ATTWATER'S PRAIRIE-CHICKEN
(*Tympanuchus cupido attwateri*)

DRAFT RECOVERY PLAN

Second Revision

Photo by George Levandoski.

Southwest Region
U.S. Fish and Wildlife Service
Albuquerque, New Mexico

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DISCLAIMER

Recovery plans delineate reasonable actions believed necessary to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official position or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service. They represent the official position of the agencies mentioned only after they have been signed as approved by appropriate personnel and posted on the public registry. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

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EXECUTIVE SUMMARY

Current Status and Distribution: The Attwater's prairie-chicken (APC) (*Tympanuchus cupido attwateri*) was listed as endangered with extinction in 1967. This listing was "grandfathered" into the Endangered Species Act of 1973. The APC represents the southern-most subspecies of *T. cupido*, and currently occurs in the wild at only two locations - the Attwater Prairie Chicken National Wildlife Refuge (Colorado County, Texas) and the Texas City Prairie Preserve (Galveston County, Texas). Approximately 50 birds remained in these two populations as of March 2006. In addition, 160 breeding individuals were held in captivity at the Abilene Zoo (Abilene, Texas), Caldwell Zoo (Tyler, Texas), Fossil Rim Wildlife Center (Glen Rose, Texas), Houston Zoo (Houston, Texas), San Antonio Zoo (San Antonio, Texas), Sea World of Texas (San Antonio, Texas), and Texas A&M University (College Station, Texas).

Habitat Requirements: Lehmann (1941) described APC habitat requirements as follows:

> "Optimum prairie chicken range apparently consists of well-drained grassland supporting some weeds or shrubs as well as grasses, the cover varying in density from light to heavy; and with supplies of surface water available in summer. In short, diversification within the grassland type is essential."

Lehmann (1939) succinctly summarized habitat needed by APC:

> "It is therefore upon the existence of adequate prairie habitat that the welfare of the prairie chicken depends."

Reasons for Listing and Limiting Factors: The APC once occupied expansive prairie grasslands of coastal Texas and Louisiana. Habitat destruction and degradation, and to a lesser extent overharvesting, are the primary factors contributing to historic population declines. Current threats include extremely small populations, habitat and population fragmentation resulting in genetic isolation, diseases and parasites in both the wild and captive setting, inability of captive breeding facilities to produce large numbers of captive-reared birds that are capable of survival and reproduction in wild habitats, and poor brood survival in wild populations.

Recovery Goal: The goal of this plan and recovery effort is to protect and ensure the survival of the APC and its habitat, allowing the population to reach a measurable level of ecological and genetic stability so that it can be reclassified to threatened status (downlisted) and ultimately removed from the endangered species list (delisted).

Recovery Strategy: APC recovery must be focused on 3 primary areas: (1) habitat management, (2) captive and wild population management, and (3) public outreach. It is imperative that habitat management, enhancement, and restoration be carried out to maintain existing grasslands currently suitable as habitat and to restore degraded grasslands. These grasslands must be provided at a landscape scale so that multiple areas $\geq$25,000 acres (ac) (10,120 hectares (ha)) are available to support viable APC populations and provide for gene flow between them. Population management consists of actions

required to manage captive and wild populations. If viable populations are to be established in presently unoccupied but suitable habitat, large (>100) numbers of birds at multiple release sites will be required. It is clear the captive program must be retooled in dramatic fashion to achieve APC recovery. Numerous challenges face the wild APC population. Predation (raptors, mesocarnivores, snakes), red imported fire ants (*Solenopsis wagneri*), disease, ectoparasites, accidents (flying into fences, wires), flooding, incompatible grazing, altered fire regimes, and countless other factors are collectively suppressing optimal recruitment of the two remaining wild populations. Additional applied research efforts are essential to identify factors limiting recruitment in free-ranging populations, which currently depend heavily on release of captive-reared birds. However, conducting meaningful research with broad ranging applicability is very challenging given the low population numbers and varied grassland habitats at these two sites. An ongoing challenge to recovery has been difficulty in attracting a large constituency engaged in APC conservation. A broader support base is critical for timely implementation of actions required for APC recovery.

Recovery Objectives and Criteria:

1. Downlist to threatened status when the overall population maintains a minimum of 3,000 breeding adults annually over a 5-year period. These birds should be distributed along a linear distance of no less than 50 miles (80 km) to mitigate for environmental stochasticity (e.g., hurricanes) while maintaining gene flow.

2. Delist when the overall population reaches a minimum of 6,000 breeding adults annually over a 10-year period, and occupies habitats along a linear distance of no less than 100 miles.

Specific objectives and criteria for habitat management, captive and wild population management, and public outreach necessary to accomplish these recovery goals are:

Objective 1: Maintain and improve 300,000 ac (121,457 ha) of coastal prairie habitat for APC throughout the bird's historical range on both private and public lands. APC recovery will require a network of large, high quality coastal prairie habitats containing multiple core areas distributed along at least 100 linear miles (160 km). A core area is defined as an area of habitat capable of supporting a population of 500 (250 displaying males), or approximately 25,000 ac (10,121 ha) (assuming a carrying capacity of 1 bird/50 ac (20 ha) (Lehmann1941).

Objective 2: Enhance propagation and release efforts to boost wild populations to viable levels and re-establish physically and behaviorally healthy birds to their former range, as measured by the following criteria:

(a) Maintain 90% of original gene diversity for 20 years with a minimum of 200 birds in the captive flock.

(b) Produce enough chicks annually to release at multiple sites (approximately 100 birds per release site).

- Increase capacity of breeding pairs to a minimum of 100 pairs within two years.
- By 2008, increase survival in the captive environment so that 50% of eggs produced survive to 8 weeks of age.

(c) When number of young available for release exceeds 100, pilot releases of no fewer than 30 should be considered on private lands.

Objective 3: Establish populations of at least 500 birds in multiple core areas, providing for gene flow between populations (see *Objective 1*).

Objective 4: Broaden public support and partner in efforts to conserve the APC and its coastal prairie ecosystem.

Estimated Date and Cost of Recovery: Because the APC is an *r*-selected species, it is capable of explosive population growth. Assuming exponential population growth, and a maximum growth rate of $r = 1.1$ (the maximum metapopulation growth rate observed during 1971–1996 for any one year; M. Morrow, APCNWR, unpublished data), the threshold population size of 6,000 required for delisting could be achieved within 5 years. However, a more realistic sustained *r* of 0.1 (1971–1975 average for statewide population during last recorded 5-year interval of population growth – see Appendix 1) would require 48 years to achieve the population threshold for delisting. An average *r* of 0.08 was observed from 1972-1987 on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) during a period of general population increase (M. Morrow, APCNWR, unpublished data). Estimated costs for implementation of tasks described in the implementation schedule (Section III) over a 50-year recovery period are provided in Table 1.

Table 1. Cost estimates ($1,000) for implementation of Attwater's prairie-chicken recovery actions over a projected 50-year recovery period.

Year	Habitat (Action # 1)	Captive Population Management (Action # 2)	Wild Population Management (Action #3)	Public Outreach (Action # 4)	Total
1	3,862	1,715	400	225	6,202
2	3,687	1,357	325	50	5,419
3	3,612	957	348	50	4,967
4	3,612	797	350	50	4,809
5	3,612	797	350	50	4,809
50	102,600	13,363	7,698	425	124,086

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I. BACKGROUND INFORMATION

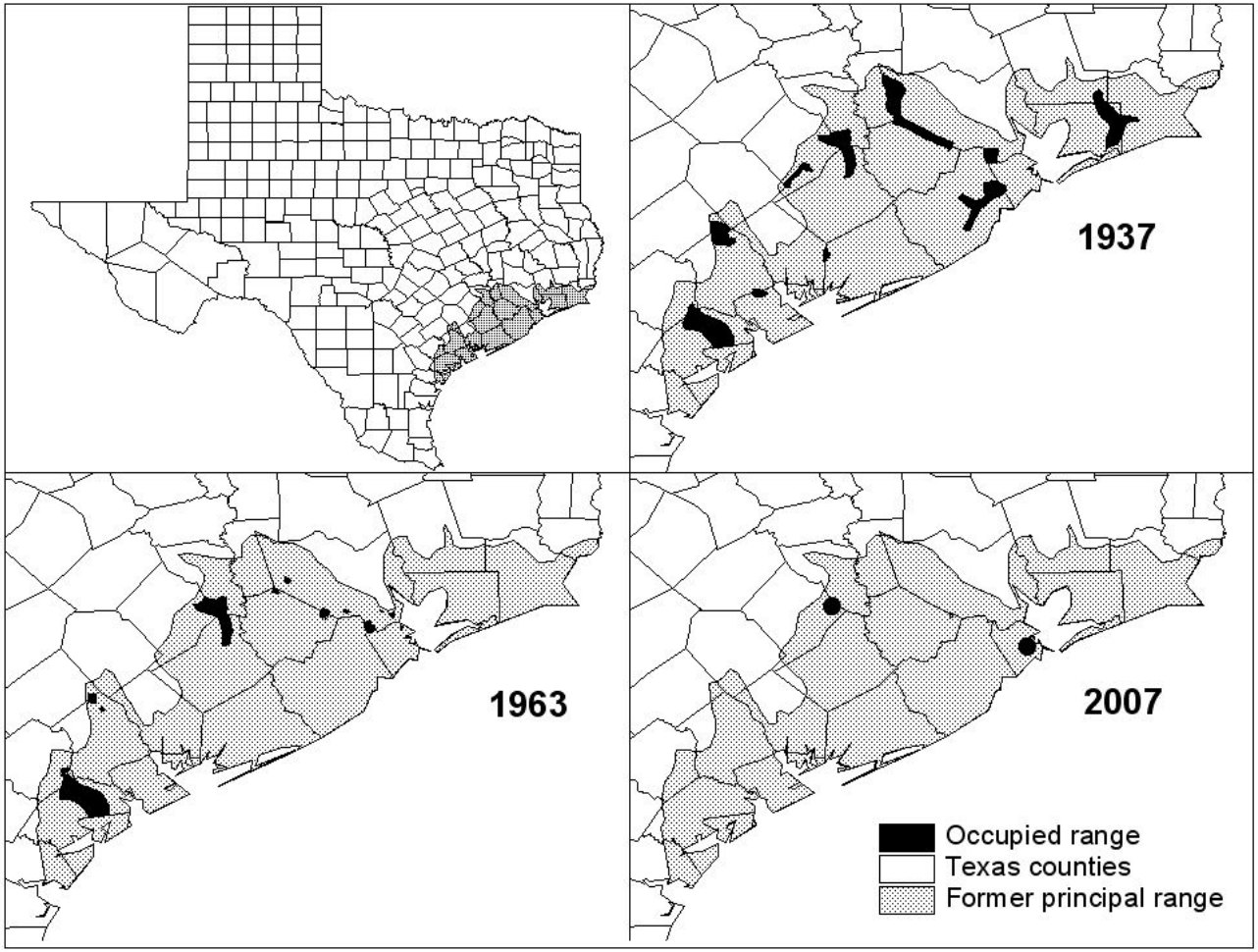
A. BRIEF OVERVIEW

The Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) (APC) is a subspecies of prairie-chicken endemic to prairies along the Gulf of Mexico (Bendire 1894). Historically, APC populations approached 1 million individuals on an estimated 6 million acres (2.4 million ha) of prairie habitat (Lehmann 1968). By 1937, populations had declined to an estimated 8,700 individuals and have continued to decline. As of spring 2006, approximately 50 remained in two free-ranging populations (Figure 1). The APC was listed as endangered in March 1967 under the Endangered Species Preservation Act (ESA) of 1966 (32 FR 4001). It is currently listed as endangered by the U.S. Fish and Wildlife Service (USFWS) under provisions of the ESA of 1973 (50 CFR 17.11) and by Texas Parks and Wildlife Department (TPWD) (31 TAC 65.181-184). The APC has a recovery priority ranking of 3 on a scale from 1 (high priority) –18. This ranking reflects a high degree of threat, high potential for recovery, and the APC's taxonomic status as a subspecies. Priority 3 is the highest ranking assigned to subspecies (48 FR 43104).

Loss and fragmentation of its coastal prairie ecosystem and associated isolation of sub-populations brought about by agricultural conversion, urban and industrial expansion, overgrazing, and invasion of prairies by woody species have been the ultimate factors responsible for the APC's decline (Lehmann 1941, Jurries 1979, Lawrence and Silvy 1980, McKinney 1996, Morrow et al. 1996). Probable proximate contributors to range-wide population declines in recent history include stochastic weather events (Morrow et al. 1996), reduced genetic variability (Osterndorff 1995), parasites (Peterson 1994, Purvis 1995), disease (Peterson et al. 1998), and red imported fire ants (Mueller et al. 1999). These and possibly other factors have contributed to reduced survival and reproductive output (Peterson 1994, Peterson and Silvy 1994).

A captive breeding program was initiated for the APC in 1992. This program had two primary goals: (1) preserve as much genetic variability as possible, and (2) provide birds for supplementation of remaining populations and the re-establishment of extirpated populations. From 1995–2006, a total of 1,005 captive-reared birds has been released in an effort to buoy failing populations at the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) and at The Nature Conservancy's (TNC) Texas City Prairie Preserve (TCPP) (APCNWR, unpublished data). As of October 2006, 166 APC were held in breeding facilities at the Abilene, Caldwell, Houston, and San Antonio Zoos, and at Fossil Rim Wildlife Center, Sea World of Texas, and Texas A&M University (TAMU) (H. Bailey, APC Species Survival Plan (SSP) Coordinator, Houston Zoo, Inc.).

Figure 1. Approximate distribution of Attwater's prairie-chicken in southeast Texas historically, 1937, 1963, and 2007 (from Morrow et. al 2004 with modification).



B. TAXONOMY AND DESCRIPTION

Tympanuchus cupido attwateri is a member of the class Aves, family Phasianidae, and subfamily Tetraoninae (American Ornithologists' Union 1998). It shares its subspecies status with the greater prairie-chicken (GPC) (*T. c. pinnatus*), which occupies grasslands of the North American great plains, and the extinct heath hen (*T. c. cupido*), which once occupied grasslands of the northeastern United States (Aldrich 1963, Silvy and Hagen 2004). The APC was described by Bendire (1894):

> **"**Smaller than *T. americanus* [greater prairie chicken], darker in color, more tawny above, usually with more pronounced chestnut on the neck; smaller and more tawny light colored spots on the wing coverts, and much more scantily feathered tarsus, the latter never feathered down to base of toes, even in front; a broad posterior strip of bare skin being always exposed, even in winter, while in summer much of the greater part of the tarsus is naked.**"**

Physical differences between the APC and the GPC are minor. Smaller measurements of wing, tail, bill, and total length and differences in general ruddiness and buffiness of the underparts are characteristic and can be used to separate the APC as a subspecies (Lehmann 1941). Oberholser (1974) described the APC subspecies as similar to the GPC,

> "…but smaller; feathering of tarsus somewhat shorter and sometimes leaving lower half of leg bare; coloration somewhat more rufescent and buffy, particularly on flanks and other lower parts; dark bars on lower surface usually narrower."

Lack of feathering extending onto the feet of the APC, less feathering on the tarsus, and lack of well-developed pectinae on the toes of the APC during winter are probably the most concrete phenotypic differences between the APC and GPC subspecies. Other differences, such as plumage coloration and size, are more subtle.

Svedarsky (1979) reported average breeding season weights for Minnesota GPC females (hens) of 919 grams (2.0 lbs) (n = 16). Breeding season weights for combined GPC age classes from Wisconsin and Minnesota, weighted by sample size from Toepfer (1988:68), were 1,033 grams (2.3 lbs) for males (cocks) (n = 89) and 929 grams (2.0 lbs) for females (n = 55). APC weights reported by Lehmann (1941) averaged 1,112 grams (2.5 lbs) (n = 5) for males and 737 grams (1.6 lbs) for females. Morrow and Silvy (unpublished data) observed average breeding season weights of 986 grams (2.2 lbs) for male (n = 26) and 874 grams (1.9 lbs) for female (n = 28) APC captured on APCNWR booming grounds from 1983–1985. Toepfer (1988) observed that maximum weights of wild GPC cocks from Wisconsin and Minnesota occurred approximately 3–4 weeks before the breeding peak, while female weights peaked just before egg laying. Toepfer (1988) observed that minimum weights for GPCs occurred during August in Wisconsin, with both sexes losing an average of 14% from their peak April weights. Similarly, Svedarsky (1979), also working with the GPC subspecies, observed a 14.6% weight loss during summer for Minnesota hens. This summer weight loss was attributed primarily to

high energy demands of the annual molt (Toepfer 1988). Immature GPCs do not reach full size until late fall or early winter of their second year, with males gaining an average 9% and females 6% compared to their hatch-year weights (Toepfer 1988).

From a genetics perspective, the APC does not represent a phylogenetically distinguishable group based on criteria of monophyly when compared to all recognized species within the genus *Tympanuchus*, based on analysis of mitochondrial DNA (mtDNA) control region sequence data (Palkovacs et al. 2004, Johnson and Dunn 2006. Johnson et al. 2007). In fact, with the exception of the heath hen (Palkovacs et al. 2004, Johnson and Dunn 2006), studies utilizing a number of different molecular markers including allozymes, mtDNA, and nuclear intron sequence data (Ellsworth et al. 1994, Dimcheff et al. 2002, Drovetski 2002, Palkovacs et al. 2004, Johnson and Dunn 2006, Spaulding et al. 2006) with traditional gene-tree approximations found no clear phylogenetic differentiation among any species of this genus, which also includes sharp-tailed grouse (*T. phasianellus*) and lesser prairie-chicken (*T. pallidicinctus*). However, recent analyses by J. Johnson (University of Michigan, unpublished data) using a coalescent approach to investigate the demographic history associated with each taxon based on mtDNA sequence data indicate that despite morphological and behavioral similarities between APC and GPC, these two taxa are as genetically divergent from each other as either is from morphologically distinct lesser prairie-chickens and sharp-tailed grouse. In a recent unpublished study using nuclear microsatellite DNA allele frequency data, J. Johnson (Univ. of Michigan) was also able to identify significant population genetic differentiation between all *Tympanuchus* taxa, including the APC population, suggesting that no contemporary gene flow exists between sampled populations.

The apparent lack of reciprocal monophyly among these taxa based on traditional phylogenetic methods is due to incomplete lineage sorting rather than contemporary gene flow (Johnson et al. 2007). Ellsworth et al. (1994), Drovetski (2002), and Spaulding (2007) suggested that morphological and behavioral differentiation among species in this genus, particularly for those with overlapping geographic distributions, is largely driven by sexual selection and has progressed more rapidly than mtDNA or allozyme differentiation. This suggestion is consistent with the significant amount of time that would be required for attainment of reciprocal monophyly due to the recent diversification within this genus and its large ancestral effective population size associated with this genus and its recent ancestry (e.g., Hudson and Coyne 2002, Johnson et al. 2007).

In summary, most molecular approaches to date have not been able to identify distinct groups associated with commonly accepted species taxonomy within Tympanuchus (i.e., lesser prairie-chicken, GPC, and sharp-tailed grouse) suggesting that this genus experienced a rapid diversification within the past 10,000 years. However, more recent genetic analyses have suggested that APC and GPC are as differentiated from each other as either is from other recognized species within the genus (J. Johnson, University of Michigan, unpublished data). Therefore, APC and GPC may warrant separate species status despite any observable behavioral or morphological differences.

C. DISTRIBUTION AND ABUNDANCE

The APC represents the southernmost extension of the genus *Tympanuchus*. Historically, APCs ranged from southwest Louisiana to possibly near Brownsville, Texas (Lehmann 1941, Oberholser 1974, Peterson 1994, Silvy et al. 2004). However, in reviewing historical accounts Lehmann and Mauermann (1963) concluded:

> "…Attwater's prairie chickens have almost certainly never been abundant in any part of the southern coastal prairie south of the Nueces River from the mid-1800's to the present."

These authors suggested the propensity for severe droughts along the lower Texas coast and the Rio Grande River plain limited establishment of long-term populations in those areas. Lehmann (1941) reported the northern distribution of the APC was limited by the northern edge of the coastal prairie. Oberholser (1974) reported data that suggest APCs may have ranged as far north as Bastrop and Travis counties in Texas, but Lehmann (1941) considered records from these two counties as being questionable. Silvy et al. (2004), citing data from Oberholser (1974), reported a 2-county overlap in the historic distribution of APC and GPCs in Texas. GPCs were extirpated from Texas by 1920, with the last records occurring in northeast Texas near Marshall (Oberholser 1974).

APCs were extirpated from Louisiana by 1919 (St. Amant 1959, Oberholser 1974), although St. Amant (1959) reported huntable populations existed in 12 parishes by as late as 1890. Only an estimated 8,700 individuals remained in 19 Texas counties by 1937 (Lehmann 1941), down from a historic distribution of up to 48 Texas counties (Silvy et al. 2004) which may have supported numbers approaching 1 million in peak years (Lehmann 1941). Population declines continued and by 1999, APC remained in only two counties (Morrow et al. 2004, Silvy et al. 2004) (Figure 1, Appendix 1). Populations in these two counties have been buoyed since 1996 by supplementation with birds reared in captivity (Morrow et al. 2004, Silvy et al. 2004). In spring 2006, approximately 50 APC remained in free-ranging populations at the APCNWR (Colorado County, Texas) and TCPP (Galveston County, Texas) (APCNWR, unpublished data) (Figure 2, Appendix 1)

Loss of its prairie grassland habitat was the primary cause for the APC decline (Figure 3). Lehmann (1941) indicated that 93% of the 6 million acres (2.4 million ha) of coastal prairie that once supported APC had been lost by 1937. Coastal prairie loss continued through the remainder of the 20th century. From 1952–1990, grassland acreage containing the two largest remaining APC populations declined by 67% in Austin and Colorado counties and by 46% in Aransas, Goliad, and Refugio counties (McKinney 1996). Smeins et al. (1991) estimated that <1% of the coastal prairie ecosystem remained in relatively pristine condition.

Population densities for the APC and GPC subspecies reported in the literature are extremely variable, depending upon the quality of the habitat, time of year, how the area was surveyed, and how the area of interest was defined. Lehmann (1941:7) stated that under pristine conditions, not all coastal prairies had equal carrying capacities with respect to the APC. He suggested that well-drained areas (15% of the former range) may have supported up to 1 bird/acre (0.4 ha) fairly well drained areas (55% of former range)

Figure 2. Attwater's prairie-chicken population trends in southeast Texas, 1937–2006.

