SHOREBIRD HABITAT USE AND RESPONSE TO

BURNED MARSHES DURING SPRING

MIGRATION IN SOUTH-CENTRAL

KANSAS

By

KELLI LEE STONE

Bachelor of Science

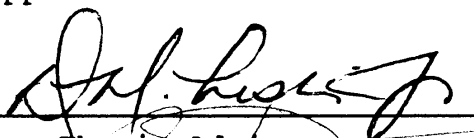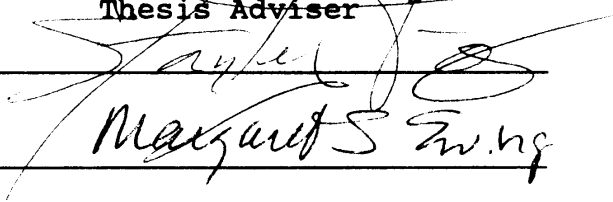Colorado State University

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Thesis Approved:

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Thesis Adviser

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Dean of the Graduate College

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CHAPTER I

INTRODUCTION

This thesis is composed of 2 manuscripts written in formats suitable for submission to selected scientific journals. Each manuscript is complete without supporting materials. Chapter II, "Spring migration chronology of shorebirds at Quivira National Wildlife Refuge in south-central Kansas" is written in the format of the Wilson Bulletin. Chapter III, "Shorebird habitat use and response to burned marshes during spring migration in south-central Kansas," is written in the format of the Journal of Wildlife Management.

CHAPTER II

SPRING MIGRATION CHRONOLOGY OF SHOREBIRDS AT QUIVIRA

NATIONAL WILDLIFE REFUGE IN SOUTH-CENTRAL KANSAS

Abstract.--We censused migrating shorebirds at an important
stop-over site, Quivira National Wildlife Refuge (NWR), in
south-central Kansas in spring 1992 and 1993. Richness of
the shorebird community was similar in both years: 29
species in 1992 and 24 species in 1993. We grouped
shorebirds by mean tarsus length and foraging guild; both
methods resulted in similar classification. Shorebirds
occurred at Quivira NWR in early April, peaked in late April
and late May, and declined by early June. The small size
class was most abundant, followed by the medium and large
size classes, albeit large shorebirds were a minor component
in both years. Size classes were temporally segregated at
Quivira NWR in both years: large shorebirds early in the
spring, medium in mid-spring, and small at the end of
spring. Each size class was dominated by 1-2 species.
Generally, dominant species in all size classes were
temporally segregated in both years, which may have
minimized interspecific competition.

Each spring millions of shorebirds (Aves: Charadrii)

migrate from Central and South America to breed in North
America--a round trip of 12,000 to >25,000 km (Myers et al.
1987). The Great Plains is one of three primary migration
corridors (Myers et al. 1987). Northbound shorebirds
migrate along a sequence of stopover areas where they forage
intensely to accumulate lipid reserves required for
subsequent long-distance flights and reproductive success
(Ashkenazie and Safriel 1979, Hilden 1979). On coastal
stopover areas, food resources are limited and can be
depleted by migrating shorebirds (Schneider and Harrington
1981). Interspecific competition for prey may explain
migration timing of various shorebird species (Recher 1966,
Myers 1981, Helmers 1991). Loss of shorebird habitat (Myers
1983), coupled with high energy costs associated with
migration, make management of stopover areas critical to
conservation of these species (Myers et al. 1987, Eldridge
1990, Skagen and Knopf 1993).

Knowledge of the shorebird community and migration
chronology is necessary so that habitat manipulations on
stopover areas can be timed appropriately (Reid et al.
1983). In south-central Kansas, spring migration chronology
has been documented at Cheyenne Bottoms Wildlife Management
Area (WMA) (Parmelee et al. 1969a, b; Helmers 1991) and at
Quivira National Wildlife Refuge (Skagen and Knopf 1994).
Our objective was to further evaluate community composition
and migration chronology of shorebirds at an important
stopover site in the south-central Great Plains.

STUDY AREA

We conducted our study at Quivira NWR in Stafford, Rice, and Reno counties in south-central Kansas. The 8,728-ha refuge contained grasslands, rangelands, natural salt marshes, and 34 developed impoundments or water units. Water units were filled naturally or by water diverted from Rattlesnake Creek through a system of canals and water control structures. Refuge waters were slightly to moderately saline; soils ranged from light sands to clay loam and were neutral to alkaline (U.S. Fish and Wildl. Serv. [FWS] 1990). Average annual precipitation was 62 cm (1931-1991); however, the refuge received 80 cm in 1992 and 56.8 cm during January-June 1993 (Quivira NWR, unpubl. data).

METHODS

Shorebird Censuses.--We conducted censuses at least biweekly (Rundle and Fredrickson 1981, Ryan et al. 1984, Funderburk and Springer 1989, Hands et al. 1991) from April to June, 1992 and 1993. The same observer conducted all censuses with a 15-60 variable-power scope and 10 x 80 binoculars from a vehicle along a fixed survey route alternating start and finish locations. Because of typical windy (>30 mph) mid-day conditions, censuses were conducted from sunrise to 1200 h and 1600 h to sunset (Helmers 1991). At least one census was conducted in each diel period per week.

When feasible, shorebirds were identified to species.

During poor lighting or when birds were at great distances
from the vehicle, identification was made by size or species
class. During poor viewing conditions, small unidentifiable
Calidris species were labelled "peeps." Greater Yellowlegs
(Tringa melanoleuca) and Lesser Yellowlegs (T. flavipes)
that could not be identified to species were labelled
"yellowlegs." Regardless of viewing conditions, we did not
attempt to differentiate between morphologically similar
Short-billed Dowitchers (Limnodromus griseus) and Long-
billed Dowitchers (L. scolopaceus). At Quivira NWR, Short-
billed Dowitchers are rare compared to Long-billed
Dowitchers (Skagen and Knopf 1994); therefore, we considered
all dowitchers to be Long-billed Dowitchers. We did not
enumerate Snowy Plovers (Charadrius alexandrinus) and
Killdeer (C. vociferus) in our censuses because they were
primarily breeding not migrating. American Avocets
(Recurvirostra americana), Black-necked Stilts (Himantopus
mexicanus), and to a lesser degree, Spotted Sandpipers
(Actitis macularia) and Wilson's Phalaropes (Phalaropus
tricolor) also nested at our study site. Individuals of
these species that displayed breeding or nesting behavior
(i.e., copulation, incubation, nest defense, etc.) were not
included in analyses. Shorebirds that flushed from a census
unit as the vehicle approached also were excluded from
analysis.

   Grouping Shorebirds.--Most wildlife communities contain
a relatively large number of individuals belonging to a few

species and relatively few individuals of many species
(Krebs 1989). Therefore, we grouped similar species to
evaluate the shorebird community. We grouped species in two
ways to identify if results were influenced by grouping
methods. The first method utilized only leg length. Except
for swimming Phalaropes (Phalaropus spp.), shorebirds are
primarily limited to water depths proportional to leg length
and body size (Baker 1979) and have been grouped accordingly
(Morrison et al. 1993, Skagen and Knopf 1993). We
identified three size classes (small, medium, and large)
based on mean tarsus length (Haymen et al. 1986). The small
size class included shorebirds with a mean tarsus length
between 19-25 mm; i.e., most Calidris species and Charadrius
species. Medium and large size classes included shorebirds
with mean tarsus lengths of >25-47 mm and >47 mm,
respectively (Appendix A). Phalaropes were removed from the
medium size class because they were not restricted by water
depth and were placed in their own class, "swimmers."

Because foraging modes can differ between groups of
similar sized shorebirds, shorebird species also have been
grouped by foraging guilds (Wilcox 1986, Helmers 1991). In
our second method of grouping, we identified foraging guilds
based on foraging modes (sweeping action, gleaning, and
probing) as well as tarsus length (small [<25 mm], medium
[>25-47 mm], and large [>47 mm]) following Helmers (1991).
There were too few individuals in the medium gleaner and
large prober guilds for analysis. As a result, we redefined

only two tarsus length classes (small [<25 mm] and large
[>25 mm]) in conjunction with the three foraging modes
(Appendix A).

Data Analysis.--Migration chronology and relative
abundances of shorebird species and classes were derived
from at least two censuses per week. We defined peak
migration as the date(s) of the highest relative abundance
of the class during census periods. We examined temporal
segregation at Quivira NWR on two levels: (1) size classes
and dominant species throughout both field seasons and (2)
daily relative abundances of dominant species. Percent
abundances of each size class and foraging guild were
plotted against census periods. To determine if similar
sized shorebirds with similar foraging modes were temporally
segregated on the refuge throughout the censusing period, we
plotted abundance of the three most dominant species in each
size class against time. We also plotted relative daily
abundances of the three dominant species in size classes and
foraging guilds against time (i.e., the abundance of each
dominant species relative to the total number of all three
dominant species of each class seen each day). We
hypothesized that relative daily abundances of similar
species (relative to tarsus length) would be complementary;
i.e., when one species was abundant, others would be rare.
Individual species were considered dominant community
members if they were >5% of the total community and
prevalent if they were 1-5%.

RESULTS

In 1992, we conducted 15 censuses from 26 April to 5 June and observed 23,604 shorebirds (x = 1,573 shorebirds/census). In 1993, we extended the field season from 6 April to 12 June; we conducted 32 censuses and observed 68,552 shorebirds (x = 2,142 shorebirds/census).

Shorebird Community.--Richness of the shorebird community was similar in both years (Table 1). We observed 29 species in 1992 and 24 in 1993. In 1992, four species were dominant and comprised 62.2% of the total shorebird community: Wilson's Phalaropes, Stilt Sandpipers (Calidris himantopus), White-rumped Sandpipers (C. fuscicollis), and Long-billed Dowitchers (Table 1). Five species were prevalent: Semipalmated Sandpipers (C. pusilla), Lesser Yellowlegs, Pectoral Sandpipers (C. melanotus), American Avocets, and Baird's Sandpipers (C. bairdii). During the comparable time period in 1993, 56.9% of the total community consisted of only 2 dominant species: White-rumped and Stilt Sandpipers. Prevalent species were Semipalmated Sandpipers and Wilson's Phalaropes, which comprised 6.6% of the total community in 1993.

Except for Long-billed Dowitchers and Wilson's Phalaropes, the same species or species group were dominant during comparable time periods in both years, but their relative proportions in the total community changed from 1992 to 1993 (Table 1). In 1992, Wilson's Phalaropes were the largest component (23.7%) of the total shorebird

community, but they comprised only 3.1% of the community in 1993. White-rumped Sandpipers increased from 12.4% of the total community in 1992 to 46.1% in 1993.

Size classes (Table 1) and foraging guilds (Table 2) generally resulted in the same classification of species, except for American Avocets. Most species in the small class also were classified as small probers, except for Semipalmated Plovers (Charadrius semipalmatus), Piping Plovers (C. melodus), and Spotted Sandpipers, which were classified as small gleaners. Small gleaners comprised <2% of the small class both years; therefore, we did not separate the small size class into probers and gleaners but treated the class as the small prober/gleaner guild.

The large prober guild and the medium size class contained about the same species (Tables 1 and 2). Ninety-seven percent of the large prober guild consisted of medium shorebirds in both years. Additionally, the same species dominated both groups.

Generally, the large gleaner guild and the large size class contained the same species. Large shorebirds comprised 96.5% of the large gleaner guild in 1992 and 88.6% of the guild in 1993. The major difference between the large size class and the large gleaner guild was the American Avocet, which was dominant in the large class both years (Table 1) and the only species in the large sweeper foraging guild (Table 2). Because size classes and guilds were identical or very similar in species composition and

abundance, we generally report results from size classes, unless guild results were notably different.

The shorebird community was dominated by the same size classes in both years, but their relative abundance in the total community changed (Table 1). Small shorebirds dominated the shorebird community in 1992 (39.7%) and 1993 (84.0%); the increase between years was primarily due to White-rumped Sandpipers. In 1992, we observed only 194 White-rumped Sandpipers per census compared to 1,351 per census in 1993. The medium size class was the second most abundant class in both years: 28.5% in 1992 and 12.2% in 1993. Swimmers were 23.7% of the total community in 1992 but declined to 3.1% in 1993, due to the decline in Wilson's Phalaropes from 373 per census in 1992 to 90 per 1993 census. Large shorebirds were a minor component of the community in both years: 8.1% in 1992 and 0.8% in 1993. Despite the greater censusing effort and extended field season in 1993 compared to 1992, all species in the large size class were more abundant in 1992. However, the number of American Avocets per census was only slightly higher in 1992 (25) than in the extended 1993 field season (23).

Migration Chronology.--Size classes and foraging guilds displayed similar migration patterns at Quivira NWR; therefore, we present migration chronologies of only size classes (Fig. 1). In both years, large shorebirds generally peaked early in the censusing period, medium shorebirds peaked mid-period, and small shorebirds were most common at

the end of the period. That pattern largely reflected migration chronologies of the dominant species of each size class (White-rumped Sandpipers in the small class [Fig. 2] and Stilt Sandpipers in the medium class [Fig. 3]). Species from all size classes were observed on the refuge throughout censusing periods in both years (Appendix B).

Seasonal Segregation of Dominant Species.--Peak abundances of the dominant species in the small size class occurred at different times in both years; however, that pattern was more obvious in 1993 than 1992 (Fig. 2). In 1992, peak abundances of Baird's and Semipalmated Sandpipers overlapped in late April (Fig. 2A); however, Baird's Sandpipers are early migrants (i.e., late March to early April [Parmelee et al. 1969b]) and overlap in 1992 was likely a function of late censusing (after 26 April). Peak abundances of White-rumped Sandpipers occurred in late May 1992. In 1993, peak occurrences of these three species differed throughout the censusing period (Fig. 2B). Baird's Sandpipers were most abundant in early-April 1993; Semipalmated Sandpipers remained at a relatively low and constant level of occurrence from mid-April through early June; and White-rumped Sandpipers were observed most often in late-May (Fig. 2B).

In the medium class, peak abundances of Stilt Sandpipers and Long-billed Dowitchers coincided in mid-May 1992, but Pectoral Sandpipers peaked in late May (Fig. 3A). In 1993, Long-billed Dowitchers peaked in early May and were

temporally separated from Stilt Sandpipers and Dunlins (<u>Calidris</u> <u>alpina</u>), which both peaked in mid-May (Fig. 3B). We did not plot dominant species in the large size class and large gleaner guild against time. After unidentified yellowlegs and breeding American Avocets and Black-necked Stilts were removed, sample sizes were small (3.0% of the total community in 1992 and 0.4% in 1992). Additionally, most large shorebirds were early migrants and because of late censusing in 1992, peaks in abundance were probably skewed.

