RESULTS FROM THE 2006 FISHERY ASSESSMENT SURVEYS CONDUCTED ON THE VALENTINE NATIONAL WILDLIFE REFUGE

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INTRODUCTION

The Valentine National Wildlife Refuge (NWR) was established in 1935 to provide feeding and resting areas for migrating waterfowl. Public recreation that is compatible with the purposes of the refuge, including hunting and fishing, is promoted. Management of the fisheries is defined in a 1978 Cooperative Agreement between the U.S. Fish and Wildlife Service (Service) and Nebraska Game and Parks Commission (NG&P).

The Valentine NWR contains 39 lakes. The majority of the lakes are small, shallow, potholes that are subject to frequent winter-kills. Nine Lakes are open to fishing: Pelican, Hackberry, Dewey, Clear, Willow, Watts, Duck, Rice, and West Long. These lakes have varying degrees of potential for fisheries management. All of the designated fishing lakes, except Rice Lake, are accessible by vehicles.

Common carp (*Cyprinus carpio*) gained access to the Valentine NWR lake system through Gordon Ditch, which was dug during the 1930's. Carp reproduce well in the shallow, highly-vegetated refuge lakes and generally dominate the fishery within 10 years after introduction. Degradation of aquatic habitats by carp is well documented and high numbers of carp are detrimental to waterfowl and game fish habitat. These refuge lakes have a long history of renovation to remove carp. Historically, for about five years following a renovation, fishing is excellent, duck use is high, and then both decline due to carp-induced habitat degradation. Fisheries biologists from the Service and NG&P have experimented with the use of northern pike (*Esox lucius*) as a biological carp-control. The first attempts were unsuccessful because northern pike were introduced after carp were well established.

In 1988, northern pike and largemouth bass (*Micropterus salmoides*) length limits were changed for Valentine NWR lakes in an attempt to increase abundance and size structure of predators. The size restrictions appear to be successful as carp numbers have stabilized in lakes where the restrictions were enacted. The success has not been without perceived drawbacks. Predation by northern pike reduces the abundance of small largemouth bass and all sizes of yellow perch (*Perca flavescens)*, and bluegills (*Lepomis macrochirus)*, and alters the relationship between largemouth bass and panfish (Paukert and Willis 2003). Although large numbers of northern pike have probably impacted game fish populations, environmental conditions such as a 1987-88 winter-kill, low reproduction/ recruitment due to drought conditions during the summers of 1989 – 1990 and 2002-2006, and an extremely cool spring/summer ($<21^{o}$C) during 1992 and 1993 probably had equal impact. The springs of 1994-97 were exceptionally wet, and these conditions provided good habitat and conditions for strong year classes for most fish species. However, high water levels also connect lakes that are usually isolated, which allows fish movement. Of special concern during high water years are the inter-lake movement of carp as observed during 1996 and 1997.

Northern pike have been identified as a possible tool for controlling common carp, and evaluating their potential is a high priority for the refuge's fisheries. Many of the results from fishery assessments identified in this report are directed at: 1) evaluating northern pike as biological control agent for carp, 2) evaluating northern pike recruitment and condition in response to the special regulation allowing harvest of northern pike less than 28 inches, and 3) evaluating the impacts of the special northern pike regulations on other game fish species with special emphasis on the bluegill and yellow perch populations.

CLEAR LAKE

Clear Lake is accessed by gravel roads from County Highway 16B or U.S. Highway 83. Ice fishing is popular during winter with good ice, although heavy snow sometimes causes road closures and limits access to this lake. During the spring and again during fall, northern pike fishing is popular.

Clear lake is in the middle of a series of four lakes on the refuge connected by natural drainage and man-made ditches. A ditch dug from Dewey Lake (upstream from Clear Lake) feeds into Clear Lake. The interconnection of these lakes has created problems with controlling inter-lake fish movement in past years. The spring of 1995 and 1997 were years of high run-off resulting in extremely high lake levels. Water flowed from Clear to Willow Lake for much of the spring and summer and inter-lake fish movement was observed. Beginning in 2002 and continuing to date, the refuge lakes have experienced lowered water levels due to below precipitation and low winter accumulations of snow.

Clear Lake is 172 surface ha (424 acres) with a maximum depth of 3.5 m (10.2 ft.) and mean depth of 1.7 m (6 ft.) during high pool (Figure 1). A dike on the east end can hold the lake about 1.2 m higher than the natural pool level. The added area is primarily flooded sand dunes and provides little fisheries habitat. The bottom is relatively flat with few drop-offs or depressions. Most of the bottom is sandy, but a small bay on the east end of the lake contains an expanse of highly organic bottom. The surrounding shoreline is predominately grass with a few willows (*Salix spp.*) and cottonwoods (*Populus spp.*). High water levels are required to flood shoreline vegetation for spring spawning sites. The limited littoral area reduces spawning and subsequent survival for most of the lake's game fish species. Aquatic vegetation is sparse around the edges. Less than 2% of the lake contains emergent vegetation (primarily cattails [*Typha spp.*]), and submergent vegetation is absent. The lack of vegetation is related to the infertile sandy bottom and turbidity. Conductivity averages 590 µS/cm at 25 ^{0}C. Total alkalinity is 308 and phenolphthalein alkalinity is 0 ppm. The lake's pH averages about 8.5 through most of the year and Secchi disk averages about 0.3 m. The lake is too shallow to develop a thermocline.

The lake was chemically renovated with rotenone in 1983 and restocked with game fish, such as northern pike and largemouth bass. During the 1986 survey, sub-adult carp were collected for the first time since the 1983 renovation. A major winterkill occurred during 1987-1988 and poor recruitment of yellow perch and bluegill was seen in subsequent years. Beginning January 1988, a 36 in. minimum length limit for northern pike was implemented in an attempt to develop a predator population capable of controlling carp recruitment. The size limit was reduced to 30 in. during 1990 and returned to 36 in. during 1991. Beginning January 1993, regulations were enacted that protected only northern pike greater than 28 in. Since enactment of these regulations, fall surveys generally indicate strong northern pike year-classes, excellent size structure, and good condition. Length and bag limits are summarized in Appendix A and the history of fish stockings are summarized in Appendix B.

Primary fish species include: northern pike, carp, largemouth bass, bluegill, yellow perch, black bullhead (*Ameiurus melas*), and black crappie (*Pomoxis nigromaculatus*). The lake has been described as having a boom or bust fishery.

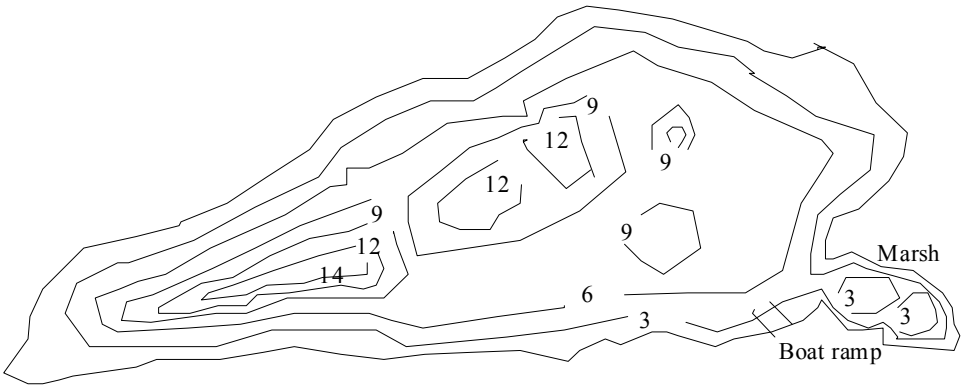

Figure 1. Contour map (in feet) of Clear Lake (Full pool).

Methods

In 2006, electrofishing was conducted in Clear Lake on 5 June, trap nets were set overnight on 7 June, and gill nets were set overnight on 29 August. Electrofishing was conducted for 2 hours after dusk with a Smith and Root 5.0 GPP electrofishing system using 200 volts pulsed DC, 8-9 amps, and a pulse frequency of 120 cycles per second (cps). Electrofishing was conducted in 15 minute transects along the shoreline. Ten trap nets and five gill nets were set perpendicular to the shore for 24 hours (Figure 2). Trap nets had 13-mm (0.5 in.) mesh, single throats, and 15.2-m (50 ft.) leads. Gill nets were 38.1 m (125 ft.) long by 1.8 m (6 ft.) high monofilament experimental nets consisting of five 8-m (25 ft.) long panels with bar mesh sizes of 19 mm (0.75 in.), 25 mm (1 in.), 38 mm (1.5 in.), 51 mm (2.0 in.), and 76 mm (3 in.).

Water quality parameters collected were water temperature, dissolved oxygen, pH, salinity, alkalinity, and conductivity (Table 1).

Glossary of fishery terms are summarized in Appendix C and data collation and analysis techniques are summarized in Appendix D.

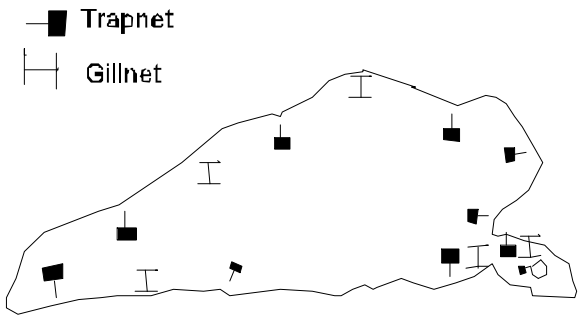

Figure 2. Net locations for Clear Lake.

Table 1. Clear Lake surface water quality parameters.

Date	Water temp. (°C)	D.O. (mg/L)	Secchi depth (cm)	pH	Salinity (ppt)	Phenolphthalein alkalinity (mg/L)	Total alkalinity (mg/L)	Specific conductivity (µS/cm)
08/2006	21	8.1		7.1	0.30	0	257	649
08/2005	22			7.2		0	290	
09/2003		9.2						
09/2002	21	6.0		8.1		0	513	500
09/2001	18		60	7.2		0	205	486
07/2001 dusk	26	13.0		7.7		60	196	
07/2001 dawn	23	7.4		9.5		0	196	
09/2000	17		30	8.4		0	308	590
09/1999	16			8.2				

Results and Discussion

Black bullhead

No black bullhead were collected in 2006. Black bullhead gill net mean CPUE declined from a high of 55 fish/net in 1987 to less than 1 fish/net, where it has remained since 1993. Black bullheads now make up a minor part of the Clear Lake fishery.

Black crappie

Three sub-stock and one stock size black crappie were collected in trap nets in Clear Lake in June 2006. Ten sub-stock crappie were captured in trap nets in 2005

Bluegill

35 bluegills were captured electrofishing and 43 in trap nets. Although not substantial, bluegill relative abundance did increase since 2005. However, proportional stock density (PSD) declined (Figure 3).

Strong year classes were produced in 1999 and 2001, but failed to recruit to longer sizes and the 2006 surveys indicated a bluegill fishery comprised of few angler preferred length fish (Figure 4) with relative weights indicating above average growth rates for those fish sampled (Table 2).

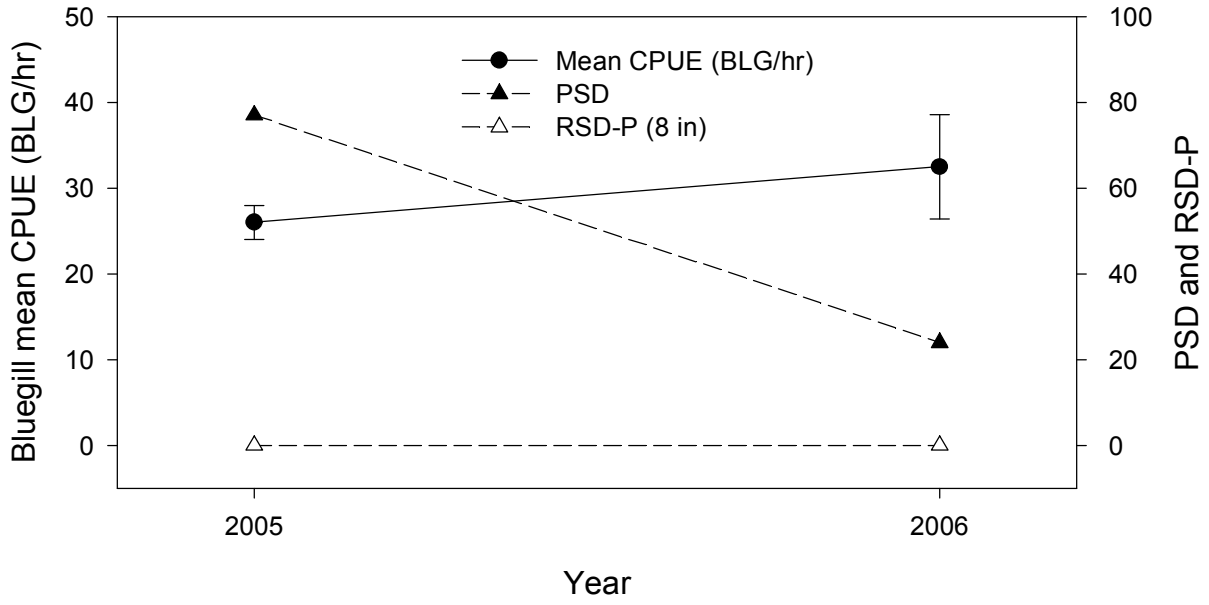

Figure 3. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of bluegills caught by electrofishing (bluegill/hr) in Clear Lake, Valentine NWR from 2005 to 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

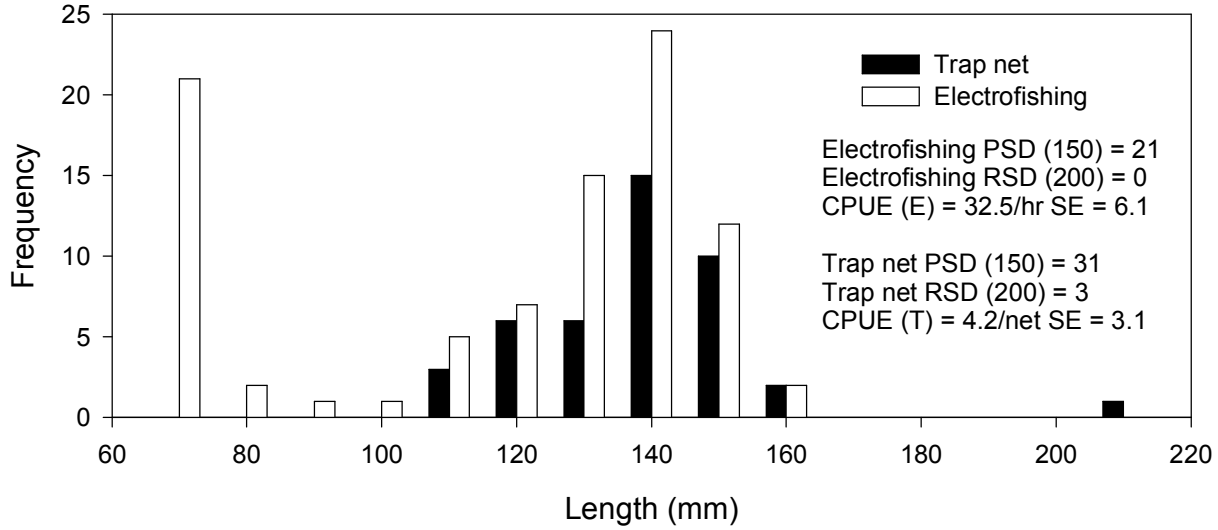

Figure 4. Bluegill length frequency distribution (10-mm length groups) by gear type for Clear Lake, Valentine NWR, June 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Table 2. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for bluegill captured by electrofishing and trap nets in Clear Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Stock – quality (80 – 149 mm)	39	50 (3.3)	116 (2.4)
Quality – preferred (150 – 199 mm)	14	91 (3.7)	114 (4.0)
Preferred – memorable (200 – 249 mm)	1	320	133
Memorable – trophy (250 – 299 mm)	0		
Trophy (≥ 300 mm)	0		
Total	54	66 (5.9)	115 (2.0)

Common carp

In 2006, 57 carp were captured in gill nets of which 11 were sub-stock length category (Figure 5) with an overall Wr = 109 (SE =2.9). Mean CPUE (≥ stock length) was 8.6 (SE = 1.7), but was not substantially different from 2005. The PSD increased to 100 compared to 44 in 2005. In 2002 and 2004, a large number of sub-stock carp were captured in gill nets. It appears that those carp have recruited as mean CPUE substantially increased in 2005 and 2006 (Figure 6). However, sub-stock length carp were found in the stomachs of northern pike in August 2006.

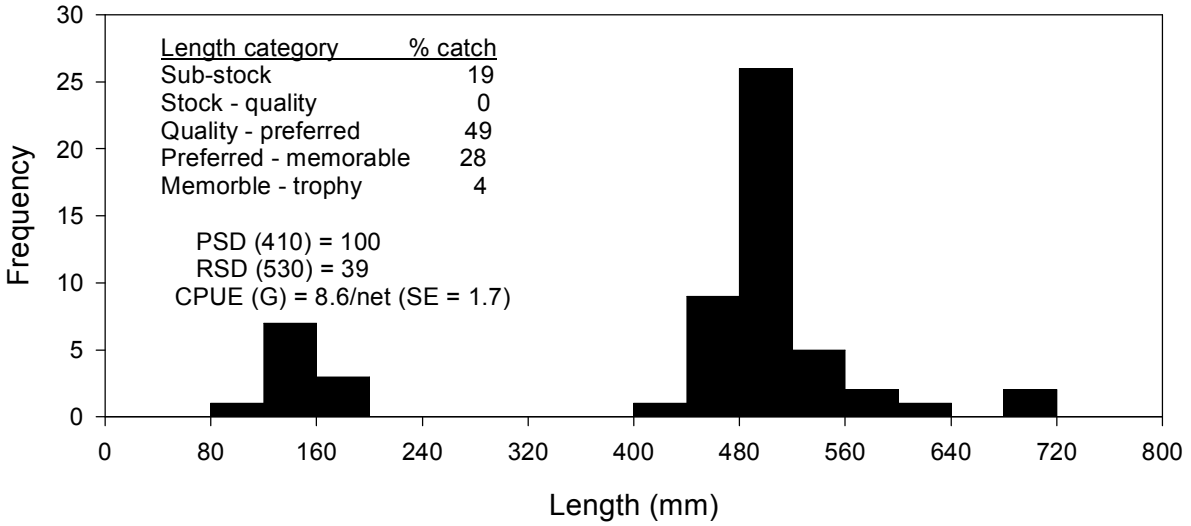

Figure 5. Length frequency distribution (40-mm length groups) of common carp captured in gill nets in Clear Lake, Valentine NWR, August 2006. Mean catch per unit effort (CPUE) for carp ≥ stock length (280 mm).