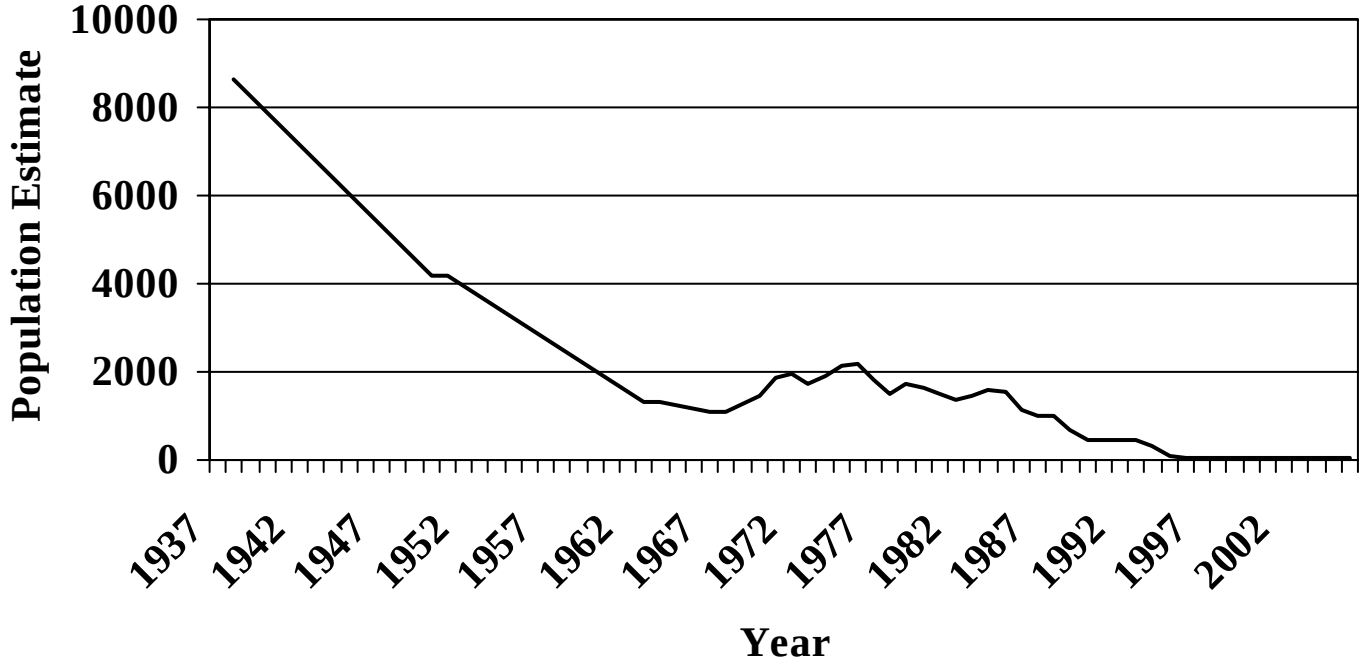
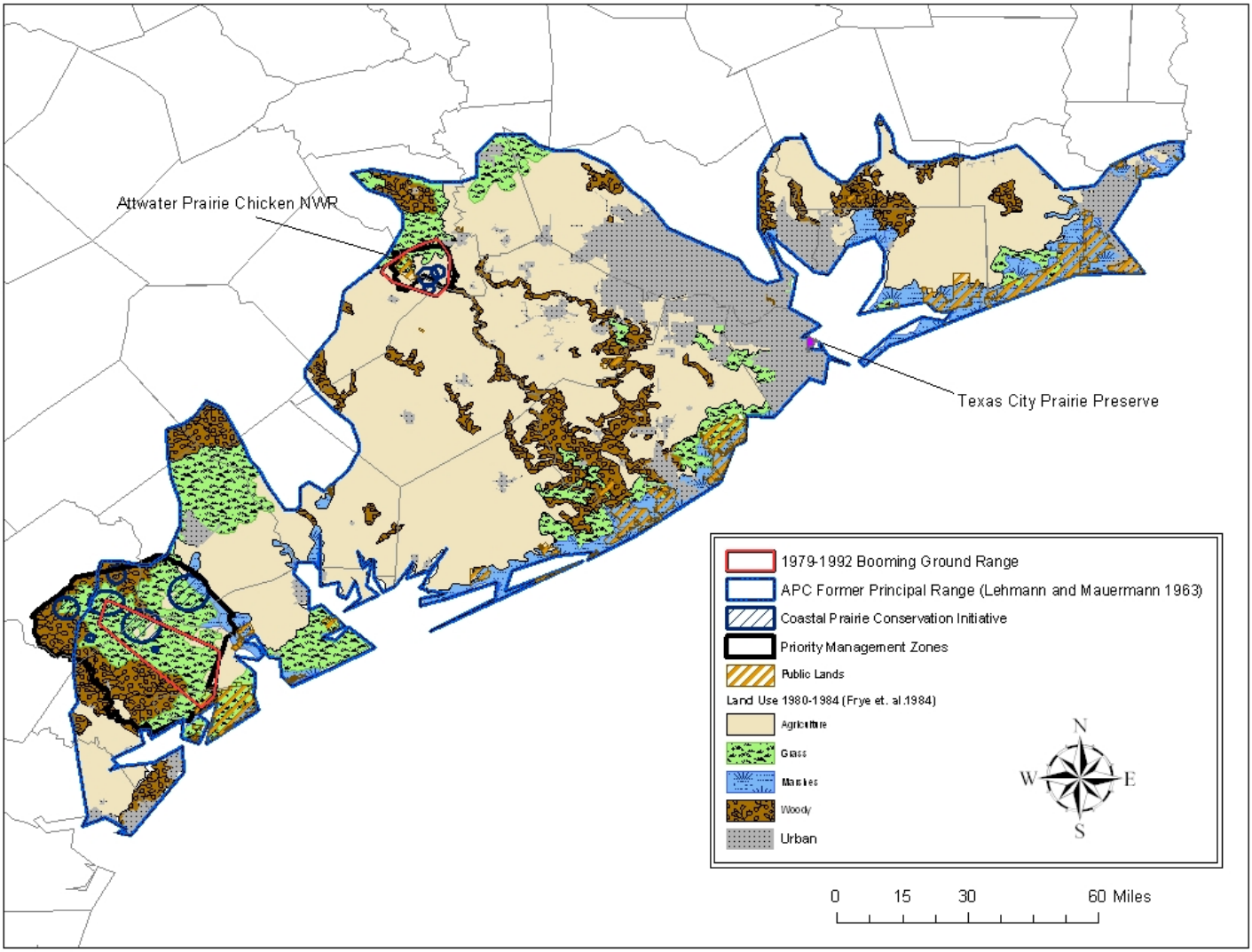


Figure 3. Land use (1984) and its relationship to Attwater's prairie-chicken priority management zones.



supported maximum densities of 1 bird/10 acres (4 ha) and poorly drained areas (30% of former range) supported not more than 1 bird/50 acres (20 ha). However, densities suggested by Lehmann (1941) are high, at least for the best range, compared to those reported for the GPC subspecies. Hamerstrom et al. (1957) reported that observed densities for the best habitat within each state or Canadian province ranged from less than 1 cock/1,000 acres (405 ha) in Ontario to 1 cock/16 acres (6 ha) in Kansas. Maximum population densities reported for GPCs on areas of managed habitat (i.e., considering only the area under management in density estimates) ranged from 1 cock/6–8 acres (2–3 ha) (1 bird/3–4 acres, assuming 1:1 sex ratio) of ecologically-patterned habitat (Missouri Department of Conservation 1984). Arthaud (1970) observed a density of 1 males/3.5 acres (1.4 ha) on a 1,680-acre (680 ha) management area in Missouri.

However, Toepfer (2003) cautioned that one must evaluate a population's health based on range-wide density estimates, and suggested that for prairie-chickens, a population's range be determined by a minimum convex polygon which connects the outer-most booming ground locations. Taking this approach, Toepfer (2003) reported a range-wide density of approximately 1 bird/section for Wisconsin and 1.5 birds/section for Minnesota. Using booming ground location data described by McKinney (1996) and census data compiled by APCNWR, 1979 density estimates calculated with this approach for the two geographically separated APC populations described by McKinney (1996) were 3.3 and 4.5 birds/section for the Aransas-Goliad-Refugio (254 mi^2, 659 km^2) and the Austin-Colorado (113 mi^2, 292 km^2) County populations, respectively (Figures 4, 5). The Austin-Colorado County population contains the APCNWR. However, because APC were traditionally surveyed on fixed routes to monitor population trends, these estimates are likely very conservative.

Toepfer (2003) suggested that high densities of wildlife are not necessarily reflective of healthy populations, especially from a genetic perspective. He suggested that for prairie-chickens, a key objective must be to maintain gene flow among populations within relatively large areas (see Johnson et al. 2004). Toepfer (2003) holds the Minnesota population, with an average density of roughly 1.5 birds/section, up as "the real prairie chicken success story in the U.S." Despite going through several population bottlenecks within its roughly 3,000 mi^2 (7,770 km^2) range, by 2003 the Minnesota population had recovered to the point that it was able to sustain its first hunting season since 1942 (Toepfer 2003).

However one reports population-level data, it is clear from a review of the literature that as an *r*-selected species, prairie-chicken populations of both subspecies are subject to sudden, catastrophic population declines. For example, Oberholser (1974) suggested that GPC populations in north-central Texas may have numbered 500,000 circa 1850. Oberholser (1974) continued:

> "Between 1870 and 1890, these birds were shot by the wagon load for meat and blood sport; even worse was the plowing up or overgrazing of their grassland habitat…. the last small flock disappeared after June 1920… Along the Texas coast, the Attwater's Greater Prairie Chicken, *T. c. attwateri*, was slaughtered with customary frontier abandon between 1840 and 1900…. For *attwateri*, as for other races, plowing under of the

> native sod was even more damaging than gunshots. Where overgrazing by livestock weakened the turf, huisache (*Acacia farnesiana*), mesquite (*Prospis*), retama (*Parkinsonia aculeata*), and other brush species encroached, reducing suitable acreage for this prairie chicken. As of about 1880, the Attwater's was still generally distributed over the Texas coastal prairie… some 810,000 birds… By 1937, the occupied area had shrunk to disjunct colonies…at this time Lehmann determined there were only about 8,700 *attwateri* in Texas – and the world…."

Smaller, isolated populations can disappear with even greater rapidity. For example, Walk (2004) reported that in 1962 approximately 2,000 GPCs remained in Illinois. By 1966, fewer than 400 remained. Since 1987, range-wide APC populations declined from an estimated 1,108 individuals to 42 in 1996 (Figure 2). Remaining APC populations have been supplemented with captive-reared birds since 1996. In the absence of this supplementation, APCs populations would have undoubtedly become extinct in the wild (Morrow et al. 2004). Toepfer (2003) stated that historical GPC data suggests isolated populations generally disappear once they fall below 100 cocks unless intensive management is implemented. APC population trends support that hypothesis, and suggest that populations dropping below 250 cocks for more than 3 years in succession have a high probability of ultimately going extinct (Appendix 1).

D. HABITAT/ECOSYSTEM

Description of habitat required by the *T. cupido* species in general, and the APC subspecies in particular, is relatively simple: they require lots of grass and open space (e.g., Lehmann 1939, 1941; Schwartz 1945; Baker 1953; Hamerstrom et al. 1957; Cogar et al. 1977; Toepfer 1988, 2003; Johnson et al. 2003, 2004; Silvy et al. 2004; Niemuth 2005). Lehmann (1939) summarizes APC habitat requirements:

> "True to its name, the Attwater [sic] prairie chicken is a bird of the prairie. Woodland, brushland, fallow land, and cultivated land furnish some food and cover at certain times and under certain conditions, but use of these types by prairie chickens is optional, not vital. Individually or in combination, these types of land furnish little or nothing in the way of critically necessary courtship grounds and nesting cover. Moderately grazed and moderately burned grassland, on the other hand, provides prairie chickens with everything they need at all seasons. It is therefore upon the existence of adequate prairie habitat that the welfare of the prairie chicken depends."

While native prairie is most often identified as a habitat requirement for the APC subspecies (Lehmann 1939, 1941; Cogar et al. 1977, Horkel 1979), Toepfer (2003) stated there is no evidence GPCs prefer or require native grasses. However, both Hamerstrom et al. (1957) and Toepfer (2003) stressed the importance of permanent grassland as GPC habitat, especially for nesting, brood rearing, and year-round night roosting. Hamerstrom et al. (1957) indicated that total grassland appeared to be a rough index of GPC habitat quality.

Although there is general agreement that quantity of grassland is directly related to prairie-chicken population levels (Hamerstrom et al. 1957, Newell et al. 1987, Toepfer 2003), there is no consensus on the size and composition of management areas required. Hamerstrom et al. (1957) found minimum populations of GPCs in 10-40% permanent grassland, while areas with more than 40% permanent grassland supported proportionately larger populations. These authors observed the densest population on record at that time (38.8 cocks/640 ac) in an area of 77% permanent native prairie, and "low lingering" populations in 10-15% relatively undisturbed grassland. Based on these observations, Hamerstrom et al. (1957) stated that as a rule of thumb, GPCs occurred on a sustainable basis in areas which were at least 33% grassland, but were abundant only where grass comprised 50-75% of the area.

Minimum areas required to support a viable population of *T. cupido* range from several hundred to several thousand acres (Niemuth 2000, Toepfer 2003). However, Toepfer (2003) stated that previous estimates of minimum management area size for prairie-chickens "…all are much too small." Toepfer (2003) observed the approximately 3,000 mi^2 (7,770-km^2) Minnesota GPC range has undergone several population bottlenecks and still maintained its genetic viability, whereas prairie-chickens occupying smaller ranges have declined, become extirpated, or undergone substantial declines in genetic diversity (see Johnson et al 2003, 2004). Toepfer (2003:55) concludes:

> "At this point in time we still do not know the minimum size necessary to sustain a viable greater prairie chicken population….We should all now understand that to be successful, management would have to spread thousands of acres of grassland habitat over a landscape of several thousand square miles and maintain connectivity."

While grass has long been recognized as an important component of prairie-chicken habitat, open space has been given less detailed attention (Toepfer 1988). Prairie-chickens occasionally use trees for food, roosting, or loafing (Lehmann 1941, Hamerstrom et al. 1957, Toepfer 1988), but in general have an aversion to being closed in by woodland or overhanging cover (Hamerstrom et al. 1957, Toepfer 2003). Hamerstrom et al. (1957) indicated good prairie-chicken cover should contain less than 20-25% woodland cover where woody cover is distributed in scattered blocks, whereas Ammann (1957) observed GPCs in Michigan survived best with 10-25% woody cover. Toepfer (1988) reported the mean size of treeless areas and open space was positively associated with the number of cocks attending booming grounds in Wisconsin. Toepfer (1988) and Niemuth (2003, 2005) found landscapes surrounding GPC booming grounds in Wisconsin contained more grass and less forest than unused random points. Similarly, Merrill et al. (1999) found Minnesota booming grounds occurred in landscapes containing less residential farmstead, smaller amounts and smaller patches of forest, and greater amounts of Conservation Reserve Program (CRP) lands, which provide suitable grasslands for prairie-chickens (Toepfer 2003). Hamerstrom et al. (1957), Anderson (1969), and Toepfer (2003) have reported movement or abandonment of booming grounds in response to natural or artificial structures near booming grounds. Toepfer (2003) reported that increasing the treeless area from 140–540 acres (57–219 ha) around a Wisconsin booming ground by removal of scattered trees increased annual survival of

cocks from this booming ground by at least 20% compared to males from control booming grounds.

Hamerstrom et al. (1957) indicated the distribution of woods and openings is probably more important than total acreage. Specifically, Hamerstrom et al. (1957) stated nesting habitat should have a tree-free area of at least 0.5 mi (0.8 km) in one, and preferably two dimensions (i.e., length and width), and Keenlance (1998) found distance to nearest woodline was greater at nests compared to random points. McKee et al. (1998) found nest success decreased substantially when more than 5% woody cover was present at nest sites. Merrill et al. (1999) found no traditional booming grounds within 1 mi (1.6 km) of any town or forest patch greater than 75 ac (30 ha), although Toepfer (STCP, personal communication) has since observed several booming grounds within 1 mi (1.6 km) of towns in the Merrill et al. (1999) study area following a substantial GPC population increase.

Hamerstrom et al. (1957) succinctly summarized the foregoing discussion on *T. cupido* habitat requirements:

> "Grassland is of vital importance to prairie chickens, the keystone in prairie chicken ecology….Wherever one looks, the answer is the same: to save the prairie chicken, grasslands must be preserved and managed for them. There are no substitutes."

E. LIFE HISTORY/ECOLOGY

Reproduction

Booming Behavior. The most conspicuous phase of the APC life cycle occurs on communal display areas known as booming grounds, named after the resonant vocalizations made by displaying males. Courtship behavior of the APC and GPC subspecies is similar (Bent 1963). Several studies have pointed to the importance of booming grounds as focal points for prairie-chicken ecology (Schwartz 1945; Hamerstrom et al. 1957; Toepfer 1988, 2003). Toepfer (2003) states:

> "The booming ground is the social center of prairie chicken ecology. Movements are best characterized as being associated with the habitat within and surrounding a complex of booming grounds…The role of the booming ground in prairie chicken ecology cannot be overstated as most, if not all, of the life history of individual birds occurs within a mile of a booming ground. This concept goes back to Schwartz (1945) who believed that each booming ground had its own 'sphere of influence' with its own group of cocks and hens. This idea is supported by years of radio tracking that indicate the majority of radio-tagged regular adult cocks of adjacent booming grounds rarely come together, and that areas used by these adult cocks show little overlap unless an individual shifts booming grounds."

Booming grounds vary in size from about one-eighth to several acres (Jurries 1979). They may be naturally occurring short grass flats or artificially maintained areas such as roads, airport runways, oil well pads, plowed fields and drainage ditches (Jurries 1979, Horkel 1979). Numerous studies have observed that active booming grounds are usually in close proximity to grass suitable for nesting and night roosting (e.g., Lehmann 1941; Horkel 1979; Niemuth 2000, 2003; Toepfer 1988, 2003). Due to the large number of artificially maintained areas currently available within the APC range, sufficient booming areas are generally available to all males (Horkel 1979). However, booming grounds found on artificial areas are sometimes less stable than ancestral booming grounds. For example, Lehmann (1941), Kessler (1978) and Jurries (1979) observed recently established booming grounds on fallow rice fields had poor territorial hierarchy when compared to ancestral grounds. Similarly, Horkel and Silvy (1980) found booming grounds on narrow, linear areas such as roads and pipeline rights-of-way were less stable than more typical circular-shaped leks. Stable GPC booming grounds appear to have greater male visitation on average than unstable booming grounds (Hamerstrom and Hamerstrom 1973, Schroeder and Braun 1992, Merrill et al. 1999). Merrill et al. (1999) found traditional GPC booming grounds were surrounded by proportionately less forest and cropland (i.e., more grass) than were temporary booming grounds. Schroeder and Braun (1992) noted, that on average, 22.9% of GPC booming grounds in their Colorado study disappeared each year. Jurries (1979) observed temporary booming grounds usually resulted from increased populations, which were often abandoned when populations decline. Cover changes also may influence location and attendance of booming grounds (Lehmann 1941, Hamerstrom et al. 1957, Anderson 1969, Toepfer 2003).

Males gather on booming grounds in early morning and late evening to establish individual territories and to attract females, although attendance in the morning is more regular (Schwartz 1945). Jurries (1979) reported the number of cocks on an APC booming ground ranged from 3–40, but averaged 6–15. Hamerstrom and Hamerstrom (1973) observed annual average numbers of GPC cocks/booming ground during their 22-year study from 6.4–13.5 (range 1–45, $n = 529$) for stable booming grounds, and 1–4.5 for booming grounds of uncertain status (range 1–7, $n = 82$). Attendance by APC males is sporadic in fall (October–December), but both attendance and intensity of territorial defense increases by late January to early February (Lehmann 1941, Jurries 1979). Lehmann (1941) stated that courtship activity was at its peak in March, while Horkel (1979) indicated the "height of the booming season" occurred in late February to early March. Counts of cocks (minimum of 3 recommended), taken 45 minutes before sunrise to one hour after sunrise during the 2–3-week period of peak display, are recommended for use as population indices (Hamerstrom and Hamerstrom 1973, Svedarsky 1983). APC booming activity typically ends by the third week in May (Lehmann 1941).

Largest groups of females are generally observed on booming grounds a few days prior to the peak in breeding (Hamerstrom and Hamerstrom 1973, Robel and Ballard 1974). Booming intensity increases when hens are present. Several males may follow the hen(s) as they walk across the booming ground, resulting in a temporary break down of cock territorial boundaries (Jurries 1979). Copulations begin to occur in late February, peak in early March, and gradually decrease through April and early May (Jurries 1979, Lutz 1979). Secondary peaks in breeding occur in April resulting from hens attempting

to re-nest after initial attempts fail (Jurries 1979). Hens may copulate with more than one male (Lehmann 1941).

GPC studies have shown males occupying territories near the center of booming grounds are generally the most dominant, and usually perform the majority of copulations (Robel 1970). Robel (1970) reported that only approximately 10% of the male GPC population was directly involved with breeding. However, Hamerstrom and Hamerstrom (1973) observed 18% of copulations by known-age GPC cocks (n = 506) were by juveniles, and 31% (n = 555) were by cocks with exterior territories. Rates of booming ground visitation appear to be similar for adult and juvenile cocks, although juveniles visit more booming grounds during the breeding season than adults (Schroeder and Braun 1992). However once established, males maintain strong fidelity to booming grounds. Toepfer (1988) observed 84.6% of surviving GPC cocks returned to the booming ground on which they displayed the previous year (n = 66), and 80.0% of those that shifted to a new ground were between their first and second booming season. All juveniles (both sexes) attempt to breed during their first booming season (Schroeder and Robb 1993). A detailed description of behaviors and vocalizations associated with APC booming grounds is provided by Lehmann (1941).

Nesting. After the female has mated, she leaves the booming ground to initiate egg laying within approximately four days (Svedarsky 1983). The earliest date observed for initiation of incubation for APC was before March 21, based on observations of a hen with young chicks at the TCPP on 16 April 1999 (M. Morrow, APCNWR, personal observation). The latest initiation of incubation recorded was May 29 (Lehmann 1941). Eggs pip approximately 23-24 days after the onset of incubation, and hatch approximately 48 hours later (Lehmann 1941). Hatching dates ranged from April 16 (M. Morrow, APCNWR, personal observation) to the third week in June (Morrow 1986). Hens lose approximately 15–20% of their body mass during incubation (Rumble et al. 1987, Toepfer 1988).

