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GROWTH, CONDITION, AND MORTALITY OF BLACK CRAPPIE, BLUEGILL, AND YELLOW PERCH IN NEBRASKA SAND HILLS LAKES

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ABSTRACT—The growth, condition, and mortality of black crappie, bluegill, and yellow perch were measured in 30 Nebraska Sand Hills lakes (1998, 1999) to determine the value of these parameters in these fish populations compared to other Great Plains populations. Growth was variable for all three fish species, but similar to or higher than populations in other midwestern states. Bluegill condition, as measured by mean relative weight, ranged from 115 to 123, indicating these populations were in very good condition. Mean relative weight by length for black crappie ranged from 94 to 114, but only 83 to 95 for yellow perch. Mean total annual mortality did not vary significantly among the three species, with 38.6% for black crappie, 30.9% for bluegill, and 37.9% for yellow perch ($p > 0.50$). These mortality estimates were similar to other lightly exploited or unexploited midwestern populations. This study indicates that high-quality panfish populations in the Nebraska Sand Hills had characteristic growth, condition, and mortality traits, and it provides baseline information for future comparisons with other Great Plains fish populations.

Key Words: fish populations, growth, condition, mortality, Nebraska, Sand Hills lakes

Introduction

Biologists commonly use parameters such as growth, condition, and mortality to assess the dynamics of populations (Van Den Avyle 1999). These parameters vary substantially with environmental conditions across geographic regions. Specifically, the Nebraska Sand Hills panfish populations provide high-quality angling opportunities (e.g, high abundance of large fish) that are relatively unique to the Great Plains. Therefore, comparison of growth, condition, and mortality data for fish from these water bodies can provide insights into the current status of these pan-fish populations for understanding and management. Our objective was to provide baseline data for growth, condition, and mortality for these high-quality populations of black crappie *(Pomoxis nigromaculatus)*, bluegill *(Lepomis macrochirus)*, and yellow perch *(Perca flavescens)*, in Nebraska Sand Hills lakes. This information also can provide insight into the differences among populations of these fish in other Great Plains lakes.

Methods

Study Sites. Thirty Nebraska Sand Hills lakes were selected in Brown, Cherry, Garden, Grant, Holt, and Rock Counties in north-central Nebraska (Fig. 1; Appendix 1). Sand Hills lakes are typically shallow, alkaline, and have a wide range of submergent vegetation coverage (McCarraher 1977). Most lakes selected had limited recreational fishing, but three private lakes had been closed to fishing for at least 10 years. Seven of the lakes were located on the Valentine National Wildlife Refuge and experienced moderate (11-16 angler hours/ha) recreational fishing (Nebraska Game and Parks Commission unpublished data), particularly during periods of ice cover.

Field Methods. The fish (black crappies, bluegill, and yellow perch) were collected with modified fyke trap nets during May and June of 1998 and 1999. Each net had 1.1 x 1.5 m frames, 22 m leads, and 16 mm bar measure mesh. Nets were set overnight at randomly selected shoreline locations on each lake. Sampling effort consisted of 10 overnight net sets for lakes ≤50 ha and 20 overnight net sets for lakes >50 ha. Fifteen lakes were sampled in 1998 and 15 other lakes were sampled in 1999.

Analysis. To measure growth, scales were removed just below the lateral line and directly behind the pectoral fin from a subsample of five fish