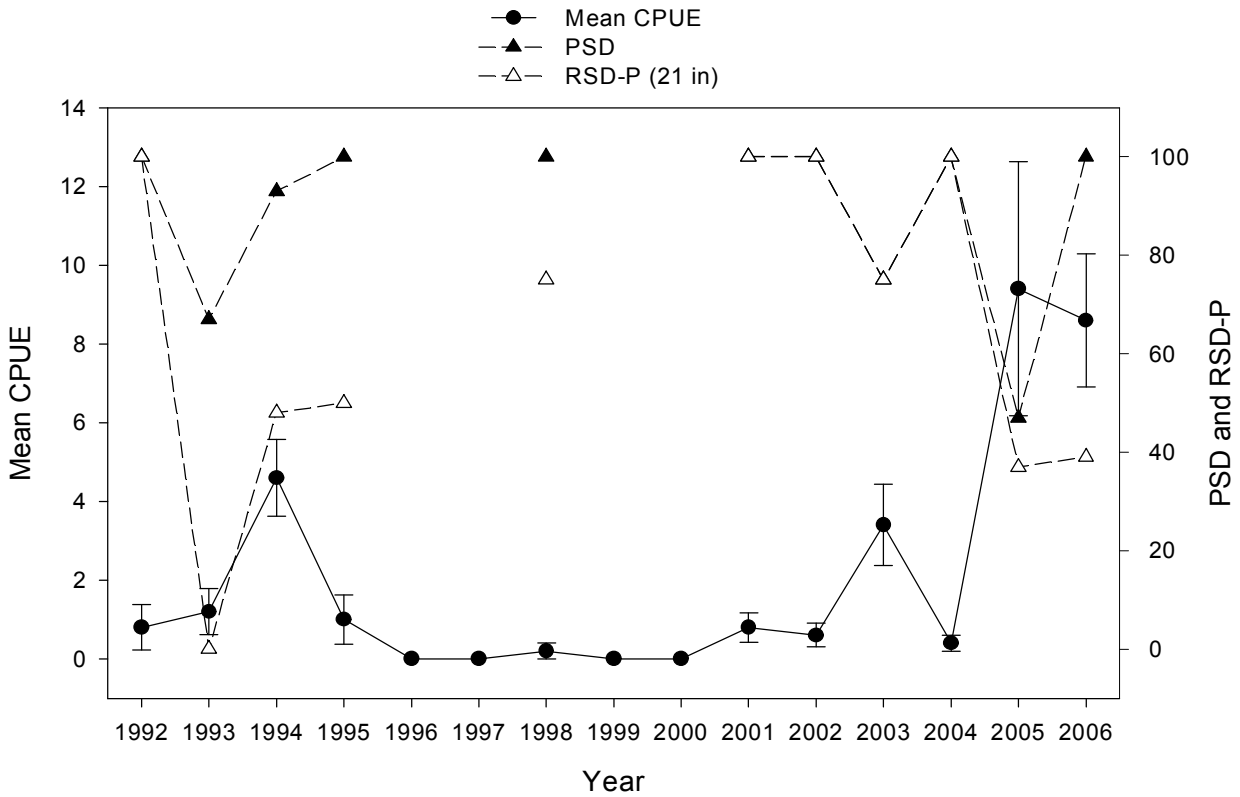

Figure 6. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of common carp caught by gill netting (carp/net) in Clear Lake, Valentine NWR from 1992 to 2006. Mean catch per unit effort (CPUE) for carp ≥ stock length (280 mm).

Largemouth bass

Electrofishing mean CPUE of largemouth bass (≥ stock length) increased from 0.0 bass/hr in 2005 to 2.5 bass/hr in 2006. The increase in relative abundance was likely due to increased effectiveness of electrofishing with higher water levels in 2006 compare to 2005 at the time of sampling. The largemouth bass population in Clear Lake was dominated by sub-stock length fish (Figure 7). The overall Wr = 114 (SE = 2.4) (Table 3) and was similar to other Sandhill lakes.

Largemouth bass mean CPUE declined from 17 fish/hr of electrofishing (≥ stock length) during 1989 to about 1 fish/hr by 1991. Largemouth bass electrofishing mean CPUE has ranged between 60 during 1996 to 6.3 during 2000. Few fish have been longer than stock length since 2000.

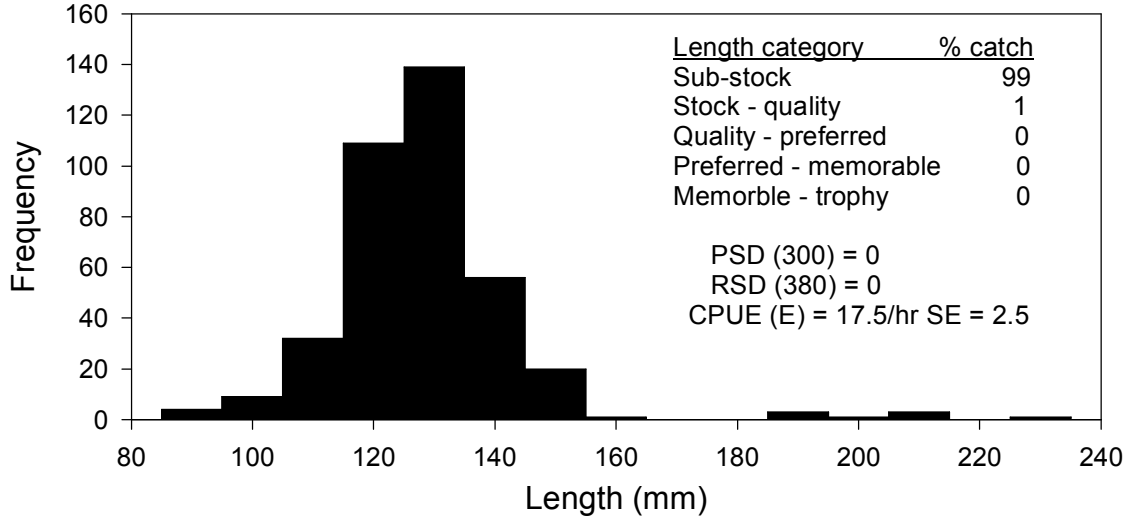

Figure 7. Length frequency distribution (10-mm length groups) of largemouth bass captured by electrofishing in Clear Lake, Valentine NWR, June 2006.

Table 3. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for largemouth bass captured by electrofishing in Clear Lake, Valentine NWR, June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 200 mm)	38	34 (3.8)	118 (1.9)
Stock – quality (200 – 299 mm)	5	111 (4.2)	86 (5.2)
Quality – preferred (300 – 379 mm)	0		
Preferred – memorable (380 – 509 mm)	0		
Memorable – trophy (510 – 629 mm)	0		
Trophy (≥ 630 mm)	0		
Total	43	43 (5.1)	114 (2.4)

Northern Pike (*Esox lucius*)

In 2006, the northern pike population was dominated by quality to preferred and preferred to memorable length fish with limited recruitment (Figure 8). Relative weights (Wr) (Table 4) were similar to other Sandhill lakes (Paukert and Willis 2003). The relative abundance was not significantly different ($P > 0.20$) compared to the relative abundance from 1995 to 2005 (Figure 9). The relative abundance of preferred length ($\geq$ 28 in) fish did increase in 2006 compared to 1999 – 2005 (Figure 10). The increase in relative abundance may be due to reduced fishing mortality. Ice fishing occurred almost exclusively in the month of December during the unusually warm winter of 2005-2006.

During 1988, a 36 in. minimum size limit for northern pike was implemented. The minimum size regulation was reduced to 30 in. beginning in 1990 and returned to a 36 in. minimum during 1991. In 1993, the regulations were changed to allow only harvest of northern pike less than 28 in. It is difficult to interpret how these changes have impacted the northern pike population, but the northern pike appeared to respond poorly to 36 in. minimum size limit, which was reflected in declining abundance and condition. The new regulation allowed harvest of northern pike less than 28 in. and protected larger individuals, which was enacted to increase the number of larger northern pike thought to be necessary for controlling carp recruitment. Northern pike mean CPUE for size classes preferred and larger (i.e., >28 inches) individuals has generally increased since this regulation was imposed, but the increase has not been linear. Since the 28 in. size limit, the most notable differences in RSD values have occurred for memorable to trophy length fish. Fish in this length category have usually been collected every year since 1996 (except 2000) with incremental RSD-M values ranging from 5 to 27 since 1996. However, before 1996, northern pike in this size class were only collected once in 1989 with a RSD value of two (Table 5).

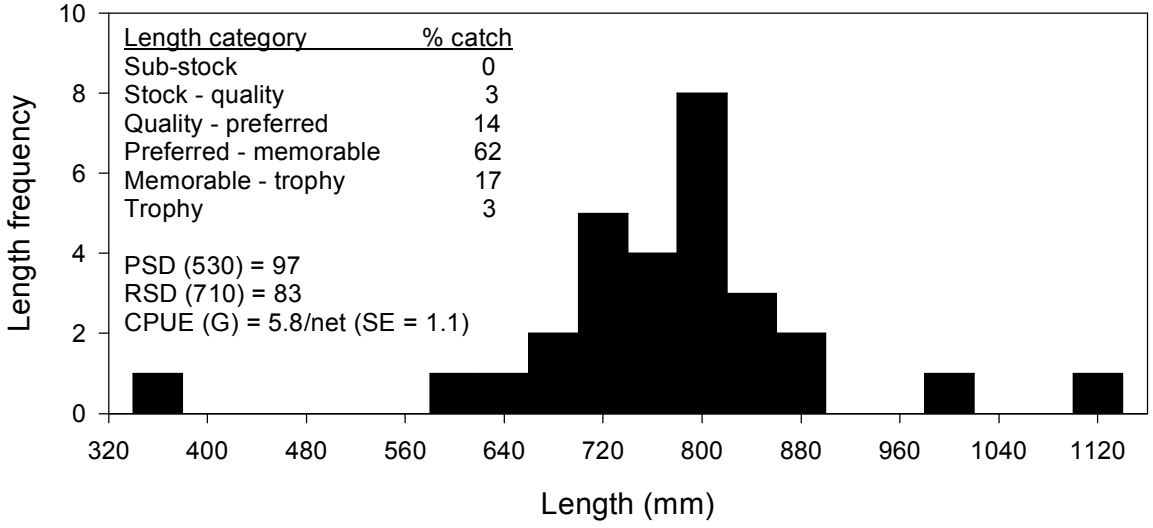

Figure 8. Length frequency distribution (40-mm length groups) of northern pike captured by gill nets in Clear Lake, Valentine NWR, August 2006.

Table 4. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for northern pike captured by trap nets (TN) in June 2006 and gill nets (GN) in August 2006 in Clear Lake, Valentine NWR.

Length category	Trap net (n)	TN mean weight (g)	TN mean Wr	GN (n)	GN mean weight (g)	GN mean Wr
Sub-stock (< 350 mm)	0			0		
Stock – quality (350 – 529 mm)	0			1	380	123
Quality – preferred (530 – 709 mm)	0			4	2,075 (188.7)	98 (3.1)
Preferred – memorable (710 – 859 mm)	3	2,433 (120.2)	81 (2.5)	18	3,164 (123.5)	94 (2.7)
Memorable – trophy (860 – 1,119 mm)	0			5	4,420 (558.9)	83 (3.2)
Trophy (≥ 1,120 mm)	0			1	8,250	74
Total	3	2,433 (120.2)	81 (2.5)	29	3,310 (264.9)	93 (2.3)

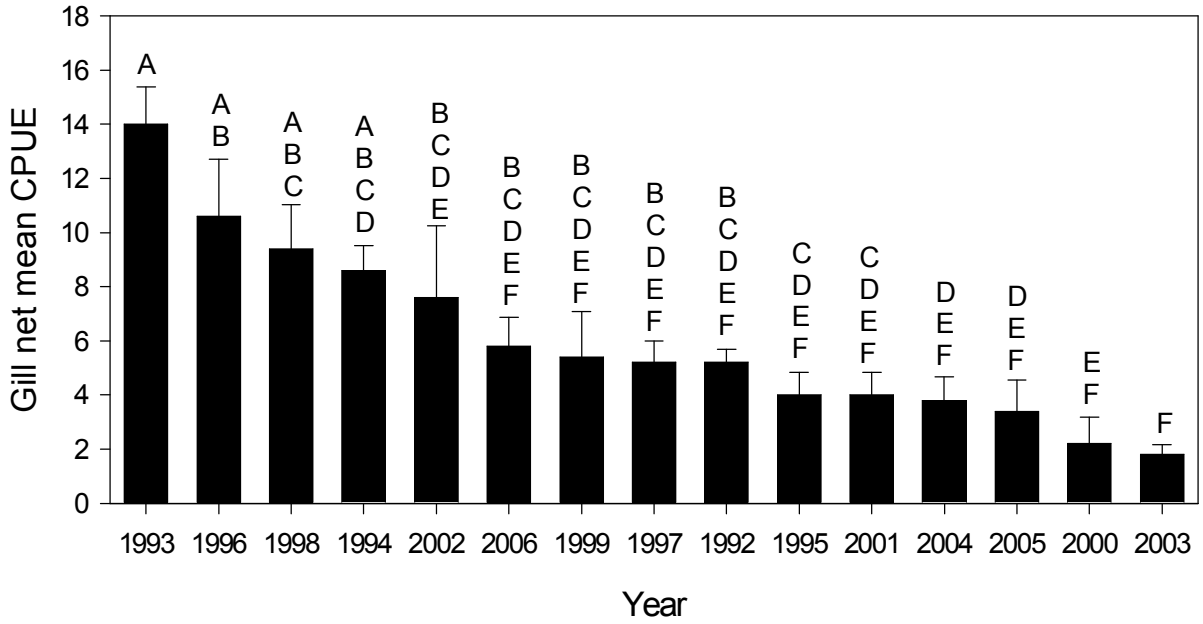

Figure 9. Northern pike gill net mean catch per unit effort (CPUE) in Clear Lake, Valentine NWR from 1992 to 2006. Years with the same letter are not significantly different (P > 0.20) using ANOVA with Tukey-Kramer multiple comparison test.

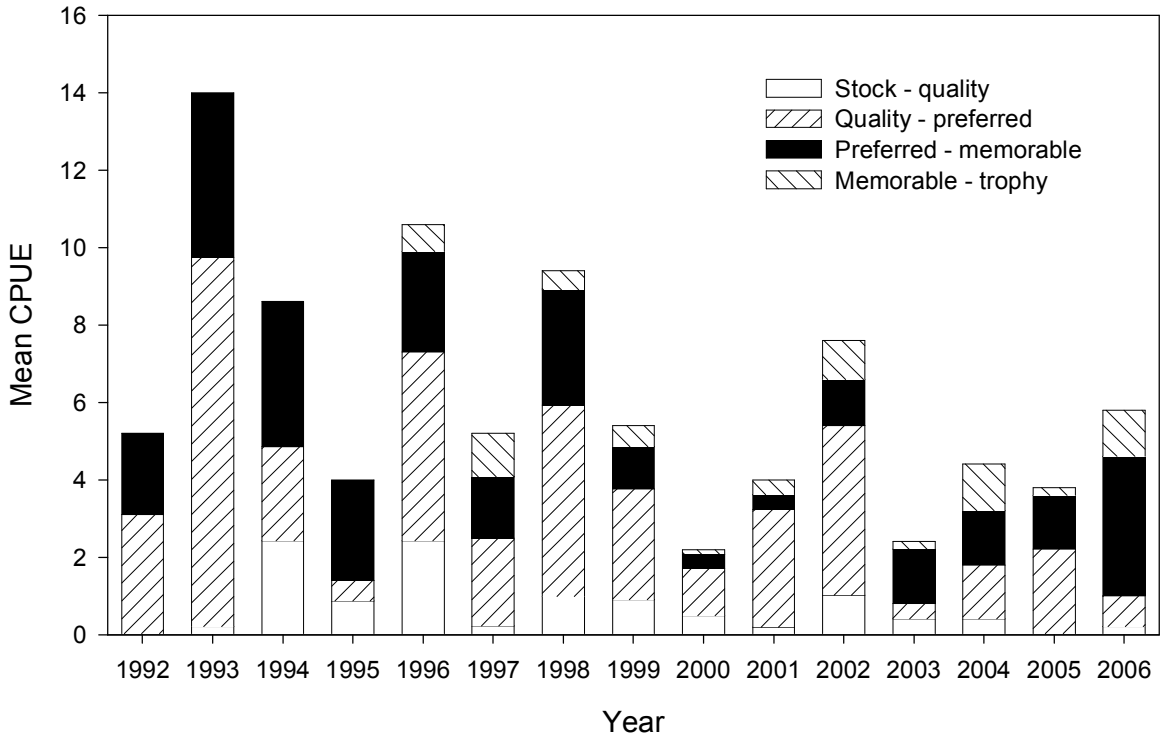

Figure 10. Gill net mean catch per unit effort (CPUE) for northern pike by length category in Clear Lake, Valentine NWR for years 1992-2006.

Table 5. Population size structure, traditional proportional stock density (PSD) and incremental relative stock density (RSD) with relative weights (*Wr*) of northern pike in Clear Lake, Valentine NWR during the fall. 2006 Data for fall gill netting only. Data are pooled for trap and gill nets from 1988 to 2005. Data are summarized by length categories with 80 % confidence intervals (+/-) and "a" denotes small sample size, confidence intervals could not be calculated.

Year	% ≥ Quality		S-Q (350-530mm) (14-21 in)			Q-P (530-710mm) (21-28 in)			P-M (710-860mm) (28-34 in)			M-T (860-1120mm) (34-44 in)		
	PSD	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*
2006	97	93	3	a	123	14	a	98	62	22	94	17	a	83
2005	100	93	0	a		60	a	92	35	a	95	5	a	86
2004	91	106	9	a	102	32	a	113	32	a	104	27	a	101
2003	83	89	17	a	89	17	a	100	58	a	88	8	a	79
2002	87	86	13	a	86	58	16	88	16	a	85	13	a	83
2001	95	87	5	a	100	76	16	87	10	a	74	10	a	98
2000	77	79	23	a	87	59	5	76	18	a	74	6	a	76
1999	80	84	20	a	83	53	14	82	20	12	87	10	a	94
1998	89	90	10	6	95	53	10	91	32	9	89	5	a	82
1997	96	94	4	a	100	46	7	105	29	6	93.0	21	6	97
1996	76	101	24	14	101	48	13	102	25	14	101	6	a	88
1995	78	95	22	14	99	13	13	98	63	15	92	0	a	
1994	71	105	28	9	115	28	9	98	43	11	95	0	a	
1993	98	97	1	a	97	68	11	101	30	9	98	0	a	
1992	100	96	0	a		60	9	96	40	9	97	0	a	
1991	100	92	0	a		87	a	94	13	a	90	0	a	
1990														
1989	93	90	7	a	95	68	a	90	23	a	80	2	a	87
1988	55	110	45	a	115	30	a	110	15	a	95	0	a	

Yellow Perch

In 2006, all perch captured in gill nets were stock-quality and quality-preferred length (Figure 11) with Wr similar to other Sandhill lakes (Table 6). The relative abundance of yellow perch in Clear Lake has remained low since 2003 (2.8 fish/gill net) and there is evidence of limited reproduction and recruitment since then. The 2006 survey did show the highest PSD value in the last 14 years (Figure 12). However, no preferred length fish were captured. There appears to be low recruitment of yellow perch in Clear Lake, either due to environmental conditions such as low water levels or an abundance of large predators.