A summary by Peterson and Silvy (1996) of several APC nesting studies indicated clutch size ranged from 7–16 eggs, averaging 12.1 for initial attempts (n = 106), and 9.5 for renesting attempts (n = 25). The 11.6-egg average for all attempts was not statistically different from clutch sizes reported for GPCs (Peterson and Silvy 1996). Peterson and Silvy (1996) observed an average APC egg hatchability of 87.3% (n = 648), which was not statistically different than the 88.7% reported for GPCs. Peterson and Silvy (1996) found that APC nest success averaged 32.2% for 143 nests observed during studies conducted 1937–1985, significantly lower (P = 0.0087) than the average 49.5% reported for 480 GPC nests. Lehmann (1941) observed an average nest success of 31.5%, so the observed difference between APC and GPC nesting success is not a phenomenon that has developed in recent history. If a female's first nest is destroyed, she may re-nest (Lehmann 1941, Jurries 1979), with egg-laying in the second clutch beginning as soon as 8–9 days later (Schroeder and Robb 1993). McKee et al. (1998) reported when all nesting attempts were considered, 56% of Missouri GPC hens hatched chicks even though average nest success was only 35%. Newell (1987) observed 57.9% of radio-tagged GPC hens in North Dakota successfully hatched chicks. Toepfer (1988) found re-nesting by Wisconsin GPCs provided 38% of the production for a year. Similarly, Newell et al. (1987) observed 36% of North Dakota GPC chicks came from re-

nesting attempts. Newell (1987) found 28% of subadult and 88% of adult hens re-nested, respectively. Fields et al. (2006) observed the survival of Kansas prairie-chicken nests declined as the nest aged and as the nesting season progressed. They found survival probability of early-, mid-, and late-season nests was 0.77, 0.61, and 0.19, respectively. Later ring-necked pheasant (*Phasianus colchicus*) hatches resulted in smaller clutch sizes, lower chick weights, and reduced chick survival (Riley et al. 1998)

APC nest predators include skunks (*Mephitis mephitis*, *Spilogale putorius*), opossum (*Didelphis virginianus*), raccoon (*Procyon lotor*), coyote (*Canis latrans*), armadillos (*Dasypus novemcinctus),* snakes, and domestic dogs and cats (Jurries 1979). Abandonment caused by human disturbance, nest flooding, or unknown causes also has been reported (Lehmann 1941, Horkel 1979, Lutz 1979). Nest flooding has been observed in several studies (Lehmann 1941; Jurries 1979; Lawrence 1982; M. Morrow, APCNWR, unpublished data). Lehmann (1941) recounts observations recorded in his 1938 field notes:

> "The prairie has been transformed into a miniature ocean dotted by tiny islands that previously had been the tops of knolls and ridges. On these islands sit wet and bedraggled prairie chickens and other birds that seem as confused and astounded as I by the sudden change in their environment. About a 5-inch depth of water covers the sites of nests 14 and 17, and former nest 15. Nest 16 has escaped by a hair's breadth, but the lining is very soggy. Problems due to hawks, skunks, and other predators seem so petty when excessive rain destroys virtually everything at a single stroke."

Poor surface and internal drainage is a characteristic feature of the APC's coastal prairie ecosystem resulting from low relief and dense clay subsoils (Smeins et al. 1991). In some years, nest losses from flooding can be substantial. For example, Lehmann (1941) observed a 33% loss due to flooding (n = 6) during 1938. Lawrence (1982) attributed abandonment of 1 of 3 active nests to flooding in 1981. Morrow (APCNWR, unpublished data) attributed abandonment of 4 of 15 nests during 2004 to nest flooding at APCNWR. Water partially covered eggs in two of these nests, and nesting materials in the other two nests were water soaked. One of 3 nests observed at TCPP during 2004 was flooded (B. Crawford, TCPP, personal communication).

Most nests are located in grasslands within 1 mile (1.6 km) of a booming ground (Lehmann 1941, Horkel 1979, Toepfer 1988), although nests may not be nearest to the booming ground on which the hen mated (Toepfer 1988). Females display fidelity to general nesting areas between years, although this is not the case for all hens (Toepfer 2003). While most nests are located in grasslands, Kessler (1978) and Jurries (1979) found a small number of nests in fallow rice fields. These nests were generally unsuccessful. Ryan et al. (1998) also observed substantially decreased success for nests located in agricultural habitats.

Plant species composition at nest sites varies by region and even from location to location within regions, but in general *T. cupido* requires grass for nesting habitat (e.g., Lehmann 1941, Hamerstrom et al. 1957, Hamerstrom and Hamerstrom 1973, Toepfer 1988, Toepfer 2003). Toepfer (1988) indicated that nesting GPC hens seek out

undisturbed residual grass cover 6-20 inches (15–50 cm) in height. Toepfer (1988) found 63% of GPC nests in residual grass from 10–20 inches (26–50 cm), and found these nests to be more successful than those found in shorter vegetation. Newell (1987) and Golner (1997) also observed lower effective heights of vegetation at unsuccessful GPC nests. Buhnerkempe et al. (1984) recommended that *T. cupido* nesting habitat should have 90% of standing vegetation distributed below 16 inches (40 cm), with vegetation vertically dense to that point. Lutz et al. (1994), working on private ranches, found obstruction of vision (OV) (Robel et al. 1970) values at APC nests averaged 9 inches (23 cm), and were higher ($P = 0.04$) at successful (10 inches, 25 cm) than at unsuccessful nests (9 inches, 22 cm). Morrow (1986), working on the APCNWR, also observed an average OV of 9 inches (23 cm) at APC nest sites ($n = 26$). It should be noted that Buhnerkempe et al.1984, Lutz et al. 1994, and Morrow (1986) did not obtain OV data until after completion of the nesting attempt. Lehmann (1941) observed that rapid plant growth in April and May provided cover for nests that may have been relatively exposed when found. However, Svedarsky (1979), who determined OV measures at nests when found, also recommended that nesting habitat should have residual vegetation with 100% OV at 10 inches (25 cm), and 50% OV at 14 inches (35 cm).

Vegetation can become too tall and dense for nesting *T. cupido* (Westemeier 1972, Svedarsky 1979, Buhnerkempe et al. 1984). Speaking of Illinois GPCs, Westemeier (1972) stated "We have not found prairie chicken nests in any rank vegetative cover…" Westemeier (1972) described rank vegetation such as big bluestem (*Andropogon gerardi*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*) which when undisturbed "…develop a rank impenetrable layer of cane-like stems and residual cover." Supporting this observation, McKee et al. (1998) found horizontal litter cover was the best single variable predictor of GPC nests. These authors indicated that nests with >25% litter cover had a failure rate twice that of nests with less litter cover. Svedarsky (1979) found greater litter depths at unsuccessful than at successful GPC nests. Morrow et al. (1996) discussed the importance of variability in grassland structure for nesting and brood rearing. Grasslands with tall (>39 inches, >1 m) vegetation appear to be avoided by nesting hens (Svedarsky 1979, Toepfer 1988), although such vegetation may be important for night roosting during periods of inclement weather (J. Toepfer, personal communication). Other nest-site vegetation threshold values identified by McKee et al. (1998) beyond which GPC nest success declined substantially include >5% woody cover, ≤5% forb cover, and ≤25% grass cover.

Brood rearing. Hens leave the nest with their chicks after the last egg has hatched (Lehmann 1941). *T. cupido* chick weights at hatch average approximately 16–17 grams (0.6 oz) (Gross 1932:255; O. Dorris, Fossil Rim Wildlife Center, unpublished data). Griffin (1998) reported average chick weights for captive APC, GPC, and APC x GPC hybrids as 15.4–17.8 grams (0.5–0.6 oz), 15.4–20.4 grams (0.5–0.7 oz), and 14.6–17.3 grams (0.5–0.6 oz), respectively. Chicks are not capable of thermoregulation until approximately 10–14 days (Toepfer 2003) and are brooded by the hen approximately 50% of the daylight hours during the first week (Lehmann 1941). By two weeks of age, Lehmann (1941) observed that APC chicks were brooded little except early in the morning, during inclement weather, and at night. Toepfer (2003) stated that GPC hens brood their chicks for up to five weeks post-hatch. Contrary to behavior of some gallinaceous species, there is no evidence that prairie-chicken brood hens feed chicks or

show them what to eat (Schroeder and Robb 1993). Lehmann (1941) described the behavior of hens leaving nests with their broods:

> "When leading chicks from the nest, old birds traveled through the lightest cover or followed trails, probably because heavy matted vegetation impeded progress and increased the chance of chicks getting lost. Cow trails were favorite travel ways. Chicks ranged in front, behind, and on both sides of the hen over an area of 1 to 5 yards in radius. Interruptions for sporadic feeding and for frequent brooding, which was probably more necessary for assembling than for warming the young, made progress slow."

Lehmann (1941) suggested this loose feeding formation resulted in chicks becoming separated from the brood unit. Chicks can perform weak flights by two weeks of age, and can fly ≥120 feet (36 m) by three weeks (Lehmann 1941).

APC broods spend the first weeks after hatching in grasslands near the nest, typically moving less than 900 ft/day (274 m/day) (Lehmann 1941). Lehmann (1941) observed two broods within 0.5 mi (0.8 km) of their nests until they were 7 and 12 days of age. Similarly, Morrow (1986) found APC broods moved approximately 0.4 mi (0.7 km) by 7–10 days post-hatch, and Svedarsky (1979) observed GPC broods in Minnesota moving an average 0.6 mi (1 km) from the nest site within two weeks. Toepfer (1988) observed movements by GPC broods in Wisconsin of just over 330 ft/day (100 m/day) during the first week and approximately 990 ft/day (300 m/day) by 14 weeks. However, broods are capable of movements of 1.8–2.4 mi (3–4 km) during the first week of life (Cebula 1966, Viers 1967, Silvy 1968, Svedarsky 1979). Newell et al. (1987) observed 5 of 22 North Dakota GPC broods moved 1.2–9 mi (2–15 km) within 34 days of hatch.

Newell et al. (1987) observed brood home ranges during the first 2–3 months post-hatch averaging 1,205 ac (488 ha) (range 54–5,553 ac, 22–2,248 ha), but small areas within these home ranges averaging 99.8 ac (40.4 ha) were used more intensively. Newell (1987) observed home ranges for broods hatching from re-nests and adult hens were smaller than those from initial nests and sub-adult hens, respectively. Distance between siblings increases among brood members, progressing toward brood break-up (Schroeder and Robb 1993). For the APC, brood break-up begins at 6–8 weeks, although some chicks may remain with the hen until late October or November (Lehmann 1939, 1941).

Cogar et al. (1977) and Morrow (1986) found broods less than 5–6 weeks old used grasslands types similar to those used for nesting. Broods move away from the dense residual cover associated with nesting cover to less dense cover which facilitates movement by the hen and chicks (Lehmann 1941, Toepfer 1988). Kessler (1978) and Svedarsky (1979) recommended that APC and GPC brood cover respectively, should have sufficient canopy cover to provide shade during the summer, but be open enough at ground level to allow uninhibited chick movement. Jones (1963) noted the importance of areas dominated by forbs in supporting high insect populations, which form a large proportion of the chick's diet (e.g., Lehmann 1941, Savory 1989).

Toepfer (1988) found Wisconsin GPC brood rearing habitat consisted of grass or mixed grass in the 10–39 inch (25–100 cm) range that was undisturbed during the season of use, but disturbed within the past 6–24 months. Golner (1997) observed 77% of Wisconsin GPC brood hen locations were in grass or grass/forb cover. Night roosts for North Dakota GPC broods had 4-10 inch (10-25 cm) OV ($\bar{x}$ = 4 inches, 10 cm) with vegetation heights of 10-20 inches (25–50 cm) for 86% of observed locations (Newell et al. 1987). Toepfer (1988) stated that non-grass vegetation types were relatively unimportant to GPC hens with broods, and Newell et al. (1987) found brood hens avoided cash crops, especially row crops during summer. Toepfer (2003) found little evidence for disturbed areas being a habitat requirement for GPC broods in Minnesota, North Dakota, or Wisconsin.

Starting about 4–6 weeks post-hatch, APC broods use more open habitats associated with mid-grass nesting cover (Cogar et al. 1977, Horkel 1979, Morrow 1986). Lehmann (1941) attributed this shift in habitat use to movements to areas of shade and surface water. Lehmann (1941) stated:

> "More than 95 percent of the more than 500 Attwater's prairie chickens observed from June 24 through September 4, 1937, were in heavy cover within a mile, generally within less than half a mile of surface water….Prairie chickens require abundant shade in summer, for birds that were herded from such cover at midday panted vigorously, drooped their wings, and showed other signs of discomfort."

Toepfer (2003) observed that Minnesota GPC broods began feeding in agricultural fields (wheat and soybeans) at about six weeks of age during the day while usually night roosting in adjacent grasslands.

Mortality of broods is typically high during the first four weeks after hatch (Lehmann 1939, 1941; Jurries 1979). Lehmann (1941) observed 50% mortality by 4–6 weeks, and Morrow (1986) observed 62% mortality of APC brood units by 8 weeks. Newell et al. (1987) observed that 62.8% of North Dakota GPC chick losses occurred during the first 2.5 weeks. Lehmann (1939) observed that APC brood mortality was approximately 12% after four weeks post-hatch. Toepfer (2003) noted that once GPC chicks reach six weeks of age, survival to 12–16 weeks is 75-85%. Peterson and Silvy (1996) observed the mean number of chicks per brood reported for APCs was less (P = 0.0001) than observed for GPCs.

Heavy or persistent rain during the brooding season, predation, and separation from the brood are the most commonly reported sources of mortality for APC chicks (Lehmann 1939, 1941; Jurries 1979). Egg quality as influenced by nutrition of the hen, ability of the hen to care for chicks as influenced by hen condition, and the quality of brood rearing habitat relative to the abundance of insects required by chicks may contribute to high chick mortality during the first weeks of life (Peterson and Silvy 1996, Riley et al. 1998, Toepfer 2003). Fields et al. (2006) found that daily survival rates of prairie-chicken broods increased as broods aged, and decreased as the season progressed (i.e., late broods were less successful). Age of brood hens was also an important

indicator of brood survival. Survival probability to 60 days was 0.49 and 0.05 for broods reared by adults and sub-adults, respectively (Fields et al 2006).

Habitats Used Outside the Breeding Season

During summer, males and hens without broods use areas where shade is available in the form of weeds, tall grasses, and shrubs (Lehmann 1941, Yeatter 1943, Baker 1953). Svedarsky (1979) observed that vegetation providing dense canopy cover, understory openness, and forb abundance were important for GPCs during summer. However, Toepfer (1988) stated the greatest difference in habitat use by adults without broods compared to those with broods was greater use of shorter vegetation by broodless adults during the day, with both groups using predominantly grass or mixed grass cover. Kessler (1978) found APCs in the rice belt region of Texas dispersed from native prairie cover to surrounding forb-dominated fallow rice fields during summer months. Jones (1963) indicated that mid-forb communities were important for GPC day loafing cover in Oklahoma. Morrow (1986) observed APCs in the rice belt region using a wide variety of cover types during the summer–fall months. Jurries (1979) described summer months as a time of wandering for the APC, although Lehmann (1941) observed that once APCs found suitable summer cover, they moved little until fall.

Beginning in late August–early September, flocks begin to form which move as a unit in their daily activities (Yeatter 1943, Schwartz, 1945, Baker 1953, Kessler 1978, Jurries 1979). Jurries (1979) noted APC males showed a pronounced movement back to booming grounds in September–early October. By approximately November 15, Lehmann (1941) observed APCs moved to pastures

> "….where food and cover conditions are adequate. Having found such an area, they remain until spring. Probably the best way to attract a good breeding population, therefore, is to provide suitable food and cover conditions during the preceding winter."

Morrow (1986) found selection of vegetation types by the APC during the winter was correlated with vegetation density. Moderate–heavy cover at least 6 inches (15.2 cm) in height is generally adequate to provide protection from weather and predators (Schwartz 1945). The range of flock movements during fall and winter depended on the relative proximity of booming grounds, feeding areas, roost sites, and loafing areas (Schwartz 1945).

Food Habits

Lehmann (1941) summarized the food habits of the APC (scientific names of plants have been added to Lehmann's text):

> "The food of adult prairie chickens is about 85 percent vegetable matter and 15 percent animal. With young birds the ratio of vegetable to animal is approximately reversed. Favorite sources of plant food are ruellia (*Ruellia spp.)*, perennial ragweed (*Ambrosia psilostachya)*, blackberry (*Rubus spp*.), doveweed (*Croton capitatus)*, and sensitive briar (*Schranka*

> *spp.).* Leading animal foods are grasshoppers and beetles. Greens (leaves, flowers, buds) are lowest in the diet in November and December; seeds are taken in the smallest proportions in January, February, and March. Insects are least frequently captured in November, December, and January."

Lehmann (1941) observed 50 species of plants and more than 65 species of insects being consumed by the APC. He indicated native plants were the most important source of food, with ruellia being the most important single food (Lehmann 1941). Lehmann (1941) also noted APCs used cultivated crops such as corn, peanuts, and rice as food sources. Kessler (1978) found APC diets consisted of more than 50% forbs in all seasons except fall when peanuts and rice were heavily used. Grasses and grass-like plants also were used heavily, but less than forbs. Kessler (1978) also observed seasonal use of insects, with greatest use occurring in the summer when insects were most available. Cogar (1980) found 74% of the APC annual diet in a predominantly rangeland ecosystem was composed of foliage, 18% by seeds, and 8% insects. Forbs were the primary source of foliage and seeds in this study.

Lehmann (1941) observed APCs consuming water only once, despite close observation of birds near water and thorough examination of soft mud bordering ponds in inhabited prairie chicken-range. However, Lehmann (1941) writes:

> "The summer movements of prairie chickens to heavy cover near water are not satisfactorily explainable on the basis of cover, water, and food, but these habitat conditions must be provided where stable populations are desired….The balanced prairie chicken habitat should offer a generous supply of surface water throughout the year. Although Attwater's prairie chickens may not be dependent on free water for survival during normal years…it has been established that their favorite summer range is rather well watered."

Survival and Mortality Factors

Toepfer (1988) estimated survival of GPCs from hatch to the following May of approximately 25%. Horkel (1979) and Lutz (1979) observed 57% and 77% mortality, respectively, for color-banded APCs captured during the breeding season in predominantly rangeland habitats on private property. Unpublished data from APCNWR on the relationship between productivity and annual population change from 1988–1993 suggested that mortality on the refuge averaged 43% in those years (M. Morrow, personal communication). Hamerstrom and Hamerstrom (1973) reported an average mortality of 54% for banded GPCs in Wisconsin ($n = 942$), while Toepfer (1988) also working in Wisconsin with banded birds reported an average 51% mortality ($n = 270$). Therefore, Toepfer (2003:31) concluded that GPC survival in central Wisconsin averaged approximately 50%, with survival slightly higher for hens than cocks. Toepfer (2003) reported that preliminary analysis of survival data from radio-marked GPCs was also 49%, comparable to that of banded birds. Morrow (1986:28) reported 36% survival of known-fate radioed APCs, although this value was not statistically different from 50% ($P < 0.05$).

Factors which contribute to APC mortality or otherwise limit their populations include "natural" factors such as unfavorable weather, predators, and disease; and "artificial" factors such as cultivation, heavy grazing, burning, and overshooting (Lehmann 1941). The last APC hunting season occurred in 1936 (Jurries 1979). Except for hunting, the "artificial" factors primarily result in reduction of the grassland habitats required for prairie-chickens, although ill-timed agricultural operations may cause mortality of nesting hens and broods (e.g., Jurries 1979, Morrow 1986:58, Toepfer 2003). Encroachment of woody vegetation in the APC range has resulted in dramatic declines in habitat (Lehmann 1941, McKinney 1996). Lehmann (1941) observed:

> "The encroachment of mesquite, live oak, various acacias, and other kinds of brush onto open prairie land has been an extremely important factor in reducing the range and doubtless the numbers of Attwater's prairie chickens….Within the memory of living men extensive prairies have been transformed into brush jungles."

A number of studies have identified adverse weather as a direct mortality factor for nests and young broods (Lehmann 1939, 1941; Schwartz 1945; Jurries 1979; Svedarsky 1979; Lawrence 1982; Svedarsky 1988; Morrow et al. 1996) although Peterson and Silvy (1994) found no relationship between spring precipitation variables they examined and proportional changes in APC populations. Lehmann (1939, 1941) suggested, based on examination of rainfall records, that on average 2 of 5 years were favorable for prairie-chicken production, 2 of 5 years were fair, and 1of 5 years was poor. Other adverse weather conditions that tend to have a more local impact include hurricanes and tropical storms, hail, and drought (Lehmann 1939, 1941, 1968).

Predators of APC include red-tailed hawks (*Buteo jamaiciencis),* white-tailed hawks (*B. albicaudatus),* peregrine falcons (*Falco peregrinus),* Cooper's hawks (*Accipiter cooperi),* great-horned owls (*Bubo virginianus),* coyotes, skunks, raccoons, bobcats, and domestic dogs and cats (Lehmann 1941; Jurries 1979; M. Morrow, APCNWR, unpublished data). Toepfer (2003) reported 69.9% of observed GPC predation was by raptors and 30.4% by mammals. Toepfer (1988) indicated only perching raptors could be considered serious predators of wild adult GPCs, and noted that the presence of trees in prairie-chicken habitat provided perching raptors with hunting opportunities. Toepfer (2003) observed 78.9% of GPC mortality in Wisconsin was attributed to predation, unknown causes 13.2%, electric wire collisions 6.5%, auto collisions 1.0%, and fence collisions 0.6%.

Peterson (2004) conducted an extensive review of information available on parasites and infections diseases of prairie grouse. Peterson (2004) concluded that macroparasites *Dispharynx nasuta* and *Trichostrongylus cramae*; the microparasites *Eimeria dispersa*, *E. angusta*, *Leucocytozoon bonasae*, and *Plasmodium pedioecetii*; and infectious bronchitis and reticuloendotheliosis viruses (REV) have the potential to regulate prairie grouse populations. *E. dispersa* and *E. angusta* are coccidia while *L. bonasae* and *P. pedioecetii* are malarial agents (Peterson 2004). Peterson (2004) also indicated *Histomonas meleagridis* (causative agent for blackhead), *Pasteurella multocida* (causative agent for avian cholera), *E. dispersa, E. angusta,* and other microparasites

which result in high mortality have the potential to extirpate small, isolated prairie grouse populations.

Peterson et al. (1998) observed 4 of 27 (14.8%) APCs sampled were serologically positive for *P. multocida* antibodies. These four birds came from two of three remaining APC populations. Purvis et al. (1998) also observed specific antibodies to *P. multocida* in 3 of 53 (5.7%) northern bobwhites (*Colinus virginianus*) collected from the APCNWR. Periodic outbreaks of avian cholera have occurred in wintering waterfowl in coastal Texas (Peterson et al. 1998). How easily avian cholera can be transmitted from waterfowl to other species, including prairie-chickens is not known (Peterson et al. 1998, Purvis et al. 1998). Peterson et al. (1998) found *T. cramae* in eight of nine suitable samples from APC, representing the first report of this parasite in prairie grouse. Infected individuals, which came from all three remaining APC populations, had *T. cramae* infection intensities averaging 1,019.3, similar to that seen for *T. tenuis* in red grouse (*Lagopus lagopus scoticus*) (Peterson et al. 1998). *T. tenuis* has been experimentally shown to affect red grouse body condition, productivity, and survival (Peterson et al. 1998). Purvis et al. (1998) found *T. cramae* in 97% of northern bobwhites collected from APCNWR. Peterson et al. (1998), Purvis et al. (1998), and Peterson (2004) all stressed the importance of determining whether *T. cramae* limits or regulates APC populations.