<u>Daily</u> <u>Segregation</u> <u>of</u> <u>Dominant</u> <u>Species.</u>--Relative daily abundances of dominant species in the three size classes generally were inversely proportional to each other in 1992 and 1993 (Figs. 4-6). In all size classes, there were a few days when the relative proportions of two species were similar; however, daily relative abundances of dominant species were generally dichotomous. For example, in the small size class, Semipalmated Sandpipers were relatively abundant on days when Baird's and White-rumped Sandpipers were relatively rare (Fig. 4). Similarly, in the medium class in 1993, Long-billed Dowitchers were relatively abundant on days when Stilt Sandpipers were relatively rare (Fig. 5).

DISCUSSION

Many Nearctic breeding shorebirds migrate round-trip distances of 12,000-25,000 km (Myers et al. 1987). Shorebirds briefly interrupt northbound migration to forage

at prairie stopover sites in the central United States. Fat
reserves accumulated there fuel their remaining journey to
the breeding grounds (Myers et al. 1987, Castro and Myers
1989) and enhance reproductive success (Davidson and Evans
1988). It is critical to shorebird conservation that
habitat is available at stopover sites during migration
(Skagen and Knopf 1993). Effective management of these
sites requires knowledge of the shorebird community
composition and migration chronology.

Shorebird Community.--We documented shorebird community
composition and migration chronology during a spring of
relatively normal water availability (1992) and a spring of
extremely high precipitation and water conditions (1993) at
Quivira NWR. Species richness was similar in both years
and was comparable to other studies in south-central Kansas
(Helmers 1991, Skagen and Knopf 1994), south-central
Saskatchewan (Colwell et al. 1988), and northwest Arkansas
(Smith et al. 1991). During comparable time periods in 1992
and 1993, Stilt and White-rumped Sandpipers dominated the
shorebird community. Long-billed Dowitchers and Wilson's
Phalaropes also were dominant in 1992 but not 1993. Lesser
Yellowlegs, Baird's Sandpipers, and Pectoral Sandpipers were
prevalent in 1992 but not 1993; however, Semipalmated
Sandpipers were prevalent in both years. All these species
were likewise major components of the spring shorebird
community at Quivira NWR in 1989-1991 (Skagen and Knopf
1994) and neighboring Cheyenne Bottoms WMA (Helmers 1991).

Although species composition at Quivira NWR was similar in both years, relative proportions of many species changed, perhaps in response to contrasting water availability. Large species such as Greater and Lesser Yellowlegs and Hudsonian Godwits (<u>Limosa</u> <u>haemastica</u>) declined on the refuge in 1993 compared to 1992. Phalaropes and many medium species, notably Long-billed Dowitchers, also declined in 1993. Similarly, Dowitchers and Greater and Lesser Yellowlegs varied notably in abundance at Mingo NWR and Ted Shanks WMA in Missouri between 1979-1981 (Reid et al. 1983). Such variation of shorebird use likely depends on habitat conditions, hydroperiod, vegetation structure, and prey availability (Reid et al. 1983). During spring 1993, the interior United States and Quivira NWR had extremely high precipitation. Precipitation on the refuge from January through June 1993 exceeded the mean amount for that period by 23.8 cm ($\underline{n}$ = 61) (Quivira NWR unpubl. data). Abundant precipitation in 1993 rejuvenated many prairie wetlands and most likely provided additional habitat to migrating shorebirds. Shorebird movements across the plains are characterized by dispersion and opportunism (Skagen and Knopf 1993). We speculate that Phalaropes and large and medium species dispersed more widely throughout the plains in 1993, explaining their decline at Quivira NWR.

Unlike medium and large shorebirds, small species, notably White-rumped Sandpipers, increased on the refuge from 1992 to 1993. High water conditions may have forced

small shorebirds to wetland edges, making them easier to
census. High water conditions in early spring also may have
improved habitat conditions for small shorebirds by
enhancing availability of their aquatic prey species. By
late May 1993, water receded and exposed foraging habitat,
concurrent with peak migration of White-rumped Sandpipers at
Quivira NWR. During May and early June, White-rumped
Sandpipers use a major staging zone in Kansas, notably
Cheyenne Bottoms WMA (Harrington et al. 1991). During high
water conditions in spring 1993, Cheyenne Bottoms WMA had
very little habitat (i.e., water <10 cm) available to small
shorebirds (H. Hands, pers. comm.), and White-rumped
Sandpipers may have been displaced to Quivira NWR. We
observed 27,021 White-rumped sandpipers from 26 April to 5
June 1993, in contrast to 2,914 in 1992. These sandpipers
are vulnerable to the loss of prairie stopover sites because
during northbound migration they primarily move through
interior North America (Myers et al. 1987, Harrington et al.
1991). In 1993, 15,158 White-rumped Sandpipers (22.1% of
the total shorebird community) were observed on 27 May,
which highlights the importance of Quivira NWR as a
migratory stopover area.

Classifying species by size or foraging guilds
generally resulted in the same groups of species, except in
the large size class and large gleaner foraging guild. Most
shorebirds are opportunistic foragers (Eldridge 1992) and
use more than one foraging mode, primarily probing and

gleaning (Helmers 1992). This makes classification by foraging guilds somewhat subjective (Verner 1984). Our size classes were similar to Morrison et al. (1993), except for Dunlins and Pectoral Sandpipers, which they classified as small and we classified as medium. Our size classes also were similar to Skagen and Knopf (1993), who grouped species by total body length. Upland Sandpipers (Bartramia longicauda), Solitary Sandpipers (Tringa solitaria), and Lesser and Greater Yellowlegs were classified as medium in Skagen and Knopf (1993) but were classified as large in our study.

The shorebird community at Quivira NWR was dominated by the same size classes in both years, but their relative abundances changed. The small size class was dominant in both years: 39.7% in 1992 and 84.9% in 1993. Medium size shorebirds were the second most prevalent class (28.5% in 1992 and 10.5% in 1993), and the large size class was a minor (<8.1%) component of the community both years. Our 1992 results were similar to composition of size classes reported throughout the Great Plains (Skagen and Knopf 1993). Our 1993 results were similar to those from the refuge between 1989-1991 when the small size class comprised 50-70% of the total shorebird community (Skagen and Knopf 1993).

Migration Chronology.--In 1993 when we began censuses early, shorebird use of Quivira NWR began in early April, peaked in late April and late May, and sharply declined in

early June. This was similar to other spring migration studies (Colwell et al. 1988, Helmers 1991, Smith et al. 1991, Skagen and Knopf 1994). However, some shorebird species prevalent at Quivira NWR have been documented at other spring stopover sites as early as March. Early arrivals of Lesser Yellowlegs were documented at Cheyenne Bottoms WMA on 1 March (Parmelee et al. 1969b) and Mingo NWR and Ted Shanks WMA in southeastern Missouri on 11 and 18 March, respectively (Reid et al. 1983). Greater Yellowlegs have been reported at Cheyenne Bottoms on 8 March (Parmelee et al. 1969b), in western Washington in mid-February and mid-March (Buchnanan 1988), and at Mingo NWR in mid-April (Reid et al. 1983). We cannot compare most arrival dates at Quivira NWR between years due to late censusing efforts in 1992. First observation dates in 1993 were generally later than those at Mingo NWR and Ted Shanks WMA in 1978-1982 (Reid et al. 1983), which may have been a function of high water conditions at Quivira NWR in 1993.

Several dominant species in the small and medium size classes (Stilt Sandpipers, Long-billed Dowitchers, and White-rumped Sandpipers) peaked for longer periods in 1992 than in 1993. In 1992, these species peaked for about a week, which was slightly shorter than migration peaks reported in south-central Saskatchewan (1-2 weeks) (Colwell et al. 1988) and longer than the 1-3 day peaks at the refuge in 1993. During wet conditions in 1993, shorebirds may have stopped more frequently at replenished wetlands to forage

and therefore, did not stay as long at Quivira NWR.
Alternatively, if high water conditions in 1993 improved
habitat for aquatic prey species at Quivira NWR, shorebirds
may not have had to stay as long in 1993 compared to 1992 to
gain necessary fat reserves.

Temporal Segregation.--At Quivira NWR, we found
temporal segregation of shorebirds on several levels; size
classes were separated throughout censusing periods in both
years. Large shorebirds generally peaked early in the
censusing period, medium shorebirds peaked in mid-period,
and small shorebirds were most common at the end of the
period.

Variable migration timing may allow similar-sized
shorebirds to avoid competition for limited resources at
migratory stopover areas where population densities are high
(Recher 1966, Myers 1981). During spring migration along
California and New Jersey coasts, Recher (1966) found
temporal separation between similar-sized shorebirds.
Helmers (1991) made similar observations at Cheyenne Bottoms
WMA. At Quivira NWR, dominant species in the small and
medium size classes were segregated throughout the censusing
period in 1993. In the small size class, Baird's and White-
rumped Sandpipers were clearly segregated in 1993. The most
dominant species in the medium size class, Stilt Sandpipers
and Long-billed Dowitchers, were not segregated temporally
in 1992, but they were in 1993. Helmers (1991) found
overlap in foraging depths between these two species during

fall migration and concluded that they could be negatively impacted by resource overlap. In mid-May 1993, Stilt Sandpipers overlapped with Dunlins, the third dominant species in the class. Dunlins were a minor (1.7%) component of the class, and their numbers likely were not high enough to result in competitive interactions.

Temporal segregation among shorebirds at Quivira NWR also was indicated by inversely proportional relative daily abundances of dominant species in all three size classes in 1992 and 1993. Such a pattern may have reflected differing migration pulses that minimized concurrent occurrence of similar-sized species on the refuge and thus minimized interspecific competitive interactions. Conversely and assuming that resources were limited and competitive interactions operative, one species may have displaced others to habitats off our census route. However, we view this scenario as unlikely because random observations of shorebirds off our census route did not indicate that different species occurred elsewhere in the area.

MANAGEMENT IMPLICATIONS

Effective management of inland stopover areas used by shorebirds (Rundle and Fredrickson 1981, Eldridge 1992, Helmers 1992) should be properly timed with migration to meet habitat requirements of physiologically stressed migrants (Skagen and Knopf 1993). South-central Kansas and Quivira NWR are crucial to shorebirds from April through June (Harrington et al. 1991; Helmers 1992; Skagen and Knopf

1993, 1994). We observed the maximum number of shorebirds and species in late April through late May, but some species arrived in early April (and probably in late March [Parmelee et al. 1969b, Reid et al. 1983, Buchnanan 1988] prior to our censusing).

Managers should provide a matrix of wetland types with varying water depths (Colwell et al. 1988, Helmers 1992) in mid-May when the maximum number of shorebird species and individuals often occur. Many species in the medium size class were most abundant in mid-May including Stilt Sandpipers and Long-billed Dowitchers, which are major components of shorebird communities in south-central Kansas (Helmers 1991, 1992; Skagen and Knopf 1993, 1994).

Habitat availability also is critical in late May when White-rumped Sandpipers were most abundant. These sandpipers migrate to the breeding grounds primarily through interior North America and thus are vulnerable to loss of stopover areas in the Great Plains (Harrington et al. 1991; Helmers 1991, 1992; Skagen and Knopf 1993, 1994). Quality habitat must be available in south-central Kansas in late May to ensure reproductive success of White-rumped Sandpipers.

Our data highlight the importance of Quivira NWR to shorebirds during a variety of water and habitat conditions. Stopover habitat at Quivira NWR may be critical to migrating shorebirds particularly small species, during dry conditions when unmanaged habitat is limited and when habitat at large

staging areas, such as Cheyenne Bottoms WMA, is scarce due
to drought, flooding or vegetation encroachment (Smith et
al. 1991, Skagen and Knopf 1993).

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Table 1. Relative abundances of shorebird size classes by species or species groups (as a percentage of the total community) at Quivira National Wildlife Refuge, Kansas, 1992 and 1993.

		Census Period		
		1992	1993	1993
		26 Apr – 5 Jun	26 Apr – 5 Jun	6 Apr – 12 Jun
Class[a]	Species/species group[b]	(n = 15 censuses)	(n = 20)	(n = 32)
Large Size	American Avocet	1.6	0.3	1.2
	Black-necked Stilt	0.2	0.1	0.1
	Greater Yellowlegs	0.3	<0.1	<0.1
	Hudsonian Godwit	0.4	<0.1	<0.1
	Lesser Yellowlegs	1.9	0.1	0.1
	Marbled Godwit	0.1	0	0
	Upland Sandpiper	<0.1	<0.1	<0.1
	Whimbrel	<0.1	0	0
	Willet	0.3	<0.1	<0.1
	Unidentified Godwits	0.2	0	<0.1

Table 1. Continued.

Class	Species/species group[a]	Census Period		
		1992	1993	1993
		26 Apr - 5 Jun (n = 15 censuses)	26 Apr - 5 Jun (n = 20)	6 Apr - 12 Jun (n = 32)
	Unidentified Yellowlegs	3.0	0.2	0.3
	Total	8.1	0.8	1.8
Medium Size	Black-bellied Plover	<0.1	<0.1	<0.1
	Dunlin	0.2	0.2	0.2
	Lesser Golden-plover	<0.1	0	<0.1
	Long-billed Dowitcher	6.5	0.8	0.7
	Pectoral Sandpiper	1.5	<0.1	<0.1
	Ruddy Turnstone	<0.1	0.1	0.1
	Solitary Sandpiper	<0.1	0	0
	Stilt Sandpiper	19.6	10.8	9.3

Table 1.   Continued.

Class	Species/species group[a]	Census Period		
		1992	1993	1993
		26 Apr - 5 Jun (n = 15 censuses)	26 Apr - 5 Jun (n = 20)	6 Apr - 12 Jun (n = 32)
	Unidentified	0.4	<0.1	<0.1
	Total	28.5	12.2	10.5
Swimmer	Red-necked Phalarope	<0.1	<0.1	<0.1
	Wilson's Phalarope	23.7	3.1	2.8
	Total	23.7	3.1	2.8
Small Size	Baird's Sandpiper	1.0	0.1	3.8
	Least Sandpiper	0.2	0.2	0.1
	Piping Plover	<0.1	<0.1	<0.1
	Sanderling	0.2	0.1	0.1
	Semipalmated Plover	0.1	0.1	0.1
	Semipalmated Sandpiper	1.9	3.5	4.4

Table 1.   Continued.

		Census Period		
		1992	1993	1993
		26 Apr - 5 Jun	26 Apr - 5 Jun	6 Apr - 12 Jun
Class	Species/species group[a]	(n = 15 censuses)	(n = 20)	(n = 32)
	Spotted Sandpiper	0.2	<0.1	<0.1
	Western Sandpiper	<0.1	0	0
	White-rumped Sandpiper	12.4	46.1	41.9
	Unidentified Peeps	23.5	33.7	34.2
	Total	39.7	84.0	84.9
Number of shorebirds		23,604	58,632	68,552
Total number of species		29	23	24

[a]Size classes (small, medium, and large) based on mean tarsus length (Hayman et al. 1986).   Phalaropes (Phalaropus spp.) as separate class; "swimmers."

[b]See appendix A for scientfic names.

Table 2. Relative abundances of shorebird foraging guilds by species or species groups (as a percentage of the total community) at Quivira National Wildlife Refuge, Kansas, 1992 and 1993.