Yellow perch mean CPUE declined from 90 fish/gill net during 1987 to 0 fish/gill net by 1989 and perch remained a negligible part of the Clear Lake fishery until 1997 surveys. From 1997 to 2002, there appeared to be successful multiple year classes and recruitment into sizes preferred by anglers. However, gill net mean CPUE has been low since 2003.

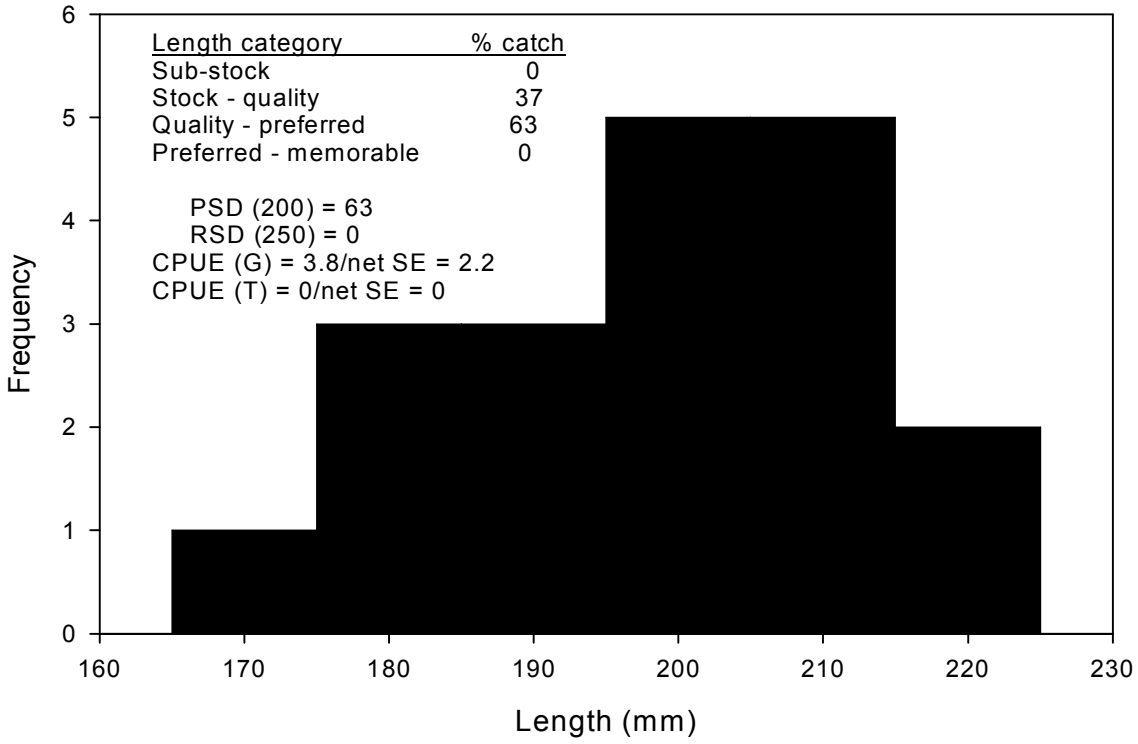

Figure 11. Length frequency distribution (10-mm length groups) for yellow perch captured in gill nets in Clear Lake, Valentine NWR, August 2006.

Table 6. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for yellow perch captured by gill nets in Clear Lake, Valentine NWR in August 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 130 mm)			
Stock – quality (130 – 199 mm)	6	96 (5.8)	108 (2.2)
Quality – preferred (200 – 249 mm)	11	126 (6.0)	96 (2.9)
Preferred – memorable (250 – 299 mm)			
Memorable – trophy (300 – 380 mm)			
Total	17	115 (5.6)	100 (2.4)

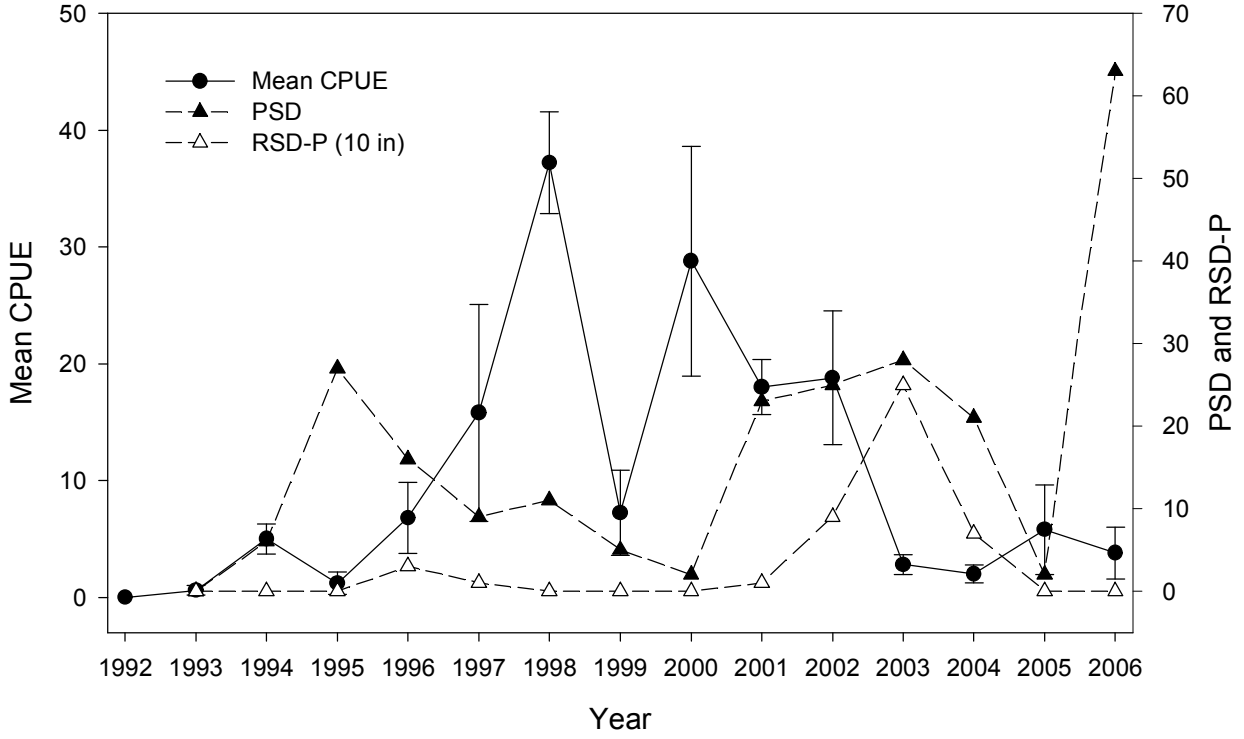

Figure 12. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of yellow perch caught by gill nets (perch/net) in Clear Lake, Valentine NWR from 1992 to 2006. Mean catch per unit effort (CPUE) for perch ≥ stock length (130 mm).

Summary

Common carp - In previous years it appeared that northern pike predation did not allow common carp to recruit to adult sizes in Clear Lake. Prior to 2005, the population of common carp was dominated by only a small number of preferred length and sub-stock fish. However, there was an increase in stock length carp in 2005 and 2006 after the large increase in sub-stock length fish in 2004. The low relative abundance of northern pike from 2003 to 2005 may have allowed carp recruitment.

Northern pike - Gill net CPUE remained similar to previous years. The northern pike population in Clear Lake was dominated by larger older individuals as little recruitment has occurred in recent years. Northern pike mean Wr was average compared to other sandhill lakes.

Largemouth bass – The largemouth bass population was dominated by sub-stock length fish.

Yellow perch - No preferred length yellow perch were captured in 2006.

Bluegill – Few preferred length bluegill were captured in 2006.

Black crappie – Few black crappie were captured in trap nets in 2006 in the same locations as in 2005. A population may develop in this lake, assuming that young black crappies can survive predation by northern pike.

Management Recommendations

1. Continue the 28 in. maximum size limit for northern pike and evaluate its impact on northern pike abundance and size structure.

2. Clear Lake has limited spawning habitat compared to other refuge lakes, especially during low water years. Stock fingerling northern pike to supplement the population during low water years. Evaluate the effects of stocking northern pike on relative abundance, size structure, and condition of northern pike and other fish species.

3. Continue annual surveys.

4. Continue to evaluate the use of black crappie as an additional game species.

DEWEY LAKE

Dewey Lake is accessible by gravel roads from County Highway 16B or U.S. Highway 83. The lake is heavily utilized during the ice fishing season when accessible, but this can be difficult during rare winters with heavy snow. Angling pressure can also be heavy during spring and fall, but fishing pressure declines during summer when dense submergent vegetation covers much of the lake.

Dewey Lake is in the middle of a series of four lakes on the refuge connected by natural drainage or man-made ditches. A ditch was dug to connect Hackberry (the first in the series) to Dewey. A ditch was also dug from Dewey to Clear (downstream from Dewey), and Dewey now feeds into Clear. The interconnection of these lakes has created problems with controlling inter-lake fish movement in past years.

Dewey Lake is 223 surface ha (560 acres) with a maximum depth of 2.7 m (8') and a mean depth of 1.4 m (4') (Figure 1). A dike on the east end of Dewey Lake allows the water to be held about 1.3 m above natural pool. The surrounding shoreline is predominately grassland with few willows and cottonwoods. The west end of the lake has a muck bottom comprised of a broad area of littoral vegetation with small areas of open water. The lake bottom on the north-east edge is sandy and sparsely vegetated; the south-east edge has a muck bottom and is heavily vegetated with emergent vegetation such as cattails and bulrush (*Scirpus spp.*). During summer, submergent and emergent vegetation is abundant in a band around the edge and is often referred to as "weed choked". The bottom of Dewey Lake is relatively flat with few drop-offs or depressions. Conductivity averages 344 μS/cm at 25^{0}C. Total alkalinity is 308 ppm, and phenolphthalein alkalinity is 0 ppm. The lake's pH averages between 9 during summer and 8 during fall/spring. Secchi disk averages 0.6 m. The lake is too shallow to develop a summer thermocline. Summer surface water temperatures often exceed 30 ^{0}C (80 ^{0}F), and dense algae blooms are noted.

Dewey Lake was chemically renovated with rotenone in 1981 and restocked with game fish the following year. However, the renovation was either not 100% successful or carp migrated into Dewey from other lakes. A fisherman reported the first post-renovation carp in 1984. Beginning in January 1988, a 36 in. minimum length limit for northern pike was implemented in an attempt to develop a predator population capable of controlling carp recruitment. Beginning in 1993, size regulations were enacted that protected only northern pike greater than 28 in. in length. In the spring of 1993, large numbers of carp were noted in the ditch between Dewey and White Water, likely making their upstream spawning migration. These carp were removed with an estimate of several tons of carp removed. Extremely high lake levels during spring (and through much of the summer) provided opportunities for inter-lake movement of fish. Length and bag limits are summarized in Appendix A and the history of fish stockings are summarized in Appendix B.

Primary fish species include: yellow perch, northern pike, largemouth bass, bluegill, black bullhead, and carp. In 1987 and 1988, adult flathead catfish (*Pylodictis olivaris*) were stocked to control an expanding slow growing population of black bullhead. Dewey Lake is considered one

of the better fishing lakes on the Refuge but also has a history of becoming dominated by carp shortly after chemical renovations.

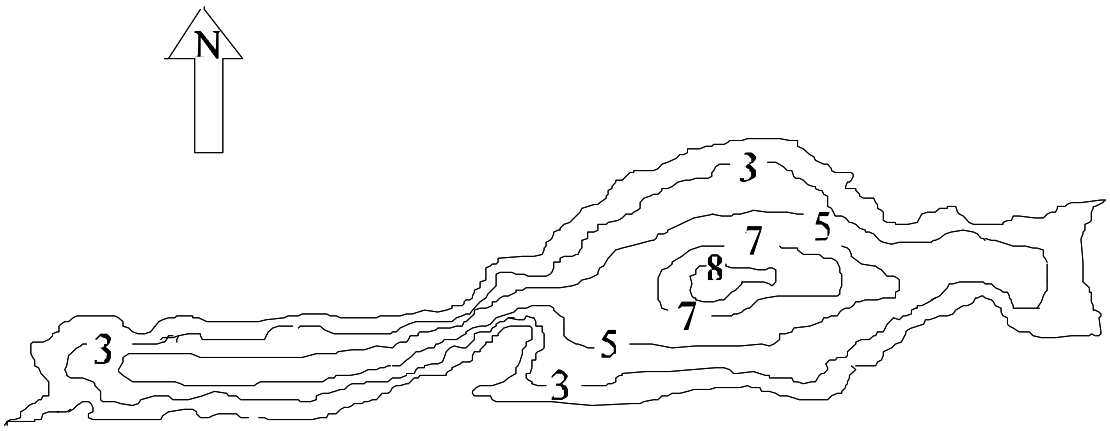

Figure 1. Bottom profile of Dewey Lake, Valentine NWR, contour intervals are measured in feet.

Methods

Night time electrofishing was conducted 5 June 2006, trap net were set overnight on 9 June 2006, and gill nets were set overnight on 30 August 2006. Electrofishing was conducted for two hours after dusk with a Smith and Root 5.0 GPP electrofishing system using 200 volts pulsed DC, 9 amps, and a pulse frequency of 120 cycles per second (cps). Electrofishing was conducted in 15 minute transects along the shoreline. Ten trap nets and 5 gill nets were set perpendicular to the shore for 24 hours (Figure 2). Trap nets had 13-mm (0.5 in.) mesh, single throats, with 15.2-m (50 ft.) leads. Gill nets were 38.1 m (125 ft.) long by 1.8 m (6 ft.) high monofilament experimental nets consisting of five 8-m (25 ft.) long panels with bar mesh sizes of 19 mm (0.75 in.), 25 mm (1 in.), 38 mm (1.5 in.), 51 mm (2.0 in.), and 76 mm (3 in.).

Water quality parameters collected were water temperature, dissolved oxygen, pH, salinity, alkalinity, and conductivity (Table 1).

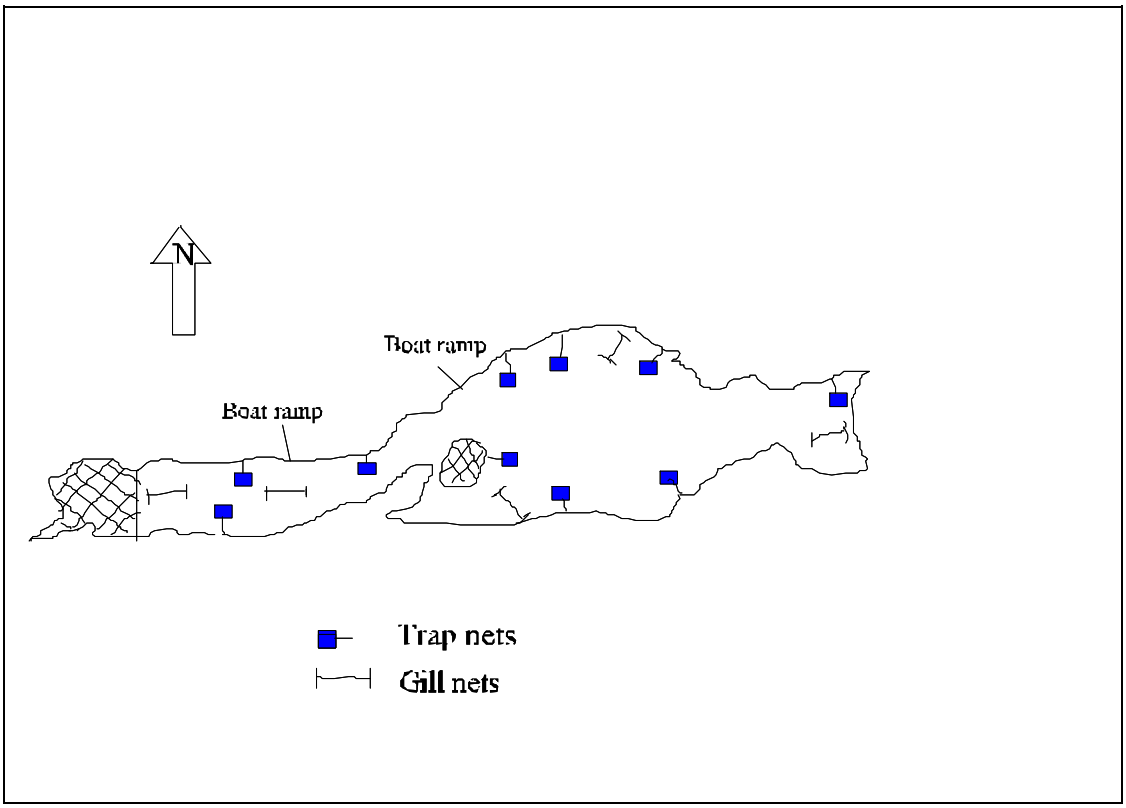

Figure 2. Net locations for Dewey Lake.

Table 1. Dewey Lake surface water quality parameters.

Date	Water temp. (°C)	D.O. (mg/L)	Secchi depth (cm)	pH	Salinity (ppt)	Phenolphthalein alkalinity (mg/L)	Total alkalinity (mg/L)	Specific conductivity (µS/cm)
08/2006	21	11.7		8.1	0.02	0	188	395
08/2005	23			8.5		0	240	320
09/2004	20		42	8.7		0	139	
09/2003	21	9.2						
09/2002	21	9.5		9.8		0	410	320
09/2001	118		66	7.0		0	145	346
07/2001 dusk	27	11.2		7.3		0	171	
07/2001 dawn	23	7.2		8.2		0	154	
09/2000	18		60	9.5		0	308	344
09/1999	15			11.5				

Results and Discussion

Black bullhead

No bullheads were collected in 2006. Since the 1987 introduction of flathead catfish into Dewey Lake, the black bullhead gill net mean CPUE has declined from a high of 30 fish/gill net in 1987 to near 0 in 1997. Mean CPUE has remained at 0 since 1997.

Bluegill

In 2006, the bluegill population in Dewey Lake was dominated by sub-stock and stock-quality length fish (Figure 3). Bluegill Wr values for all size classes were good (Table 2). The relative abundance of bluegills increased substantially from 2005 to 2006 while PSD declined (Figure 4).

