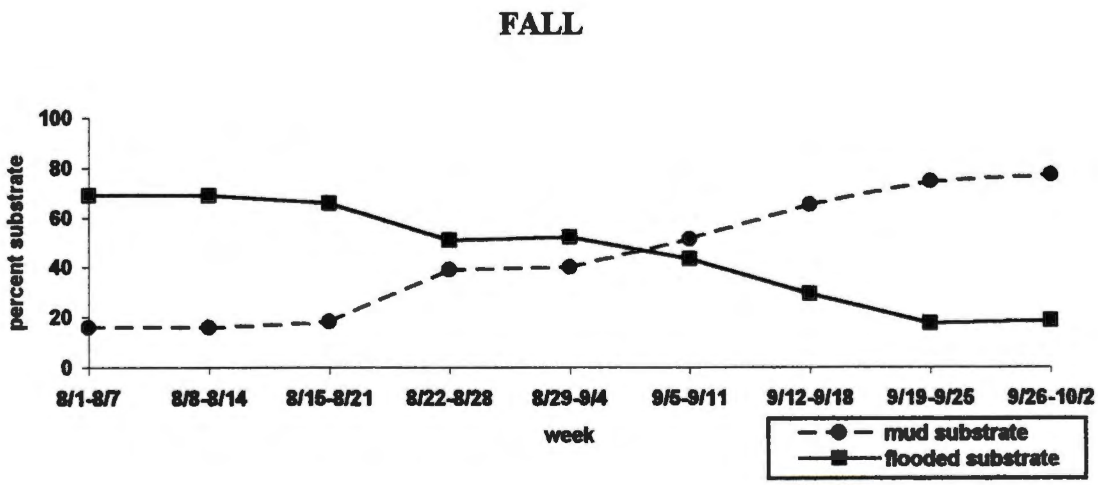
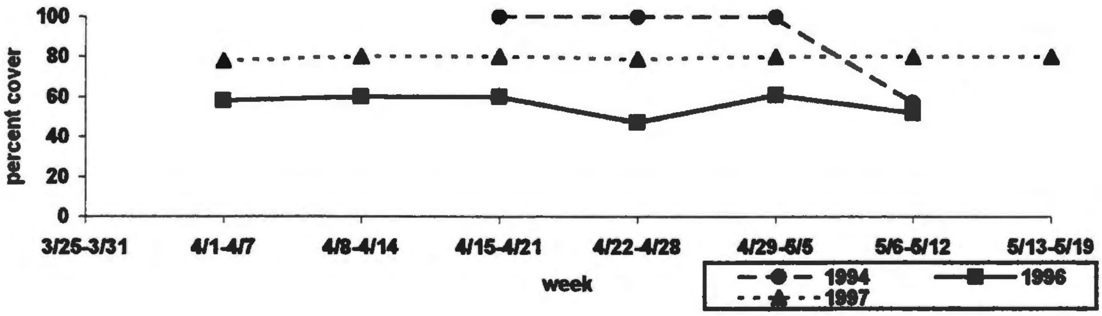


Figure 24. Percent cover with less than 25 percent vegetation density at Eagle Lake, Shelby County, Tennessee, area 3 (includes compartment 2M) in 1994 and compartment 2m in 1996 and 1997.

SPRING



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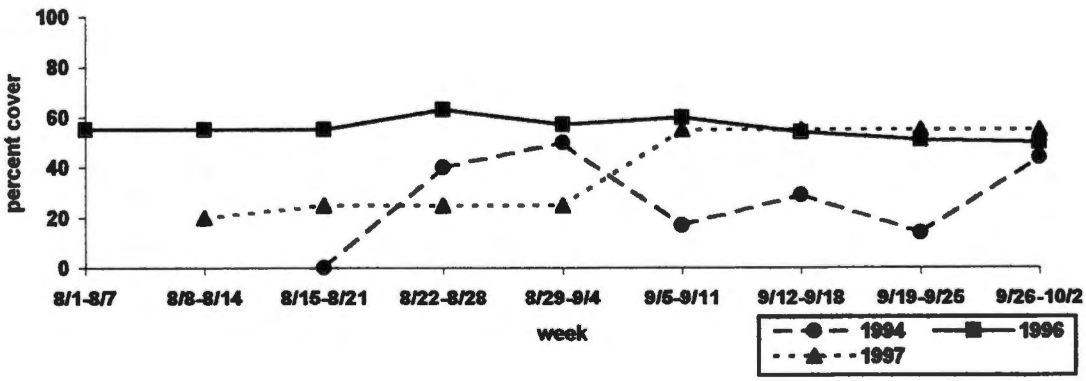
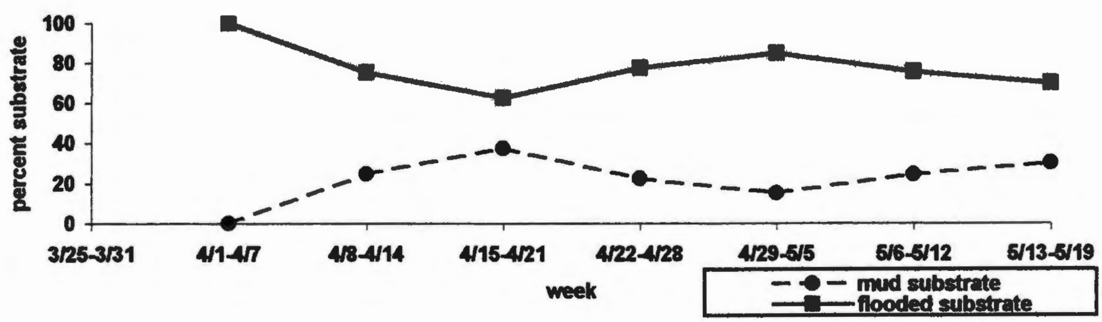


Figure 25. Percent mud and flood substrate available to migrant shorebirds at Eagle Lake, Shelby County, Tennessee, compartment 2M in 1997.

SPRING



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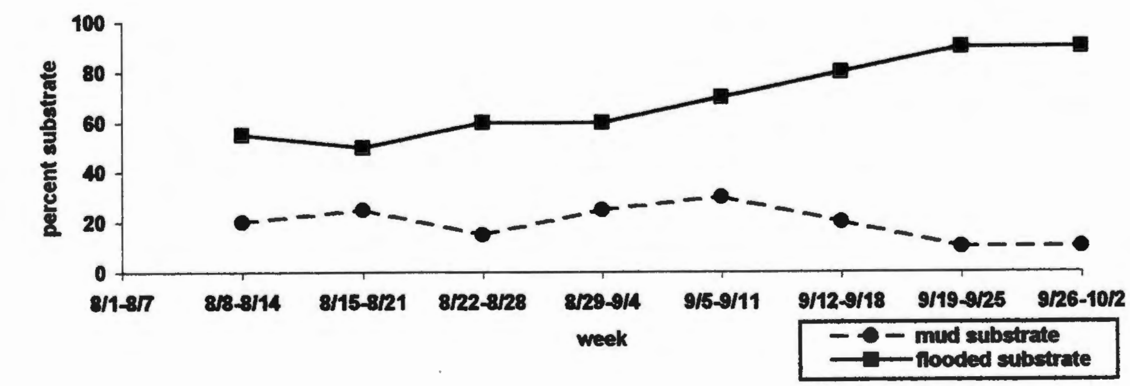
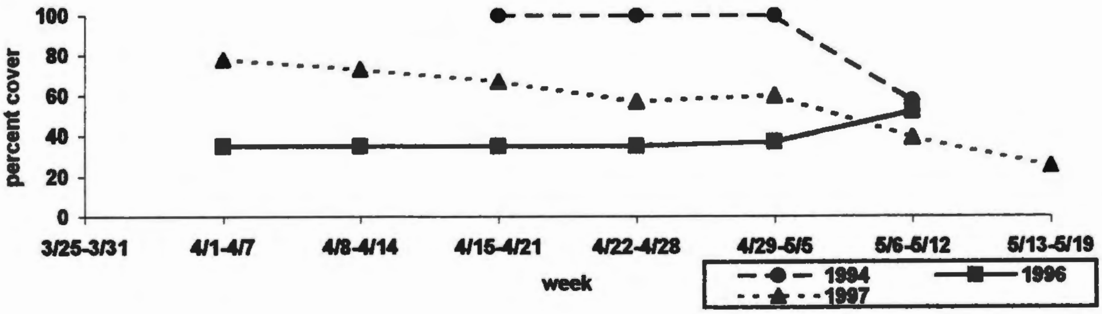


Figure 26. Percent cover with vegetation 0-10 cm at Eagle Lake, Shelby County, Tennessee, area 3 (includes compartment 2M) in 1994, and compartment 2M in 1996 and 1997.

SPRING



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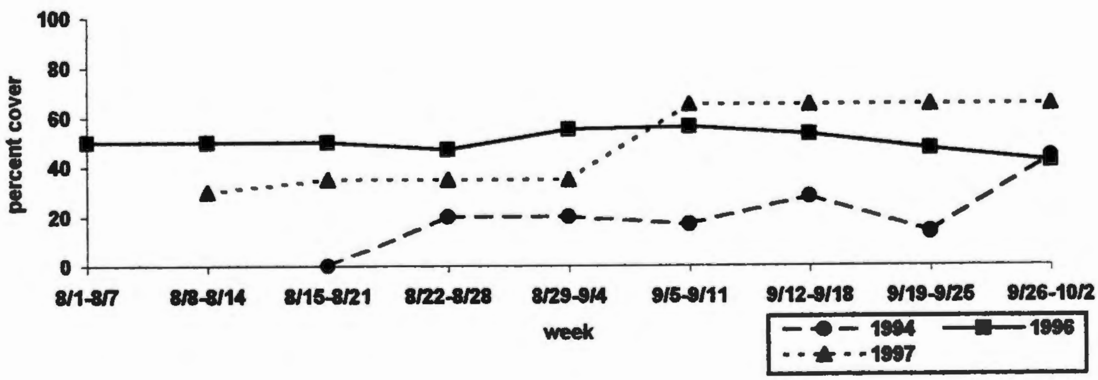
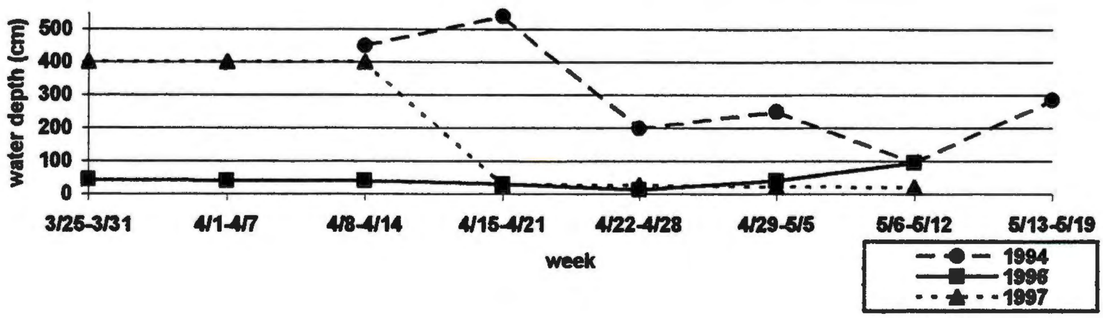


Figure 27. Average water depth of flooded substrate at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1994, 1996, and 1997.

SPRING



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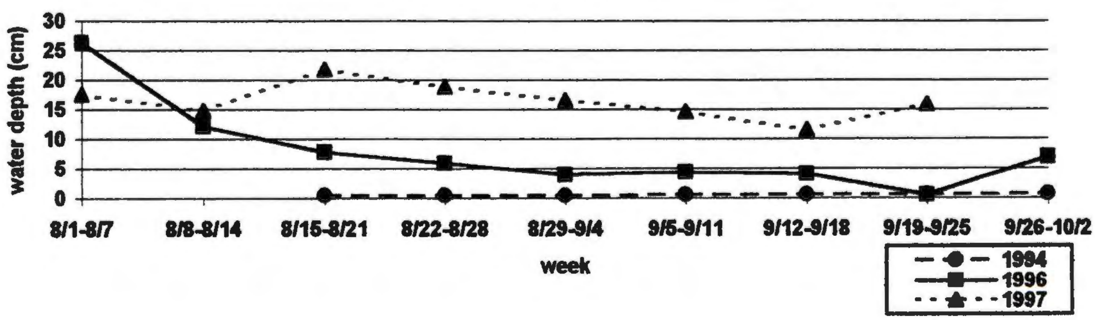
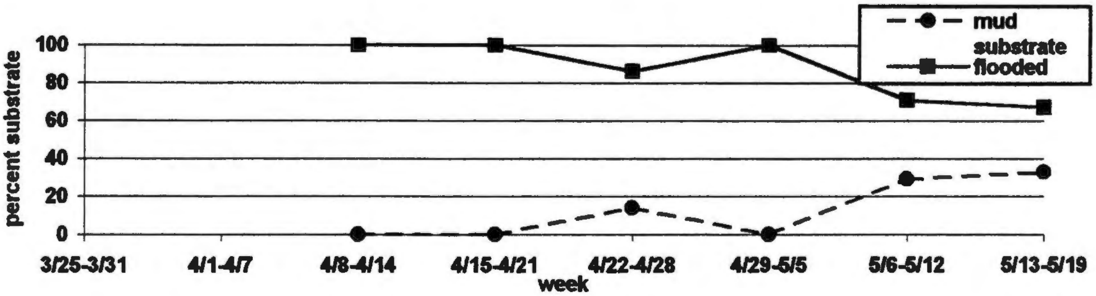


Figure 28. Percent frequency of mud and flood substrate available to migrant shorebirds at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1994.

