

Status of White-tailed Deer in the Stairsteps Unit of Big Cypress National Preserve

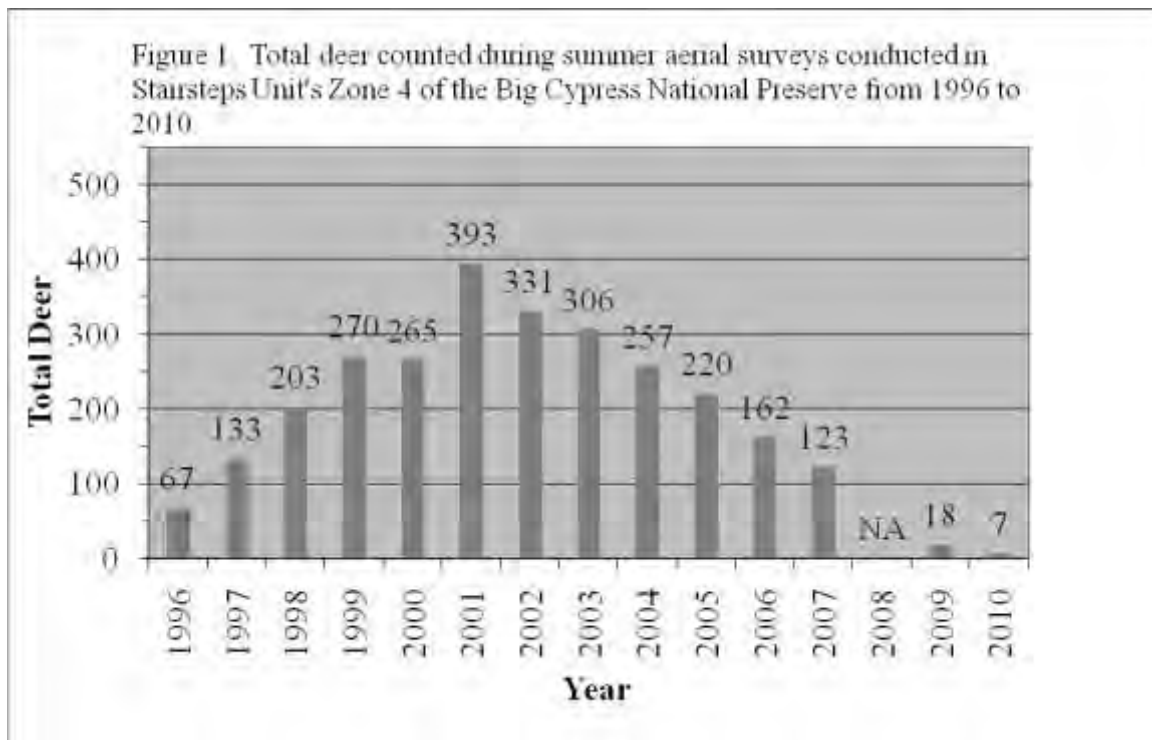
May 18, 2011

Purpose

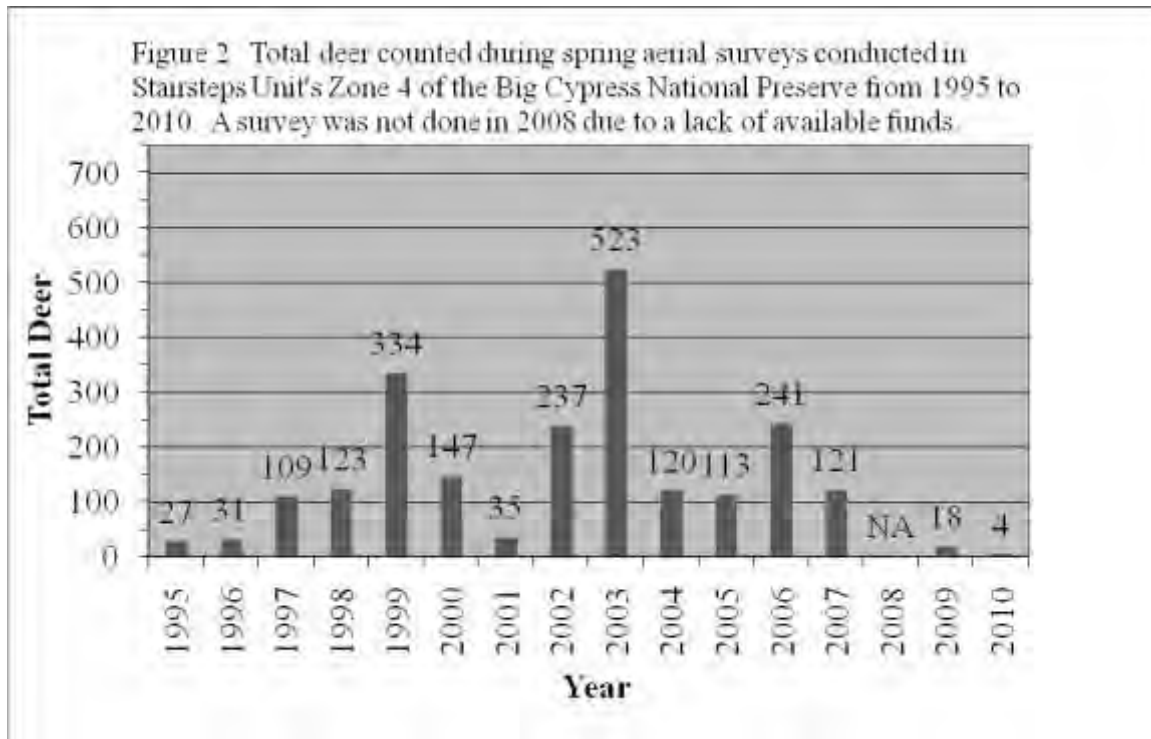
To provide available information regarding the current status of white-tailed deer within the Stairsteps Unit of the Big Cypress National Preserve (BCNP; Appendix 1).

Available Data

Aerial deer count surveys have been conducted annually since 1995 by BCNP staff on the Stairsteps Unit with the exception of 2008, when funds were unavailable. Transects are surveyed by helicopter. The aerial counts are conducted twice each year; once in the spring (usually May) and once in the summer (July or August). The spring counts are intended to measure fawn to doe ratios, and the summer counts are to determine adult buck to doe ratios, but they may also be used to track deer population trends. Summer counts generally increased between 1996 and 2001, then declined to a low of 7 in 2010 (Figure 1). Spring counts were more erratic, but were lowest in 2010 (Figure 2). The 2011 surveys have not been conducted.



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The FWC initiated aerial surveys within the Stairsteps Unit during the spring of 2010 to gather additional information regarding deer densities. The 2010 FWC aerial surveys conducted from a helicopter in April through June using line transect methods, resulted in a population estimate of 21 deer for zone 4 and 27 deer for zones 2 and 4 combined.

BCNP is established as a Wildlife Management Area (WMA), and hunting on the area is regulated and managed by the Florida Fish and Wildlife Conservation Commission (FWC). Deer hunting in the Stairsteps Unit of BCNP is a long-standing tradition. Historically, access was unlimited, and hunters were able to reach the most remote areas of the unit using airboats and ORVs. Beginning in 2000, a designated trail system was established and access to the area was limited to designated trails. Hunting remains a popular recreational activity in the Stairsteps Unit. The hunting season includes a 30-day archery season, a 16-day muzzleloading gun season and a 51-day general gun season. Only antlered deer (deer with at least one antler, 5 inches or more in length) may be harvested with a daily bag limit of 1 and a combined season bag limit of 2. Therefore, the maximum number of deer a hunter could harvest during the archery, muzzleloading gun and general gun seasons combined is 2 antlered deer.

Deer harvested in the Stairsteps Unit must be reported to the FWC by checking the deer in at a check station. In the past, zone-specific harvest data were not collected. Beginning with the 2009-2010 season, harvest and hunter effort is being documented by zone. For this report, harvest data for the entire unit was evaluated to determine harvest trends. The total reported deer harvest for the Stairsteps Unit has decreased from the 2000-2001 season to the 2009-2010 season (Figure 3). Prior to the 2000-2001 season, deer harvest was variable, but was higher than in recent years. Some variation in harvest can be explained by area closures enacted due to high water levels (Table 1). However,

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the number of deer harvested per 100 hunter-days of effort has also decreased in recent years (Figure 4).

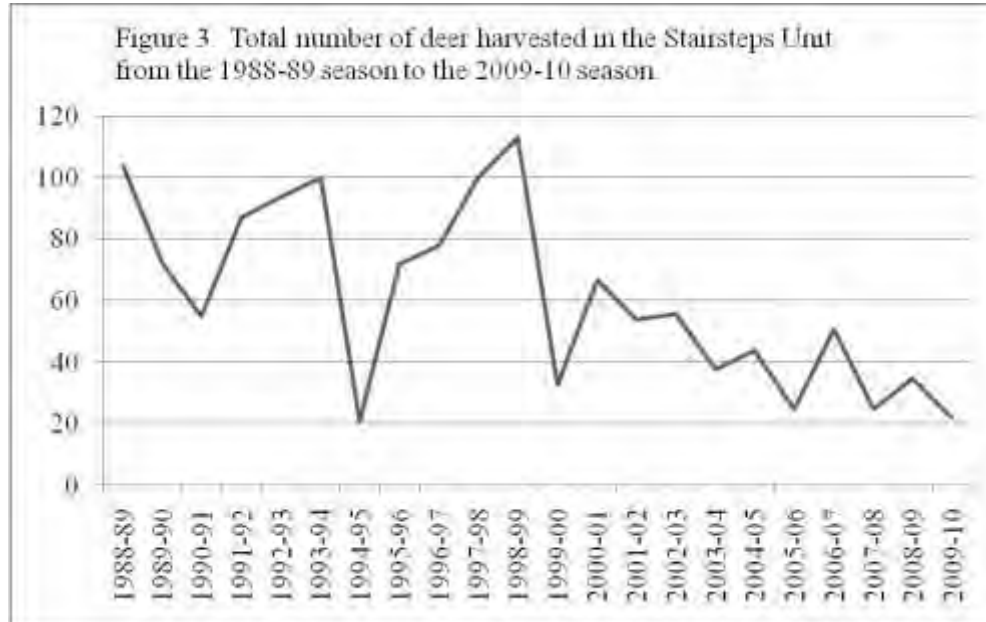
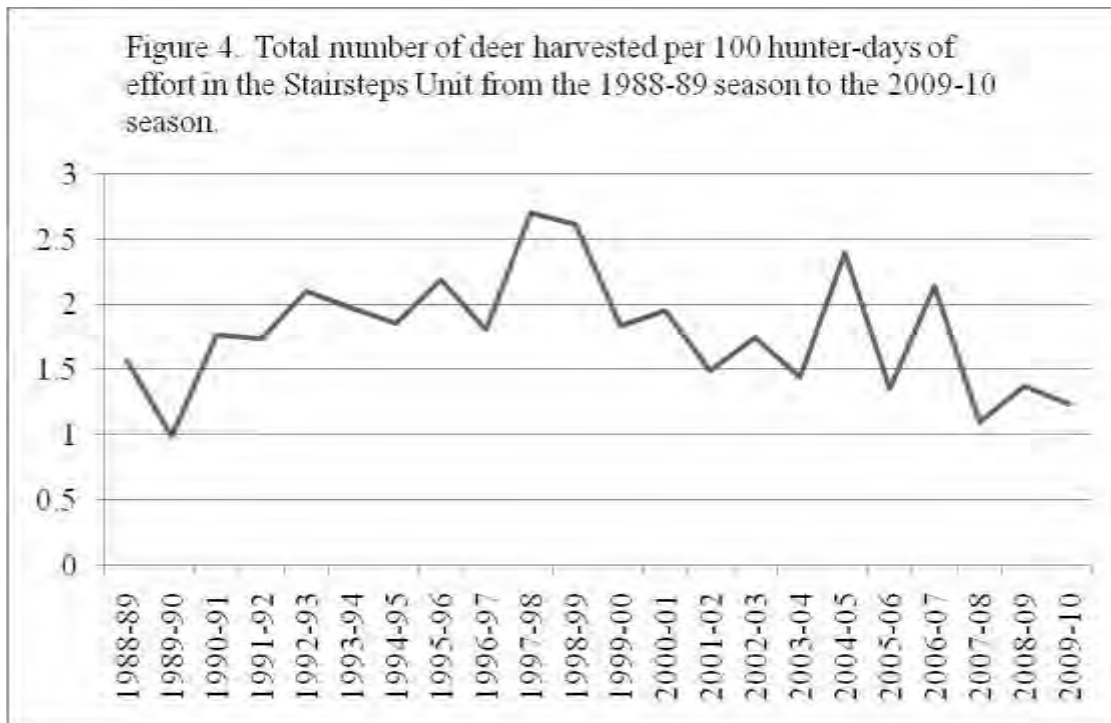