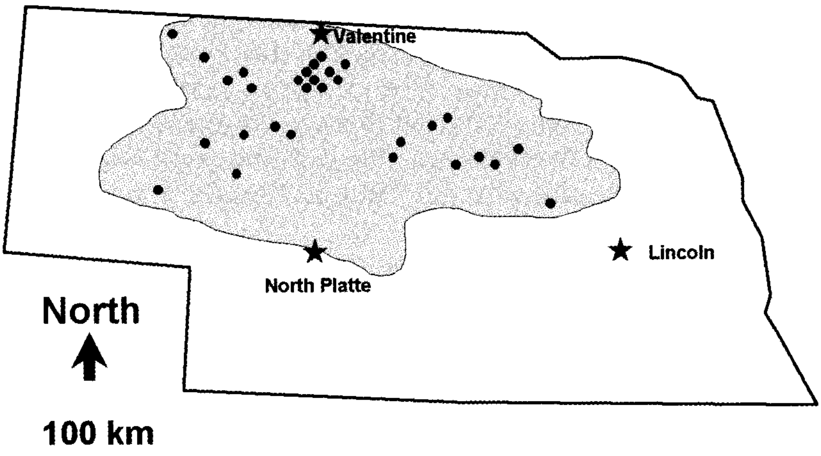

Figure 1. Map of Nebraska lakes sampled for bluegill, black crappie, and yellow perch during 1998 and 1999. The Sand Hills is depicted by the shaded area.

per cm length group (DeVries and Frie 1996). Total length at age was determined using the Fraser-Lee method (DeVries and Frie 1996):

$$L_i = \left(\frac{L_c - a}{S_c} \right) S_i + a,$$

where L_i is the calculated total length at age i, L_c is the length of the fish at capture (which is measured in the field), S_c is the radius of the scale at capture, and S_i is the radius of the scale at age i; both S_c and S_i are measured in the laboratory. The standard intercept parameter, a, is the approximate length at which scales first form on fish. These intercept values were obtained from the literature: 20 mm for bluegill and 35 mm for black crappie and yellow perch (Carlander 1982). Scales were used in lieu of other aging structures (e.g., otoliths) because collection is nonlethal and generally precise in northern latitudes (Kruse et al. 1993; Hoxmeier et al. 2001).

Fish condition was estimated using relative weight as an index (W_r; Blackwell et al. 2000):

$$W_r = \frac{W}{W_s}$$

where W_r is relative weight, W is the weight of an individual fish, and W_s is a length-specific standard weight. The length-specific standard weight is

calculated using a regression equation specific for an individual species across the entire geographical range of the fish (Blackwell et al. 2000):

black crappie: $\log_{10}(W_s) = -5.618 + 3.345\log_{10}(\text{total length})$,
bluegill: $\log_{10}(W_s) = -5.374 + 3.316\log_{10}(\text{total length})$,
yellow perch: $\log_{10}(W_s) = -5.386 + 3.230\log_{10}(\text{total length})$.

Mean W_r was calculated for length categories (e.g., stock, quality, preferred, etc.), which are defined as percentages of world-record length, as proposed by Gabelhouse (1984) (Table 1). These length categories represent standard length groups used in fisheries management for population assessments. They are used as a more sensitive measure of condition because biologists can compare relative weight for fish of small (i.e., stock to quality) length and large (i.e., preferred to memorable) length to determine if there is a change in condition across lengths.

Total annual mortality (A) was estimated using fish samples collected in the trap nets. In this analysis, a plot of fish age versus abundance of each age (e.g., a catch curve as defined by Ricker 1975) is used where the slope for the descending limb of the regression of $\log_e$ abundance on fish age represents the rate of death and an estimate of instantaneous annual mortality (Z) (see Ricker 1975). Survival (S) was estimated by:

$$S = e^{-Z},$$

and total annual mortality was estimated by:

$$A = 1 - S.$$

Only ages fully recruited to the gear (i.e., the youngest age that was sampled effectively by our trap nets and all subsequent older ages), and only age groups with at least five fish represented (to avoid the influence of zeros on the regression analyses) were used in this analysis (Ricker 1975). Because we expect the youngest ages to have the highest number of fish in the population, the fully recruited age was determined as the age at which abundance was highest (usually age 2 or 3, depending on fish species and lake).

