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A Sparrow in the Grass:

An endangered species and the Everglades ecosystem on which it depends



Stuart L. Pimm, Oron L. Bass Jr., and Julie L. Lockwood (editors)

Cover photo by Kelly Boadway (c)

The Cape Sable seaside-sparrow synthesis report

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Orientation

These maps provide general information of where the sparrows live and the features of the landscape. We shall refer to them extensively in the text, so group them here for convenience.

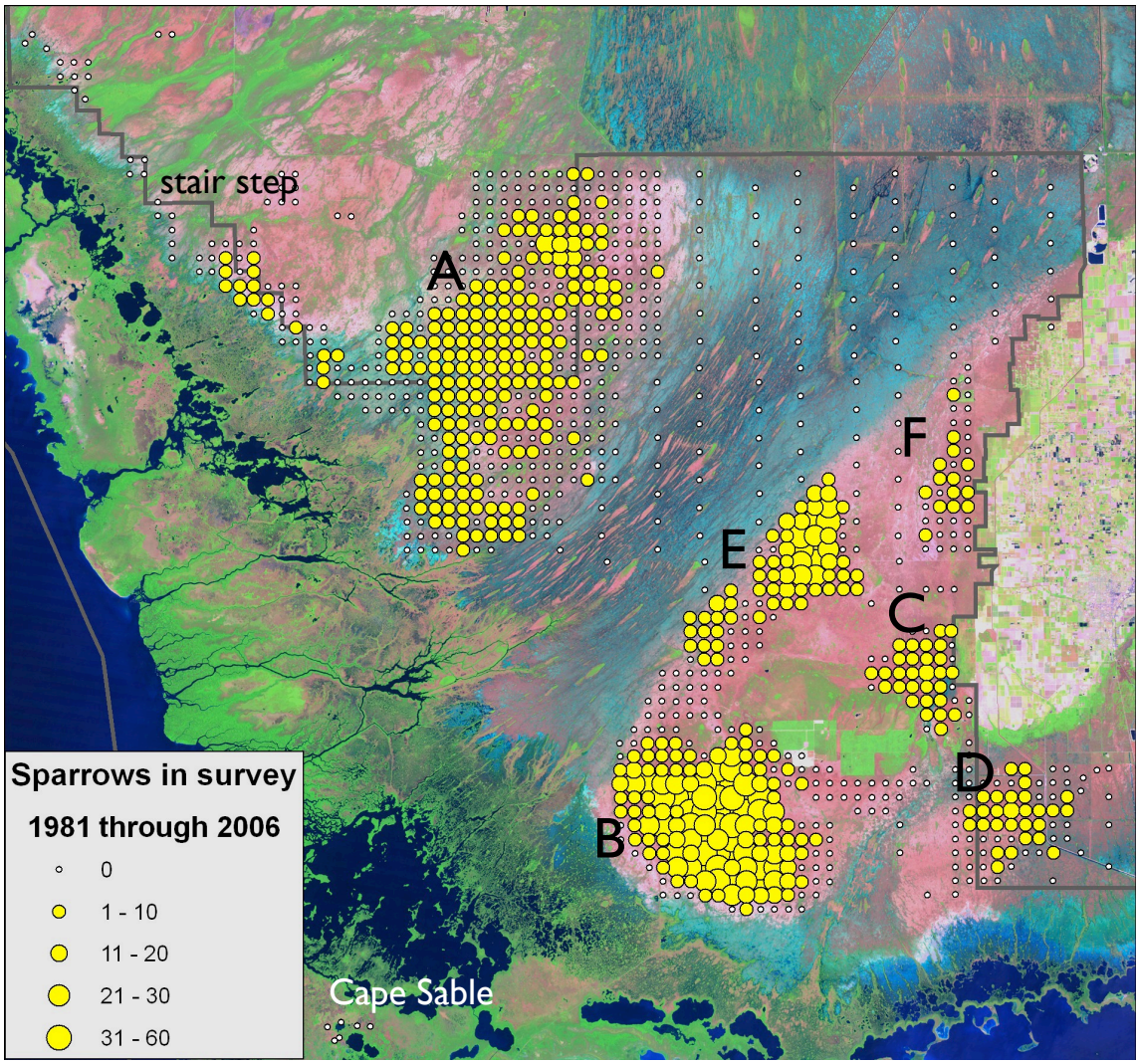


Figure i Sparrow numbers seen on the extensive surveys from 1981 to 2006 on a background of a false colour Landsat image of the southern Everglades. On the image, blue indicates freshwater, dark blue are deeper water and marine environments, green areas are forests, including mangroves, while pink areas are drier prairie habitats. The letters indicate the subpopulations to which the text will refer.

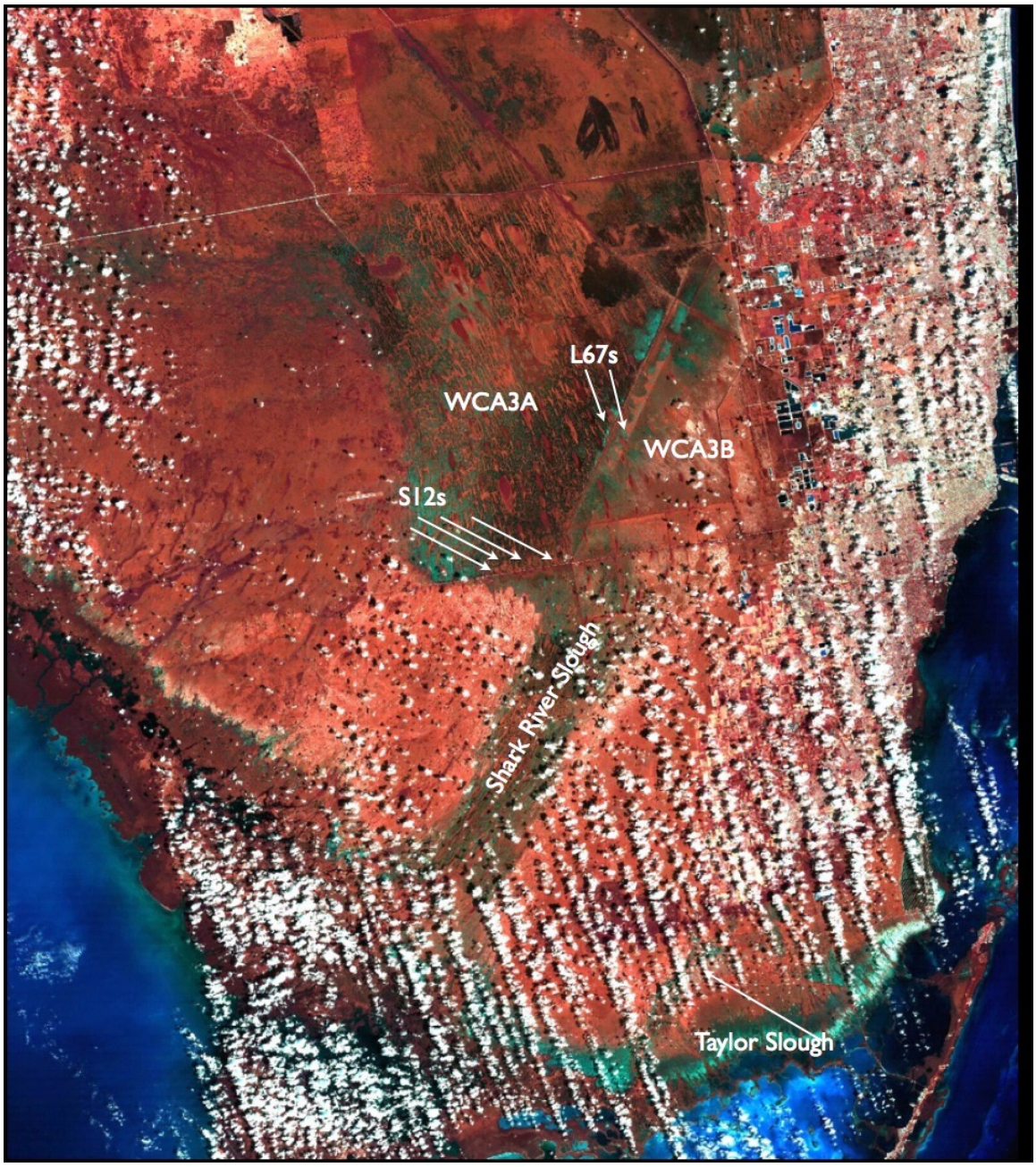


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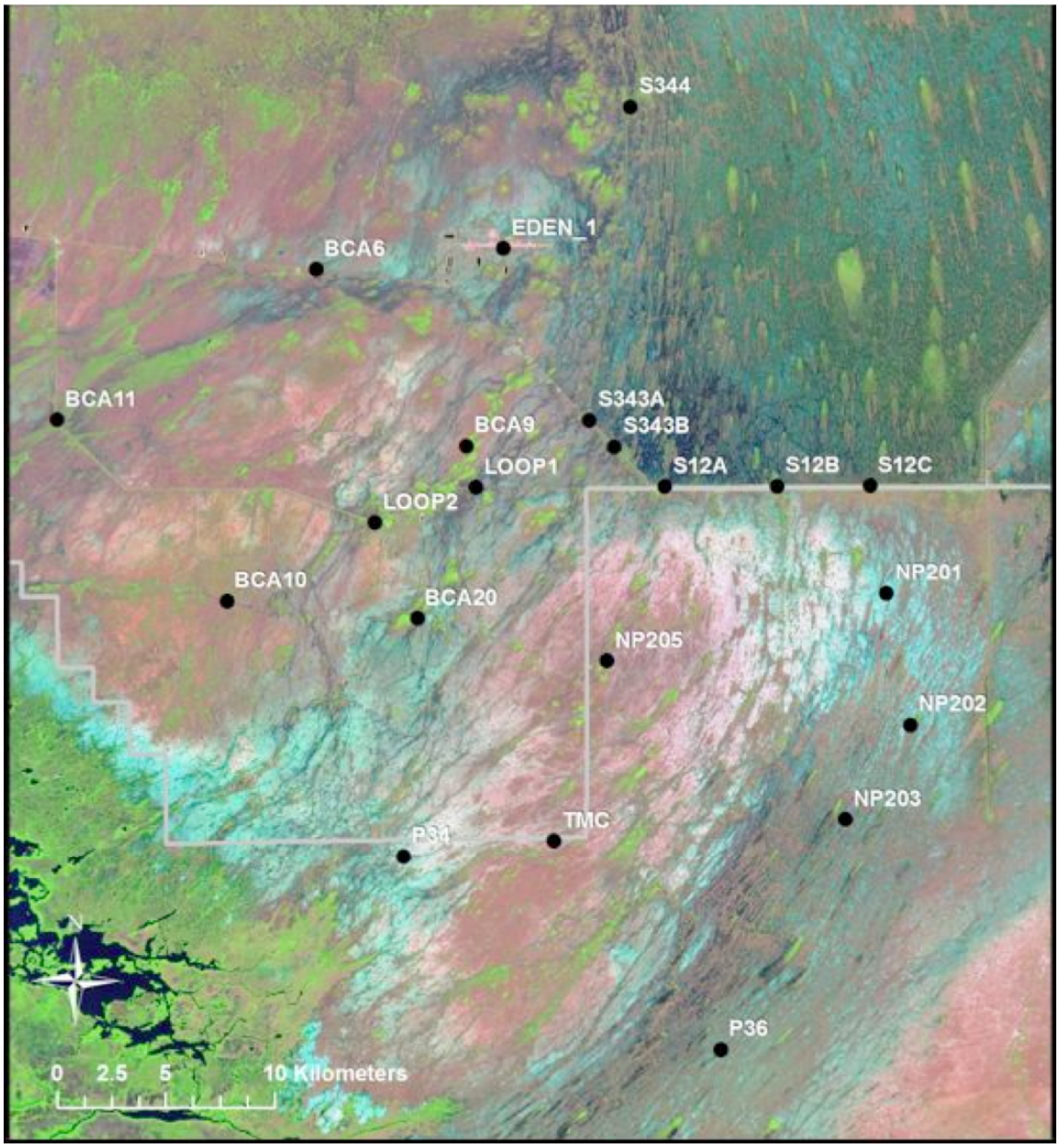


Figure iv. Water monitoring stations west of Shark River Slough

The study plots

We established numerous study plots between the 1993 and 2000 field seasons. Following the Lopez fire of 2001, we created a temporary field camp near it —"East Camp." We also established a similar field camp west of Shark River Slough "West Camp." Helicopter trips supported these camps. The other sites we could reach by road. We intended to investigate our plots long-term, and for them to be rectangular areas that originally spanned 36–1100 ha. We standardized all active plots in 1999 to 0.5 km2 (50 ha). Then, as needs changed at both Camps, we covered larger areas as needed.

We placed plots non-randomly, with their location being determined by the nature of the question we wished to address. Nest observations, feeding observations, and survival estimates of large numbers of birds are best investigated in areas with high densities of sparrows and within easily accessible areas. For that reason we established most plots within population B along either Main Park Road, or Old Ingraham Highway.

Description of study plots

All plots are 50 ha unless otherwise specified.

Taylor Slough; established 1993. This plot is 1100m by 600 m (66 ha) and lies within the plot that Harold Werner established in 1974. It runs along the east side of Taylor Slough and is bisected by the Main Park Road. The vegetation is dominated by sawgrass with some muhly grass and consists of large areas of "pinnacle rock" (exposed limestone) with infrequent patches of well-developed soil. Being at the edge of the slough, and downstream from a floodgate, this plot can become inundated early in the wet season by rain or by the opening of the floodgate. This plot is located within population D and is no longer in use.

Aerojet; established 1993. This plot is 600m by 600 m (36 ha) and is located halfway between the two sets of buildings on the former Aerojet Corporation property (now jointly managed by the South Florida Water Management District and the Florida Game and Freshwater Fish Commission). The area predominantly has a long hydroperiod and is dominated by sawgrass; however, there are small, drier patches dominated by muhly grass. This plot is located in one such patch, which accounts for its small size. This plot is within population D and we were not able to sustain its use.

Sweetbay; established 1993. This plot is located ca. 400 m southeast of Sweetbay Pond, south of the remnants of Old Ingraham Highway, within population B. The plot is dominated by sparse to moderate muhly grass, but remnant furrows from past agricultural activity provide habitat for a wide range of other herbaceous species. This plot usually remains dry throughout April and May. We eventually discontinued its use.

Curnutt Plot; established 1993. This plot is 800m by 800 m (64 ha) and is located on the west side of Shark Slough within population A. When originally established in 1993, the habitat was about 40% sawgrass and 60% mixed prairie. There were substantial patches of muhly grass. This plot was completely inundated throughout the 1993 field season, remained dry through most of the 1994 season, but was inundated again in 1995. The vegetation changed dramatically, and the study population was extirpated. For this reason we did not study this area after 1995.

Old Ingraham Highway North; established 1993. This plot is located less than 100 m north of the west end of the Old Ingraham Highway within population B. The plot is mixed prairie dominated by muhly grass and sawgrass, and remains dry throughout April and May.

Old Ingraham Highway South; established 1994. This plot is located south of the west end of Old Ingraham Highway within population B. The northeast corner of this plot is ca. 500 m south of Old Ingraham Highway North. Like the previous one, the plot is mixed prairie dominated by muhly grass and sawgrass, with little surface water throughout April and May. However, the grass cover at this plot is, on the whole, much more dense than at OIHN.

Dogleg; established.1994 This plot, located within population B between the Main Park Road and the remnants of the Old Ingraham Highway, is much longer than wide (hence its name) but covers 50 ha. Muhly grass and sawgrass dominate the vegetation.

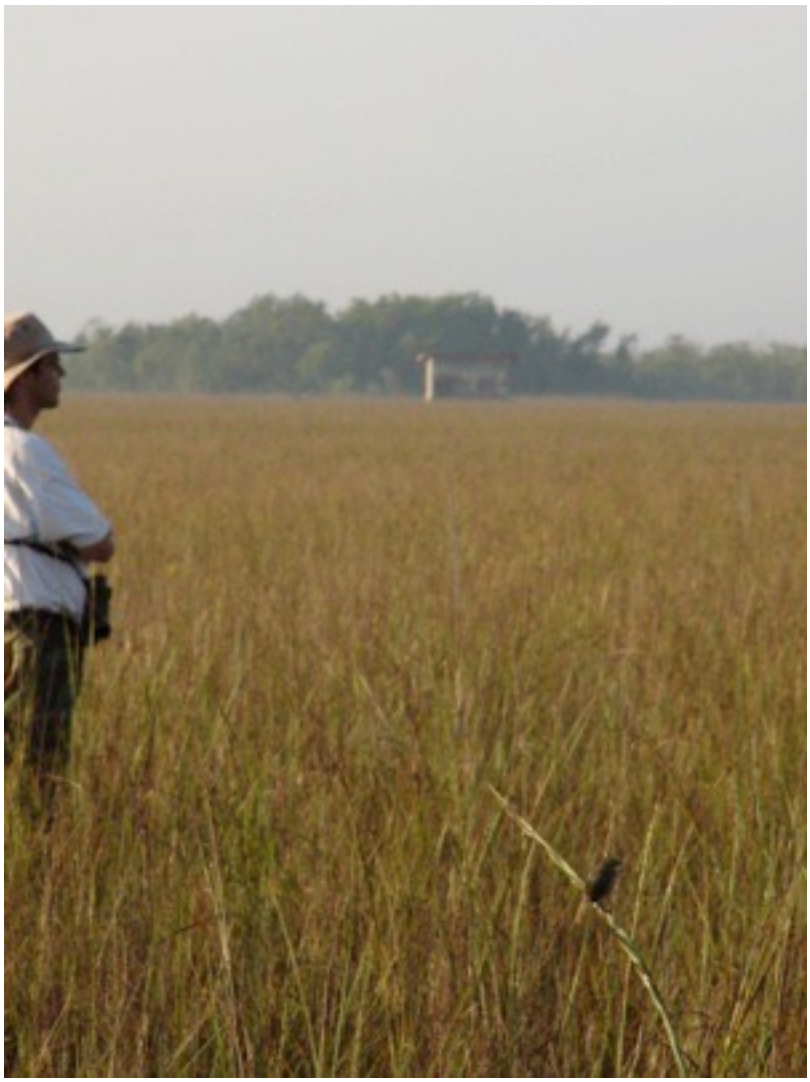
Finger Glade; established 1995 This plot is located in a large finger glade west of the "Holein- the-Donut" and north of the (unpaved) Long Pine Key Road within population B. The vegetation is dominated by muhly grass and *Spartina* spp. Cover is very dense throughout the plot, indicating a lack of fire in recent years. Remnants of furrows indicate that much of the plot was once farmed. Sparrows have never occupied this plot, and thus we have not visited this plot since 1996.