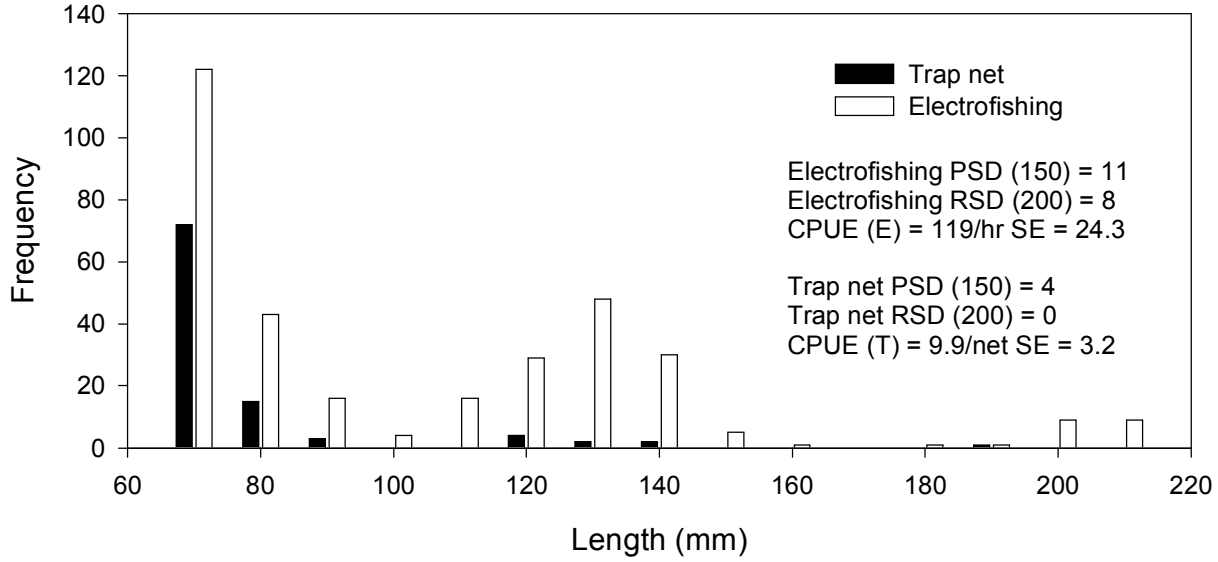

Figure 3. Length frequency distribution (10-mm length groups) for bluegill captured in trap nets and electrofishing in Dewey Lake, Valentine NWR, 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Table 2. Bluegill mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category that were captured by electrofishing and trap nets in Dewey Lake, Valentine NWR in June 2006.

Length category	n	Mean weight (g)	Mean Wr
Stock – quality (80 – 149 mm)	50	37 (3.2)	119 (1.7)
Quality – preferred (150 – 199 mm)	9	131 (18.8)	126 (3.1)
Preferred – memorable (200 – 249 mm)	10	247 (9.6)	119 (4.9)
Memorable – trophy (250 – 299 mm)	0		
Trophy (≥ 300 mm)	0		
Total	69	80 (9.8)	120 (1.5)

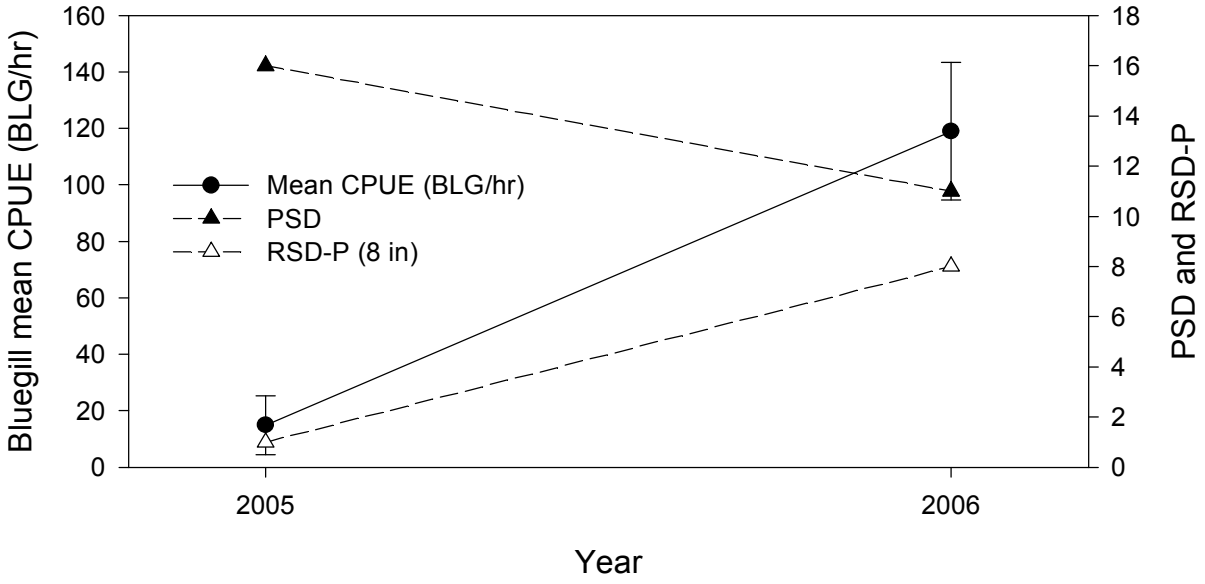

Figure 4. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of bluegills caught by electrofishing (bluegill/hr) in Dewey Lake, Valentine NWR from 2005 to 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Common carp

In 2006, nine sub-stock fish and seven preferred length common carp were captured in gill nets (Figure 5). Carp spawning appears to be successful, but with low recruitment to longer sizes. No sub-stock length carp were collected in 2005 indicating little or no recruitment. Mean CPUE has been low since 1992 and PSD and RSD-P has been high indicating low or no recruitment (Figure 6).

Although gill net mean CPUE has oscillated up and down, these changes have not been substantial between years, and carp abundance appears to be stable (Figure 6). During the spring of 1993, refuge personnel trapped and killed large numbers of carp in the ditch between Dewey and White Water lakes, which may have contributed, to the decline noted in the fall 1993 surveys. In past surveys, length frequency and PSD/RSD data indicated poor recruitment of smaller length groups with a population comprised mainly of large old fish. However, young-of-the-year fish were caught in 1997, and these fish appeared to recruit successfully. Ten carp were caught in gill and trap nets during 1998 and ranged from 415 to 745 mm. In the 1999 survey, 12 of the 16 carp collected were sub-stock length. In general, carp spawning appears to be successful, but recruitment seems sporadic and only one carp was caught in a trap net during the 2000 surveys. In 2001, spawning was successful as 30 sub-stock length carp were caught in trap nets. In 2003, no sub-stock carp were collected and in 2004, almost all carp collected were sub-stock.

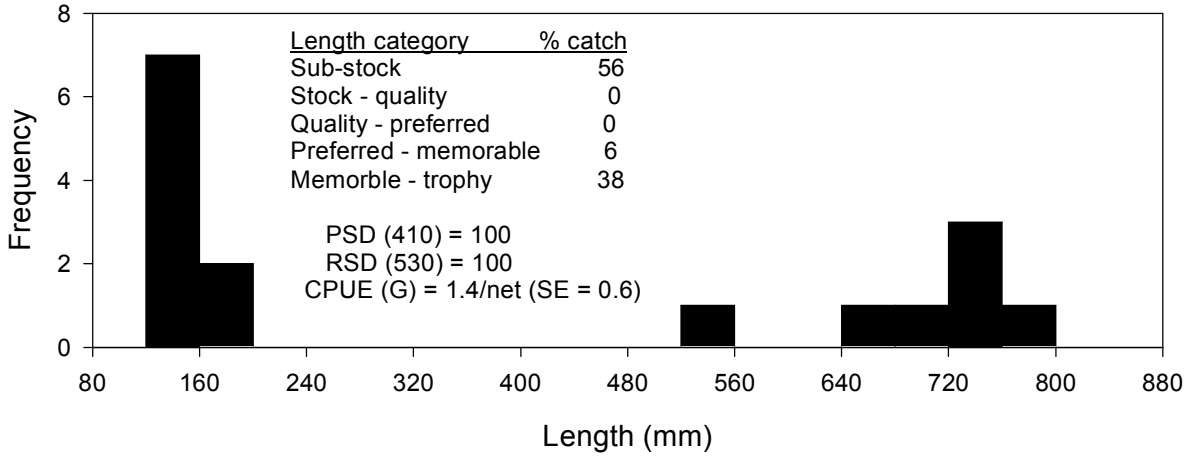

Figure 5. Length frequency distribution (40-mm length groups) of common carp captured in gill nets in Dewey Lake, Valentine NWR, August 2006. Mean catch per unit effort (CPUE) for carp ≥ stock length (280 mm).

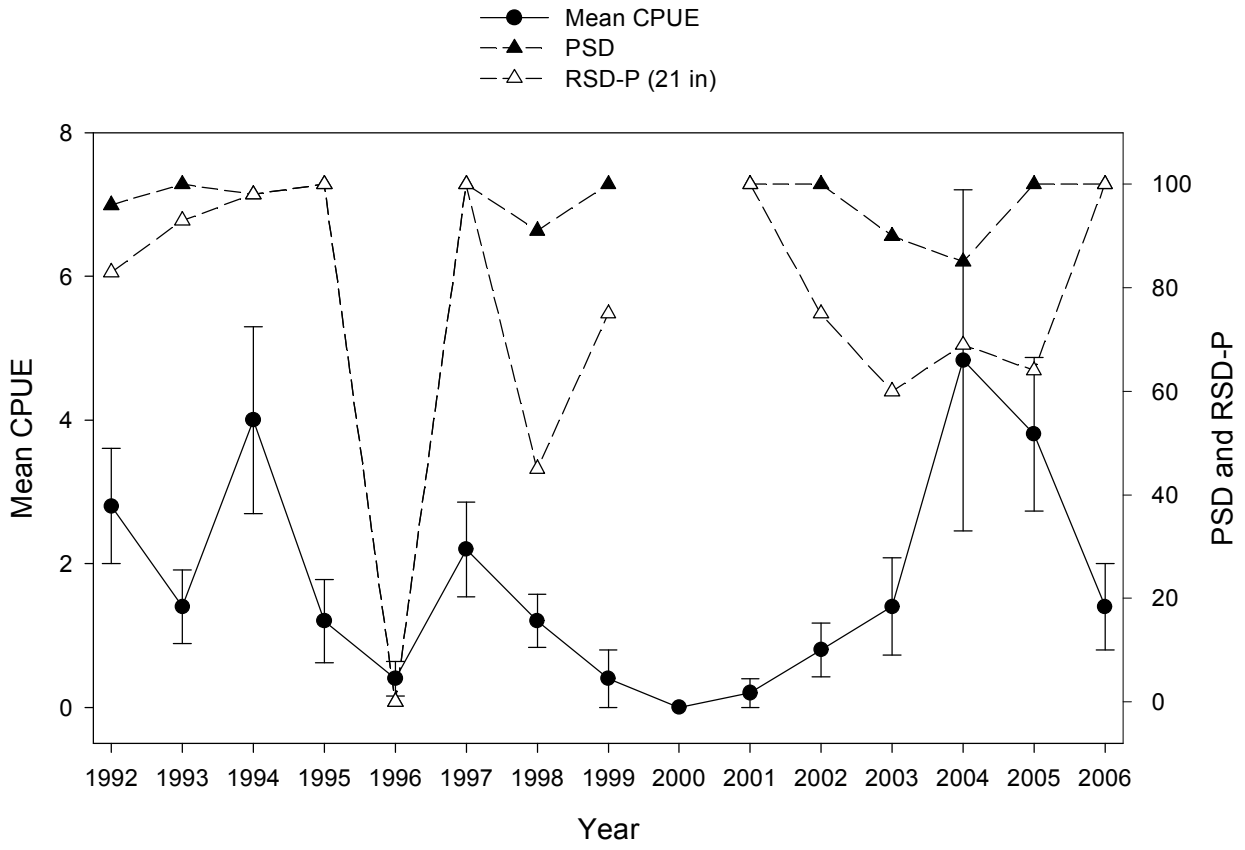

Figure 6. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of common carp caught by gill netting in Dewey Lake, Valentine NWR from 1992 to 2006. Mean catch per unit effort (CPUE) for carp ≥ stock length (280 mm).

Largemouth bass

In 2006, the largemouth bass population was dominated by sub-stock (< 200 mm) and preferred-memorable length (380-509 mm) fish (Figure 7). Mean Wr were exceptional for largemouth bass in Dewey Lake (Table 3). There was a substantial decrease in electrofishing mean CPUE for largemouth bass ≥ stock length with a slight increase in PSD compared to 2005 (Figure 8). Angler opportunities remain exceptional for Dewey Lake with PSD = 100 and RSD-P = 94.

Largemouth bass electrofishing mean CPUE for stock size and larger fish has been less than 10 fish/hour from 1989 to 2004. Prior to 2005, length frequency data indicated strong year classes but few of these fish recollected in subsequent years.

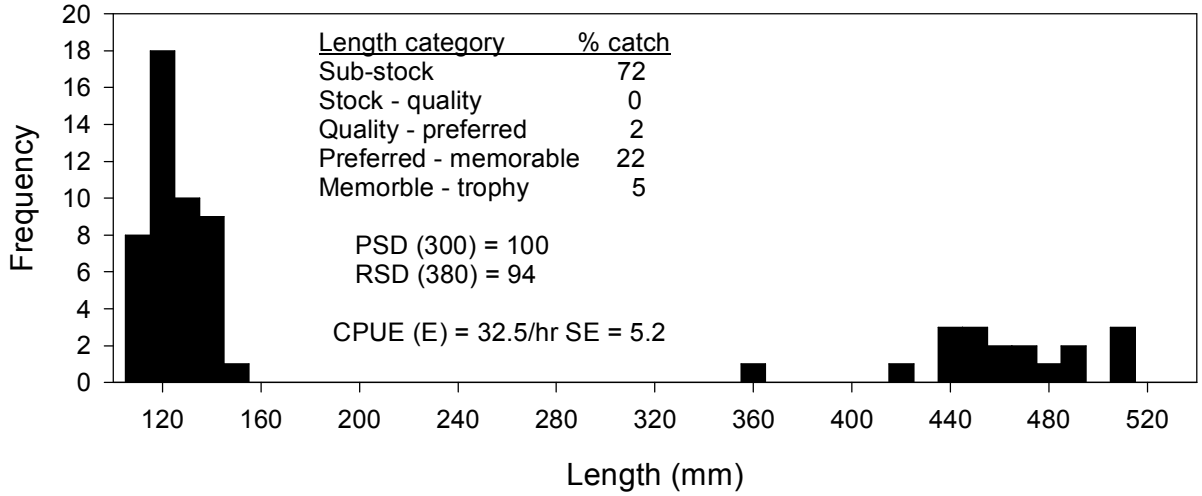

Figure 7. Length frequency distribution (10-mm length groups) for largemouth bass in Dewey Lake, Valentine NWR, June 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length (200 mm).

Table 3. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for largemouth bass captured by electrofishing in Dewey Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 200 mm)	22	33 (2.6)	127 (2.6)
Stock – quality (200 – 299 mm)	0		
Quality – preferred (300 – 379 mm)	1	800	112
Preferred – memorable (380 – 509 mm)	14	1664 (99.8)	104 (2.9)
Memorable – trophy (510 – 629 mm)	3	2433 (66.7)	110 (3.6)
Trophy (≥ 630 mm)	0		
Total	39	823 (148.4)	117 (2.5)

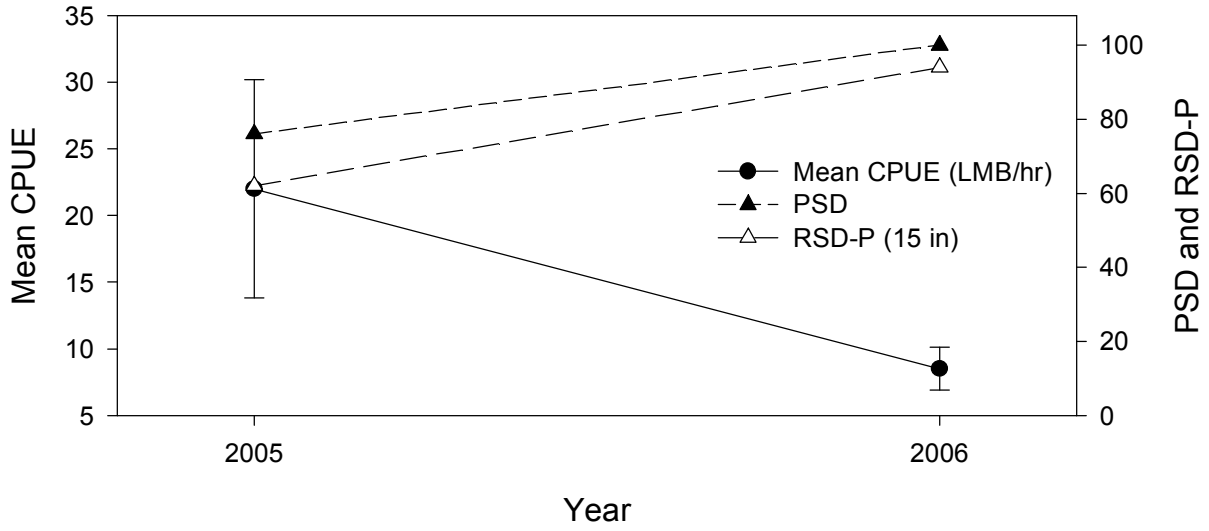

Figure 8. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of largemouth bass caught by electrofishing (LMB/hr) in Dewey Lake, Valentine NWR from 2005 to 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length (200 mm).

Northern pike

In 2006, the northern pike population was dominated by quality length (≥ 530 mm) fish with some successful spawning and recruitment (Figure 9). Mean Wr were similar to other Sandhill lakes (Table 4). Relative abundance increased in 2006, but was not significantly ($P > 0.20$) higher than 2005 (Figure 10). Gill net mean CPUE of preferred length (≥ 28 in.) did increase (Figure 11). Overall, mean Wr increased in 2006 compared to the mean Wr from 1998 to 2005 (Table 6). In 2005, northern pike gill net mean CPUE was lowest since surveys began in 1992 (Figure 10), where only quality length fish were collected. The increase in relative abundance may be due to reduced fishing mortality. Ice fishing occurred almost exclusively in the month of December during the unusually warm winter of 2005-2006.