		Census Period		
		1992	1993	1993
Foraging		26 Apr – 5 Jun	26 Apr – 5 Jun	6 Apr – 12 Jun
Guild	Species/species group[a]	(n = 15 censuses)	(n = 20)	(n = 32)
Large Gleaner	Black-bellied Plover	<0.1	<0.1	<0.1
	Black-necked Stilt	0.2	0.1	0.1
	Lesser Golden-plover	<0.1	0	<0.1
	Lesser Yellowlegs	1.9	0.1	0.1
	Greater Yellowlegs	0.3	<0.1	<0.1
	Solitary Sandpiper	<0.1	0	0
	Upland Sandpiper	<0.1	<0.1	<0.1
	Willet	0.3	<0.1	<0.1
	Unidentified Yellowlegs	3.0	0.2	0.3

Table 2. Continued.

Foraging Guild	Species/species group[a]	Census Period		
		1992	1993	1993
		26 Apr – 5 Jun (n = 15 censuses)	26 Apr – 5 Jun (n = 20)	6 Apr – 12 Jun (n = 32)
	Total	5.9	0.6	0.7
Large Prober	Dunlin	0.2	0.2	0.2
	Hudsonian Godwit	0.4	<0.1	<0.1
	Long-billed Dowitcher	6.5	0.8	0.7
	Marbled Godwit	0.1	0	0
	Pectoral Sandpiper	1.5	<0.1	<0.1
	Ruddy Turnstone	<0.1	0.1	0.1
	Stilt Sandpiper	19.6	10.8	9.3
	Whimbrel	<0.1	0	0

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Table 2. Continued.

Foraging Guild	Species/species group[a]	Census Period		
		1992	1993	1993
		26 Apr - 5 Jun (n = 15 censuses)	26 Apr - 5 Jun (n = 20)	6 Apr - 12 Jun (n = 32)
	Total	28.5	12.5	10.4
Large Sweeper	American Avocet	1.6	0.3	1.2
	Total	1.6	0.3	1.2
Small Prober/Gleaner[b]				
	Total	39.7	84.0	84.9
Swimmers	Red-necked Phalarope	<0.1	<0.1	<0.1
	Wilson's Phalarope	23.7	3.1	2.8
	Total	23.7	3.1	2.8

Table 2. Continued.

		Census Period		
		1992	1993	1993
Foraging		26 Apr – 5 Jun	26 Apr – 5 Jun	6 Apr – 12 Jun
Guild	Species/species group[a]	(n = 15 censuses)	(n = 20)	(n = 32)
	Number of shorebirds	23,604	58,632	68,552

[a]See Appendix A for scientific names.

[b]Species composition was identical to the small size class; see table 1.

FIGURE LEGENDS

Fig. 1. Migration chronology of shorebird size classes (small, medium, and large based on mean tarsus lengths) as a percentage of total observed in each class during (A) 26 April-5 June 1992 and (B) 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas.

Fig. 2. Migration chronology of the 3 dominant shorebird species in the small size class and small prober/gleaner foraging guild as percent abundance of each species: (A) Baird's Sandpiper (n = 244), Semipalmated Sandpiper (n = 451), and White-rumped Sandpiper (n = 2,914) during 26 April-5 June 1992 and (B) Baird's Sandpiper (n = 2,634), Semipalmated Sandpiper (n = 3,000), and White-rumped Sandpiper (n = 28,744) during 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas.

Fig. 3. Migration chronology of the 3 dominant shorebird species in the medium size class and large prober foraging guild as percent abundance of each species: (A) Stilt Sandpiper (n = 4,621), Long-billed Dowitcher (n = 1,529), and Pectoral Sandpiper (n = 365) during 26 April-5 June 1992 and (B) Stilt Sandpiper (n = 6,400), Long-billed Dowitcher (n = 495), and Dunlin (n = 118) during 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas.

Fig. 4. Relative daily abundances of the 3 dominant

shorebird species in the small size class and small prober/gleaner foraging guild: (A) Baird's Sandpiper (n = 244), Semipalmated Sandpiper (n = 451), and White-rumped Sandpiper (n = 2,914) during 26 April-5 June 1992 and (B) Baird's Sandpiper (n = 2,634), Semipalmated Sandpiper (n = 3,000), and White-rumped Sandpiper (n = 28,744) during 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas. Solid inverse triangles indicate census dates.

Fig. 5. Relative daily abundances of the 3 dominant shorebird species in the large prober foraging guild and medium size class: (A) Stilt Sandpiper (n = 4,621), Long-billed Dowitcher (n = 1,529), and Pectoral Sandpiper (n = 365) during 26 April-5 June 1992 and (B) Stilt Sandpiper (n = 6,400), Long-billed Dowitcher (n = 495), and Dunlin (n = 118) during 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas. Solid inverse triangles indicate census dates.