Table 1. Changes to the length of deer hunting seasons on BCNP based on calendar year changes and high water events.

Season	Change
1990-1991	Overall season reduced by 5 days and designated trails for Lostman's Pines area of Stairsteps Unit.
1992-1993	Overall season increased by 3 days and partial closures due to high water.
1993-1994	Overall season increased by 3 days.
1994-1995	General gun season was closed in Stairsteps and Loop units.
1995-1996	Restricted harvest - Portions of Stairsteps Unit closed for muzzleloading gun. Stairsteps Unit closed for general gun until Dec 23.
1996-1997	General gun season increased by one day.
1997-1998	Decreased overall season by 3 days.
1998-1999	Increased overall season by 3 days and partial closure during archery season due to high water.
1999-2000	Full closure in Stairsteps and Loop units during muzzleloading gun. Full closure in Stairsteps and Loop units during general gun season.
2000-2001	Designated trails enacted in Stairsteps Unit.
2004-2005	Closure due to Hurricane Francis and Ivan and affected all units during archery season.
2005-2006	Closure in Loop and parts of Zones 3 and 4 of the Stairsteps Unit due to high water and Hurricane Wilma and affected all of muzzleloading gun season.
2010-2011	The take of deer not allowed in Zones 3 and 4 of the Stairsteps Unit due to low density estimates.

Status of Deer in the Stairsteps Unit



In summary, hunters have reported seeing fewer deer in the Stairsteps Unit in recent years. Deer counts from summer helicopter surveys conducted by BCNP staff have resulted in fewer deer being observed each year since 2001 in zone 4 of the Stairsteps Unit. Counts from spring helicopter surveys conducted since 1995 were lowest in 2010. The reported harvest of antlered deer has decreased from the 2000-2001 season to the 2009-2010 season, and hunter effort to harvest a deer has been increasing. All of the available data indicate a declining deer population that has reached a very low density. FWC and BCNP staff agreed that the taking of deer should not be allowed in Zones 3 and 4 of the Stairsteps Unit during the 2010-2011 hunting season. This measure was taken as a precaution while FWC and BCNP staff continued to investigate potential causes of the decline.

Possible Causes of Declining Deer Densities

A number of hypotheses have been proposed as causes of declining deer abundance in the Stairsteps Unit. The list includes high water levels, which could impact survival of adult and, especially, fawn deer; infectious diseases and parasites, harvest (particularly illegal or unintentional harvest of does); predation; habitat changes; or interactions among several of these factors.

Hydrology - Water level data for the Stairsteps Unit were analyzed a number of ways in an effort to detect correlations between water levels and declining deer densities (Appendix 2). The number of high water events has increased significantly since 1996 and fawn survival may have been impacted by these high water events. Previous studies have found that the recruitment of fawns can be negatively influenced by high water levels. The influence of high water events on fawn survival is likely to result in limited mobility, reduced forage ability and increased vulnerability to predation or diseases. Higher water levels have been occurring in the Stairsteps Unit since 1995. Changing

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habitat conditions also have been mentioned as a possible reason for the deer decline. Ross et al. (2004) indicated that vegetation in the Stairsteps Unit transitioned from wet prairie to marsh beginning in the mid-1990s. Wet prairies were preferred forage habitat by adult females in the Stairsteps Unit (Labisky et al. 1995). Labisky et al. (1995) stated that adult female preference for wet prairie habitats may have been a strategy to avoid predation on their fawns as these habitats are open and it would be difficult for predators to ambush fawns. In addition, some area users believe that airboat trails within the Stairsteps Unit have more preferred browse species than surrounding marsh habitats. Accordingly, with the loss of many miles of airboat trails due to BCNP's designated trail system, the vegetation on the unused old trails would have reverted, reducing the amount of browse and limiting the area's productivity as deer habitat.

Predation - Predation as a factor in the deer decline is difficult to document, particularly since there are a number of predators that will take deer. Possible predators of deer in the Stairsteps Unit would include bobcats, panthers, pythons, bears, alligators and possibly coyotes. Although a number of potential predators are found in the Stairsteps Unit, pythons, bears and alligators would likely consume only an occasional deer. Coyotes have been reported to be in the northern portions of the Stairsteps Unit, but an established coyote population has not been documented. Previous studies in BCNP have shown that bobcats can be a significant source of mortality for deer. During a radio-telemetry study conducted from 1987 to 1991, 26 of the 57 marked deer died during the study (Land 1991). Of these, 10 were taken by bobcats, 4 by panthers, 1 by an alligator, 4 deer died of natural causes, 5 were harvested (3 legally, 2 illegally), and 2 died of unknown causes (Land 1991). The average annual survival rate was 81% with 64% of the annual mortality attributable to predation. Another study conducted in Everglades National Park and the Stairsteps Unit showed that predation, primarily by bobcats, accounted for a significant portion of fawn mortality (Labisky et al. 1995). Much has changed since these studies were conducted. As noted earlier, water levels have increased and the duration of high water events has increased. This would likely reduce the amount of available fawning habitat, sometimes limiting it to tree islands, making it easier for predators to locate fawns. In addition, the thick habitat found on tree islands (as compared to wet prairie) would allow for predators to more easily ambush both adult and fawn deer. Also, panther numbers have increased throughout their range since the mid-1990's (Figure 5). There was very little sign of panthers south of Hwy 41 prior to the mid-1990s, but several panthers have more frequently used this area of BCNP since the late-1990s (Land personal communication). However, a single panther's home range would be larger than the Stairsteps Unit suggesting that their pressure on prey items would be distributed over a larger geographic area beyond the Stairsteps Unit.

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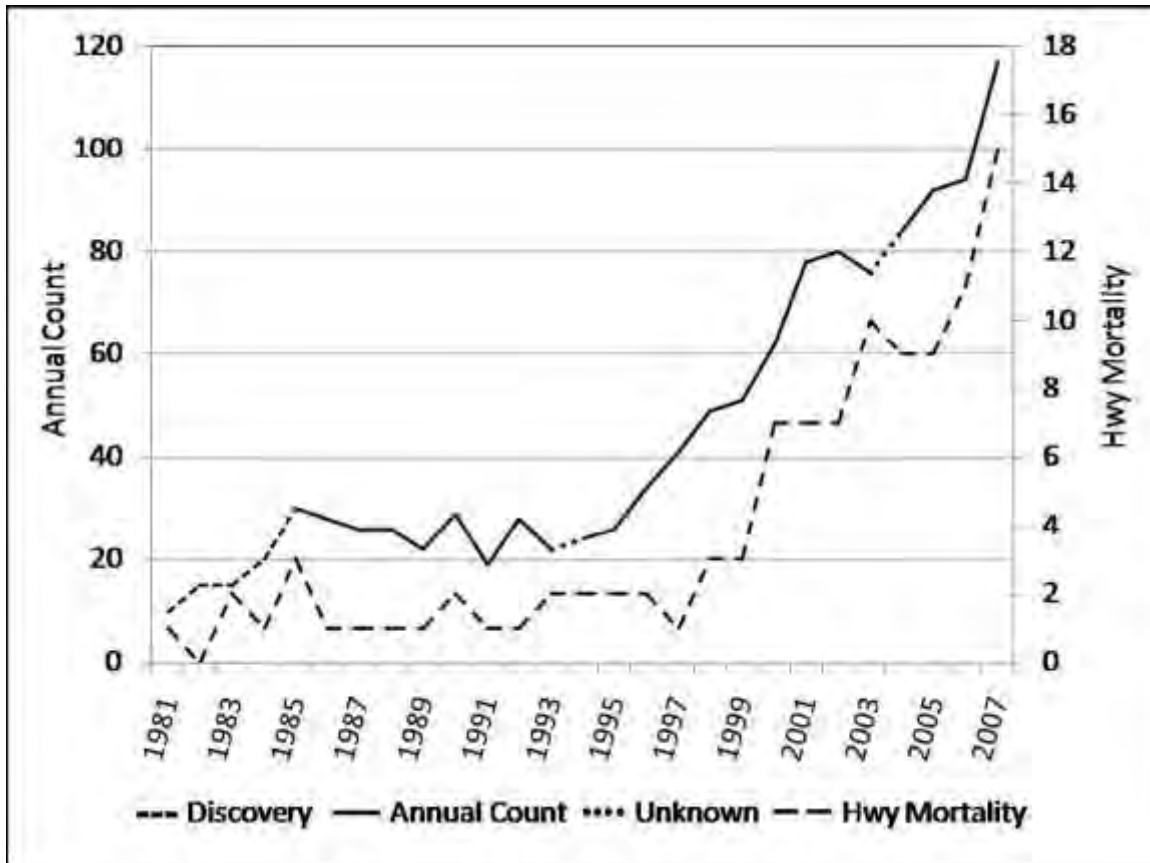


Figure 5. A comparison of the annual count to annual highway mortalities of Florida panthers. The number of annual highway mortalities is derived from FWC unpublished data. This figure demonstrates similar trends in both indices (McBride et al. 2008).