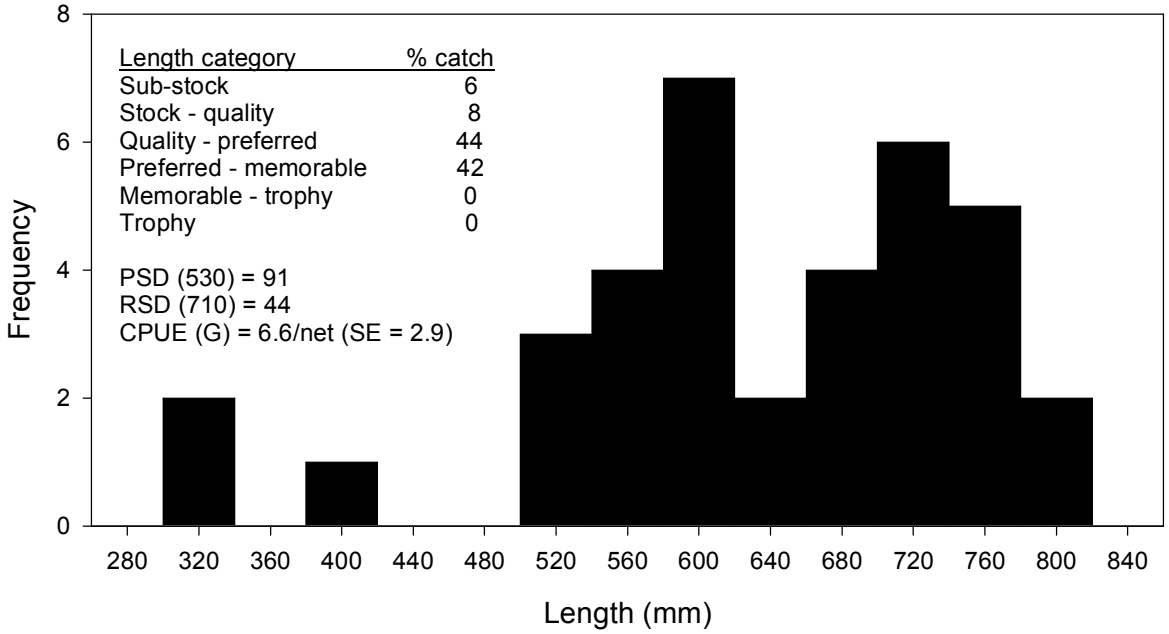

Figure 9. Length frequency distribution (40-mm length groups) for northern pike captured in gill nets in Dewey Lake, Valentine NWR, August 2006.

Table 4. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for northern pike captured by trap nets (TN) in June 2006 and gill nets (GN) in August 2006 in Dewey Lake, Valentine NWR.

Length category	TN (n)	TN mean weight (g)	TN mean Wr	GN (n)	GN mean weight (g)	GN mean Wr
Sub-stock (< 350 mm)	0			2	237 (7.5)	101 (3.4)
Stock – quality (350 – 529 mm)	0			3	1,107 (293.3)	133 (10.9)
Quality – preferred (530 – 709 mm)	2	1,600 (100.0)	98 (2.4)	16	1,778 (97.7)	111 (2.9)
Preferred – memorable (710 – 859 mm)	5	2,433 (120.2)	84 (5.2)	13	2,700 (113.7)	76 (8.4)
Memorable – trophy (860 – 1,119 mm)	0			0		
Total	7	2,414 (229.3)	88 (3.0)	34	1,981 (135.1)	98 (5.0)

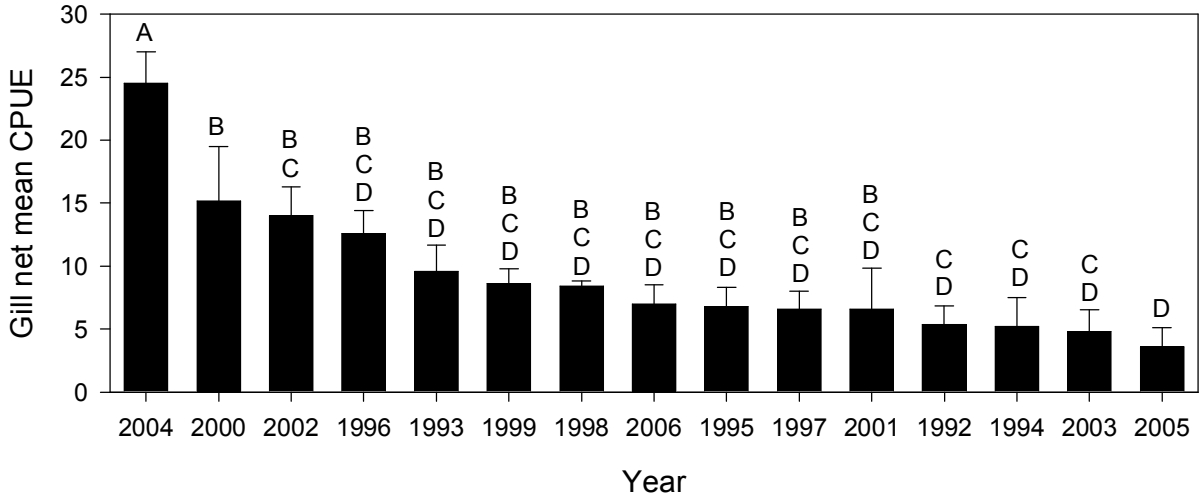

Figure 10. Northern pike gill net mean catch per unit effort (CPUE) in Dewey Lake, Valentine NWR from 1992 to 2006. Years with the same letter are not significantly different ($P > 0.20$) using ANOVA with Tukey-Kramer multiple comparison test.

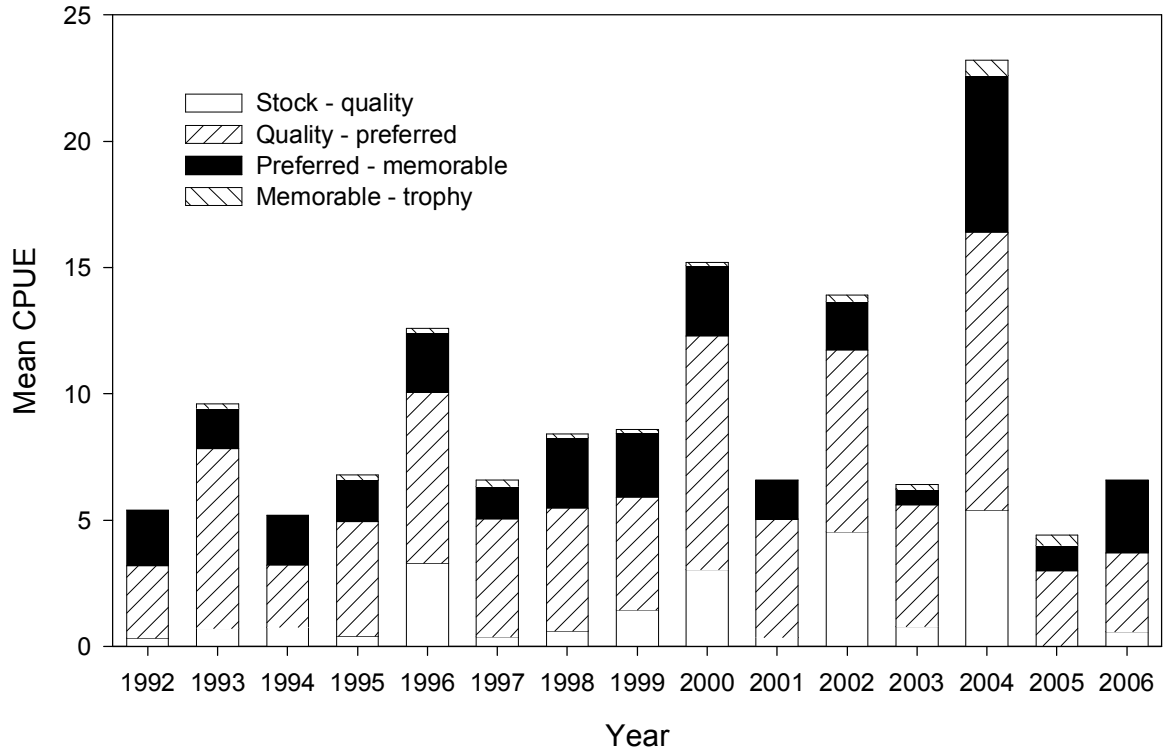

Figure 11. Gill net mean catch per unit effort (CPUE) for northern pike by length category in Dewey Lake, Valentine NWR for years 1992-2006.

Table 5. Population size structure, traditional proportional stock density (PSD) and incremental relative stock density (RSD) with relative weights (*Wr*) of northern pike in Dewey Lake, Valentine NWR during the fall. 2006 Data for fall gill netting only. Data are pooled for trap and gill nets from 1987 to 2005. Data are summarized by length categories with 80 % confidence intervals (+/-) and "a" denotes small sample size, confidence intervals could not be calculated.

Year	% ≥ Quality		S-Q (350-530mm) (14-21 in)			Q-P (530-710mm) (21-28 in)			P-M (710-860mm) (28-34 in)			M-T (860-1120mm) (34-44 in)		
	PSD	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*	RSD	+/-	*Wr*
2006	91	98	9	a	133	47	a	111	44	22	76	0	a	
2005	100	89	0	a	a	100	a	93	32	a	81	9	a	78
2004	79	97	21	11	98	47	9	103	27	11	92	3	a	88
2003	88	94	12	a	104	75	12	94	9	a	89	3	a	86
2002	62	84	38	13	80	40	12	87	19	a	88	3	a	89
2001	95	95	5	a	109	71	99	90	24	10	85	0	a	
2000	80	90	20	9	87	62	7	71	17	6	79	1	a	84
1999	78	91	22	7	88	52	10	91	30	9	94	2	a	91
1998	89	92	11	7	90	54	10	92	33	9	92	2	a	80
1997	87	100	13	8	105	63	10	102	25	9	96	5	a	99
1996	69	103	31	9	101	48	11	105	19	9	104	1	a	96
1995	93	107	7	9	122	61	12	107	28	11	106	4	9	103
1994	86	103	14	9	115	47	12	103	38	12	97	0	a	
1993	92	98	8	9	111	71	8	99	21	a	98	0	a	
1992	94	85	6	8	100	51	9	85	43	8	83	0	a	
1991	95	88	5	a	94	59	a	91	36	a	86	0	a	
1990	96	90	4	a	84	72	a	87	24	a	93	0	a	
1989	88	103	12	a	95	65	a	97	19	a	102	4	a	109
1988	85	110	15	a	110	75	a	105	10	a	105	0	a	
1987	17	110	83	a	95	12	a	90	5	a	96	0	a	

Yellow perch

The 2006 survey indicates the yellow perch population was dominated by stock-quality and quality-preferred length fish (Figure 12). Mean Wr = 89 in 2006 (Table 6), which was a substantial decline compared to 2005 (Mean Wr = 97) and was low compared to other Sandhill lakes. Gill net mean CPUE = 3.8 (SE = 2.2) in 2006 and has declined since 2004. The PSD and RSD-P increase is likely due to low spawning success or high predation on sub-stock and stock-quality length fish (Figure 13).

The PSD/RSD values declined during the years with strong year classes but this is usually a reflection of the increased abundance of smaller fish. However, low mean CPUE and PSD values indicated little or no recruitment in Dewey Lake since 2003.

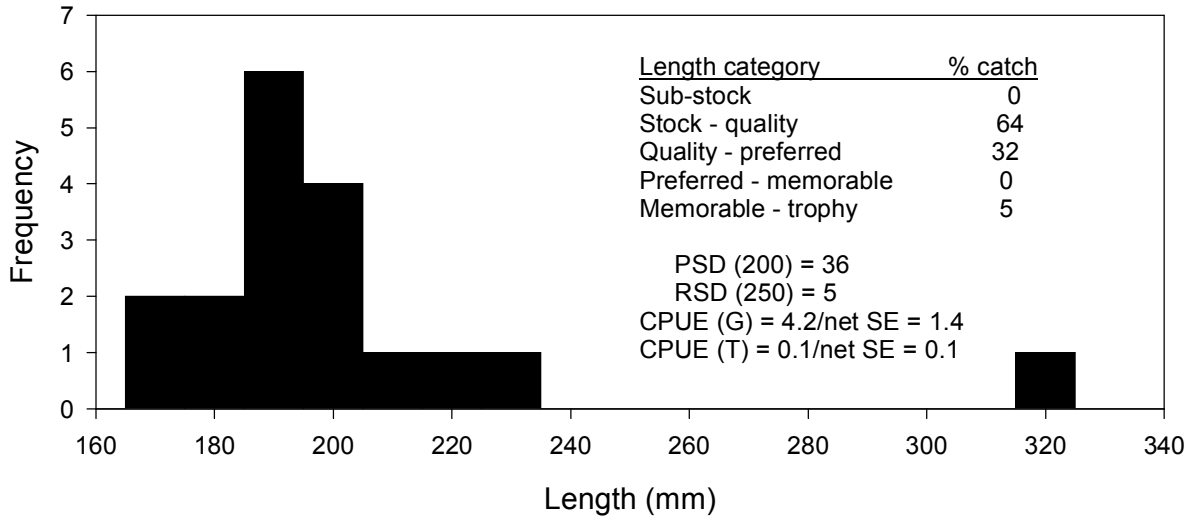

Figure 12. Length frequency distribution (10-mm length groups) of yellow perch captured in gill nets for Dewey Lake, Valentine NWR in August 2006.

Table 6. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for yellow perch captured by gill nets in Dewey Lake, Valentine NWR, August 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 130 mm)	0		
Stock – quality (130 – 199 mm)	8	87 (3.9)	85 (11.3)
Quality – preferred (200 – 249 mm)	7	129 (10.2)	94 (3.8)
Preferred – memorable (250 – 299 mm)	0		
Memorable – trophy (300 – 380 mm)	1	490	92
Total	16	130 (25.0)	89 (6.1)

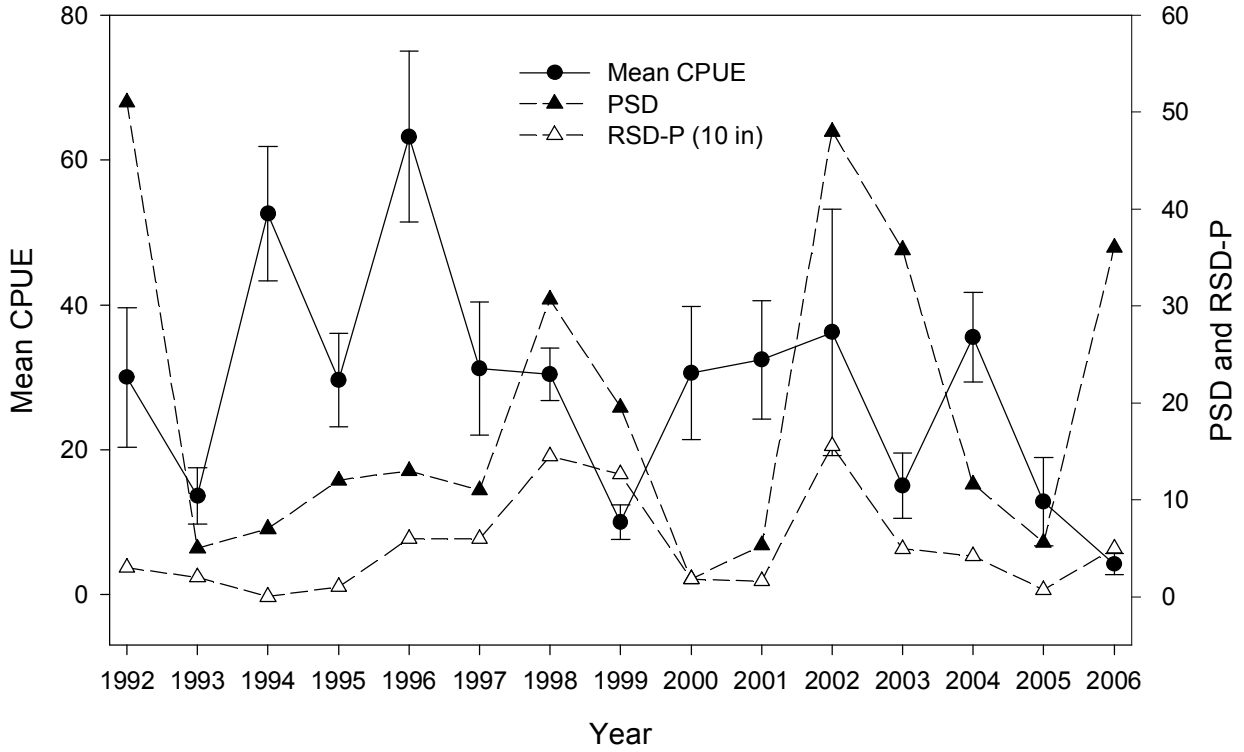

Figure 13. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P)of yellow perch caught by gill nets in Dewey Lake, Valentine NWR from 1992 to 2006. Mean catch per unit effort (CPUE) for perch ≥ stock length,.

Summary

Common carp – The relative abundance of carp declined in 2006. Carp are spawning but few appear to recruit to stock length or larger. Carp mean CPUE oscillated between 1992 and 2004 but has since decreased each year.

Northern pike – It does appear that the northern pike regulations are helping to control common carp abundance, but northern pike are likely controlling abundance and size of other important game species in Dewey Lake. The relative abundance and mean Wr improved in the northern pike population in 2006.

Bluegill - In 2006, the bluegill population in Dewey Lake was dominated by sub-stock and stock-quality length fish with a substantial increase in relative abundance. Mean Wr were good for all size classes and similar to other Sandhill lakes.

Yellow perch – The relative abundance of yellow perch in Dewey Lake continues to decline with an increase in size structure likely due to poor recruitment during the low water levels over the past five years. Mean Wr were low compared to other Sandhill lakes. The substantial increase

in bluegill abundance may have contributed to the decline in yellow perch mean Wr while competing for available prey.

Largemouth bass – The relative abundance of largemouth bass in Dewey Lake decreased from 2005 to 2006. Prior to 2005, largemouth bass length frequency data indicated strong year classes but few of these fish recollected in subsequent years. Now there are excellent angler opportunities for largemouth bass as fish have been collected in the preferred length groups. Mean Wr were exceptional for largemouth bass in Dewey Lake.

Bullhead – In 1987, flathead catfish were introduced to Dewey Lake to control the bullhead population which was at a high of 30 bullheads/gill net. Since 1997, mean CPUE has remained at 0 bullheads/gill net.

Management Recommendations

1. Maintain the current size regulations and monitor abundance and size structure of northern pike.

2. Continue to evaluate black crappie in Clear Lake before introducing black crappie as an additional game species to Dewey Lake.

3. Continue to use Dewey – White Water ditch as a means for trapping and controlling carp. This effort needs to be set up in a systematic fashion and evaluated for success and cost efficiency.

4. Continue annual surveys.

HACKBERRY LAKE

Hackberry Lake is adjacent to the Refuge's headquarters and is easily accessible from State Highway 16B. This lake receives heavy fishing pressure during winters when other refuge trails and fishing lakes are inaccessible. Angling is greatest during the ice fishing season through late spring/early summer and then declines as the lake becomes heavily vegetated.

Hackberry Lake is the first in a series of four lakes on the refuge that are connected by natural drainage or man-made ditches. In high water years, a water control structure between Hackberry and Dewey Lake (the next lake downstream) controls water levels in Hackberry. During the spring and summer of 1995-1997, lake levels were near record highs and many lakes and creeks were connected. These connections allowed carp migration.