SPRING



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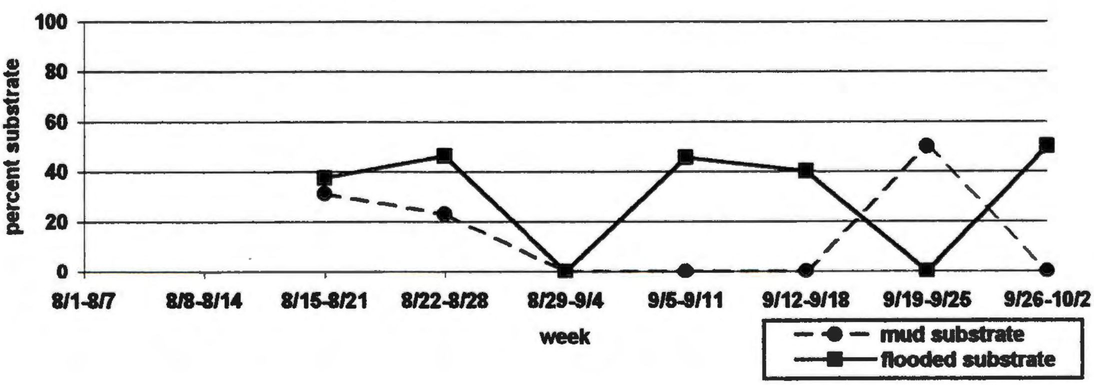
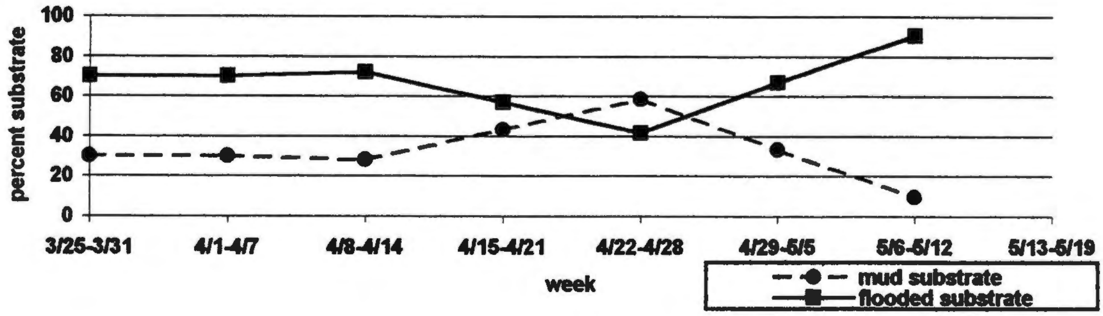


Figure 29. Percent mud and flood substrate available to migrant shorebirds at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1996.

SPRING



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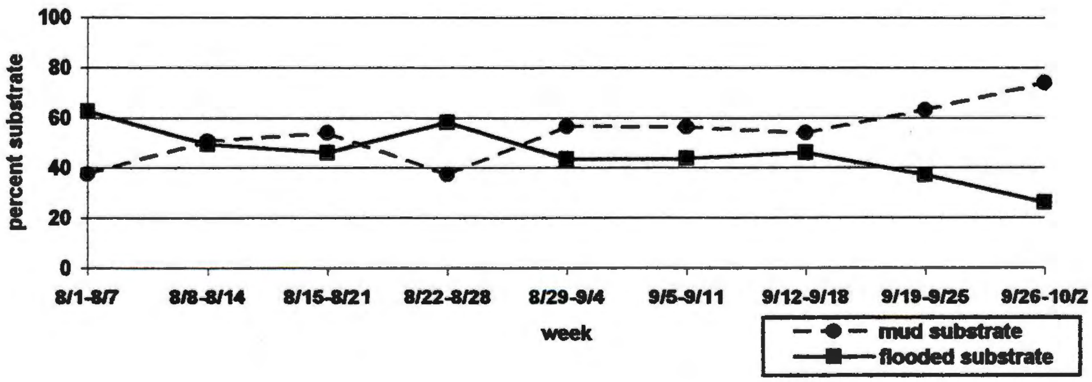
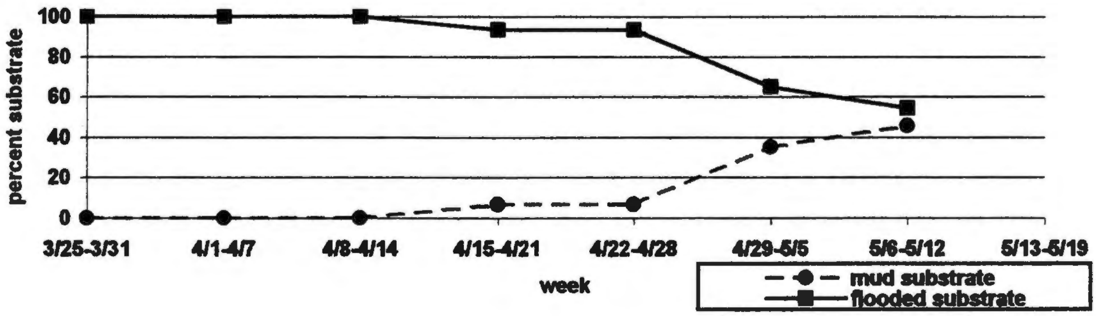


Figure 30. Percent mud and flood substrate available to migrant shorebirds at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1997.

SPRING



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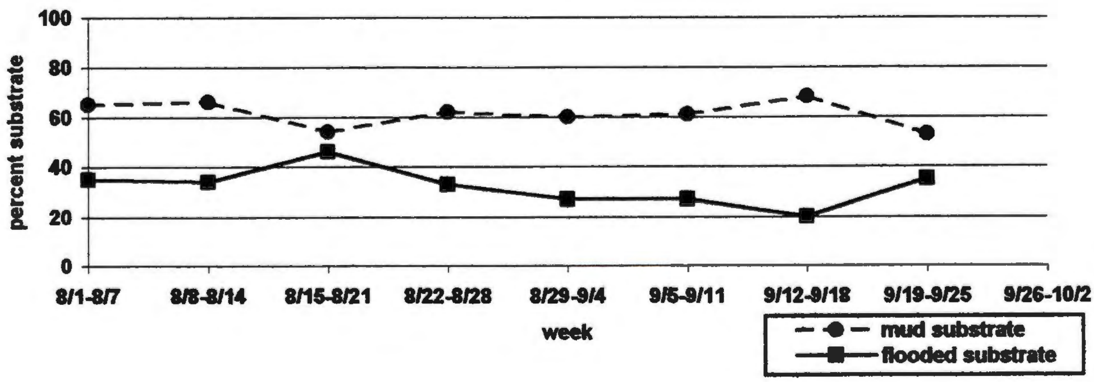
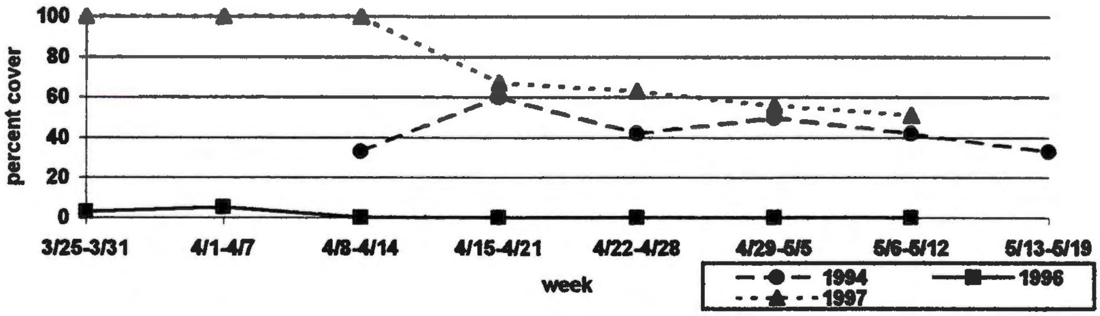


Figure 31. Percent cover with vegetation 0-10 cm at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1994, 1996, and 1997.

SPRING



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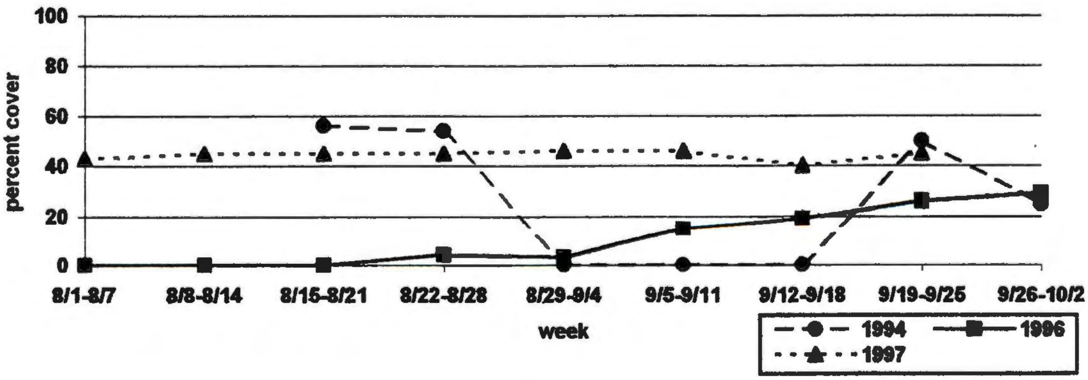
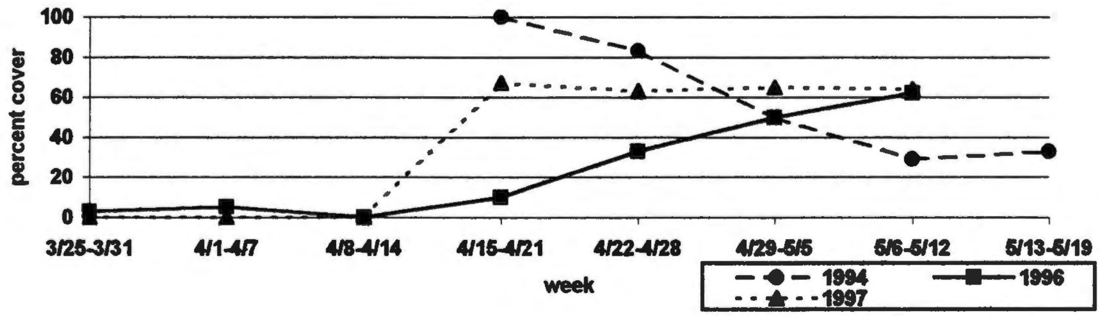


Figure 32. Percent cover with less than 25 percent vegetation density at White Lake, Dyer County, Tennessee, compartment WL in spring and fall 1994, 1996, and 1997.

SPRING



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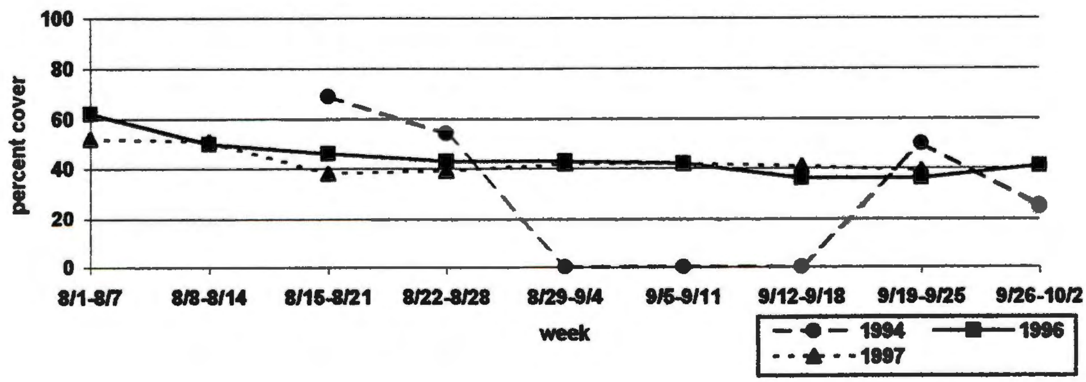
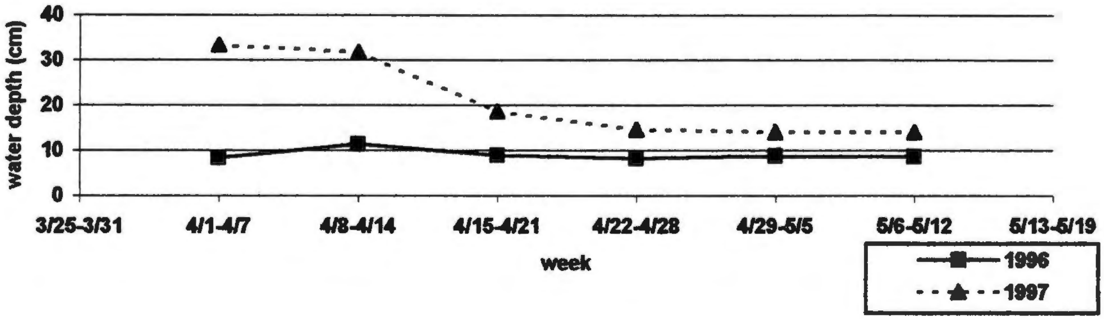


Figure 33. Average water depth of flooded substrate at Black Bayou, Lake County, Tennessee, compartment FP in spring 1996 and GP in spring 1997, fall 1996 and 1997.