Fig. 6. Relative daily abundances of the 3 dominant shorebird species in the large size class: (A) Lesser Yellowlegs (n = 459), Hudsonian Godwit (n = 94), and Greater Yellowlegs (n = 72) during 26 April-5 June 1992 and (B) Lesser Yellowlegs (n = 85), Hudsonian Godwit (n = 40), and Greater Yellowlegs (n = 50) during 6 April-12 June 1993, Quivira National Wildlife Refuge, Kansas. Solid inverse triangles indicate census dates.
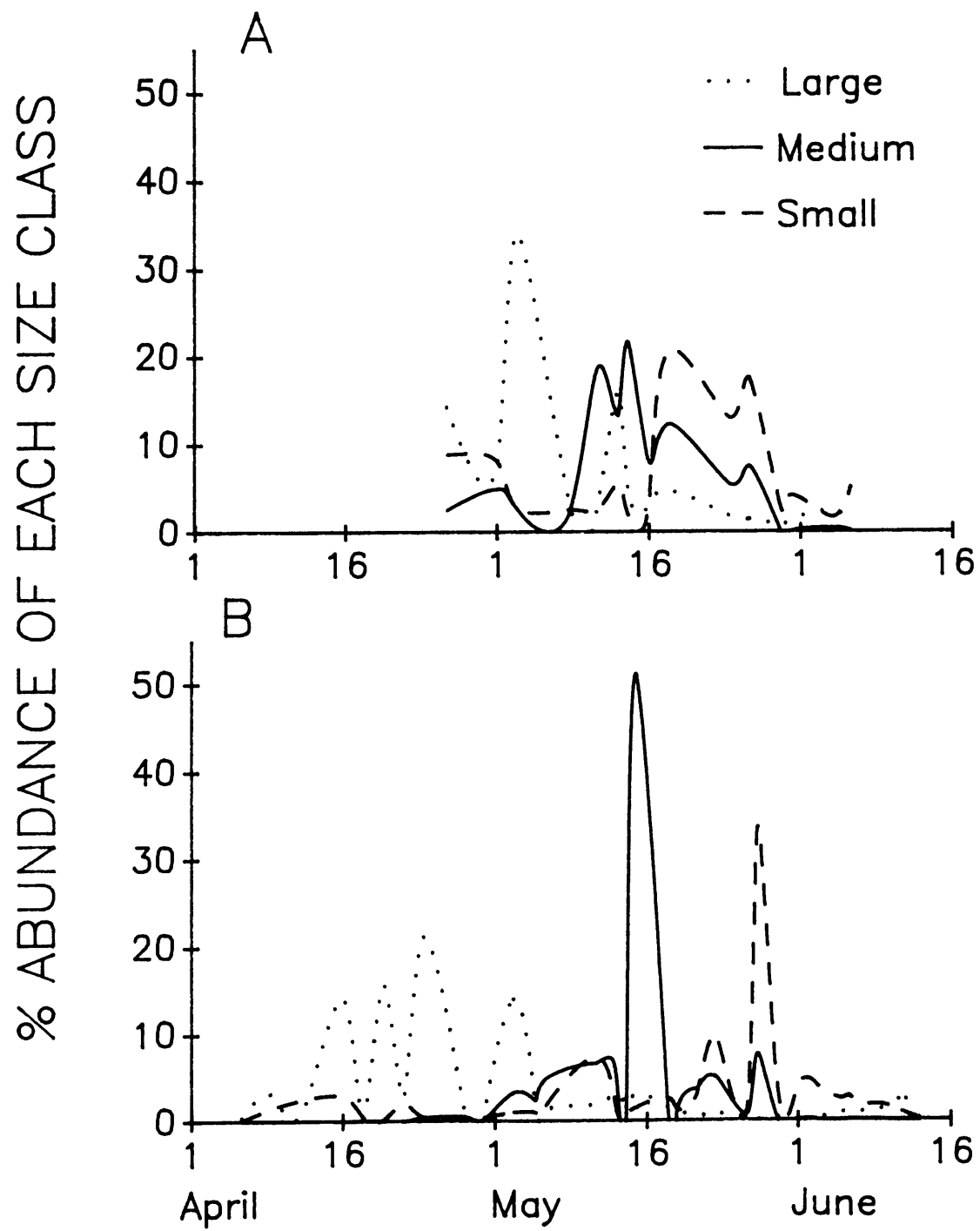
Fig. 1
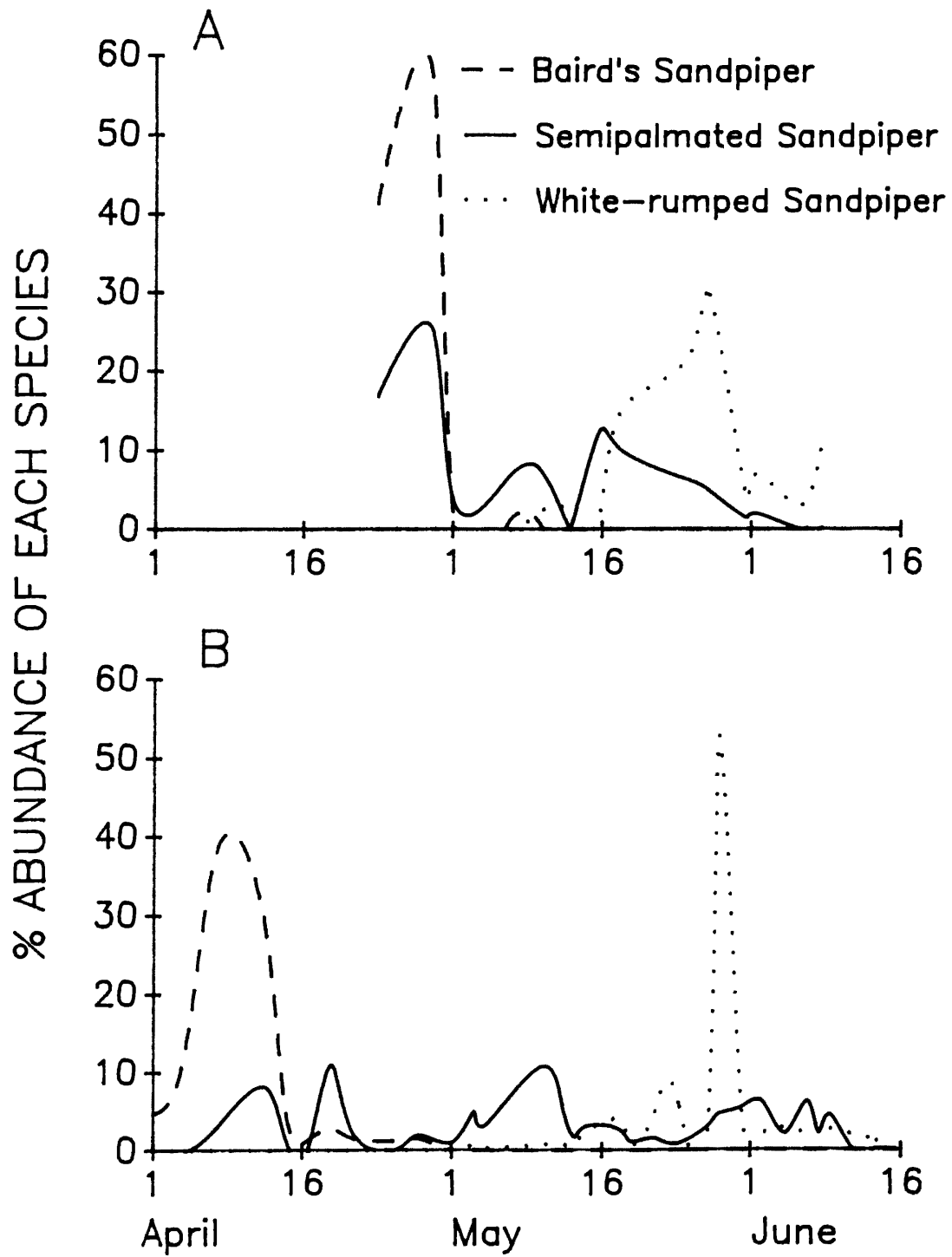
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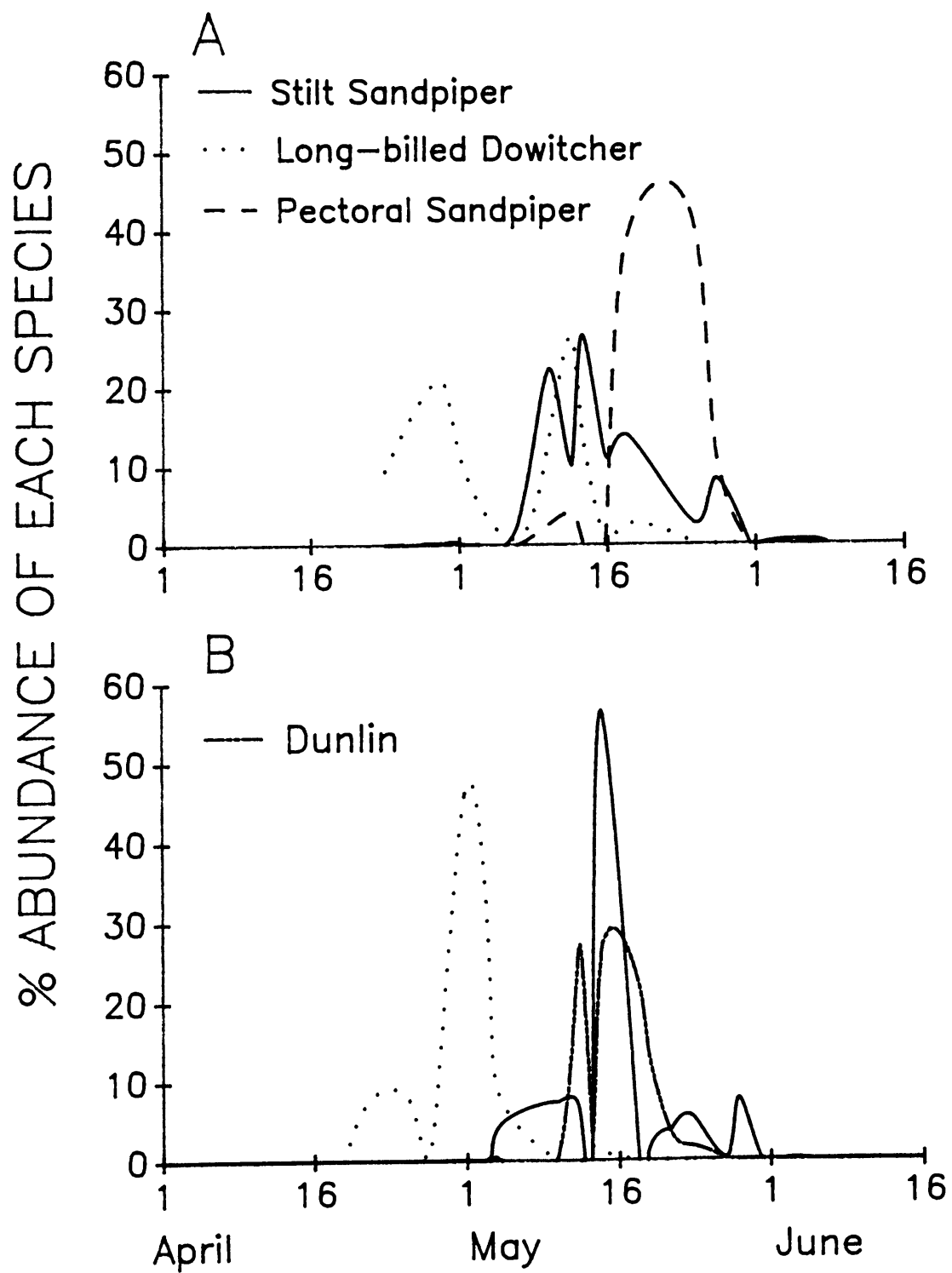
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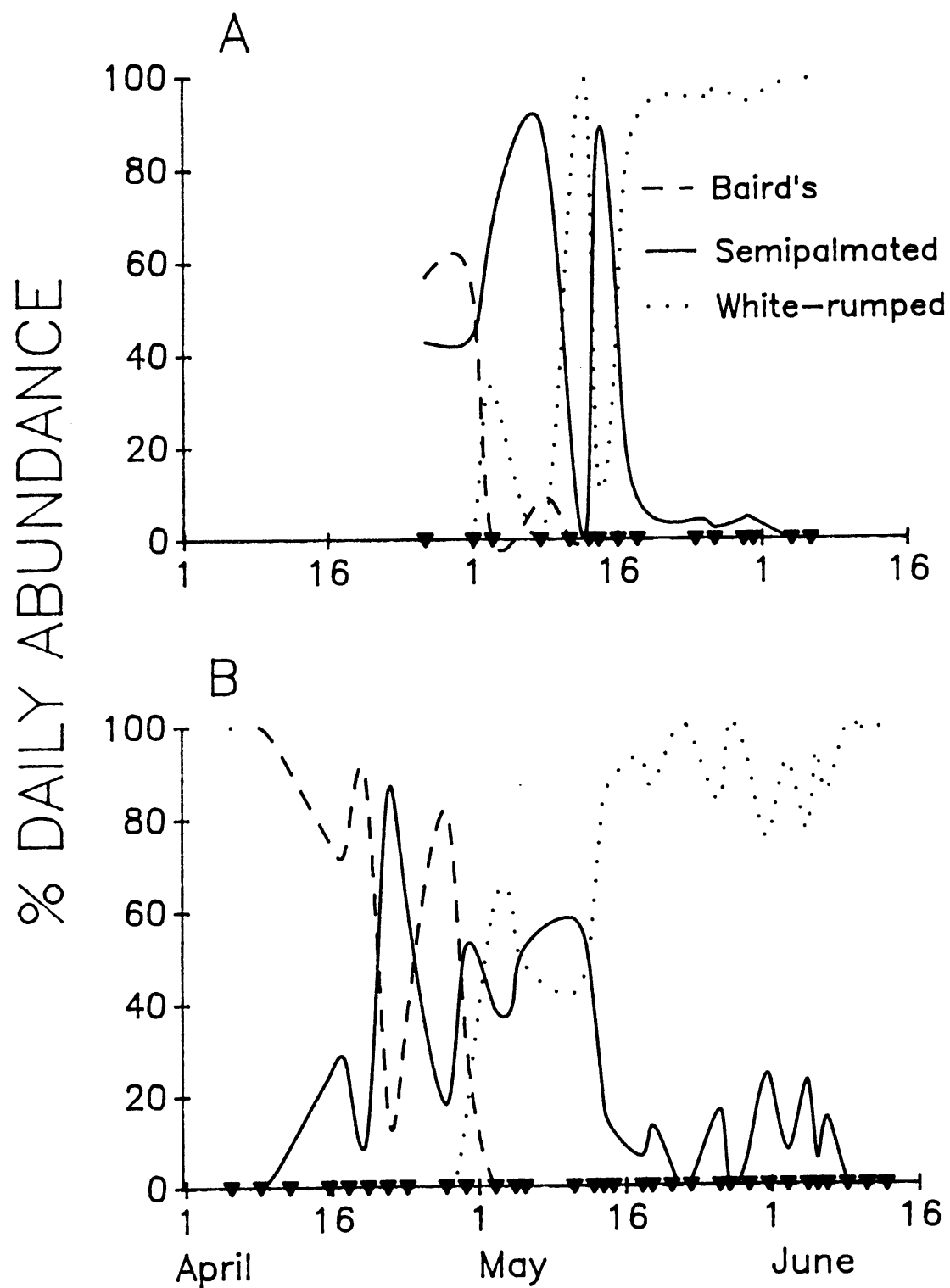
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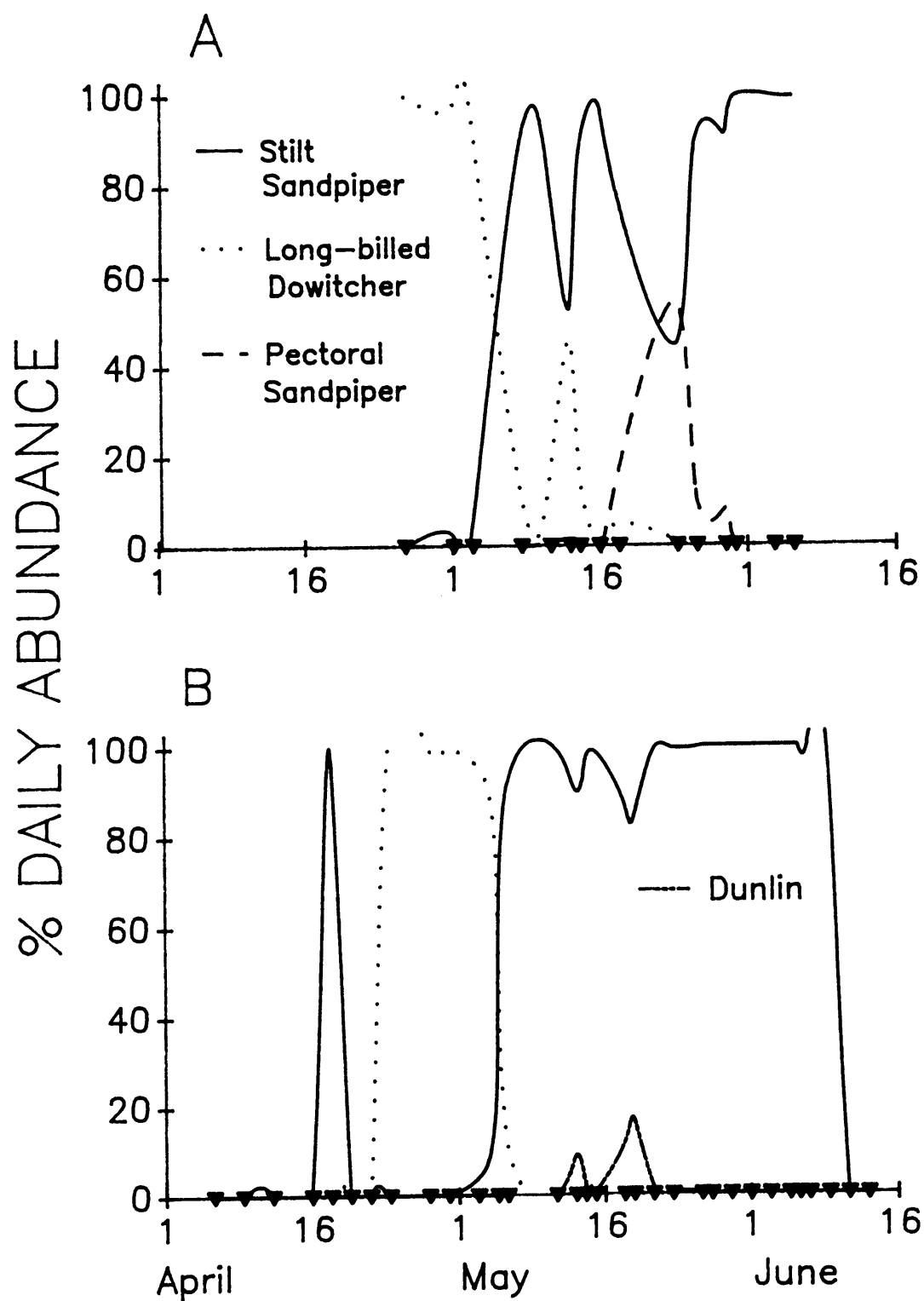
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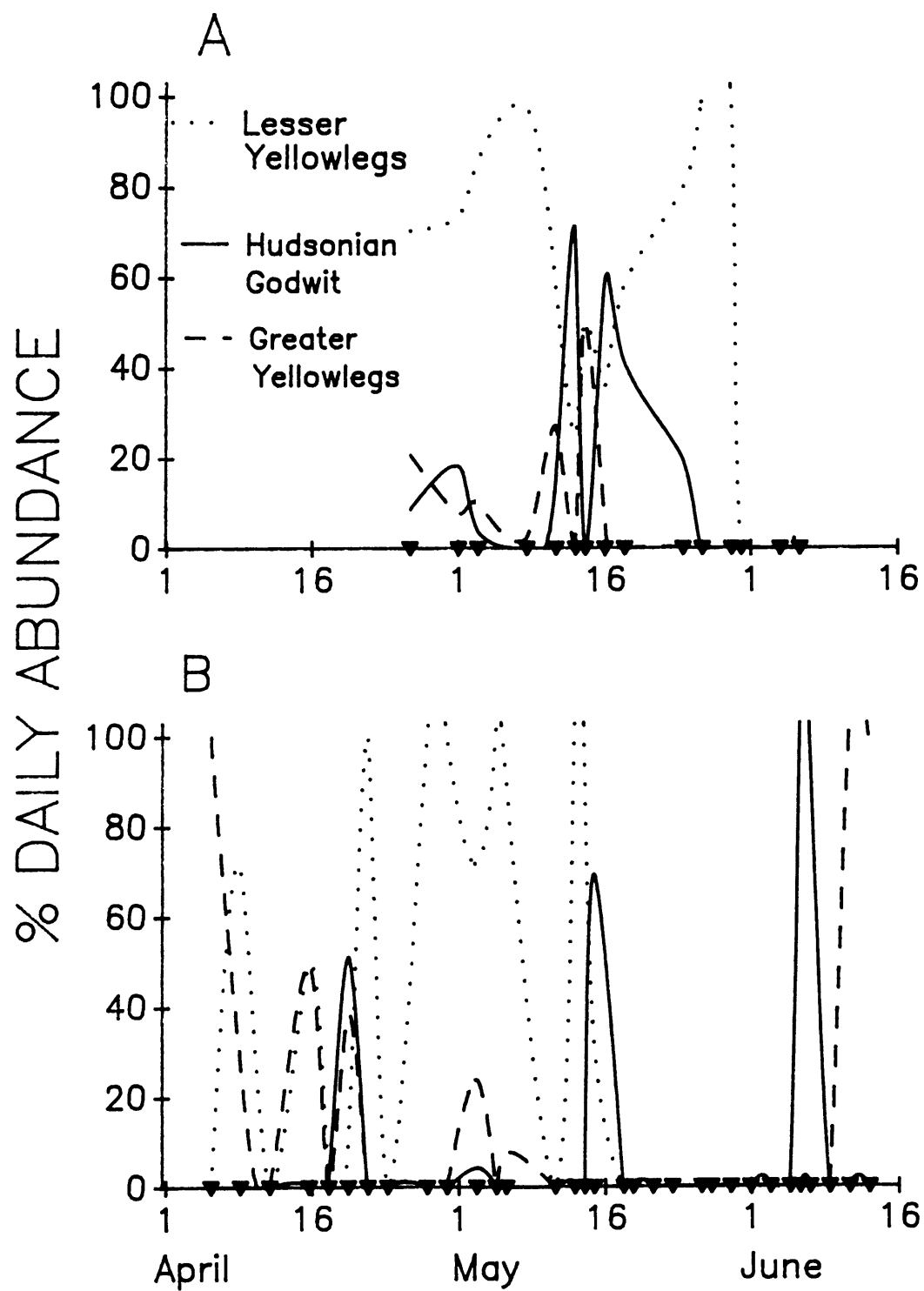
Fig. 6

CHAPTER III

SHOREBIRD HABITAT USE AND RESPONSE TO BURNED MARSHES DURING SPRING MIGRATION IN SOUTH-CENTRAL KANSAS

Abstract.--We evaluated spring migrating shorebird (Aves: Charadrii) use of macrohabitat types in 3 management areas (spring burns, unvegetated, and vegetated) at Quivira National Wildlife Refuge (NWR) in south-central Kansas. Grouping shorebirds by size classes based on mean tarsus lengths or foraging guilds generally resulted in the same conclusions on habitat use. Shorebird size classes (small, medium, and large) preferred macrohabitats in all 3 management areas; however, small shorebirds preferred more macrohabitats than any other size class. Shorebird response to burned habitats depended on size class and type of wetland burned. In 1992, large shorebirds preferred burned water units, and small shorebirds preferred burned semi-permanent reservoir. Microhabitat composition and availability were dynamic within and between years and influenced macrohabitat selectivity of small shorebirds.

Each spring, millions of shorebirds from >39 species migrate from Central and South America through the Great Plains to breed in the Arctic (Myers et al. 1987).

Shorebirds briefly interrupt migration to forage intensely on prairie stopover sites. Lipid reserves obtained on these stopover sites fuel the remaining journey to the breeding grounds (Davidson and Evans 1988, Harrington et al. 1991). Short arctic summers permit only 1 nesting attempt per year (Myers et al. 1987). Early arrival in optimal body condition at the breeding grounds and rapid nesting increase reproductive success (Hilden 1979). Therefore, it is critical to shorebird conservation that prairie stopover sites provide adequate foraging habitat in early spring. Effective management of these sites requires knowledge of migrant shorebird use of prairie wetland habitats (Helmers 1992).