Peterson et al. (1998) also found that one of three APC samples contained *D. nasuta*. They hypothesized that because *D. nasuta* is particularly pathogenic for chicks of other grouse species, its presence in APC populations could explain the low number of juvenile APCs surviving per brood as compared to GPCs (Peterson and Silvy 1996). Peterson (2004) also stated that while ectoparasites are relatively common on prairie grouse, their population-level significance is not known. Routine surveillance of APC blood samples from captive and free-ranging birds has yielded several positive antibody titers for West Nile virus (WNV), indicating exposure to this virus has occurred (J. Flanagan, Houston Zoo, Inc., unpublished data). Neither active disease nor mortalities attributed to WNV have been observed for APC or GPC in Wisconsin and Minnesota (J. Flanagan, Houston Zoo, Inc., J. Paul-Murphy, University of Wisconsin-Madison, and J. Toepfer, STCP, unpublished data).

Disease caused by mycotoxins, pesticides, and toxic compounds also could lead to the extirpation of small populations (Peterson 2004). Lehmann and Mauermann (1963) described an account of several hundred dead APCs near a cotton field that had been dusted aerially with arsenic (no longer in use) as a defoliant. Flickinger and Swineford (1983) observed that organochlorine, polychlorinated biphenyl (PCB), and metal residues in APCs and northern bobwhites from cropland areas were low.

Home Range and Movements

Annual home range size reported by Morrow (1986) for APC hens averaged 1,470 ac (595 ha) while those of males averaged 889 ac (360 ha). Jurries (1979) observed a median home range of 726 and 456 ac (294 and 185 ha), respectively, for hens and cocks in the ricebelt region and 1,490 and 1,796 ac (603 and 727 ha), respectively, in the native prairie region, where the primary land use was ranching. Morrow's (1986) study was conducted at the APCNWR, and is included in Jurries' (1979) ricebelt region.

Although Lehmann (1939) stated "…Attwater [sic] prairie chickens frequently travel several miles in a day….", radio telemetry data indicate that movements are generally more local in nature. Of 49 radioed APCs, Morrow (1986) observed only 10 movements that were classified as "extensive". Eight of these were by hens and averaged 2.3 mi (3.8 km); the two "extensive" movements by males averaged 1.8 mi (3.0 km). Maximum cumulative APC movements observed by Morrow (1986) were 3.5 mi (5.8 km). Lawrence and Silvy (1987) observed a maximum movement of 4.4 mi (7.3 km) for a translocated APC. Daily movements observed by Horkel (1979) in the native prairie region were greatest for cocks in December (1,914 ft, 580 m) and lowest in August (396 ft, 120 m), while female movements ranged from 429 ft (130 m)/day in June to 1,518 ft (460 m)/day in November. Morrow (1986) also observed mean movements by male APC were greatest during December (2,845 ft, 862 m) and lowest in August (657 ft, 199 m), while non-reproductive (without nests or broods) female movements were greatest in March–May corresponding with the nesting season. Average daily movements for all females were least during July (700 ft, 212 m). Jurries (1979) described the breeding season as a period of limited daily movement. After the booming season ended, the APC began summer movements which Jurries (1979:23) described as "wandering". Daily movements during summer were 300–500 yards (300–500 m), but cumulative movements of 5–10 mi (8–16 km) were observed. During September–October birds moved back to the vicinity of booming grounds (Jurries 1979).

Maximum movements observed for GPCs are larger than observed for APCs. Hamerstrom and Hamerstrom (1973) reported 49% of cock (n = 588) and 85% of observed hen movements (n = 59) were at least 2 mi (3.2 km) from their "home" booming ground. In general, juveniles were more mobile than adults, and hens more mobile than males (Hamerstrom and Hamerstrom 1973, Toepfer 2003). Hamerstrom and Hamerstrom (1973:34) reported 38% (n = 156) and 17% (n = 222) of observed moves by juvenile and adult hens, respectively were greater than 5 mi (8 km). Halfmann (2002) observed 14% of hens (n = 88) dispersed more than 7.5 mi (12 km) from their natal areas prior to their first breeding season, whereas only 3% of immature cocks (n = 71) did so. Natal dispersal distance for hens ranged from <0.1–43.4 mi (0.1–70.0 km) ($\bar{x}$ = 4.3 mi, 6.9 km) and <0.1–10.8 mi (0.1–17.2 km) ($\bar{x}$ = 1.4 mi, 2.3 km) for hens and cocks, respectively (Halfmann 2002). Halfmann (2002) concluded, based on observation of Wisconsin GPCs, little probability existed for juvenile cocks dispersing more than 11 mi (18 km) from their natal areas by their first breeding season, and <10% probability for hens. However, Toepfer (2003) observed dispersal distances by juveniles in Minnesota were greater than observed in Wisconsin or North Dakota, with movements of 15–30 mi (24–48 km) not uncommon. Toepfer (2003) observed one Minnesota brood dispersed over 1,000 mi^2 (2,600 km^2). However, Toepfer (2003) indicated that juvenile dispersal was not aimless:

> "One thing is certain; dispersing young prairie chickens find other prairie chickens…In 13 years we have yet to find a dispersing juvenile end up by itself."

As a result of their social nature, Toepfer (2003) observed, despite the fact that prairie-chickens are strong fliers capable of dispersing relatively long distances, they do not

readily colonize unoccupied habitat. He also stated that range expansion was not likely to occur in the absence of increased competition associated with population increases. It should be noted that comparable data on dispersal distances for juvenile APCs are not available.

Habitat Management

As stressed in the foregoing sections, *T. cupido* requires grass and open space. Therefore, management for this species must be focused on providing these life requisites at a landscape level. Hamerstrom et al. (1957) summarized management for *T. cupido*: "Prairie chicken management is primarily grassland management: no grass, no chickens." In general, Lehmann (1941) described ideal APC habitat:

> "Optimum prairie chicken range apparently consists of well-drained grassland supporting some weeds or shrubs as well as grasses, the cover varying in density from light to heavy; and with supplies of surface water available in summer. In short, diversification within the grassland type is essential."

A variety of management tools has been used to maintain or enhance grasslands for APCs and GPCs including prescribed burning, grazing, haying, mowing, herbicide application (for brush management), tree cutting, and cultivation (for food plots) (e.g., Lehmann 1941; Chamrad and Dodd 1972; Westemeier 1972; Kessler 1978; Jurries 1979; Morrow 1986; Svedarsky 1979, 1988; Toepfer 1988). However, because there are so many differences in soils, climatic conditions, and management histories that occur geographically and temporally across the range of *T. cupido* in general, and the APC in particular, the focus of grassland management for this species must be on the end results desired (i.e., habitat objectives) – not on the details of how the tools should be applied. Each situation will dictate how the "bag of tools" should be employed, recognizing there may be more than one approach to accomplish management objectives. However, clear elucidation of habitat objectives is essential for proper and consistent application of management tools. The following habitat management objectives for *T. cupido* in general, and *T. c. attwateri* in particular, were identified through review of the literature:

- *T. cupido* management areas should be ≥33%, and preferably ≥50% grassland (Hamerstrom et al. 1957).
- Priority for management should be given to habitats within 1mile (1.6 km) of existing and historical booming grounds (Toepfer 1988, 2003).
- Mowing in APC habitat should not occur before 1 July (Lehmann 1941).
- Prescribed burning should be completed in APC habitat by 1 February (Lehmann 1941:56).
- Availability of grasslands for nesting and brood rearing cover most often limit *T. cupido* populations (Hamerstrom et al. 1957:18, Morrow 1986:91, Toepfer 1988:482). As such,
    - No more than 33% (Toepfer 1988) to 60% (Lehmann 1941) of grassland habitat managed for *T. cupido* should be burned on an annual basis.

  - Patches of unburned cover should be as large as possible, but at least 80 (Toepfer 1988) to 618 ac (32–250 ha) (Kessler 1978) (but see Lehmann 1941).
  - More than 50% of grassland residual cover (still standing from growth of previous seasons) should be 10–39 inches (25–100 cm) in height during spring (Toepfer 1988). Cover with OV values averaging 10 inches (25 cm) should be readily available and well distributed within grasslands as nesting sites (Cogar et al. 1977, Svedarsky 1979, Morrow 1986, Lutz et al. 1994).
  - Cover which becomes rank [>39 inches (1 m) tall (Buhnerkempe et al. 1984), >25% horizontal litter cover (McKee et al. 1998)] should be disturbed by burning, grazing, or mowing (Westemeier 1972, Toepfer 1988, McKee et al. 1998).
  - Brush must be carefully controlled to prevent excessive encroachment into grassland habitats (Hamerstrom et al. 1957, Toepfer 1988, DeHart 2003), and trees, especially near booming grounds should be cut down (Svedarsky 1979, Toepfer 2003). Less than 25% of the landscape should be wooded, with woodlands in scattered blocks (Hamerstrom et al. 1957). In order to support booming grounds, open grasslands must be as large as possible. At a minimum, open grasslands of >1,480 ac (600 ha), and preferably >2,175 ac (880 ha) should be maintained (Toepfer 1988).

- Although some disagreement exists regarding the value of food plots in APC management, agricultural crops are probably not essential for APCs because of their southern distribution (Lehmann 1937, 1941). Although Cogar (1980) observed only slight use by APCs of available grain sorghum, agricultural crops are usually readily used when available (Lehmann 1941, Kessler 1978, Jurries 1979, Morrow 1986). Therefore, 10–15 ac (4–6 ha) food plots distributed at a density of approximately one for every three booming grounds may be provided (Toepfer 1988). Food plots should be carefully monitored for aflatoxin development in crops such as peanuts, soybeans, corn, and cereal grains (Fraser et al. 1991). While Peterson (2004) found no records of prairie grouse mortality caused by mycotoxins, hot, humid conditions characteristic of APC range are ideal for growth of aflatoxin-producing *Aspergillus* fungi (Reddy and Waliyar 2000, Larson 2002). Aflatoxicosis associated with waste corn has caused wintering goose mortality in Colorado County, Texas, within 20 mi (32 km) of APCNWR (M. Morrow, APCNWR, unpublished data). Birds appear to be more susceptible than mammals to aflatoxicosis (Davidson and Nettles 1988).

Lehmann (1939) summarizes habitat management for APC:

> "Moderately grazed and moderately burned grassland…provides prairie chickens with everything they need in all seasons. It is therefore upon the existence of adequate prairie habitat that the welfare of the prairie chicken depends."

F. CRITICAL HABITAT

Critical habitat has not been designated for the APC.

G. ON-GOING CONSERVATION EFFORTS

Research

Prior to the late 1960s, APC conservation efforts consisted of life-history research (Lehmann 1941), periodic population surveys (Lehmann 1941, Lehmann and Mauermann 1963, Lehmann 1968), and protection from hunting (since 1937) (Lehmann 1941, Jurries 1979). Beginning in 1967 through the present, a multitude of research projects has been conducted primarily at TAMU on topics including life history, habitat management, predator management, genetics, limiting factors, captive breeding, and population supplementation (Morrow et al. 2004). Silvy et al. (1999) provided a review of much of this research. In 1969, TPWD initiated a series of research projects that addressed a range of basic life history and population inventory issues. This research culminated in a monographic work on the APC (Jurries 1979).

Habitat Management

The APCNWR was established in 1972 to protect and enhance the APC's severely diminished prairie habitat. This refuge contains 10,538 ac (4,265 ha), including 2,500 ac (1,027 ha) added since 1998. Most of the recently acquired lands were formerly in rice production, and need restoration to provide optimal prairie-chicken habitat. APC populations on the refuge have ranged from an estimated 25 when the refuge was established to 222 in 1987 (APCNWR unpublished data). The refuge population has declined since 1987, corresponding to range-wide population declines (Figure 1). Morrow et al. (1996) discussed factors affecting the refuge decline. They observed acreage burned within the APC's core habitat, variability in grassland structure, off-refuge APC population changes, and several climate variables were correlated with APC population changes on APCWNR.

Even though recovery plans (USFWS 1983, 1993) emphasized the need for habitat protection and restoration in geographically separate areas, little habitat protection or management was accomplished other than at APCNWR until approximately 1990. Since then, considerable effort and funds have been spent in cooperative private-lands projects. Initially, these efforts were spear-headed by TPWD with federal aid to states dollars made available through Section 6 of the ESA. Beginning in 1995, an initiative was undertaken with the primary mission of restoring native prairie grasslands within the APC's former range. This effort, now known as the Coastal Prairie Conservation Initiative (CPCI) is a diverse partnership effort involving private landowners, local soil and water conservation districts, the USFWS, the Sam Houston Resource Conservation and Development Board, the U.S. Natural Resources Conservation Service (NRCS), TNC, TPWD, and the Grazing Lands Conservation Initiative (GLCI). Integral to the CPCI has been incorporation of Safe Harbor Agreements into management plans where desired by cooperators. The purpose of Safe Harbor Agreements is to promote voluntary

management for federally listed species on private property while giving assurances to landowners that no additional future regulatory restrictions will be imposed if these species colonize or increase in numbers as a result of management activities. As of October, 2006, approximately 76,681 ac (31,045 ha) have been enrolled under Safe Harbor Agreements for APC management, with cost-share assistance provided on approximately 66,626 ac (26,974 ha) (T. Anderson, USFWS, personal communication). In addition, TPWD and NRCS landowner assistance agreements have been implemented on several thousand acres for the purpose of restoring coastal prairie habitat within the APC's former range.

TNC took ownership of the TCPP in 1995 through a donation from Mobil Oil Corporation. Since 1985, the APC population on this site has numbered fewer than 50 individuals (Morrow et al. 2004). TCPP and APCNWR currently contain the last free-ranging APC populations. Both of these populations have been supplemented with releases of captive-reared birds since 1996, although net additions from released birds to the TCPP population have been minimal since 1999.

Currently, APC restoration efforts are focused in three priority management zones (Figure 3). The 2,396-ac (970-ha) TCPP supports the only population still containing wild-hatched birds. Although remnant prairies exist in the area that could be restored through removal of woody species [primarily Chinese tallow, (*Sapium sebiferum*)], management potential for this area is limited because of rapid urbanization. Current land-use data for this area is lacking. The Austin-Colorado County priority management zone, which historically supported relatively large APC populations (Lehmann 1941, 1968; Appendix 1), contains the 10,538-ac (4,265-ha) APCNWR. The boundary for this zone represents the 58,193-ac (23,560-ha) priority acquisition area for the APCNWR (Figure 4). This does not reflect plans for future refuge boundaries, but delineates an area where land acquisition should be focused. Currently, the approved target acquisition size for this refuge is 30,000 ac (12,145 ha). The Austin-Colorado County priority management zone contains 80% of the minimum convex polygon that encompassed the occupied range defined by booming ground distributions from 1979-1992 (McKinney 1996). Based on most recent land-use data available (1990 data from McKinney 1996), the Austin-Colorado County priority management zone contains approximately 17,806 ac (7,209 ha) of grass (31% of total area). A total of approximately 15,525 ac (6,285 ha) (27% of the total area) are currently under grassland management or restoration in this area (Figure 4).

The 663,670-ac (268,690-ha) Refugio-Goliad County priority management zone also historically supported large prairie-chicken populations (Lehmann 1941, 1968; Appendix 1) and contains the largest contiguous blocks of coastal prairie remaining in Texas (Figure 3). The boundary for this zone was delineated by TNC (Miller and Halstead 2003). The minimum convex polygon delineating 1979–1992 booming ground distributions for the APC population in this vicinity (McKinney 1996) is almost entirely contained within the zone (Figure 5). This 162,785-acre (65,905-ha) former booming ground range currently contains three relatively contiguous grassland blocks totaling approximately 50,550 acres (20,445 ha), or 31% of the historic booming ground range (Figure 5; W. Harrell, TNC, unpublished data). Currently, 58,948 ac (23,865 ha) (8.9%)

Figure 4. Land use within the Austin-Colorado County, Texas priority management zone.

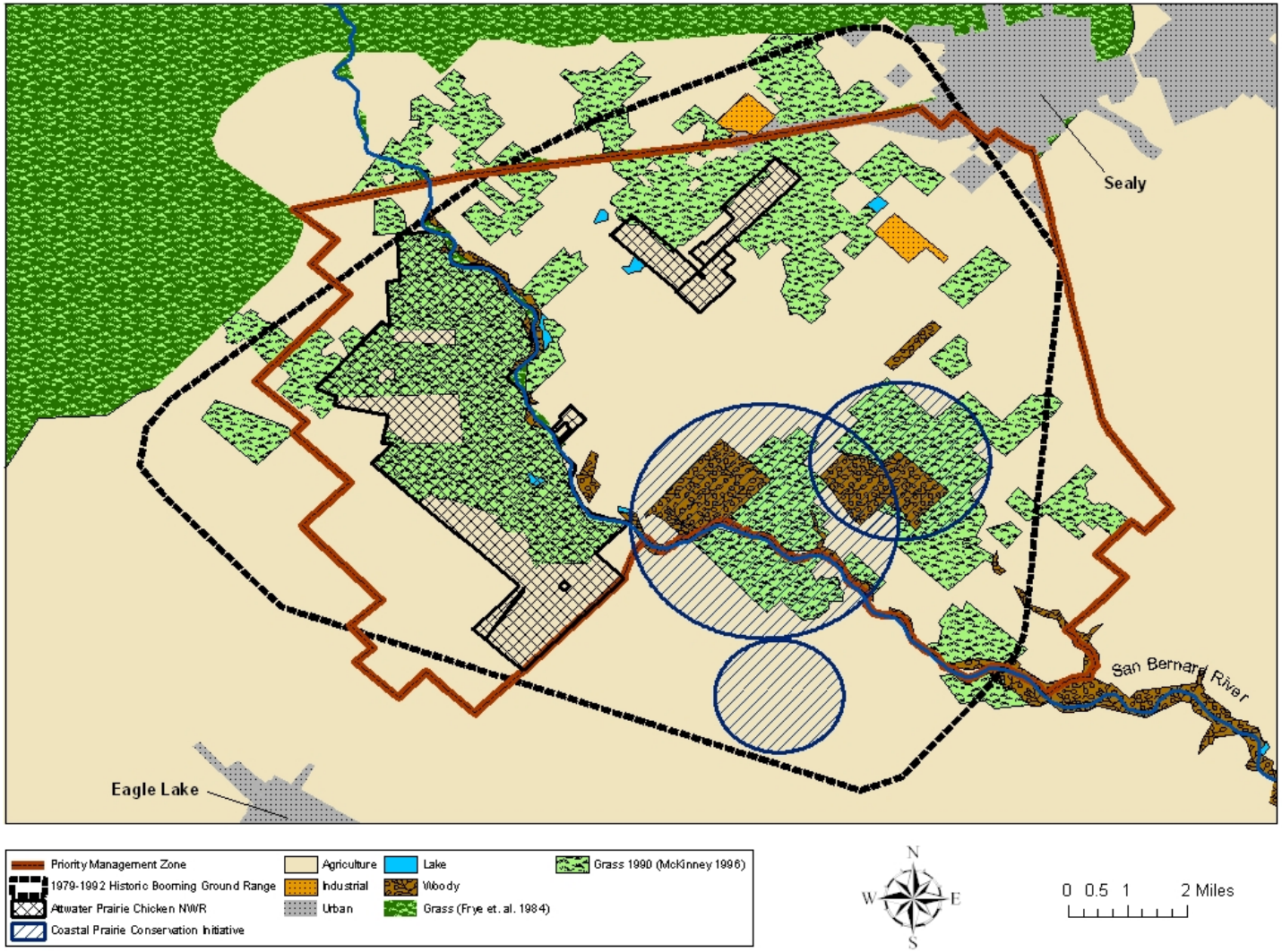
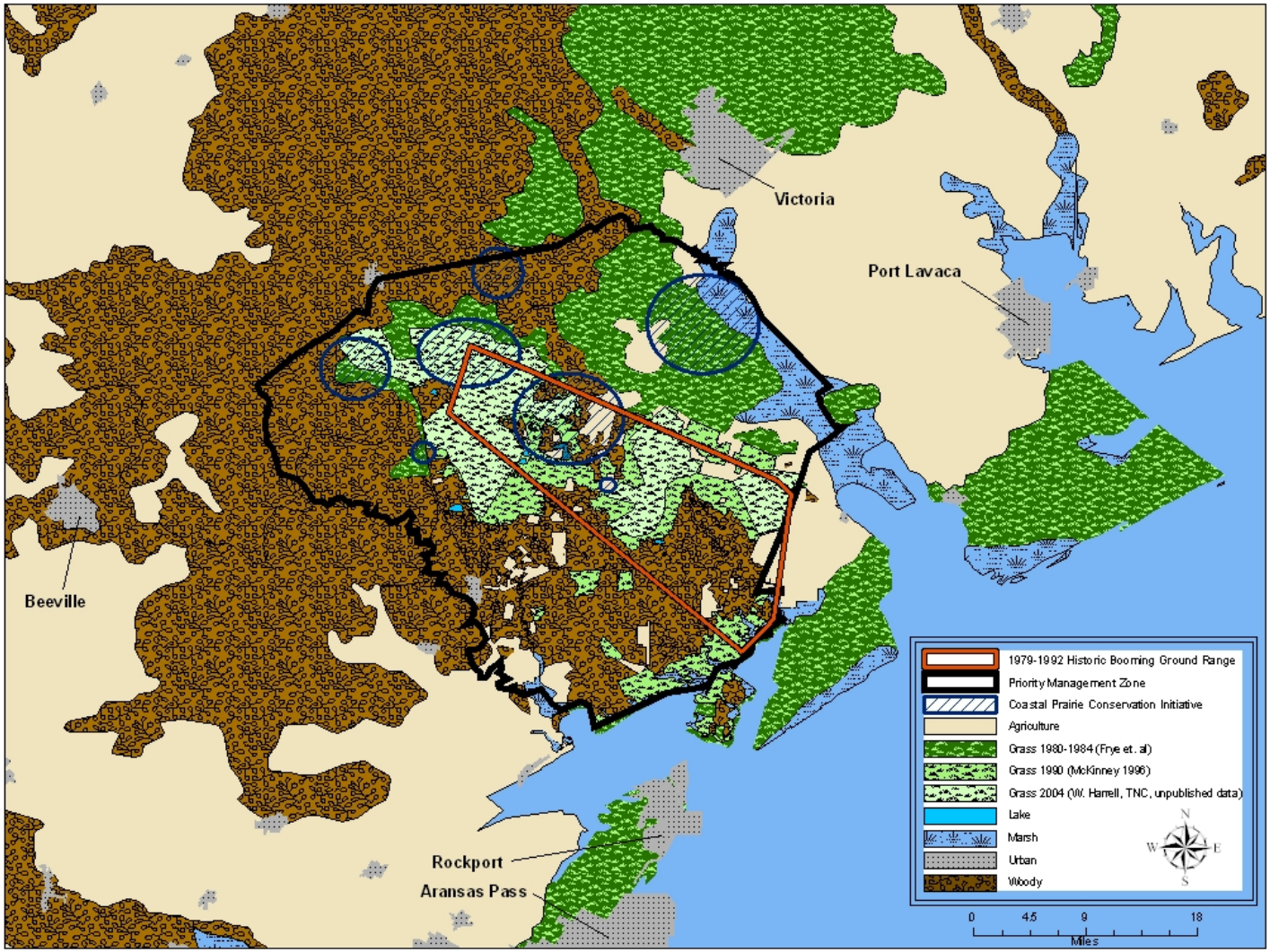


Figure 5. Land use within the Refugio-Goliad County, Texas priority management zone.



of the Refugio-Goliad priority management zone are under prairie restoration through the CPCI (T. Anderson, USFWS, personal communication) (Figure 5).