Hunting – Hunting has historically occurred throughout the Stairsteps Unit. While deer densities have fluctuated over time, extremely low densities similar to those that are present today have not been documented previously. There is a low risk of hunters negatively impacting the reproductive potential of a deer population with a buck-only harvest regime. Deer are polygamous, and a single buck can breed many does. Further, the Stairsteps Unit hunting season has historically occurred after the area’s breeding season meaning that most does would have been bred prior to the onset of the hunting season (Labisky et al. 1995). Population models developed by Labisky et al. (1995) indicated that a high or low harvest of the buck population had little impact on the ability of the population to sustain itself. However, these models did indicate that any increase in adult doe or fawn mortality, including illegal harvest, could result in a declining deer population.

Other factors – A number of other factors have been suggested as possible causes of the deer decline. Disease and parasites can affect deer populations. However, there is no indication that the Stairsteps Unit deer herd has experienced any significant die-offs due to disease, parasites or malnutrition. Aerial surveys seem to indicate a steady decline in deer densities over time. Severe die-off events usually occur in noticeable spikes, which have not been observed in the Stairsteps Unit and are not apparent in survey numbers.

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However, due to limited access, evidence of small numbers of dead deer may have gone undiscovered.

Conclusion - The reproductive potential of a deer population is dependent on breeding age females, and population growth is dependent on recruitment. Recruitment of fawns into the 1.5 year old age class when they would become reproductively mature is critical for population maintenance or growth. In two studies in BCNP conducted in the late 1980s and early 1990s, fawn survival was low, primarily due to predation from bobcats. Labisky et al. (1995) noted that a population crash was likely in the deer population that was studied in Everglades National Park based on heavy predation of fawns. During this three-year study, none of the radio-tagged fawns survived long enough to reach reproductive maturity. This area was adjacent to Zone 4 of the Stairsteps Unit. Labisky et al. (1995) modeled the deer populations within the Stairsteps Unit and adjacent Everglades National Park using information gathered during the study. These mathematical models included information such as the annual survival rate for fawns and adult deer and the reproductive potential for each adult doe. These models suggested that minor reductions in fawn survival or adult doe survival would result in a declining deer population. According to these models, changes in adult male survival rates had little impact on the ability of the population to sustain itself suggesting that buck-only hunting is sustainable. Based on these findings and this assessment of recent and current conditions, FWC staff believes that fawn, and to a lesser extent, adult female deer survival likely has been decreased by high water events, habitat changes and high predation rates acting synergistically and resulting in a population decline to the current levels. If the trends in these conditions reverse in the future, deer reproductive potential likely would increase and numbers would likely rebound.

Moving Forward

FWC and BCNP staffs will continue to monitor the deer population within the Stairsteps Unit to determine population trends. Aerial surveys will be conducted annually. In addition, check station staff will continue to collect tissue samples and body measurements to assess deer condition and monitor for health problems. Harvest management will be reviewed to determine what opportunities for deer hunting could be allowed while minimizing any possible effects on the reproductive potential of the deer herd.

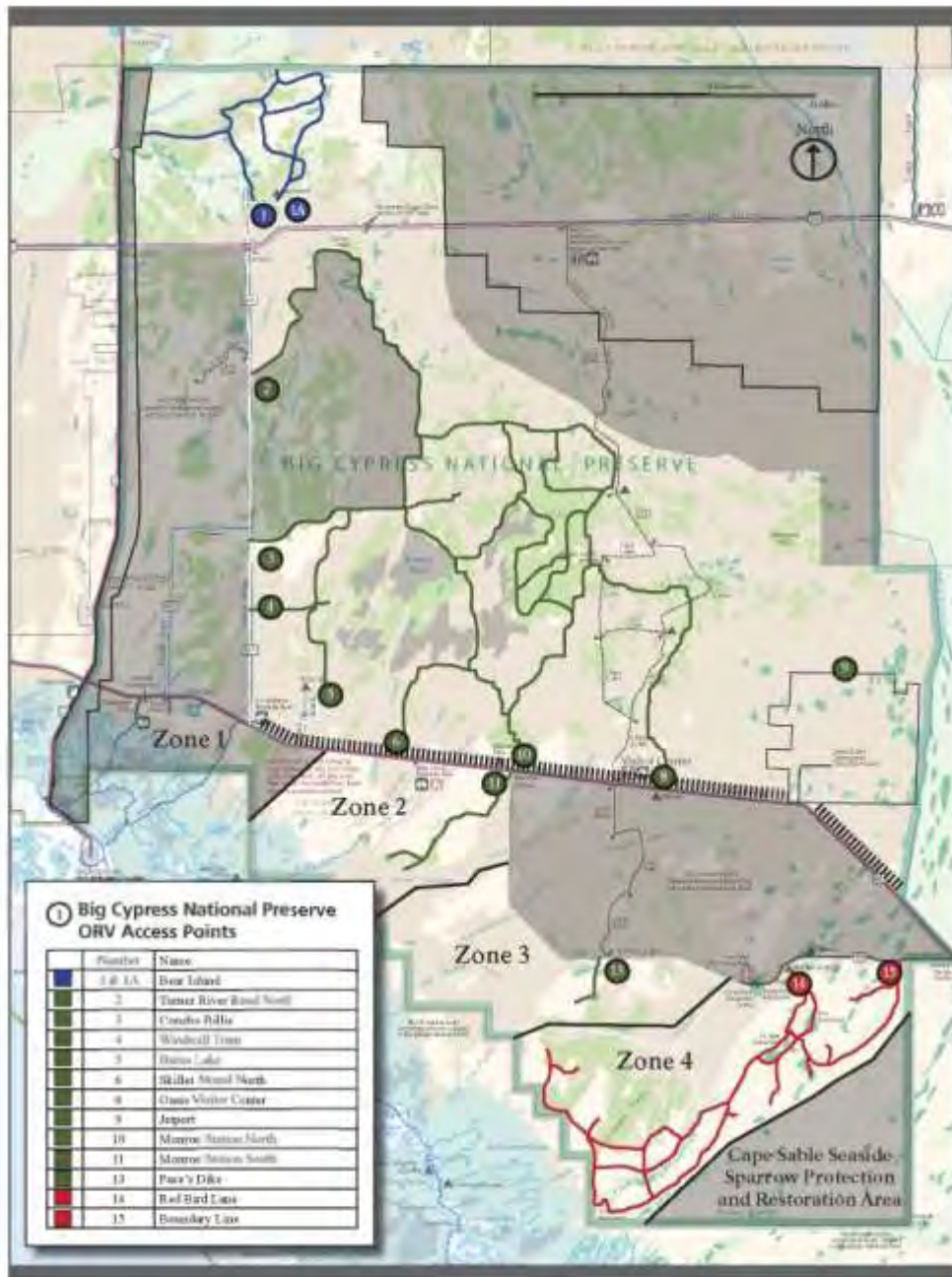
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Appendix 1. Access map for Big Cypress National Preserve.



Big Cypress National Preserve ORV Access

- ORV Access Point
- Airboat Access Trails
- Swamp Boggy, ATV, and Street Legal 4x4 Trails
- Swamp Boggy and ATV Trails
- Closed to ORV Use
- US 41 Buffer Zone

This map is for reference only. Use topographic maps for navigation and orienting.

ORV Table Page 004a BDC/STC/STP Revised 12/2004 - English 8 permits version

ORV travel in open areas south of I-75 and north of US 41, is dispersed use until trails are designated. Prairies are closed to ORVs. This area is accessible to swamp buggies and ATVs only.

Travel in Zones 2, 3 and 4 is along designated primary and secondary trails only.

Appendix 2. Preliminary Analysis of Hydrological Impacts on Harvest in the Big Cypress National Preserve Stairsteps Unit.

Analysis of Hydrological Impacts on White-tailed Deer in the Stairsteps Unit, Big Cypress National Preserve

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Introduction:

The white-tailed deer (*Odocoileus virginianus seminolus*) population in the Stairsteps Unit of Big Cypress National Preserve (BCNP) has declined during the past decade. The decline has been observed in the number of deer harvested in the Stairsteps Unit and the number of deer observed during National Park Service (NPS) and Florida Fish and Wildlife Conservation Commission (FWC) aerial surveys. In addition, hunters have voiced concerns about observing lower than normal deer densities, particularly in Zone 4. Several hypotheses have been suggested to explain the decline, including high water levels, predation, infectious diseases and parasites, legal and illegal harvest of deer (particularly illegal or inadvertent harvest of does), habitat degradation, and a combination of these factors.

Deer in the BCNP are impacted by unique environmental factors. Seasons are driven primarily by rainfall; therefore, plant phenology is determined mainly by hydrological patterns (Boulay 1992). Although the growing season is long, soils in the region are relatively infertile, and availability of high nutrient forage is low (Harlow and Jones 1965, Labisky et al. 1995). Furthermore, the nutritional value of the fast growing forage rapidly diminishes during the growing season (Fleming et al. 1994). Climatic stress due to the hot and humid summers can also affect food consumption, compromising the nutritional status and health of does and growth rate and survival of fawns (Short et al. 1969). In general, deer populations in southern Florida are characterized by a lower density and fecundity than in other areas of the state (Fleming et al. 1994). During a 1990-1992 study, fawn survival (n=44) in an area encompassing the southern portion of the Stairsteps Unit Zone 4 was 43%, with most (52%) mortality attributed to bobcat predation (Boulay 1992, Labisky et al. 1995). None of the radio-collared (n=35) fawns in a connected study area in Everglades National Park (ENP) survived (Boulay 1992).

Most notably, the ecology of BCNP is attuned to the seasonal and annual flow of water, and fluctuations in water depth can influence all aspects of deer population ecology (BCNP 2006). The cyclical rise and fall of water levels can impact deer movement patterns, including habitat use and

home-range size. When water depths are high, movement requires increased energy expenditure and deer may be restricted to higher elevation sites. Such concentrations can increase stress and vulnerability to predation, diseases, and malnutrition (Loveless 1959, Labisky et al. 1995, MacDonald-Beyers and Labisky 2005). Ensuing stress and lower nutritional condition can also have a negative impact on reproduction; after hurricane Andrew, adeno-corticol stress imposed on pregnant females was believed to have a negative influence on productivity (Labisky et al. 1999). In the Everglades, annual productivity has been related to the average water level during gestation, with peak productivity occurring during intermediate marsh water depths (Fleming et al. 1994). Recruitment of fawns can also be negatively influenced by high water level (MacDonald-Beyers and Labisky 2005). Although mortality due to drowning has been documented, influence of water levels on fawn survival is most likely indirect limiting mobility, reducing forage ability, and increasing vulnerability to predation or diseases (Loveless 1959).