North Mahogany; established 1996. This plot is located 0.5 mile north of the Mahogany Hammock turnoff along Main Park Road within population B. The plot originally encompassed both sides of the road but now is only east of the road. This plot is dry throughout April and May and is dominated by sawgrass and muhly grass. In the summer of 1994, the back portion of this plot burned.

Alligator Hammock; established 1996. This plot is located along Main Park Road directly across from Dogleg and Sweet Bay within population B. Despite its proximity to DL, it is more densely covered in vegetation, and sawgrass is more common than muhly grass. The area floods earlier, and stays wet longer, than the plots on the east side of Main Park Road. The road itself acts as a levee, restricting water flow and forcing water to accumulate on its "upstream" side within this plot.

Far East; established 1997. This plot is located directly east of Old Ingraham Highway North, along the north side of the Ingraham Highway and within population B. The two plots share a border. Despite its proximity to Old Ingraham

Highway North, this plot has less cover and vegetation is much sparser. Muhly grass and sawgrass with significant amounts of *Schizachyrium rhizomatum* dominate the plot. This plot is dry throughout April and May, and usually stays drier than either of the two Old Ingraham plots.



West Camp; established 1997
This plot is located in population A, about 5 miles southwest of the Shark Valley Lookout Tower. This plot lies along the western border between Everglades National Park and Big Cypress National Preserve. This plot is by far the wettest, typically containing standing water in all months except April and May. The plot is dominated by sawgrass. (At left, David Okines, left, a sparrow, front right, and the camp in the background.)

East Camp; established.1998. This plot is located in population E about 1 mile north of an old tomato field and 1 mile northeast of Context Road. The plot remains dry for several months of the year; it is the last of our study plots to hold standing water during the summer storms. Sawgrass and muhly grass dominate this plot, although it contains much *Schizachyrium rhizomatum*. This plot lies adjacent to the former (pre- 1980s) eastern boundary of Everglades National Park and as such contains a mosaic of burn frequencies.

Chapter 1

History

John Curnutt

This chapter first appeared in Pimm et al. (2002) and has only been slighted edited since.

Abstract

In 1918, A. Howell discovered the Cape Sable seaside-sparrow(*Ammodramus maritimus mirabilis*), the last new "species" ever recorded in the continental United States. He found it in the saltmarshes of Cape Sable, the southeastern tip of the Everglades. This population must always have been tiny—there was never enough habitat on Cape Sable to support a viable population — and it was almost certainly only a peripheral and perhaps ephemeral subpopulation. The 1935 Labor Day hurricane, which devastated the Cape, almost certainly eliminated it.

In 1954, L. A. Stimson rediscovered the sparrow in the vast *freshwater* prairies of the Everglades. He realised then that the true range of the sparrow must cover an area much larger than the scattered saltmarshes near the coast. In fact, the distribution of the sparrow belies its appellation of "seaside", being found as far as 40 km inland from the Gulf of Mexico. There is no evidence that it only recently moved into freshwater marshes. Stimson understood that the sparrow has likely been a freshwater sparrow over geological time spans. The Cape Sable seaside-sparrow was among the first group of species listed as endangered by the U.S. Fish and Wildlife Service on March 11, 1967. The sparrow was listed because of its limited distribution and threats to its habitat posed by large-scale conversion of land in southern Florida to agricultural uses.

Surveys of the sparrow, employing helicopters to ferry observers to its remote locations, began with Harold Werner in 1974. The first range-wide survey was in 1981, repeated in 1992, and range-wide surveys have continued every year since. These surveys show that sparrows live in a set of populations (A through F) separated to various degrees by unsuitable vegetation.

Discovery

In 1918, Arthur Howell, a biologist with the United States Biological Survey, received a commission that would invite the envy of any modern day ecologist. He was charged with undertaking a systematic and complete survey of the bird life of Florida (Howell 1932). After considering travel arrangements, the time of year, and the threats of heat and violent storms that sweep the southern end of the state, Howell decided to begin his journey in midwinter in southern Florida and move

northward. His first stop was Royal Palm, Dade County, a place that later became Royal Palm State Park and ultimately part of Everglades National Park. After thoroughly surveying this already famous ornithological mecca he proceeded to Cape Sable, at the extreme southwest corner of the Florida mainland. It is a testament to Howell's skill that on his visit, which postdated those of countless amateur and professional ornithologists, including John James Audubon, he discovered the Cape Sable seaside-sparrow(*Ammodramus maritimus mirabilis*), the last new "species" recorded in the continental United States. The surprise at finding a new species in the already well-documented bird life of the U.S. prompted Howell to give it the specific name *mirabilis* (Howell 1919).

The genus in which seaside-sparrows belong, *Ammodramus*, translates from Latin to English roughly as 'sand runner' or 'ground runner'. It is affixed to this group, along with the species name of *maritimus* (i.e. of the sea), due to their habit of spending most of their time on the ground in the depths of marsh grasses well hidden from predators and the harsh coastal elements.

That countless birders missed this drab and unassuming little bird is not surprising. Audubon stopped only on the beach of Cape Sable while freshwater was loaded onto his ship (Buchanan 1915). Even had he ventured beyond the thick wall of trees, shrub, and cactus into the elongated, 1 by 9 km swale of coastal prairie, he may have, as many had doubtless done before, mistaken the Cape Sable seaside-sparrowfor the more numerous Savannah Sparrows (*Passerculus sandwichensis*) and Saltmarsh Sharp-tailed Sparrows (*Ammodramus caudacutis*) which winter in the area. Howell, however, was observant and either meticulous or fortunate. He must have caught a glimpse of the unique olive tint of the soon-to-be-named sparrow, which proved novel to his already broad experience with birds of the southeastern U.S. (Anon. 1940).

The adult Cape Sable seaside-sparrowis a medium-sized sparrow (ca. 14 cm long) with a dull olive-grey back and head, olive-brown wings and tail, and light-grey breast and sides streaked with dark olive-grey. The legs and bill are grey. The chin is white; lores are yellow; and a white stripe over a dark whisker stripe extends from the jaw. Immatures exhibit an even more subdued appearance. The back is streaked with brown to light buff, the breast is light grey to light buff with reduced streaking relative to adults, and the whisker mark and yellow of the lores are absent (Howell 1919, Werner 1978). Based on its appearance and its isolation relative to the distribution of the other seaside-sparrow species, Howell (1919:87) successfully argued for full species status of the Cape Sable seaside-sparrow(which he named *Thryospiza mirabilis*), stating "This species differs so strikingly from all the other Seaside-Sparrows that intergradation with any of the forms seems very improbable." The Cape Sable seaside-sparrowwas to enjoy this status until 1973, when it was reduced to subspecies status by the American Ornithologists' Union (Eisenmann 1973).

Howell (1919) does not state the extent of his traverse of the cape's coastal prairie on his first visit. If he did not cover it in its entirety he was lucky to see a bird that, as

would become evident over the next five decades, is not always where it is supposed to be or where it has been in the past. He discovered the sparrow in the narrow linear swale of prairie typically found just inside the first vegetated berm of sandy shorelines. This prairie, dominated by *Spartina* species., had dimensions of "about six miles in length and not more than half a mile in breadth" (Howell 1932:462). Howell was doubtful that the range of the species could be so restricted. He suggested that "further search in this region may show that the species has a wider range than our present knowledge indicates" (Howell 1919:87).

Indeed, less than 1 km inland lay a great expanse of prairie covering most of the cape, but we have no indication as to whether Howell ventured there. As late as 1932 the known range of the Cape Sable seaside-sparrow was restricted to the above-mentioned strip of prairie. Howell revisited the area in 1926 and, after much searching, found a colony of sparrows "several miles distant from the spot where they had been discovered" (Howell 1932:462). Again, Howell made no mention of any efforts to find the sparrow outside of the original location. More intriguing is a visit by famed ornithologist George Miksch Sutton who, on a bird collecting expedition in 1924, traveled on foot from Flamingo to the Gulf of Mexico (Holt and Sutton 1928). Sutton eventually found the sparrow, complaining that

> "More downright labor was required to find this rare and little-known species than any other encountered. Many hours were spent before even the right environment was located. Then, when it was decided that a certain area ought to harbor the birds, if they were to be found anywhere, it took great strength of conviction to keep plowing through the tall grass in the full sun." (Holt and Sutton 1928:435)

Sutton's description of the location indicates that it was the same prairie Howell visited (Holt and Sutton 1928). To get to that location, Sutton had to traverse the large inland prairie that made up most of the Cape proper. By all accounts, this should have been prime Cape Sable seaside-sparrow habitat, but Sutton mentions only the birds at Howell's site. We are left with no evidence for or against scenarios of ignorance, inattention, or accidents of biogeography.

Destruction

Holt and Sutton's (1928) was the last published report of the Cape Sable seaside-sparrow on the cape before a devastating hurricane pummelled the area beyond recognition in 1935. The Labor Day Hurricane of 1935 has been called "the storm of the century" and "the most powerful storm to ever strike the U. S. coastline. . . on record" (Barnes and Frank 1998). The storm developed over the Bahamas and in four days struck the Florida Keys as a Category 5 hurricane. Winds were in excess of 380 km/hr and, before the barometer at the Key West weather station was lost in the rage of the storm, the barometric pressure of 26.35" (669.3 mm Hg) became the lowest ever recorded in the United States. A "wall of water" perhaps as high as 6 to 7 m washed over parts of the Keys; "the destruction of buildings, roads, viaducts, and bridges was practically complete" (McDonald 1935:269). Over 400 deaths were

attributed to the storm: 244 known dead and 165 reported missing, assumed dead. Many of those who lost their lives were residents of three relief-work camps inhabited by veterans of World War I (McDonald 1935). Stimson (1956:490) relates his impressions of the hurricane's effects on Cape Sable:

> "[The hurricane] must have reached the vicinity of Cape Sable about midnight [2 September 1935]. The center of the storm passed Cape Sable at an undetermined distance at sea, but supposedly within a few miles. . . . Cape Sable was buried under a wave of eight feet or more.
>
> Members of the Roberts family then living at Flamingo had received radio warning and started to walk out just prior to the arrival of the hurricane wave. On December 6, 1935, the elder Mrs. Roberts told me that when they reached the road along the bank of the Flamingo canal the water in the canal was very low, but within a few minutes the water was up to their armpits; and the only thing that saved their lives was the recent elevation, of about two feet, of the road along the canal bank. Going westward from Flamingo that same day I found a line of bleached seaweed festooned for long distances in the trees about eight feet or more above the normal high water mark."

Stimson goes on to state that it is inconceivable that a population of small, ground-nesting birds could have survived the catastrophe. This was apparently the case. Expeditions to Cape Sable with the express intention of finding the Cape Sable seaside-sparrow were launched in 1937, 1938, and 1949; none were found (Stimson 1956). There was, however, one published account of the sparrow observed at Cape Sable in April of 1936 (Semple 1936). Could it be that this celebrated population of sparrows survived the hurricane only to be driven to extinction within a year? Or was this simply a case of misidentification?

Semple is known to the field of ornithology by a few short descriptive notes on Florida birds that appeared in the *Auk*, and by the following editor's note that appears in Holt and Sutton (1928:409): "Mr. Sutton went to Florida as the guest of Mr. John B. Semple of Pittsburgh, who has done much to increase the ornithological collections of the Carnegie Museum." In a letter to Arthur Howell dated January 1930, Semple wrote that the Cape Sable Seaside-Sparrows were still in "their old haunts" after an October storm "pushed five feet of saltwater over the entire region" (Howell 1932:463). The only recorded hurricane that may have affected southwest Florida in 1930 occurred in October, but its closest approach to the cape was ca. 300 km to the west; the claim of five feet of saltwater may be an exaggeration. In Semple's only other published account regarding the Cape Sable Seaside-Sparrow, he claims to have observed the sparrow in April 1936, eight months after the Labor Day Hurricane, "pursuing, manifestly, its normal, unbroken cause of life." (Semple 1936:341). However, when Semple accompanied Arthur Howell and others on the above-mentioned expedition to find the sparrow in May 1937 none were found (Stimson 1956). It seems probable that Semple, visiting the cape at a time of year when wintering Savannah and Sharp-tailed sparrows and, possibly, eastern Seaside-Sparrows (*Ammodramus maritimus maritimus*) would have

been present, mistook these for the Cape Sable Seaside-Sparrow. It is safe to say that the hurricane in 1935 did, in fact, obliterate the Cape Sable seaside-sparrow from its known range on the cape for at least a few decades.

A knowledgeable visitor to the Cape Sable of today would be hard pressed to find accordance between the habitat he observes and that described by Holt and Sutton (1928). At the time Howell made his discovery, the cape was primarily a vast coastal prairie consisting mostly of sparse cordgrass (*Distichlis spicata* and *Sesuvium portulacastrum*), *Spartina* spp., and the requisite fringe of mangrove (Harshberger 1914, Holt and Sutton 1928). By the early 1940s, mangrove encroachment had diminished the extent of prairie to roughly half the area of the cape (Davis 1943). Currently, of the roughly 180 km^2 that the cape covers, less than 10 km^2 remain in any sort of prairie habitat (FGAP 1994); the remainder consists of mangroves and halophytic forbs interspersed with bare mudflats (Bass and Kushlan 1982). As for the swale of prairie where the Cape Sable seaside-sparrow was discovered, it has changed from primarily *Spartina* to more salt-tolerant species, most notably *Batis* spp.

The initial cause of this drastic conversion of habitat was undoubtedly the Labor Day Hurricane of 1935. However, one would expect that with time the cape would revert to its previous state. Although very severe, the 1935 hurricane was surely only one of a series of storms that have raked the cape from time immemorial. The apparent permanence of the habitat conversion suggests that more insidious agents were at work. Two possible causes are sea level rise and the alteration of freshwater flows in the Everglades, already well underway in the early 1930s. The effects of neither of these phenomena have been investigated in relation to the vegetation dynamics of Cape Sable.

The mystery remains as to whether the Cape Sable seaside-sparrow inhabited the interior prairie of the cape. A consideration of biogeography would lead one to suppose that the sparrows that inhabited the thin strip of coastal prairie where Howell discovered them formed a satellite population of sorts to a larger population in the interior cape. In support of this supposition, sparrows were eventually found in this area. In 1971 Werner located a small population near the Fox Lakes in a remnant *Spartina* marsh (Werner 1975). As for earlier records, we have only Sutton's expedition (Holt and Sutton 1928). It does not mention the sparrow outside of the swale cited by Howell (1919). Stimson (1966:154) states that after the discovery of the sparrow, "Further investigation on the Cape Sable prairies showed that the bird occupied a range from a few miles west of Flamingo to well up behind Northwest Cape." As this is the only published mention of the sparrow in the area and no supporting references are given, we are left to wonder if common knowledge superseded scientific publication.

Extinction

After it became certain that the Cape Sable seaside-sparrow had disappeared from the cape, many believed that this newest species to the United States was lost to

oblivion (Stimson 1956). Before the sparrow was accorded this fate, however, there remained one dim hope. On 3 May 1928, Donald J. Nicholson, an avid and prolific ornithologist whose publications span four decades, stood on a large prairie in Collier County, "lying between pine forests and an extensive cypress swamp" (Nicholson 1934:389). A prolonged drought had made the prairie "as dry as powder." Nicholson spotted a single bird that he believed to be a Cape Sable Seaside-Sparrow, a species he knew only by published accounts (Nicholson 1934). Four years later, on 21 April 1932, he returned to the same spot and found 15 to 20 pairs over a ca. 8-km^2 area. He reported the site as being "6 miles northeast of Pinecrest" (Nicholson 1934:389). If a sparrow population persisted here, far inland from the cape, the species may have survived the hurricane after all.

Pinecrest was, and is, something less than a hamlet in southern Collier County. It lies on the Loop Road, a secondary road originally constructed to be part of the great Tamiami Trail that links the two coasts of southern Florida. When the Trail was built, however, it passed north of Pinecrest, leaving the Loop Road nothing more than a handy access point to the wilderness of the Everglades and the Big Cypress.

Nicholson's report was given little attention; however, it did receive a short mention in Howell's (1932) definitive book. A glance at a map explains the lack of confidence in what should have been surprising news. Six miles northeast of Pinecrest lay the Tamiami Trail, completed in 1926. That the author would report the location relative to Pinecrest instead of the much closer town of Fifty-mile Bend must have cast some suspicion. More importantly, the area was in the middle of an extensive cypress forest—not seaside-sparrow habitat by any means. Later correspondence between Stimson and Nicholson established the actual location to be southwest of Pinecrest in a savannah near the Lostman's Pine area, the error in direction apparently being caused by the windings of the Loop Road, which was used as a reference point (Stimson 1956). Nicholson persevered and, after accompanying Arthur Howell and others on a trip to the cape in March 1937 in a fruitless search for Cape Sable Seaside-Sparrows, he guided the party to the location where he had found sparrows in 1928 and 1932 (Nicholson 1938). After a half-day of searching, no sparrows were found. The time for the eulogy of the Cape Sable seaside-sparrow had arrived, and it was delivered by Nicholson (1938:44) in the ethnocentric language of the day:

> "And while I would like to think some [Cape Sable Seaside-Sparrows] may still exist in some isolated place rarely frequented by white men, I can entertain no great hope that this is the case. It may be that another of our most interesting birds has gone forever, known only to modern science for the short span of twenty years."

Interlude

The Cape Sable seaside-sparrow was rediscovered four years after its eulogy was published. Let's make use of this hiatus in the annals to review the perceptions of the major players concerning the distribution of the sparrow. Howell suspected that the sparrow's range must extend beyond the ca. 1 by 9 km swale where he discovered the species. Sutton agreed: "Though the birds were very rare, or at least were very rarely flushed, it is hardly conceivable that the species is restricted to so extremely small a range" (Holt and Sutton 1928:435). But the common belief that the sparrow had a ridiculously small range seems to have held sway. Why else would Stimson (1956:492), after reviewing the corrected reports of Nicholson's find in Collier County, feel compelled to write ". . . we now know that the sparrows were in the presently known range long before the [1935] hurricane. They were not blown up there by the storm."

The dynamic nature of the sparrow's habitat was also hinted at in early reports. Howell (1932:464) wrote:

> "Conditions in their habitat vary from year to year. . . occasionally flooded by heavy rains and tidal waves at other times becoming practically dry and having the vegetation destroyed by frequent fires. For this reason the birds are forced to move from time to time and find suitable breeding places, and quite possibly their numbers are kept down by these agencies."