A two-way analysis of variance (ANOVA) with species and length category as the main effects was used to determine differences in mean relative weight values (Littel et al. 1991). A one-way ANOVA was used to

TABLE 1

MINIMUM TOTAL LENGTHS (MM) FOR CATEGORIES USED TO CALCULATE MEAN RELATIVE WEIGHTS FOR BLACK CRAPPIE, BLUEGILL, AND YELLOW PERCH

	Length category				
Species	Stock	Quality	Preferred	Memorable	Trophy
Black crappie	130	200	250	300	380
Bluegill	80	150	200	250	300
Yellow perch	130	200	250	300	380

Source: Gabelhouse (1984)

Note: Length categories are accepted standards in the fisheries profession; they are percentages of all-tackle world-record length.

compare mean total annual mortality estimates among species. In all ANOVA procedures, a Levene's test of homogeneity of variance was used to test the assumption of equal variances. When the ANOVA model was significant, a least-squares means procedure (LSMEANS in SAS; Littel et al. 1991) was used to determine which means were significantly different.

Results

Age and Growth. We were able to estimate growth and maximum age for 8 black crappie, 21 bluegill, and 24 yellow perch populations (Table 2). Growth for all three species was highly variable, particularly at older ages (i.e., age 4 and older). For example, black crappie growth, measured by mean total length at age 6, ranged from 202 mm to 361 mm (Table 2), and maximum age was relatively old at 11 (Table 2; Fig. 2A). Bluegill growth was relatively fast in most lakes, with mean length at age 4 for all lakes being 172 mm (range 98-201) (Table 2; Fig. 2B). However, in one lake (Cottonwood), growth was lowest across all ages and fish only attained 174 mm by age 10. In addition, this lake had the oldest bluegill, at age 12 years. The mean length of yellow perch at age 2 ranged from 104 to 186 mm, and length at age 6 from 194 to 306 mm (Table 2). Of the 24 yellow perch

populations that were aged, 21 contained fish that were age 7 and older, and the oldest fish sampled was age 12 (Table 2; Fig. 2C).

Condition. Fish condition differed among length categories and species. There was an interaction in the two-way ANOVA comparing mean relative weight among species and length categories (F = 3.33, DF = 6, 160 $p < 0.001$). Therefore, we tested differences among length categories and species separately. Mean relative weight of bluegill ranged from 115 to 123 (Fig. 3) and did not differ among length categories (F = 0.80, DF = 3, 63 $p = 0.497$). However, there was a decreasing trend in relative weight as fish length increased for black crappie and yellow perch (Fig. 3). Mean relative weight for black crappies was highest (114) in smaller (i.e., stock- to quality-length fish) and decreased in larger sizes (i.e., memorable- to trophy-length fish) to 94 (F = 6.53, DF = 3, 29 $p = 0.002$). Yellow perch relative weight was also highest in stock- to quality-length fish (95) and was lowest in memorable- to trophy-length fish (83) (F = 4.79, DF = 3, 77 $p = 0.004$) (Fig. 3).

Mortality. Total annual mortality was estimated for 5 black crappie, 13 bluegill, and 19 yellow perch populations. Fewer populations were used in the mortality estimates because there were fewer populations that met the assumptions of the catch curve (e.g., consistent year-class strength with few strong and weak age classes). The mean total annual mortality estimate (Fig. 4) for black crappie was 38.6% (range 10.9%-70.9%), bluegill was 30.9% (range 4%-52.7%), and yellow perch was 37.9% (range 3.5%-64.3%). These estimates did not differ among the three panfish species (ANOVA, F = 0.66, DF = 2, 36 p=0.523).