Severe impacts on deer due to high water events in the past have mainly occurred in the impounded marshes of northern Everglades (GFC 1984, Fleming 1994). Due to topography, Stairsteps, particularly Zone 4, is also vulnerable to impacts from high water (BCNP 2006). During an extreme flooding event that extended from fall of 1994 to spring of 1995, researchers documented accelerated mortality and reduced productivity of deer in an area that included the southern part of Stairsteps Zone 4 (MacDonald-Beyers and Labisky 2005). Since the 1994-95 floods, the Stairsteps Unit has not experienced a high water incident of that intensity in terms of duration; however, hydrological data shows that, in general, water levels have increased over time (Robert Sopczak, BCNP, personal communication).

Our objective was to investigate the relationship between white-tailed deer population indices and hydrological data in the Stairsteps Unit of BCNP from the late 1980s to 2010.

Study Area and History

The BCNP is a 291,602 ha area located in southwest Florida. The area spans parts of Collier, Dade and Monroe counties and borders Everglades National Park (ENP). Big Cypress Wildlife Management Area (WMA) consists of 228,990 ha within the BCNP and is divided into 6 management units (Figure 1). The Stairsteps Unit is located in the southern portion of the BCNP and consists of four Zones (1-4) that differ in elevation, vegetation, and hydrology.

The topography of Zone 1 is relatively flat, and the vegetation communities include marshes, mangroves, and cypress strands (Duever et al. 1986). The topography of Zones 2 and 3 is also flat and characterized by a mix of cypress strands and dwarf cypress prairies (Duever et al. 1986). The Lostman's Pines area of Zone 3 is dominated by wet prairies and pine communities (Duever et al. 1986). The single cypress strand, Gum Slough, runs east-west, and surface waters run over the prairies as sheet flow (Duever et al. 1986). The topography of Zone 4 is flat and similar to ENP topography, and the vegetation community is mostly wet prairie interspersed with hardwood tree islands (Duever et al. 1986, Miller 1993). The wet prairie is characterized by grasses and sedges. The tree islands are elevated above the surrounding wet prairie and experience little or no seasonal flooding under normal water levels

(Craighead 1984). The drier, more elevated tree islands are comprised of flood-intolerant species including live oak (*Quercus virginiana* L.), gumbo limbo (*Busera simaruba* [L.] Sarg.), cabbage palm (*Sabal palmetto* [Walt.] Lodd.), and saw palmetto (*Serenoa repens* [Bartram] Small) (Duever et al. 1986). The forage in hammocks is generally of low nutritive quality due to the poor soils (Harlow and Jones 1965) and the late successional stage of woody vegetation (Belden et al. 1988).

Both tropical and temperate zone influences have an effect on the climate in BCNP (Duever et al. 1986). BCNP is characterized by hot, humid summers and mild, dry winters (Duever et al. 1986). Seasonal distribution and amount of annual rainfall is highly variable, but averages 140-150 cm with most of the precipitation occurring from late-May through October. Dry season conditions prevail from November to May.

Deer hunting in the Stairsteps Unit of Big Cypress WMA has been a long-standing tradition. Historically, access was unlimited and hunters were able to reach the most remote areas of the unit using airboats. Beginning in 2000, a designated trail system was established and access to the area was limited to designated trails. Hunting has been allowed during a 30-day archery season, 16-day muzzleloading gun season and an approximately 51-day general gun season (the take of deer was prohibited during the 2010-2011 season to allow staff to investigate possible causes of decline). Harvest has been limited to antlered deer (deer with at least one antler 5 inches or more in length), and the daily bag limit is one antlered deer per day with a combined season bag limit of 2 antlered deer. Therefore, the maximum number of deer a hunter could harvest during the archery, muzzleloading gun, and general gun seasons combined has been 2 antlered deer. Deer harvested in the Stairsteps Unit must be reported to the FWC by checking the deer in at either a staffed or un-staffed check station.

Methods

Deer Population Indices

We used total and effort-adjusted harvest and aerial survey data as deer population indices. FWC harvest data was used from the 1988-89 season onward. Harvest data were available for the Stairsteps Unit as a whole, and, therefore, we could not evaluate harvest by Zone (e.g., in Zone 4 only). To account for the variable harvest pressure, we calculated the effort-adjusted harvest as the number of deer harvested per 100 days hunted (pressure). Prior to 2000, pressure was estimated using vehicle counts. These were counts conducted on Saturdays where all vehicles in the WMA were counted and the counts were then used to estimate the number of people. Since 2000, days hunted have been obtained from hunter check-in forms.

Aerial surveys were conducted by both the FWC and NPS in the Stairsteps Unit; however, methods, timing, and location of transects varied (Figure 2). FWC surveys were flown annually within Zone 4 from

1982-2002. The FWC surveys were conducted in early summer (May-June) from a fixed-wing plane using systematic reconnaissance flight methods. The transects were permanent (i.e., the number of miles surveyed stayed constant over the years); we used the number of deer observed per mile as the deer population index for the FWC survey data. FWC resumed surveys in the Stairsteps Unit in 2010 using distance sampling methods from a helicopter. The FWC survey data were used as a reference on deer population trends; however, due to the gap in data from 2002 to 2009, they were not used in any analyses.

The NPS surveys began in 1994 and have continued twice annually since then, with the exception of 2008 when lack of funding prevented any surveys (Deborah Jansen and Steve Schuze, BCNP, personal communications). The BCNP survey transects encompass Zone 4, but extend slightly into Everglades NPS. The NPS surveys were conducted in spring (mid-to-late May) and late summer (late July-early August) using a helicopter (Deborah Jansen and Steve Schuze, BCNP, personal communications). The spring survey was used to determine fawn:doe ratios and the summer survey to determine doe:buck ratios. The helicopter was flown along permanent transects; however, in an attempt to determine sex and age of the deer, the helicopter would leave the transect to allow the surveyors a closer look at each deer or group of deer. To adjust for the variation in the survey time per flight (and therefore possible variation in the total area surveyed per flight) we used time (total survey time) as a measure of effort and calculated the population index as number of deer observed per minute.

Hydrology Data

The BCNP hydrologic monitoring network includes 20 water level stations that record continuous daily stage data. Each station is equipped with telemetry providing constant (15-minute interval) stage updates via an internet-connected database maintained by the South Florida Water Management District (SFWMD). Hydrology staff periodically visits each station to perform routine maintenance and calibration. Periodic site visits are also arranged ad hoc to correct problems and perform long-term improvements (i.e., rebuilding platforms).

We selected hydrological stations A10, P34, Loop 1, and Loop 2 to represent water levels for the Stairsteps Unit based on their relevance to the study area, extended period of record, and recommendations of the BCNP hydrologist (Robert Sobczak, personal communication; Figures 2 and 3). The P34 hydrological station located in the southern portion of Stairsteps Unit Zone 4 gave the best indication of water levels specifically for Zone 4. Combined data from A10, P34, and Loops 1 and 2 were used to generate overall water levels for the Stairsteps Unit. To prepare hydrological data for analysis, the elevation was subtracted from the raw stage data for each station. This was done to standardize the water stage across the stations so that at each station the threshold values (described below) would translate to the same habitat effect. This stage corrected water levels were converted from inches to cm, and the water levels from selected stations were averaged together for each week from 1986-2009.

We used 4 water levels as threshold values and indicators of high water; 30, 50, 60, and 70 cm. These cut-off values were based on previous research on the influence of water levels on deer habitat and populations. Water depths at 70 cm and above constitute extreme high water events and severely

impact deer movement, survival, and productivity (Loveless 1959, MacDonald-Beyers and Labisky 2005). Loveless (1969) identified 60 cm as the maximum depth that can be endured by deer without negative influences. At depths of 61-76 cm, mesic pine and tree islands are inundated with water. However, MacDonald-Beyers and Labisky (2005) later recommended 50 cm as the maximum depth that can be endured by deer before survival and productivity are impeded. At this level, water has entered the hydric pine/bayhead habitat. Finally, 30 cm was used as a cut-off for optimal habitat. Schortemeyer (1980) reviewed the history of flooding in Water Conservation Area 3A and recommended that optimal water levels should fluctuate between 0 and 25 cm (30 cm maximum) over the annual cycle in order to maintain deer habitat. Below 30 cm water is found in swamp forest, cypress/slough habitat.

In addition to average water levels and the number of high water events per year and per month, we also estimated water levels during 3 seasons; Fawn Vulnerability 1 and 2 and Hunting season. We defined seasons as Fawn Vulnerability 1 (FV1: Feb 1st – April 30th), Fawn Vulnerability 2 (FV2: May 1st – August 31st) and Hunting (Sept 1st – Dec 31st). Weeks where the average water depth was greater than the threshold levels were labeled as 'high water events' and the number of weeks that included high water events (per year and season) were calculated. The number of high water weeks was then converted to a percent scale to account for the varying number of weeks in the seasons among years.

Relationship between Deer Population Indices and Hydrological Conditions

The deer population indices were graphed (Figures 4 and 5) to represent population trends over time, and, based on visual examination of the graphs, periods of interest were defined. Harvest indices indicated deer populations began to decline in Stairsteps in 1999, whereas survey data indicated the decline began in 2002. Chi-square analyses were performed using SAS v9.2 for each period of interest (1984-1998 v 1999-2009; 1984-2001 v. 2002-2009) to assess differences in the number of months with high-water events prior to and following these apparent population declines. A month was designated as high water if any week within that month had a water level that exceeded the designated water levels (30, 50, 60 or 70 cm). Data from 1995 were excluded from all analyses because of the abnormal flood levels that year. Given our interest in understanding changes in water level at different time periods, including 1995 may wash-out any underlying trends given the extremely high water levels in that year. In addition, based on hydrological graphs, it appeared there was an overall shift to more frequent and longer high water events beginning in 1994. Thus, chi-square analysis was also performed to compare the number of high-water events in 1984-1994 v. 1995-2009.

In order to assess whether changes in water levels could be attributed to rainfall, total rainfall was compared for each period of interest using a t-test. Rainfall was summed across the 12 months for each year. Rainfall data were compiled from 23 hydro monitoring stations within the BCNP and averaged to provide a Big Cypress Basin-wide rainfall estimate.