How Howell surmised all of this from the small range he was aware of is peculiar, but, more importantly, he was proven right by future investigations. Sutton again echoed Howell's view, albeit in a more alarming fashion, by mentioning the danger of fire to the only known colony of sparrows: "It is quite possible that the whole area might be devastated by a single blaze" (Holt and Sutton 1928:436).

So, even before the 1935 hurricane obliterated the Cape Sable seaside-sparrow population on the cape, there existed the intuition, if not the knowledge, that the search for the sparrow would prove to be a sort of ecological shell game. The sparrow's low population densities and its dynamic habitat, not to mention its secretive and unassuming habits, repeatedly confounded efforts to delineate range and status. In hindsight this is not surprising, for the searchers were not going to the best possible place. Howell, Nicholson, and the other early surveyors of the Cape Sable seaside-sparrow were unknowingly nibbling at the edges of the species' range. The range dynamics of grassland birds vary across space and time (Curnutt *et al.* 1995). Typically, species of grassland birds have a high abundance, low variability, core population. Proceeding from the core toward the edges of the range, abundance decreases and variability increases. The edges of ranges are constituted of ephemeral, widely dispersed pockets of individuals. This continental-scale model of population dynamics applies as well to the regional scale in which the Cape Sable seaside-sparrow exists (Curnutt *et al.* 1998). A clear understanding of the sparrow and its temporal and spatial dynamics would only come with the discovery of a core population, and this would have to wait until the 1970s.

Resurrection

Given what appeared to be universal acceptance that the Cape Sable seaside-sparrow was extinct, its rediscovery was unsought and unexpected. On 28 June 1942, a young William Anderson was making observations on Swallow-tailed Kites (*Elanoides forficatus*) "in a little savannah next to the Big Cypress" (Collier County) when he heard, then saw, two or three Cape Sable Seaside-Sparrows (Anderson 1942) . Soon after this surprising discovery, Anderson enlisted with the U.S. Army to fight in World War II. He took the time while in boot camp to write to Stimson and ask that he confirm the sighting (Stimson 1944). On 22 May 1943, Stimson, A. J. Dietrich, and Bob Woodmansee followed Anderson's directions to the spot. For a bird that had always been reported as scarce, low in numbers, and difficult to observe, what Stimson found must have astounded him. "Within a hundred yard circle there were at least ten male birds. More distant songs indicated the presence of still more" (Stimson 1944:31). This new location was "many miles from Pinecrest, and many more from Cape Sable." The sparrow lived and, moreover, in larger numbers and in a more accessible location than the cape afforded.

Five years later this was still the only known site with Cape Sable Seaside-Sparrows. Even though reaching the area required an arduous 2-hr walk, the exact location was a sworn secret among the four men who knew it. "To publish or divulge the location of this one known spot might well lead to the extermination of the species," Stimson wrote (1948:69). He continued, "May this rare and miraculous species continue to live safe from any collector's gun." Nevertheless, Stimson suspected more than ever that the sparrow could be found in other locations. The publication of Davis' (1943) *The Natural Features of Southern Florida* provided the first relatively accurate vegetation map of the little-explored Everglades. On it Stimson saw that saltmarsh prairies were scattered from near Naples all the way south to the Shark River Basin and that these sites seemed no different from the ones that he knew held sparrows (Stimson 1948). The problem was getting there. After relating an episode involving a cottonmouth (*Agkistrodon piscivorus*), Stimson wrote: "Most of the possible area where the Cape Sable seaside-sparrow might thus nest would be very difficult to access and perhaps also slightly dangerous" (1948:69).

Stimson was a tenacious and thorough ornithologist, known to disappear into the wilds of the Everglades on foot or in a canoe for days at a time, without telling anyone where he was going or when he might return (W. B. Robertson, Jr.; pers. comm.). In the spring of 1953 Stimson's efforts paid off (Stimson 1956). He found sparrows at two separate locations, one about 2 km southwest of Ochopee and the other near the Turner River. Both sites were saltmarsh prairie, dominated by *Spartina* spp. On 25 April 1954, Stimson accompanied Everglades National Park rangers on a trek via swamp buggy to check on a water gauge inside the park boundary. As they entered the extensive sawgrass (*Cladium jamaicensis*) prairie, Stimson saw a Cape Sable seaside-sparrow flush. This sighting was followed by two or three singing sparrows heard at the water gauge, another site dominated by sawgrass. Sawgrass, unlike *Spartina*, is found in long-hydroperiod freshwater marshes. Stimson had, if not an epiphany, at least a realisation that the sparrow could be found in the vast freshwater prairies of the Everglades. If this proved to be

the case, the potential range of the sparrow would cover an area much larger than the scattered saltmarshes near the coast presented.

Over the next year, and through the exertion of many 30 to 50 km treks, Stimson (1956:501) determined the range of the Cape Sable seaside-sparrow to be "the salt marshes lying to landward of the mangrove fringe along the southwest coast of Florida from northwest of Everglades City to near the headwaters of the Huston River; and in salt marsh and fresh water marsh prairie from the mouth of Gum Slough to the Shark River Basin." The distribution of the sparrow was beginning to belie its appellation of "seaside," being found by Stimson (1961) as far as 40 km inland from the Gulf of Mexico.

For 15 years, from 1956 to 1971, the known range of the Cape Sable seaside-sparrow was vast and, for the most part, inaccessible. There are no other published reports of sparrow observations as far into the Everglades as Stimson ventured. Near Ochopee, which lies on the Tamiami Trail, one could easily access a few sites that regularly held sparrows, but encroaching human activity was beginning to adversely affect the birds (Stimson 1961). Altered hydrology, road construction, and saltwater intrusion had severely altered Cape Sable seaside-sparrow habitat by the mid-1970s (Werner 1975), but this process probably began in 1926 with the construction of the Tamiami Trail and its accompanying canal. The completion of the Turner River Canal in the mid-1950s must have exacerbated the problem. With less surface water came more frequent and intense fires. Stimson (1961) reported on the status of three areas in Collier County that held sparrows; all three had recently burned. A site near Ochopee was intentionally burned by "snake hunters" in late May 1961. Stimson could find no sparrows there two weeks later. The more divine agent of lightning caused a fire at a site near Lostman's Pines in April or May 1957; again Stimson could find no birds there even four years after the blaze. The third area was the "secret" location discovered by Anderson (1942). This area burned in the early part of 1959 and Stimson found sparrows there in June of that year. On returning in 1961, however, Stimson found no sparrows.

The complex relationship between sparrows and fire will be addressed later in this volume. It is sufficient here to say that Stimson and others who followed the drama of the Cape Sable seaside-sparrow were alarmed that colonies of sparrows were disappearing more rapidly than new ones were being discovered. The fact that the interior prairies of the Everglades held sparrows must have been of little consolation, since the population there had never been enumerated.

The Cape Sable seaside-sparrow was in the first group of species listed as endangered by the U.S. Fish and Wildlife Service, on 11 March 1967, pursuant to the Endangered Species Preservation Act of 1966 (32 FR 4001, Title 16, Chapter 5a, Section 2). The sparrow retained that unenviable distinction under the Endangered Species Conservation Act of 1969 (Title 16, Chapter 5a, Section 668) and the Endangered Species Act of 1973 (Title 16, Chapter 35, Section 1531), as amended. The Cape Sable seaside-sparrow was listed because of its limited distribution and threats to its habitat posed by large-scale conversion of land in southern Florida to

agriculture. This latter reason may seem odd until one remembers that previous to the establishment of Big Cypress National Preserve in 1974, a large portion of the known population of sparrows was found on private land.

In 1970, Harold Werner, a graduate student of Glen Woolfenden, undertook the task of determining the status of the sparrow. Werner revisited all of the locations in which the sparrow had been found in the past (Werner 1975). What he found was at once surprising and disheartening. Werner found sparrows at six sites in and around the Ochopee area, but over his five years of observation (1970–1975) he noticed a marked decline in the number of sparrows and the quality of their habitat. Werner also found a few birds in the southern Big Cypress area, near the location where Nicholson (1928) made the first off-cape observations of the species. The sparrow was reported as very rare in this area in the early 1970s (Werner and Woolfenden 1983). The most surprising find made byWerner was of four singing male sparrows and five juveniles in the remnant cordgrass marshes of the interior of Cape Sable in 1970; in 1975, Werner found only one sparrow there (Werner 1975). In effect, the known boundaries of the Cape Sable Seaside-Sparrow's range had changed little from the 1950s to 1970. The numbers of birds at those boundaries, however, were frighteningly low. The cape population could hardly be thought of as self-sustaining, the Ochopee populations were visibly declining, and the southern Big Cypress populations had never been very numerous.

Revelation

The first inkling of the true distribution of the Cape Sable seaside-sparrow came in 1972 and, in keeping with the sparrow's enigmatic history, it arrived unexpectedly. In that year a wildlife technician at Everglades National Park took advantage of the doubly rare circumstance of a Short-tailed Hawk (*Buteo brachyurus*) nesting in an accessible place, just off the Main Park Road west of Taylor Slough. To investigate the food habits of the hawk, the technician climbed to the nest and retrieved a mangled ball of feathers. The remains were not identifiable in the field, and the story would have ended there but for the work of Roxie Laybourne of the Smithsonian Museum of Natural History. Laybourne was a pioneer in the science of species identification by feather structure. From a sample she was sent, she determined that the Short-tailed Hawk's meal was a Cape Sable seaside-sparrow (Ogden 1972).

The discovery of a Cape Sable Seaside-Sparrow, even a dead one, east of Shark River Slough opened up a new venue for discovery. Werner (1975) surveyed the prairies of Taylor Slough and found sparrows there. He continued searching and found sparrows as far north as the east Everglades and south on both sides of Taylor Slough to near the northern limit of mangroves. The mother lode had been discovered. Over a ca. 10,000-ha area, Werner (1978) estimated the Cape Sable seaside-sparrow population to be between 1900 and 2800 birds.

That the sparrow inhabited the eastern prairies of the Everglades and went undetected for so long gives one pause. The northern reaches of Taylor Slough had been surveyed in the early 1950s by William Robertson, Jr., an outstanding

ornithologist, and no sparrows were found. In 1957 a tourist reported seeing a Cape Sable seaside-sparrow in the area, but park staff did not investigate (Bass and Kushlan 1982). It may be that this area was home to an ephemeral edge population similar to the one that produced the discovery of the species. More puzzling is the population between the Taylor and Shark River Sloughs south of Long Pine Key. This area, which currently holds the lion's share of sparrows, has been accessible to birders since the creation of the road to Flamingo. Indeed, countless birders, including Howell, traversed the Old Ingraham Highway, which bisects the present heart of the sparrow population, on their pilgrimages to Flamingo. It seems incredible that these avid ornithologists never stopped to look over the vast prairies in an attempt to find, if not Cape Sable Seaside-Sparrows, at least some bird of interest. There remains the possibility that the sparrows simply were not there and that their current distribution is the result of ecological changes over the last 50 years. The reduction of freshwater flow into the southern Everglades began with the Central and Southern Florida Project, which commenced in 1948 (House Document No. 643, 80th Congress, Second Session) . The Flood Control Acts of 1958 and 1965 allowed the destruction of the head of Taylor Slough and the subsequent drying of the eastern Everglades. It is possible that the sparrow recently increased in abundance in the prairies east of Shark River Slough as the available habitat was augmented by water management actions.

Investigation

The discovery in 1972 of Cape Sable Seaside-Sparrows east of Shark River Slough was fortunate in that it allowed scientists easy access to the sparrows via the Main Park Road. Before that date anyone interested in studying the sparrow had to face the problem of accessing the wilderness south and east of the Loop Road. In the 1970s, science did not come to the Cape Sable Seaside-Sparrow; the sparrow came to science.

Werner (1975) established an intensive study plot straddling the western edge of Taylor Slough. The area was dominated by *Muhlenbergia filipes* and was home to the greatest known density of sparrows. Here he set out to find out as much he could about the ecology of the sparrow. Most of what Werner observed about the autecology of the sparrow we will discuss in later chapters of this volume. We will address here only his work on the relationship of fire and the sparrow, because this topic was of interest to the Park Service and it spawned one other short-term study of interest. Werner collected reams of data not only on the sparrow, but also on the vegetation, hydrology, and fire history of his plot in Taylor Slough (Werner 1976). He found that a site burned shortly before the breeding season held no sparrows that year, but sparrow density increased each subsequent year until maximum density was reached the third year. Sparrow densities at sites that had burned four years previous were low, and Werner found no sparrows at sites that had burned five or more years earlier. Werner (1976) correlated this orderly sequence of sparrow behaviour with the more predetermined dynamics of prairie vegetation. A burned prairie has an aboveground biomass of essentially zero immediately following the fire. At Werner's sites this biomass increased steadily until three years post fire.

After that point the total biomass fluctuated but the percent live biomass decreased (Werner 1976). From these observations, Werner and Woolfenden (1983:63) concluded that: ". . . in *Muhlenbergia* prairie, decreased sparrow density and increased territory size may be related to decreasing ratios of live biomass and increasing amounts of old dead biomass after 3 years."

Of course, nature rarely abides by such unambiguous rules, and sparrows do inhabit sites that have burned five and more years previously (Taylor 1983, Curnutt *et al.* 1998). Beginning in 1978, Dale Taylor conducted a study designed to determine the impact of fire on the Cape Sable seaside-sparrow (Taylor 1983). Taylor worked west of Werner's study plot in an area that encompassed a wider variety of habitat types. Specifically, Taylor included both shallow and deep soil sites, whereas Werner's site included only the latter. Taylor (1983) found that sparrow population response depended on soil depth and rate of vegetation recovery. On deeper soils (> 40 cm) vegetation recovered rapidly, sparrows reinvaded within two years of a fire and increased in density until four years post fire; after that sparrows inhabited marginal sites at relatively low numbers. This concurs with Werner's (1976) findings. On shallow soil sites (< 20 cm), however, re-invasion by sparrows was delayed for up to four years. After colonisation, sparrow numbers remained lower than the peak numbers found on deep soil sites, but the sites remained occupied longer (up to 10 years).

Werner's and Taylor's work proved invaluable to the National Park Service personnel who developed a management plan for the Cape Sable Seaside-Sparrow. It should be remembered, however, that Werner and Taylor were investigating the ecology of a bird for which neither range nor population estimates had been determined. As unsettling as this uncertainty was, by the late 1970s tragic events were occurring 300 km north of the Cape Sable seaside-sseaside-sparrow parrow's range involving a close relative, the Dusky seaside-sparrow (*Ammodramus maritimus nigrescens*).

The Dusky seaside-sparrow shared many attributes with the Cape Sable Seaside-Sparrow. Like the Cape Sable, the Dusky had a range isolated from other seaside-sparrows by geographic barriers, it lived in brackish to freshwater marshes, and its habitat was heavily influenced by natural disturbance (Baker 1978). Unlike the Cape Sable, the Dusky had the misfortune of living in the path of a relentless drive for "progress." The decline and ultimate extinction of the Dusky seaside-sparrow happened with alarming rapidity. Beginning in the 1940s, its habitat was heavily dosed with DDT in an effort to control mosquitoes. This led to an estimated decrease of 70% in the sparrow population by 1957 (Trost 1968). As the mosquitoes developed resistance to chemical control, the Florida Board of Health launched an ambitious project of ditching and impounding coastal marshes. By the late 1960s all coastal marshes within the Dusky Seaside-Sparrow's range were thus altered (Sykes 1980). Within the remnants of the Dusky's range the decade of the 1970s was witness to the following assaults: (1) the construction of a major expressway to link Walt Disney World in Orlando to the Kennedy Space Center; (2) the digging of a large drainage canal to allow residential construction in a wetland; and, (3) repeated

uncontrolled fires set by ranchers for land management (Kale 1996). The drop in sparrow numbers was precipitous: in 1972 a survey of the total population detected 110 males; in 1973, 54 males; in 1978, 23 males (Baker 1978). When only four Dusky Seaside-Sparrows could be found they were taken into captivity for breeding (Delany *et al.* 1981). Since all of the birds were male, back-crossing was used in an attempt to develop a population of "mostly" Dusky Seaside-Sparrows (Kale 1996). The last Dusky died in captivity on 16 June 1987; ironically, it was housed at Disney World.

News of the Dusky Seaside-Sparrow's imminent demise and the legal responsibility of the National Park Service to protect and increase populations of endangered species on their lands intensified the call for better estimates of the status of the Cape Sable Seaside-Sparrow. The situation was all the more urgent given the dynamic nature of sparrow habitat and the sparrow's enigmatic history (H. Kale, II, pers. comm.). Oron "Sonny" Bass, Jr., and James Kushlan, biologists at Everglades National Park, undertook the daunting task of characterising the distribution and habitat use of the Cape Sable seaside-sparrow by conducting extensive surveys from 1978 to 1980. Their efforts culminated with a census of all available sparrow habitat in 1981 (Bass and Kushlan 1982). The principal difficulty in surveying Cape Sable Seaside-Sparrows lies in reaching areas nestled deep inside the nearly 1,000-km2 wilderness of Everglades National Park and Big Cypress National Preserve. For their 1978 through 1980 surveys, Bass and Kushlan covered easily accessible areas on foot and used a Bell C-47 helicopter outfitted with pontoons to reach the more remote areas (Bass and Kushlan 1982). In reference to the sparrow's coastal marsh habitat, Stimson (1956:494) commented: "In years of normal rainfall this whole. . . area is accessible only by airboat, or perhaps helicopter. Neither is hardly [sic] the type of conveyance from which to seek a small bird." Bass and Kushlan had, in fact, developed a novel method of using a helicopter to conduct sparrow surveys. The method entailed landing at a predetermined census site and turning off the helicopter engine. Surveyors then watched and listened for sparrows for 7 min while making observations on the vegetation and surface-water conditions before re-boarding the helicopter and advancing to the next site (Bass and Kushlan 1982). To the uninitiated this may seem somewhat bizarre. Wouldn't the sparrows simply fly away on the approach of the roaring machine? The authors can attest to the fact that the birds do not scatter (although one hopes that they have enough sense to get out from under the pontoons before it's too late). If singing sparrows are present, they are usually heard within a few minutes of the engine being cut (and we have seen some singing as the helicopter lands).

Bass and Kushlan's (1982) preliminary censuses showed the continuing constriction of the sparrow's range as outlined by Werner (1976). In 1978, sparrows were observed at two sites on Cape Sable, but none were found there in 1979 or 1980. Sparrows have not been seen on Cape Sable since 1978, marking the end of the sparrow's occupancy of its place of discovery and namesake. In 1978 and 1979, sparrows were found at one and two sites, respectively, near Ochopee, but none were found there in 1980. In 1980, Bass and Kushlan intensified their search of the

prairies on either side of Shark River Slough, including north of Taylor Slough and south of Long Pine Key. They found substantially more sparrows than expected. These preliminary censuses set the stage for the extensive survey of 1981.