Most data on shorebird habitat use have been collected in coastal areas (Burger et al. 1977, Harrington 1982, Funderbuck and Springer 1989, Withers and Chapman 1993) or at inland stopover sites in the midwestern United States (Rundle and Fredrickson 1981, Eldridge 1990, Hands et al. 1991). Migrant shorebird habitat use also has been documented in Saskatchewan (Colwell and Oring 1988) and south-central Kansas (Helmers 1991; Skagen and Knopf 1993, 1994). However, shorebird selectivity or avoidance of prairie wetland types has not been documented.

South-central Kansas is an important staging area for migrant shorebirds (Harrington et al. 1991, Skagen and Knopf 1993). At Quivira NWR, shorebirds forage in discrete man-made water units and ephemeral wetlands (Skagen and Knopf

1994). Managers can manipulate water levels in water units and provide critical shorebird habitat when availability of ephemeral wetlands is limited. As with many prairie wetlands, these water units have become overgrown with emergent vegetation. Most shorebird species use shallow water habitats with <25% vegetative cover (Burger et al. 1977, Colwell and Oring 1988, Hands et al. 1991, Helmers 1991), and reduction of vegetation-free wetland edges may diminish habitat suitability to foraging shorebirds (Colwell and Oring 1988). Prescribed burning may maintain wetlands in early successional stages and provide a relatively vegetation-free habitat for shorebirds (Eldridge 1990, Helmers 1991). Responses of migrating shorebirds to burned habitats, however, have not been evaluated. Consequently, we burned several vegetated water units at Quivira NWR to expand vegetation-free shallow water habitat for shorebirds.

Our objectives were to: (1) evaluate habitat preferences of spring migrating shorebirds, particularly their use of burned habitats; (2) determine if spring burning was a viable tool in managing habitat for migrating shorebirds; and (3) quantify changes in habitat availability in seasonally dynamic prairie wetlands. We tested the null hypothesis that migrating shorebirds used habitats, including burned areas, in proportion to their availabilities.

STUDY AREA

We conducted our study at Quivira NWR in Stafford,

Rice, and Reno counties in south-central Kansas. The 8,728-ha refuge contained grasslands, natural mudflats and salt marshes, saline semi-permanent reservoirs, and 34 man-made water units constructed between 1963 and 1966. Around the periphery of each water unit was a "borrow" area that resulted from dirt being "borrowed" from the unit to build the dike; the resulting area was like a ditch with greater depth than other parts of the water unit. We formally distinguished this borrow area from the rest of the water unit. Water units were filled naturally or by water diverted into borrow areas from Rattlesnake Creek through a system of canals and water control structures. Semi-permanent reservoir was an extensive natural salt marsh used to store water for diversion purposes. The periphery of semi-permanent reservoir was vegetated, primarily with cattails (<u>Typha</u> <u>latus</u>), phragmites (<u>Phragmites</u> spp.), salt grass (<u>Distichlis</u> <u>spicata</u>), and other wetland vegetation. Water levels in semi-permanent reservoir fluctuated due to precipitation, wind, and water levels in Rattlesnake Creek.

Refuge waters were slightly to moderately saline; soils ranged from light sands to clay loam and were neutral to alkaline (U.S. Fish and Wildl. Serv. [FWS] 1990). Average annual precipitation was 62 cm (1931-1991); however, the refuge received 80 cm in 1992 and 56.8 cm during January-June 1993 (Quivira NWR unpubl. data).

METHODS

<u>Habitat Alterations and Characteristics.</u>--We burned

water units to reduce vegetation, primarily cattail and grasses (i.e., prairie cordgrass [Spartina pectinata], Indian grass [Sorghastrum nutans], and switch grass [Panicum virgatum]). We planned to reflood burned water units immediately after burning to provide shallow water habitat for invertebrate colonization. Spring prairie burns rarely remove all vegetation (Wright and Bailey 1982); therefore, we anticipated that partially burned and flooded plant debris would provide a detrital base attractive to invertebrates, the primary food source of shorebirds (Baldassare and Fischer 1984, Eldridge 1987, Helmers 1991).

In late March and early April 1992, we burned 89.6 ha in 6 disjunct water units. Due to a lack of impounded water, we were not able to reflood water units until 3-4 weeks after burning. Independent of our study, refuge personnel burned 1.6 ha along the edge of semi-permanent reservoir in early March 1992 to reduce phragmites. In 1993, the refuge had abnormally high water conditions due to extreme precipitation and high incoming flows from Rattlesnake Creek. Prior to the 1993 field season (Oct 1992-Mar 1993), the refuge received 14.6 cm of precipitation; the 60-year average during this time was 6.5 cm (Quivira NWR unpubl. data). High water levels in 1993 prevented burning semi-permanent reservoir and limited burning efforts in water units. Nevertheless, we burned 27.2 ha in 2 disjunct water units on 2 and 26 April 1993.

We evaluated migrant shorebird use of 3 major

management areas: burned, unvegetated, and vegetated. In
1992, a total of 8 macrohabitats among the 3 management
areas was sampled: burned semi-permanent reservoir, burned
water units, borrow area, unburned semi-permanent reservoir,
mudflat, mixed flats, mosaic flats, and salt grass edge
(Table 1). Unburned semi-permanent reservoir was a segment
of the open, unvegetated part of the reservoir. Mudflats
were >6 ha of open, unvegetated substrate. In contrast,
mosaic flats had patches <6 ha of open, unvegetated
substrate within expanses of salt grass. Mixed flats had
clumps of vegetation (i.e., <0.25 m in diameter), usually
salt grass, and equal areas of unvegetated substrate. Salt
grass edge was the 1-3 m perimeter of mudflats. In 1993, we
sampled 6 of these 8 macrohabitats because semi-permanent
reservoir was not burned and borrow areas contained >1 m of
water, which rendered them unavailable to shorebirds.

We identified microhabitats within each macrohabitat on
the basis of soil moisture and vegetation (Burger et al.
1977, Kelsey and Hassall 1989, Funderburk and Springer 1989,
Helmers 1991, Skagen and Knopf 1993). In unvegetated
macrohabitats, 6 microhabitats were identified: dry
unvegetated substrate (dry mud); damp unvegetated substrate
(wet mud); unvegetated substrate with a 1-2 mm film of water
(water-mud interface); shallow water (up to a small _Calidris_
spp. belly; 2-4 cm); medium water (up to an American avocet
[_Recurvirostra americana_] belly; 5-10 cm); and deep water
(too deep for American avocets to stand in; >11 cm). In the

Great Plains, high winds can move water from 1 end of a mudflat or semi-permanent reservoir to another within hours (Skagen and Knopf 1994), altering microhabitat composition and availability. As a result, we visually estimated percent availability of each microhabitat type in unvegetated macrohabitats during each census (Weir and Cooke 1976, Helmers 1991, Skagen and Knopf 1994). In vegetated and burned macrohabitats, these six microhabitats were identifiable in conjunction with vegetative characteristics (e.g., wet mud/salt grass and shallow water/burned stem) resulting in a mosaic of many microhabitats. However, we could not visually estimate the availability of all these microhabitats with accuracy and therefore we grouped shorebird use of them into a single "vegetated" microhabitat.

Shorebird Censuses.--We conducted censuses at least biweekly (Rundle and Fredrickson 1981, Ryan et al. 1984, Funderburk and Springer 1989, Hands et al. 1991) from April to June, 1992 and 1993. The same observer conducted all censuses with a 15-60 variable-power scope and 10 x 80 binoculars from a vehicle along a fixed survey route alternating start and finish locations. Due to typically windy (>30 mph) mid-day conditions, censuses were conducted from sunrise to 1200 h and 1600 h to sunset (Helmers 1991). At least 1 census was conducted in each diel period per week.

When feasible, shorebirds were identified to species.

During poor lighting or when birds were at great distances from the vehicle, identification was made by size or species class. For example, small unidentifiable _Calidris_ species were labelled "peeps." Greater yellowlegs (_Tringa melanoleuca_) and lesser yellowlegs (_T. flavipes_) that could not be identified to species were labelled "yellowlegs." Regardless of viewing conditions, we did not attempt to differentiate between morphologically similar short-billed dowitchers (_Limnodromus scolopaceus_) and long-billed dowitchers (_L. griseus_). At Quivira NWR, short-billed dowitchers are rare compared to long-billed dowitchers (Skagen and Knopf 1994); therefore, we considered all dowitchers to be long-billed dowitchers. We did not enumerate snowy plovers (_Charadrius alexandrinus_) and killdeer (_C. vociferus_) in our censuses because they were primarily breeding at the refuge versus migrating. American avocets, black-necked stilts (_Himantopus mexicanus_), and to a lesser degree, spotted sandpipers (_Actitis macularia_) and Wilson's phalaropes (_Phalaropus tricolor_) also nested at our study site. Individuals of these species that displayed breeding or nesting behavior (i.e., copulation, incubation, nest defense, etc.) were not included in analyses. Shorebirds that flushed from a census unit as the vehicle approached also were excluded from analysis.

A tape recorder was used during censuses to record the macro- and microhabitat (when possible) that each shorebird occupied. When shorebirds were in water microhabitats,

water depth was described by relating water level to an individual's upper tarso-metatarsal joint; i.e., below the joint, at the joint, above the joint, and to the belly (Baker and Baker 1973, Colwell and Oring 1988, Helmers 1991).

Most wildlife communities contain a relatively large number of individuals belonging to a few species and relatively few individuals of many species (Krebs 1989). Therefore, we grouped similar species to evaluate the shorebird community. Except for swimming Phalaropes (Phalaropus spp.), shorebirds are primarily limited to water depths proportional to leg length (Baker 1979) and body size and have been grouped accordingly (Morrison et al. 1993, Skagen and Knopf 1993). We reasoned that tarsus length was the critical factor in shorebird use of water microhabitats and identified 3 size classes (small, medium, and large) based on mean tarsus length (Hayman et al. 1986). The small size class included shorebirds with mean tarsus lengths between 19-25 mm; i.e., most Calidris species and smaller Charadrius species. Medium and large size classes included shorebirds with mean tarsus lengths of >25-47 mm and >47 mm, respectively (Appendix A). Because phalaropes were not restricted by water depth, they were classified as "swimmers."

Foraging modes can differ between groups of similar sized shorebirds, so they also have been grouped by foraging guilds (Wilcox 1986, Helmers 1991). We defined foraging

guilds based on 2 classes of mean tarsus lengths (small [<25 mm] and large [$\geq$25 mm]) in conjunction with 3 foraging modes: probing, gleaning, and sweeping (Helmers 1991). Small gleaners comprised <2% of the small size class; therefore, we did not analyze the small class based on foraging guilds but considered it the small prober/gleaner guild. We had 5 foraging guilds: small prober/gleaners, large probers, large gleaners, pelagic gleaners (phalaropes), and large sweepers (American avocets) (Appendix A). The pelagic gleaner guild and the large sweeper guild each contained 1 species; therefore, analyses focused on the small prober/gleaner, large prober, and large gleaner foraging guilds.

Data Analysis.--We used chi-square analyses (Cochran 1954) to test the null hypothesis that shorebird size classes and foraging guilds used macro- and microhabitats in proportion to their availabilities and a Bonferroni Z-statistic (Neu et al. 1974, Leslie and Stancill 1990, Leptich 1992) to evaluate macro-and microhabitat preferences. We combined censuses in each year to analyze macrohabitat preference. We used aerial photographs (1:7,920) and a planimeter to delimit each macrohabitat along the census route. We considered availability of each macrohabitat to be the actual area it occupied on the census route, regardless of availability of "useable" shorebird microhabitats (wet mud, water-mud interface, and shallow water). For example, in 1992, we considered all of the 89.6

ha of burned water unit available, even if portions of them were unusable (i.e., >0.5 m of water or >25% cover) for shorebirds.

Our approach to the statistical evaluation of microhabitat selection was hierarchical (Leslie and Stancill 1990); we evaluated small shorebird selection of microhabitats in only preferred macrohabitats. We evaluated microhabitat selection by census day due to daily changes in microhabitat availability. We could evaluate shorebird selection of microhabitats in only unvegetated macrohabitats. In burned and vegetated macrohabitat types, we could not visually estimate microhabitat availabilities because microhabitat types were so numerous and because they occurred in small patches. Statistical significance was set at $P < 0.05$.

RESULTS

In 1992, we conducted 15 censuses from 26 April to 5 June and observed 23,604 shorebirds (x = 1,573 shorebirds/census). In 1993, we extended the field season from 6 April to 12 June; we conducted 32 censuses and observed 68,552 shorebirds (x = 2,142 shorebirds/census).

Shorebird Community.--We observed 29 species in 1992 and 24 in 1993 (Chapter II). In 1992, dominant community members (>5% of the total community) were Wilson's phalaropes, stilt sandpipers (Calidris himantopus), white-rumped sandpipers (C. fuscicollis), and long-billed dowitchers; they comprised 62.2% of the total community.

During the comparable time period in 1993, 56.9% of the total community consisted of only 2 dominant species, white-rumped sandpipers and stilt sandpipers (Chapter II). The small shorebird class dominated the community both years; 39.7% in 1992 and 84.0% in 1993. The medium size class was second most abundant in both years; 28.5% in 1992 and 12.2% in 1993. Swimmers comprised 23.7% of the total community in 1992 but declined to 3.1% in 1993. Large shorebirds were a minor component of the community in both years; 8.1% in 1992 and 0.8% in 1993.

Grouping Shorebirds.--In 1992 and 1993, grouping species by size versus foraging guilds generally resulted in the same classification of species (Chapter II). The small size class was identical to the small prober/gleaner guild, and the medium class was very similar in species composition and relative abundance to the large prober guild. There were some differences, notably American avocets, between the large class and large gleaner guild. Many shorebird species are opportunistic foragers (Eldridge 1992) and use >1 foraging mode, primarily probing and gleaning (Helmers 1992). This makes classification by foraging guilds somewhat subjective (Verner 1984).

Macrohabitat Use and Availability.--Although shorebirds were observed in every macrohabitat, small and medium shorebirds were prevalent (>20% of the class) in only 2 macrohabitats, and large shorebirds were prevalent in only 1 macrohabitat in both years (Table 2). In 1992, small

shorebirds were most common in unburned semi-permanent reservoir (40.4%) and mudflat (32.0%); medium shorebirds were most common in unburned semi-permanent reservoir (46.0%) and burned water units (29.5%); and large shorebirds were most common in burned water units (72.1%). In 1993, shorebirds were observed most frequently in mudflat: 69% of small, 49.6% of medium, and 50.9% of large shorebirds.

For most of the 1993 censusing period, unburned semi-permanent reservoir was inundated by water too deep (i.e., >0.5 m) for shorebird use. However, during 1 census, 55 large shorebirds were observed in an isolated pocket of relatively shallow water of unburned semi-permanent reservoir. Therefore, we included it in our analysis of large shorebird macrohabitat selection. As a result, we analyzed small and medium shorebird selection of 5 macrohabitat types and large shorebird selection of 6 macrohabitats in 1993.

Shorebirds--either by size classes and foraging guilds--did not use macrohabitats in proportion to their availabilities (Table 3). Additionally, macrohabitat selection was identical between size classes and respective foraging guilds, except for a few differences between the large size class and large gleaner foraging guild (Table 3). We present only size class results, except when the large size class differed from large gleaners.