SPRING



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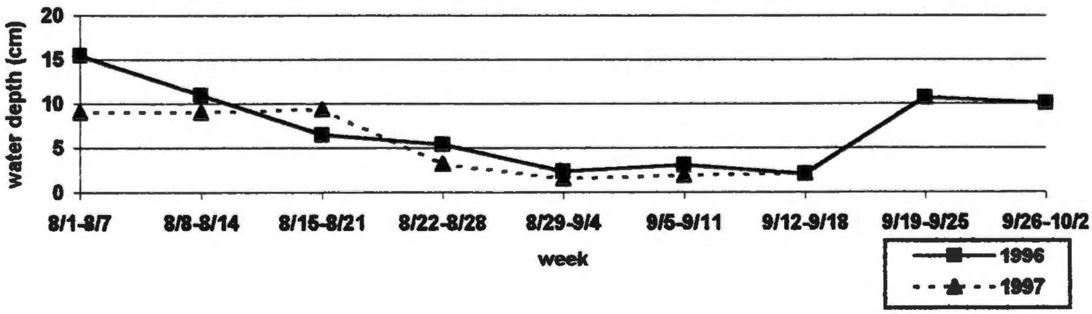
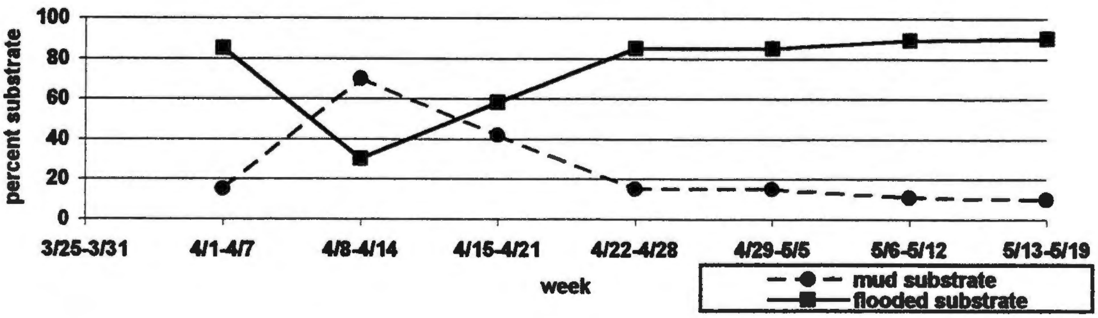


Figure 34. Percent mud and flood substrate available to migrant shorebirds at Black Bayou, Lake County, Tennessee, compartment FP in spring 1996, and compartment GP in fall 1996.

SPRING



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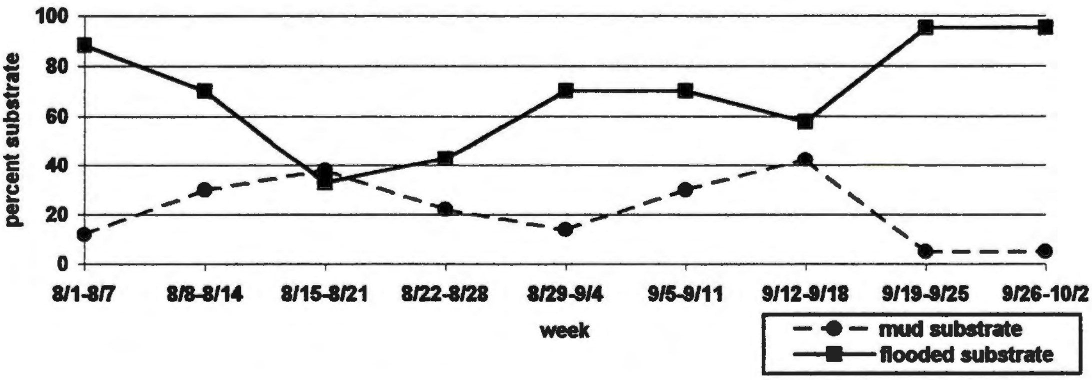
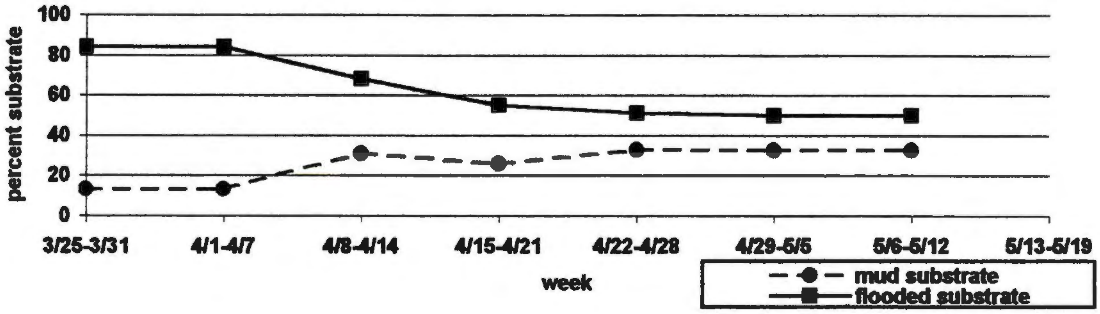


Figure 35. Percent mud and flood substrate available to migrant shorebirds at Black Bayou, Lake County, Tennessee, compartment GP in spring and fall 1997.

SPRING



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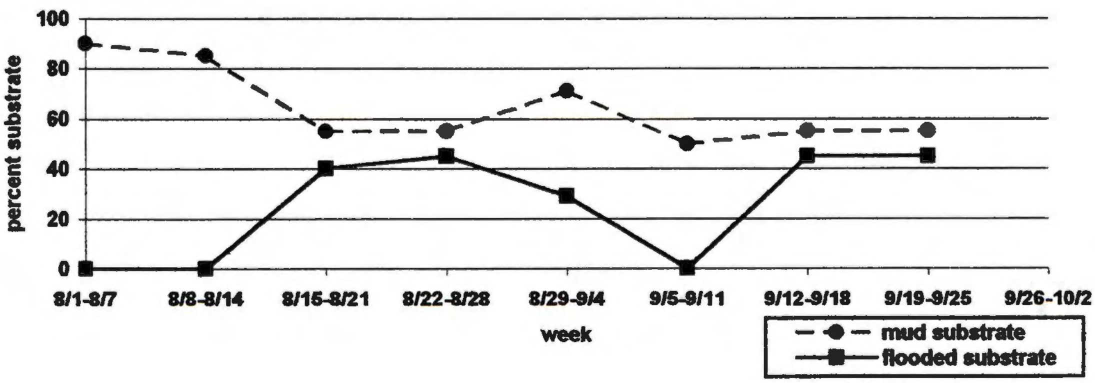
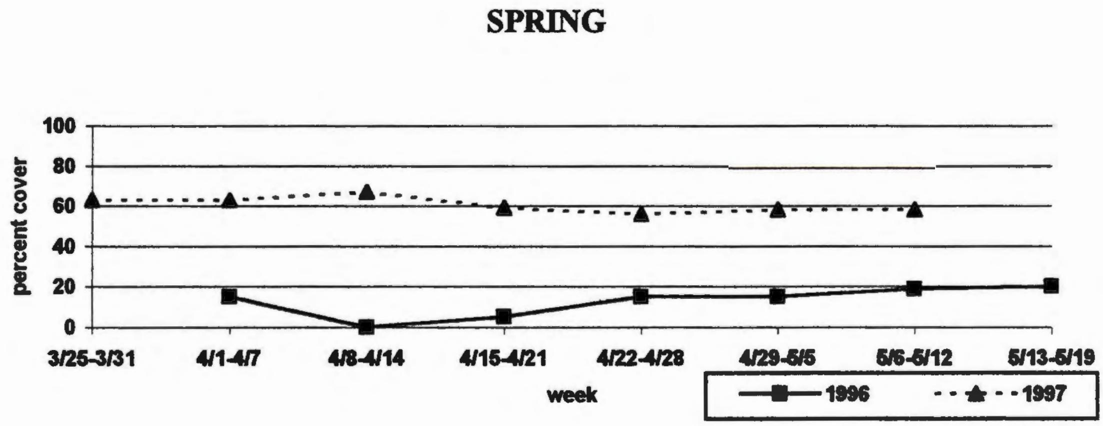


Figure 36. Percent cover with vegetation 0-10 cm at Black Bayou, Lake County, Tennessee, compartment FP in spring 1996 and compartment GP in spring 1997, fall 1996, and 1997.



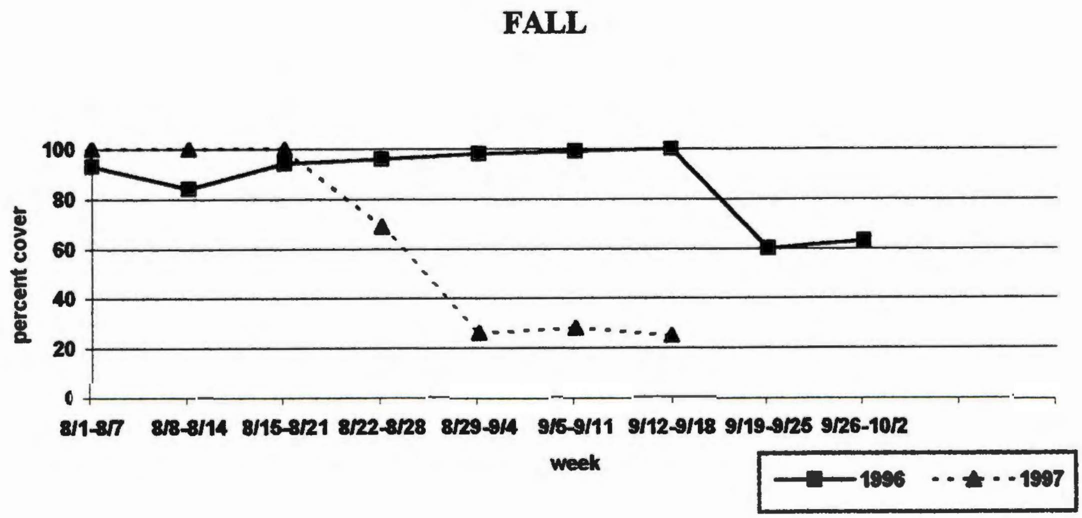
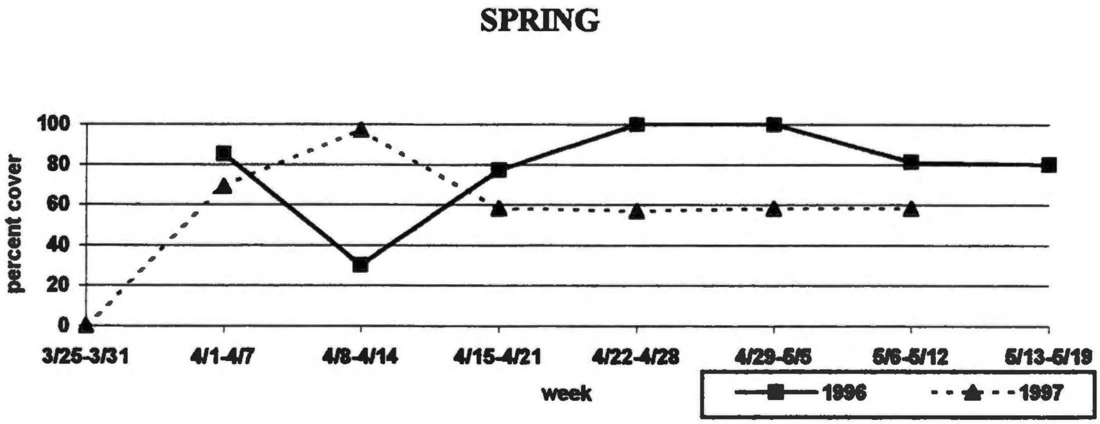


Figure 37. Percent cover with less than 25 percent vegetation density at Black Bayou, Lake County, Tennessee, compartment FP in spring 1996 and compartment GP in spring 1997, fall 1996, and 1997.