In 1981, Bass and Kushlan's goal was to systematically census all potential sparrow habitat (Bass and Kushlan 1982). Census points were determined by gridding U.S. Geological Survey 7.5-minute ortho-photo quadrangles into 1-km2 blocks. The intersections of the grid lines that fell in prairie habitats that were not monotypic stands of sawgrass were designated as census sites. Using the above-described helicopter method, Bass and Kushlan surveyed 864 sites from 31 March through 16 June 1981. The results were staggering. Cape Sable Seaside-Sparrows were found in virtually all prairies of considerable size that were not dotted by trees or exposed to long hydroperiods. These "dry prairies" are typically dominated by *Muhlenbergia* grass or have this species as a major component (Bass and Kushlan 1982).

West of Shark River Slough, a small cluster of six sites just south of Gum Slough held sparrows, but the greatest part of the sparrow population was found in a more or less continuous prairie that stretched over 20 km south of the Tamiami Trail and bordered the slough itself. Here over 150 sparrows were seen at 117 sites. East of Shark River Slough the pattern was more complex. Of 396 sites surveyed, 155 held a total of 248 birds. About a third of the sites with sparrows formed a contiguous block south of Long Pine Key that stretched nearly the entire distance between Shark River Slough and Taylor Slough. The remaining sites were north and east of Long Pine Key, with an isolated group east of Taylor Slough near the Aerojet canal, and a small cluster of sites isolated to the north in the East Everglades.

The estimation of population numbers from census data is a difficult task (Ralph and Scott 1981). Nonetheless, Bass and Kushlan were compelled to make such an estimate. They estimated the detection distance of a singing sparrow at 200 m and consequently assumed a census coverage of 12.6 ha at each site visited. The number of singing birds at each site was used to calculate a density for the 1 km2 surrounding the census point. Bass and Kushlan obtained a population estimate by multiplying the average density of birds per 1 km2 by the number of occupied sites, then doubling that number to include uncounted (non-singing) females. This rough estimate of the number of Cape Sable Seaside-Sparrows served two important functions. First, it gave a ballpark figure of the population size. Second, it established a baseline for detecting population changes by comparison with results of future surveys.

Bass and Kushlan (1982) estimated the minimum population of the Cape Sable seaside-sparrow to be ca. 6,600 birds: 3,700 east of Shark River Slough and the remainder west. The final discovery of the size and spatial distribution of the sparrow population was as surprising as it was welcome. Those who may have harboured a crisis mentality toward the status of the sparrow could now be assuaged. The optimism produced by the 1981 results was tempered, however, by the realisation that peripheral populations of sparrows had disappeared (Bass and Kushlan 1982). Furthermore, the sparrow, though currently numerous, was subject

to the vagaries of fire and the exploits of the water managers who controlled the timing and amount of freshwater flow into the sparrow's range.

Complacency?

For a species that was thought to number in the hundreds throughout its history, the realisation that the Cape Sable seaside-sparrow actually had a population of greater than 6,000 was a source of relief and, perhaps, complacency. After the 1981 census Kushlan *et al.* (1982) produced a management plan, the objectives of which were "to determine and maintain the present distribution of the Cape Sable seaside-sparrow, and to prevent it from becoming in danger of extinction" (p. 19). The plan called for increased censusing, intensive research on habitat use and reproduction, studies on the relationship of fire, water management, and sparrows, and management activities to maintain the peripheral population of Ochopee. The management plan was well developed and scientifically sound, but none of the actions were carried out until a decade after they were proposed. The proposed re search would cost a considerable sum of money — especially if it entailed repeating the extensive census — and the funds, although requested annually, were not made available. Crises get funding, and 6,000 sparrows was not a crisis. Consequently, the next census of sparrows was in 1992. It initiated the work that the rest of this synthesis compiles.

Chapter 2

Life History

Julie Lockwood, Rebecca Boulton, Michelle Davis, and Tom Virzi

Abstract

Cape Sable seaside-sparrows are a subspecies of the more widely distributed seaside-sparrow group. Their life history is very consistent with that of their sister species, with some notable differences related to their occupation of sub-tropical non-tidal marshes. Cape Sable seaside-sparrows are year-round residents of the Everglades ecosystem. Their breeding season extends from late March to July, with the beginning of the breeding season dictated by the depth of ground water levels and the amount of daily rainfall in the months prior to the onset of breeding.

Ground water levels must be low enough to allow the construction of sparrow nests, but rainfall levels must be high enough prior to breeding to stimulate the emergence of the invertebrates sparrows utilise as prey. The factors that signal the end of the breeding season are more obscure, however, very few sparrow nests are active after July. Sparrows moult their plumage every year, and this process begins in August and is completed by October. During this time, sparrows are very secretive. During the non-breeding season, sparrows most survive the changing water flow conditions of their habitat typical of the Everglades wet season. Although they remain within marl prairie habitat (same habitat they use for breeding), they tend to use micro-habitats within that habitat that allows them to escape high water events.

Sparrows are highly faithful to their breeding sites, returning to the same 2 hectare territories yearly. Territory size tends to increase, and site fidelity tends to decrease, in areas of low sparrow density. Juvenile sparrows prospect for breeding habitat, and likely use song and calls of established breeding adults for cues as to what habitats lead to higher nesting success. This behavioural attribute makes the use of song-playback systems a reasonable conservation management tool. Sparrow nests are constructed of dead grasses and sedges that are locally abundant. They lay between 2–4 eggs per clutch, and incubate those eggs for 12–13 days. The majority of eggs in a clutch will hatch, and the young will stay in the nest for 9–10 days before fledging. Most nests fail due to predation, and predation rates rise sharply as the breeding season progresses into the wet season. Sparrows will re-nest from 1–3 times in a single season. Clutch size varies through the season with the average number of eggs per nest peaking in the second nesting attempt. Nestlings eat a variety of invertebrate prey, all of which are locally abundant.

Overview

Cape Sable seaside-sparrows are considered one of seven subspecies of the broader seaside-sparrow group (Post and Greenlaw 2009). It is the most southerly located subspecies, with its entire range situated at the southern tip of the Florida peninsula. The other subspecies occupy a thin line of tidal marsh habitat along the coastline of eastern North America, ranging as far north as southern Maine on the Atlantic coast and as far west as central Texas along the Gulf of Mexico (Post and Greenlaw 2009).

Despite their relative ubiquity within coastal marshes, their proclivity to duck for cover within the grass makes them very difficult to observe and thus many elements of their life history have been under-studied (Post and Greenlaw 2009). Most of what we do know comes from the relatively abundant subspecies that occupy tidal marshes from South Carolina to New York. Most elements of the Cape Sable seaside-sparrow's life history are in accord with their sister subspecies. However, this subspecies has unique elements to its life history, largely due to its occupancy of freshwater wetland habitats instead of tidal marshes. For example, Cape Sable seaside-sparrows do not contend with tidal flooding of their nests as do nearly all other populations of seaside-sparrows. Some of these unique elements contribute to its extreme vulnerability to extinction, a point we will highlight in later Sections.

Yearly Cycle

Seaside-Sparrows as a group are facultative migrants. Some populations migrate south for the winter months, whereas others remain in the same habitats year round (Post and Greenlaw 2009). Like many other avian species that demonstrate facultative migration, it is the southerly groups that remain residents in coastal marshes year round, and the northerly groups that fly south in the autumn (Post and Greenlaw 2009). Even those groups that do migrate tend only to move far enough south to escape the harsher moments of winter. Most migratory seaside-sparrows will overwinter in the southern coastal marshes of South Carolina, Georgia, and Florida (Post and Greenlaw 2009).

Given their southerly range, Cape Sable seaside-sparrows remain in the marshes of the Everglades year round as expected. Their breeding season begins in March and extends until August (Boulton et al. 2011). The rest of the year is spent foraging and surviving the annual variations in water conditions typical of the Everglades. Besides the beginning and end of breeding, there are very few marked events in the Cape Sable seaside-sparrow's yearly cycle.

The one exception is moult. Sometime in August, Cape Sable seaside-sparrows will begin their yearly moult of all body and flight feathers (Dean and Morrison 2001). During moult, sparrows become even more elusive than in the rest of the year presumably because the loss and replacement of feathers makes them less efficient flyers and thus more vulnerable to predators. Certainly, growing a whole set of new feathers is energetically expensive making it efficient to simply eat and make feathers. But new feathers are needed each year since the marsh grasses typical of

seaside-sparrow habitat tends to abrade their feathers, and they spend most of their lives moving within these grasses.

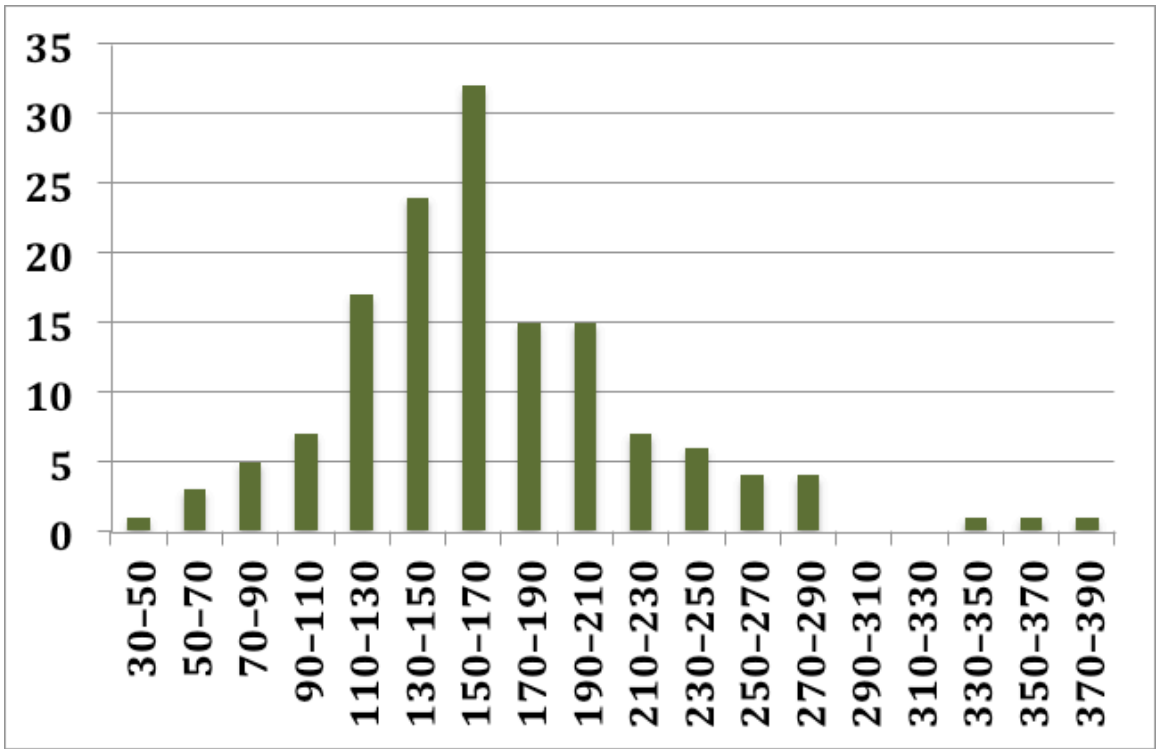


Figure 2.1. Frequency of height off the ground (mm) of Cape Sable seaside-sparrow nests as measured from the soil surface to the bottom of the nest cup. Distribution is based on a sample of 143 nests found between 2002 and 2005 within subpopulation E.

The cues used by Cape Sable seaside-sparrows to mark the beginning and end of their breeding season have been difficult to discern. Certainly their yearly cycle is highly influenced by the seasonal flood regime of the Everglades. It is no mistake, for example, that Cape Sable seaside-sparrows begin breeding in late March or early April, when water levels in the Everglades are at, or below, ground level. Cape Sable seaside-sparrows need water levels to be relatively low since they build their nests an average of about 16cm off the soil surface. There is some flexibility in the height of nests off the ground but the distribution of nest heights is a near perfect bell-shape, and thus most nests fall right around the mean (Figure 2.1). We discuss the mechanisms determining this distribution of nest heights in the next section. Relative to the onset of breeding, however, this distribution provides us with an expectation that breeding can begin when water levels are consistently below 16cm.

Breeding does not always begin when water levels are below 16cm, however. If we measure the beginning of the breeding season as the earliest date each year when a Cape Sable seaside-sparrow nest held an egg, our data shows wide annual variation

(Figure 2.2). Boulton et al. (2011) showed the earliest date on which an egg was observed in a sparrow nest varied from 20 March (2004 and 2007) to 21 April (2009). The earliest median first egg laying date was 25 March (2004) and the latest 30 April (2009). In an effort to uncover the reasons for this variation, Boulton et al. (2011) used eight years (March-July 2002-2009) of sparrow breeding data to test whether timing of breeding was associated with water conditions (both rainfall and ground water levels) during the preceding months.

Boulton et al. (2011) predicted that the Cape Sable seaside-sparrow would commence breeding when they acquired enough resources to form a clutch. Within the Everglades, rain falls mainly during the hot, humid wet season (June–September) as intense thunderstorms and severe tropical storms. In contrast, weather conditions during the mild dry season (October–May) are generally dry with low humidity. At the beginning of the sparrows' breeding season, towards the end of the dry season, ground water levels tend to be low with very little or no permanent water in solution holes across the marl prairie. Solution holes are eroded depressions within the limestone bedrock that underlies their marl prairie habitat (see *Habitat* Section), and unlike sinkholes, they do not meet the water table but fill via rainwater. It is around these solution holes that sparrows primarily forage during dry conditions as the holes serve as important refuges for aquatic invertebrates (Loftus et al. 1992).

Boulton et al. (2011) evaluated the effect of both daily rainfall and ground water levels on timing of breeding. They created four water variables: average rainfall and ground water levels three months prior to breeding (mid December-mid March), and two months prior to breeding (mid January-mid March). They regarded these variables as potentially important periods throughout the sparrows' annual cycle, as they represent abiotic conditions experienced by sparrows prior to, and during, pair formation. Their results indicated there was a significant negative relationship between median first egg laying date and average rainfall two months prior to breeding (Figure 2.2), with sparrows initiating breeding earlier with wetter rainfall conditions. Although rain late in the dry season is not as episodic or widespread as wet season rainfalls, its absence appears to delay breeding significantly by up to a month (most evident in 2009). There was no clear association with ground water levels and median first egg laying date.

The relationship between rainfall and initiation of egg laying may be driven by the response of the sparrow to their dominant prey items. We would expect a multi-brooded species to commence breeding as soon as sufficient resources become available to form a clutch (Crick et al. 1993). In the Everglades, prior to the sparrow's breeding season, water levels are often below ground level throughout their habitat with no available standing water. The significance of rainfall, not ground water levels, during this period suggests rapid invertebrate response to localised rainfall or that sparrows are capable of using rainfall as a cue for future food availability (Zann et al. 1995). Although Boulton et al. (2011) did not measure arthropod abundance in this study, Lockwood et al. (1997) show that during the breeding season sparrows feed largely on the insect orders Orthoptera, Lepidoptera

and Odonata and are capable of shifting their diet composition in response to these insects' changing availability.

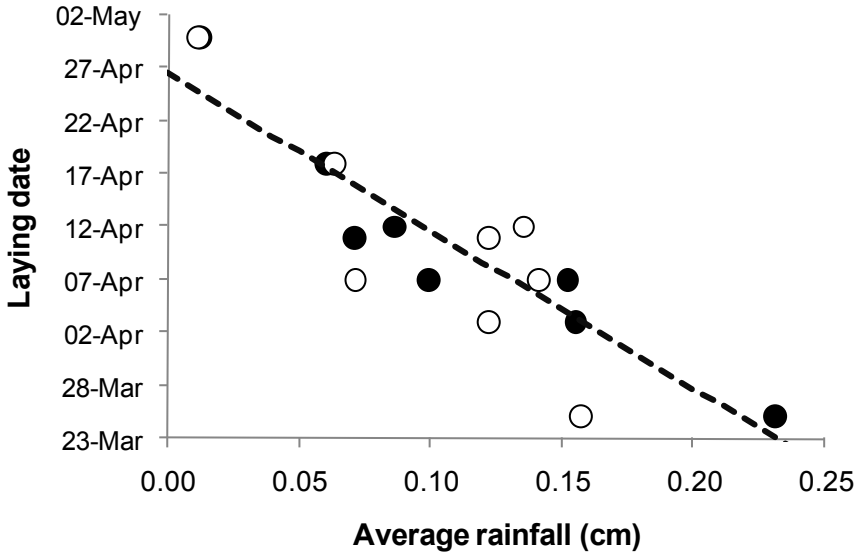


Figure 2.2. Scatter plot of Cape Sable seaside-sparrow median first egg laying dates (2002-2009) and average rainfall levels two months (filled circles; mid January-March) and three months prior to breeding (open circles; mid December-mid March), Everglades National Park, Florida. Dashed line represents the statistical relationship between median first egg laying date and rainfall conditions two months prior to breeding. From Boulton et al. (2011).

The cessation of breeding in Cape Sable seaside-sparrows is not as well understood. Part of this uncertainty is the difficulty in continuing nest monitoring activities for sparrows at the height of the wet season. Nevertheless, the nesting record is best for subpopulation E in the years 2007 to 2009. If we plot the number of nests observed by week using this information, it is clear the bulk of sparrow nests are active from late April to early June (Figure 2.3). However, nests have been observed well into July. By the end of July, nearly all sparrows have ceased nesting, and individuals will have completed their moult by the end of September (Dean and Morrison 2001). Certainly sparrows (or any other bird) will not breed while moulting, and thus the onset of moult may be the surest indication that the breeding season has ended. Beyond these generalisations, there is not much known about the specific cues sparrows use to end their breeding season.