Selection of burned macrohabitats varied depending on shorebird size class and the type of wetland that was burned

(Table 3). In 1992, burned semi-permanent reservoir, although very uncommon on the refuge (0.7%), was preferred by small shorebirds. Medium and large shorebirds showed no selection for it. Semi-permanent reservoir was not burned in 1993. Small and medium shorebirds avoided burned water units in both years. The large shorebird class and the large gleaner guild responded differently to burned water units. Large shorebirds preferred burned water units in 1992 when the class was dominated (65.1%) by lesser yellowlegs and greater yellowlegs, but they showed no selection for it in 1993 when American avocets were dominant (58.0%). Large gleaners, primarily lesser yellowlegs and greater yellowlegs, preferred burned water unit in both years. Additionally, burned water unit was the only macrohabitat preferred by large gleaners in 1992.

Shorebirds responded to burned water units immediately after burning, but use was short term (Fig. 1B). Burned water units were not preferred by the medium class, but some species in the class (solitary sandpipers [Tringa solitaria], lesser golden-plovers [Pluvialis dominica], and upland sandpipers [Bartramia longicauda]) were observed only in burned water units in both years. Additionally, most long-billed dowitchers (70.8% in 1992 and 62.4% in 1993) were observed in burned water units.

Most macrohabitats were preferred by >1 size class, except for mudflat in 1992 and mixed flat in both years (Table 3). Unburned semi-permanent reservoir was preferred

in 1992 by all size classes except large gleaners, which avoided it. Salt grass edge was preferred by all size classes in both years, except for large shorebirds that showed no selection for it in 1992.

Small shorebirds preferred the greatest number of macrohabitats in both years; 5 of 8 in 1992 and 3 of 5 in 1993 (Table 3). Additionally, in 1992, the small size class preferred macrohabitats in all 3 management areas. The medium size class, primarily comprised of stilt sandpipers and long-billed dowitchers, preferred unburned semi-permanent reservoir and salt grass edge in 1992 and only salt grass edge in 1993. The large size class preferred burned water units and unburned semi-permanent reservoir in 1992 and mudflat and salt grass edge in 1993. Large gleaners preferred burned water units and salt grass edge in both years and unburned semi-permanent reservoir in 1992.

Size classes were fairly consistent in macrohabitat selection between years, except for mudflat. It was avoided in 1992 by all size classes and preferred in 1993 by all classes, except the medium size class and large gleaner guild (Table 3). With the exception of mudflat, small and medium shorebirds consistently preferred and avoided the same macrohabitats in both years. The large shorebird class and large gleaners varied the most in selection of macrohabitats between years.

Microhabitat Use.--We focused our analyses of microhabitat selection on the small shorebird class because

it was the most abundant class in both years at Quivira NWR. In most macrohabitats, small shorebirds were observed in all 5 microhabitats (Table 4). Regardless of macrohabitat type or selectivity, small shorebirds were most abundant in unvegetated shallow water, except in mixed flat in 1992 salt grass edge and burned macrohabitats in both years (Table 4). In those latter cases, small shorebirds were most abundant in vegetated microhabitats, particularly in burned macrohabitats.

In preferred unvegetated macrohabitats, small shorebirds generally selected the same microhabitats (Table 4). In 1992, we analyzed 7 censuses in borrow area and unburned semi-permanent reservoir (Fig. 2A). Small shorebirds preferred shallow water and avoided wet mud microhabitats in all of these censuses. They showed no selection for water-mud interface in 2 censuses, avoided it in 2, and preferred it in 3 censuses. In the comparable period in 1993, small shorebirds displayed similar selection of microhabitat types in preferred mudflat (Fig. 2B). In 1993, we analyzed 18 censuses, and small shorebirds preferred shallow water in 17 censuses and avoided it in only 1 census. Wet mud was avoided in 16 censuses, preferred in 1 census, and shown no selection in 1 census. Water-mud interface was preferred during 3 censuses, avoided in 10, and neither preferred nor avoided in 5.

Medium shorebirds rarely were observed in enough microhabitat types (in preferred unvegetated macrohabitats)

to analyze their selection. In 1992, the medium class

preferred only 1 unvegetated macrohabitat; there were only 2

census days when medium shorebirds were in >2 microhabitat

types, and the microhabitat types were not the same during

those 2 days. In 1993, medium shorebirds were observed in 3

microhabitats (wet mud, shallow water, and medium water) on

only 5 census days. Wet mud was avoided during 5 days, and

shallow water was avoided on 1 day and preferred on 4 days.

Medium water was avoided on 1 day, neither preferred or

avoided on 2 days, and preferred on 2 days. Sample sizes of

large shorebirds in preferred unvegetated macrohabitats were

not sufficient for analysis of microhabitat selection.

Microhabitat Availability.--Selection of the mudflat

macrohabitat and composition and relative availabilities of

the 6 microhabitats in mudflat varied markedly between 1992

and 1993 (Table 3, Fig. 3). When mudflat was avoided by all

shorebird size classes in 1992, dry mud dominated the

mudflat during the first of May, but wet mud, water-mud

interface, shallow water, and medium water became more

available by mid-May (Fig. 3A). Deep water dominated during

the last part of the 1992 field season. Conversely, when

mudflat was preferred by most shorebird classes in 1993, all

microhabitats were consistently available throughout May

(Fig. 3B). That pattern was similar for the entire 1993

censusing period.

In 1992, small shorebirds preferred 2 of the 3

unvegetated macrohabitats (i.e., semi-permanent reservoir

and borrow areas), and a pattern of consistent microhabitat availability existed in those macrohabitats throughout the migration period (Fig. 4), as it did in mudflat in 1993 (Fig. 3B). In unvegetated macrohabitats preferred by small shorebirds in both years, dry mud was minimal, and about 50% of each macrohabitat was inundated with water throughout the field season.

DISCUSSION

Shorebird response to burned habitats varied depending on shorebird size class and type of habitat burned. The small shorebird class preferred the burned edge of a natural saline semi-permanent reservoir, but medium and large shorebird classes showed no selection for it. Small shorebirds may have preferred burned semi-permanent reservoir because after burning, habitat conditions were ideal for prey species. Dipteran larvae (primarily Chironomid larvae, one group of "midges") are a major component in the diet of shorebirds migrating through the interior United States (Baldasssare and Fischer 1984, Eldridge 1990). These benthic invertebrates feed on algae and bacteria that thrive on living and decaying plants (Eldridge 1992, Helmers 1992), and their productivity is enhanced by the warm water temperatures found in shallow unshaded water (Wrubleski and Rosenberg 1990). After semi-permanent reservoir edge was burned, phragmite stubble was quickly, but shallowly, reflooded by the reservoir's fluctuating water levels. Additionally, burned semi-

permanent reservoir was adjacent to open water habitat, and this edge may have attracted small shorebirds (Calidris spp.). Semipalmated sandpipers (C. pusilla) and other small shorebirds display an affinity for water edge microhabitats on wintering and breeding grounds (Baker 1979). Conversely, medium and large shorebirds, with relatively long bills and legs, are not as restricted to the water's edge (Baker 1979, Colwell and Oring 1988).

Burned parts of water units were primarily upland areas adjacent to borrow areas and were preferred by large shorebirds (61.3% lesser and greater yellowlegs) in 1992 and by large gleaners (primarily lesser and greater yellowlegs, black-necked stilts, black-bellied plovers [Pluvialis squatarola] and upland sandpipers) in both years. Our results are similar to other studies in which shallowly flooded, sparse vegetation (e.g., pastures maintained by mowing, grazing, or burning) provided feeding and nesting habitat for several large shorebird species (Ryan et al. 1984, Ryan and Renken 1987, Colwell and Oring 1988). Shorebirds use vegetated habitats, but most species generally use habitats with vegetation less than half their own height (Helmers 1992). After burned water units were reflooded, shorebird use was immediate and intense, even by small shorebirds. Vegetation regrowth, however, was extremely rapid and may have limited shorebird use, especially by small species. Conversely, species in the large size class and large gleaner guild (lesser and greater

yellowlegs, and godwits [Limosa spp.]) are more tolerant of vegetation (Baker 1979, Helmers 1992) and often exploit upland vegetated habitats associated with wetlands (Eldridge 1992).

Small and medium shorebird classes avoided burned water units in 1992 perhaps because impounded water levels were low after burning. Burned areas in water units were difficult to reflood because borrow areas had to be filled before water moved onto upland burned flats. As a result, there may not have been sufficient time (i.e., 3-4 weeks) between flooding of burned water units and shorebird arrival to allow invertebrate recolonization (Eldridge 1992, Helmers 1992). In 1993, shorebirds avoided burned water units perhaps because burning was not completely effective at removing vegetation due to wet conditions. Finally, observability (from the vehicle) decreased as burned water units revegetated, which may have biased counts of shorebirds, especially small species. When the observer walked through burned water units, small shorebirds were observed that were not visible from the vehicle. Future studies in burned habitats need to use censusing methods that are not influenced by vegetation regrowth (Rundle and Fredrickson 1981, Colwell and Oring 1988, Funderburk and Springer 1989, Hands et al. 1991).

Shorebirds in the 3 size classes preferred a range of macrohabitat types in burned, unvegetated, and vegetated management areas. These results parallel those of Colwell

and Oring (1988), who documented shorebird use of a broad range of habitats in the Great Plains. Salt grass edge was the only macrohabitat preferred by most shorebird classes in both years. Vegetated habitats also were used by spring migrating shorebirds in south-central Saskatchewan and Missouri (Colwell and Oring 1988, Hands et al. 1991). Shorebirds in the small and medium size classes have been observed pecking prey items off vegetation stems (Baker 1979). Flooded salt grass may harbor an abundance of insects and provide thermal cover to shorebirds during severe spring weather.

Small shorebirds preferred more macrohabitats than any other shorebird class: 5 of 8 macrohabitats in 1992 and 3 of 5 in 1993. In 1992, the small size class preferred macrohabitats in all 3 management areas. Small shorebirds also used a variety of habitat types (wetland edges and terrestrial) during spring migration in south-central Saskatchewan (Colwell and Oring 1988). In unvegetated macrohabitats, the small size class preferred shallow water (1-4 cm), and preference for other microhabitats increased as water saturation increased. Throughout both years, however, shallow water comprised <10% of these macrohabitats. Small shorebirds may have used a variety of macrohabitats to maximize their ability to use limited shallow water microhabitats.

Variable selection of mudflat between 1992 and 1993 was likely due to differences in microhabitat composition and

availability. In 1993 (unlike 1992), abundant water availability in mudflat before and during shorebird migration likely improved habitat for aquatic prey species. Invertebrate species diversity increases with water permanency (Eldridge 1992), and more importantly, water is necessary for midges to emerge (Helmers 1992). In 1993, after mudflat had been inundated throughout winter and early spring, high winds moved water around the mudflat, and it gradually receded with time, exposing invertebrates.

Microhabitat composition and availability were critical in small shorebird selection of unvegetated macrohabitats at Quivira NWR. In preferred unvegetated macrohabitats, water microhabitats were abundant and consistently available, and as water levels shifted, new sources of prey were probably exposed. Migrating shorebirds quickly respond to the first appearance of suitable microhabitats (Skagen and Knopf 1994), and small shorebirds preferred unvegetated macrohabitats with consistent fluctuation of water levels.

Microhabitat availability at Quivira NWR was very dynamic between and within years, similar to previous years at the refuge (Skagen and Knopf 1994) and at other inland stopover sites (Reid et al. 1983, Hands et al. 1991, Helmers 1991). Shorebirds, especially small species, depend on the dynamic availability of ephemeral microhabitats in the Great Plains to gain vital fat reserves. Therefore, management and coordination of wetland complexes along the migration corridor are recommended (Skagen and Knopf 1994).

MANAGEMENT IMPLICATIONS

Our results and those from other studies (Colwell and Oring 1988, Helmers 1991, Hands et al. 1991, Skagen and Knopf 1994) underscore the importance of providing a complex of different macrohabitat types to migrating shorebirds. A variety of macrohabitats provides foraging habitat to a diverse community of shorebirds and dampens effects of fluctuating microhabitat availabilities (Skagen and Knopf 1994).

Burning has great potential as a tool for managing shorebird habitat because early colonizing midges flourish in wetlands maintained in early successional stages (Eldridge 1990). Invertebrates are fundamental to wetland wildlife communities, but they receive almost no mention in fire-wetland literature (Kirby et al. 1988). The potential for burning to improve shorebird habitat needs to be further evaluated, particularly effects of season of burn and wetland type.

Flooding mudflats on prairie stopover sites prior to shorebird migration may be more effective than gradually lowering long-standing water levels in water impoundments (Fredrickson and Taylor 1982), which is commonly used in the midwestern United States. In the south-central Great Plains, water availability is unpredictable and often limited. Managers may not have enough water to initially fill water units, or they may not be able to drawdown scarce water supplies (Helmers 1992); however, it would take less

water to flood a mudflat to a shallow depth.

We restricted our evaluation of habitat use to shorebird classes because from a management perspective, it is not practical to manage a wetland complex and all of its biotic components on a species-specific basis. Unless a particular species is in need of management action (i.e., an endangered species), it is prudent to focus on maintenance of community-level attributes of a given ecosystem.

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Table 1. Macrohabitats in the 3 management areas at Quivira

National Wildlife Refuge, Kansas.

Management area	Macrohabitat[a]
Burned	Semi-permanent reservoir
	Water unit
Unvegetated	Borrow area
	Mudflat
	Semi-permanent reservoir
Vegetated	Mixed flat
	Mosaic flat
	Salt grass[b] edge

[a]See text for definitions.

[b]<u>Distichlis</u> <u>spicata</u>

Table 2. Relative abundances (as a percentage of each size class) and total numbers of small, medium, and large shorebirds observed in macrohabitats at Quivira National Wildlife Refuge, Kansas, 1992 and 1993.

| Management Area | Size Class[a] | | | | | |
| | Small | | Medium | | Large | |
Macrohabitat	1992	1993	1992	1993	1992	1993
BURNED						
Semi-permanent reservoir	3.2	NA[b]	0.9	NA	0.8	NA
Water unit	3.1	0.2	29.5	4.4	72.1	14.1
Total	6.3	0.2	30.4	4.4	72.9	14.1
UNVEGETATED						
Borrow area	8.8	NA	2.6	NA	5.2	NA
Mudflat	32.0	69.0	8.1	47.2	6.1	50.9
Semi-permanent reservoir	40.4	0	46.0	0	14.0	4.4
Total	81.2	69.0	56.6	47.2	25.3	55.3

Table 2. Continued.

| Management Area | Size Class[a] | | | | | |
| | Small | | Medium | | Large | |
Macrohabitat	1992	1993	1992	1993	1992	1993
VEGETATED						
Mixed flat	1.5	0.9	0.4	1.9	0.5	4.1
Mosaic flat	4.2	28.1	0.3	18.6	0.1	16.9
Salt grass edge	6.9	1.8	12.3	27.9	1.3	9.5
Total	12.6	30.8	13.0	48.4	1.9	30.5
n	9,364	58,171	6,716	7,208	1,922	1,258

[a]Size classes based on mean tarsus lengths (Hayman et al. 1986); small 19-25 mm, medium >25-47 mm, and large >47 mm.