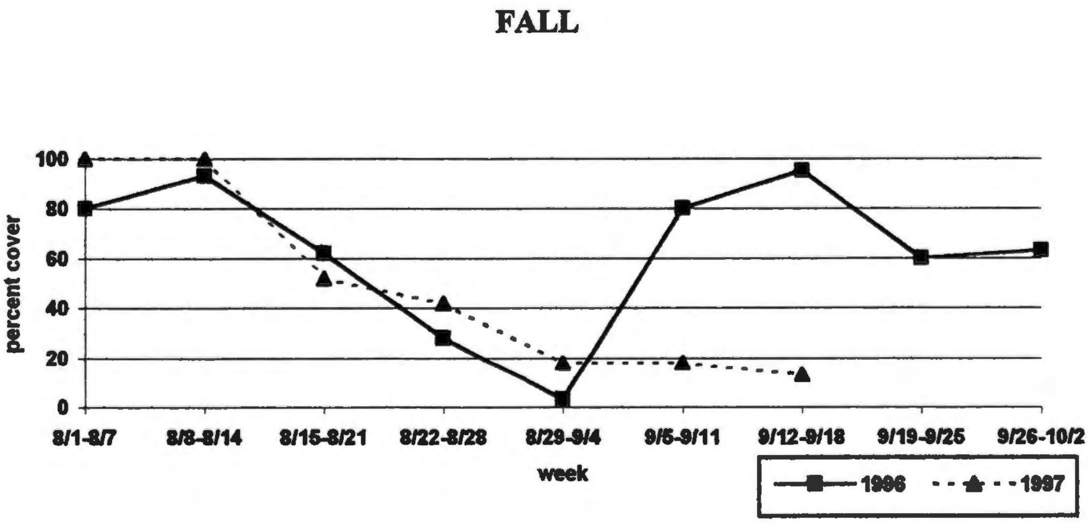
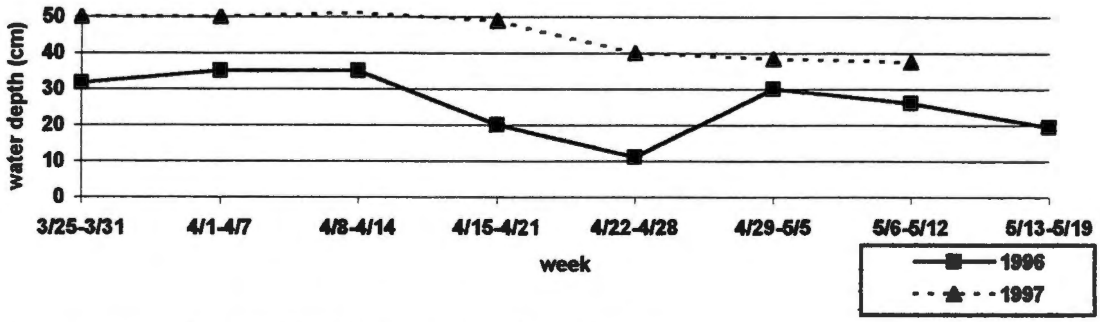


Figure 38. Average water depth of flooded substrate at Phillippy Pits, Lake County, Tennessee, compartment 2 in spring 1996, compartments 1&2 in spring 1997, compartment 2 in fall 1996, and 1997.

SPRING



** Compartments 1&2 compbined in spring 1997 due to flooding.

FALL

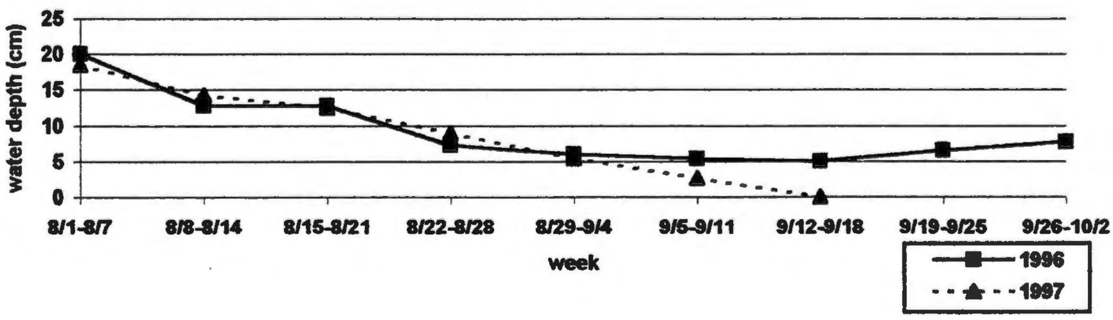
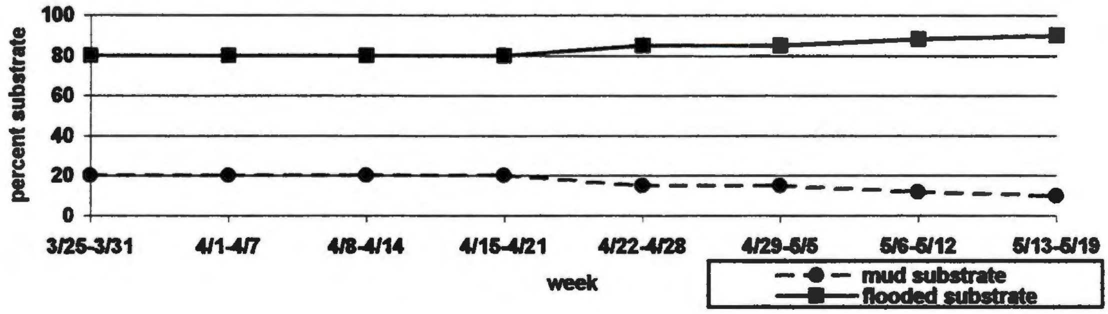


Figure 39. Percent mud and flood substrate available to migrant shorebirds at Phillippy Pits, Lake County, Tennessee, compartment 2 in spring and fall 1996.

SPRING



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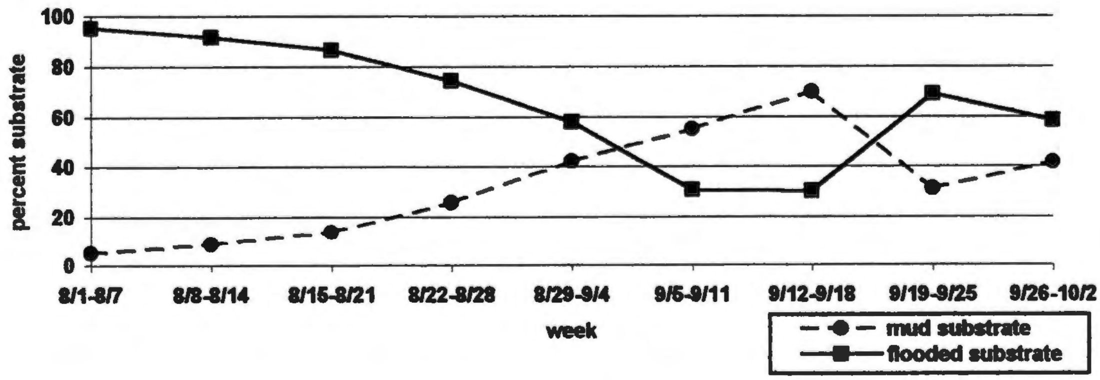
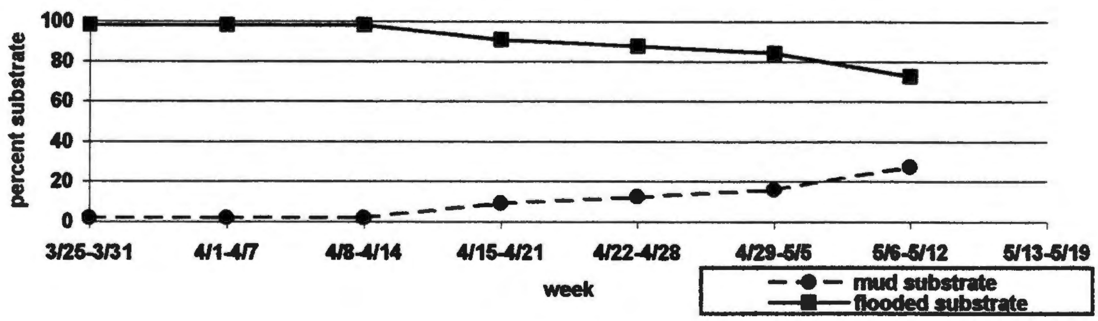


Figure 40. Percent mud and flood substrate available to migrant shorebirds at Phillippy Pits, Lake County, Tennessee, compartment 1&2 in spring 1997, and compartment 2 in fall 1997.

SPRING



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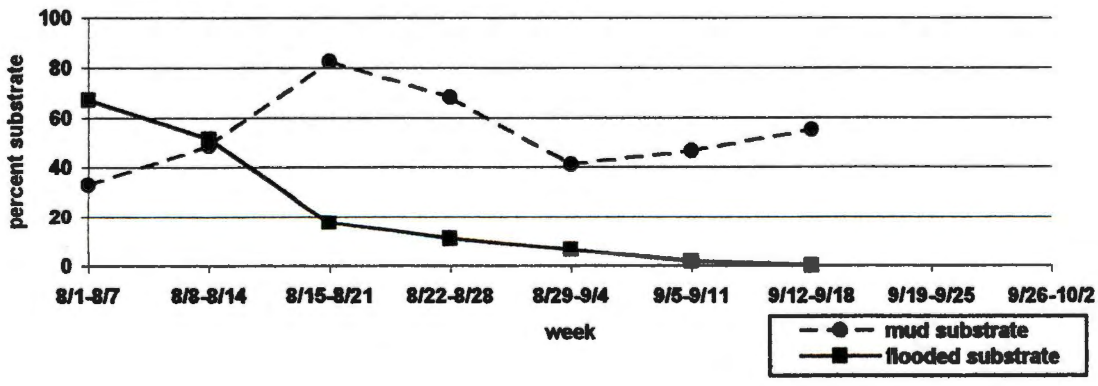
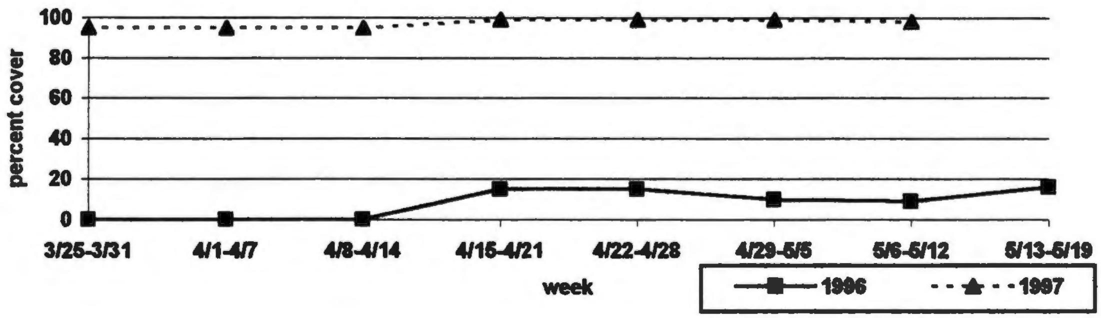


Figure 41. Percent cover with vegetation 0-10 cm at Phillippy Pits, Lake County, Tennessee, compartment 1&2 in spring 1996 and compartment 2 in spring 1997, fall 1996, and 1997.

SPRING



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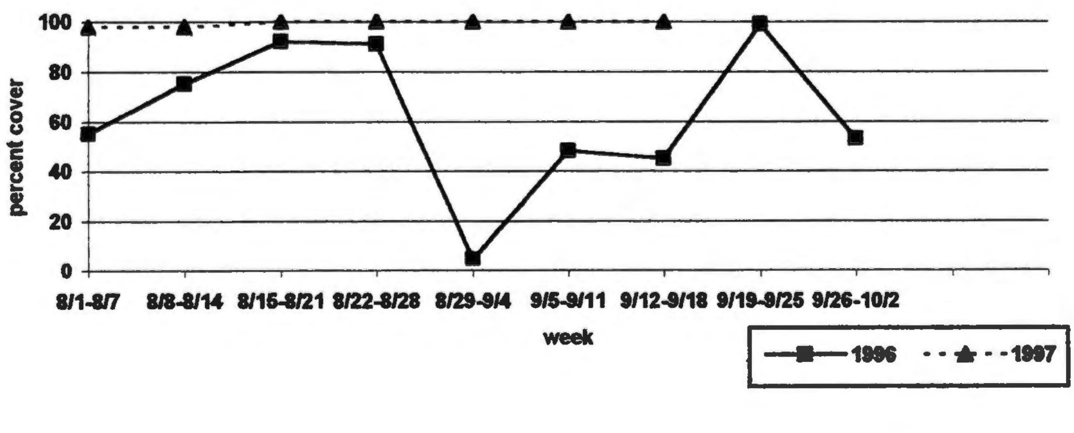

Figure 42. Percent cover with less than 25 percent vegetation density at Phillippy Pits, Lake County, Tennessee, compartment 2 in spring 1996 and compartment 1&2 in spring 1997, and compartment 2 in fall 1996, and 1997.