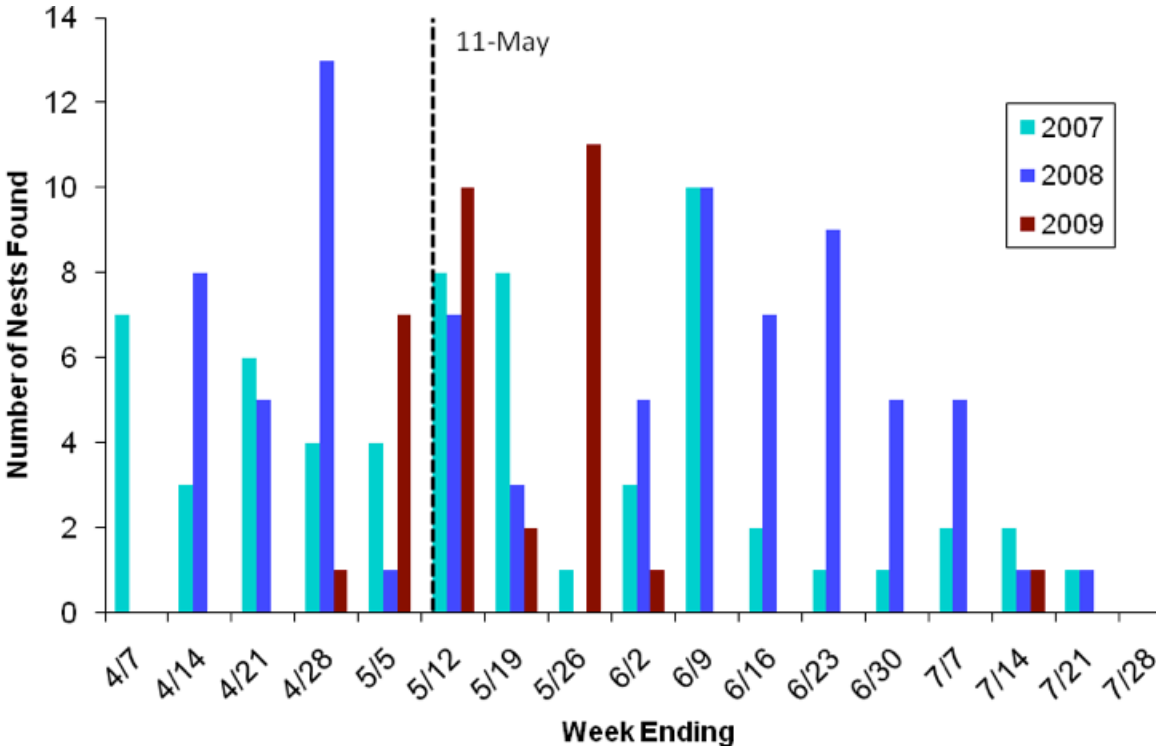


Figure 2.3. Number of Cape Sable seaside-sparrow nests observed in subpopulation E each week during the 2007 – 2009 breeding seasons. The dashed line marks the official beginning of the 2009 wet season, which was much delayed compared to the other years depicted here. The number of nests observed declines markedly in July of each year, even when the onset of the wet season is delayed (e.g., 2009). Figure originally produced by T. Virzi and appeared in Lockwood et al. (2009).

By October sparrows have completed their moult and they thus begin the process of surviving through the non-breeding season. This phase of their yearly cycle is the most enigmatic portion of their life history. Information on the wintering habits of most races of seaside-sparrows is sporadic (Post and Greenlaw 2009). Sightings of Cape Sable seaside-sparrows decline beginning at the end of the breeding season in July and reach a yearly low around November. Thereafter, the number of sightings will began to increase, until individual sparrows begin to form and defend breeding territories in mid–February.

Sparrows spend their non-breeding time in the same marl prairie habitats that they utilise for breeding (Dean and Morrison 2001). They do, however, show a change in microhabitat use within those prairies. Dean and Morrison (2001) showed that non-breeding season habitat selection of sparrows seemed to shift with the hydrologic condition of marl prairies. When water levels were low, sparrows chose sites dominated by low vegetation. However, when water levels rose sparrows increased their use of dense sawgrass sways. This switch suggests that small-scale variations in habitat structure are a critical element in the non-breeding season ecology of the Cape Sable seaside-sparrow. This small-scale variation may be produced by micro-

differences in topography within marl prairies. Dean and Morrison (2001) suggested that these small-scale habitat features help buffer sparrows from extreme hydrologic conditions during the non-breeding season. This movement to higher (stem-wise), and more dense vegetation likely provides cover, refuge and perhaps an increased food supply for the sparrows during the wet season.

Through radio-tracking 31 individual Cape Sable seaside-sparrows for between 1 and 7 months in the non-breeding season, Dean and Morrison (2001) found that sparrows occasionally made long-range movements (>500m) when not breeding. They documented three individuals vacating their breeding territories and moving from 450 to 7000m before settling into a consistently occupied home range. (We discuss dispersal in more detail in Chapter 6.) The juveniles (i.e. fledglings) that Dean and Morrison (2001) followed ranged more widely than adults. They also tended to move as members of small flocks of five to ten juvenile sparrows. These flocks are relatively stable in membership, with some members of the flock being siblings from a nest initiated earlier in the breeding season. Flocking behaviour continued until the onset of moult in August and September. After completing moult, they settled into a non-breeding season home range. It was not clear whether this non-breeding season home range contains the juveniles' breeding territory for the oncoming breeding season. If so, juveniles may be using these months just after fledgling to explore potential breeding locations. Their association with each other may function to reduce predation, and allow more efficient assessment of occupied versus unoccupied habitats. We revisit the benefits of this behaviour below.

Breeding Season

Territories

Cape Sable seaside-sparrows maintain territories within which all nesting and feeding activities occur (Lockwood et al. 1997). Territories are mutually exclusive such that no two males will share a substantial proportion of their territorial space. Males establish territories beginning in late February. Males establish and defend territories by singing, but occasionally will aggressively chase males and females that violate territory boundaries. A male can increase the audibility of his song, and his visibility, by perching on stalks of grass that rise well above the average height of the surrounding grasses and sedges. These territorial perches are almost exclusively provided by sawgrass seed-heads.

Females presumably choose males based on the quality of their territory, as do other subspecies of seaside-sparrow (Post and Greenlaw 2009). This choice is critical as sparrows are socially monogamous and the female will be confined to feeding herself, and any young she produces, from the resources contained within the male's territory boundaries. The size of that territory likely determines his ability to attract a mate and successfully raise young (Post and Greenlaw 2009). Territories are typically 2ha in spatial extent, and can be tightly packed; anywhere from 20 to 50 males will hold territories within an area of $1km^2$ in densely populated sections of their range (e.g. subpopulation B). Territory sizes increases in spatial extent as

population density declines, with some sparrows occupying territories in excess of 5ha when few other individuals compete for that space (e.g., subpopulation C; Baiser et al. 2008).

Polygyny in the Cape Sable seaside-sparrow has been recorded sparingly, and may be more common in populations that hold few individuals (Baiser et al. 2008). Post and Greenlaw (2009) report only one other instance of confirmed polygyny in seaside-sparrows more generally, which occurred in South Carolina tidal marshes. It is not clear if the prevalence of polygyny is more common in Cape Sable seaside-sparrows than in other subspecies, or if stepped-up scrutiny of other pairs across the species' entire range will reveal more evidence of polygyny.

Site Fidelity

Cape Sable seaside-sparrows show a strong fidelity to their breeding sites, as do other subspecies of seaside-sparrow (Post and Greenlaw 2009). Adult male and female sparrows tend to return to the same breeding territory each year, or within about 200m of that site. Juvenile sparrows will disperse over larger distances, but most will settle and breed within 500m of their site of hatching (Van Houtan et al. 2010).

Between sub-population movements are relatively rare (Van Houtan et al. 2010), but may be more common for sparrows that occupy the smaller subpopulations (Boulton et al. 2009a; Virzi et al. 2009). The higher rate of dispersal corresponds to a more dynamic site fidelity pattern in small subpopulations. Boulton et al. (2009b) provide an estimate of adult annual survival probability of 60% using information derived from the large sparrow subpopulations B and E. If this rate is applied as a rule of thumb (i.e. assuming all else is equal including dispersal rates across subpopulations), then every year just over half of all banded adults in small subpopulations should be re-sighted. Instead, for most years Boulton et al. (2009a) show a return rate of 17% for adults (range 0-28%) in the small subpopulations. These low return rates certainly must reflect the more common occurrence of adult immigration (see *Dispersal* section), but may also be indicative of lower adult survival rates. Unfortunately, with low sample sizes in the small subpopulations it is impossible to untangle these two explanations for the high turnover of adult sparrows within small subpopulations.

Conspecific Attraction

The selection of suitable breeding habitat is a critical choice for birds because it directly affects reproduction and survival and thus influences population dynamics. Social information in the form of songs, calls, or other overt behaviours may assist birds in assessing the quality of potential breeding habitat. Social cues provide direct public information about site quality and indirect cues (e.g., the presence of conspecifics) that may be used to infer site quality (Danchin et al. 2004). Artificial song playback has been used to demonstrate the influence of conspecific cues on the settlement decisions of passerines. Virzi et al. (2012) describe an experiment

designed to test the effectiveness of artificial song playback on the settlement decisions of the Cape Sable seaside-sparrow.

They designed a playback system to broadcast sparrow song over large areas (> 1 km radius) of sparrow habitat. They then documented the detailed response of breeding adults to the broadcast by measuring the spatial arrangement of territories within and outside of the sound field generated by the playback system (Virzi et al. 2012). Their results suggest that Cape Sable seaside-sparrows use a mixed-strategy to make settlement decisions based on philopatry and conspecific cues (songs). Sparrows responded to artificial song playback broadcast over a large area of suitable breeding habitat, with the strongest response in areas where sound quality was predicted to be closest to the sound of natural song based on sound modelling.

Virzi et al. (2012) suggest that the Cape Sable seaside-sparrow may also use late-season song as a cue for selecting territories in the following year, particularly amongst failed breeders and/or the year's fledglings. Older, more experienced individuals tend to use previous experience to select high-quality breeding sites while younger, more inexperienced birds settle near older birds (Nocera et al. 2009). It is these inexperienced settlers that are most likely to collect information on habitat quality by observing settlement decisions of others (Nocera and Forbes 2010). Since the sparrow is a resident species with strong site fidelity and sequential breeding, dispersers are likely using early-season song as an important cue for selecting habitat each year. For example, the juvenile sparrows that flock together late in the breeding season (see above) may be using late-season song as a social cue for where to establish their breeding territories in the next season.

Finally, Virzi et al. (2012) suggest managers may profitably use song playback systems to increase the number of sparrow subpopulations or promote settlement of sparrows in newly restored habitats in the Everglades. Once restored habitat becomes suitable for breeding it may be possible to encourage faster recruitment and settlement of long-distance dispersers into restored areas by strategically placing several playback systems there. However, Virzi et al. (2012) strongly suggest that care should be taken to avoid creating ecological traps in any attempts to redistribute Cape Sable seaside-sparrows across the Everglades landscape, given that careless placement could encourage settlement of species into poor quality habitats.

Courtship behaviour

Courtship rituals take place well within the grass, only a few centimetres above the soil surface. Males will sing to females, although the volume at which he sings is noticeably lower than when defending or marking his territory. Males will carry nesting material in their bill, making very short hop-flights between the base of the grass tussocks, and singing. The female may respond with "chew-chew" or "churble" call (see Werner 1975 for sound descriptions) and follow the male. Later in the nesting cycle, especially during incubation, females will regularly solicit food from males just after leaving the nest. She does so by fluttering her wings and cocking her

head back and down. She is very likely to make a “chew-chew” call in this situation as well. Males may or may not respond to this behaviour by providing food. On rare occasions, the male will chase the female in a high-speed flight across the territory. It is possible this is an aggressive reaction by a male that does not recognise his mate but instead reacts as if she is an intruder (McDonald and Greenberg 1991). Werner (1975) also reports females occasionally being ‘harassed’ by a resident male. He attributed this to the courtship of a female that had recently lost her mate by neighbouring unmated males.

Nest construction

Sparrows build cup-shaped nests that will often have a dome woven over the cup itself. Werner (1975) documented an easterly aspect for domed nests and westerly aspect to cup nests. This reflects the propensity for grasses to lean toward the west thus making domed nests possible only if they have eastern entrances. It is unknown whether both parents contribute to nest building, or if it is solely the female’s responsibility. Nests are woven entirely of dead grasses and sedges, all of which are readily available to the adults. Sawgrass typically comprises better than 50% of the total volume with muhly grass and/or black–top sedge composing the rest of the nest volume. Half of the nest volume composes the nest cup, and the cup lining is made of very fine grass fragments.

As detailed in Figure 2.1, Cape Sable seaside-sparrows place their nests an average of 16cm from the soil surface. The constraints on height of nests off the ground are physical. Nests are placed within the structurally sound low stems of species such as sawgrass, muhly grass or black-top sedge. If sparrows placed their nests too high in this grass, it would simply fall apart. There is nothing to provide structural stability for the relatively bulky grass cup sparrows build within the wispy upper stems of marsh grasses.

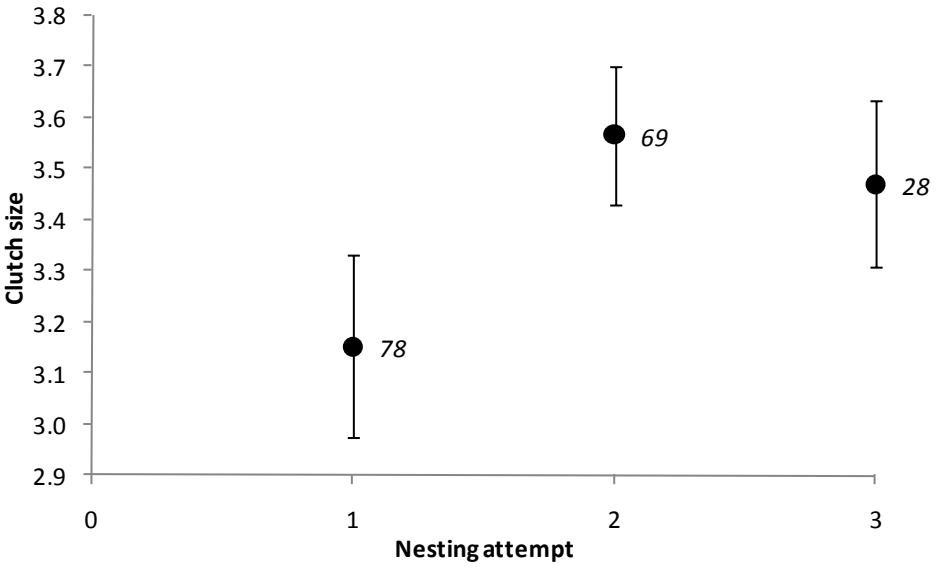
The lower end of the bell shape of Figure 2.1 is more difficult to explain. Seaside-Sparrows as a group seldom (if ever) place their nests on the soil surface (Post and Greenlaw 2009), and Cape Sable seaside-sparrows follow true to form. Since all seaside-sparrows must contend with their habitats being flooded for periods of time when their nests are active, building nests off the ground is an obvious strategy to decrease the chance of nest flooding. Most other subspecies of seaside-sparrow utilise habitat that is influenced by ocean tides. Coastal subspecies of seaside-sparrow build their nests above the spring tide line (Post and Greenlaw 2009), which effectively allows them to avoid nest loss due to flooding. Cape Sable seaside-sparrows do not exist in tidally influenced marsh, but instead occupy the freshwater marshes of the Everglades. Thus, the regular periods of water inundation come seasonally and not daily. Still, water can inundate their habitat during the breeding season due to heavy rainfall, and this may happen often enough that they retained the predilection for building their nests well off the soil surface. No matter the mechanism, Cape Sable seaside-sparrows are evolutionarily hard-wired to build nests within a relatively set range of heights off the ground.

Eggs and nestlings

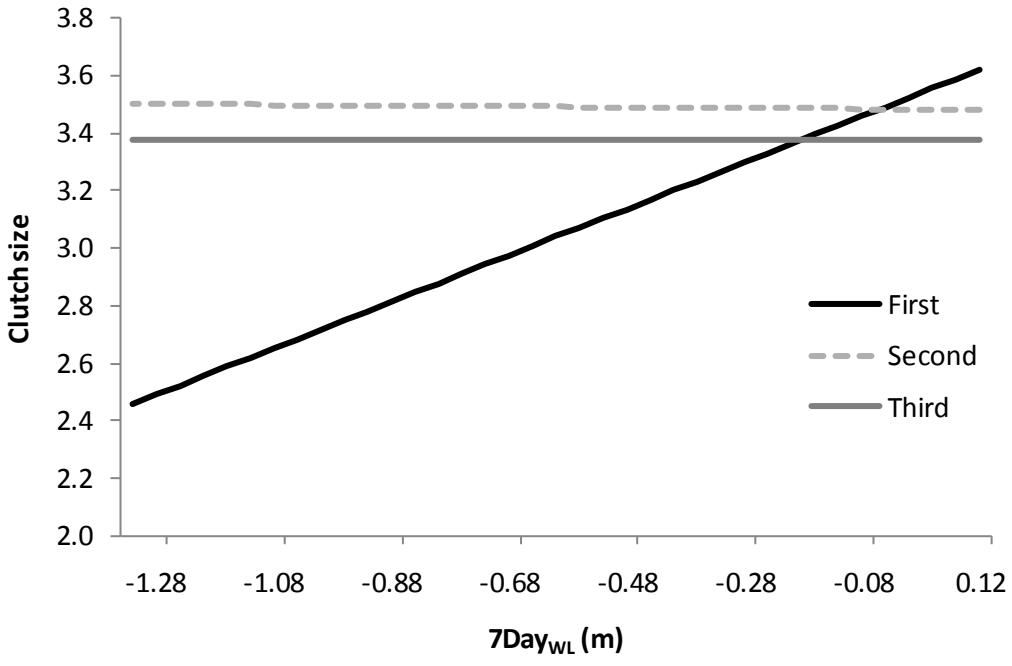
Female sparrows will initiate a clutch (i.e. lay the first egg of a clutch) 2–3 days after nest completion. They lay on average 2–4 eggs per clutch. Incubation lasts for 12–13 days, with females sitting on eggs for 15-30 minutes per incubation bout. Nearly all eggs will hatch (average = 90%), and the nestlings stay in the nest for 9–10 days before fledging. Newly fledged young are flightless for 1–3 days, during which time they hide in dense grass clumps and are fed by their parents. Juveniles gain flight skills and become independent from adults after this period. Females re-nest after both successful and failed nesting attempts, with up to 3–4 attempts per breeding season (March-July; Lockwood et al. 1997). Although some nests fail due to physical flooding (Lockwood et al. 1997), it is relatively uncommon and the majority of sparrow nests fail due to predation (97% of failures, Baiser et al. 2008). These reproductive parameters are based on observing over 280 nests between 1996 and 2011, and they are consistent with that of other races of seaside-sparrow (Post and Greenlaw 2009).