Discussion

Age and Growth. In general, growth at younger ages of Nebraska Sand Hills black crappie and bluegill was similar to the South Dakota means (Willis et al. 1992; Guy and Willis 1995) and the Midwest mean (Iowa, Indiana, Illinois, Kansas, Missouri, Nebraska, and Ohio for black crappie; Iowa, Illinois, Indiana, and Ohio for bluegill; Carlander 1977). However, black crappie growth in the Nebraska Sand Hills was considerably faster after age 4 (Fig. 2A), whereas bluegill growth was fastest at intermediate age groups (Fig. 2B). In contrast to black crappie and bluegill, yellow perch growth was very similar to that of populations from South Dakota

TABLE 2

UNWEIGHTED MEAN LENGTH BY EACH AGE CLASS FOR BLACK CRAPPIE, BLUEGILL, AND YELLOW PERCH COLLECTED IN NEBRASKA SAND HILLS LAKES, 1998 AND 1999

	Mean total length by age class (mm)											
	1	2	3	4	5	6	7	8	9	10	11	12
Black crappie	73(3)	136(6)	201(12)	243(15)	272(17)	290(19)	328(15)	333(18)	322	325	330	
Range	65-87	109-168	149-252	175-298	195-331	202-361	302-378	309-387				
N	8	8	7	7	7	7	5	4	1	1	1	
Bluegill	45(1)	96(3)	142(5)	172(5)	190(5)	205(5)	218(6)	221(7)	219(13)	220(15)	199(14)	198
Range	38-57	62-117	80-168	98-201	112-217	127-234	143-249	156-256	165-267	174-254	185-212	
N	21	21	21	21	20	20	17	14	7	5	2	1
Yellow perch	83(3)	144(5)	191(6)	220(6)	240(7)	254(7)	266(8)	272(9)	281(11)	282(18)	289(39)	362
Range	63-110	104-186	131-243	156-268	174-289	194-306	213-322	217-331	228-342	213-356	226-360	
N	24	24	24	24	23	22	21	14	11	7	3	1

Notes: Unweighted refers to each mean value for each lake received equal weight, although sample sizes differed among each lake.
Standard error is in parentheses.
N = Number of populations