Hackberry Lake is 275 surface ha (680 ac). Maximum and mean depths are 1.8 m (5 ft.) and 1.0 m (3 ft.), respectively (Figure 1). The lake bottom is relatively flat and highly organic. The lake is too shallow to thermally stratify. Abundant decaying organic matter has reduced dissolved oxygen levels to less than 1 ppm during winters with extended ice cover resulting in periodic winter-kills. Summer-kills have also been noted but are usually less severe. Emergent vegetation (cattail and bulrush) dominates the entire lake edge. Because the lake is shallow, heavily vegetated, and relatively alkaline, dense algae blooms are common and likely contribute to the periodic summer fish kills. During summer, the entire lake is essentially a large littoral area with dense submergent vegetation. Conductivity averages 425 μS/cm at 25^0 C. Total alkalinity averages 200 ppm, and phenolphthalein alkalinity averages 10 ppm. The lake's pH ranges from 8.5 during winter/spring to 10 during summer. Secchi disk averages 0.3 m during summer. The surrounding watershed consists of mixed grass sandhills, which are lightly grazed by cattle.

Hackberry Lake has a history of high carp abundance. In 2004, refuge staff consulted with the Nebraska Game and Parks Commission and agreed to cooperate as a joint effort to lower Hackberry Lake and chemically renovate the fishery. Draw down began on the lake began in August of 2004 and the lake was chemically renovated using rotenone. By October 2004, Hackberry Lake was declared carp free. Fish stockings were initiated during the fall of 2004 with additional stockings in 2005 and 2006 (Appendix B). The last chemical renovation prior to 2004 was conducted during 1975 and the lake was restocked the following year. With the 1975 renovation, Hackberry Lake was presumed to be carp free until carp were captured during the 1988 surveys. From 1988 to 1992, Hackberry Lake was identified as the "control lake" for evaluating northern pike as a biological agent for controlling carp recruitment and followed state size and bag limits. During January 1992, the 36" northern pike minimum size limit was extended to include Hackberry Lake. During the 1992 northern pike spawning operation, approximately 1,000 northern pike collected from Pelican Lake were transferred to Hackberry Lake to increase the northern pike population in the lake. Beginning January 1993, regulations were implemented to allow the harvest of northern pike 28 in. or less.

The primary fish species in Hackberry lake are largemouth bass, yellow perch, and bluegills. Length and bag limits are summarized in Appendix A and the history of fish stockings are summarized in Appendix B.

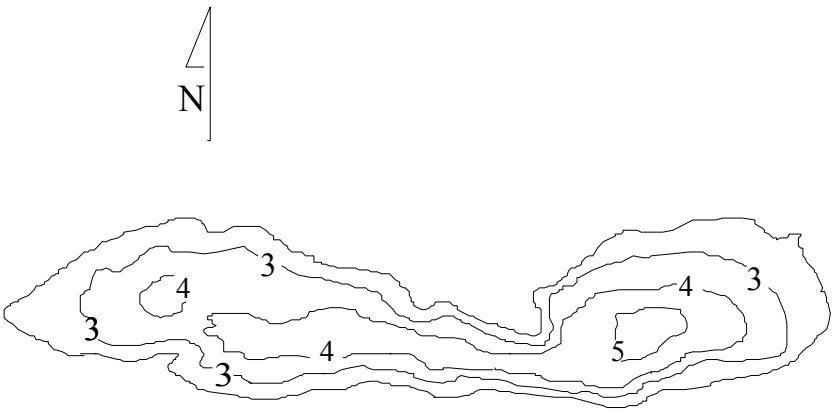

Figure 1. Contour map of Hackberry Lake, Valentine NWR.

Methods

Night time electrofishing was conducted 8 June 2006. Water temperature was 22 ^{o}C.

Electrofishing was conducted for 0.5 hours after dusk with a Smith and Root 5.0 GPP electrofishing system using 200 volts pulsed DC, 9 amps, and a pulse frequency of 120 cycles per second (cps). Electrofishing was conducted in 15 minute transects along the shoreline.

Past surface water quality parameters are reported in Table 1.

Table 1. Hackberry Lake surface water quality parameters.

Date	Water temp. (°C)	D.O. (mg/L)	Secchi depth (cm)	pH	Salinity (ppt)	Phenolphthalein alkalinity (mg/L)	Total alkalinity (mg/L)	Specific conductivity (µS/cm)
08/2002	20	11.0		9.7		137	393	430
09/2001	18		75	7.2		8	154	368
07/2001 dusk	28	12.0		7.1		17	137	
07/2001 dawn	23	4.0		8.0		17	137	
09/2000	18		30	8.5		10	200	425
09/1999	16			7.1				

Results and Discussion

In 0.5 hr of electrofishing, we attempted to capture all fish we encountered in our post-renovation survey of Hackberry Lake.

Bluegill

No bluegill were captured in 0.5 h of electrofishing in June 2006.

Common carp

No carp were observed in 0.5 h of electrofishing in June 2006.

Largemouth bass

In June 2006, the largemouth bass population was dominated by sub-stock and stock-quality length fish (Figure 2). Hackberry Lake was just recently stocked with fingerling bass in 2005. Mean Wr was exceptional compared to other Sandhill Lakes (Table 2).

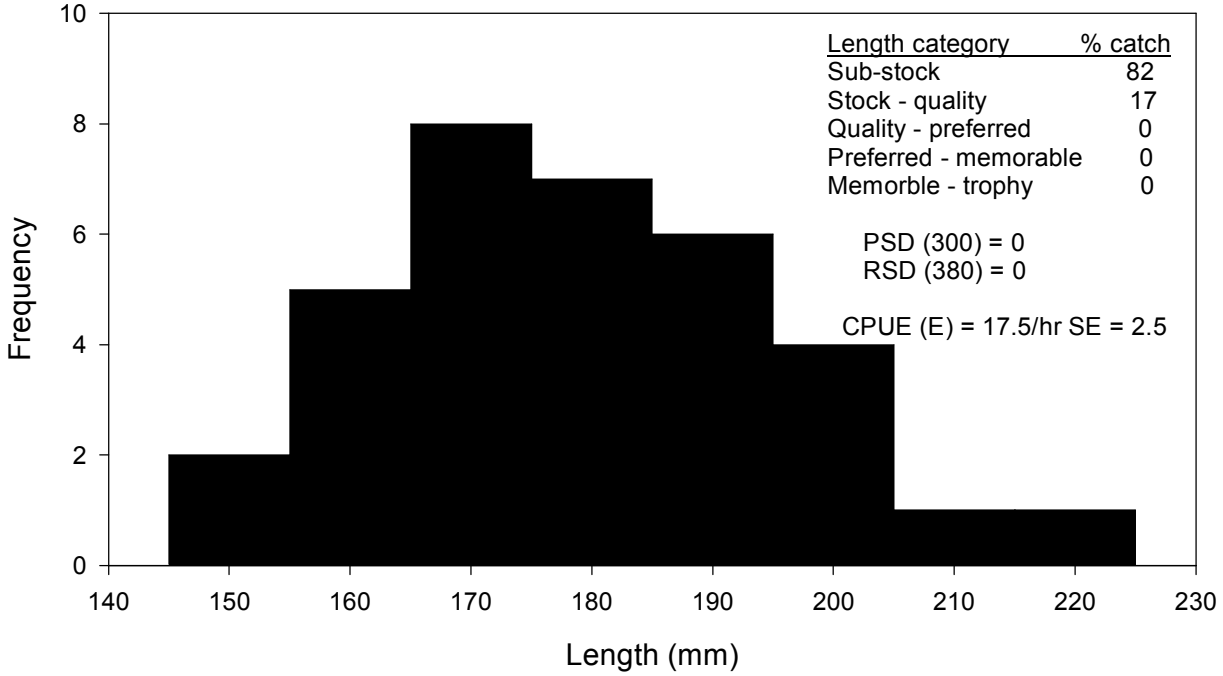

Figure 2. Largemouth bass length frequency distribution (10-mm length groups) for Hackberry Lake, Valentine NWR, 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length (200 mm).

Table 2. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for largemouth bass captured by electrofishing in Hackberry Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 200 mm)	21	87 (4.6)	127 (3.1)
Stock – quality (200 – 299 mm)	6	154 (13.8)	132 (5.7)
Quality – preferred (300 – 379 mm)	0		
Preferred – memorable (380 – 509 mm)	0		
Memorable – trophy (510 – 629 mm)	0		
Trophy (≥ 630 mm)	0		
Total	27	102 (7.1)	128 (2.7)

Northern pike

No northern pike were observed in 0.5 h of electrofishing.

Yellow perch

Although electrofishing is not typically used in standard surveys for yellow perch, we attempted to capture all fish we encountered in our post-renovation survey of Hackberry Lake. The yellow perch population was dominated by stock-quality length fish, which is typical of a recently stocked lake (Figure 3). Mean Wr was above average compared to other Sandhill lakes (Table 3).

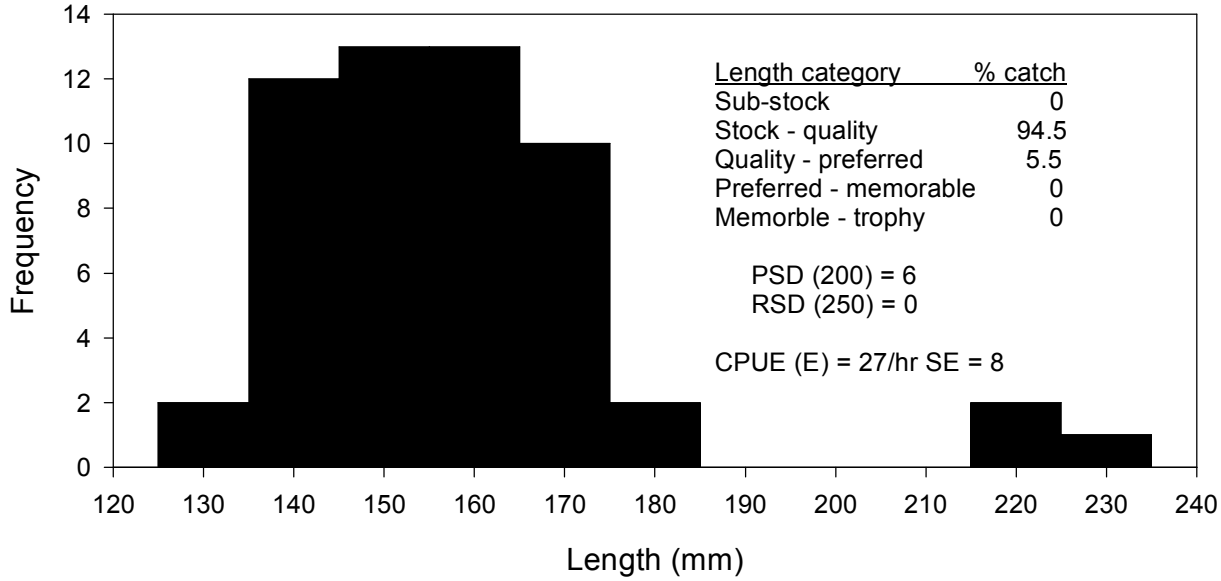

Figure 3. Yellow perch length frequency distribution (10-mm length groups) for electrofishing in Hackberry Lake, Valentine NWR, June 2006.

Table 3. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for yellow perch captured by electrofishing in Hackberry Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (<130 mm)	0		
Stock – quality (130 – 199 mm)	25	58 (3.1)	107 (3.7)
Quality – preferred (200 – 249 mm)	3	200 (11.5)	115 (8.1)
Preferred – memorable (250 – 299 mm)	0		
Memorable – trophy (300 – 379 mm)	0		
Trophy (≥ 380 mm)	0		
Total	28	73 (9.0)	108 (3.4)

Summary

Common carp – No carp were observed in 2006.

Northern pike – No northern pike were observed in 2006.

Largemouth bass – Mean Wr was exceptional for largemouth bass indicating an abundance of prey.

Yellow perch – Mean Wr was exceptional for yellow perch indicating an abundance of prey.

Bluegill – No bluegill were observed even after bluegill stocking in 2004 and 2005.

Management Recommendations

1. Continue electrofishing in the spring to evaluate the fish stockings.

2. Continue bluegill stocking to establish a population.

3. Improve boat ramps. The west end of Hackberry Lake was not accessible due to high organic matter throughout the water column. The east boat ramp was choked off by bulrush and cattails during the spring and not accessible during the fall. A raised, gravel ramp leading out to deeper depths at the east boat ramp would improve access to Hackberry Lake.

4. Conduct creel surveys to gather information on angler harvest as soon as angling increases.

PELICAN LAKE

Pelican Lake is located three miles south of Highway 16B just west of Valentine NWR headquarters then two miles east along the Pelican Lake sub-headquarters road. The roads are black topped most of the way to the lake, and the west boat ramp is usually accessible. The lake receives heavy angling pressure during the spring and again during the winter ice-fishing season. Pelican Lake contains the best fishery on the refuge and is noted for producing trophy bluegill. The excellent fishery is related to the lake depth, the ratio of open water to submergent vegetation during summer, and the abundance of emergent vegetation.

Pelican Lake has had a similar history of carp infestation as the other refuge lakes but to a lesser degree. Pelican Lake was chemically renovated during 1979, but a complete kill did not occur as carp were captured in 1980 surveys. A limited winter-kill was noted during 1987-88. The spring and summer of 1995-1997 were years with excessive run-off and high water. Many of the refuge lakes, including Pelican, were full and flowing over. The high water resulted in many of the lakes becoming inter-connected, and fish movement was noted.

Pelican Lake is 331 surface ha (817 acres). Maximum depth is 3.3 m (10 ft), and mean depth is 1.3 m (4 ft) (Figure 1). Conductivity averages 375 at 25 ^{0}C; total alkalinity averages 205 ppm and phenolphthalein alkalinity is 0 ppm. The lake's pH ranges from 8 during winter through spring to 9 during summer. Secchi disc reading averages 0.3 m. The lake does not develop a thermocline and is a closed system except during periods of excessive rainfall when sheet flow occurs. The lake is situated in the lowlands of the surrounding sandhills, and these conditions create many springs within the lake. The springs provide summer thermal refuge for cool-water species (e.g., northern pike) and are important because surface water temperatures can exceed 30 ^{0}C. The bottom is relatively flat and highly organic. These conditions coupled with the shallow depth make the lake susceptible to winter kills when the ice remains snow covered for extended periods. However, the springs likely reduce the occurrence of winter kills. Emergent vegetation is primarily cattail, bulrush and *Phragmites*, but scattered stands of wild rice occur. Submergent vegetation includes milfoil (*Myriophyllum spp.)*, curly-leaf pondweed (*Potamogeton spp.)*, and scattered areas of coontail. The surrounding watershed is rolling sandhills with mixed grasses with a few cottonwoods and willows along the shoreline.

Pelican Lake is one of three refuge lakes in which a 36 in. minimum length limit for northern pike was implemented during 1988 to develop an abundance of large predators. It was hypothesized that a population of large predators would be more effective at controlling carp recruitment. A 22-26 in. northern pike slot limit was implemented during 1991 to remove an over abundance of this size class. The slot limit was scheduled to be open until 4,000 northern pike were removed. This regulation continued into the spring because of weak ice and poor angling during the 1991-1992 winter ice-fishing season. The slot limit was continued through 1992 because spring surveys indicated a northern pike population with mean Wr below 80. Beginning January 1993, the northern pike regulations were changed to allow harvest of northern pike 28 in. and less. Length and bag limits are summarized in Appendix A and the history of fish stockings are summarized in Appendix B.

The fishery includes yellow perch, northern pike, largemouth bass, bluegill, black bullhead, and carp.

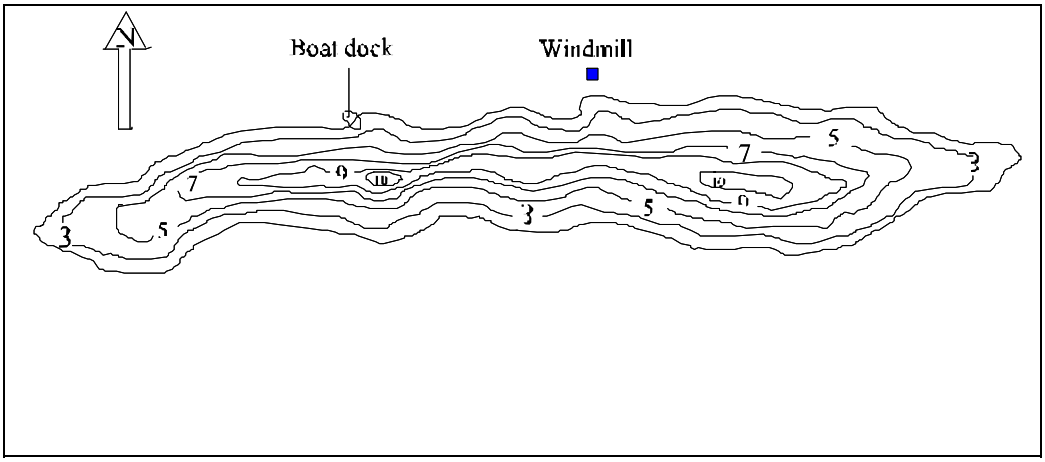

Figure 1. Contour map of Pelican Lake at full pool (depth in feet).

Methods

Night time electrofishing was conducted 6 June 2006 and trap nets were set overnight on 5 June 2006. Gill nets were not deployed due to inaccessibility because of low water levels.

Electrofishing was conducted for 2 hours after dusk with a Smith and Root 5.0 GPP electrofishing system using 200 volts pulsed DC, 9 amps, and a pulse frequency of 120 cycles per second (cps). Electrofishing was conducted in 15 minute transects along the shoreline. Twelve trap nets were set perpendicular to the shore for 24 hours (Figure 2). Trap nets had 13-mm (0.5 in.) mesh, single throats, with 15.2-m (50 ft.) leads.

Water quality parameters collected were water temperature, dissolved oxygen, pH, salinity, alkalinity, and conductivity (Table 1).

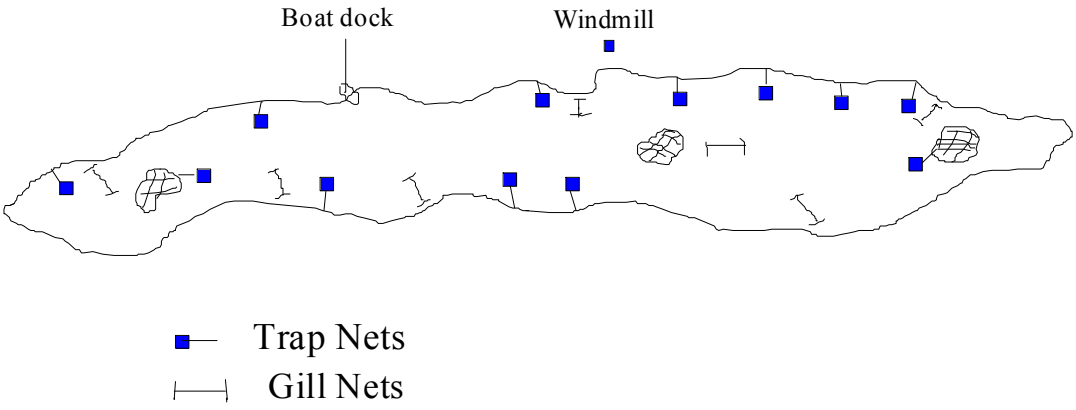

Figure 2. Trap and gill net locations on Pelican Lake, Valentine NWR in 2005.