Boulton et al. (2011) found that the clutch size varied between nesting attempts with first nesting attempts having significantly smaller clutches than both second and third attempts (Figure 2.4). Figure 2.4 also shows that ground water levels negatively affected the female's first nesting attempts only, with drier conditions limiting clutch size. They found that hatching success was negatively associated with rainfall prior to hatching. Also, Boulton et al. (2011) found that the probability of a nest surviving until the young fledged for first nesting attempts was 40%, which is considerably higher than for both second (19%) and third nesting attempts (8%) (see also Baiser et al. 2008). Thus water, as either rainfall or ground water, helped explain both within-nest and within-season variation in reproductive measurements for the Cape Sable seaside-sparrow. Whereas wetter conditions favoured earlier breeding and larger clutch sizes for first nesting attempts, they hampered nest survival especially as the breeding season progressed into the wet season.

Boulton et al. (2011) hypothesised that this variation may indicate both food-mediated and predator-mediated processes influencing sparrow reproductive decisions during different stages of their breeding cycle. Drier conditions during first nesting attempts were associated with smaller clutches. With predation pressure in this system lowest at the beginning of the breeding season (Baiser et al. 2008), we would expect females to lay larger first clutches, as clutch size is strongly related to predation rates in the closely related tidal-marsh sparrows (Greenberg et al. 2006). It appears that Cape Sable seaside-sparrows lay their first clutch in suboptimal conditions (Crick et al. 1993), perhaps to allow additional time to raise multiple broods throughout the season or to avoid increasingly higher nest predation rates later in the season.



(a)



(b)

Figure 2.4. The best statistical model explaining clutch size variation in the Cape Sable seaside-sparrow during the 2002-2008 breeding season, Everglades National Park, Florida. (a) Least square means (± standard error) clutch size for first, second and third nesting attempts. Italicised numbers represent sample sizes. (b) Clutch size estimates for first, second and third nesting attempts across different ground water levels (7Day$_{wl}$). Model controls for individual female and yearly variation as random effects. From Boulton et al. (2011).

Cape Sable seaside-sparrow clutch size increases mid-season coinciding with the onset of the wet season, when ground water levels begin to rise and solution holes

start to contain standing water. While this increase in clutch size is in accord with a multi-brooded species model, it is somewhat surprising given the increase in nest predation associated with wet-season conditions (Boulton et al. 2011). However, females experience relatively high nest success during their first nesting attempt, and with increasingly favourable conditions, make the decision to lay larger second clutches. Then, after experiencing higher predation rates, they may assess future offspring value and reduce their reproductive investment (e.g., Eggers et al. 2006). Boulton et al. (2011) only observed a slight decline in clutch size towards the end of the breeding season. Unfortunately, because of extremely high nest predation, their sample of third nesting attempts was small, and with larger sample, they may have observed a significant decline in clutch size.

Nestling diet

Lockwood et al. (1997) characterised the diet of nestlings as including Lepidoptera, Orthoptera, and Odonata but rarely Coleoptera and Araneae, despite the latter groups being more abundant than the former in marl prairie habitats. The array of nestling prey items and the flexibility of sparrows in incorporating different prey species led Lockwood et al. (1997) to conclude that the Cape Sable seaside-sparrow is a dietary generalist. The reliance of Cape Sable seaside-sparrows on Orthoptera and Lepidoptera is much like other seaside-sparrow races (Post and Greenlaw 2009). The absence of Diptera and other mud-dwelling insects from the Cape Sable seaside-sparrow nestling diet is consistent with seaside-sparrow populations studied in northern Florida (Post and Greenlaw 2009). However, this diet contrasts with that of sparrows inhabiting salt marshes in the northern parts of the species' range (Post and Greenlaw 2009). Southern races, including Cape Sable seaside-sparrows, depend less on open mud flats (Post and Greenlaw 2009). There are few, if any, expansive mud flats within our study areas. Cape Sable seaside-sparrows appear unique among the seaside-sparrow races in their use of Odonata. This is not surprising since this is the only extant race to exclusively inhabit freshwater marshes (Post and Greenlaw 2009).

Chapter 3

Demography

Julie Lockwood, Rebecca Boulton, Benjamin Baiser, Tom Virzi, and James Gilroy

Abstract

Because restoration actions are chosen, in part, based on their influence of Cape Sable seaside-sparrow survival and fecundity, it is imperative that we have the best available information on these rates and their variances. Based on an extensive collection of field data, we found the maximum recorded age of sparrows was 8–9 years. Most sparrows appear to live 2–3 years. We estimated that adult sparrows have a 48–68% probability of surviving from one year to the next, and that this survival rate has remained constant over our period of record (14 years). Adult male sparrows survive at a slightly better rate than females. Juvenile survival is about half the rate of adults (34%). Both juvenile and adult survival vary substantially across years, and some of this variation can be explained by water levels these individuals experience during the non-breeding season. Cape Sable seaside-sparrow nests have an overall success rate (measured from egg laying to fledging) of 18%. Nests failed most often due to predation (97% of all recorded failures). As the initiation date of a nest moves further into the breeding season, the likelihood of that nest successfully fledging young decreases substantially. Optimal sparrow breeding occurs when there is a balance between having enough water over the course of the breeding season to provide suitable food resources, while not having too much water around a nest at the time in which it is active. Neither nest success or survival rates differ across sparrow subpopulations, including within those that host very low densities. The demographic rates of Cape Sable seaside-sparrows explain the previous drastic declines in sparrow numbers. When suboptimal conditions persist for more than two years, most sparrow nests will fail. Sparrows will re-nest in the same sites for several years in a row, however, they tend die after three years of age. Thus, environmental conditions that restrict nesting success for two or three years will leave a local population greatly diminished through attrition of breeding adults that were unable to replace themselves in the population through reproduction.

Introduction

Although policymakers have generally agreed upon the need to restore Everglades' hydrologic patterns, the details are far from settled (Curnutt et al. 2000). One measure of Everglades restoration success is a viable population of Cape Sable seaside-sparrows, resulting in the sparrows use as an indicator species when attempting to evaluate how chosen restoration plans might impact native species (DeAngelis et al. 1998). During restoration implementation it is important for

managers to understand which of the sparrow's demographic parameters are more likely to respond to restoration efforts and contribute significantly to the populations' growth. Simple demographic models in the past have considered nest success and the duration of the sparrows breeding season as two of the most important demographic parameters (Lockwood et al. 2001). Recent modelling suggests factors increasing mortality of both adult and juvenile sparrows pose more of an extinction risk than either the length of the breeding season or female mating success (Elderd and Nott 2008). However, the reliability of any model is determined by the accuracy and the variance estimate of the demographic parameters they utilise (Ludwig 1999). Here we synthesise the most up to date information on Cape Sable seaside-sparrow survival and fecundity. In addition, we review how these demographic rates are influenced by water flows in the Everglades. Finally, we review evidence for the influence of small population size itself as being a factor influencing demographic rates. In many species, individuals that exist with few others will show either reduced survival or breeding success. This possibility has been explored for Cape Sable seaside-sparrows in terms of nest success rates.

Survival

Survival, compared to other demographic parameters, is often difficult to estimate due to cryptic behaviour and difficulties in marking and monitoring individuals (Murray and Patterson 2006). Boulton et al. (2009) provide the first statistically robust understanding of Cape Sable seaside-sparrows survival dynamics. They use a 14-year record to explore how survival changed according to an individual's sex, age, and population membership. Attempting to understand the cause of temporal variation in survival estimates is essential when trying to mediate species recovery. Thus, Boulton et al. (2009) also explored the effect of ground water levels, the central component of the Everglades ecosystem, on annual sparrow survival.

Longevity

Based on 1690 captures and re-sights, representing 1161 individuals (605 adults and 556 juveniles) within populations A, B and E, Boulton et al. (2009) showed sparrow return rates (i.e. individuals that returned to the study sites and were re-sighted at least once >12 months after marking) of 43% for adults and 12% for juveniles. The maximum age recorded for breeding males was nine years, and the maximum age for females was eight years. Because individuals were banded as adults, these are conservative values. Using only known-aged birds, (i.e. banded as juveniles) Boulton et al. (2009) recorded a maximum age of eight years for males and four years for females. Most sparrows appear to live 2-3 years and the majority of individuals banded as adults appear likely to be first time breeders with similar senescence as known-aged birds (Figure 3.1).

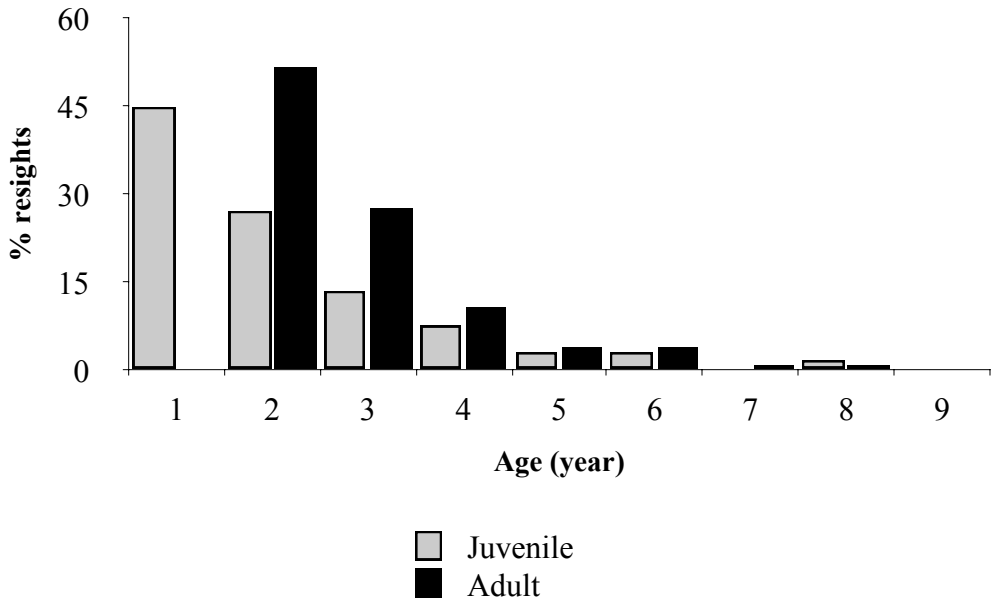


Figure 3.1. Age-structure of juvenile (*n* = 67) and adult (*n* = 273) Cape Sable seaside-sparrows that were re-sighted at least once during the period 1997-2007 in populations A, B and E. The age of adults is assumed to be a minimum value as all adults are banded at 1+ years of age. From Boulton et al. (2009).

Adult Survival

Boulton et al. (2009) estimated adult time-dependent survival estimates ranging from 48-68%. This range of survival estimates falls within the range produced previously using subsets of this 14-year record (Pimm 1995, 50%; Lockwood et al. 2001; 66%). The survival estimates of Boulton et al. (2009), however, fall well below those produced using much smaller sample sizes and from largely anecdotal interpretations of data (Werner 1975, 88%; Kushlan et al. 1982, 90%). In addition, the estimate of apparent adult survival rate made by Boulton et al. (2009) falls within the range recorded for other Emberizid sparrows (Sandercock and Jaramillo (2002); 35-56%).

Juvenile Survival

The analysis of Boulton et al. (2009) showed that there is clearly a difference in survival between adults and juveniles, with both age groups evincing substantial changes in survival across years (Figure 3.2).

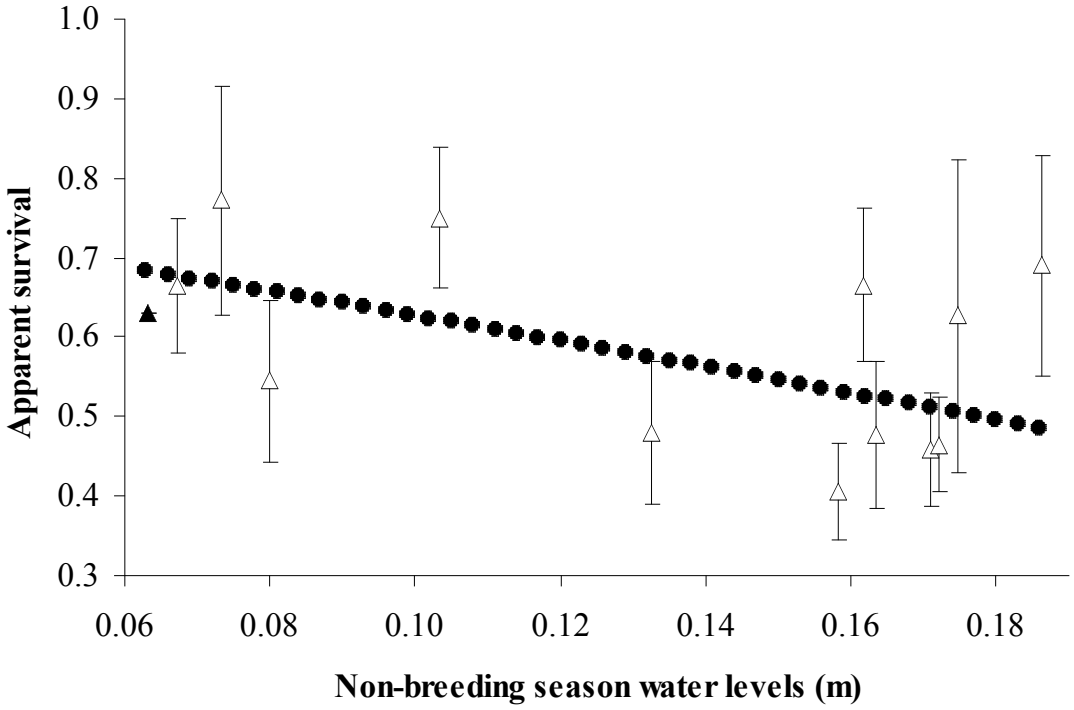


Figure 3.2. Fitted relationship between sparrow survival probability and the average non-breeding season water levels recorded at water station NP46 using estimates derived from parameters in model 1 of Boulton et al. (2009) (●). Because of the presence of time-dependence in this model, Boulton et al. (2009) were unable to estimate the standard error for the last interval (2006, ▲). Values for maximum and minimum ground water levels were those recorded across the non-breeding season between 1994 and 2006 at NP46 water station.

The minimum survival for adults was in 2005, with a survival estimate of 42%, while the maximum survival was in 2002 with survival of 79%. The overall mean survival rate for juveniles reported by Boulton et al. (2009) was 18%. The minimum survival for juveniles was in 1997, with a survival estimate of 5%, while the maximum survival was in 2002 with a survival of 43%.

Since the inception of analytical methods for survival estimation from live-recapture data, researchers have struggled to develop widely-applicable methods to deal with the confounding issue of permanent emigration (Marshall et al. 2004; Zimmerman et al. 2007). This issue is especially relevant for estimating survival of individuals that are likely to permanently emigrate away from their point of original capture, which in Cape Sable seaside-sparrows are the juveniles (Van Houtan et al. 2010). Failing to account for this type of emigration within standard survival analysis results in sometimes severe under-estimations of annual survival rates. By combining information on survival and dispersal within a Bayesian framework,

Gilroy et al. (2012a) developed a way to generate unbiased estimates of survival despite high rates of permanent emigration. They applied this model to the data in Boulton et al. (2009) and provided an unbiased estimate of juvenile survival of 34%, which was more than double that of Boulton et al. (2009) but still well below the adult survival rate.

Sex-Specific Survival

Because many sparrow species are monomorphic during winter capture periods, both sexes are often lumped during analyses (Sandercock and Jaramillo 2002). By capturing Cape Sable seaside-sparrows in the breeding season, Boulton et al. (2009) could reliably sex adults. They ascertained a slightly higher survival rate for males than females, with males showing 47–83% and females 29–69% survival. There was also a slightly higher recapture probability for males than for females, however, recapture rates were consistently high (>50%). High recapture rates, for both male and female sparrows, reflects the high site fidelity and non-migratory behaviour of Cape Sable seaside-sparrows (Dean and Morrison 1998, Lockwood et al. 2001).

Influence of Water Levels on Adult Survival

Water levels can quickly rise in the Everglades, particularly in the wet-season when a single thunderstorm can produce 10-30 cm of rain in a 24h period. Water flows and levels throughout the Everglades are somewhat mediated by management actions that divert water through the extensive canal systems there, but Boulton et al. (2009) still observed >20 cm increases in water levels within 24h periods across all of their study plots. To explore the influence of these variations in water flows on adult sparrow survival, Boulton et al. (2009) related survival to breeding and non-breeding season water levels and compared survival across populations that experienced very different water flow regimes (i.e. dry populations B and E vs. wet population A).

Each year was divided into two periods, the non-breeding season (1 August-14 March) and breeding season (15 March-31 July). Water levels were calculated across these periods using the daily average water level in meters above and below ground level (ground level set to zero). Boulton et al. (2009) chose these two water covariates as they represent two very different behavioural periods in the sparrow's life-cycle and biologically they anticipated that stress associated with variation in water levels at either time could effect adult survival.

Breeding season water levels did not have a detectable impact on adult sparrow survival despite the fact that there was substantial year-to-year fluctuations in survival rates (Boulton et al. 2009). In addition, there is no clear evidence that sparrows in the wetter population A survived any worse than sparrows in the drier populations B and E. Survival estimates from Boulton et al. (2009) ranged from 44 to 75% in populations B and E, while population A experienced an overall survival rate of 56%. In contrast, there was a clear impact of non-breeding season water levels on adult survival. Survival ranged from 48–68% across years with lower survival recorded in non-breeding seasons with high average water (Figure 3.3).