Captive Breeding

Mass propagation of most grouse in captivity has proven particularly difficult (McEwen et al. 1969, Johnson and Boyce 1991). The first documented attempt at breeding and rearing APC in captivity occurred at the TAMU Poultry Science Department (Watkins 1971). Thirteen male and 13 female APCs were trapped from the wild during December 1967–January 1968. Two hens laid 10 eggs in spring 1968. Two of these eggs hatched, four were infertile, and four died as embryos. During spring 1969, one hen produced seven eggs. Three of these eggs were infertile, two died as embryos, and two hatched. No data were available on chick survival, but Watkins (1971:3) observed that none of the chicks were as strong and active as expected of precocial young. An additional 10 female and 8 male APCs were trapped from the wild in February–March 1970. In addition, 21 eggs were collected from wild nests that year. Of the 18 adults taken into captivity, six died within three weeks. The remaining birds produced 18 eggs, thought to have been produced by two hens. All eggs were infertile. Eight of the remaining adults eventually succumbed to Newcastle's disease, fowl pox, and injury. Nineteen of the 21 wild-collected eggs hatched, but one chick drowned in a water pan of the incubator. Sixteen of the remaining 18 died within one week post-hatch.

APC captive breeding was not attempted again until 1992. By that time, the wild population had already declined to an alarmingly low level of 456 birds, and the need for an aggressive captive breeding program was established to (1) preserve as much of the genetic representation of the wild stock remaining as possible, and (2) provide stock to re-populate depleted or extirpated populations. Fossil Rim Wildlife Center, after working with GPCs during the previous year, received 4 clutches totaling 49 eggs (1 clutch from APCNWR and 3 from what is now TCPP). While hatchability of the eggs was good (86%), the chicks proved very difficult to rear. Only 5 (3 females, two males) of the 42 hatched chicks survived to the following breeding season. While previous rearing attempts with GPC chicks reported reduced survivability related to feeding problems during the first few days of life (Kruse 1984), most problems experienced at Fossil Rim during this first year were related to development of enteritis. Various attempts at antibiotic therapy were ineffective.

More wild collected eggs (29) were transported to Fossil Rim in 1993. However, 15 eggs were infertile, including 1 entire clutch from APCNWR. Of the 14 remaining eggs, 12 hatched. Additionally, 50 eggs (30 viable) produced by chicks reared in 1992 resulted in 26 chicks. However, despite aggressive treatment by Fossil Rim staff, enteritis continued to be problematic with respect to chick survival.

In part due to recommendations resulting from a population and habitat viability analysis conducted for the APC (Seal 1994) to substantially expand the captive breeding effort, two additional facilities began rearing APCs in 1994. Twenty-three wild collected eggs were provided to the TAMU Department of Wildlife and Fisheries Sciences and 26 to the Houston Zoo. TAMU had been working with GPCs since 1991. The Houston Zoo also had previous experience with GPCs. In addition, Fossil Rim continued to rear APC

from their captive flock. The addition of more insects to the chick diet appeared to improve chick survival. Overall, 36 chicks were reared to 8 weeks from 52 hatched eggs.

The San Antonio Zoo was added as a breeding facility in 1996. They received breeding stock from other facilities, two wild-caught males, and one clutch of 12 eggs from APCNWR. Five chicks were reared to eight weeks of age from these eggs. San Antonio experienced periodic mortalities of older chicks and adults over the next two years from a *Clostridial* enteritus. After intensive research, it was concluded that soil in the breeding pens was contaminated with the *Clostridium* bacterium causing the observed enteritis deaths. Therefore in 1998, all APC were removed from the San Antonio facility to allow for complete sterilization of pen infrastructure and substrate. No mortalities from *Clostridial* enteritis have been observed at that facility since. Sea World of Texas, the Abilene Zoo, and the Caldwell Zoo were added as breeding facilities in 1999, 2000, and 2002, respectively. As of the spring 2007 breeding season, approximately 50% of the captive flock will be housed at Fossil Rim Wildlife Center (H. Bailey, APC SSP Coordinator, Houston Zoo, Inc., personal communication) (Figure 6). Additional breeding facilities are being sought to dilute the risk of a potential catastrophe to the breeding program and to increase the capacity of the program to produce more birds for release into suitable habitats.

In summary, a total of 175 eggs (representing 14 clutches) and 9 males were collected from wild populations for inclusion in the captive breeding program during 1992–1998. Because not all of these founders survived to contribute offspring, and conservative assumptions were made about the relatedness of founder individuals, the captive population was derived from 19 founders representing 8.5 founder genome equivalents.

Comparing the survivorship at various stages of the APC captive breeding process with two GPC mass propagation efforts, the APC program has performed comparably to Kruse (1984) and substantially better than McEwen et al. (1969) with respect to egg viability, hatchability, and chick survival (Figure 7). However, the average 11 eggs/hen observed in the APC program is substantially less than the average 23 eggs/hen observed by Kruse (1984) (Figure 8).

Medical issues most commonly encountered by the APC breeding program include poor chick survival during the first days post-hatch, enteritis (particularly among young chicks), wryneck in newly hatched chicks, dispharynxiasis, capillariasis, leg rotations among growing chicks, curled toes, self-induced trauma from collision with pen structures, gastrointestinal tract obstruction by impacted vegetation, and REV (J. Flanagan, DVM, APC Recovery Team Veterinary Advisor, Houston, Zoo, Inc., personal communication). Development of protocols for prophylactic treatment of macroparasites has largely minimized their impacts on the captive flock. Although both enteritis and leg rotations may have multiple causes, research currently focused on nutritional quality of breeder and chick diets will hopefully lead to reductions in the incidence of these maladies. Wryneck also results from various causes, but analysis of historic captive-breeding records strongly suggests a genetic influence (K. Willis, APC SSP Small Populations Advisor, Minnesota Zoo, personal communication).

Figure 6. Projected Spring 2007 distribution of captive Attwater's prairie-chickens by location (*n* = 164).

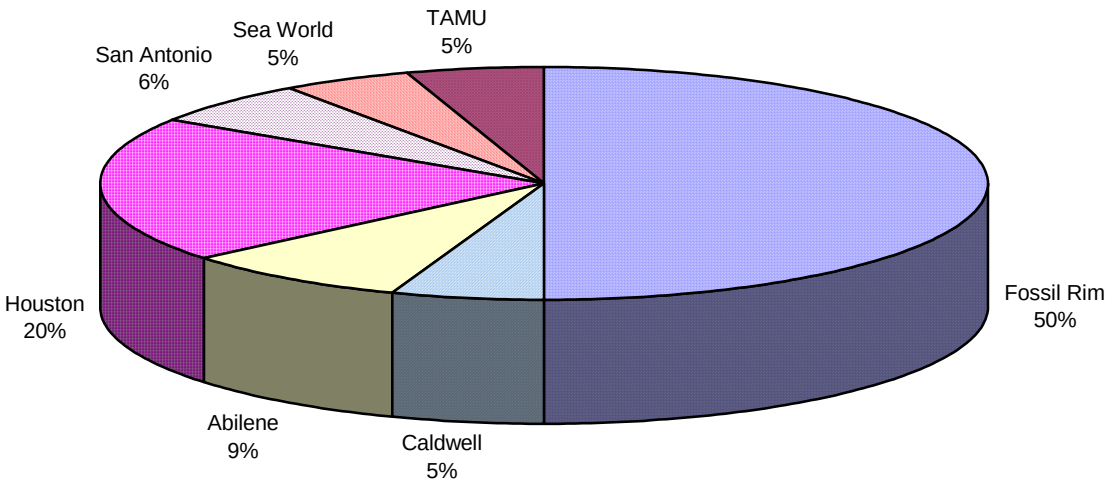


Figure 7. Comparison of Attwater's and greater prairie-chicken mass propagation efforts.

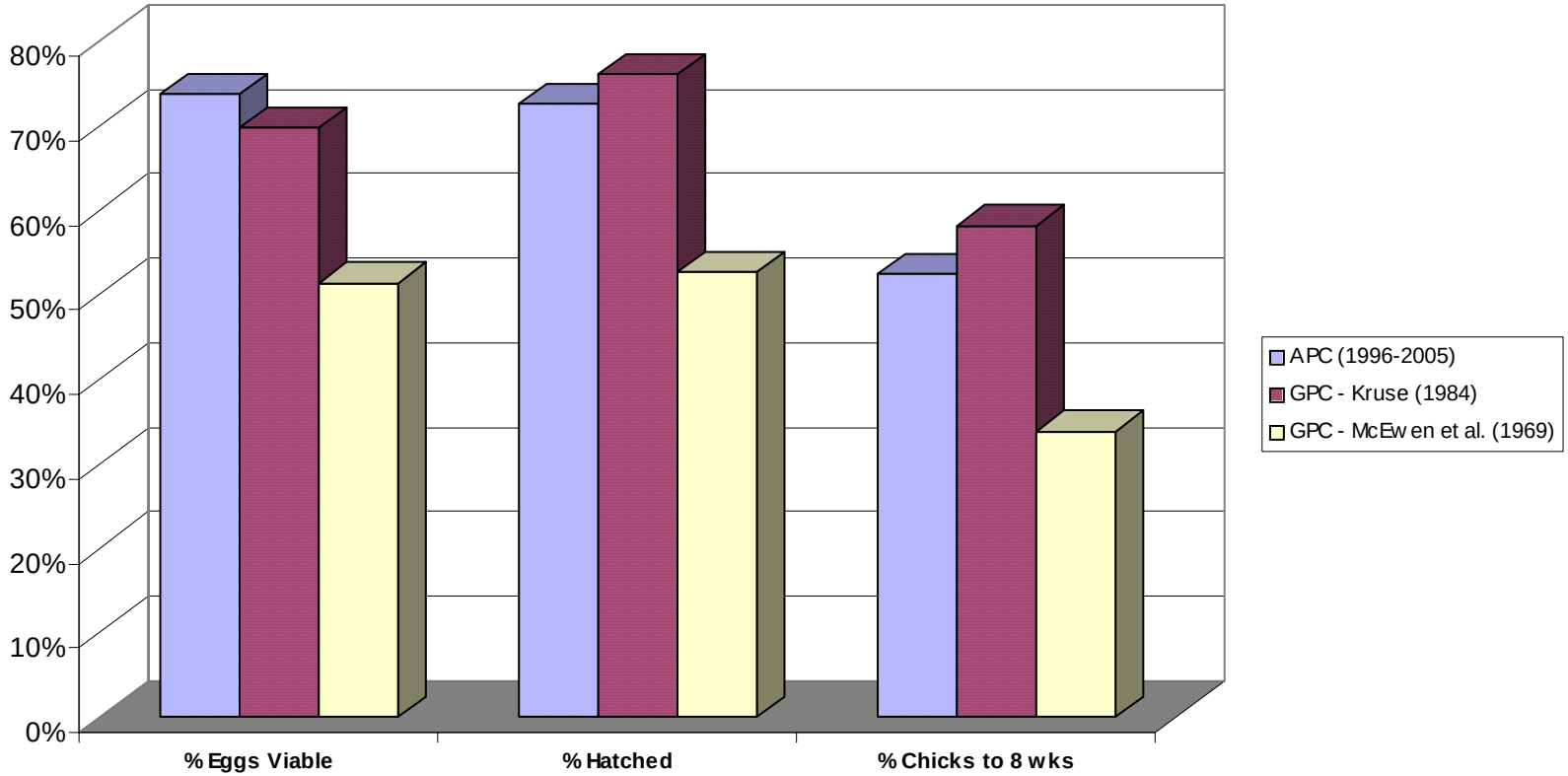
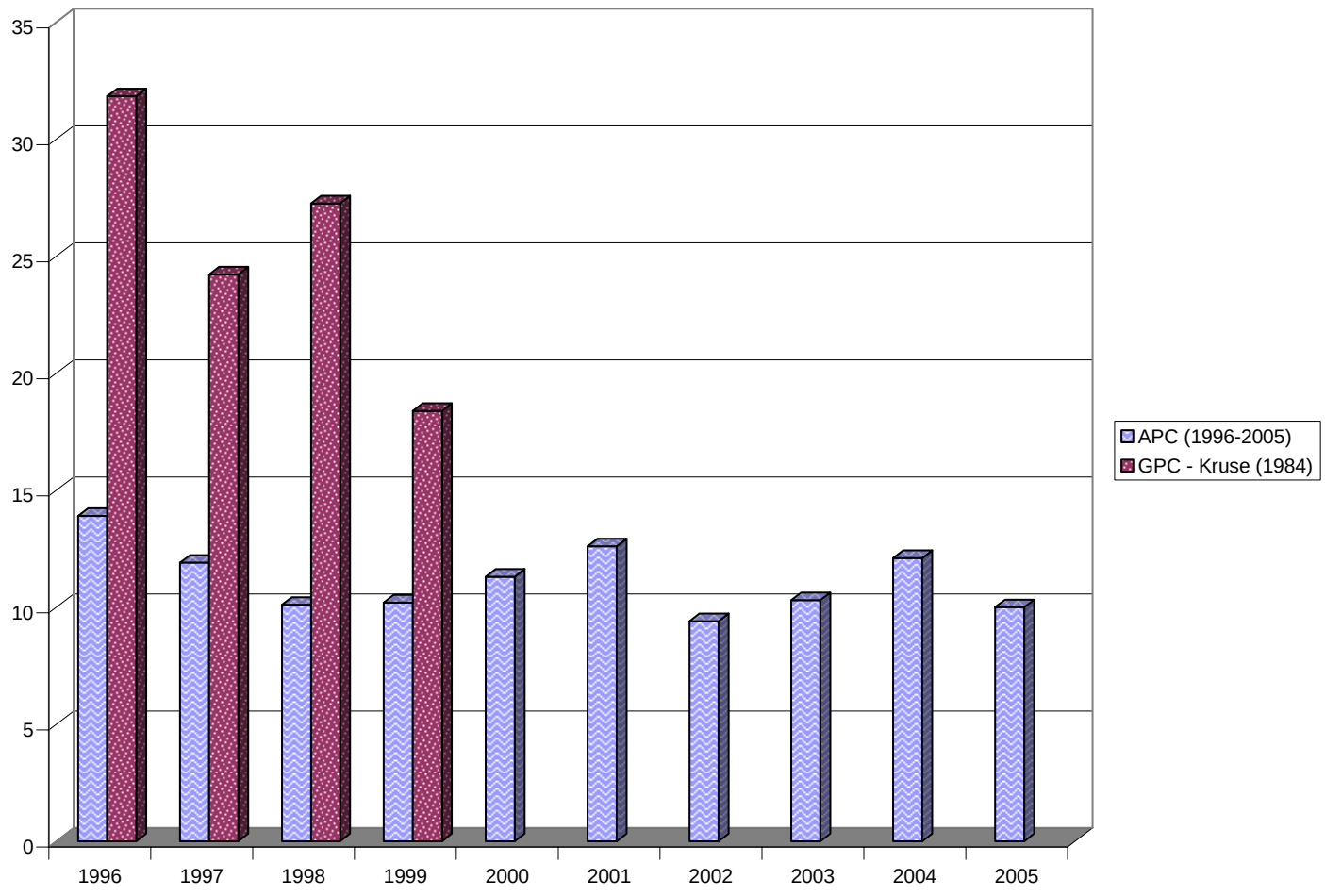


Figure 8. Comparison of Attwater's (1996–2005) and greater prairie-chicken (1972–75) (Kruse 1984) captive egg production.



Approximately 34% of hatched APC chicks die during the first 10 days of life (Figure 9) (K. Willis, APC SSP Small Populations Advisor, Minnesota Zoo, unpublished data). Cause of death for these chicks is most commonly attributed to enteritis or "failure to thrive". Johnson and Boyce (1991) observed 85% mortality of sage grouse (*Centrocercus urophasianus*) chicks produced by captive hens within a few days of hatch. Most of these deaths were attributed to peritonitis (Johnson and Boyce 1991). In contrast, 84% of chicks collected from the wild, or produced from wild-collected eggs survived 7–9 weeks. These authors speculated that inadequate hen diets in captivity may have contributed to low chick viability. Kruse (1984:12) observed that 78% of mortality observed in their GPC propagation program occurred during the first week of life, and was usually associated with the chick's reluctance to eat. Drake (1994) and Griffin (1998) stressed the importance of insects in the diet to survival of captive APC chicks. The importance of insects in the diet of other captive-reared gallinaceous species, especially early in chick growth, has also been observed (e.g., Thomas 1987, Johnson and Boyce 1990). Johnson and Boyce (1990) observed that 25 sage grouse chicks hatched in captivity not provided with insects all died within 4–10 days, whereas all chicks provided with insects survived the initial 10 days.

The inability to effectively manage major outbreaks of REV which have occurred in recent years at San Antonio Zoo and Fossil Rim Wildlife Center has severely hampered APC propagation efforts. TAMU and University of Georgia continue to research the etiology, testing protocol, and management of REV. Researchers at TAMU believe they are very close to developing a vaccine for this disease (E. Collison, Department of Veterinary Pathology, TAMU, personal communication).

REV was first diagnosed in GPCs at TAMU in September 1993 (Drew et al. 1998). Initial testing of captive GPCs and APCs at TAMU in December 1994 revealed that >50% of the flock were viremic (Drew et al. 1998). Although REV was ultimately detected at the Houston Zoo and Fossil Rim a year or two later, monitoring efforts precipitated by experiences and research efforts at TAMU prevented the disease from spreading beyond a few birds at each facility until 2002. In 2002, an REV outbreak coupled with an outbreak of avian pox at San Antonio Zoo ultimately required their flock be euthanized to affect control. Fossil Rim experienced an outbreak of REV and avian pox in November, 2003, which also proved very difficult to contain using the standard test and cull protocol.

Population Supplementation

By 1995, the captive flock had grown to a point that 13 excess males were available for a pilot release at APCNWR. From 1995–2006, a total of 1,005 captive-reared APCs has been released at APCNWR and TCPP (Figure 10). Most of these birds have been fitted with radio transmitters (<3% of body mass) using necklace or poncho attachments (Amstrup 1980) to facilitate evaluation of post-release survival. Release candidates, surplus to the captive breeding program as determined using SPARKS

Figure 9. Captive Attwater's prairie-chicken mortality during the first month post-hatch (K. Willis, APC SSP Small Populations Advisor, Minnesota Zoo, unpublished data).

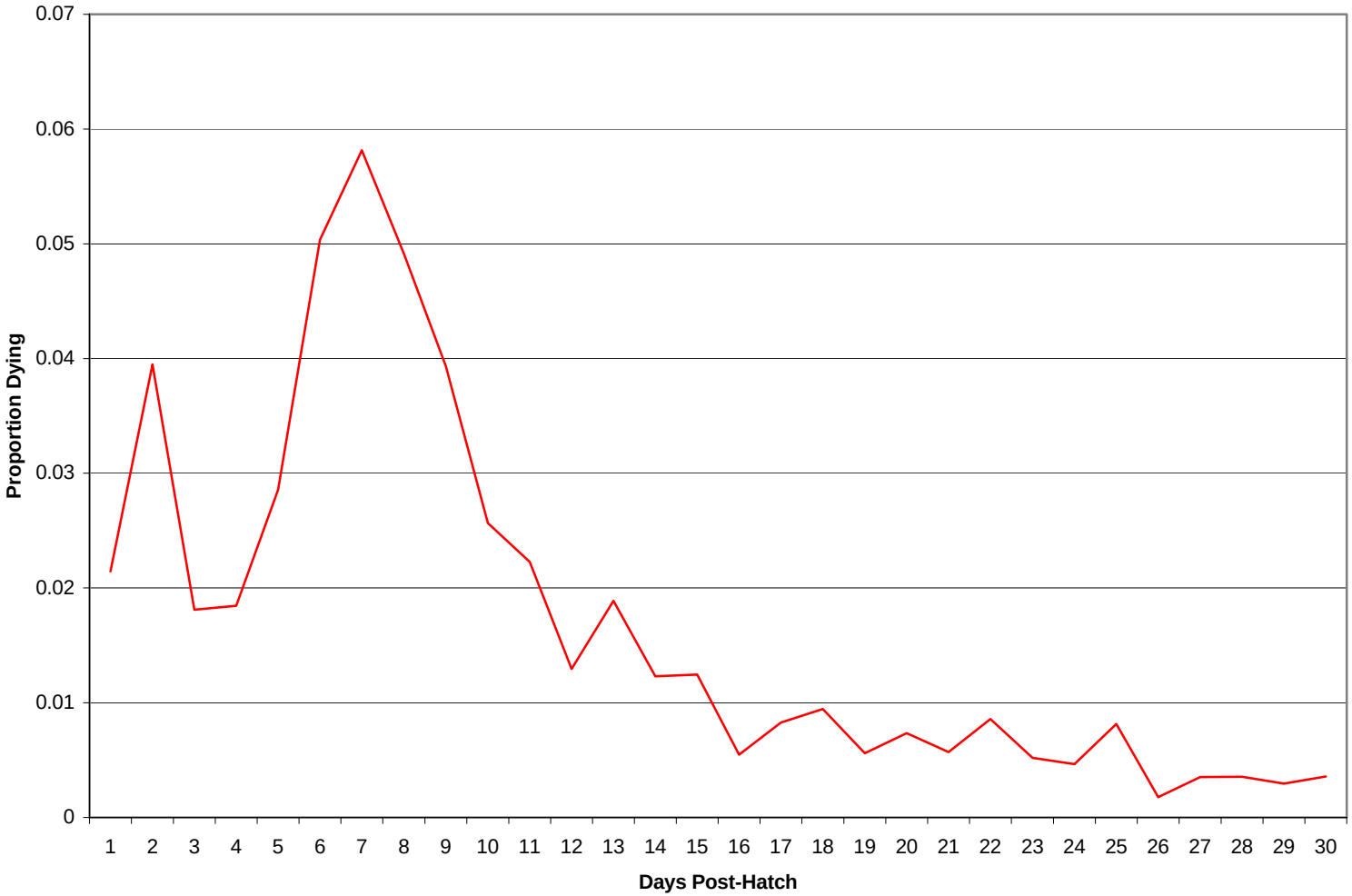
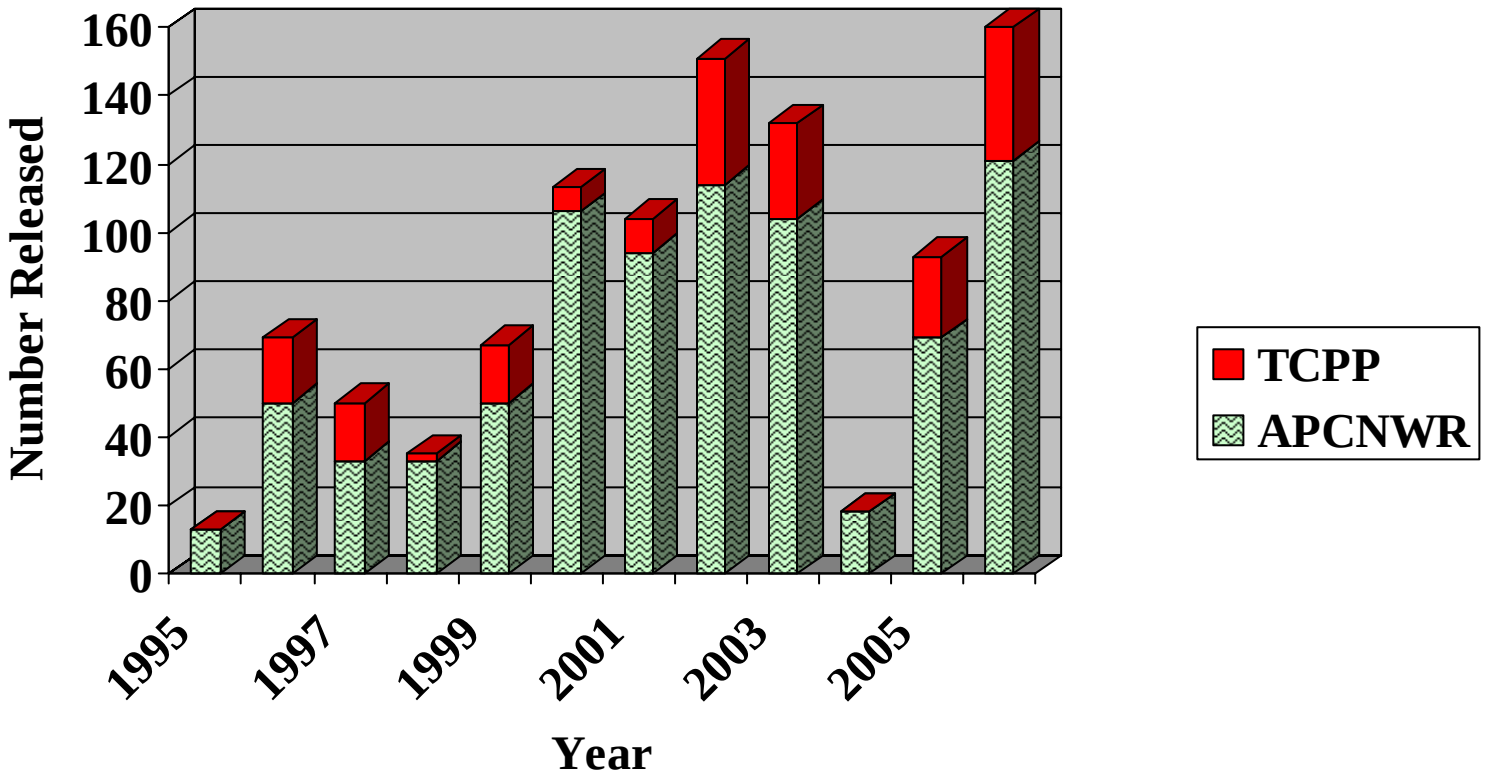