[b]Habitat type not available due to high water.

Table 3. Macrohabitat selectivity using Bonferroni confidence intervals (Neu et al. 1974; + = preferred, 0 = no preference, - = avoided, $P < 0.05$) by shorebird size classes and foraging guilds at Quivira National Wildlife Refuge, Kansas, 1992 and 1993. Empty cells indicate classes or guilds with too few observations to conduct analysis.

Management Area Macrohabitat	Yr.	% Avail.	Size Class[a]			Foraging Guild[b]			
			Small[c]	Medium	Large	Large Prober	Large Gleaner	Pelagic Gleaner	Large Sweeper
BURNED									
Semi-permanent reservoir	1992[d]	0.7	+	0	0	0	0	-	
	1993[e]	NA[f]							
Water unit	1992	39.3	-	-	+	-	+	-	-
	1993	15.7	-	-	0	-	+	-	-
UNVEGETATED									
Borrow area	1992	6.9	+	-	-	-	-	-	0
	1993	NA							
Mudflat	1992	38.5	-	-	-	-	-	-	-

Table 3. Continued.

Macrohabitat	Yr.	% Avail.	Size Class[a]			Foraging Guild[b]			
			Small[c]	Medium	Large	Large Prober	Large Gleaner	Pelagic Gleaner	Large Sweeper
	1993	44.2	+	0	+	0	−	+	+
Semi-permanent reservoir	1992	6.0	+	+	+	+	−	+	+
	1993	8.0			−			+	0
UNBURNED/VEGETATED									
Mixed flat	1992	5.5	−	−	−	−	−	−	−
	1993	7.2	−	−	−	−	−	−	−
Mosaic flat	1992	1.9	+	−	−	−	−	−	0
	1993	23.5	+	−	−	−	+	−	−
Salt grass edge	1992	1.1	+	+	0	+	0	+	
	1993	1.5	+	+	+	+	+	+	+
Overall Chi-square[g]	1992		25,560	27,431	1,381	25,025	1,575	54,109	1,311

Table 3. Continued.

Macrohabitat	Yr.	% Avail.	Size Class[a]			Foraging Guild[b]			
			Small[c]	Medium	Large	Large Prober	Large Gleaner	Pelagic Gleaner	Large Sweeper
	1993		18,813	31,415	611	31,625	369	971	903

[a]Size classes based on mean tarsus lengths (Hayman et al. 1986); small 19-25 mm, medium >25-47 mm, and

large >47 mm.

[b]Foraging guilds based on mean tarsus lengths (Hayman et al. 1986); small <25 mm and large ≥25 mm and

foraging mode.

[c]Small size class was not analyzed by foraging guild because they were identical groups.

[d]26 April-5 June

[e]6 April-12 June

[f]Habitat type not available due to high water.

[g]All Chi-squares significant at $P < 0.001$.

Table 4. Relative abundances (as a percentage of each species) of small shorebirds in microhabitats at Quivira National Wildlife Refuge, Kansas, 1992 and 1993.

Management Area Macrohabitat	Year	$\underline{n}$	Macrohabitat selectivity[a]	Microhabitat					No data[c]
				Dry mud	Wet mud	Water-mud interface	Shallow water	Vegetation[b]	
BURNED									
Semi-permanent reservoir	1992	296	0	0	1.7	0	13.2	81.4	3.7
	1993	0		NA[d]	NA	NA	NA	NA	NA
Water unit	1992	293	–	22.2	7.5	1.7	23.3	40.3	5.1
	1993	93	–	0	0	0	23.7	76.3	0
UNVEGETATED[e]									
Borrow area	1992	823	+	1.5	18.7	15.7	56.9	NA	7.3
	1993	0		NA	NA	NA	NA	NA	
Mudflat	1992	2,997	–	0.7	10.5	27.2	61.5	NA	2.1
	1993	40,142	+	0.9	23.7	10.6	62.9	NA	1.8
Semi-permanent reservoir	1992	3,778	+	0.1	7.9	16.8	74.2	NA	1.0

Table 4. Continued.

| Management Area | | | | Microhabitat | | | | | |
| | | | | Dry | Wet | Water-mud | Shallow | | No |
Macrohabitat	Year	n	selectivity[a]	mud	mud	interface	water	Vegetation[b]	data[c]
	1993	0		NA	NA	NA	NA	NA	0
VEGETATED									
Mixed flat	1992	140	−	0	7.9	22.9	23.6	42.9	2.9
	1993	496	−	3.2	14.1	0	67.1	15.5	0
Mosaic flat	1992	392	+	0	1.0	16.6	70.9	11.5	0
	1993	16,342	+	0	6.7	10.9	47.9	24.5	10.0
Salt grass edge	1992	645	+	NA	NA	NA	NA	100.0	0
	1993	1,052	+	NA	NA	NA	NA	100.0	0

[a]Bonferroni confidence intervals (Neu et al. 1974); + = preferred, 0 = no preference; − = avoided (P < 0.05).

[b]Dry mud, wet mud, water-mud interface or shallow water microhabitats in conjunction with vegetative characteristics (i.e., wet mud/salt grass).

Table 4. Continued.

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[c]Percentage of observations that could not be identified to microhabitat.

[d]Not available due to either high water or lack of occurrence in macrohabitat.

[e]See Fig. 2 and text for Bonferroni selection results of microhabitat types.

FIGURE LEGENDS

Fig. 1. Shorebird size class (small, medium, and large) response to burned water units in 1992 (A) and 1993 (B) (solid circles indicate burning dates and solid inverse triangles indicate first and last census dates) at Quivira National Wildlife Refuge, Kansas.

Fig. 2. Relative percentages of 26 April-5 June censuses in which small shorebirds preferred (+), avoided (-), or displayed no preference (0) (Neu et al. 1974) for microhabitats in preferred unvegetated macrohabitats: (A) borrow area and semi-permanent reservoir (1992; no. censuses = 7) and (B) mudflat (1993; no. censuses = 18).

Fig. 3. Microhabitat availabilities in unvegetated mudflat in 1992 (A) when it was avoided by small shorebirds and 1993 (B) when it was preferred by small shorebirds at Quivira National Wildlife Refuge, Kansas (solid inverse triangles indicate census days; DM = dry mud, WM = wet mud, WMI = water-mud interface, SW = shallow water, MW = medium water, and DW = deep water).

Fig. 4. Microhabitat availabilities in unvegetated macrohabitats preferred by small shorebirds in 1992 in semi-permanent reservoir (A) and borrow area (B) at Quivira National Wildlife Refuge, Kansas (solid inverse triangles

indicate census days; DM = dry mud, WM = wet mud, WMI =
water-mud interface, SW = shallow water, MW = medium water,
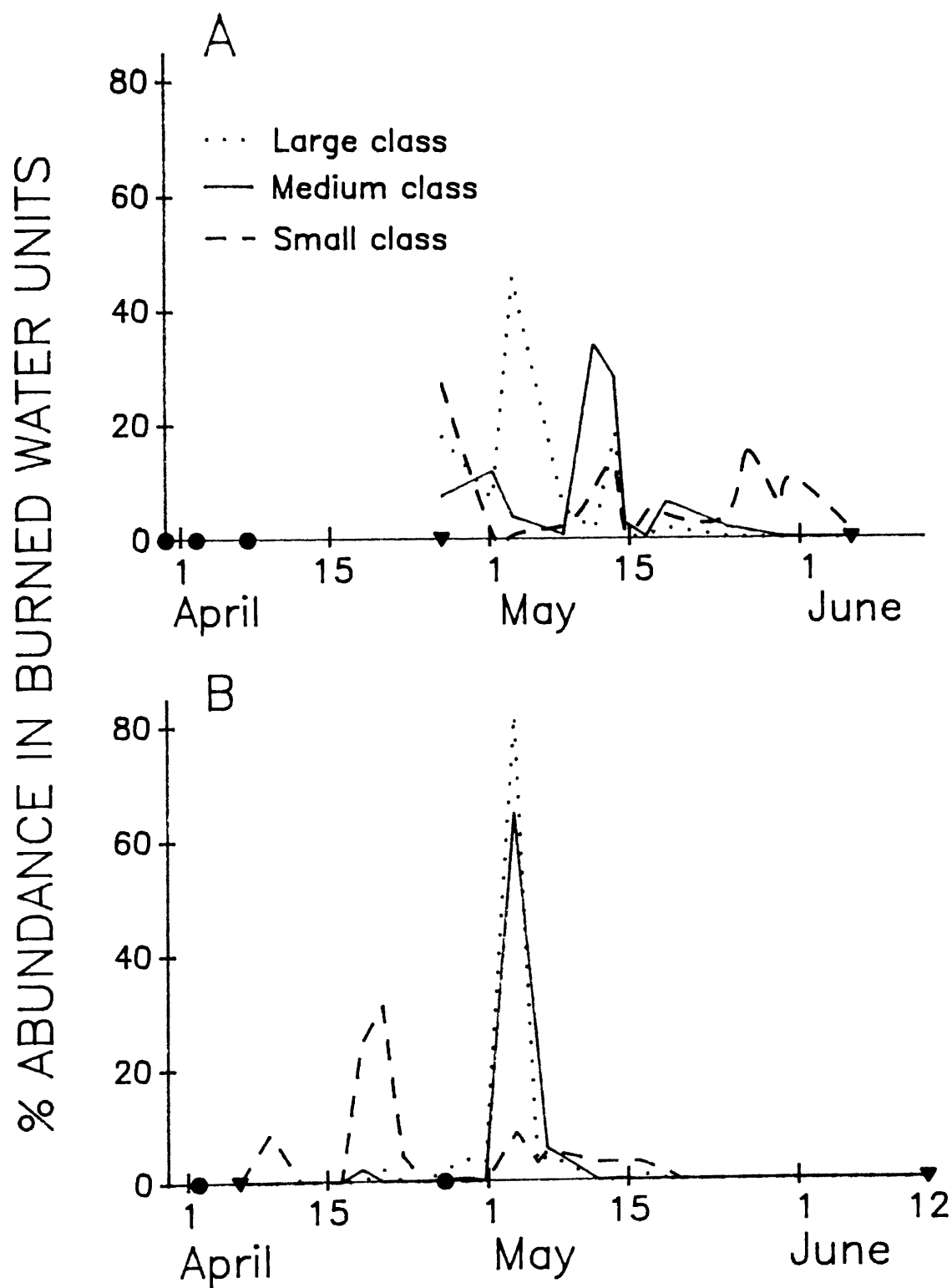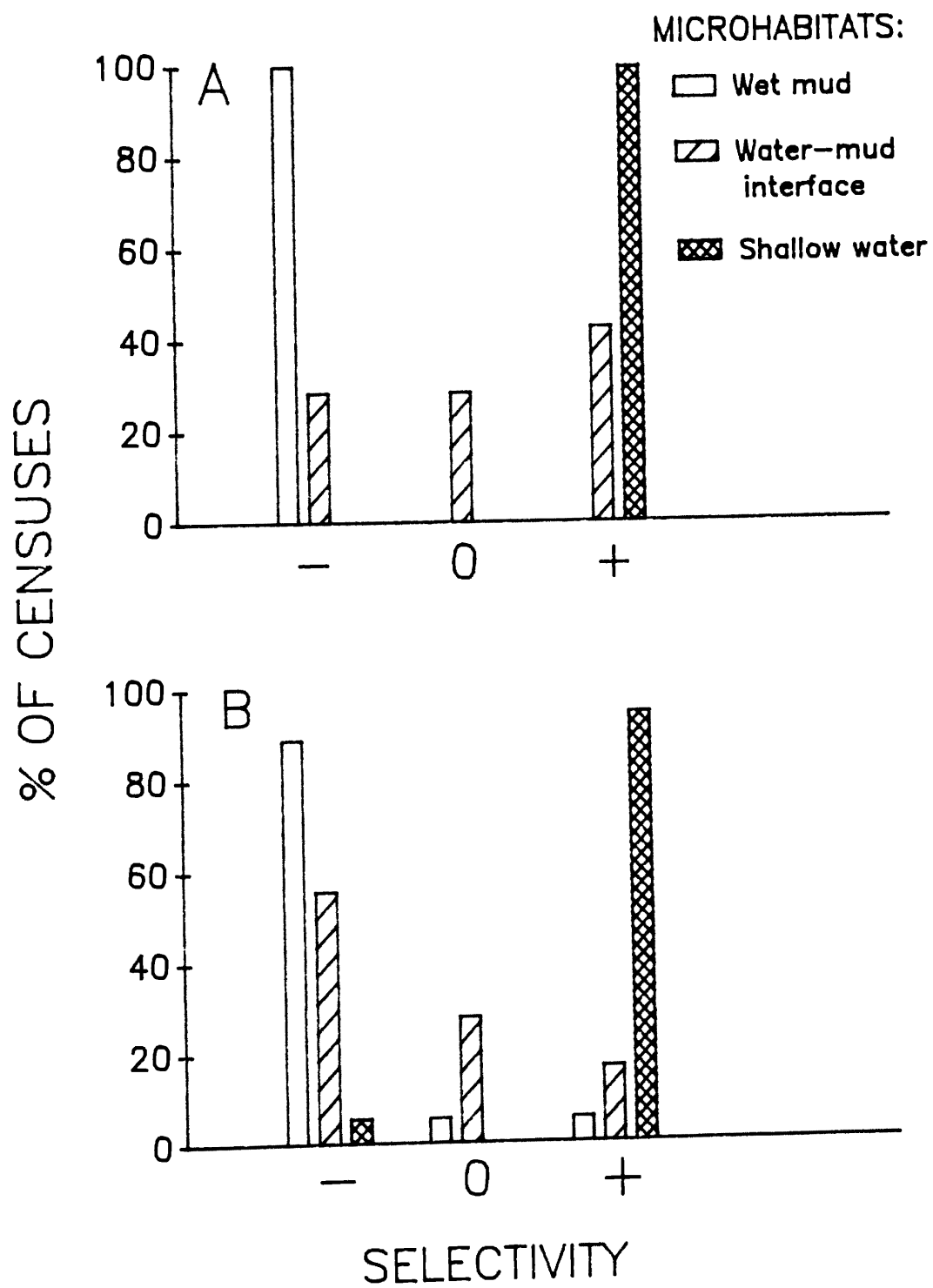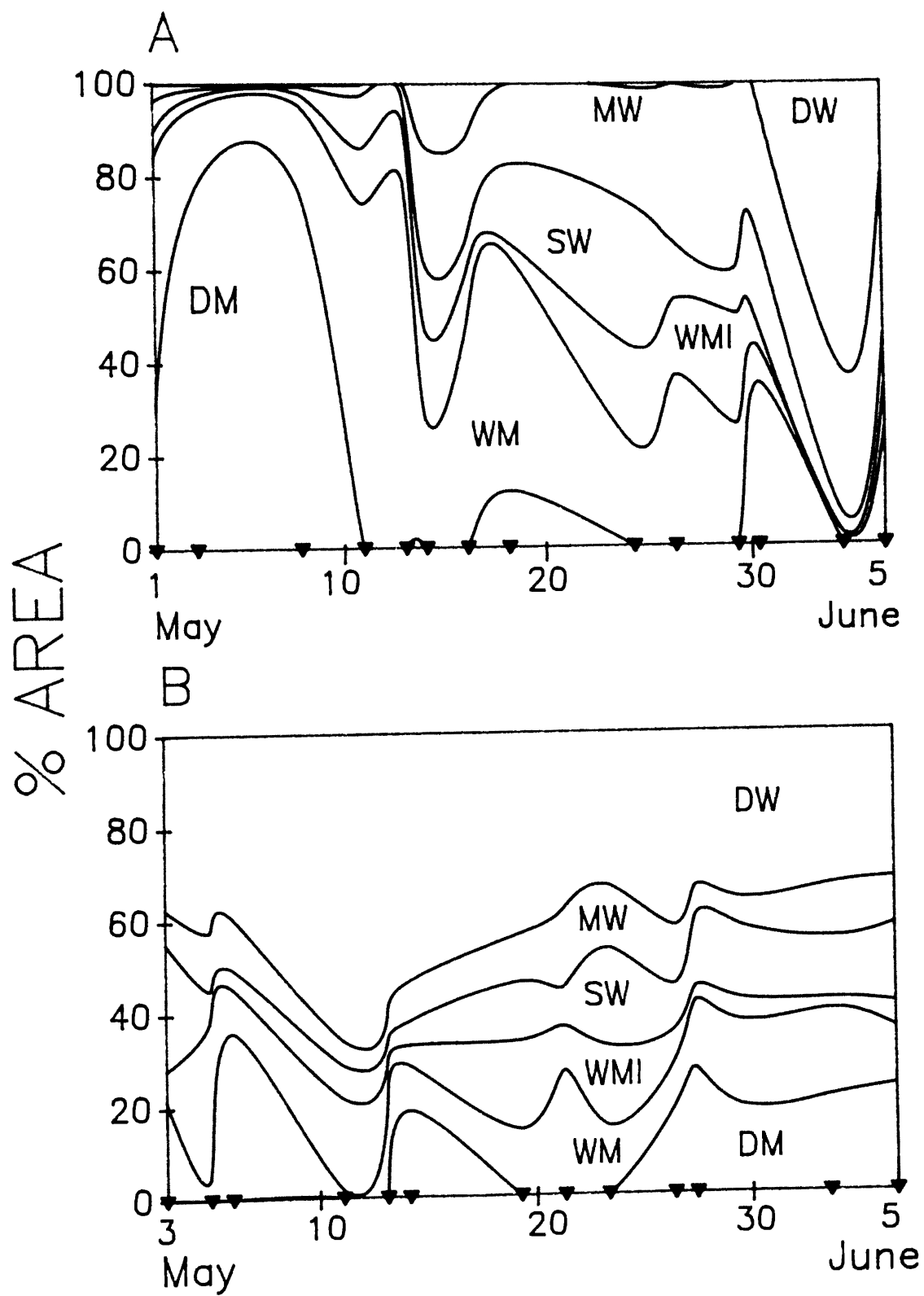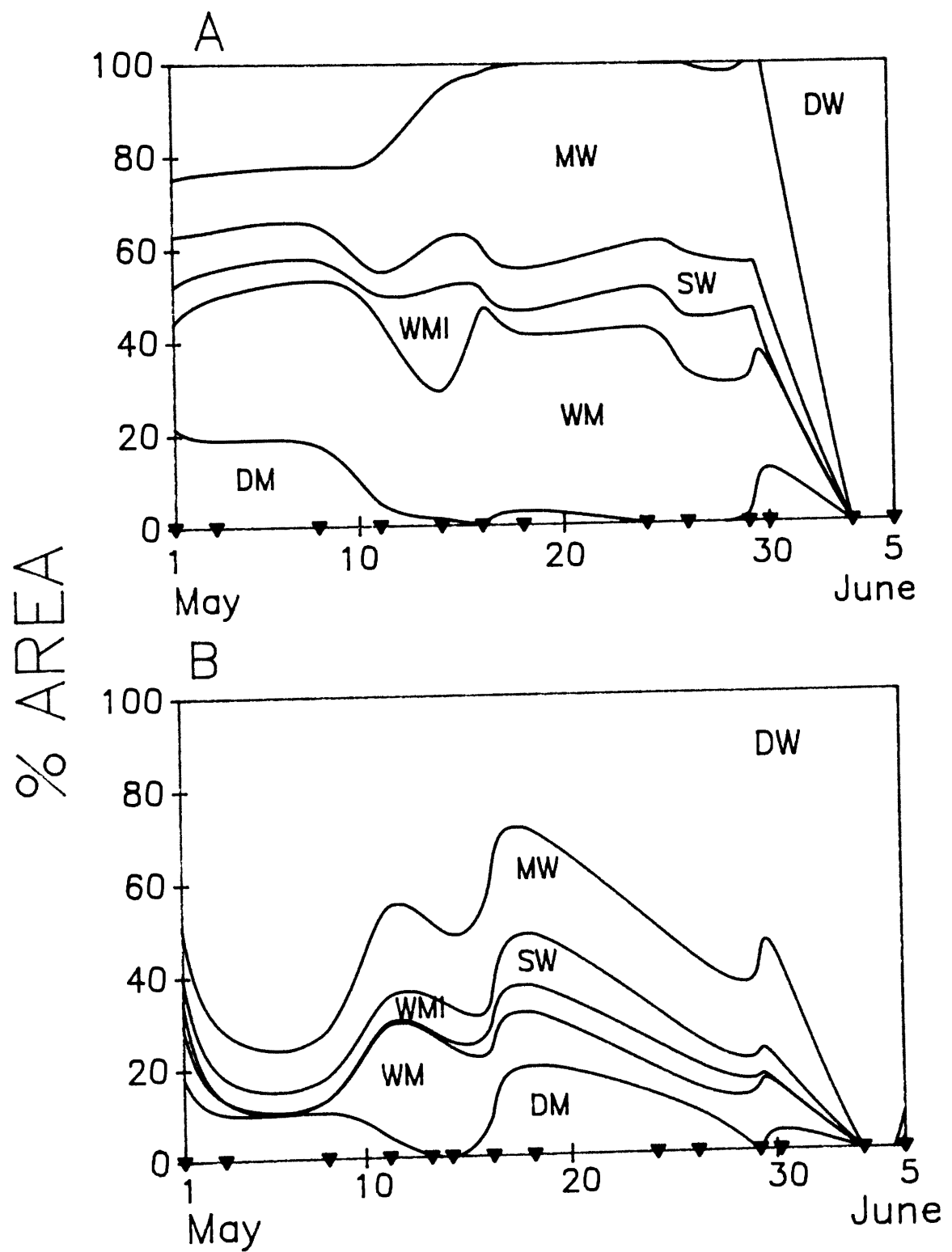and DW = deep water).