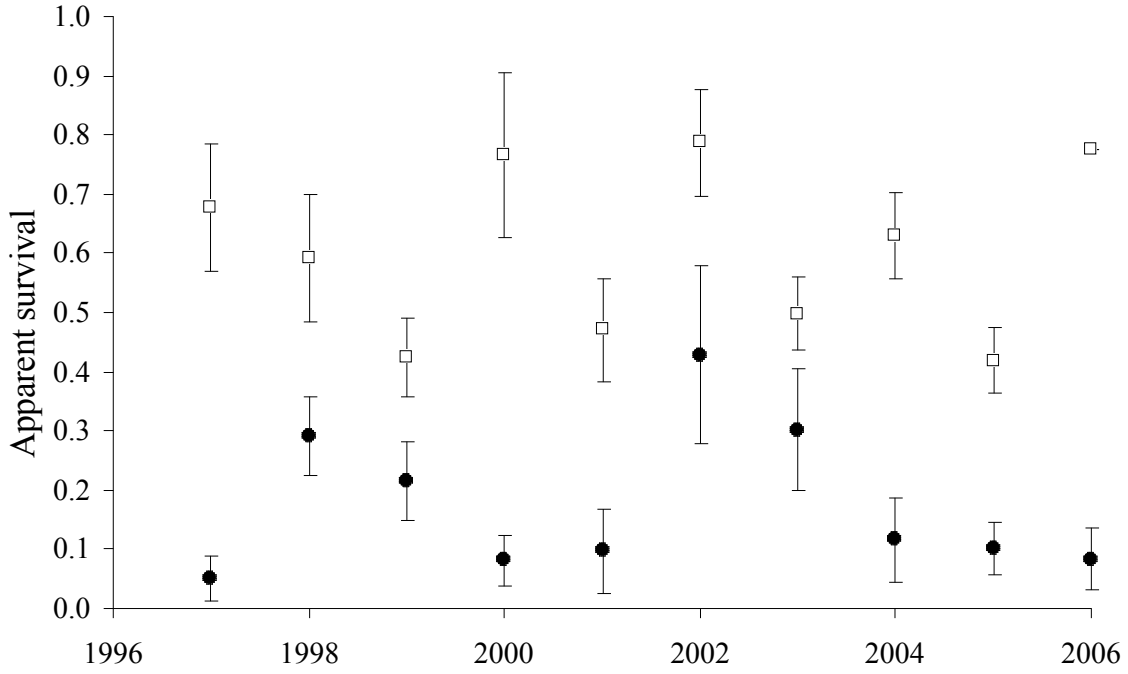


Figure 3.3. Annual variation in apparent survival rates (mean ± standard error) of Cape Sable seaside-sparrows marked as adults (□), and juveniles (●) from population A, B and E, 1997-2007. Because of the presence of time-dependence in survival and recapture probabilities in some candidate models, Boulton et al. (2009) were unable to estimate the SE for the last interval. From Boulton et al. (2009).

While flooding in the non-breeding season is a natural process in the Everglades, this result does highlight the susceptibility of the sparrow to extended unnatural flooding throughout their habitat. Wetter conditions can rapidly convert marl prairie into less suitable sparrow habitat (Jenkins et al. 2003), at the same time exposing sparrows to greater mortality risk.

Overview of Survival

The lack of a downward trend in sparrow survival across the 14-year record analysed by Boulton et al. (2009) is encouraging in terms of the species' persistence. However, their overall results do not bode well for the recovery of this species and help explain much of the observed declines in sparrow numbers and occupancy since 1981 (Cassey et al. 2007). Post et al. (1983) regarded Cape Sable seaside-sparrow population declines as paradoxical in light of their relatively high reproductive potential and high survival rate. The results of Boulton et al. (2009) help resolve this paradox, demonstrating why the sparrows' variable survival and short-lifespan make it quite susceptible to population declines. Given the link between water levels and low survival, even a few consecutive years of high water

could severely impact population growth rate, particularly as flooding may also severely impact nest survival (see next section). This observation coupled with the Boulton et al. (2009) estimates of low adult survival during high water and an average life span of only two to three years suggest that even two years of unusually high water levels or other damaging environmental factors (i.e. fire or severe hurricanes) can cause sharp drops in sparrow numbers.

Fecundity

Water flows have been shown to be a principal driver of sparrow fecundity and population dynamics (Lockwood et al. 2001, Pimm and Bass 2002). The effects of water operate to reduce nest success regardless of, for example, how suitable the vegetation is for nesting or how diligent parents are in their nest attendance. Thus, management decisions that affect the extent, timing and duration of water flows in any given area will likely have strong effects on population dynamics. Indeed, the entire premise of Everglades restoration is that restoring water flows will serve to recover endangered species that depend on the ecosystem (Sklar et al. 2002). Thus, a concentration on understanding the influence of water flows on sparrow breeding success is a way of explicitly acknowledging that for this subspecies, and for many others in the Everglades, most conservation actions will primarily involve manipulating water flows.

Baiser et al. (2008) provided comprehensive analyses of how water affects Cape Sable seaside-sparrow breeding success, and in the process provided guidance for restoration of water flows through the ecosystem. Baiser et al. (2008) utilised nest monitoring information collected in two subpopulations, B and E, over a 10-year period from 1996 to 2006. They built two variables that directly reflect the manner in which water flows through sparrow habitat and one variable that captures the change in conditions that accompany the transition from the dry to wet season.

The amount of water that flows through the Everglades in any given year is a product of prevailing climatic conditions, including the effects of the El Nino Southern Oscillations (Kwan et al. 2006). Thus, some years are naturally much wetter than others although this can be moderated via water management decisions to some extent (Light and Dineen 1994). Naturally wet years should be manifest as high base water values throughout the everglades ecosystem. Thus, Baiser et al. (2008) calculated the daily water levels averaged over the extent of the sparrow's breeding season (March 15-July 24).

During the wet season, and occasionally in the late dry season, strong convection thunderstorms develop in the afternoon and deposit significant amounts of rainfall over localised areas. Such precipitation events, as well as localised managed water inputs, have a large impact on local water levels including those in short-hydroperiod marl prairies (Davis et al. 2005). Thus, nests may by chance be active during the few days or weeks when there is relatively more water in their habitat than in subsequent days and weeks. To capture this local-scale difference in water

flows Baiser et al. (2008) calculated the daily height of water averaged over the active nesting period for each nesting attempt.

Finally, the sparrow's breeding season has historically been broken into two parts (before and after June 1st) to reflect the large change in climatic conditions observed between the dry and wet seasons, and then daily nest survival probability was estimated for each period (e.g., Lockwood et al. 2001). There are other seasonal changes that can influence nest success rates, which principally include changes in predator abundance and activity, or the availability of prey (Hochachka, 1990). Since nearly all sparrow nests fail due to predation, and predation rates appear to increase as water levels rise (Lockwood et al. 1997, 2001), Baiser et al. (2008) transformed the dichotomous wet-dry season variable into a continuous measure of the date in the overall breeding season when a nest is active.

Baiser et al. (2008) found that, of the 429 Cape Sable seaside-sparrow nests monitored between 1996 and 2006, 210 failed (i.e. fledged no young), and 219 succeeded (i.e. produced at least one fledgling). Of those nests that failed, presumed predation accounted for over 97% of nest failure (204 nests). Accounting for bias in under-sampling nests that failed before they were observed by researchers, the overall nest success for the entire nesting period (laying to fledging) for all 429 nests was 18%.

Baiser et al. (2008) indicated that the principle driver of Cape Sable seaside-sparrow nest success is the time of the season when the nest is active. This effect is negative indicating that as the initiation date of a nest moves further into the breeding season, the less likely that nest is to successfully fledge young (Figure 3.4).

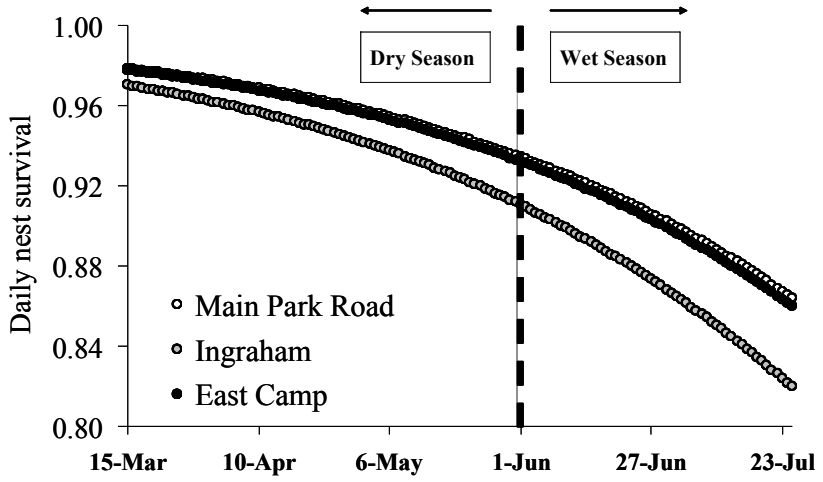


Figure 3.4. Estimates of daily survival probability of Cape Sable seaside-sparrow nests at three sites in the Florida Everglades, 1996-2006. These estimates are derived from parameters estimated from Model 2 in Baiser et al. (2008). Also shown are daily water levels across the Cape Sable seaside-sparrow breeding season. Values for each day were averaged across the length of the study from three water

monitoring stations. Dotted lines represent 95% confidence intervals. From Baiser et al. (2008).

Baiser et al. (2008) suggest that the mechanism for this trend is a change in predation rate. Absent the influence of water flows that flood active nests (e.g., Pimm et al. 2002), nearly all Cape Sable seaside-sparrow nests that fail succumb to predation. Lockwood et al. (1997) show a connection between the presence of surface water and elevated nest predation rates and certainly sparrow nests that are active early in the breeding season (first broods) experience very different water flow conditions than those that are active late (second and third broods). Sparrow nest predators include but are not limited to the rice rat (*Oryzomys palustris),* which we have observed preying on sparrow eggs, and the water moccasin (*Agkistodon piscivorus),* which has been known to prey on adult sparrows (Dean and Morrison 1998). However, it remains unclear how the behaviour of these predators (or others) may be influenced by the presence of water. It is possible that predators experience increased mobility or that nests are easier to find when water levels are high.

Despite the apparent connection between higher water levels and nest predation rates, Baiser et al. (2008) found only marginal support for the direct effects of water levels themselves. Although they observed a gradient in water levels across study sites, this did not translate into a clear trend in nest success rates across space. Baiser et al. (2008) show that the site that experienced the wettest conditions (Main Park Road) evinced daily nest survival probabilities that are indistinguishable from one of the drier sites (East Camp). This pattern suggests that site differences beyond water flow are driving nest success rates, although this unknown effect must have a connection with time of season when nests are active and predation rates as these effects do not vary across sites.

Baiser et al. (2008) also show that an increase in average breeding season water level has a positive effect on nest success, while an increase in average water levels during when a nest is known to be active (i.e. while it is being observed) has a negative effect. This pattern suggests that optimal sparrow breeding occurs when there is a balance between having enough water over the course of the breeding season but not too much water at the time that the nest is active. Biologically, this could simply mean having enough water so that food availability remains high, but not too much water to set off the predation associated with standing water seen by Lockwood et al. (1997). This result is echoed in the results of Boulton et al. (2011) who show similar influence of water flows on the initiation of breeding and clutch size (see Life History section).

Overview of Fecundity

The drastic drop in daily probability of Cape Sable seaside-sparrow nest survival across the span of a single breeding season has profound implications for the viability of the entire subspecies. Daily nest survival probability ranged from a high

of around 97% early in the breeding season to a low of around 84% near the end of the breeding season, which translates into overall chances that a Cape Sable seaside-sparrow egg laid will result in a fledgling of 47% and 1% respectively. Lockwood et al. (2001) show that the ability for Cape Sable seaside-sparrows to have a successful second and third breeding attempt in a given year is critical for realising positive population growth. Baiser et al. (2008) show that these attempts have a much lower success rate than previously reported. This trend suggests that, to realise positive population growth, managers must structure water flows such that a large number of sparrows can attempt late-season nests since most of these attempts will fail. This recommendation is on top of the need to prohibit water flows through sparrow habitat that are so high that they prevent breeding altogether, or transform habitat into a suboptimal state for sparrow nesting. Of note is that prior PVAs (e.g., Lockwood et al. 2001, Eldred and Nott 2008) did not include the large reduction in nest success rates across the season that Baiser et al. (2008) observe, and thus may have produced too optimistic an evaluation of sparrow persistence in the absence of major flooding or loss of habitat.

Another management option that stems from the work of Baiser et al. (2008) is to directly decrease nest predation rates via active management of sparrow nests initiated late in the breeding season. Since the predators thus far identified are native to the ecosystem and there is no evidence for predator-release in the Everglades via the influence of human disturbance, predator reduction programs are unwarranted. However, predator-proof fencing has been used with other seaside-sparrows, and these efforts resulted in considerable improvement in the probability that the protected nest will produce young (Post and Greenlaw 1989). The trials of predator-proof fences for Cape Sable seaside-sparrows, however, showed poor acceptance rates by attending parent sparrows and thus largely negate the usefulness of this management approach (Boulton and Lockwood 2010).

Allee Effects

Factors that cause declines in individual fitness with decreasing population density, termed Allee effects, are important determinants of extinction risk (Courchamp et al. 1999). Various lines of evidence hint that they may be widespread in nature (Leung et al. 2004), and they have played deciding roles in the extinctions of various once-abundant species such as the passenger pigeon *Ectopistes migratorius* and Carolina parakeet *Conuropsis carolinensis* (Bucher 1992). However, they are difficult to detect and are seldom documented even amongst well-studied species (Courchamp et al. 2008).

Positive relationships between population density and fitness can arise through a wide variety of mechanisms, including the inhibition of mate-finding, offspring-protection and successful foraging (Courchamp et al. 2008). Mechanisms operating on a single demographic rate are typically referred to as component Allee effects (Stephens et al. 1999). In the absence of compensatory negative density dependence in other demographic rates, these component effects can cause negative population growth, resulting in a demographic Allee effect (Stephens et al. 1999). Although

demographic effects are of greatest significance for conservation, the difficulty of measuring population growth rate means that field studies typically focus on evaluating component Allee effects individually (Kramer et al. 2009). Gilroy et al. (2012b) developed an approach to detecting component Allee effects that involves demographic comparisons between spatially-isolated subpopulations of varying size. Such fragmented populations are commonplace amongst threatened taxa, and effectively represent 'natural experiments' on the effects of population density. They demonstrated their use of their methods using breeding success information for Cape Sable seaside-sparrows.

Gilroy et al. (2012b) take advantage of the fact that the Cape Sable seaside-sparrow occurs in six spatially isolated subpopulations that vary considerably in size and population density. The smallest low-density subpopulations (particularly subpopulation A) have shown limited recovery following significant declines in the 1990s, despite the imposition of direct management actions (Walters et al. 2000, Cassey et al. 2007). Possible reasons for the failure of sparrow populations to recover post-management include: (1) management actions were insufficient to ameliorate threats, (2) other unmanaged environmental factors have prevented population recovery, or (3) the biology of the species itself dictates limited population increases despite the alleviation of threats, i.e. via Allee effects.

Gilroy et al. (2012b) examined the likelihood that breeding productivity in small sparrow populations is subject to a component Allee effect, evaluating the weight of evidence for (or against) the latter factor as the responsible agent for the failure to recover. Plausible mechanisms by which decreased population density might influence nest survival include weakened nest defence (Soutullo et al. 2006) and decreasing parental investment (Møller and Legendre 2001). They analysed nest survival data collected between 2002 and 2009 within the large and relatively stable subpopulation E, together with plots covering two of the small subpopulations A and C. Territory mapping indicated that densities were an order of magnitude lower in the small subpopulations (1-4 males km^{-2} $year^{-1}$) than in the large subpopulation E (13-26 males km^{-2} $year^{-1}$).

Gilroy et al. (2012b) tested for Allee effects by controlling for a suite of environmental variables that are likely to influence nest survival. Given the results of Baiser et al. (2008) showing sparrow nest survival is closely linked to water flows, they evaluated the influence of six hydrological variables on nest success. Using MARK, they selected the best model from a candidate set including all combinations of these hydrological variables, together with a categorical term indicating membership to large high-density (E) or small low-density (A and C) subpopulations. They then applied a bootstrap prediction method they developed that utilised the best model fitted to data exclusively from the high-density subpopulation (E) and then calculating errors between model-predicted nest survival rates and actual nest survival estimates for each small subpopulation (A and C).

Gilroy et al. (2012b) observed lower nest survival probability in small subpopulations (18%) than in the large high-density subpopulation (23%). However, they found no statistical support for an effect of subpopulation membership and hence no evidence for a component Allee effect. Rather, variation in nest survival across all subpopulations was best explained by seasonal water table depth and timing of nest activity relative to onset of flooding, with some support for a positive effect of the number of days of flooding during the time when a nest was active.

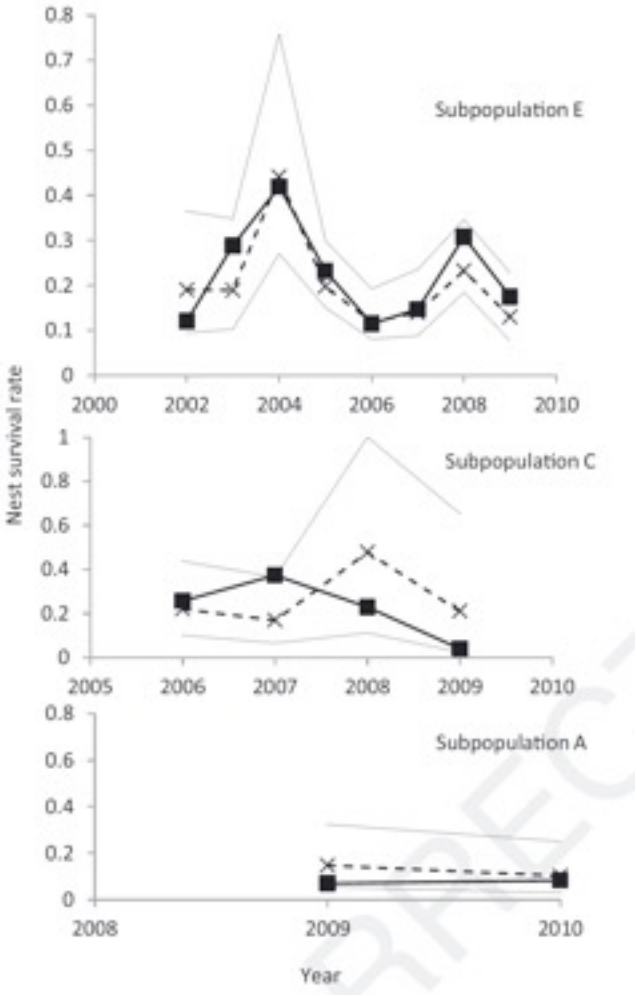


Figure 3.5. Comparisons between observed Cape Sable seaside-sparrow nest survival rates (black squares joined by solid lines) and predicted values from a model built exclusively using data from the large subpopulation E (crosses joined by broken lines). Upper panel shows observations and predictions for the large subpopulation E, middle and lower panels show small subpopulations C and A respectively. Dotted lines show limits of 95% null intervals generated by applying the model to bootstrap resamples of large subpopulation data (1,000 resamples of equivalent size for each data point). From Gilroy et al. (2012).

Prediction bootstrapping confirmed the underlying similarity of survival rates between high- and low-density subpopulations, as the best model for data from the large high-density subpopulation generated broadly accurate predictions when applied to the small subpopulations (Figure 3.5).