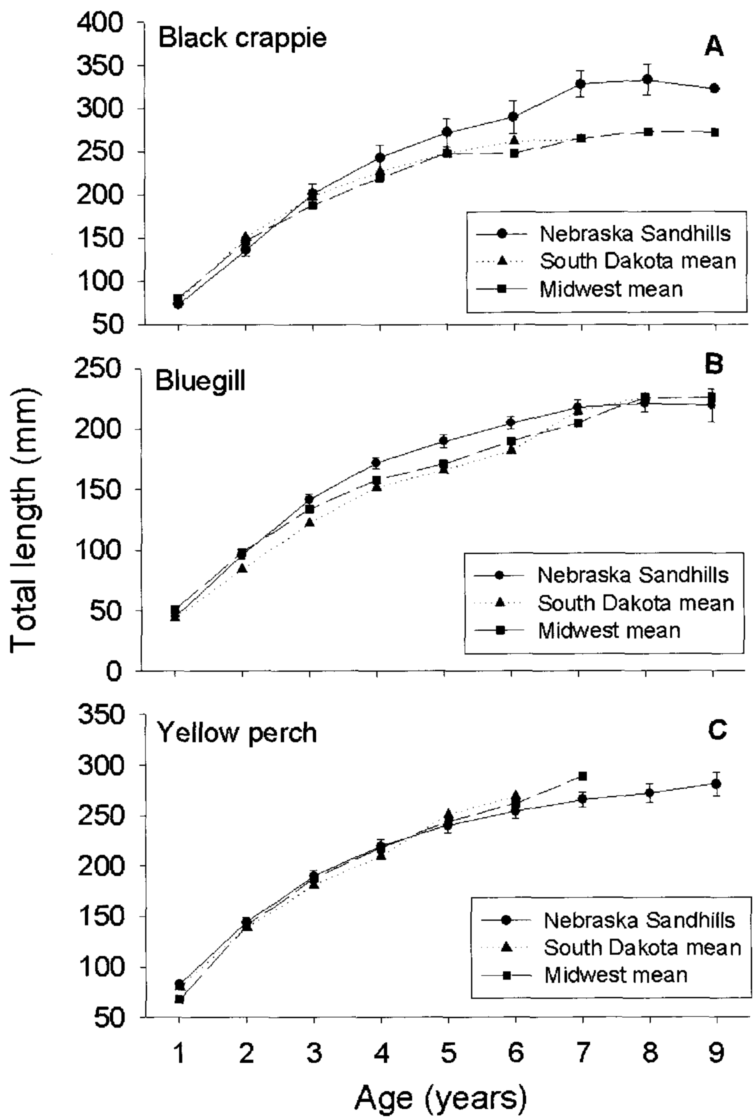

Figure 2. Unweighted mean total length at age (±1 SE) for black crappie (A), bluegill (B), and yellow perch (C) in Nebraska Sand Hills lakes. Comparisons with South Dakota (Willis et al. 1992; Guy and Willis 1995) and Midwest means are also presented. Midwest means for all panfish are from Iowa, Indiana, Illinois, Kansas, Missouri, Nebraska, and Ohio (Carlander 1977, 1997). However, black crappie means also include Kansas and Missouri means (Carlander 1977). Unweighted indicates that each mean value for each lake received equal weight, although sample sizes (number of fish collected) differed among lakes.

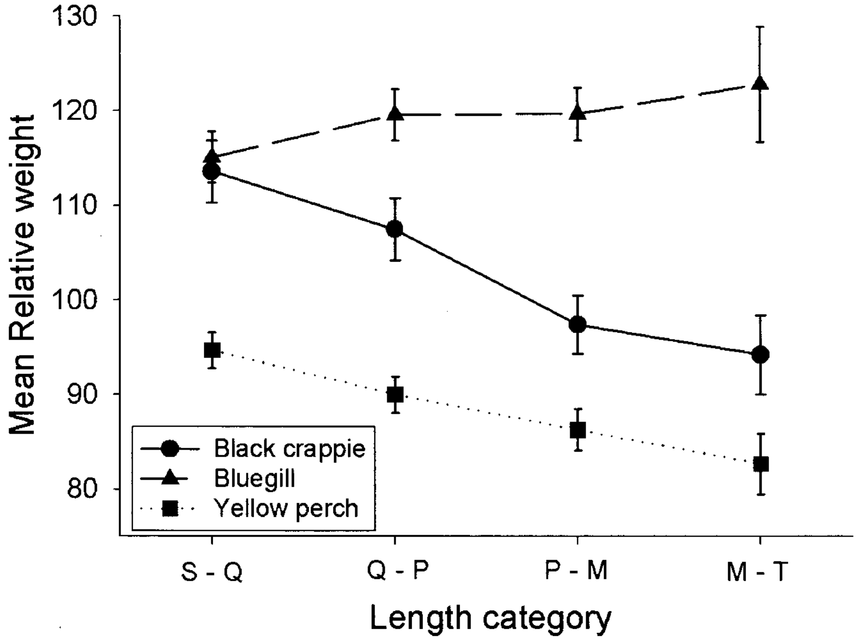

Figure 3. Unweighted mean relative weight (W_r) values (±1 SE) for black crappie, bluegill, and black crappie in Nebraska Sand Hills lakes. Specific lengths for the length categories are delineated in Table 2. S-Q = stock to quality length, Q-P = quality to preferred length, P-M = preferred to memorable length, and M-T = memorable to trophy length. Unweighted indicates that each mean value for each lake received equal weight, although sample sizes (number of fish collected) differed among lakes.

(Willis et al. 1992) and the rest of the Midwest (Iowa, Illinois, Indiana, Nebraska, Ohio; Carlander 1997) (Fig. 2C).