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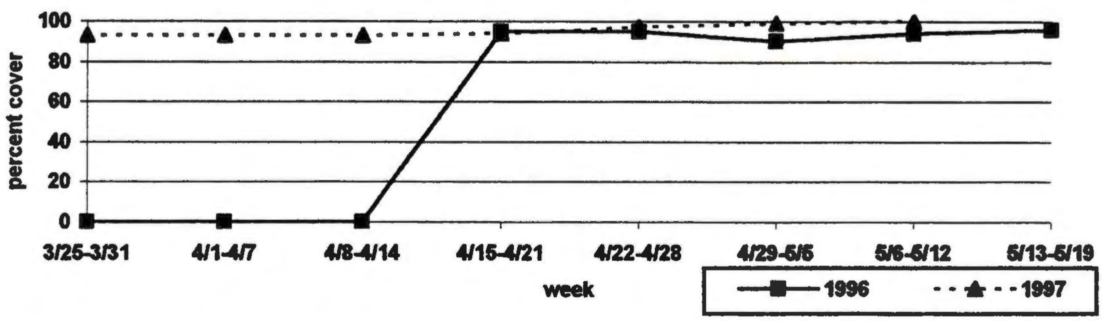

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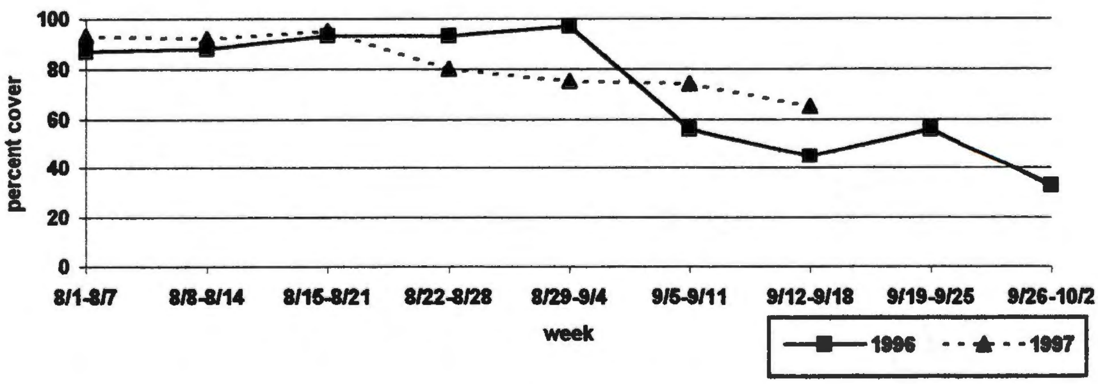


Figure 43. Plot of shorebirds/count/100 ha (index) by average water depth (cm) available on five study areas in western Tennessee, 1996-1997.

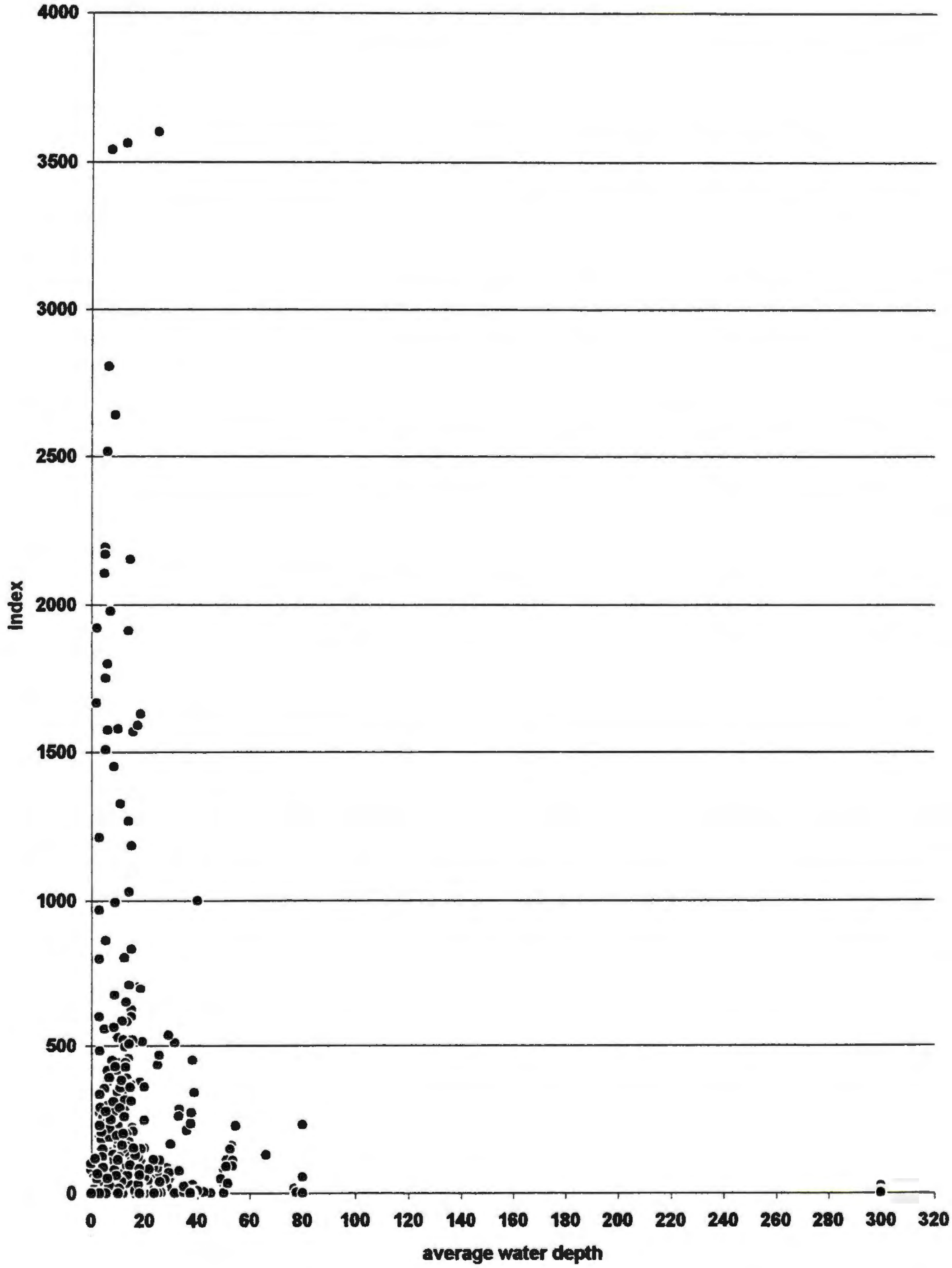


Figure 44. Plot of shorebirds/count/100 ha (index) against percent cover with vegetation density of 0-25% available on five study areas in western Tennessee, 1996-1997.

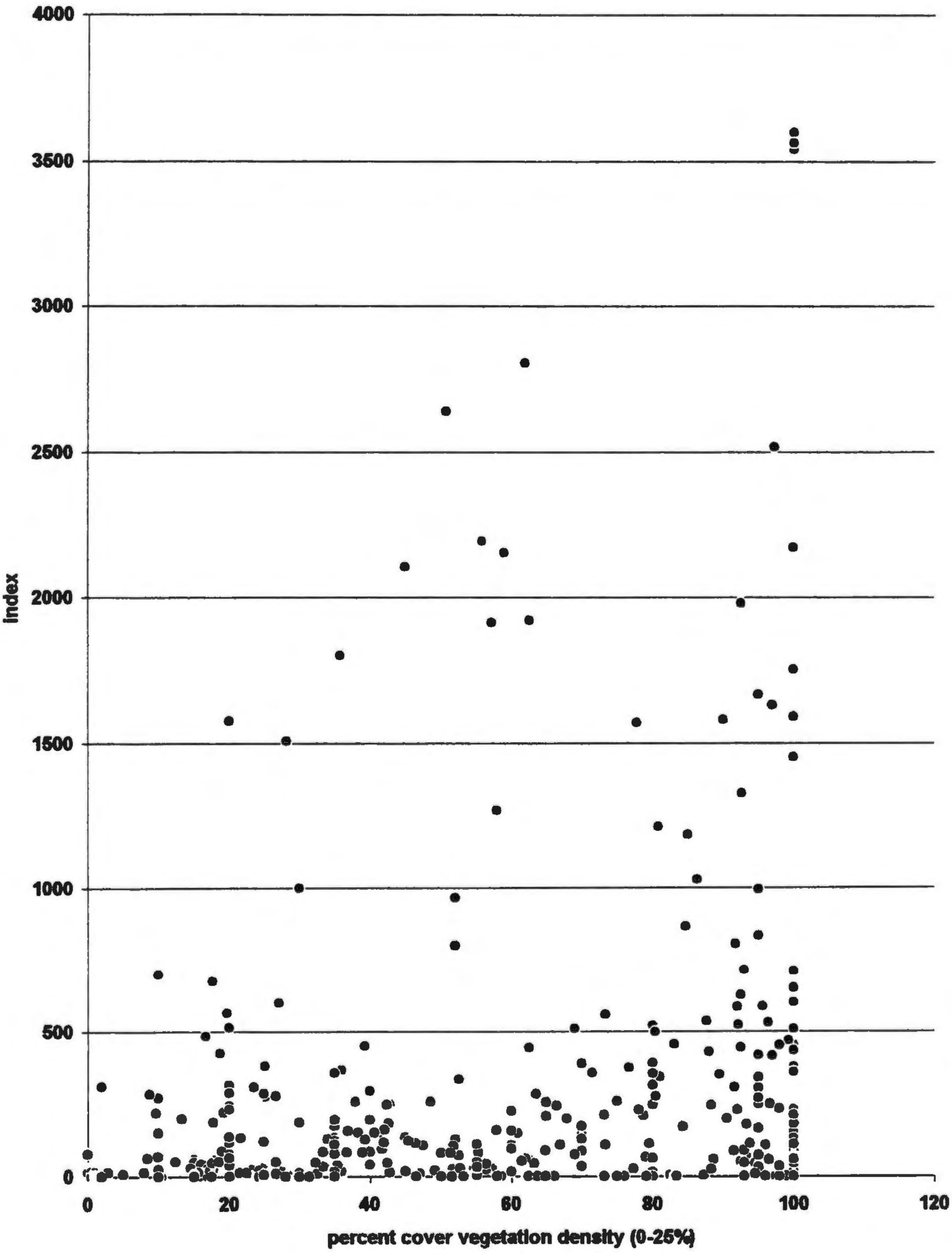


Figure 45. Plot of shorebirds/count/100 ha (index) against percent of area in mud substrate on five study areas in western Tennessee, 1996-1997.

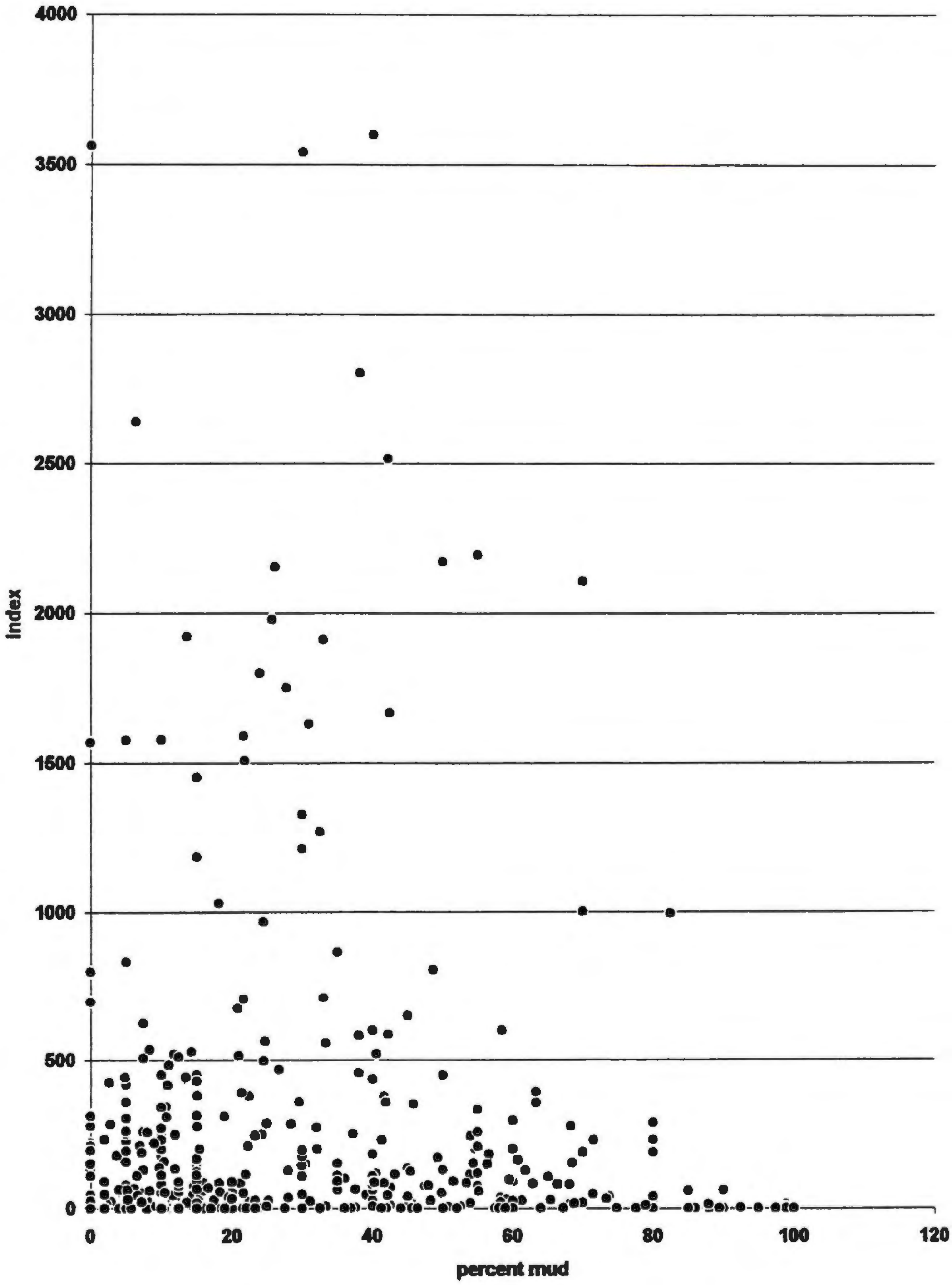


Figure 46. Plot of shorebirds/count/100 ha (index) against percent of area in flooded substrate on five study areas in western Tennessee, 1996-1997.