We used non-parametric Spearman rank correlations to evaluate the relationship between hydrological conditions during a hunting season and corresponding total and effort-adjusted harvest. Periodically the Unit was closed to hunting due to high water events. These closures could extend throughout the entire Unit for a given season (e.g., archery) but also consisted of partial closures,

limiting access during a shorter period of time (e.g., 2 weeks of archery) or to specific Zones (e.g., Zone 3 walk-in hunting only). Therefore, we performed two separate analyses, one for the entire hunting season and a separate analysis taking into account closure periods. The analysis incorporating all harvest and hydrological data for the entire period from September – December attempted to account for high water effects on deer during a complete season, regardless of access or presence of hunters. For the second analysis we excluded both harvest and water data corresponding to a season (e.g., archery) if an area was closed, whether the closure was partial or full. This was done to analyze possible correlations of hydrological conditions and harvest on deer populations when the Unit was open and access was not limited.

We also used non-parametric Spearman rank correlations to relate harvest levels to hydrological conditions during fawn vulnerability seasons 2.5 years prior. For example, the majority of bucks harvested are 2.5 years old; therefore, if water levels during a given fawning season had an effect on recruitment we would expect a 2.5 year lag for those impacts to be evident during harvest. In addition, we tested for a correlation between hydrological conditions during fawn vulnerability seasons and the corresponding fawn:doe ratios from aerial surveys. High water events greater than 60 and 70 cm during fawn vulnerability periods were extremely rare; therefore, these parameters were not included in the analyses.

We constructed multiple regression models to relate harvest and effort-adjusted harvest to the hydrological data. However, an examination of influence and collinearity diagnostics revealed a high degree of collinearity (correlation and inter-relationships) between the majority of variables, bringing into question the validity of the results. Therefore, to address the collinearity, principle components were constructed. Principle components are independent, linear, combinations of the original parameters which can be used in subsequent analyses. Multiple regression models were then built with the principle components, allowing us to investigate the relationship between hydrological data and harvest without introducing bias to the results.

Results

The number of high water events has increased significantly in recent decades (Figures 6a-c). There was a significant difference in the occurrence of high water weeks from 1984-1994 to 1996-2009 for 30cm, ($\chi^2 = 11.46$, $p < 0.001$), 50cm ($\chi^2 = 37.62$, $p < 0.001$), and 60cm ($\chi^2 = 6.55$, $p = 0.01$), but not for 70cm ($\chi^2 = 0.06$, $p = 0.81$). However, there was no difference in yearly total rainfall during the same periods ($t_{23} = 1.41$, $p = 0.17$).

Harvest data indicated a decline in the deer population beginning in 1999, and the difference in the occurrence of high water weeks from 1984-1998 to 1999-2009 was significant for 30cm ($\chi^2 = 5.17$, $p = 0.02$), 50cm ($\chi^2 = 14.56$, $p < 0.001$), and 60cm ($\chi^2 = 7.25$, $p = 0.007$), but not for 70cm ($\chi^2 = 0.06$, $p = 0.81$). Again, there was no difference in yearly total rainfall during the same time periods ($t_{23} = 0.98$, $p = 0.34$).

There were no differences in the occurrence of high water weeks from 1984-2001 to 2002-2009 for 30cm ($\chi^2 = 2.28$, $p = 0.13$) and 70cm ($\chi^2 = 0.09$, $p = 0.76$), when survey data showed an apparent decline in the population, but there were significant differences for 50cm ($\chi^2 = 4.92$, $p = 0.027$) and 60cm ($\chi^2 = 3.97$, $p = 0.46$). As with the previous comparisons, there was no difference in yearly total rainfall during the same time periods ($t_{23} = 0.47$, $p = 0.64$).

Spearman rank non-parametric correlations between hydrological parameters during the hunting season (all water data) and the corresponding harvest suggested relationships only for the season's average water level and the total harvest ($p = 0.090$, Table 1). There was no correlation between effort-adjusted harvest and hydrological conditions. When data during closure periods were excluded, average water depth and high water weeks greater than 60cm were significantly correlated with harvest; as the water levels increased, harvest decreased (Table 2). As with the previous analysis, when harvest was adjusted for effort, there was no correlation. These significant correlations for non-closure time periods appear to be a function of reduced pressure, as we also found significant correlations between pressure and water levels (Table 2).

There was a positive correlation between high water events greater than 30cm and 50cm during the first fawn vulnerability period and harvest 2.5 years later (Table 3). All hydrological parameters during the first fawn vulnerability period (February 1 – April 30) were negatively correlated with the corresponding fawn:doe ratios (Table 4, Figure 7). None of the hydrological conditions of the second (May 1 – August 31) fawn vulnerability period were correlated with fawn:doe ratios (Table 4).

While neither of the multiple regression models with the principle components was significant at the $\alpha = 0.05$ level ($p = 0.27$ and $p = 0.0965$), the adjusted R^2 were 0.4338 and 0.7045, respectively. Because principle components are a linear combination of the original parameters, the most straightforward interpretation of this analysis is that, while hydrological parameters may relate to harvest (particularly to the effort-adjusted harvest), they are not significant in their ability to model, or predict, harvest.

Discussion

The white-tailed deer population in the Stairsteps Unit of the BCNP has sharply declined in the past decade, with recent surveys and harvest numbers indicating a near complete population crash. High water levels have been hypothesized as a cause of the decline. Evaluation of hydrological data confirmed that the number and duration of high water events, weeks where water depth exceeded 50 cm and even 60 cm, has become significantly more common in Stairsteps since the 1994-1995 floods. Comparison of water levels pre-and-post deer population declines also demonstrated a significant change in the hydrological parameters between these periods.

Based on deer population indices, it appears that following the 1994 flood there was a period of recovery for about 3-6 years, followed by a steady decline. Harvest trends were stable to increasing during the early 1990s, but began declining considerably after 1997. Population trends based on NPS aerial surveys showed a steady increase after the 1994 flood, followed by high deer counts in 1999-2001

and a decline after 2001. In a decade's time, total counts dropped from a high of 642 in 2001 to a low of 7 in 2010.

When all hydrological data were included in the analyses, regardless of closure, average water levels were somewhat negatively correlated with total harvest. However, when harvest was adjusted for effort, none of the hydrological parameters were significantly correlated with harvest. When we excluded closure data we found a negative correlation between harvest and all of the hydrological parameters. However, again, once harvest was adjusted for effort the correlations disappeared. These patterns suggested that the harvest declines were a direct result of reduced pressure associated with higher water levels; and in fact we found significant negative correlations between pressure and high water (Table 2). It would appear that during years where water levels were high, even with only partial closures, the number of hunters declined. In other words, the correlation of high water with low harvest was mainly due to the number of hunters decreasing and, therefore, overall harvest dropping. It is important to note that because the area was closed when water levels exceeded the BCNP closure criteria (BCNP 2006), data to answer what would happen to harvest levels (i.e., deer vulnerability) during extreme water events are not available. It seems likely that deer confined to higher ground during high water events would be more vulnerable to harvest; however, data to evaluate this do not exist.

Hydrological conditions during the early fawning period appeared to have an effect on fawn survival, as shown by decreasing fawn:doe ratios with increasing water levels (Figure 7). Most fawning occurs in February – March, a period that coincides with the driest months (Richter and Labisky 1985, Boulay 1992). Fawn:doe ratios were lowest during years where water levels were above 30 cm or 50 cm during the period when fawns are presumably most vulnerable (Boulay 1992). This suggests that recruitment is lower during years with high water. Previous research has shown that water levels can have a significant impact on recruitment. For example, Fleming et al. (1999) found that recruitment in the Everglades was inversely related to the average marsh water depths during the fawning season (January-May); recruitment declined sharply when water levels reached 45 cm or above. Similarly, based on aerial surveys, 71% of radio-collared females (n = 24) were associated with a fawn prior to the 1994 flood, whereas only 7% (n = 28) of females were associated with a fawn post-flood (MacDonald-Beyers and Labisky 2005). Unfortunately recruitment data from the late 80s to early 90s, when the deer population appeared to be stable to increasing, are not available. However, based on average weekly water depths during fawn vulnerability periods from 1985 to 1994, there were only few instances where average water depths exceeded 30 or 50 cm (Figures 6a and 6b).

We also investigated the relationship between hydrological conditions during fawning season and harvest, as it seemed plausible if water levels influence recruitment, any drop or increase in recruitment would be evident in the harvest when that particular cohort reaches legal harvest age. Our results, however, were conflicting; while there was no relationship between hydrological conditions during the fawning season 2.5 years prior and unadjusted harvest, there was a positive correlation with effort-adjusted harvest levels. That is, when water levels during fawn vulnerability were high, the subsequent effort-adjusted harvest levels were high. This discrepancy may be due to the fact that, although harvest provides good population trend data, it does not translate well into point estimates of

a population status due to the variety of factors that affect harvest levels. Even when accounting for pressure, variables such as equipment used (airboats, buggy), partial closures (e.g., area is open for hunting but only for walk-in hunting), and weather can influence the harvest level significantly.

Further downstream, in the ENP, based on anecdotal evidence, deer populations also appear to be declining (Sonny Bass, ENP, personal communication). In addition, small mammal populations in the ENP have declined in recent years (Sonny Bass, ENP, personal communication). It is not clear if the declines are due to changes in hydrology, although it may be one of the many causes (Sonny Bass, ENP, personal communication). Based on harvest records and limited aerial survey data, deer populations in other Big Cypress WMA Units, apart from the Loop Unit, do not appear to be declining (Figure 8). Harvest in the Loop Unit, north of Stairsteps Unit Zone 4, has decreased since 2001. The Loop Unit is impacted by the flows across Tamiami Trail; however, the Loop Unit is at slightly higher elevation than the Stairsteps Unit.

Testing hypotheses on free-ranging wildlife populations is challenging even with sound study design but becomes more difficult when attempted with limited, correlational data. For the time period of interest, there are no estimates of deer productivity and survival in the Stairsteps Unit, or data on causes of mortality and deer movement that would allow us to better understand the possible causes of decline. The available data do, however, suggest that increasing water levels have had a negative impact on the deer population in the Stairsteps Unit. As previous research has shown, higher water can influence deer in several ways, including increasing energy expenditure for movement and foraging; reducing quality forage; increasing stress; causing shifts in habitat use patterns; and increasing vulnerability to parasites, diseases, and predators (Loveless 1959, Boulay 1992, Fleming et al. 1994, Labisky et al. 1995, Labisky et al. 1999, MacDonald-Beyers and Labisky 2005).