Maximum age of black crappie and bluegills in the Sand Hills was similar to other populations. A maximum age of 13 (which was similar to the Sand Hills' age 11) was reported for black crappies in Massachusetts waters. Few fish, however, exceed age 8 across the black crappie geographic range (Carlander 1977). Our bluegill maximum age (12) was the same as that in Wisconsin natural lakes (12) (Carlander 1977). However, the maximum age of yellow perch in the Sand Hills was considerably younger than the age 20 that was reported in a Massachusetts lake (Carlander 1997).

Condition. Relative weights of bluegill, black crappie, and yellow perch indicated that these fish were not emaciated. A relative weight value

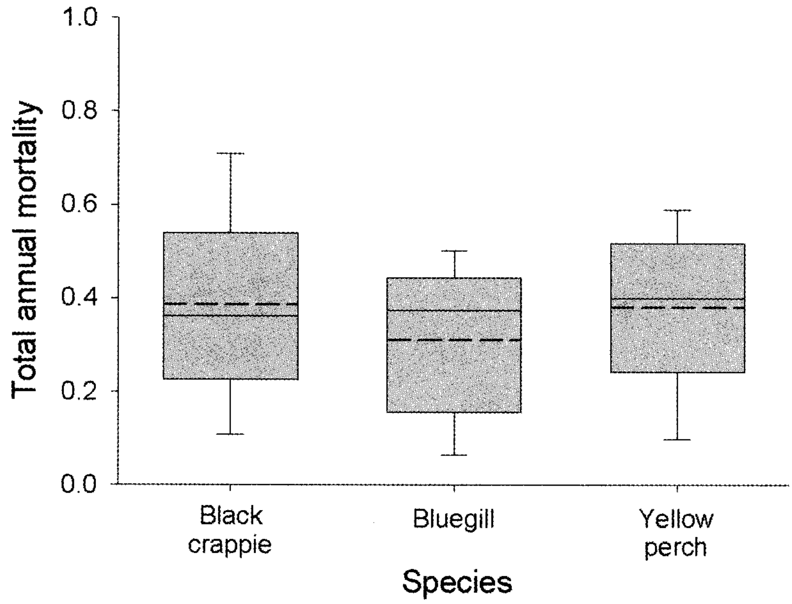

Figure 4. Median (horizontal solid line) and mean (horizontal dashed line) total annual mortality estimates for black crappie, bluegill, and yellow perch collected in Nebraska Sand Hills lakes. The gray box represents the middle 25% of the observations and the bars represent the middle 80% of the observations.

of 100 represents the optimum weight (e.g., 75th percentile) for a given length across the species entire range (Blackwell et al. 2000). Thus, bluegill and black crappie populations in the Sand Hills (with a mean relative weight range of 94 to 123) were in very good condition. However, the condition of yellow perch was below the optimum but still was not terribly low, ranging from 83 to 95. Because relative weight is a measure of plumpness (Blackwell et al. 2000), it has been used an index of food prey availability (Porath and Peters 1997). High relative weight indicates that food was not limiting fish growth or condition. Reduced relative weights at larger sizes of black crappie and yellow perch suggest that less food of an appropriate size or type was available to these larger-sized fish that likely eat other small fishes (Pflieger 1997). Alternatively, bluegills had high relative weights for all fish lengths, and they primarily eat aquatic invertebrates and zooplankton (Pflieger 1997).

Mortality. Mean mortalities of all the panfish species in the Sand Hills were low, ranging from 30.9% for bluegills to 38.6% for black crappies. These low values likely reflect natural mortality since these lakes typically had low angler exploitation. Bluegill mortality in other midwestern waters ranged from 30% for unexploited populations in Wisconsin lakes (Goedde and Coble 1981) to 82% in a heavily exploited Indiana population (Gerking 1952). Parsons and Reed (1998) determined that total annual mortality for bluegill was 74% and for black crappie was 59% in four lakes in west-central Minnesota, with 8% to 34% attributed to exploitation. Our black crappie estimate of 38.6% would be near Parsons and Reed's values if exploitation were removed. In addition, Reed and Davies (1991) determined that total annual mortality for both black crappie and white crappie *(Pomoxis annularis)* was 73%, with 20% attributed to exploitation, in Weiss Lake, AL. Their 53% natural mortality exceeded the total mortality (mean = 38.6%) we recorded for the Sand Hills populations. Our mean total annual mortality estimate of 37.9% for yellow perch was lower than the estimate for some unexploited Wisconsin lakes (68%-69%; Goedde and Coble 1981) and for Lake Superior (58%; Bronte et al. 1993). Given that our total annual mortality estimates for all three panfish species are from unexploited to moderately exploited populations, our estimates of 31% to 39% likely are similar to natural mortality estimates in other populations.