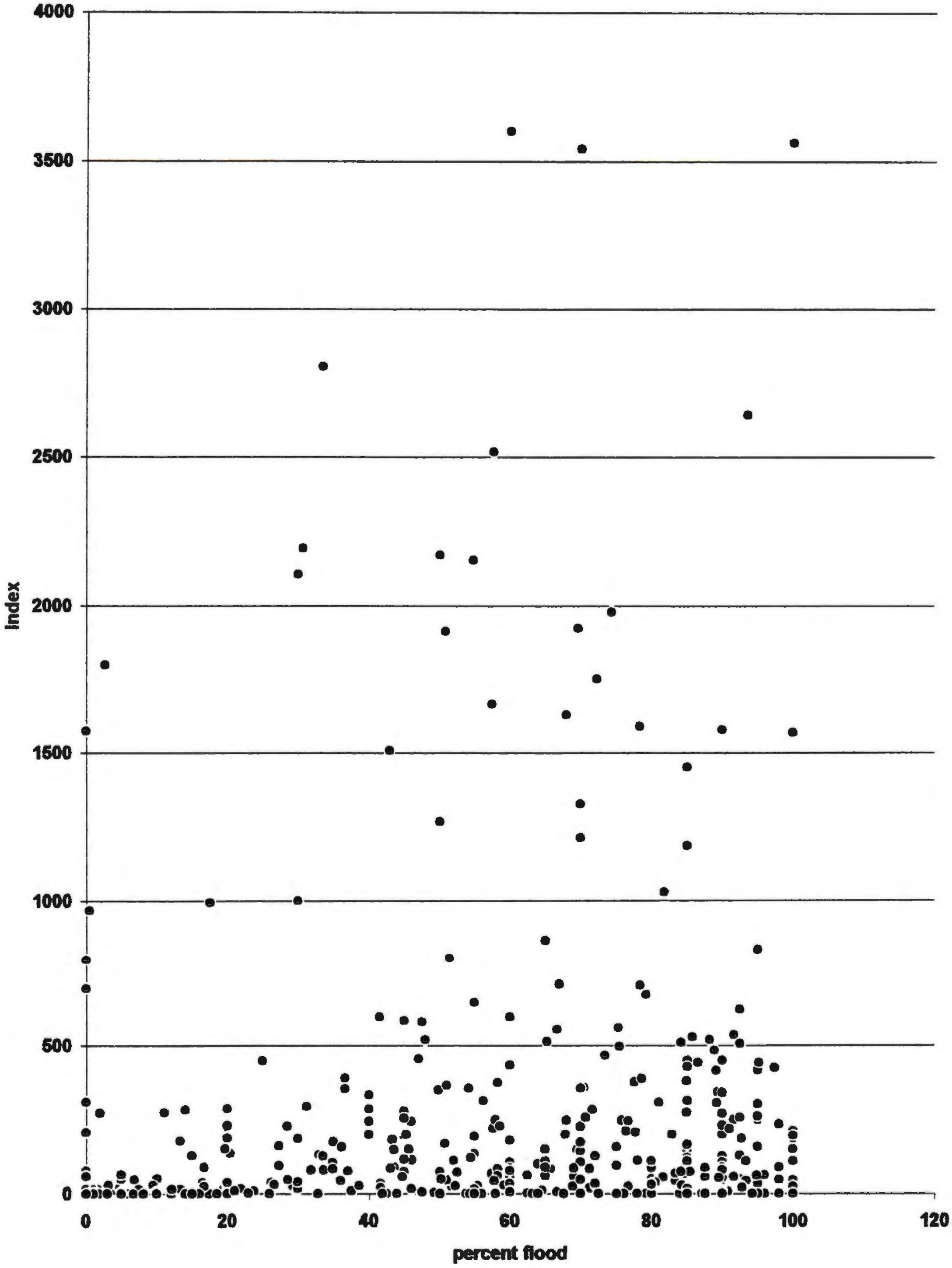


Figure 47. Plot of shorebirds/count/100 ha (index) against percent of area covered with vegetation 0-10 cm in height on five study areas in western Tennessee, 1996-1997.

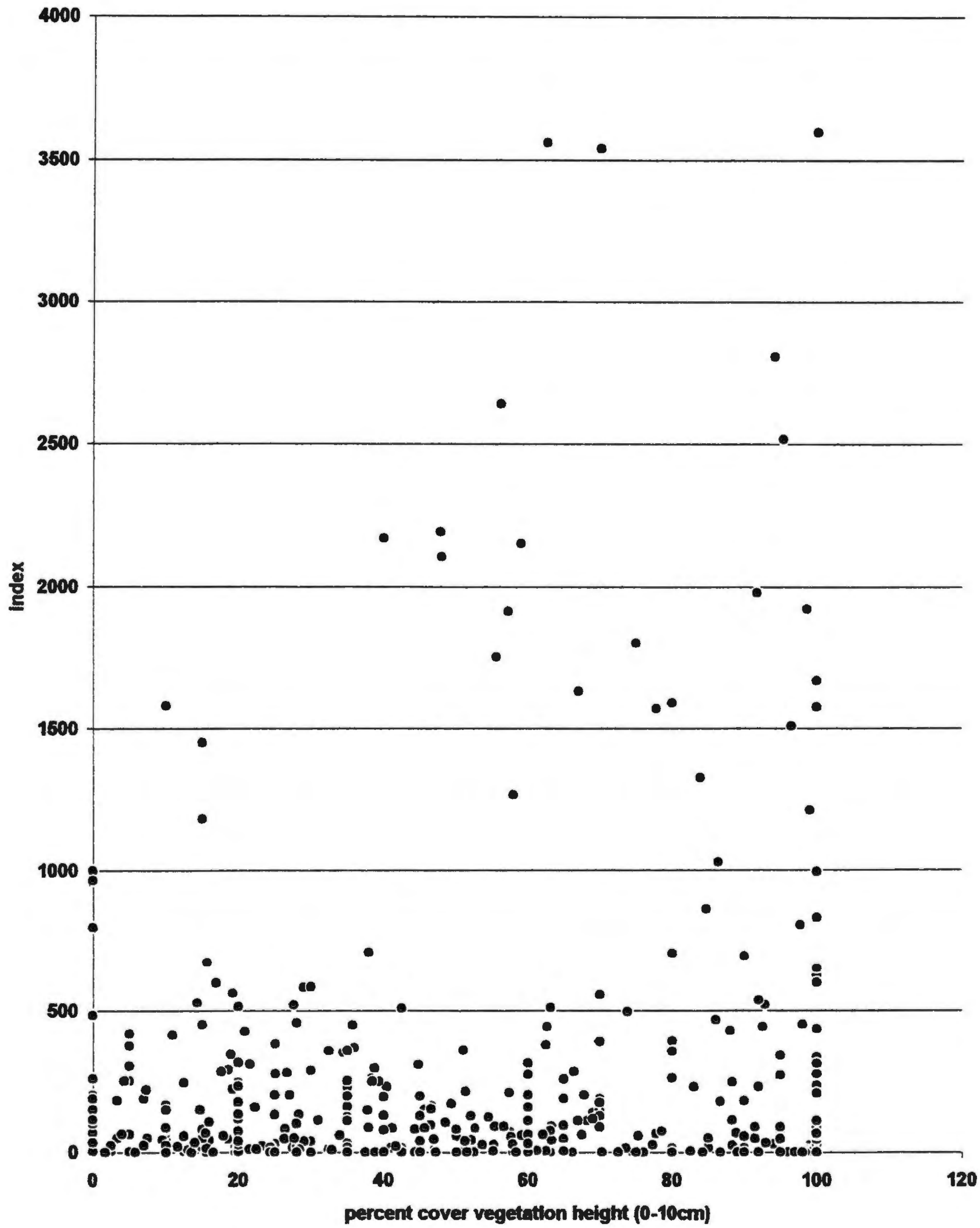
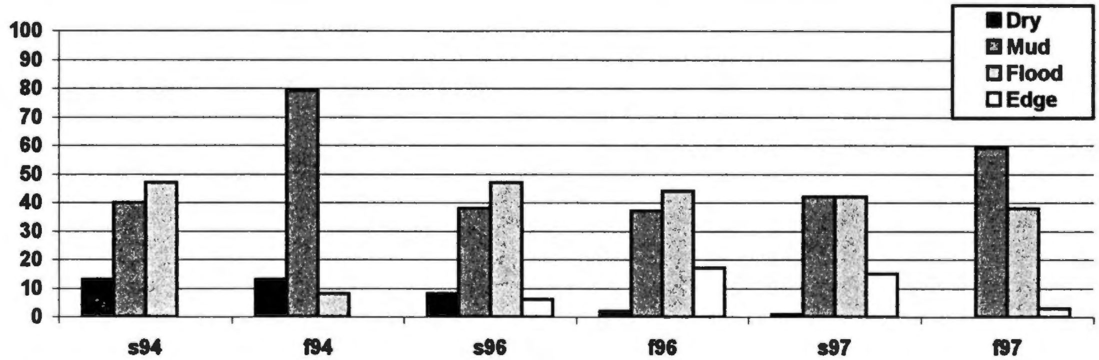
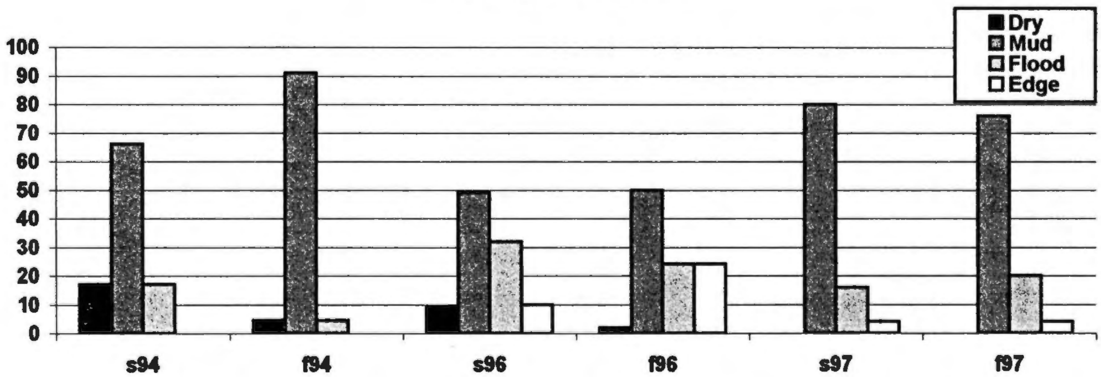


Figure 48. Substrate use for top 7 shorebird species observed on five study areas in western Tennessee in 1994, 1996, and 1997.