The Stairsteps Unit deer population appeared to have recovered from the 1994-95 floods. However, the following recurring years of high water events and the various impacts high water has on deer populations may have caused the population to decline over time due to lower productivity, reduced recruitment, and higher mortality. Long-term research on causes of mortality and survival rates of fawns and adults may be necessary to clarify the role of hydrology on deer populations in the area. Other factors, such as the role of predators, the impact of hunting, and changes in habitat conditions should also be measured to allow for interpretation of study results.

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Tables

Table 1. Spearman rank correlations (and p-values) for Stairsteps Unit hydrological conditions (average and 4 threshold water levels) during hunting season (Sept 1st – Dec 31st) and harvest (total and effort-adjusted harvest). All hydrological data were included, regardless of closures. Significant correlations (p < 0.1) are in **bold**.

Parameters	Total Harvest	Effort-adjusted Harvest
Average	-0.370 (0.090)	0.084 (0.710)
30 cm	-0.234 (0.296)	0.217 (0.331)
50 cm	-0.354 (0.106)	0.199 (0.374)
60 cm	-0.326 (0.139)	-0.017 (0.940)
70 cm	-0.359 (0.101)	0.055 (0.810)

Table 2. Spearman rank correlations (and p-values) for Stairsteps Unit hydrological conditions (average and 4 threshold water levels) during hunting season (Sept 1st – Dec 31st), number of days hunted and harvest (total and effort-adjusted harvest). Hydrological data during closures were not included. Significant correlations (p < 0.10) are in **bold**.

Parameters	Total Harvest	Number of Days Hunted	Effort-adjusted Harvest
Average	-0.397 (0.067)	-0.544 (0.009)	0.118 (0.601)
30 cm	-0.262 (0.238)	-0.401 (0.064)	0.232 (0.298)
50 cm	-0.356 (0.104)	-0.518 (0.013)	0.212 (0.343)
60 cm	-0.405 (0.061)	-0.490 (0.021)	0.044 (0.845)
70 cm	-0.174 (0.439)	-0.241 (0.280)	0.278 (0.210)

Table 3. Spearman rank correlations (and p-values) for Stairsteps Unit hydrological conditions (average and 4 threshold water levels) during fawning periods (Fawn Vulnerability Period, FV1: Feb 1st – April 30th; FV2: May 1st – August 31st) and harvest (total and effort-adjusted) 2.5 years later. Significant correlations ($p < 0.10$) are in **bold**.

Parameters	Total Harvest	Effort-adjusted Harvest
FV1 average	0.094 (0.678)	0.307 (0.165)
FV1 30 cm	0.174 (0.438)	0.429 (0.046)
FV1 50 cm	0.244 (0.274)	0.451 (0.035)
FV2 average	-0.136 (0.546)	0.080 (0.725)
FV2 30 cm	-0.084 (0.710)	0.147 (0.513)
FV2 50 cm	-0.194 (0.388)	-0.271 (0.222)

Table 4. Spearman rank correlations (and p-values) for Stairsteps Unit hydrological conditions (average and 4 threshold water levels) during fawning periods (Fawn Vulnerability Period, FV1: Feb 1st – April 30th; FV2: May 1st – August 31st) and the corresponding fawn:doe ratio obtained from National Park Service (NPS) spring surveys. Significant correlations ($p < 0.10$) are in **bold**.

Parameters	Fawn:Doe Ratio
FV1 average	-0.868 (<0.001)
FV1 30 cm	-0.656 (0.011)
FV1 50 cm	-0.563 (0.036)
FV2 average	-0.178 (0.543)
FV2 30 cm	-0.033 (0.911)
FV2 50 cm	0.137 (0.640)

Figures

Figure 1. Map of Big Cypress Wildlife Management Area, Florida.

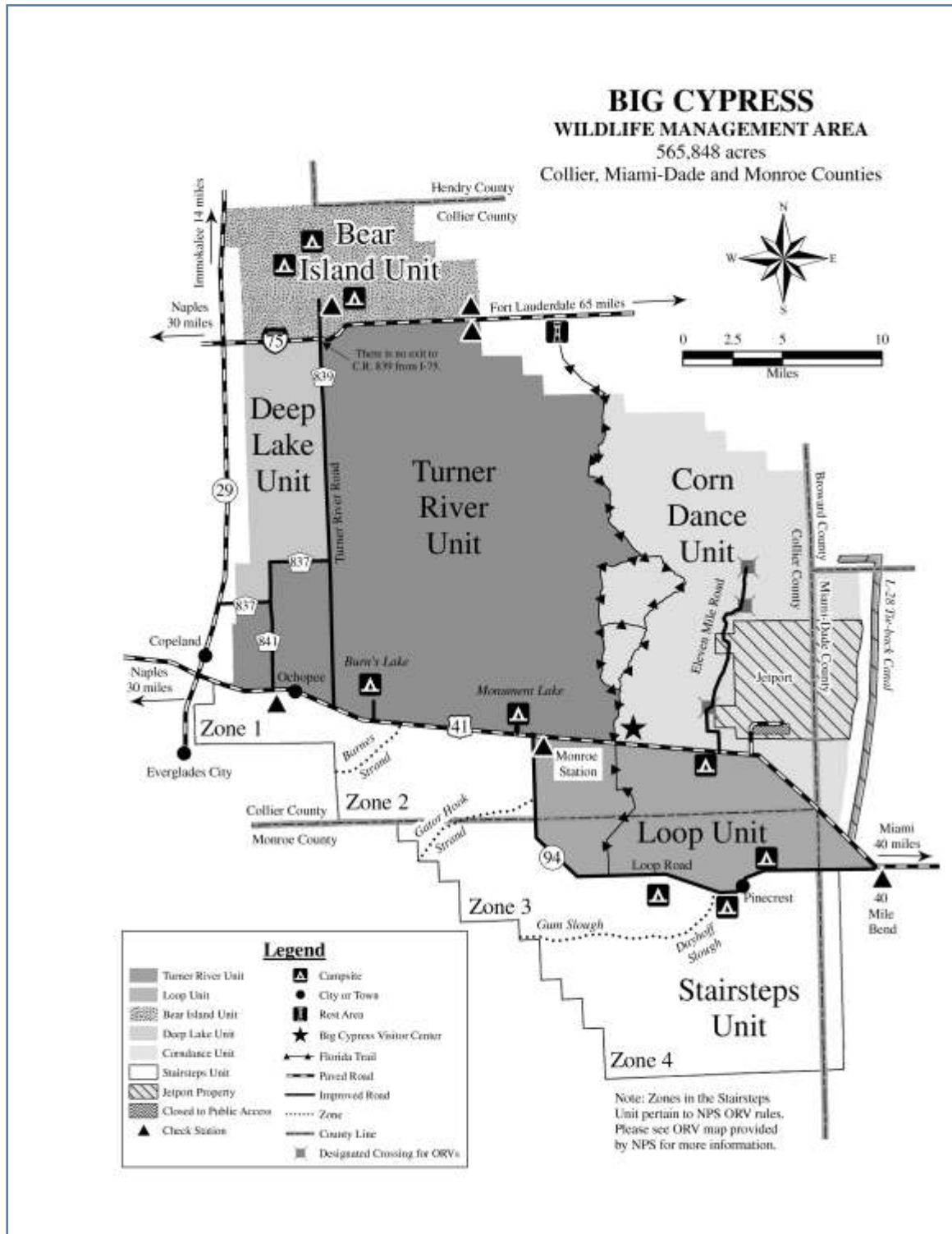


Figure 2. Florida Fish and Wildlife Conservation Commission and National Park Service aerial survey transects, Big Cypress National Preserve

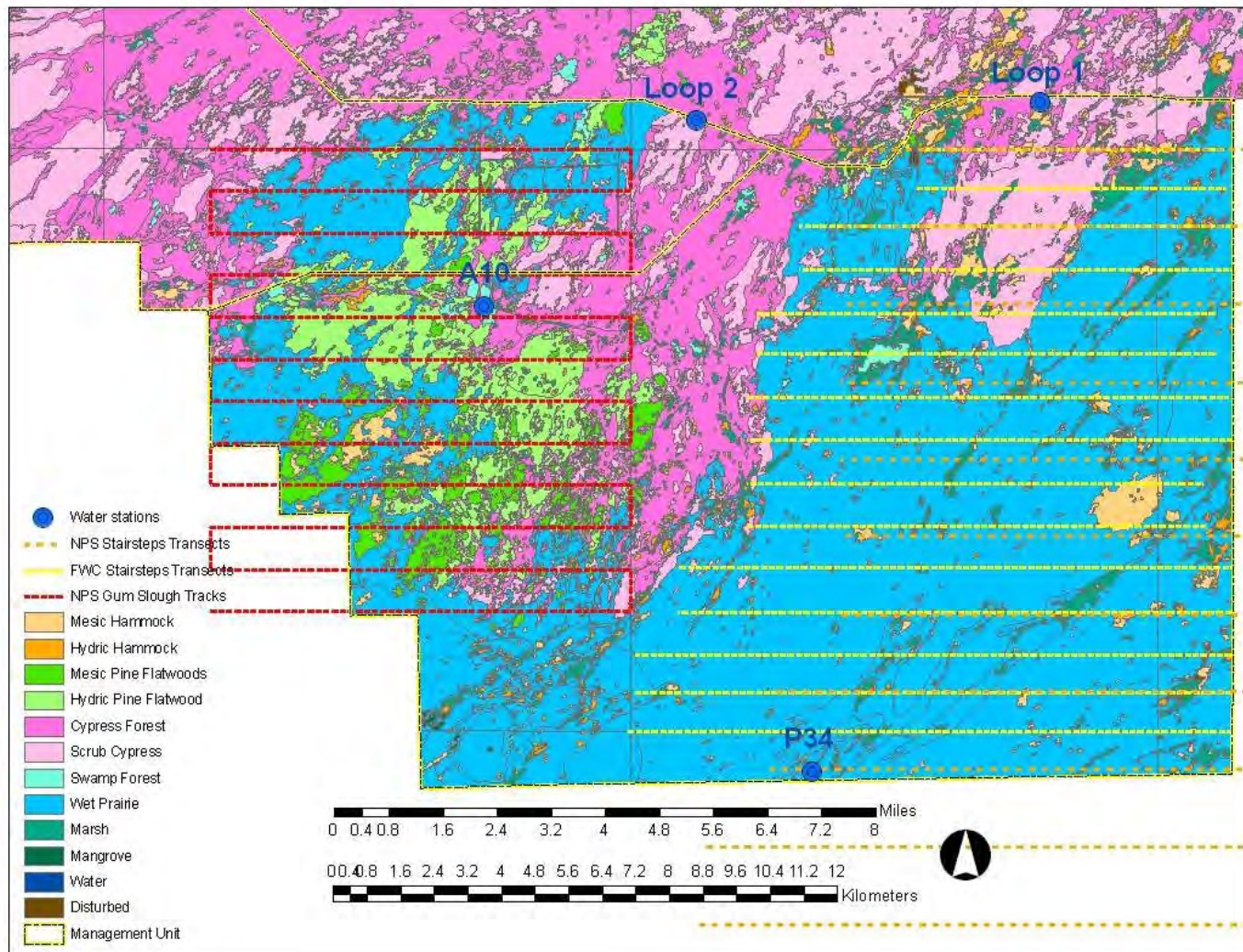
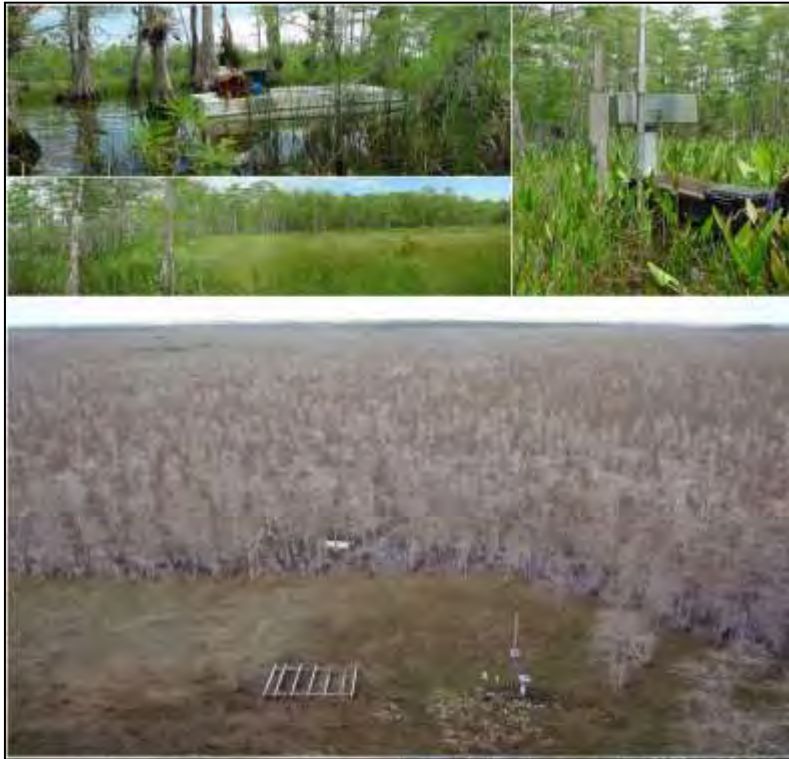