Figure 10. Captive Attwater's prairie-chickens (*n* = 1,005) released at the Attwater Prairie Chicken National Wildlife Refuge (APCWR), Colorado County, Texas and the Texas City Prairie Preserve (TCPP), Galveston County, Texas from 1995–2006.



(www.isis.org) and Population Management 2000 (Pollak et al. 2002) software, were placed in 30 X 50 ft (9.1 X 15.2 m) holding pens at the release site to recover from the stress of transport and to acclimate to release site surroundings. At the end of the acclimation period, pen doors were opened and birds generally allowed to exit at their own pace. Food and water were provided outside the release pens for up to 30 days post-release to allow for a gradual transition to a natural diet. Findings to date suggest (1) mortality during the first 30 days was more than five times higher in birds acclimated for 3 days versus 14 days ($P < 0.005$); (2) birds released during seasons when migrant raptors were present (1 October–19 April) experienced 1.9 times higher mortality during the first 30 days than those released when migrant raptors were absent ($P < 0.005$); no difference ($P > 0.05$) has been detected in post-release survival attributable to the age of birds at release (after hatch-year versus hatch-year) (APCNWR, unpublished data).

Lockwood et al. (2005) observed movements and monthly ranges of released APCs were similar to those of wild APCs. Lockwood (1998) also observed use of habitat structure by released birds was comparable to wild birds observed by Morrow (1986) and Horkel (1979). Hess (2004:10) observed no difference in flight speed between pen-reared APCs released at APCNWR and wild GPCs from Kansas and Minnesota, but observed that wild GPCs flew farther when flushed than pen-reared APCs ($\bar{x} \geq 250$ m versus ≤ 97 for GPCs and APCs, respectively). Hess (2004) observed wild GPCs and APCs >365 days post-release flushed at greater distances from humans than those <90 days post-release and GPCs flushed at longer distances from a dog than released APCs. However, with reference to *T. cupido,* Oberholser writes in The Bird Life of Texas (1974):

> "Flight, strong but not protracted, is seldom indulged in except when the prairie chicken is suddenly surprised. Individuals or flocks flush with heavy whirring of wings; after birds have risen about ten to twenty feet, they level off and alternately flap and sail for forty to seventy yards, then drop again into the grass."

Since *T. c. pinnatus* was extirpated from Texas by 1920, Oberholser (1974) was undoubtedly describing flight characteristics of wild *T. c. attwateri*. Jurries (1979) observed that while on day roosts, APCs "…appear to be asleep and often can be closely approached before flushing."

Toepfer (1988), working with released pen-reared GPC at the same location as wild birds, also noted a reluctance to flush and shorter flight distances in pen-reared as compared to wild birds. Leopold (1944) noted that hybrid pen-reared X wild eastern wild turkeys (*Meleagris gallopavo silvestris*) displayed little aversion to humans in contrast to wild stock. Toepfer (1988) observed that differences in behavior between released pen-reared and wild GPC were due to differences in body and wing condition, strong selective pressures in the pen environment for birds that are poor flyers, and learned behaviors reinforced by the pen environment which discourage flying. Toepfer (1988) and Leopold (1944) working with prairie-chickens and eastern wild turkeys, respectively, observed that pen environments do not alter the ability of these birds to recognize predators, but do alter their response to predators. Toepfer (1988) stated that wild prairie-chickens respond to predators by first crouching, and then flushing if predators get too

close. The pen environment conditions prairie-chickens to run rather than flush (Toepfer 1988).

Kaplan-Meier estimates of annual post-release survival have ranged from 9% (1999) to 35% (1996) ($\bar{x}$ = 19%) (Morrow et al. 2004). Since 2000, annual survival estimates have been more consistent (13–18%, $\bar{x}$ = 15%) (APCNWR unpublished data). Survival of released pen-reared stock has typically been low for many species (e.g., Roseberry et al. 1987, Toepfer 1988, Hernandez et al. 2006). Toepfer et al. (1990) noted that of upland game, prairie grouse have the poorest record with regard to establishment of populations with translocated birds. Toepfer (1988) reported that 90% of released pen-reared GPCs were dead within 90 days, and none survived 120 days. Survival of released APCs to 120 days through 2004 averaged 51%, ranging from 76% in 1996 to a low of 17 and 18% in 2000 and 1999, respectively (APCNWR, unpublished data). Survival to 120 days for all birds released during 2001-2004 averaged 58%, ranging from 49–71%.

Despite higher mortality observed in released pen-reared birds compared to wild cohorts, enough have survived to produce viable nests during the spring following release. Number of nests from released birds has ranged from two in 2001 to 19 in 2004 (APCNWR, unpublished data). However, documented survival of offspring from these nests has been extremely poor to non-existent (Lockwood et al. 2005; APCNWR, unpublished data). Nesting success has been enhanced by installation of predator deterrent fences around most nests since 2000 (J. Toepfer, Society of Tympanuchus Cupido Pinnatus, and M. Morrow, APCNWR, unpublished data). Nesting success at APCNWR from 2000–2004 averaged 64% for fenced nests (n = 36) and 0% for unfenced nests (n = 9) (APCNWR, unpublished data). In 2003, intensive observations on eight broods at the APCNWR found no chicks survived past 11 days post-hatch (APCNWR, unpublished data). Several chicks were found dead or dying at night roosts, suggesting that predation was not the sole cause of chick mortality.

This type of mortality has also been observed in wild GPCs, but with much lower incidence (J. Toepfer, STCP, personal communication). Previous attempts to allow captive APC hens to parent-rear their chicks have ended in failure unless the brood was confined to a relatively small space (Drake 1994, J. Carviotis, Houston Zoo, Inc., and N. Silvy, Department of Wildlife and Fisheries Sciences, TAMU, personal communication). Increased, although still limited, chick survival was achieved at APCNWR during 2003-2006 by confining hens with their broods to an approximately 4 x 8 x 2-ft (1.2 x 2.4 x 0.6–m) pen immediately after hatch. These broods were provided insects (collected from area herbaceous vegetation) and water (in most cases) *ad libitum*, and released with the hen at approximately 2–4 weeks post-hatch. A limited number of similarly-aged chicks hatched in captivity were also added to confined APCNWR broods to evaluate the efficacy of artificially increasing the number of chicks/brood, especially for smaller broods. The limited evaluation of this technique to date suggests that this technique may be useful in future recovery activities (APCNWR, unpublished data). Poor survival of chicks produced by released captive-reared APCs is currently the single-most factor limiting significant progress toward recovery.

Poor productivity in other species of released captive-reared birds has been observed (Leopold 1944). Leopold (1944) observed differences in the size of the brain,

pituitary, and adrenals of domestic-strain and wild turkey poults, and Liukkonen-Anttila (2001) observed differences in gut dimensions and liver weights of wild and captive grey partridge (*Perdix perdix*) and capercallie (*Tetrao urogallus*). Liukkonen-Anttila (2001:37) stated that "According to Dahlgren (1987) the effects of an insufficient diet during growth may last until the first breeding season." Grindstaff et al. (2005) suggested that resource limitation may have transgenerational effects on immune function. Lochmiller et al. (1993) found that deficiencies in northern bobwhite (*Colinus virginianus*) chick diets can lead to atrophy or suppressed development of primary and secondary lymphoid organs. Thomas (1987) speculated that survival of captive-reared birds in the wild may depend on a digestive system conditioned anatomically and physiologically to bulky, low quality diets as compared to commercial diets designed for maximum digestibility. Thomas (1987) also hypothesized that providing monotypic, nutrient-dense commercial rations may preclude development of optimal foraging and food selection behaviors needed for survival in the wild. These observations suggest that anatomical, physiological, and behavioral changes attributable to the captive environment may contribute to poorer survival and reproduction of released pen-reared birds compared to wild birds.

H. REASONS FOR LISTING/CURRENT THREATS

Section 4(a)(1) of the 1973 ESA (50 CFR 17.11) requires a 5-factor analysis of threats to endangered species. A general discussion of threats facing APC within this 5-factor framework is presented in the following sections. This 5-factor analysis is also used in Section II.D (Reduction or Alleviation of Threats) of this plan as a framework for evaluating how proposed recovery actions address recognized threats.

Factor 1: The present or threatened destruction, modification, or curtailment of habitat or range.

Remaining populations have become geographically fragmented and genetically isolated (Toepfer 2003; Johnson et al. 2003, 2004). This scenario, observed at the continental scale, was manifested regionally with regard to the APC (Lehmann 1941, Jurries 1979, Lawrence and Silvy 1980, McKinney 1996, Morrow et al. 2004, Silvy et al. 2004). Smeins et al. (1991) estimated <1% of the APC's coastal prairie grasslands remain in relatively pristine condition. Small, isolated populations were subjected to genetic drift and the vagaries of environmental and demographic stochasticity so that currently only two extremely small populations remain (Figures 1, 2). The APC population at the APCNWR is currently maintained only as a result of population supplementation with captive-reared birds. The TCPP population remains perilously close to extinction.

Factor 2: Overutilization for commercial, recreational, scientific, or educational purposes.

Overharvesting was undoubtedly a historical threat, at least at the local population scale (Lehmann 1941). Lehmann (1941) indicated prairie-chicken shoots began in early July when broods would have been particularly vulnerable, and continued through fall and winter. However, the last legal hunting season was held in 1936 (Jurries 1979).

Currently, illegal take by dove, quail, and waterfowl hunters is a possibility, but no evidence exists that this has occurred in >10 years.

Factor 3: Disease or predation.

Disease. Peterson (2004) provided an extensive overview of information available on parasites and infectious diseases of prairie grouse, including the APC. This overview was summarized previously in Section I.D (*Survival and Mortality Factors).* Briefly, Peterson (2004) concluded that macroparasites *Dispharynx nasuta* and *Trichostrongylus cramae*; microparasites *Eimeria dispersa*, *E. angusta*, *Leucocytozoon bonasae*, and *Plasmodium pedioecetii*; and infectious bronchitis and reticuloendotheliosis viruses (REV) have the potential to regulate prairie grouse populations. Peterson (2004) also indicated *Histomonas meleagridis* (causative agent for blackhead), *Pasteurella multocida, E. dispersa, E. angusta,* and other microparasites which result in high mortality have the potential to extirpate small, isolated prairie grouse populations.

Positive serologic tests for *P. multocida*, and infestations of *T. cramae* and *D. nasuta* have been documented from wild APC samples (Peterson et al. 1998). Diligent prophylaxis in the captive setting is required to prevent significant mortality from *D. nasuta* (J. Flanagan, Houston Zoo, Inc., personal communication). REV remains problematic in captivity (see Section I.G. *Captive Breeding*). REV has been documented in free-ranging APC populations (Drew et al 1998; M. Morrow, APCNWR, unpublished data), but its population-level impacts are unknown. Insects are possible sources of REV infection through mechanical transmission of the virus (Davidson and Braverman (2005). Peterson (2004) stressed that wildlife managers need ecologically-based studies which address the potential significance of parasites and diseases to prairie grouse populations, especially for small isolated populations subject to stochastic extinction. Hudson et al. (2006) speculated that increased temperatures and climatic disruption brought about by global warming will result in increased frequency and intensity of outbreaks of some parasite populations like *Trichostrongylus tenuis*.

Predation. APC predation, including nests, has been discussed in previous sections. Predation of captively-reared released birds is heavy in some years, especially during the first weeks following release (Lockwood 1998, 2005; M. Morrow, APCNWR, unpublished data). However, survival of released APC has been higher than that seen with other similar efforts (e.g., Roseberry et al. 1987, Toepfer 1988). Survival of released birds still living one year post-release approximates the 50% survival expected from wild *T. cupido* populations. Pre-release conditioning and modification of rearing techniques to enhance post-release predator avoidance behaviors may offer promise for increasing post-release survival (e.g., see van Heezik et al. 1999, Hess 2004). However, survival of broods from released hens in the wild is currently the factor most limiting APC recovery, not post-release survival. Current thinking is this poor brood survival is related to physiological, behavioral, or habitat quality issues rather than predation (see discussion in Section I.G. *Population Supplementation*). Peterson and Silvy (2004) observed that spring breeding success, measured by summer juvenile:adult ratios, drives APC population changes. Such ratios are a composite not only of brood survival, but also of nesting success. Peterson and Silvy (1996) observed both APC nest success and brood survival were lower than those for GPC. Predation likely plays a role under some

environmental conditions to APC's relatively poor reproductive success. Therefore, due diligence is necessary in managing predation, especially that associated with reproductive success.

Factor 4: Inadequacy of existing regulatory mechanisms.

As was the case with many species, the APC become endangered primarily due to habitat loss that occurred prior to the enactment of current conservation legislation. In general, the current legal framework (e.g., ESA, National Environmental Policy Act) provides for adequate protection and conservation. However, in some cases agency programs may conflict with APC recovery. For example, the NRCS Environmental Quality Incentive Program (EQIP) not only provides cost share assistance to landowners for management practices that improve habitat for APC (e.g., brush and grazing management), but it also provides assistance to landowners for practices that degrade or destroy APC habitat (e.g., converting native grasslands to exotic tame pasture grasses).

Factor 5: Other natural or manmade factors affecting its continued existence.

Population fragmentation. Small, fragmented populations are generally at greater risk of extinction than large, contiguous ones (e.g., Shaffer 1987, Fahrig and Merriam 1994, Frankham et al. 2002, Toepfer 2003). Further, *r*-selected species like the prairie-chicken are subject to relatively high inherent mortality, resulting in volatile, and sometimes catastrophic changes in populations when faced with environmental perturbations (Pianka 1970, Odum 1971). Population and habitat viability analyses conducted for the APC (Seal 1994) have indicated a high probability of extinction within 20 years (Seal 1994, Brooks et al. 2002) given the small, isolated nature of APC populations.

Genetics. Genetic variability has been correlated with population fitness and viability; isolated small populations lose genetic variation through genetic drift which may then result in inbreeding depression or an increased susceptibility to diseases and parasites (Frankham et al. 2002; Reed and Frankham 2003; Spielman et al. 2004a, 2004b, Whiteman et al. 2006). Bouzat et al. (1998a, 1998b) and Westemeier et al. (1998) demonstrated a reduction in fitness associated with reduced genetic variation in a small Illinois GPC population. Reduced genetic variation has also been attributed to population isolation in Wisconsin GPCs (Bellinger et al. 2003; Johnson et al. 2003, 2004; Johnson and Dunn 2006).

The genetic viability of remaining APC populations, both in the wild and captive setting is of interest for conservation and management purposes. Osterndorff (1995) assessed genetic variability in the three remaining wild populations during 1991–1994. It was during this time that many founders for the captive population were collected (see Section I.G. *Captive Breeding*). Osterndorff (1995) found the Galveston County (TCPP) and the Colorado County (APCNWR) populations exhibited genetic similarity indices, 63% and 30% greater respectively, than observed for Kansas GPCs (i.e., Galveston and Colorado County APC populations had less genetic variability than Kansas GPCs) ($P < 0.01$). The genetic similarity index for the Refugio County population was not different from the GPC sample. Osterndorff (1995) found the composite sample combining the 3

extant APC populations had a higher genetic similarity index than did the Kansas GPC sample ($P < 0.001$). Stoley (2002) examined APC samples collected from wild populations during 1936–1965 and the captive flock from 2000 and found that observed levels of microsatellite DNA heterozygosity were less than expected, even in the historic sample of wild birds. However, the historic levels of observed heterozygosity may be higher than reported by Stoley (2002) because this study did not assess potential allelic dropout issues, which is a common problem with historic samples when amplifying nuclear loci (see Miller and Waits 2003). Johnson and Dunn (2006) observed high mtDNA control region haplotype diversity (h=0.912, n = 19) using Attwater's samples from museum specimens collected between 1887-1942, while Palkovacs et al. (2004), also working with mtDNA control region, found that a sample (n = 8) of captive Attwater's had the lowest values for three measures of molecular diversity when compared to heath hens and greater prairie-chickens. In fact, in a report of preliminary analyses, Jeff Johnson (Univ. of Michigan, unpublished data) used mitochondrial DNA and microsatellite techniques to assess genetic variability in APC samples collected from Colorado, Galveston, and Refugio counties during 1992–1994. He found that

> "… analyzed as three groups, levels of mitochondrial haplotype variability and diversity were quite low, with the exception of haplotype diversity for Colorado County… The microsatellite DNA analysis agrees with the above DNA results. Compared to a large number of surveyed GPC populations, the three counties sampled in 1992–1994 had significantly low levels of genetic variability based on mean number of alleles (P<0.001;…). Based on these results and current abundance trends within the remaining populations of APC, levels of genetic variability are quite low and will require immediate attention."

An assessment of microsatellite DNA (8 loci) genetic variability remaining in the captive flock as of April, 2006, compared to wild APCs sampled during 1990–1994 (when most founders for the captive population were collected) indicated no difference ($P > 0.05$) in allelic richness (4.3 $\pm$ 0.5 (SE) vs. 5.2 $\pm$ 0.8 (SE) for captive vs. wild, respectively) or heterozygosity (0.696 $\pm$ 0.034 (SE) vs. 0.642 $\pm$ 0.067 (SE) for captive vs. wild, respectively) (J. Johnson, University of Michigan, unpublished data).

An effective population (N_e) of 500-5,000 breeding individuals has been suggested to balance the effects of genetic drift (Franklin 1980, Lande and Barrowclough 1987, Lande 1995, Franklin and Frankham 1998, Lynch and Lande 1998). Because as few as 10% of prairie-chicken males breed (Robel 1970), a prairie-chicken population of >2,750 individuals would be required to maintain a N_e >500 assuming a 1:1 sex ratio. (Roughgarden 1979:68, Walk 2004:53).

To date, there is no direct evidence that APC populations have experienced inbreeding depression. Although Peterson and Silvy (1996) reported APC reproductive parameters were substantially lower than observed for the GPC, these differences in productivity may be lineage specific because similar parameters were also observed when the first major APC life history work was conducted more than 70 years ago (Lehmann 1941). Thus these differences, while important, may not likely be classified as recent inbreeding depression. Further, Griffin (1998) observed no substantial improvement in

fertility, hatchability, or chick survival in captivity for GPC x APC hybrids when compared to comparable nonhybrid groups of GPCs and APCs, although outbreeding depression can not be ruled out in this case (e.g., Edmands 2007). A comparison of chicks from wild-collected GPC eggs (n = 27), taken from a Minnesota population that is increasing in size (J. Toepfer, STCP, personal communication) yet reared at Fossil Rim Wildlife Center using the same husbandry techniques used for the APC, initially showed better hatchability and chick survival, but they subsequently experienced the same reproductive problems observed in APCs during their first breeding season (low numbers of eggs/hen, reduced hatchability, poor chick survival) (O. Dorris, Fossil Rim Wildlife Center, personal communication). This experiment, designed to investigate the influence of husbandry and genetics with respect to fitness-related problems associated with the current APC captive breeding program, suggests that husbandry issues are playing a more significant role than genetics in limiting survivorship at this time.

However, it must be noted that current levels of genetic variability in the captive population are low and comparable to those observed in the Illinois GPC population when Westmeier et al. (1998) documented a significant decline in hatching success following a reduction in levels of genetic variability. Therefore, concern still exists that genetics may be an issue in the future, and the captive population should be closely monitored for any signs that may be associated with inbreeding depression until its effective population size has increased to levels associated with a genetically viable population (i.e., N_e>500).

Husbandry issues. As discussed previously, major biological constraints facing the captive breeding program include issues contributing to poor productivity including husbandry methods, nutrition, and management of diseases and parasites, particularly REV. Additionally, having 50% of the captive flock currently at one location (Fossil Wildlife Center) (Figure 6), has the potential for resulting in disastrous consequences to the APC captive breeding and APC recovery programs. The major REV event at Fossil Rim in recent years has heightened the gravity of this situation.