PECTORAL SANDPIPER



LEAST SANDPIPER



LESSER YELLOWLEGS

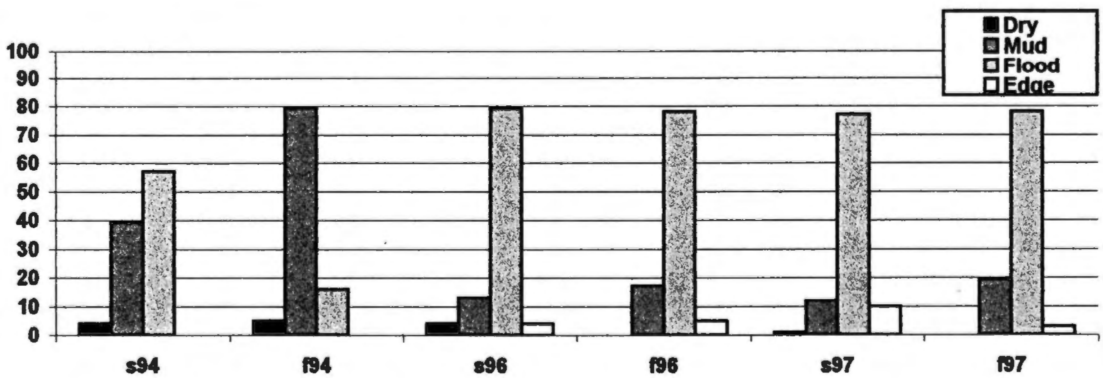
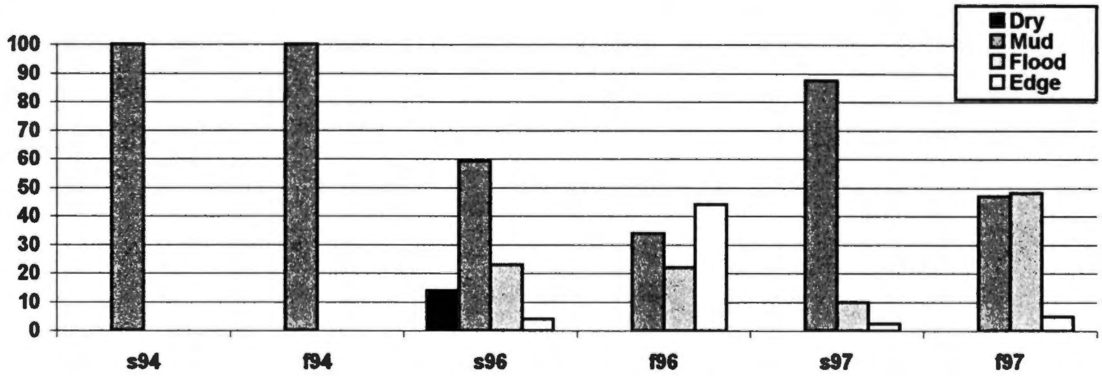
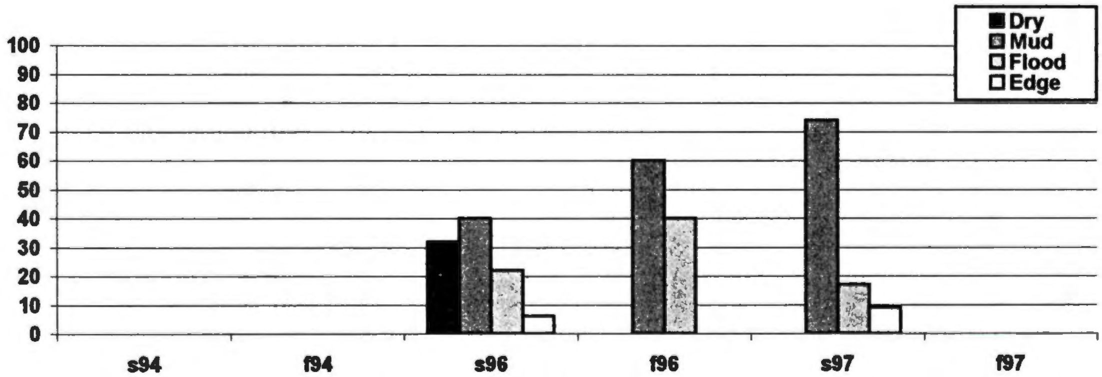


Figure 48. Continued....

SEMIPALMATED SANDPIPER



AMERICAN GOLDEN PLOVER



SOLITARY SANDPIPER

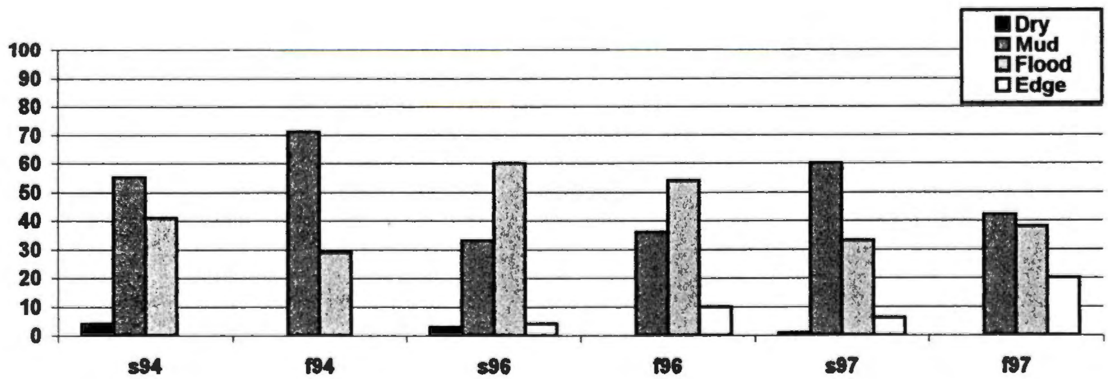


Figure 48. Continued...

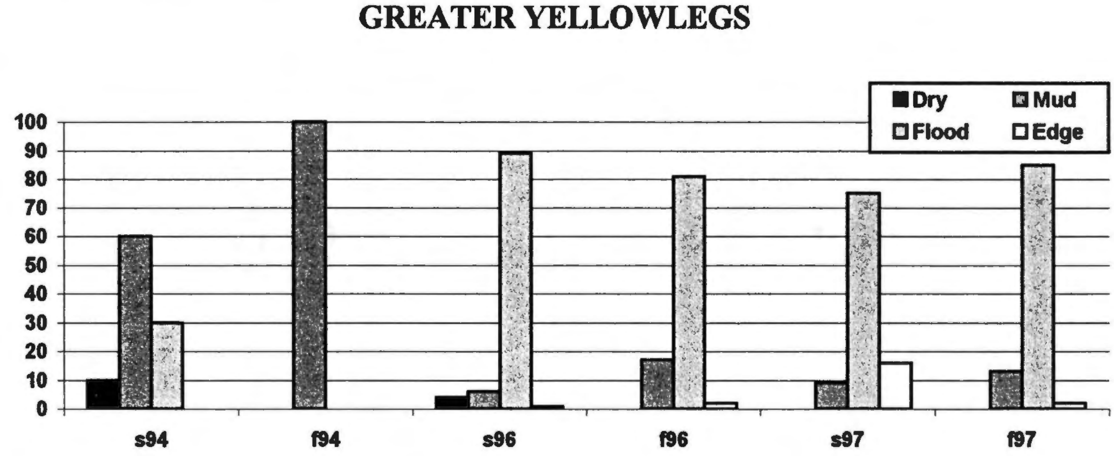
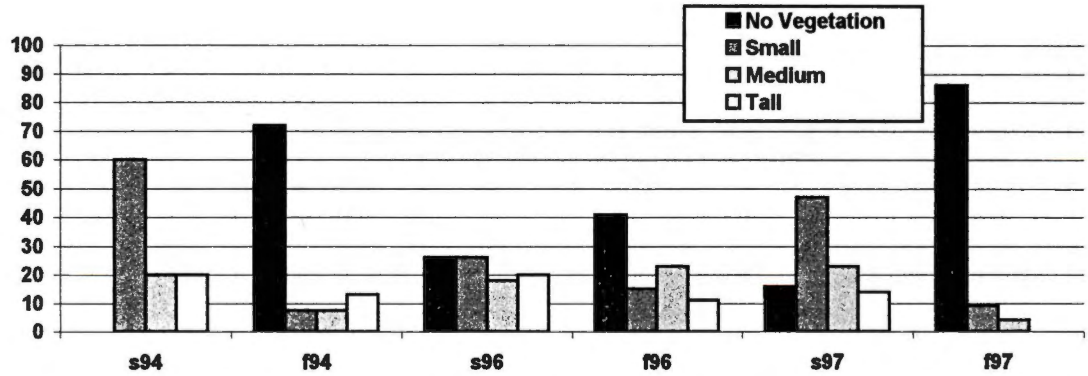
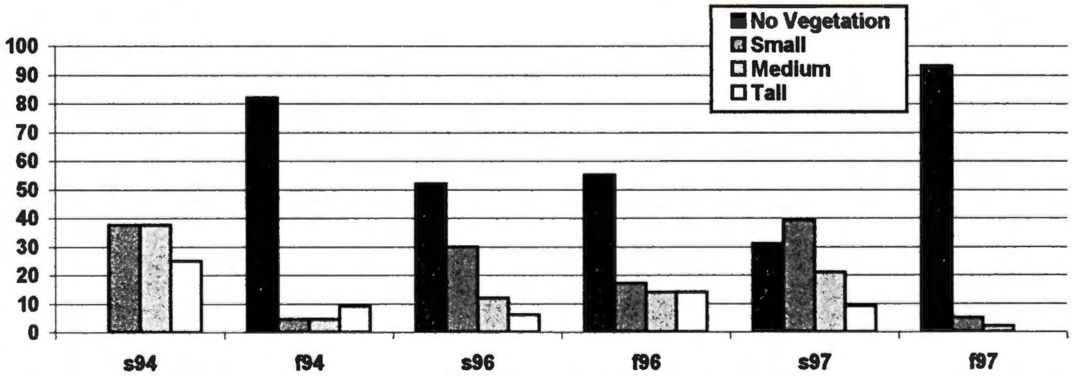


Figure 49. Height of vegetation used by top seven shorebird species on five study areas in western Tennessee in 1994, 1996, and 1997.

PECTORAL SANDPIPERS



LEAST SANDPIPERS



LESSER YELLOWLEGS

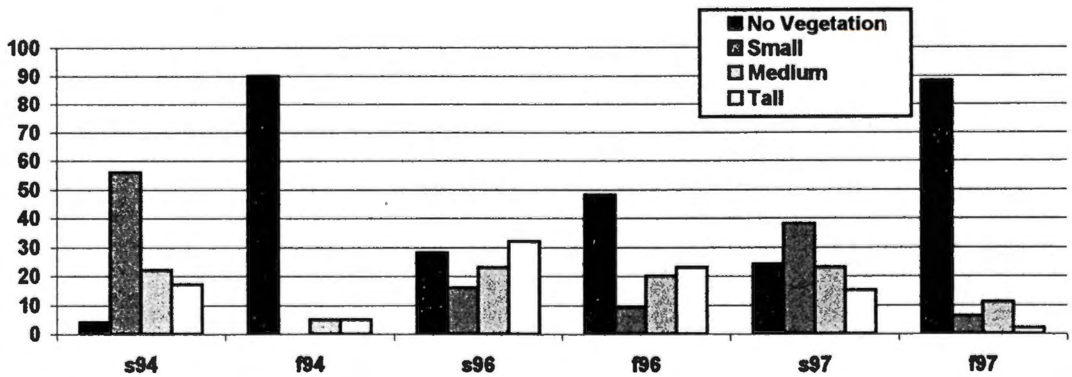
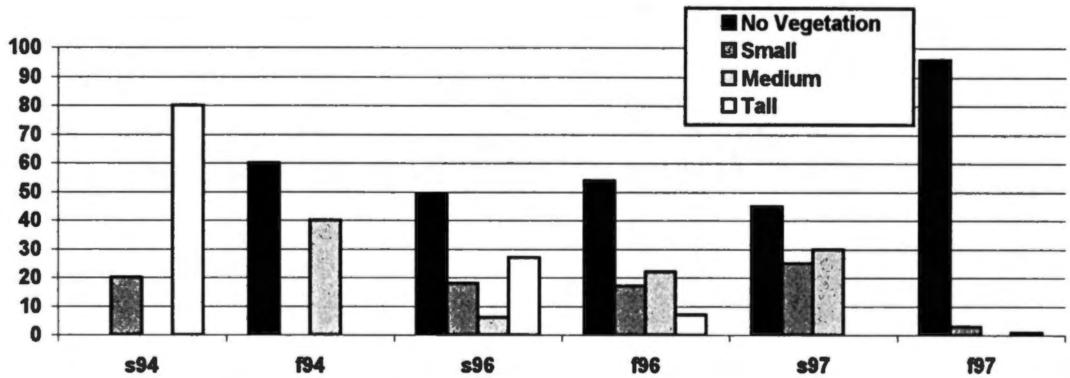
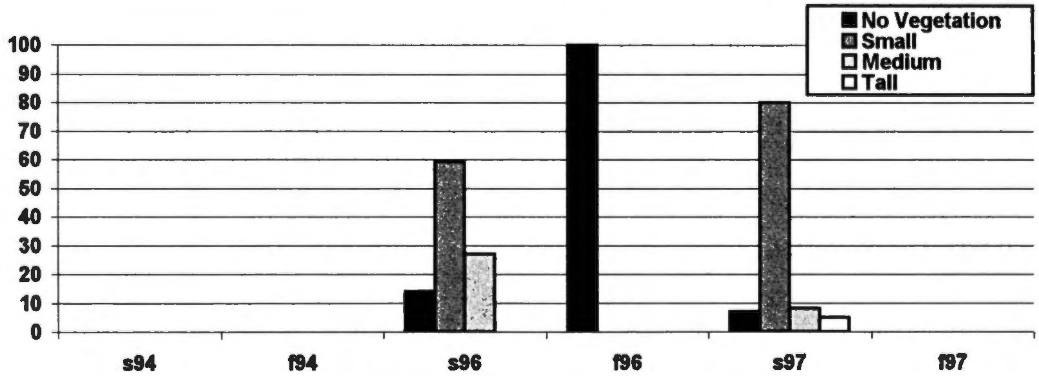


Figure 49. Continued...