Figure 3. Select hydrological monitoring stations, Big Cypress National Preserve.



A10 Hydrological monitoring station.



Loop 1 Hydrological monitoring station.



P34 Hydrological monitoring station.

Figure 4. Total (blue bars) and effort-adjusted (line) white-tailed deer harvest in Stairsteps Unit, Big Cypress Wildlife Management Area, 1988-2009.

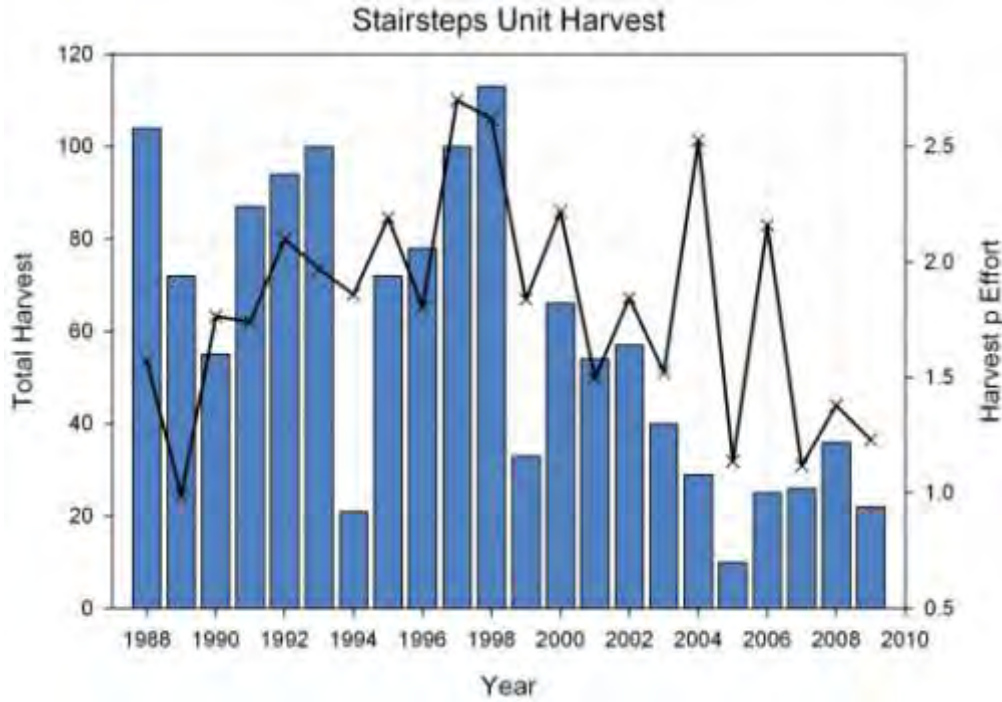
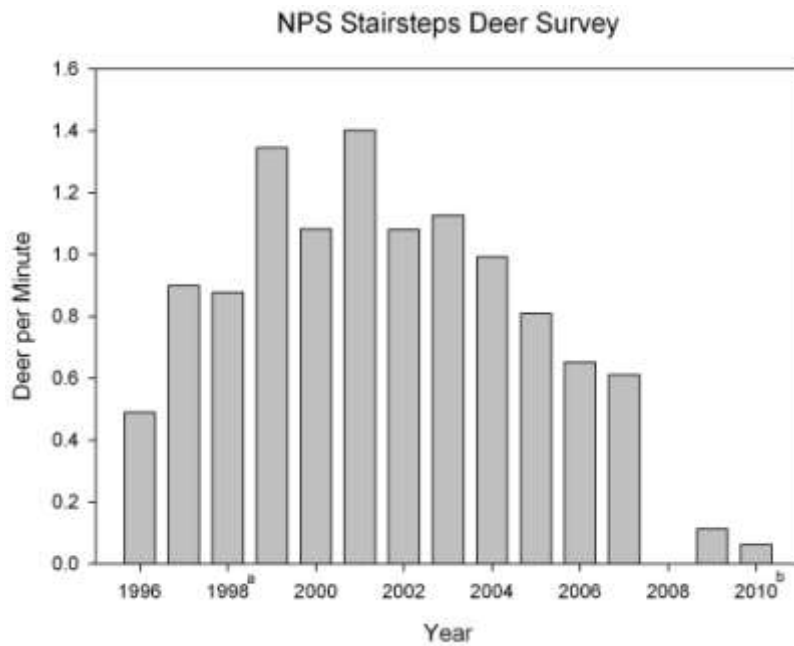


Figure 5. Effort-adjusted white-tailed deer aerial survey results, Stairsteps Unit, Big Cypress National Preserve, 1996-2010. Surveys were not flown in 2008 due to budgetary constraints.



^a number of transects flown were reduced from 16 to 14

^b only 10 (out of 14) transects were flown due to low number of observations

Figure 6a. Weekly average water depth (cm) at hydrological monitoring station P34, Stairsteps Unit Zone 4, Big Cypress National Preserve.

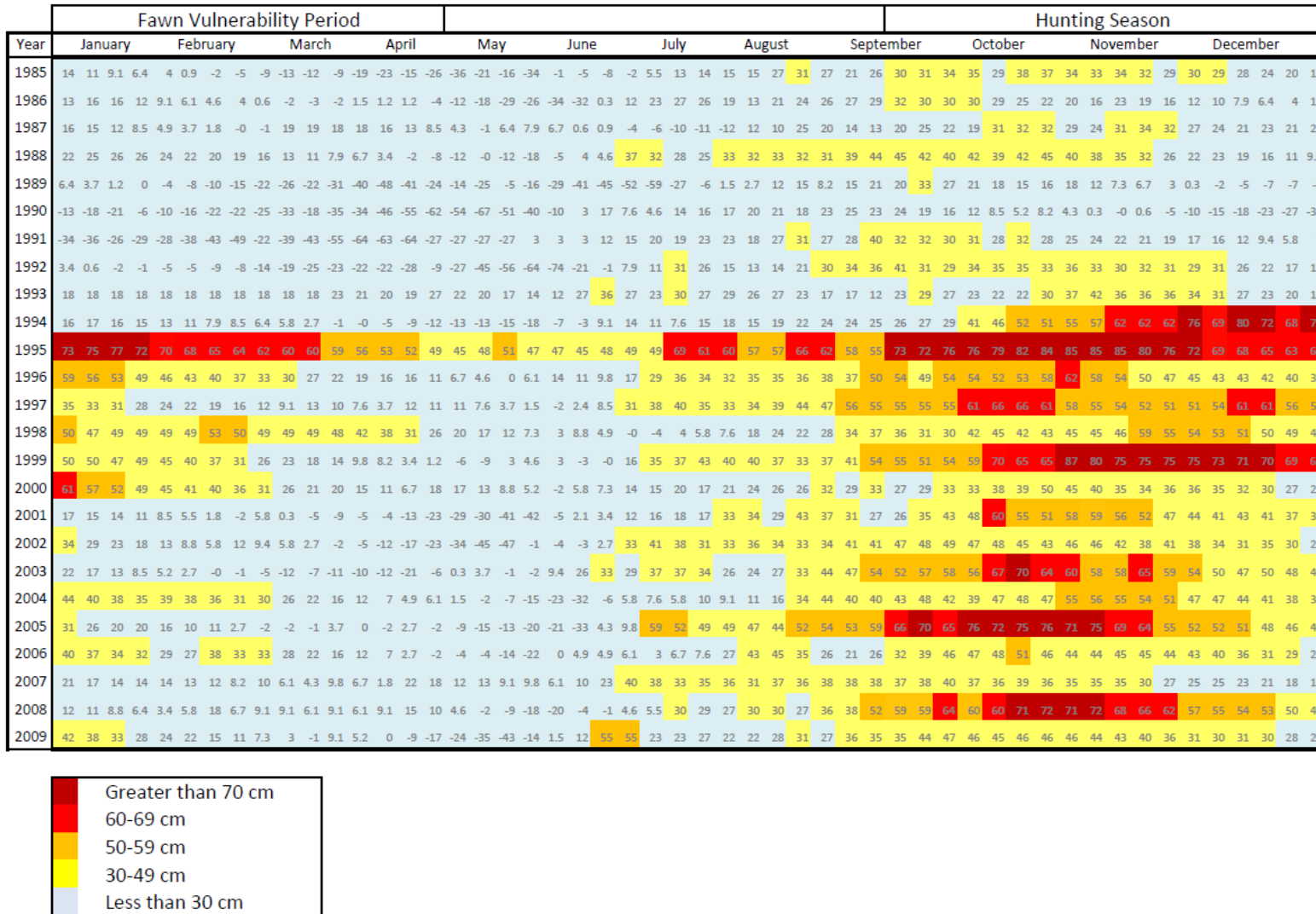


Figure 6b. Weekly average water depth (cm) at hydrological monitoring stations A10, P34, Loop 1 and Loop 2, Stairsteps Unit, Big Cypress National Preserve.