Poor brood survival. Significant progress toward recovery will not occur until factors influencing the poor survival observed for chicks produced by released captively-reared APCs (see Section I.G. *Population Supplementation)* are identified and resolved. Factors hypothesized as possible contributors to poor brood survival include: (1) habitat quality, especially as it pertains to insect availability for foraging chicks, (2) genetics, (3) physiological changes attributable to the captive environment, (4) maladaptive parental behavior as influenced by the captive environment, (5) disease/parasites, and (6) stings by the exotic red imported fire ant.

II. RECOVERY

The following sections present a strategy to recover the species, including objective and measurable recovery criteria to achieve downlisting and delisting, and site-specific management actions to monitor and reduce or remove threats to the APC, as required under section 4 of the ESA. The Recovery Plan also addresses the five statutory listing/recovery factors (section 4(a)(1) of the ESA) to demonstrate how the recovery criteria and actions will lead to removal of the APC from the lists of Threatened and Endangered Species.

A. RECOVERY STRATEGY

As described in previous sections, the APC is facing numerous threats at multiple ecological scales. Presently, the APC is functionally extinct in the wild, maintained by supplementation from captive-reared birds. Recovery efforts defined by strategies detailed in this plan must be multifaceted and managed concurrently. For example, while more investment is warranted for captive propagation programs, restoration and acquisition of potential APC habitat also must be continued. Other avian species recovery efforts have adopted such an integrated approach. The winter of 2004–2005 marked a record setting wintering population of whooping cranes (*Grus americana*). On the surface, the recovery of the whooping crane faces more complex demographic and political challenges when compared to the APC. These include low reproductive rates (K-selected), historically low population numbers, wide ranging migratory patterns, and the vulnerability of wintering wetland habitat to pollution, fragmentation, and other threats. In contrast, the APC is an *r*-selected species with a historically large population. However, at such currently low population levels brought about by habitat loss and fragmentation, and other factors identified in previous sections, the APC cannot withstand stochastic, catastrophic events. Since the last revision of the APC Recovery Plan in 1993, a core population in Refugio County has disappeared, and the two remaining wild populations are dependent upon releases of captive-raised birds. A better understanding of why other recovery efforts are succeeding is necessary as we refine existing and develop new recovery strategies.

If recovery of the APC is to be successful three primary action areas must be supported. They are (1) habitat management, (2) captive and wild population management, and (3) public outreach. Specific objectives and numeric goals will be identified in the following section. These three action areas cumulatively address the five listing/current threat factors identified in section I.H (Reasons for Listing/Current Threats) of this plan. Specific strategies for addressing these threat factors are identified in section II.D (Reduction or Alleviation of Threats).

Although only 50 APC currently exist in the wild, habitat management, enhancement, and restoration must be carried out to maintain existing high quality grasslands and restore degraded grasslands that may serve as APC habitat in the future. If existing and expanded grassland conservation efforts (e.g., CPCI) at the right scale [multiple core areas ≥25,000 ac (10,120 ha)] and context (minimal fragmentation, allow for gene flow between core areas) succeed, then viability for future APC populations is

possible. There are very few areas left in Texas that can provide the long-term requirements for APC survival. The relict population in Galveston County at the TCPP exists upon a small patch [<1,500 ac (607 ha)] of habitat and by all definitions is nonviable. Prospects for expanding this site in a meaningful way for the local APC population are nonexistent. The APCNWR population has suffered from a variety of threats before and since supplemental releases began in 1995. With the westward expansion of the Houston metropolitan area and further development pressures, expanding the habitat base from the refuge will be a key challenge to recovery efforts. However, support of habitat restoration on adjacent private lands should be continued.

Population management addresses needs for the captive and wild populations. Approximately half of the captive flock resides at Fossil Rim Wildlife Center. The remaining 50% are spread out across five facilities. Disease, limited space, and differing approaches to husbandry practices are all key challenges facing the captive management program. If viable populations are to be established in presently unoccupied, but suitable habitat, large (>100) numbers of birds at multiple release sites will be required. In 2006, a record high of only 160 birds was released. It is clear the captive population management program must be retooled and elevated in dramatic fashion if we are to recover the APC.

Numerous challenges face the wild APC population. Predation, red imported fire ants, disease, ectoparasites, accidents (e.g., flying into fences and wires), flooding, incompatible grazing, altered fire regimes, and countless other factors are collectively suppressing optimal recruitment of the two wild populations. At APCNWR, no recruitment has occurred from captive-reared released birds without very intensive intervention by APCNWR staff. Evidence suggests limited recruitment occurring at TCPP however, few brood survival data are available to positively document reproduction from captive-reared released birds. Such evidence leads to a core question: Do captive-reared birds lack essential physiological and behavioral traits that prevent their survival once released, or are there vital habitat requirements lacking that limit brood survival and population recruitment? Additional research efforts are essential to address these questions. However, conducting meaningful research with broad ranging applicability is very challenging given the low population numbers and varied grassland habitats at these two sites. Research addressing these questions should be conducted on non-endangered GPC populations to the extent practicable.

An ongoing challenge to recovery of the APC has been difficulty in attracting a large, engaged constituency to support conservation of the APC. A focused effort is needed to engage both public and private partners in funding opportunities that can be strategically used for recovery actions.

This plan outlines current strategies believed to be critical to APC recovery. Goals, objectives, and criteria were derived from information and literature discussed in previous sections of this plan or were based on the professional judgment of recovery team members. Specific observations and assumptions that weighed heavily in the formulation of goals, objectives, and criteria include:

- From a theoretical perspective, a N_e >500 is needed to maintain genetic variation within a population (Lande and Barrowclough 1987:94).
- Assuming the worst case scenario of only 10% of males breeding (Robel 1970) and a sex ratio of 1:1, a population of 2,750 would be required to produce an N_e of 500.
- A corollary to the N_e requirement is that small fragmented populations must be situated on the landscape so that gene flow among populations is maintained (Johnson et al. 2003, 2004; Toepfer 2003) and recolonization following local extinction is facilitated (Fahrig and Merriam 1994, Hanski et al. 1996).
- Prairie-chickens require lots of grass and open space (e.g., Lehmann 1939, 1941; Schwartz 1945; Baker 1953; Hamerstrom et al. 1957; Cogar et al. 1977; Toepfer 1988, 2003; Johnson et al. 2004, Silvy et al. 2004).
- *T. cupido* management areas should be ≥33%, and preferably ≥50% grassland (Hamerstrom et al. 1957).
- Brush must be controlled to prevent excessive encroachment into grasslands (Hamerstrom et al. 1957, Svedarsky 1979:102, Toepfer 1988:484, Toepfer 2003). Less than 25% of the landscape should be wooded, with woodlands aggregated in scattered blocks (Hamerstrom et al. 1957).
- The minimum management area size required to maintain a viable prairie-chicken population is unknown (Toepfer 2003). In general, prairie-chicken management areas should consist of thousands of acres of grass distributed over a landscape of several thousand square miles in a fashion that maintains connectivity among populations (Toepfer 2003, Johnson et al. 2004).

B. GOALS, OBJECTIVES, AND CRITERIA

The goal of this plan and recovery effort is to protect and ensure survival of the APC and its habitat, allowing the overall population to reach a measurable level of ecological and genetic stability so that it can be reclassified to threatened status (downlisted) and ultimately removed from the endangered species list (delisted). This goal can be achieved only if threats previously identified are sufficiently reduced or removed. Objective and measurable criteria for downlisting and delisting are as follows:

1. Downlist to threatened status when the overall population maintains a minimum of 3,000 breeding adults annually over a 5-year period. These birds should be distributed along a linear distance of no less than 50 miles (80 km) to mitigate for environmental stochasticity (e.g., hurricanes) while maintaining genetic flow.

2. Delist when there is a minimum overall population of 6,000 breeding adults annually over a 10-year period occupying habitats along a linear distance of no less than 100 miles.

Specific objectives and criteria for habitat management, captive and wild population management, and public outreach necessary to accomplish these recovery goals are:

Objective 1: Maintain and improve 300,000 ac (121,457 ha) of coastal prairie grasslands for the APC throughout the bird's historic range on both private and public lands.

Habitat is one of the major factors currently limiting APC populations. The APC's prairie grassland habitat has been reduced by an estimated 99% of historic levels (Smeins et al. 1991). Remaining habitat has become highly fragmented, making isolated APC populations more susceptible to inbreeding, localized weather extremes, land use changes, predation, and disease.

APC recovery will require a network of large, high quality coastal prairie grasslands containing multiple core areas distributed along at least 100 linear miles (160 km). A core area is defined as an area of habitat capable of supporting a population of 500 (250 displaying males), or approximately 25,000 ac (10,121 ha) (assuming a carrying capacity of 1 bird/50 ac (20 ha) (Lehmann 1941:7).

Objective 2: Enhance propagation and release efforts to boost wild populations to viable levels and reintroduce physically and behaviorally healthy birds to their former range

(a) Maintain 90% of original gene diversity for 20 years with about 200 birds in the captive flock.

(b) Produce enough chicks annually to release at multiple sites (approximately 100 birds per release site).

- Increase capacity of breeding pairs to a minimum of 100 pairs within two years, with no one facility containing more than 25% of the captive flock.
- By 2008, increase survival in the captive environment so that 50% of eggs produced survive to eight weeks of age.

(c) When number of young available for release exceeds 100, pilot releases of no fewer than 30 should be considered on private lands.

Captive propagation and release efforts must be enhanced in order to boost wild populations to viable levels and reintroduce physically and behaviorally healthy birds to their former range. Maintaining the integrity of the captive APC flock is crucial for APC recovery. Without a healthy, genetically sound captive flock the APC is doomed to extinction.

Objective 3: Establish populations of at least 500 birds in multiple core areas, providing for gene flow between populations (see *Objective 1*).

Objective 4: Broaden public support and partner in efforts to conserve the APC and its coastal prairie ecosystem.

A lack of understanding and awareness currently exists among the public and other groups concerning the perilous condition of APC populations and prairie grouse in general. As a result, public support for APC recovery efforts is lacking. There needs to be an increase in outreach activities to raise the public's awareness of the plight of the APC and its endangered coastal prairie ecosystem. Explaining why the APC has

declined, what challenges it faces for recovery, and why it is important to save this imperiled bird will increase support for recovery of the APC.

C. NARRATIVE OUTLINE OF RECOVERY ACTIONS

This section lists the site-specific actions necessary to accomplish goals and objectives outlined in Section II.B (Goals, Objectives, and Criteria). Priority 1 actions include activities that must be taken to prevent extinction or prevent irreversible population declines in the foreseeable future. Priority 2 actions include activities that must be taken to prevent a significant decline in APC populations or habitat quality, or to prevent some other significant negative impact short of extinction. Priority 3 actions include all other activities necessary to accomplish full recovery.

1. Continue to maintain and improve at least 300,000 ac (121,457 ha) of coastal prairie habitat for the APC throughout the bird's historic range through the CPCI and other habitat improvement projects on both private and public lands.

   1.1. Create a network of large, high quality coastal prairie habitats containing multiple core areas maintained compatibly with APC occupation and distributed along ≥100 linear miles (160 km). A core area is an area of suitable habitat capable of supporting a population of 500 (250 displaying males) [approximately 25,000 ac (10,121 ha) assuming a carrying capacity of 1 bird/50 ac (20 ha) (Lehmann 1941:7)] (**Priority 1**).

   1.2. Coastal prairie habitats compatible with APC occupation should be interconnected through grassland corridors (1–3 miles (1.6-4.8 km) wide) within the APC's historic range to allow for dispersal and genetic exchange and to hedge against environmental stochasticity (e.g., hurricanes) (Toepfer 2003). Areas such as national wildlife refuges (e.g., APC, Aransas, Brazoria), TNC preserves (e.g, Mad Island, TCPP), and private lands will be pivotal in making these grassland corridors a reality. To maximize benefits for APC recovery, management priority should be given to habitats in close proximity to existing populations or future release sites (**Priority 1**).
      1.2.1. Cultivate partnerships with managers of existing grasslands currently under public (e.g., Aransas, Texas Mid-Coast, and Texas Chenier Plains National Wildlife Refuges, TPWD Mad Island Wildlife Management Area or NGO (e.g., Mad Island Preserve) ownership to encourage management consistent with APC habitat requirements (see 1.3) (**Priority 1**).
      1.2.2. Cultivate partnerships with private landowners through mechanisms listed under 1.4 (**Priority 1**).

   1.3. Manage and monitor progress on public lands to maintain, improve, and/or restore native prairie grasslands as APC habitat by:
      1.3.1. grazing to maintain clumped grass structure (**Priority 1**).
      1.3.2. controlling brush and exotic plants (**Priority 1**).
      1.3.3. prescribed burning (**Priority 1**).
      1.3.4. maintaining and restoring natural hydrology to reduce nest flooding (**Priority 1**).
      1.3.5. planting food plots to provide supplemental winter foods and brood habitat (**Priority 1**).
      1.3.6. mowing as necessary to control vegetation density **(Priority 2)**.

1.3.7. restoring formerly farmed fields to native grass species (**Priority 1**).
1.3.8. monitoring and managing sympatric wildlife species giving priority to APC (**Priority 3**).
1.3.9. controlling exotic wildlife species (**Priority 1**).
1.3.10. prohibiting introductions of exotic wildlife species on public lands (e.g., ring-necked pheasants, etc.) (**Priority 2**).
1.3.11. managing waterfowl, especially geese, to minimize competition and potential for disease transmission (**Priority 1**).
1.3.12. controlling public use to prevent APC disturbance (**Priority 1**).

1.4. Secure additional habitat through:
1.4.1. acquisition of additional refuge lands including at least 20,000 ac (8,097 ha) to the existing APCNWR through a combination of fee simple and long-term easement acquisitions from willing sellers (**Priority 1**).
1.4.2. private land easements (**Priority 1**).
1.4.3. safe harbor agreements (**Priority 1**).
1.4.4. habitat conservation plans (**Priority 1**).
1.4.5. mitigation (**Priority 1**).
1.4.6. partnerships with other governmental, non-governmental organizations (NGOs), and private land managers (**Priority 1**).
1.4.7. pursuit of other mechanisms/programs for private lands work such as NRCS's Grassland Reserve Program, EQIP, Farm Bill, TPWD's Landowner Incentive Program (LIP), USFWS's Partners for Fish and Wildlife program, etc. (**Priority 1**).
1.4.8. technical assistance, economic incentives, and regulatory incentives on private lands through the CPCI program (**Priority 1**).
1.4.9. coordination with NRCS and other governmental agencies to resolve conflicting programs that are detrimental to APC recovery (**Priority 1**).
1.4.10. acquisition of grassland additions to existing national wildlife refuges within the APCs historic range (Aransas, Texas Mid-Coast, Texas Chenier Plains) (**Priority 2**).

1.5. Survey status and trends of native grasslands every five years. Identify public and private release sites that maximize the probability for success (**Priority 2**).

1.6. Cultivate market-driven financial incentives for private landowners that establish and maintain APC populations on their lands (e.g., eco-tourism, economic value of native grasses, etc.) (**Priority 1**).

1.7. Focus recovery actions in priority management zones (Figures 3, 4, 5). Priority management zones are areas within the APC's former range currently supporting APCs or that have been identified as having high potential for repatriation. Core areas will be located within priority management zones (**Priority 1**).

1.8. Conduct research necessary to:
1.8.1. Determine landscape scale habitat needs (**Priority 2**).
1.8.2. Evaluate patch burning as a management tool (**Priority 2**).
1.8.3. Evaluate current management practices on release sites (**Priority 1**).

2. <u>Continue propagation and release efforts to boost wild populations to viable levels and reintroduce physically and behaviorally healthy birds to their former range.</u>

   2.1. Maximize effectiveness and production of current captive flock by:
      2.1.1. evaluating and implementing different rearing techniques (e.g., broody hens, APC hens, etc.) to generate physically and behaviorally healthy birds (**Priority 2**).
      2.1.2. implementing different strategies for maximizing production such as:
         2.1.2.1. photoperiod manipulation (**Priority 3**).
         2.1.2.2. using the expertise of a particular facility to their fullest extent (e.g., a facility that has problems getting birds to produce eggs receives eggs from a facility that does very well at producing eggs, etc.) (**Priority 2**).
      2.1.3. identifying and rectifying disturbance issues at breeding facilities (**Priority 3**).
      2.1.4. aggressively managing diseases (e.g., REV, pox, etc.) and other health issues (**Priority 1**).
      2.1.5. sharing resources and information among all captive flock facilities and recovery partners (**Priority 3**).
      2.1.6. evaluating diets for chicks and adults to help address health and production issues that may be related to nutritional issues (**Priority 1**).
      2.1.7. completing the husbandry manual within one year to standardize husbandry techniques and strategies, while continually evaluating the effectiveness of these techniques (**Priority 2**).
      2.1.8. evaluating screening pens which house the breeding flock to minimize risk of REV transmission by insects (**Priority 2**).

   2.2. Determine and continually monitor genetic health of the captive flock. Evaluate APC genetic variability to determine if hybridization with GPCs is warranted. Also, explore and consider gene banking (**Priority 1**).

   2.3. Increase production of birds through increased efficiency at current facilities and the addition (dedicated exclusively to APCs) or expansion of breeding facilities to allow for a capacity of a minimum of 100 pairs, with no one facility containing more than 25% of the captive flock population (**Priority 1**).

   2.4. Conduct research to provide information needed for captive APC management such as:
      2.4.1. REV (**Priority 1**).
      2.4.2. Factors affecting egg production and viability and chick survival (**Priority 1**).
      2.4.3. Rearing environment/methods (**Priority 1**).
      2.4.4. Factors affecting skeletal/muscular problems (e.g., leg rotations, wrynecks, etc.) (**Priority 1**).
      2.4.5. Management of parasites and diseases (**Priority 1**).

3. <u>Establish populations of >500 birds in multiple core areas within 10 years, providing for gene flow among core populations.</u>

3.1. Continually evaluate release techniques and implement changes as needed to improve survival (**Priority 1**).

3.2. Survey APC numbers annually by conducting spring booming ground and brood survival counts when appropriate (**Priority 1**).

3.3. Expand the release of captive-bred APCs where suitable habitat exists (**Priority 1**).

3.4. Evaluate translocation of birds as a possible technique for repatriation and genetic management of existing populations (**Priority 2**).

3.5. Develop regulatory procedures (e.g., safe harbor, habitat conservation plans (HCPs)) for establishing additional populations (**Priority 1**).

3.6. Protect APC from take by enforcing current Federal and State legislation and regulations (**Priority 1**).

3.7. Conduct research to provide information needed to determine:
   3.7.1. Factors affecting wild brood survival (**Priority 1**).
   3.7.2. Factors affecting post-release survival (**Priority 1**).

4. <u>Engage the public in efforts to conserve the APC and its coastal prairie ecosystem.</u>

4.1. Develop and implement a comprehensive public outreach plan that will incorporate specific outreach tasks to target groups.

4.1.1. Contract with consulting group to develop specific marketing strategies to effectively and efficiently engage the public in APC recovery (**Priority 3**).

Although numerous outreach activities have been conducted regarding the APC and recovery activities (e.g., annual APC festival, numerous newspaper and magazine articles, television and radio newsclips and short documentaries, presentations and development of curriculum materials for school groups), outreach remains non-focused. Therefore, these actions have likely not been as effective as they could have been in engaging public support for APC recovery. With limited funding and personnel to accomplish outreach actions, it is imperative that the right groups are targeted with the proper tools to maximize effectiveness of these actions.

4.1.2. Assist in the establishment of an APC partner coalition hosted by an NGO and dedicated to supporting APC recovery objectives. A host organization with national focus and credibility is needed to liaise with corporate partners and manage potential contributions and grants (**Priority 2**).

D. REDUCTION OR ALLEVIATION OF THREATS

Factor 1: The present or threatened destruction, modification, or curtailment of habitat or range.

Destruction, modification, or curtailment of APC habitat or range is addressed in Actions 1.1–1.8 which provide for creation of large interconnected grasslands that allow for dispersal and gene flow. This grassland habitat will result from management of existing public lands for optimal APC habitat (1.3); addition of habitat to the APCNWR (1.4.1); and partnerships with other agencies and NGOs through such programs as the CPCI, GLCI, EQIP, and LIP which provide landowner incentives for habitat restoration (1.4.2–1.4.8). Actions listed under 4.1 address the need for developing more support for APC recovery, including habitat restoration.

Factor 2: Overutilization for commercial, recreational, scientific, or educational purposes.

The hunting season for APCs has been closed since 1937. Actions 1.3.12 and 3.6 address disturbance and take issues, respectively, that may still remain. Action 4.1 provides for public outreach to raise awareness of the APC's plight and its presence in the coastal prairie ecosystem.

Factor 3: Disease or predation.

Disease. Action 1.3.11 provides for management of waterfowl on public lands where APC are present to minimize potential for disease transmission. Action 1.8.3 provides for evaluation of management practices at release sites. This action could include routine disease screening to assess potential interactions between habitat management and disease issues. Captive flock health issues are addressed in 2.1.1, 2.1.4, 2.1.6, 2.1.7, and 2.4.

Predation. Assessment and management of predation threats are addressed in actions 1.3.8, 1.3.9, 3.1, and 3.7. Action 1.8.3 provides for evaluation of management practices at release sites. This action could include evaluation of predator management.

Factor 4: Inadequacy of existing regulations.

In general, the current regulatory framework provides for adequate protection and conservation. Action 1.4.9 provides for coordination among government agencies to minimize the impact of programs that may be detrimental to APC recovery.

Factor 5: Other natural or manmade factors affecting its continued existence.

Population fragmentation. Reduction in the risk of extinction associated with the small, fragmented nature of APC populations is a major focus of this recovery plan. Practically the entire plan focuses on increasing the amount of usable APC habitat, providing for connectivity among habitat blocks to minimize isolation of populations,

and the restoration of APC populations to viable levels through management of wild and captive populations. Actions 1.1, 1.2, 1.3, and 1.4 involve the broad-scale maintenance, creation, and acquisition of interconnected, suitable grassland on private and public lands to help promote dispersal and genetic exchange. Actions under the heading of 1.3 (1.3.1 – 1.3.12) cover specific management activities to maintain, improve, or restore contiguous, native habitat, while minimizing competition and human disturbance. Actions 1.8.1 and 1.8.2 call for research to determine habitat needs across the landscape and to evaluate patch burning as a management tool to form suitable habitat.

Genetics. Maintenance of gene flow among population segments is addressed in action 1.2. Action 2.2 specifies determining and monitoring the genetic health of the captive population. This action also specifically directs the evaluation of APC genetic variability to determine if hybridization with GPCs is warranted as a recovery measure. Action 2.2 also directs consideration of APC gene banking. Action 3 provides for establishment of at least two self-sustaining core populations with gene flow between the populations. Action 3.4 lists translocation as a tool for genetic management of populations. Action 3.7 provides for research to determine factors that may influence wild brood and post-release survival. This research should include an assessment of genetic factors that may affect survival of broods and released birds.