Conclusions

These data provide new information on fish in the Sand Hills for comparisons with fish populations in other shallow prairie lakes in the Midwest and Great Plains, and they serve as a baseline for future evaluations. For example, bluegill and black crappie had high condition values, and their relative weight values near 105 to 120 may be typical for these species in this region. In contrast, the mean relative weight by length group for yellow perch in the Sand Hills lakes never was above 100, and benchmark values may be lower (e.g., 90). Finally, these data can be used as inputs for population models (e.g., Maceina et al. 1998) that require specific population parameters, such as growth and mortality. Panfish in Sand Hills lakes provide a unique angling opportunity because of the abundant, high-quality black crappie, bluegill, and yellow perch populations. Part of the reason these fish provide high-quality angling is their fast growth, good condition, and low natural mortality, which results in a greater number of older, large, and robust fish.

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APPENDIX 1
NAMES, LEGAL DESCRIPTION, AND AREA OF 30 NEBRASKA SAND HILLS LAKES SAMPLED FOR BLUGILL, BLACK CRAPPIE, AND YELLOW PERCH IN 1998 AND 1999

Lake	County	Legal description	Surface area (ha)
Alkali	Cherry	T26N, R40W, S10, 11, 12	154
Big Alkali	Cherry	T30N, R28W, S27-28, 32, 33	341
Cameron	Rock	T28N, R18W, S21	66
Clear	Brown	T26N, R23W, S6, 31, 36	79
Clear (VNWR)	Cherry	T30N, R28W, S19, 20, 21	172
Cottonwood	Cherry	T37N, R34W, S21	15
Cozad	Brown	T28N, R20W, S26	32
DeFair	Grant	T23N, R38W, S15	24
Dewey	Cherry	T30N, R28W, S28, 29, 30	223
Duck	Cherry	T30N, R29W, S28	27
Goose	Holt	T25N, R11W, S26	81
Hackberry	Cherry	T19-30N, R29W, S14, 15, 22, 23	275
Hagan	Brown	T27N, R20W, S10, 11	126
Home Valley	Cherry	T27N, R37W, S5, 6	97
Island	Garden	T20N, R44W, S3, T21N, R44W, S35	283
Lackaff West	Rock	T28N, R19W, S15, 16	69
Marsh	Cherry	T27N, R32W, S23, 24	33
Marsh (VNWR)	Cherry	T29N, R27W, S29-32, 5, 6, 8, 9	907
Medicine	Cherry	T32N, R35W, S27, 28	45
Pelican	Cherry	T29, 30N, R28, 29W, S16, 34-36	332
Roseberry	Cherry	T28N, R35W, S25, 30	33
Round	Rock	T28N, R18W, S18	17
Schoolhouse	Cherry	T31N, R33W, S25, 30	42
Shell	Cherry	T34N, R40W, S16	66
Shoup	Cherry	T32N, R34W, S33	19
Tower	Brown	T28N, R22W, S35, 36	123
Twin	Rock	T27N, R19W, S12, 13	65
Watts	Cherry	T30N, R29W, S13, 14, 15	93
Willow	Brown	T29N, R27W, S21, 22, 27, 28	127
West Long	Cherry	T30N, R29W, S33-34	25

Note: VNWR = Valentine National Wildlife Refuge