Table 1. Pelican Lake surface water quality parameters.

Date	Water temp. (°C)	D.O. (mg/L)	Secchi depth (cm)	pH	Salinity (ppt)	Phenolphthalein alkalinity (mg/L)	Total alkalinity (mg/L)	Specific conductivity (µS/cm)
06/2006	24	8.1	129	6.9	0.20	0	137	378
08/2005	21			8.5			240	320
09/2004	23		30			0	205	375
09/2003	23							
09/2001	18		36	7.5		8	120	318
07/2001 dusk	28	11.7		7.7		25	110	
07/2001 dawn	24	7.0		8.7		17	127	
09/2000	18		30	8.0		0	205	
09/1999	14			10.0				

Results and Discussion

Bluegill

In 2006, the bluegill population in Pelican Lake was dominated by stock-quality length (80 – 149 mm) fish (Figure 3). Mean Wr was normal for Sandhill lakes (Table 2). There was a substantial increase in the relative abundance of ≥ stock length fish from 2005 to 2006, while the PSD and RSD-P remained relatively constant (Figure 4).

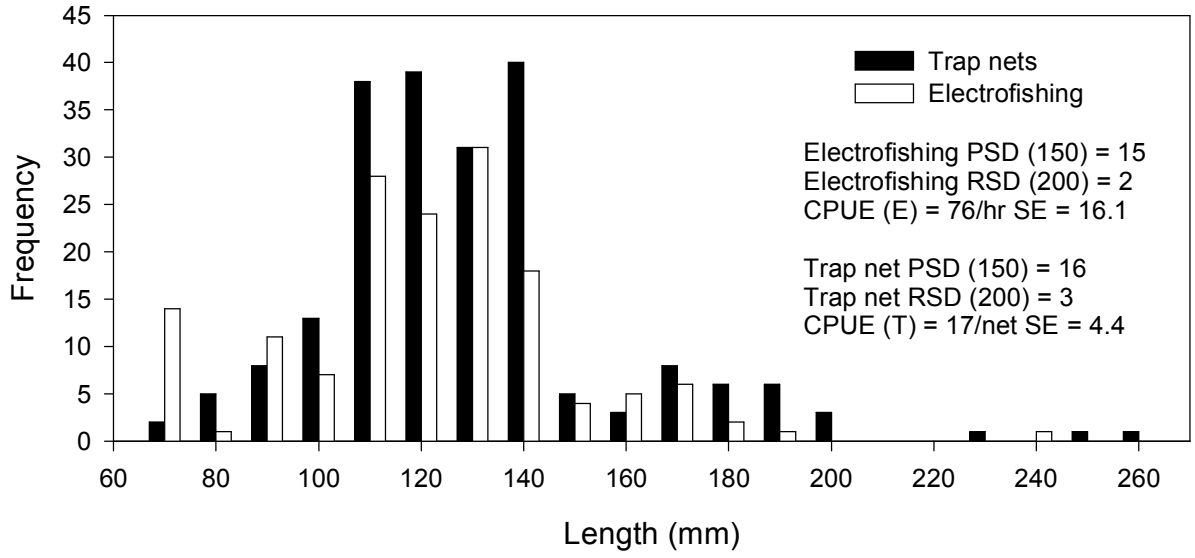

Figure 3. Bluegill length frequency distribution (10-mm length groups) for Pelican Lake, Valentine NWR, June 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Table 2. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for bluegill captured by electrofishing and trap nets in Pelican Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Stock – quality (80 – 149 mm)	66	38 (2.6)	111 (2.0)
Quality – preferred (150 – 199 mm)	40	128 (5.4)	113 (1.4)
Preferred – memorable (200 – 249 mm)	5	279 (53.0)	113 (5.5)
Memorable – trophy (250 – 299 mm)	2	480 (50.0)	113 (3.8)
Trophy (≥ 300 mm)	0		
Total	113	88 (8.2)	111 (1.3)

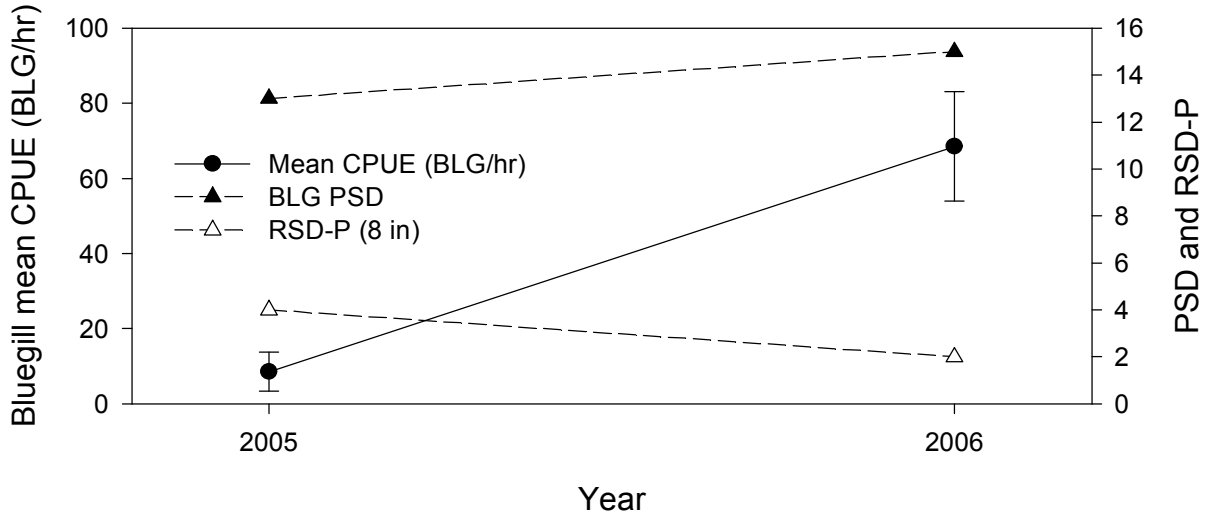

Figure 4. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of bluegills sampled by electrofishing (BLG/hr) in Pelican Lake, Valentine NWR from 2005 to 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Common carp

Only two carp were collected in trap nets in 2006. In 2005, carp gill net mean CPUE was 4.1 fish/net ± 1.9. In 2003, the mean CPUE was 12 fish/net which was dominated by young of the year fish. It appears that the 2003 year class did not recruit into the 2004 - 2005 fishery.

Largemouth bass

In 2006, it was evident that largemouth bass are successfully spawning, but have limited recruitment into longer length categories. The largemouth bass population was dominated with sub-stock and preferred-memorable length fish (Figure 5). Mean Wr for largemouth bass was good (Table 3) and similar to other Sandhill lakes. Largemouth bass mean CPUE for

electrofishing declined from 30.5 fish/hr in 2005 to 22.0 fish/hr in 2006. PSD/RSD levels were at appropriate levels for a largemouth bass population to be in balance in 2005. However in 2006, the size structure was out of balance, dominated by older, large fish (Figure 6).

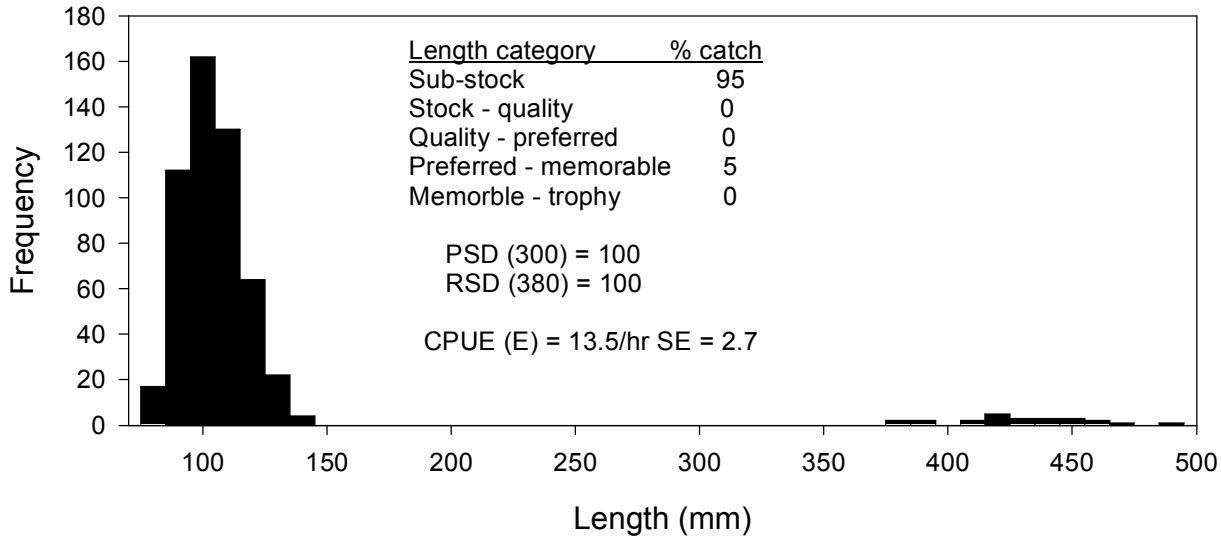

Figure 5. Largemouth bass length frequency distribution (10-mm length groups) for Pelican Lake, Valentine NWR, 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length (200 mm).

Table 3. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for largemouth bass captured by electrofishing in Pelican Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 200 mm)	33	23 (1.9)	135 (2.9)
Stock – quality (200 – 299 mm)	0		
Quality – preferred (300 – 379 mm)	0		
Preferred – memorable (380 – 509 mm)	25	1372 (59.1)	108 (3.0)
Memorable – trophy (510 – 629 mm)	0		
Trophy (≥ 630 mm)	0		
Total	58	604 (92.0)	123 (2.7)

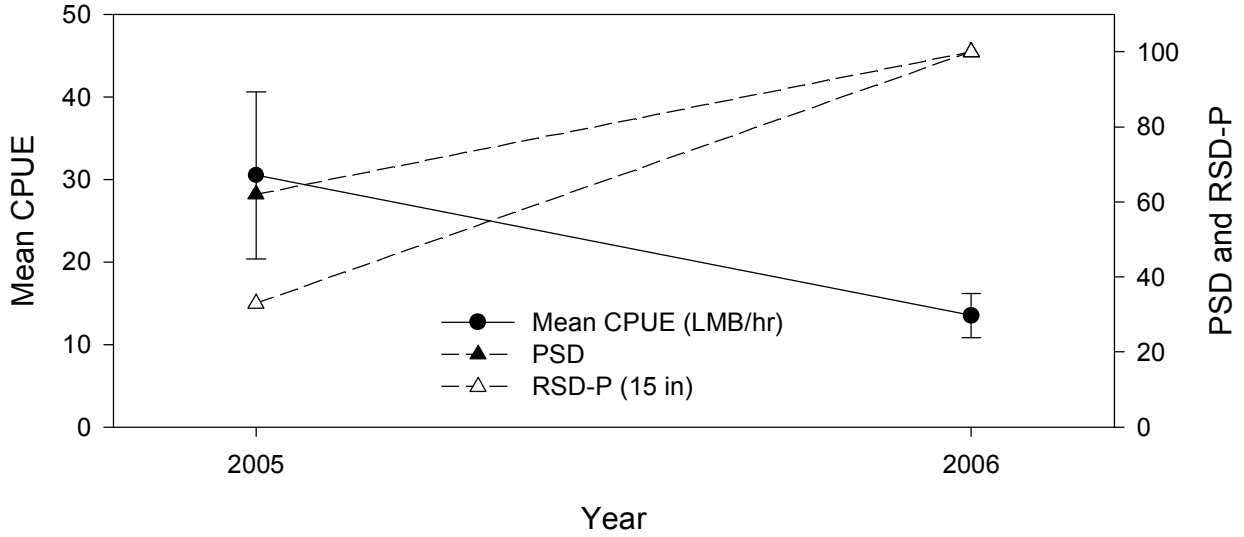

Figure 6. Annual relative abundance, proportional stock density (PSD), and relative stock density (RSD-P) of largemouth bass caught by electrofishing (LMB/hr) in Pelican Lake, Valentine NWR from 2005 to 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length (200 mm).

Northern Pike

In 2006, 17 northern pike were captured in trap nets in June 2006 (Figure7). Mean CPUE was 1.2/net (SE = 0.4) in 2006. This was a decline from 2005 (1.4/net). Mean Wr were substantially lower in Pelican Lake (Table 4) compared to Clear and Dewey lakes in 2006. Mean Wr was lower in 2005 compared to 2004 (Table 5).

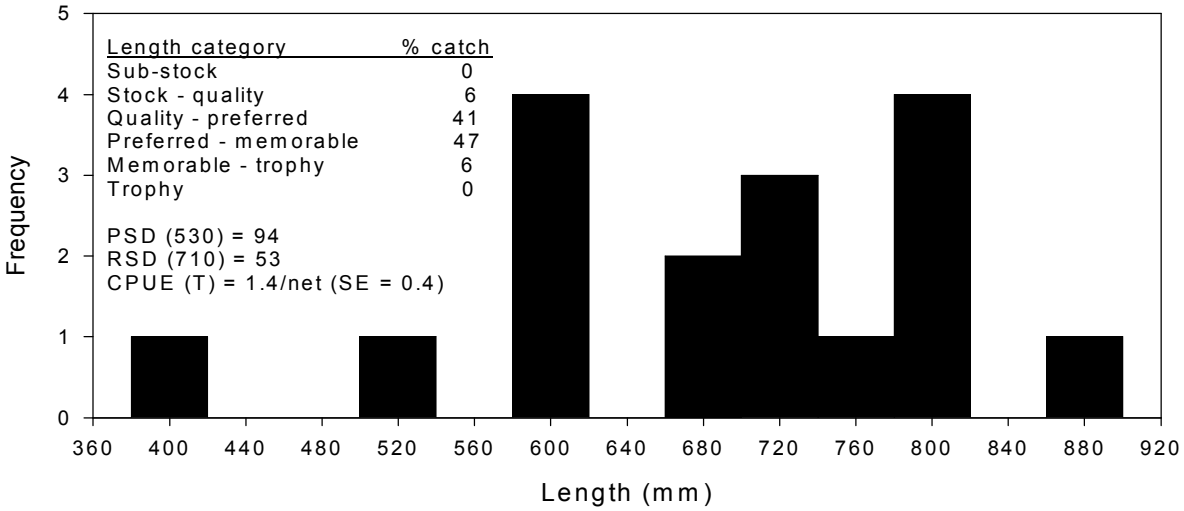

Figure 7. Length frequency distribution (40-mm length groups) for northern pike captured with trap nets in Pelican Lake, Valentine NWR, June 2006.

Table 4. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for northern pike captured by trap nets in Pelican Lake, Valentine NWR June 2006. Gill nets were not deployed in August 2006 due to low water levels.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 350 mm)	0		
Stock – quality (350 – 529 mm)	1	350	84
Quality – preferred (530 – 709 mm)	7	1,407 (128.4)	80 (2.9)
Preferred – memorable (710 – 859 mm)	8	2,172 (226.8)	65 (4.6)
Memorable – trophy (860 – 1,119 mm)	1	3,000	61
Total	17	1,798 (184.)	72 (3.1)

Table 5. Population size structure, traditional proportional stock density (PSD) and incremental relative stock density (RSD) with relative weights (*Wr*) of northern pike in Pelican Lake, Valentine NWR during the fall. Data are pooled for trap and gill nets from 1989 to 2005. Data are summarized by length categories with 80 % confidence intervals (+/-) and "a" denotes small sample size, confidence intervals could not be calculated.

Year	% ≥ Quality		S–Q (350 – 529mm) (14-21 in)			Q-P (530-709mm) (21-28 in)			P-M (710-859mm) (28-34 in)			M-T (860-1120mm) (34-44 in)		
	PSD	*W*r	RSD	±	*W*r	RSD	±	*W*r	RSD	±	*W*r	RSD	±	*W*r
2006	No fall gill net sampling in 2006 due to low water levels													
2005	93	90	7	a	108	69	15	94	25	a	74	2	a	75
2004	93	105	2	a	110	73	11	94	18	a	72	3	a	88
2003	91	89	9	14	97	52	10	93	36	12	81	3	a	84
2002	No sampling conducted in 2002 due to low water levels													
2001	100	93	0	a	0	56	9	95	41	9	87	3	a	94
2000	94	88	6	a	82	69	2	89	27	3	86			
1999	91	88	9	6	94	66	9	87	25	8	88	2	a	86
1998	83	89	17	7	90	65	9	89	16	7	87	2	a	91
1997	94	98	6	5	106	87	7	99	7	6	88			
1996	62	93	38	8	96	50	12	92	10	7	88	2	8	96
1995	74	90	26	9	92	51	12	88	20	11	90	2	9	109
1994	84	106	16	5	110	71	6	110	14	5	100	0		
1993	85	90	15	6	90	65	9	97	19	6	93	0		
1992	89	68	11		45	71		72	19		58	0		
1991	94	86	6	5	100	81	7	84	13	6	89	0		
1990	96	91	4	6	95	83	9	92	11	6	91	2		89
1989	86	98	14		101	72		93	8		101	6		102

Yellow perch

Only two perch were captured in trap nets in 2006.

Summary

Bluegill – As with other lakes sampled on Valentine NWR, bluegill relative abundance increased in 2006. The bluegill population in Pelican Lake was dominated by stock-quality length (80 – 149 mm) fish. Mean Wr levels were similar to other Sandhill lakes.

Largemouth bass – The relative abundance of largemouth bass decreased in 2006 with a size structure of older, large fish. Mean Wr levels indicate an abundance of prey for largemouth bass in Pelican Lake.

Common carp – Because gill netting did not occur in Pelican Lake in 2006, it was difficult to determine carp population status. After a substantial increase in gill net mean CPUE in 2003 consisting mainly of young of the year fish, mean CPUE did decline in 2004 and 2005 indicating low carp recruitment. Large predators are most likely doing a good job of controlling carp recruitment even when carp successfully spawn.

Northern pike – Because gill netting did not occur in Pelican Lake in 2006, it was difficult to determine northern pike population status. The 2005 mean CPUE was similar to 2004 but still substantially lower than 2003. The 2005 mean CPUE was one of the lowest levels since surveys began in 1992 in Pelican Lake. Environmental conditions have probably reduced spawning success of northern pike. The northern pike population in Pelican Lake showed an incremental decline in mean Wr values as fish attain greater lengths. However, this is a similar trend of most Sandhill lakes.

Management Recommendations

1. Conduct creel surveys to measure angler harvest of bluegill and northern pike.

2. Continue to evaluate northern pike regulations.

3. Improve boat ramps. All boat ramps were choked off by bulrush and cattails during the fall making them inaccessible. A raised, gravel ramp leading out to deeper depths at the middle boat ramp would improve access to Pelican Lake.

4. Continue annual surveys

West Long Lake

West Long Lake is approximately 2.5 miles south of Highway 16B on an unnamed county highway and about 0.5 miles south of the Pelican Lake access road. The lake receives moderate fishing pressure during the spring and fall, but dense submergent vegetation accumulates during summer and most anglers avoid the lake until the vegetation dies back in late fall. During most winters this lake receives less fishing pressure than the larger refuge lakes, but during winters with heavy snow this lake remains accessible and use increases dramatically.