Husbandry issues. Husbandry issues thought to be limiting APC recovery are addressed in all actions under the Action 2 heading (2.1 – 2.4.5). Specifically, these actions direct refinement of husbandry practices to increase production of physically and behaviorally healthy birds. Action 2.4 provides for research on issues currently limiting production including REV, egg production, chick survival, husbandry practices, skeletal/muscular problems, and parasite/disease management.

Poor brood survival. Action 3.7.1 specifically directs that research be conducted to determine factors affecting wild brood survival.

III. IMPLEMENTATION SCHEDULE

The following implementation schedule outlines and prioritizes recovery tasks over the next five years. It will be used in monitoring recovery actions and will provide the basis for funding for these actions. Actions are identified under general categories, and all headings are derived from Section II.C (Narrative Outline of Recovery Actions). This implementation schedule ranks objectives and actions, identifies respective responsible agencies/groups, defines implementation time-frames, and estimates costs. Actions must be continually revised as plans move from implementation to completion. Each revision will identify additional actions and studies that will be needed during the recovery period.

Recovery priorities are defined as follows:

Priority 1: An action that must be taken to prevent extinction or prevent the APC from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in APC populations or habitat quality or to prevent some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery (or reclassification).

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.1	Create a network of coastal prairie habitats containing multiple core areas	Ongoing	FWS-ES*, FWS-APCNWR*, TNC, USDA-NRCS, TPWD, Private, SHRC&D, GLCI	750	750	750	750	750	3,750	
1	1.2	Create interconnected grassland corridors of coastal prairie habitats between core areas to allow for dispersal and genetic exchange and hedge against environmental stochasticity	Ongoing	FWS-NWRS, FWS-ES*, TNC, TPWD, USDA-NRCS, Private, SHRC&D, GLCI	---	---	---	---	---	---	See also Action # 1.1 and 1.4.1 – 1.4.9
1	1.2.1	Cultivate partnerships on existing grasslands under public or NGO ownership	Ongoing	FWS-NWRS*, TNC, TPWD	---	---	---	---	---	---	See also Action # 1.1 and 1.4.1 – 1.4.9
1	1.2.2	Cultivate partnerships with private landowners	Ongoing	FWS-NWRS, FWS-ES*, TPWD, USDA-NRCS, TNC, SHRC&D, GLCI	---	---	---	---	---	---	See also Action # 1.4.2 – 1.4.9

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.3.1	Manage and initiate grazing on public lands to maintain clumped grass structure	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS	300	50	50	50	50	500	
1	1.3.2	Control brush and exotic plants on public lands	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS	150	150	150	150	150	750	
1	1.3.3	Conduct prescribed burning on public lands	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS	75	75	75	75	75	375	
1	1.3.4	Maintain/restore natural hydrology to reduce nest flooding on public lands	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS	25	25	25	25	25	125	
1	1.3.5	Maintain food plots to provide supplemental winter foods and brood habitat on public lands	Ongoing	FWS-NWRS*	5	5	5	5	5	25	
1	1.3.7	Restore formerly farmed fields to native grasses on public lands	Ongoing	FWS-NWRS*, USDA-NRCS	150	150	150	150	150	750	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.3.9	Control exotic wildlife species on public lands	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS, USDA-WS	50	50	50	50	50	250	
1	1.3.11	Manage waterfowl to minimize competition and disease	Ongoing	FWS-NWRS*, TPWD	5	5	5	5	5	25	
1	1.3.12	Control public use on public lands to prevent disturbance to APCs	Ongoing	FWS-NWRS*, TPWD	5	5	5	5	5	25	
1	1.4.1	Acquire at least 20,000 acres adjacent to APC NWR through a combination of fee simple and long-term easements from willing sellers	15 years	FWS-APCNWR*	2,000	2,000	2,000	2,000	2,000	10,000	See also Action # 1.1
1	1.4.2	Secure additional habitat through private land easements	15 years	FWS-NWRS, FWS-ES*, TNC, TPWD, Private,	---	---	---	---	---	---	See also Action # 1.1
1	1.4.3	Secure additional habitat through safe harbor agreements	15 years	FWS-NWRS, FWS-ES*, Private, SHRC&D, GLCI	---	---	---	---	---	---	See also Action #1.1

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.4.4	Secure additional habitat through Habitat Conservation Plans	15 years	FWS-NWRS, FWS-ES*, TPWD, USDA-NRCS, Private, SHRC&D, GLCI	---	---	---	---	---	---	See also Action # 1.1
1	1.4.5	Secure additional habitat through mitigation	Ongoing	FWS-NWRS, FWS-ES*, TPWD	20	20	20	20	20	100	See also Action # 1.1
1	1.4.6	Secure additional habitat through partnerships with other governmental, NGO, and private land managers	Ongoing	FWS-NWRS, FWS-ES*, TPWD, TNC, USDA-NRCS, Private, SHRC&D, GLCI	10	10	10	10	10	50	See also Action # 1.1
1	1.4.7	Secure additional habitat by pursuing other programs for private lands	Ongoing	FWS-NWRS, FWS-ES*, TPWD, USDA-NRCS, TNC, SHRC&D, GLCI	10	10	10	10	10	50	See also Action # 1.1

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.4.8	Secure additional habitat by providing technical assistance, economic incentives, and regulatory incentives on private lands through the CPCI program	Ongoing	FWS-NWRS, FWS-ES*, TNC, TPWD, USDA-NRCS, Private, SHRC&D, GLCI	---	---	---	---	---	---	See also Action # 1.1
1	1.4.9	Coordinate with NRCS and other governmental agencies to resolve conflicting programs that are detrimental to APC recovery	Ongoing	FWS-NWRS, FWS-ES*, USDA-NRCS, TPWD, SHRC&D, GLCI	10	10	10	10	10	50	See also Action # 1.1
1	1.6	Cultivate market-driven financial incentives for private landowners that establish and maintain APC populations on their lands	Ongoing	FWS-APCNWR, FWS-ES, TNC, TPWD*, USDA-NRCS, Private, SHRC&D, GLCI	10	10	10	10	10	50	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	1.7	Focus recovery actions in priority management zones	Ongoing	FWS-NWRS*, FWS-ES, TNC, TPWD, USDA-NRCS, SHRC&D, GLCI	---	---	---	---	---	---	
1	1.8.3	Conduct research to evaluate current management practices at release sites	5 Years	FWS-NWRS*, FWS-ES TNC, private	75	75	75	75	75	375	
1	2.1.4	Aggressively manage diseases and other health issues	Ongoing	FWS-APCNWR*, BFs	425	125	125	125	125	925	Critical Need
1	2.1.6	Evaluate diet for chicks and adults to help address problems that may be arising from current diets	5 years	FWS-APCNWR, BFs, FWZ*,SARC, STCP	25	25	25	25	25	125	Critical Need
1	2.2	Determine and continually monitor genetic health of the captive flock	1 year, ongoing	FWS-APCNWR*, STCP*, BFs	65	15	15	15	15	125	Critical Need

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	2.3	Increase production of birds through increased efficiency at current facilities and the addition/expansion of breeding facilities to allow for a capacity of 100 pairs, with no facility containing more than 25% of the captive flock population	5 years	FWS-APCNWR*, BFs	900	900	500	500	500	3,300	Critical Need
1	2.4.1	Conduct research to determine factors affecting captive breeding, such as REV	5 years	FWS-APCNWR, TAMU*, UofG	50	50	50	50	50	250	Critical Need
1	2.4.2	Conduct research to determine factors affecting egg viability and chick survival	3 years	FWS-APCNWR*, BFs	40	40	40	---	---	120	
1	2.4.3	Conduct research to determine best rearing environments/methods	3 years	FWS-APCNWR*, BFs	40	40	40	---	---	120	
1	2.4.4	Conduct research to determine factors affecting skeletal/muscular problems	3 years	FWS-APCNWR*, BFs	40	40	40	---	---	120	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	2.4.5	Conduct research to determine how to best manage for parasites in the captive setting	3 years	FWS-APCNWR*, BFs	40	40	40	---	---	120	
1	3.1	Evaluate release techniques and implement changes as needed	10 years	APCNWR*, TNC	100	100	100	100	100	500	
1	3.2	Survey APC numbers annually	Ongoing	FWS-APCNWR*, TNC, TPWD	5	5	8	10	10	38	
1	3.3	Expand the release of captive-bred APCs where suitable habitat exists	Annually as captive produc-tion permits	FWS-APCNWR*, FWS-NWRS, TNC, TPWD, -USDA-NRCS, Private, SHRC&D, GLCI	150	75	75	75	75	450	See Action # 1.1
1	3.5	Utilize procedures such as safe harbor, HCPs, etc. for establishing additional populations	5 years	FWS-APCNWR, FWS-ES*	25	25	25	25	25	125	
1	3.6	Protect APC from take by enforcing current Federal and State legislation and regulations	Ongoing	FWS-NWRS, FWS-ES, FWS-LE*, TPWD	10	10	10	10	10	50	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
1	3.7.1	Conduct research to determine factors affecting wild brood survival	5 years	FWS-APCNWR*, TNC	60	60	60	60	60	300	Critical Need
1	3.7.2	Conduct post-release survival research	10 years	FWS-APCNWR	75	75	75	75	75	375	
2	1.3.6	Mow to control vegetation density on public lands	As needed	FWS-NWRS*, TPWD, USDA-NRCS	15	15	15	15	15	75	
2	1.3.10	Prohibit the introductions of exotic wildlife species on public lands	As needed	FWS-NWRS*, TPWD	2	2	2	2	2	10	
2	1.4.10	Acquisition of grassland additions to existing national wildlife refuges	On-going	FWS-NWRS*	---	---	---	---	---	---	Costs included in Action # 1.1
2	1.5	Survey status and trends of native grasslands.	Once every 5 years	FWS-APCNWR, FWS-ES*, TNC, TPWD, USDA-NRCS	--	75	---	---	---	75	
2	1.8.1	Conduct research to determine landscape scale habitat needs	5 years	FWS-APCNWR	75	75	75	75	75	375	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
2	1.8.2	Conduct research to evaluate patch burning as a management tool	5 years	FWS-APCNWR*, USDA-NRCS	50	50	50	50	50	250	
2	2.1.1	Evaluate and implement the use of different rearing techniques to generate physically and behaviorally healthy birds	5 years	FWS-APCNWR*, BFs	25	25	25	25	25	125	
2	2.1.2.2	Use the expertise of a particular breeding facility to their fullest extent	Ongoing	FWS-APCNWR*, BFs	---	---	---	---	---	---	
2	2.1.7	Complete husbandry manual to standardize husbandry techniques and strategies	1 year, ongoing	FWS-APCNWR*, BFs	10	2	2	2	2	18	
2	2.1.8	Evaluate screening pens which house the breeding flock to minimize risk of REV transmission by insects	5 years	FWS-APCNWR*, BFs	25	25	25	25	25	125	
2	3.4	Evaluate translocation of birds as a possible technique for repatriation and genetic management of existing populations	In 3 years as popula-tions permit	FWS-APCNWR*, TNC, STCP	---	---	20	20	20	60	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
2	4.1.2	Assist in the establishment of an APC partner coalition hosted by an NGO and dedicated to supporting APC recovery objectives.	5	FWS*, NFWF	125	---	---	---	---	---	
3	1.3.8	Monitor and manage sympatric wildlife species on public lands	Ongoing	FWS-NWRS*, TPWD, USDA-NRCS	20	20	20	20	20	100	
3	2.1.2.1	Maximize effectiveness and production of current captive flock though the use of photo-period manipulation	Ongoing	FWS-APCNWR* , BFs	10	10	10	10	10	50	
3	2.1.3	Identify and rectify disturbance issues at breeding facilities	5 years	FWS-APCNWR*, BFs	10	10	10	10	10	50	

Priority #	Action #	Action Description	Action Duration (years)	Responsible Parties (* = lead)	Cost Estimate ($1,000)						Comments
					Year 1	Year 2	Year 3	Year 4	Year 5	Total	
3	2.1.5	Share resources and information among all captive breeding facilities and other partners involved with recovery	Ongoing	FWS-APCNWR*, FWS-NWRS, FWS-ES, FWS-LE, TAMU, STCP, TPWD, TNC, BFs, USDA-NRCS, FWZ, USDA-WS, UofG, Private, SHRC&D, GLCI, SARC	10	10	10	10	10	50	
3	4.1.1	Contract with consulting group to develop specific marketing strategies to effectively and efficiently engage the public in APC recovery.	5 Years	FWS-APCNWR*, FWS-NWRS, FWS-ES, TPWD, TNC, USDA-NRCS, BFs, SHRC&D, GLCI	100	50	50	50	50	300	

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APPENDIX 1. Attwater's prairie-chicken 1937–2006 population estimates by Texas county. Data are from Jurries (1979) (1937–1977) and Attwater Prairie Chicken National Wildlife Refuge and Texas Parks and Wildlife Department (unpublished data) (1978–present).

	Year														
County	1937	1950	1963	1967	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Aransas	1212	902			35	30	10	10	15	14	50	96	35	50	76
Austin	339	200	200	200	284	332	364	330	292	576	498	186		308	326
Brazoria	948	53			20	20	20	40	20	20	20	20		20	20
Calhoun	25	40	15	10											
Chambers	220	15		10	2			6	8	8					
Colorado	926	350	200	175	186	378	166	144	150	422	324	178		206	186
DeWitt	272		80		12	12	12	12	6	8	8	8			
Fort Bend	10		30	35	22	26	92	136	114	148	96	80		78	54
Galveston	332	35	90	130	96	50	148	238	166	100	140	124		132	96
Goliad	4		23	75	216	402	290	260	486	188[a]	164	80		56	34
Harris	261	123	140	120	78	56	92	92	112	58	16	24			2
Jackson	35	10													
Jefferson	220	85		10											
Lavaca	93[b]														
Liberty	10														
Matagorda	15	5													
Refugio	3030	2100	412	175	310	440	166	192	356	336	530	550		742	726
Victoria	620	200	100	90	112	234	166	224	242	342	218	110		126	64
Waller	64	32	15		20	26	26	26	10	10	10	30			
Wharton	75	50	30	40	76	214	108	72	42	24	16	20			
Total	8711[b]	4200	1335	1070	1469	2220	1660	1782	2019	2254	2090	1506	1500[c]	1718	1584

County	Year													
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Aransas	20	19	22	24	16	22	10	12	6	2	2			
Austin	234	246	292	198	114	116	150	106	46	36	48	54	26	10
Brazoria	20	20												
Calhoun														
Chambers														
Colorado	184	280	320	218	246	228	242	162	90	90	70	50	34	20
DeWitt														
Fort Bend	44	48	54	38	32	38	16	8	4	2				
Galveston	110	104	66	74	36	48	38	30	16	26	30	26	24	18
Goliad	100	62	84	114	78	34	16	12	4	12	8	0	2	
Harris	4													
Jackson														
Jefferson														
Liberty														
Matagorda														
Refugio	658	438	646	838	810	340	582	562	246	292	310	330	370	110
Victoria	64	64	112	116	94	48	54	34	20	10	8	2		
Waller														
Wharton														
Total	1438	1281	1596	1620	1426	874	1108	926	432	470	476	462	456	158

County	Year											
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Aransas												
Austin	2											
Brazoria												
Calhoun												
Chambers												
Colorado	10	14[d]	24[d]	8[d]	18[d]	20[d]	20[d]	22[d]	42[d]	40[d]	20[d]	32[d]
DeWitt												
Fort Bend												
Galveston	16	10	22[d]	36[d]	28[d]	30[d]	24[d]	18[d]	16[d]	22[d]	20[d]	18[d]
Goliad												
Harris												
Jackson												
Jefferson												
Liberty												
Matagorda												
Refugio	40	18	12	12								
Victoria												
Waller												
Wharton												
Total	68	42[d]	58[d]	56[d]	46[d]	50[d]	44[d]	40[d]	58[d]	62[d]	40[d]	50[d]

[a]Incomplete survey
[b]Jurries (1979) did not include Lavaca County which accounts for a 93 bird discrepancy between his 1937 state total and that reported by Lehmann (1941).
[c]Estimate only - survey incomplete
[d]Totals include birds released from captive breeding program

APPENDIX 2. LIST OF ABBREVIATIONS AND ACRONYMS

ac	acre
APC	Attwater's prairie-chicken
APCNWR	Attwater Prairie Chicken National Wildlife Refuge
BFs	APC Captive Breeding Facilities (includes Fossil Rim Wildllife Center, Houston Zoo, Inc., San Antonio Zoo, Abilene Zoo, Caldwell Zoo, Sea World of Texas)
CFR	Code of Federal Regulations
cm	centimeter
DNA	deoxyribonucleic acid
DVM	Doctor of Veterinary Medicine
EQIP	Environmental Quality Incentive Program
ESA	Endangered Species Act
FR	Federal Register
ft	foot
FWS-APCNWR	U. S. Fish and Wildlife Service – Attwater Prairie Chicken National Wildlife Refuge (NWR)
FWS-ES	U. S. Fish and Wildlife Service – Ecological Services
FWS-LE	U. S. Fish and Wildlife Service – Law Enforcement
FWS-NWRS	U. S. Fish and Wildlife Service – National Wildlife Refuge System (Includes Attwater Prairie Chicken NWR, Aransas Refuge Complex, and Texas Mid-Coast Refuge Complex)
FWZ	Fort Worth Zoo
GLCI	Grazing Lands Conservation Initiative
GPC	Greater prairie-chicken
ha	hectare
km	kilometer
lbs	pounds
LIP	Landowner incentive program
mi	mile
N_e	effective population size
NFWF	National Fish and Wildlife Foundation
NGO	Non-governmental organization
NRCS	U. S. Natural Resources Conservation Service
oz	ounces
PCR	polymerase chain reaction
Private	Private landowners
SSP	Species Survival Plan
TAC	Texas Administrative Code
TAMU	Texas A&M University
TCPP	Texas City Prairie Preserve
TNC	Nature Conservancy of Texas
TPWD	Texas Parks and Wildlife Department
SHRC&D	Sam Houston Resource Conservation and Development

STCP	Society of Tympanuchus Cupido Pinnatus
UofG	University of Georgia
USDA- NRCS	U. S. Department of Agriculture – Natural Resources Conservation Service
USDA-WS	U. S. Department of Agriculture – Wildlife Services
USFWS	U. S. Fish and Wildlife Service

APPENDIX 3. GLOSSARY OF TERMS

aflatoxin Toxin produced by certain fungi. Contaminated food products include cereal grains (e.g., corn, sorghum, millet, rice, wheat), oilseeds (e.g., soybeans, sunflowers, cotton), spices, nuts, and milk (Reddy and Waliyar (2000).

allele Form of a gene at a particular locus (http://www.dna.gov/glossary).

allelic dropout Failure to detect an allele within a sample or failure to amplify an allele during PCR (http://www.dna.gov/glossary). Basically, allelic dropout is a failure to detect alleles within a sample that are actually present. This may be caused by degraded DNA within the sample, or by problems with testing procedures.

booming ground Areas where male Attwater's and greater prairie-chickens gather to display in an attempt to attract females for breeding.

capillariasis Parasitic disease caused by roundworms of the genus *Capillaria*.

chromosome The biological structure by which DNA is transmitted from one generation to the next (http://www.dna.gov/glossary).

DNA Genetic material present in the nucleus of cells which is inherited from each biological parent (http://www.dna.gov/glossary).

dispharynxiasis Parasitic disease caused by the spiral stomach worm (*Dispharynx nasuta*).

effective population size The number of adults in a population contributing offspring to the next generation. Generally, effective population size is smaller than the census size, and sometimes much smaller (http://wiki.cotch.net/index.php/Effective_population_size).

etiology The assignment of a cause, origin, or reason for something. The cause of a disease or disorder as determined by medical diagnosis.

gene The basic unit of heredity; a functional sequence of DNA in a single chromosome (http://www.dna.gov/glossary).

genetic similarity indices Quantitative measures of genetic variability.

genotype The genetic constitution of an organism as distinguished from its physical appearance (http://www.dna.gov/glossary).

haplotype A way of denoting the collective genotype of a number of closely linked loci on a single chromosome (http://www.dna.gov/glossary).

heterozygosity Heterozygosity refers to the state of being a heterozygote (i.e., possesses two different alleles at one locus) . Heterozygosity can also refer to the fraction of loci within an individual that are heterozygous. In population genetics, it is commonly extended to refer to the population as a whole, i.e. the fraction of individuals in a population that are heterozygous for a particular locus (http://en.wikipedia.org/wiki/Zygosity).

inbreeding depression **Inbreeding depression** is reduced fitness in a given population as a result of breeding of related individuals (http://en.wikipedia.org/wiki/Inbreeding_depression).

lineage sorting Term describing the development of monophyly by genetic drift during the speciation process.

locus (plural loci) The specific physical location of gene on a chromosome (http://www.dna.gov/glossary).

mesocarnivores Medium-sized carnivores (e.g., coyote, fox, raccoon, skunk) as contrasted to larger carnivores (e.g., wolf, bear, lion).

mitochondrial DNA (mtDNA) The DNA found in the many mitochondria found in each cell of the body. The sequencing of mtDNA can link individuals descended from a common female ancestor (http://www.dna.gov/glossary).

monophyly A term which refers to a taxon comprised of members derived from a common ancestor which includes all descendants (http://wiki.cotch.net/index.php/Monophyly).

outbreeding depression Refers to cases when progeny from crosses between individuals from different populations have lower fitness than progeny from crosses between individuals from the same population (http://en.wikipedia.org/wiki/Outbreeding_depression).

phylogenetics The study of evolutionary relatedness among various groups of organisms (http://en.wikipedia.org/wiki/Phylogenetics).

polymerase chain reaction (PCR) **Polymerase chain reaction** (**PCR**) is a biochemistry and molecular biology technique for enzymatically replicating DNA without using a living organism (http://en.wikipedia.org/wiki/Polymerase_chain_reaction).

prairie An extensive area of flat or rolling grassland.

***r*-selected** In ecological notation, "*r*" refers to the rate of population growth per individual for a given time period, whereas "*K*" refers to the upper limit (carrying capacity) of an environment to support a population of individuals. Therefore, *r*-selected species have evolved life history strategies for rapid growth (quanity) as contrasted with *K*-selected species, which have evolved mechanisms that allow them to compete for resources when populations are near *K* (quality). *R*-selected species typically have high reproductive rates with relatively short life cycles (i.e., high mortality rates) (Odum 1971).

reciprocal monophyly Taxons of comparison are each monophyletic.

stochastic Random or statistical in nature.

taxon A group of organisms constituting one of the categories or formal units in taxonomic classification (e.g., phylum, order, family, genus, or species) and characterized by common characteristics in varying degrees of distinction.

viremic The presence of viruses in the bloodstream.

wryneck An unnatural condition in which the head leans to one side because the neck muscles on that side are contracted (http://www.thefreedictionary.com/wryneck).

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