Fig. 1

Fig. 2

Fig. 3

Fig. 4

APPENDIXES

APPENDIX A.   Shorebird species observed at Quivira National Wildlife Refuge, Kansas, 1992 and 1993; species

classified by size class (based on mean tarsus length) and foraging guild.

Common name	Scientific name	Mean tarsus length (mm)[a]	Size class[b]	Foraging guild[c]
American Avocet	Recurvirostra americana	94.0	Large	Large sweeper
Baird's Sandpiper	Calidris bairdii	23.5	Small	Small prober/gleaner
Black-bellied Plover	Pluvialiis squatarola	47.0	Medium	Large gleaner
Black-necked Stilt	Himantopus mexicanus	118.5	Large	Large gleaner
Dunlin	Calidris alpina	26.0	Medium	Large prober
Greater yellowlegs	Tringa melanoleuca	62.5	Large	Large gleaner
Hudsonian Godwit	Limosa haemastica	62.0	Large	Large prober
Least Sandpiper	Calidris minutilla	19.0	Small	Small prober/gleaner
Lesser Golden-plover	Pluvialis dominica	41.5	Medium	Large gleaner
Lesser Yellowlegs	Tringa flavipes	52.0	Large	Large gleaner
Long-billed Dowitcher	Limnodromus scolopaceus	40.0	Medium	Large prober
Marbled Godwit	Limosa fedoa	71.2	Large	Large prober

Appendix A. Continued.

Common name	Scientific name	Mean tarsus length (mm)[a]	Size class[b]	Foraging guild[c]
Pectoral Sandpiper	Calidris melanotos	27.5	Medium	Large prober
Piping Plover	Charadrius melodus	22.5	Small	Small prober/gleaner
Red-necked Phalarope	Phalaropus lobatus	20.5	Swimmer	Pelagic gleaner
Ruddy Turnstone	Arenaria interpres	26.0	Medium	Large prober
Sanderling	Calidris alba	25.0	Small	Small prober/gleaner
Semipalmated Sandpiper	Calidris pusilla	21.5	Small	Small prober/gleaner
Semipalmated Plover	Charadrius semipalmatus	24.0	Small	Small prober/gleaner
Spotted Sandpiper	Actitis macularia	23.0	Small	Small prober/gleaner
Solitary Sandpiper	Tringa solitana	32.0	Medium	Large gleaner
Stilt Sandpiper	Calidris himantopus	40.5	Medium	Large prober
Upland Sandpiper	Bartramia longicauda	48.5	Large	Large gleaner
Western Sandpiper	Calidris mauri	22.5	Small	Small prober/gleaner
Whimbrel	Numenius phaeopus	60.0	Large	Large prober

Appendix A. Continued.

Common name	Scientific name	Mean tarsus length (mm)[a]	Size class[b]	Foraging guild[c]
White-rumped Sandpiper	Calidris fuscicollis	24.5	Small	Small prober/gleaner
Willet	Catoptrophorus semipalmatus	60.0	Large	Large gleaner
Wilson's Phalarope	Phalaropus tricolor	32.5	Swimmer	Pelagic gleaner

[a]From Hayman et al. 1986.

[b]Small= 19-25 mm mean tarsus length, medium = >25-47 mm, and large = $\geq$47 mm.

[c]Based on mean tarsus length (small [<25 mm] and large [>25 mm]) and foraging mode (Helmers 1991).

Appendix B. First, peak (maximum count), and last observation dates of migrant shorebirds at Quivira National Wildlife Refuge, Kansas, 1992 and 1993.

| | 1992 | | | 1993 | | |
| | (26 April-5 June) | | | (6 April-12 June) | | |
Species/species group[a]	First	Peak	Last	First	Peak	Last
American Avocet	26 Apr	14 May	6 Jun	6 Apr	24 Apr	12 Jun
Baird's Sandpiper	26 Apr	1 May	8 May	6 Apr	12 Apr	31 May
Black-bellied Plover	1 May	26 Apr 14 May	26 May	28 Apr	15 May	12 Jun
Black-necked Stilt	26 Apr	26 Apr	5 Jun	9 Apr	22 Apr	12 Jun
Dunlin	26 May	26 May	26 May	11 May	15 May	23 May
Greater Yellowlegs	26 Apr	3 May	16 May	6 Apr	20 Apr	6 May
Hudsonian Godwit	26 Apr	13 May	24 May	20 Apr	20 Apr	15 May
Least Sandpiper	26 Apr	8 May	24 May	20 Apr	6 May	18 May
Lesser Golden-plover	26 Apr	26 Apr	3 May	18 Apr	18 Apr	18 Apr
Lesser Yellowlegs	26 Apr	3 May	29 May	9 Apr	3 May	15 May

Appendix B. Continued.

Species/species group[a]	1992 (26 April–5 June)			1993 (6 April–12 June)		
	First	Peak	Last	First	Peak	Last
Long-billed Dowitcher	26 Apr	13 May	24 May	24 Apr	3 May	15 May
Marbled Godwit	26 Apr	13 May	13 May	--[b]	--	--
Pectoral Sandpiper	1 May	24 May	29 May	3 May	5 May	13 May
Piping Plover	26 Apr	1 May	1 May	24 Apr	28 Apr	19 May
Red-necked Phalarope	30 May	30 May	30 May	14 May	14 May	14 May
Ruddy Turnstone	24 May	26 May	26 May	14 May	27 May	27 May
Sanderling	13 May	26 May	3 Jun	28 Apr	18 May	31 May
Semipalmated Plover	26 Apr	1 May	1 Jun	24 Apr	6 May	14 May
Semipalmated Sandpiper	26 Apr	1 May	5 Jun	12 Apr	11 May	10 Jun
Spotted Sandpiper	1 May	16 May	29 May	3 May	21 May	26 May
Solitary Sandpiper	8 May	8 May	13 May	--[b]	--	--
Stilt Sandpiper	1 May	14 May	5 Jun	18 Apr	15 May	8 Jun

Appendix B.   Continued.

Species/species group[a]	1992 (26 April–5 June)			1993 (6 April–12 June)		
	First	Peak	Last	First	Peak	Last
Upland Sandpiper	1 May	1 May	8 May	20 Apr	28 Apr	3 May
Western Sandpiper	11 May	11 May	11 May	--[c]	--	--
Whimbrel	8 May	8 May	29 May	--[b]	--	--
White-rumped Sandpiper	26 Apr	26 May	5 Jun	30 Apr	27 May	12 Jun
Willet	26 Apr	1 May	24 May	20 Apr	20 Apr	14 May
Wilson's Phalarope	26 Apr	14 May	5 Jun	18 Apr	11 May	12 Jun

[a]See Appendix A for scientific names.

[b]Species not observed during censusing.

[c]Species not identified but probably part of unidentfied peeps; see text.

VITA

Kelli Lee Stone

Candidate for the Degree of

Master of Science

Thesis: MIGRATING SHOREBIRD HABITAT USE AND RESPONSE TO
          BURNED MARSHES DURING SPRING MIGRATION IN SOUTH-
          CENTRAL KANSAS

Major Field: Wildlife and Fisheries Ecology

Biographical:

   Personal Data: Born in Colorado Springs, Colorado on
       August 18, 1966, the daughter of Jack and Eileen
       Stone.

   Education: Received Bachelor of Science Degree in
       Wildlife Biology from Colorado State University,
       Fort Collins, Colorado in May, 1988; completed
       requirements for the Master of Science Degree at
       Oklahoma State University, Stillwater, Oklahoma,
       in May 1994.

   Professional Experience: Biological Technician, U.S.
       Fish and Wildlife Service, National Ecology
       Research Center, May-August 1988 and May 1989-May
       1991; Biological Technician, U.S. Fish and
       Wildlife Service, Quivira National Wildlife
       Refuge, June 1991-August 1991; graduate research
       assistant, Oklahoma Cooperative Fish and Wildlife
       Research Unit, August 1991-January 1994.