SEMIPALMATED SANDPIPER



AMERICAN GOLDEN PLOVER



SOLITATARY SANDPIPER

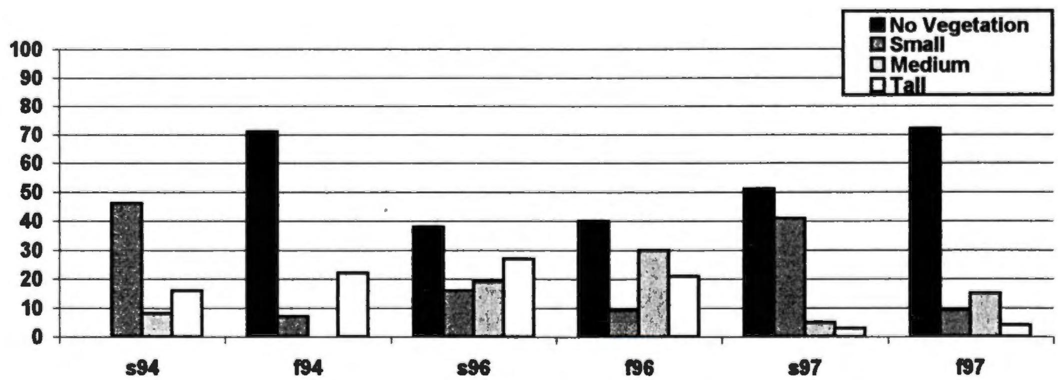


Figure 49. Continued.....

GREATER YELLOWLEGS

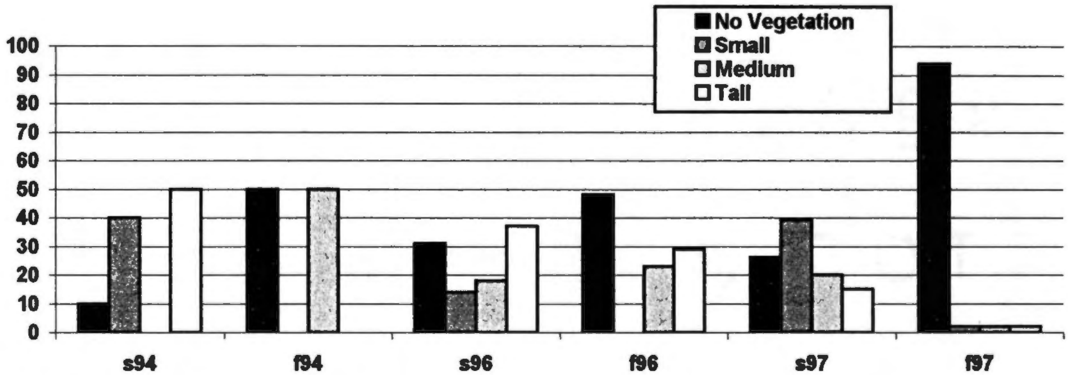
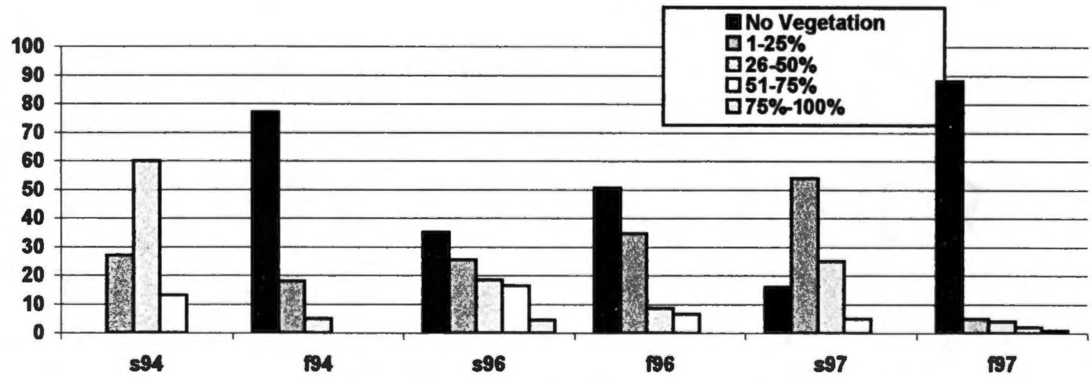
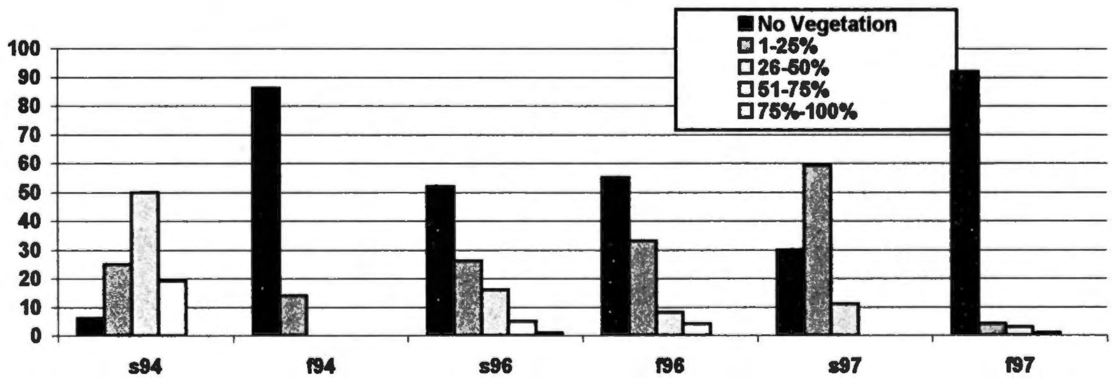


Figure 50. Vegetation density used by the top 7 species observed on five study areas in western Tennessee in 1994, 1996, and 1997.

PECTORAL SANDPIPER



LEAST SANDPIPER



LESSER YELLOWLEGS

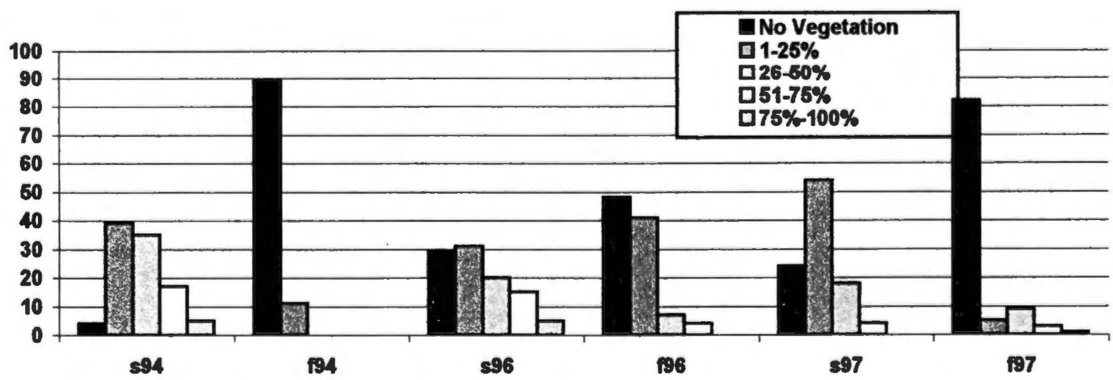
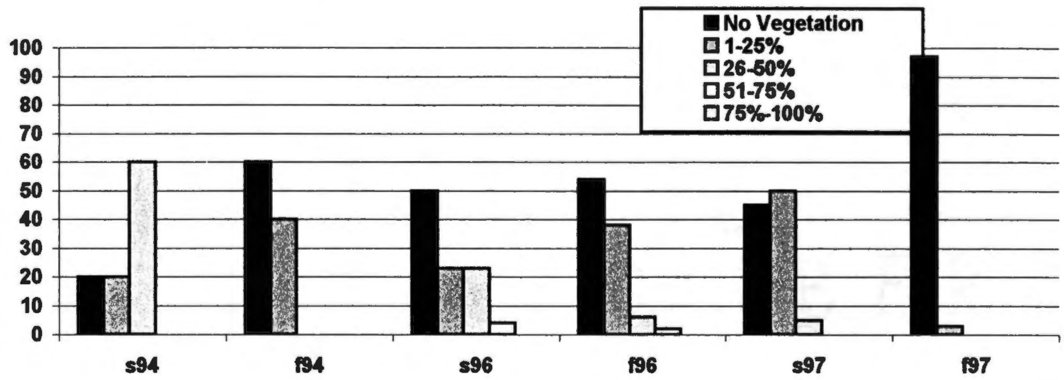
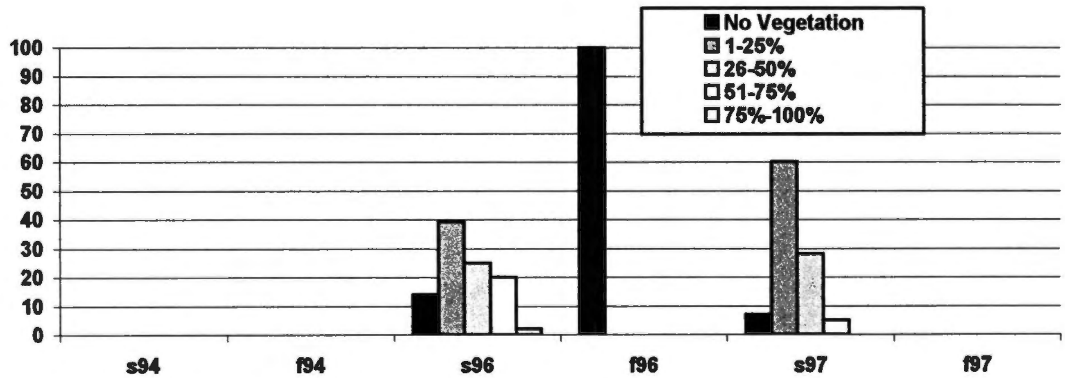


Figure 50. Continued.....

SEMIPALMATED SANDPIPER



AMERICAN GOLDEN PLOVER



SOLITARY SANDPIPER

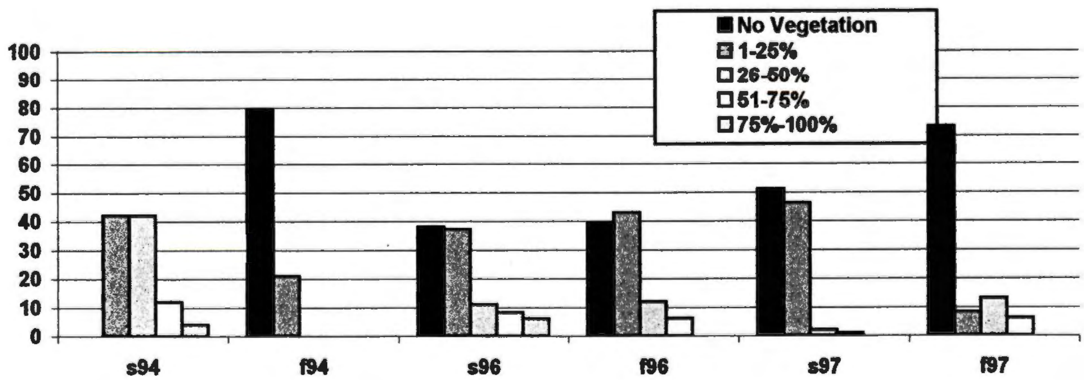
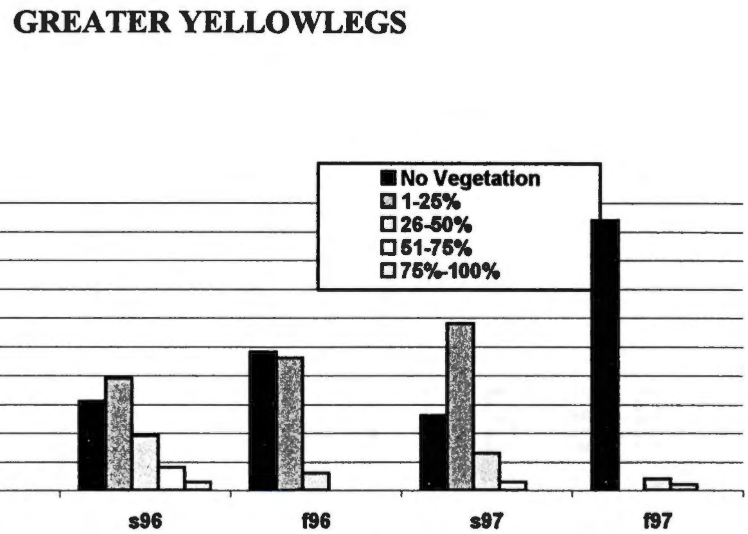


Figure 50. Continued.....



VITA

Margaret Rohs Short was born in Cincinnati, Ohio on August 20, 1973. She attended St. Ursula Academy for high school and graduated in June, 1991. She entered University of Tennessee, Knoxville during August of 1991, where she received a The Bachelor of Science in Wildlife and Fisheries Science in May of 1995. She entered the Master's program in Wildlife and Fisheries Science at the University of Tennessee, Knoxville in August of 1995, officially receiving the Master's degree in December, 1999. She is presently working as a park ranger for the state of North Carolina.

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