Carp were identified in West Long Lake and the lake was chemically renovate during the 1980's, but details are limited. No carp have been located in the lake since the last renovation and since this lake is a semi-closed system. The chance that carp will become re-established is less than any of the other refuge lakes. Still, the lake is accessible to carp during high water years such as 1995-1997 as water runs between Pelican and West Long lakes through a wet meadow on the northwest side.

The lake has a relatively flat sandy bottom with a highly organic substrate around the edges. Emergent vegetation, predominately cattail, bulrush, and scattered areas of phragmites form a band around most of the lake and has scattered "island like areas" of vegetation throughout the interior. During summer, submergent vegetation, including narrow and curly leaf pondweed, milfoil, coontail and duck weed cover almost 100% of the lake's surface. The lake has no water control structures or draw down capabilities.

Conductivity averages 380 at 25 °C; total alkalinity averages 150 and phenolphthalein alkalinity is 70 ppm. The lake's pH ranges form 9.1 during the winter through early spring to 10 by mid summer. Secchi disc readings average 2.0 m but turbidity reaches 3.2 NTU on windy days. The lake is too shallow to develop a thermocline and summer surface water temperatures reach 30 °C. Maximum lake depth is 6 ft and average depth is 4.2 ft.

The fishery includes yellow perch, largemouth bass, and bluegill. Northern pike were purposely excluded from this lake because of its relatively small size and the absence of carp, but northern pike were collected by anglers in 1999 and during spring 2000 surveys. Bullheads have also become established in the lake as they were first collected during the 2000 surveys also. Length and bag limits are summarized in Appendix A and the history of fish stockings are summarized in Appendix B.

Methods

Night time electrofishing was conducted 6 June 2006. Electrofishing was conducted for 1 hour after dusk with a Smith and Root 5.0 GPP electrofishing system using 200 volts pulsed DC, 8-9 amps, and a pulse frequency of 120 cycles per second (cps). Electrofishing was conducted in 15 minute transects along the shoreline.

Results and Discussion

Bluegill

The bluegill population in West Long Lake was dominated by sub-stock length fish (Figure 1). Mean CPUE for bluegills ≥ stock length was 41/hr (SE = 10). Mean Wr was good (Table 1) and similar to other Sandhill lakes.

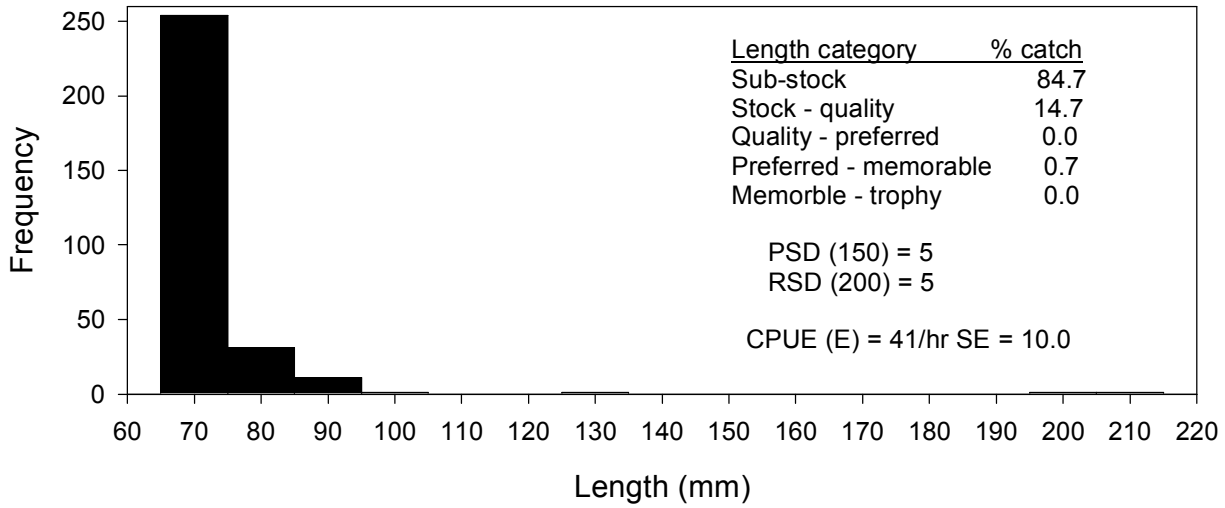

Figure 1. Length frequency distribution (10-mm length groups) of bluegill captured by electrofishing in West Long Lake, Valentine NWR, June 2006. Mean catch per unit effort (CPUE) for bluegill ≥ stock length (80 mm).

Table 1. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for bluegill captured by electrofishing and trap nets in West Long Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Stock – quality (80 – 149 mm)	12	20 (3.9)	133 (3.9)
Quality – preferred (150 – 199 mm)	0		
Preferred – memorable (200 – 249 mm)	2	255 (45.0)	116 (13.3)
Memorable – trophy (250 – 299 mm)	0		
Trophy (≥ 300 mm)	0		
Total	14	54 (23.5)	130 (4.0)

Largemouth bass

In 2006, the largemouth bass population was represented by most length categories (Figure 2). The relative abundance of ≥ stock length largemouth bass (78/hr) was the highest of all refuge lakes surveyed in 2006. Mean Wr was good (Table 2) and similar to other Sandhill lakes.

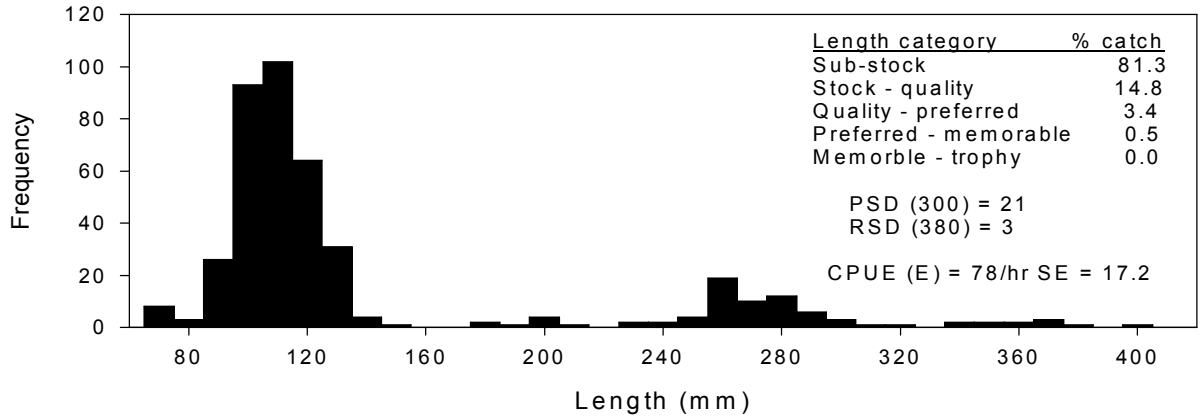

Figure 2. Length frequency distribution (10-mm length groups) of largemouth bass captured by electrofishing in West Long Lake, Valentine NWR, June 2006. Mean catch per unit effort (CPUE) for largemouth bass ≥ stock length.

Table 2. Mean weight and relative weight (Wr) with standard error (SE) in parenthesis by length category for largemouth bass captured by electrofishing in West Long Lake, Valentine NWR June 2006.

Length category	n	Mean weight (g)	Mean Wr
Sub-stock (< 200 mm)	35	31 (3.9)	131 (2.1)
Stock – quality (200 – 299 mm)	33	253 (13.8)	103 (2.1)
Quality – preferred (300 – 379 mm)	14	690 (69.3)	114 (6.9)
Preferred – memorable (380 – 509 mm)	2	1100 (0)	114 (11.5)
Memorable – trophy (510 – 629 mm)	0		
Trophy (≥ 630 mm)	0		
Total	84	254 (31.5)	117 (2.2)

Summary

Bluegill – The bluegill population in Pelican Lake was dominated by sub-stock length fish with some bluegills anglers would prefer. Mean Wr levels were similar to other Sandhill lakes.

Largemouth bass – West Long Lake has the highest relative abundance of largemouth bass of all refuge lakes surveyed in 2006 presenting excellent angler opportunities. Mean Wr levels indicate an abundance of prey for largemouth bass in West Long Lake.

Management Recommendations

1. Conduct biannual electrofishing surveys of West Long Lake to monitor bluegill and largemouth bass populations.

2. Conduct creel surveys to measure angler harvest of bluegills and largemouth bass.

Acknowledgements

I thank Dane Shuman (USFWS), Robert Klumb (USFWS), and Jeff Jolley and his technicians (South Dakota State University [SDSU]) for providing field assistance. I also thank the staff at Valentine NWR for providing housing accommodations, reviews of an earlier draft of the report, and angler information. Valentine NWR also provided funding for the fisheries assessments.

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Appendix A. Summary of fishing regulations on the Valentine National Wildlife Refuge. *Panfish species include bluegill, yellow perch, black crappie, etc. **Panfish bag limit is in aggregate.

Lake	Species	Year	Size limit	Bag limit**
Clear	Northern pike	1993 – present	28 in. max.	3
		1991 – 1992	36 in. min.	3
		1990	30 in. min.	6
		1988 – 1989	36 in. min.	6
		1987	24 in. min	6
	Largemouth bass	1988 – present	15 in. min. and 1 > 24 in.	4
		1987	12 in. min	8
	Panfish*	1988 – present		30
		1987		No limit
Dewey and Pelican	Northern Pike	1993 – present	28 in. max.	3
		1990 – 1992	36 in. min.	3
		1988 – 1989	36 in. min.	6
		1987	24 in. min.	6
	Largemouth bass	1988 – present	15 in. min. and 1 > 24 in.	4
		1987	12 in. min	8
	Panfish*	1988 – present		30
		1987		No limit
Hackberry	Northern pike	1993 – present	28 in. max.	3
		1992	36 in. min.	3
		1990 – 1991	24 in min.	3
		1987 – 1989	24 in. min.	6
	Largemouth bass	1988 – present	15 in. min. and 1 > 24 in.	4
		1987	12 in. min	8
	Panfish*	1988 – present		30
		1987		No limit
Watts	Musellunge	1988 – present	Catch and release	
		1987	36 in. min.	3
	Largemouth bass	1988 – present	Catch and release	
		1987	12 in. min.	8
	Panfish*	1988 – present		30
		1987		No limit
All refuge lakes not previously identified	Northern pike	1993 – present	28 in. max.	3
		1990 – 1992	24 in. min.	3
		1987 – 1989	24 in. min.	6
	Largemouth bass	1988 – present	15 in. min. and 1 > 24 in.	4
		1987	12 in. min	8
	Panfish*	1988 – present		30
		1987		No limit

Appendix B. Fish stocking history for Valentine National Wildlife Refuge lakes. FY: Fry (Hatch to 1.49"); FG: Fingerlings (1.5" to 5.49"); AD: Adult (Sexually mature, regardless of size); MX: Mixed (transplanted from natural sources).

		Largemouth bass			Bluegill			Northern pike			Yellow perch			Black crappie			Sauger X walleye			Muskellunge		
Lake	Year	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size
Clear	2005							3	50	AD				7	140,727	FY						
	2004													10	4,698	FG						
														10	48	AD						
	1996				10	45,000	FG															
	1991	7	6,000	FG	8	50,000	FY															
	1990	7	17,000	FG																		
	1989	7	15,000	FG																		
	1988													9	750	MX						
Dewey	2004	8	12	AD				8	195	AD	8	150	AD									
	1991	7	28,000	FG	8	50,000	FY															
		7	28,000	FG																		
		7	28,000	FG																		
Hackberry	2006				10	364,315	FG															
	2005	8	31	AD	10	148,070	FG				6	136,000	FY									
		8	68,200	FG	3	128,000	FG				2	19,068	FG									
	2004				10	86,250	FG															
	1996				10	75,000	FG															
	1992							4	1,200	MX												
	1991	8	35,000	FG																		
	1990	7	35,000	FG																		
	1989	8	37,000	SA																		
Pelican	1996				10	102,800	FG															
	1994										4	7,000	MX									
	1993										4	1,250	MX									
	1991	7	40,000	FG																		
	1990	7	40,000	FG																		
	1989	7	32,000	FG																		
Duck	1995																6	4,000	FY			
	1994																4	4,000	FG			
	1991	7	10,000	FY	8	30,000	FY				6	20,000	FY									

Appendix B continued. Fish stocking history for Valentine National Wildlife Refuge lakes. FY: Fry (Hatch to 1.49"); FG: Fingerlings (1.5" to 5.49"); AD: Adult (Sexually mature, regardless of size); MX: Mixed (transplanted from natural sources).

		Largemouth bass			Bluegill			Northern pike			Yellow perch			Black crappie			Sauger X walleye			Muskellunge		
Lake	Year	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size	Month	N	Size
Watts	2005	9	15,525	FG	10	148,070	FG				8	19,261	FG									
	1997																			9	50	SA
	1996				10	30,000	FG										6	10,000	FG	9	50	SA
	1995																6	5,000	FG			
	1994																4	5,000	FG			
	1991	7	5,000	FG																		
	1990	7	5,000	FG																		
	1989	7	5,000	FG																		
	1988																			9	29	AD
West Long	1996	9	50	AD																		
	1991	7	10,000	FG	8	20,000	FG				6	30,000	FG									
Willow	1988				9	116,000	FY	4	180,000	FY	4	4,000	AD									

APPENDIX C
GLOSSARY OF FISHERY TERMS

Alkalinity: Alkalinity is a measure of a waters ability to resist a change in pH expressed in mg/l or ppm. Because alkalinity is dependent on minerals such as calcium (Ca), and this relates to aquatic vegetation production, alkalinity is a good indicator of a water bodies potential to produce fish. Less than 40 mg/l is considered soft water; greater than 40 mg/l is hard water.

Catch per Unit Effort (CPUE): CPUE is the catch per unit of sampling effort that is used as an index of abundance or to document population changes over time. The formula is:

$$\text{CPUE} = \frac{\text{number of fish in a length class, length category, or sample}}{\text{Hour for electrofishing or net night}}$$

Conductivity: Conductivity is a measure of a water bodies ability to conduct electricity, which is dependent on the amount of ions in the water. Total dissolved solids (TDS) is equal to 0.5 X Conductivity. Conductivity is a good measure of a water bodies productivity because of the relation between minerals and productivity.

Effort: The effort is the total amount of time expended in collecting a sample. The time may be in hours, minutes, or net days. The effort is used to calculate CPUE.

Habitat Suitability Index (HSI): a numerical index (0 = poor, 1 = excellent) which is used to identify how well a fish species should perform in a lake or pond. The HSI value is computed using water quality and habitat conditions and evaluated how well a species can spawn, survive, and grown in a body of water.

Morphoedaphic Index (MEI): This index is used as a fish yield estimator based on average depth (X) and total dissolved solids (TDS). The formula is: MEI = X/TDS.

Memorable length: The memorable length is a standard category unique for each species. The memorable length is the length that most anglers remember catching and is 59 to 64% of the world record length.

Net days: A unit of time used to describe the effort required to collect a sample using Gill nets or Trap nets. For example, if 5 Gill nets were left for a 24 hour period, then 5 Gill nets days worth of effort were expended.

pH: a measure of how basic or acidic a body of water is. This information is important as many species of game fish have narrow pH tolerances.

Preferred length: The preferred length is a standard category unique for each species. The preferred length is the length that most anglers prefer to catch and is usually within a range of 45 to 55% of the world record length.

Proportional Stock Density (PSD): PSD is the number of fish greater than or equal to a minimum quality length in a sample divided by the number of fish greater than or equal to a minimum stock length. The formula is:

$$PSD = \frac{\text{number of fish} \geq \text{"quality" length}}{\text{number of fish} \geq \text{"stock" length}}$$

Quality length: The quality length is a standard length category unique for each species of fish. The Quality length is usually within a range of 36 to 41% of the world record length and generally the minimum size that most anglers will keep.

Relative Stock Density (RSD): The RSD is the number of fish greater than a minimum preferred length in a stock divided by the number of fish greater than or equal to a minimum stock size. The formula is:

$$RSD = \frac{\text{number of fish} \geq \text{"preferred" length}}{\text{number of fish} \geq \text{"stock" length}}$$

Relative weight (*Wr*): The relative weight of a fish or group of fish is referred to as a "Wr" value. The relative weight is a comparison of the condition of the fish in a sample and the condition of a theoretical optimum sample. The formula is:

$$Wr = \frac{W}{Ws} \times 100$$

where "W" is the weight of an individual and "Ws" is a length specific standard weight.

Stock length: The stock length is the smallest of the standard length category unique for each species of fish. The stock length is usually within a range of 20 to 26% of the world record length and at or near which a species reaches sexual maturity.

Trophy length: Trophy length is a standard length category unique for each species of fish. The Trophy length is size worthy of acknowledgment and is greater than 74% of the world record length.

APPENDIX D
DATA COLLECTION AND ANALYSIS PROTOCOL

For each species, five fish per 10 mm (0.4 inch) larger than 80 mm (3.2 inches) were weighted to the nearest gram (g) and measured to the nearest millimeter (mm). Fish smaller than 80 mm were tallied for length frequency analysis only. Once five fish were recorded for a 10 mm group, additional fish in that group were tallied for length frequency analysis only.

Catch per unit effort (CPUE) was recorded separately for each net and each electrofishing transect to enable calculating CPUE confidence intervals (CI) at the 80% CI level. CPUE and confidence intervals were analyzed using the one or two gears that are appropriate for each species of fish.

Analysis of Data Collected

1) Trends in relative abundance were assessed as catch-per-unit-effort (CPUE) as fish/trap net night, fish/gill net night, and for electrofishing fish/hr.

2) Calculating relative weight (Wr) assessed condition of fish by size groups.

Relative Weight (*Wr*): The relative weight of a fish or group of fish is referred to as a "Wr" value. The relative weight is a comparison of the condition of the fish in a sample and the condition of a theoretical optimum sample (Wege and Anderson 1978, Blackwell et al. 2000). The formula is: $Wr = (W/Ws) \times 100$, where "W" is the weight of an individual and "*Ws*" is a length specific standard weight.

3) Proportional stock density (PSD) and incremental relative stock density (RSD) for substock, stock, quality, preferred, memorable, and trophy size categories (Anderson 1978; Gabelhouse 1984) were calculated for each species in each gear.

The PSD is the number of fish greater than or equal to a minimum quality length in a sample divided by the number of fish greater than or equal to a minimum stock length. The formula is:

$$PSD = \frac{\text{number of fish} \geq \text{"quality" length}}{\text{number of fish} \geq \text{"stock" length}}$$

Relative Stock Density (RSD): The RSD is the number of fish greater than a minimum preferred length in a stock divided by the number of fish greater than or equal to a minimum stock size. The formula is:

$$RSD = \frac{\text{number of fish} \geq \text{"preferred" length}}{\text{number of fish} \geq \text{"stock" length}}$$