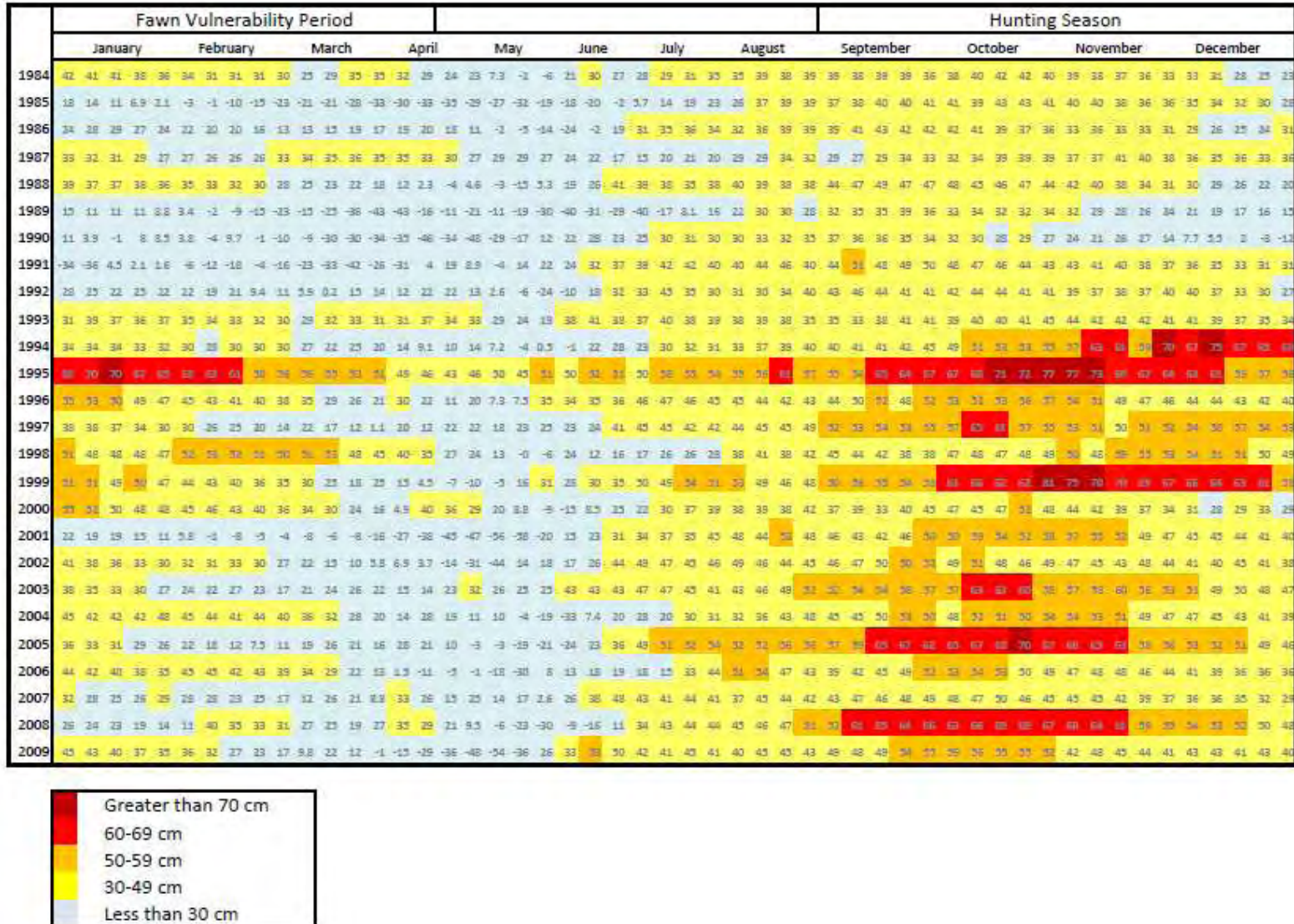


Figure 6c. The number of high water events in Stairsteps Unit, Big Cypress National Preserve, 1983-2010. Hydrological data combined from A10, P34, Loop 1 and Loop 2 stations.

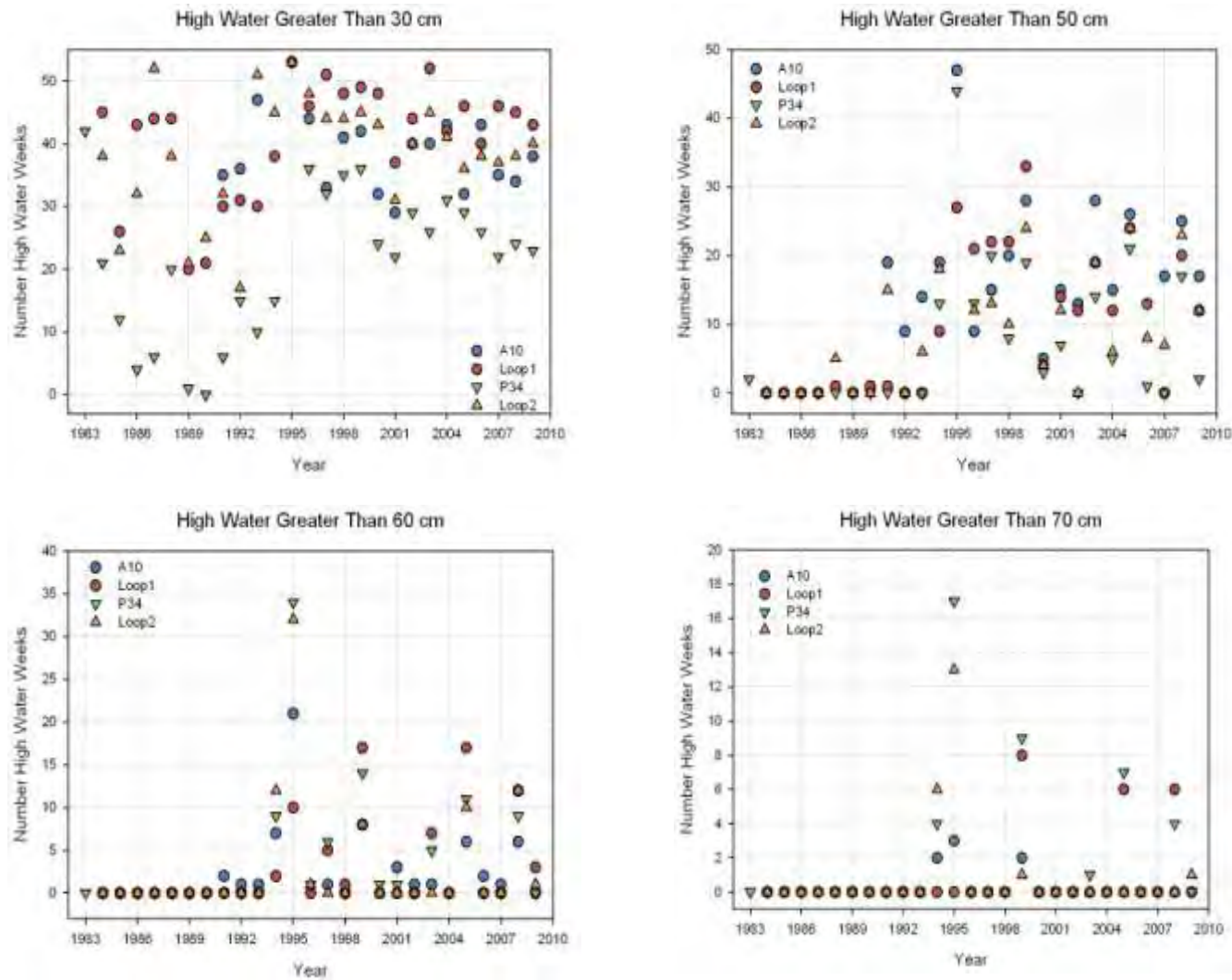


Figure 7. Relationship of fawn:doe ratio and the number (%) of high water weeks during fawn vulnerability period (Feb. 1st-April 30th), Stairsteps Unit, Big Cypress National Preserve.

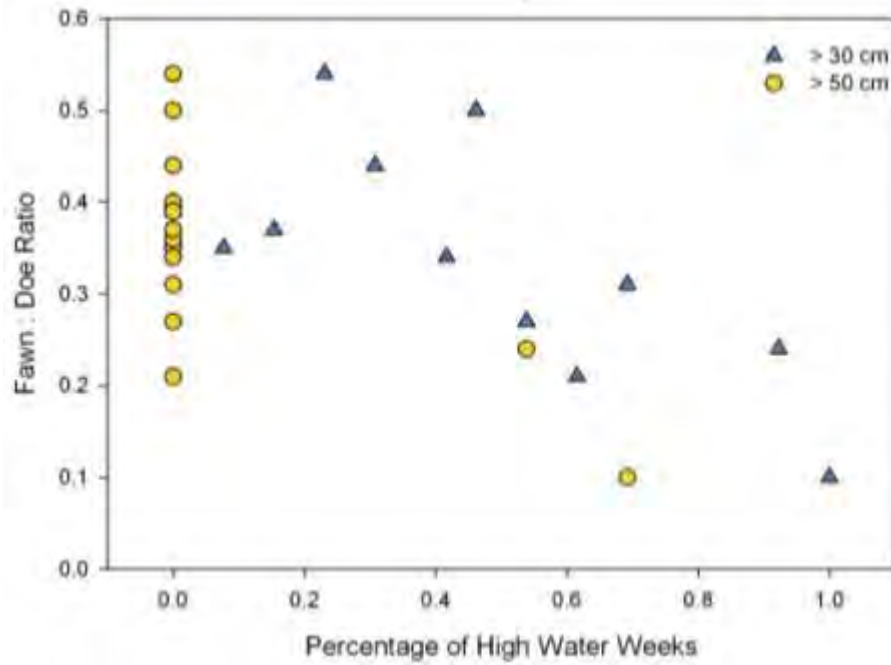


Figure 8. Deer harvest by year and by Unit, Big Cypress Wildlife Management Area.