The observed mean survival rate in small subpopulations was very close to the model prediction based on information generated in the high-density subpopulation E. This result strongly suggests that factors influencing nest survival were fundamentally similar across both large and small subpopulations. The only exception was the sample of nests monitored in subpopulation C in 2007, where the observed daily nest survival rate exceeded the range of expected values generated by prediction bootstrapping (Figure 3.5). It is notable that observed nest survival rates in subpopulation A were consistently low. Differences of this magnitude arose in only 10% of equivalent bootstrap resamples of nest information collected in subpopulation E (Figure 3.5). This result suggests that survival may have been genuinely lower than the null expectation in this small subpopulation.

In sum, Gilroy et al. (2012b) found no clear evidence of an Allee effect on nest success after controlling for habitat and seasonal water flow effects. Thus, actions targeted at increasing breeding productivity in small subpopulations (e.g. sympathetic water flow management) should be effective in, and of, themselves. They note that without further analyses on other fitness components that contribute to intrinsic population growth rate, they cannot definitively rule out the possibility of a demographic Allee effect influencing the recovery of Cape Sable seaside-sparrows (Stephens et al. 1999).

Chapter 4

Effects of Fire

Julie Lockwood and David La Puma

Abstract

Cape Sable seaside-sparrows exist within a fire-prone habitat, and thus likely show resilience to fire events. However, given their current low numbers and restricted habitat, sparrows may be more susceptible to the ill-effects of fire. Through a detailed examination of how a sparrow population responded to a single fire, and a more comprehensive analysis of how sparrow numbers correspond to range-wide fire records, we show that large sparrow populations are capable of recovering from a fire event within 2 years. There are no lasting effects on sparrow breeding success or the quality of their habitat after a fire, provided the habitat is not flooded directly after the fire event itself or fire re-occurs within 2-3 years. There is little evidence that sparrow habitat should be burned at a regular interval in order to maintain its suitability for sparrow nesting, and what evidence exists for regular burning of habitat, indicates that the interval should be on the order of 10–14 years between fires. Small populations of sparrows are likely much more likely to be harmed by fire because a single fire can encompass the entirety of their current local distribution. Once the vegetation in a previously burned habitat recovers, the individual sparrows that colonise that are come from nearby source populations. Thus, small populations that are far from areas of higher sparrow density are particularly likely to be extirpated due to fire. Such areas are common along the eastern boundary of Everglades National Park within subpopulations D and F. The regular occurrence of fire in these populations likely explains the decline in sparrow numbers in these areas since 1981 and the now persistent lack of sparrows in these locations.

Overview

Disturbance often plays an important role in maintaining habitat heterogeneity (Askins 2002; Brawn et al. 2001). In many cases this heterogeneity must be sustained for select species to persist, whether being directly responsible for the substrate required by an organism for survival or the creation of multiple habitat types that satisfy the diverse needs of a particular organism (Moran-lopez et al. 2006). However, when the species of concern is threatened with extinction even natural disturbance events must be viewed with caution. Such populations are by definition low in numbers and often restricted to small areas of suitable habitat. Thus, disturbance events may drive the population to extinction even if the event is

precipitated by natural causes and despite the fact that the disturbance may be required to maintain or create suitable habitat (Jakalaniemi et al. 2006). For this reason there is a critical need to understand how species threatened with extinction respond to disturbance events so that these events can be managed (as much as feasible) to ensure recovery.

The Everglades of south Florida is a fire-prone ecosystem (Beckage et al. 2005) that harbours many fire dependent native species and provides refuge to 31 species federally listed as threatened and endangered. Recent and extensive urbanisation of the ecosystem has altered the fire regime of the remaining natural areas (Lockwood et al. 2003), while effects of this altered fire regime on these species remains largely unknown. There are multiple feedbacks between water flows, vegetation, soil type and fire in the Everglades that creates a complex temporal and spatial burn pattern . In their fire history analysis of the Everglades from 1948 through 1992, Gunderson and Snyder (1994) outlined temporal fire patterns for the entire ecosystem. They found that fires consumed large areas (annual geometric mean >93km^2) of the Everglades about every 10 to 15 years, and these large fires were followed by years of significantly smaller total area burned. Most natural fires occurred during wet season thunderstorms typical of June and July, however very large fires occurred during May when the conditions were still relatively dry, and intensified in El Nino years (Beckage et al. 2003; Gunderson and Snyder 1994).

This naturally variable fire return interval is further complicated by the effects of incendiary fires (i.e. arson and escaped agricultural burns) and fire management practices. Everglades National Park, and other land-holding public agencies, actively pursue the use of fire as a management tool for maintaining early successional plant communities and controlling invasive plant species. Additionally, incendiary fires result in the wildland-urban interface burning both more often, and more out of season, than what is considered natural (Lockwood et al. 2003). Each of these human-derived sources of fire in the ecosystem has a spatial and temporal signature that is distinct from more natural fires. Prescribed burns tend to produce more frequent and smaller fires than those ignited by lightening, whereas incendiary fires burn a significantly larger (>2x) area and greater frequency than natural fires due to their concentration during the driest months (Gunderson and Snyder 1994).

We know from previous work that fire removes all standing vegetation within Cape Sable seaside-sparrow habitat making it unsuitable for some period of time , and that it creates a complex burn pattern that may contribute to the spatial segmentation of the sparrow population (Werner 1975; Taylor 1983). However, it is not clear how long the effects of fire last, whether fire is needed to ‘re-set’ the habitat so it remains suitable for sparrows over the long-term, or how sparrow dispersal dynamics interplay with the spatial extent of fires to influence subpopulation recovery or meta-population persistence.

La Puma at el. (2007) outline three possible scenarios of how fire may impact Cape Sable seaside-sparrow populations based on an understanding of the species and previous work (Figure 4.1).

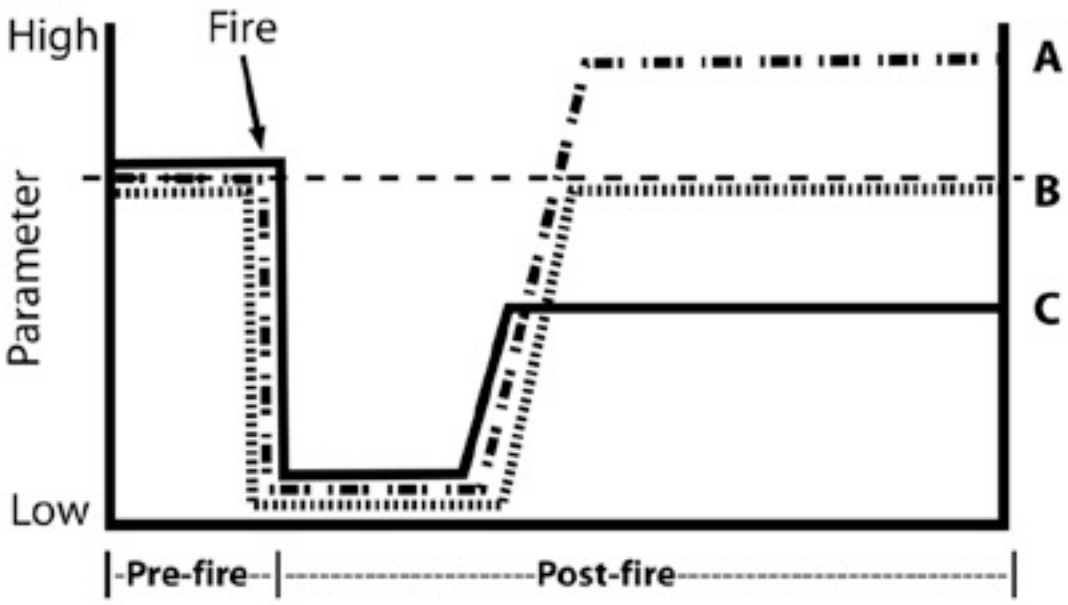


Figure 4.1. Three theoretical scenarios of the effect of fire on Cape Sable seaside-sparrows as proposed by La Puma et al. (2007). The horizontal dashed line represents the control plot, where fire is absent. After fire, each scenario is predicted to show a drop in a measured demographic parameter. This demographic parameter is expected to continue at low levels for some period of time, at which point the burned habitat will show either a measurable degradation due to fire (C), no effect of fire (B), or enhancement by fire (A). The time scale is based on previous research by Werner (1975) and Taylor (1983). From La Puma et al. (2007).

In all three cases the expectation is that the dependent variable (i.e. some measure of sparrow population size or demography) will be reduced immediately following fire and persist in a reduced state for at least one breeding season. Scenario A, where habitat is enhanced by fire, most closely represents the previous paradigm of sparrow habitat management, based on work by Werner (1975) and Taylor (1983). In scenario B, the case where fire has no lasting positive or negative effect, the demographic features of the burned site return to levels indistinguishable from the control. Finally, if fire has a lasting negative effect (C), the expectation is that demographic rates within the burned site will persist at levels significantly below the control. The following sections explore which relationship depicted in Figure 4.1 best fits existing information on the response of Cape Sable seaside-sparrows to fire.

Response To A Single Fire Event

On May 8, 2001 a human-ignited fire (hereafter the Lopez fire) began at the eastern boundary of Everglades National Park. Over the course of fifteen days the Lopez fire burned 3,410 ha until controlled on May 23, 2001. The fire left a scar that is easily seen on the November 2001 satellite image (see Chapter 9). Given the dry conditions at the time, the fire consumed the great majority of vegetation in its path, leaving little in the way of an unburned vegetation mosaic. The Lopez fire represents an early season fire event that would not be characteristic of an average fire season. However, the Lopez fire does fall well within the range of fires over the period of record provided by Gunderson and Snyder (1994) and such fires may be expected to occur more frequently given the altered water flow regime currently affecting the northeastern portion of Everglades National Park (Lockwood et al. 2003). The path of the fire included the southern portion of subpopulation E, including the southern edge of a study plot originally designed to document demographic parameters of this population. This situation permitted La Puma et al. (2007) to utilise a Before-After, Control-Impact (BACI) design to generate precise inferences on the effect of fire on sparrow demography.

La Puma et al. (2007) show that individual sparrows are apparently driven far from burned habitat, or perish due to the fire. Certainly any nests that are active at the time of a fire are lost, as are most recent fledglings, given that they are relatively weak flyers (see *Life History* section). Sparrow habitat that has burned will remain unsuitable for sparrow breeding for at least two years after the fire largely because the vegetation structure necessary for sparrow breeding does not recover for two years. However, unburned habitat, even if it directly abuts burned spaces, will support sparrow densities and nesting success indicative of unburned habitat (La Puma et al. 2007). When the burned habitat does recover it is very similar in species composition and vegetation structure to unburned places and the habitat shows no signs of being ‘enhanced’ based on the observations of La Puma et al. (2007) that sparrows re-occupy burned areas at densities indistinguishable from unburned areas. Recolonizing individuals will experience nest success probabilities that are indistinguishable from unburned habitat and equivalent to pre-fire habitat: Figure 4.2 (La Puma et al. 2007).

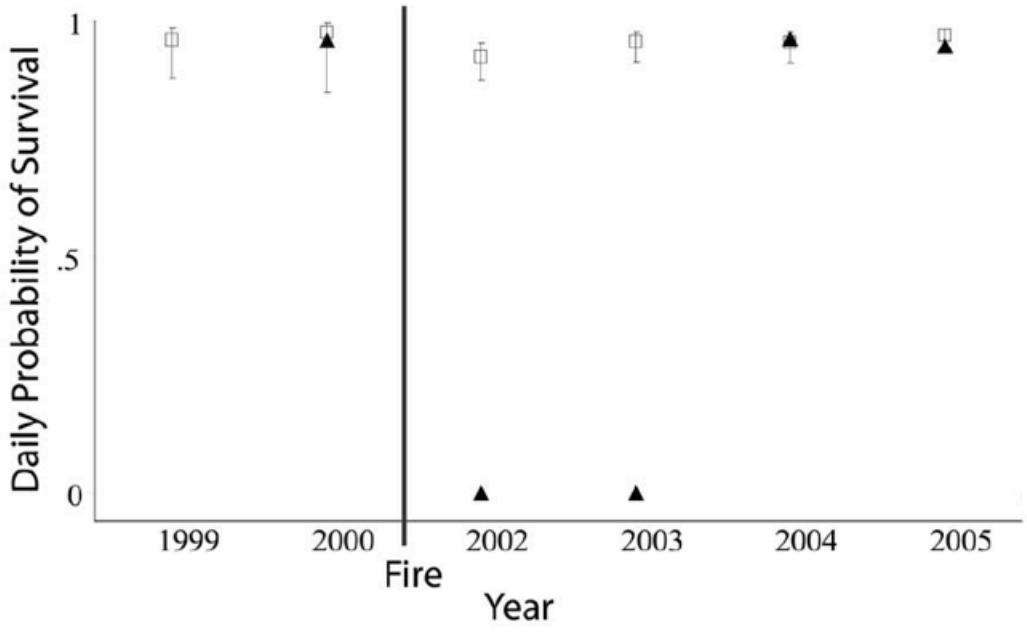


Figure 4.2. The daily probability of survival for nests of Cape Sable seaside-sparrows calculated for each year in both the unburned area (solid line with open squares) and burned plot (dashed line with solid triangles) (μ ± 95% CI). From La Puma et al. (2007).

The individuals that recolonize the burned site likely come from nearby unburned habitat, and these individuals may be relocating breeding adults or first-year breeders. There is no evidence from La Puma et al. (2007) to suggest that dispersal distances are so limited that a spatial pattern of time to recovery is apparent. However, this result may be restricted to fires that burn relatively small areas of sparrow habitat or to situations where a source population is within a few kilometres of the fire-affected places (we further consider these spatial effects below).

The results of La Puma et al. (2007) strongly support scenario B in Figure 4.1, thus contradicting the prevailing wisdom that suggested Scenario A as the guiding model of Everglades marl prairie management for Cape Sable seaside-sparrow recovery (Taylor 1983; Werner 1975). In addition, the findings of La Puma et al. (2007) show that degree of harm caused by the Lopez fire was likely limited by the fire's relatively small spatial extent, and by the fact that there was occupied sparrow habitat surrounding the fire scar. In cases where the fire is large, or it occurs within a subpopulation that is near extirpation, greater harm may occur because it is more likely to precipitate the loss of a spatially distinct subpopulation. Similarly, the Lopez fire was a typical early wet season fire in the sense that plant mortality was restricted to primarily above-ground components of the vegetation. The intensity

and seasonality of fire will have a profound effect on the regeneration of suitable sparrow habitat. For example, a hot, dry fire which consumes all above-ground and below-ground vegetation may result in a longer return interval with unpredictable species composition. This same scenario followed by a high-water period has resulted in the conversion of marl prairie to marsh vegetation which may or may not revert to marl prairie depending on site hydrology (Pimm et al. 2002).

Response To Fire Through Space and Time

Lockwood et al. (2007) explored the landscape dynamics of fire on the range-wide site occupancy of the Cape Sable seaside-sparrow. Despite the advances that La Puma et al. (2007) made in our understanding of the response of Cape Sable seaside-sparrows to fire, extrapolating larger ecological and management inferences are problematic as it is quite possible that sparrows and their habitat do not react to fire in the same manner across the entirety of their current range. For example, slight differences in soil depth or flooding regimes could influence the rate at which suitable breeding habitat returns following a fire (Ross et al. 2007; Taylor 1983). Similarly, the fire studied by La Puma et al. (2007) was an early dry season fire that produced relatively high temperatures and left little in the way of unburned vegetation mosaic. Fires that burn at other times of the year may have very different impacts on sparrow return times due to fire extent and configuration. Finally, the spatial structure of the sparrow population may have an influence on the rate of return after a fire, such that isolated populations will not recover as quickly as those that are as close to a source population.

Lockwood et al. (2007) explicitly tracked these variables and documented the relationship between sparrow site use and different characteristics of fire in the Everglades. To do this they combined a fire geodatabase spanning 16 years (1989-2005) with 13 years of sparrow range-wide occupancy survey information (1992-2005). They characterised the fire regime within sparrow habitat across the 16-year span of the geodatabase to assess whether each sparrow population has burned more frequently and to greater extent relative to the others, and whether fire regimes in sparrow habitat are qualitatively different from regimes experienced by the ecosystem as a whole. Among the different sparrow populations, they compared sparrow site occupancy between burned and unburned sites. They also evaluated the role of fires of different extent, season, and type to test whether characteristics of the fires themselves significantly influenced the probability that sparrows will occupy a site one year post-fire. Finally, they calculated the time-since-fire for each survey year and then estimated how fire events directly affect sparrow site usage across a 13-year span.

Lockwood et al. (2007) report that, of the 134 fires that burned sparrow survey points between 1989 and 2005, 23% were accidentally or deliberately ignited with malicious intent (hereafter referred to as “human-ignited incendiary fires”), 33% were natural lightning strikes, and 44% were management-ignited prescribed burns. The largest single fire during this period was the Ingraham Fire, which burned from May to July of 1989, and burned a total of 36,339 hectares. This

naturally ignited fire contributes > 40% of the total area burned during the study period. Among the remaining fires, human-ignited incendiary fires accounted for the greatest number of dry-season fires (n = 21) and burned the majority of the total area during the dry season (16,142 hectares). Very few human-ignited incendiary fires occurred in the wet season (n = 9) and averaged one-quarter the size of those that burned in the dry season. Natural fires, which are tied directly to thunderstorms during the wet season (Beckage et al. 2003; Slocum et al. 2007), accounted for 40% of all fires that together burned 5,149 hectares from 1989 – 2005. The average size of these lightning fires was 136 hectares. Several smaller naturally ignited fires (excluding the 1989 Ingraham fire) occurred during the dry season, averaging 14 hectares in size, with a maximum size of 33 hectares. Management-ignited fires accounted for the largest area burned during the wet season over the study period (27,895 hectares).

The total area burned (TAB; the cumulative area burned over all years within each population) was considerably greater than the spatial extent burned (SEB; the spatial coverage of all fires within a population) for all populations except for A. Both values for population A were nearly indistinguishable (TAB= 3,371ha, SEB= 3,220ha), indicating that fires were small and non-overlapping in this part of the landscape. All five remaining populations had TAB values >100%, indicating an estimated 6% or more of their total geographic extent burned annually over the 13 years of record. Populations B and C had SEB values of 61% and 71% respectively, suggesting that a substantial proportion of these populations have remained fire-free since 1989. Populations, D, E, and F experienced SEB values of 79%, 84% and 86%, and TAB values of 126%, 103%, and 160%, respectively. Thus, not only did very little sparrow habitat escape fire in these populations since 1989, but also substantial portions of these populations burned several times over.

Lockwood et al. (2007) show that just over half (56%) of the sparrow survey points included in our analyses (of n = 427 points) did not burned between 1989 and 2006. Across populations the proportions of survey points burned at some time between 1989 and 2005 are significantly different (Figure 4.3).

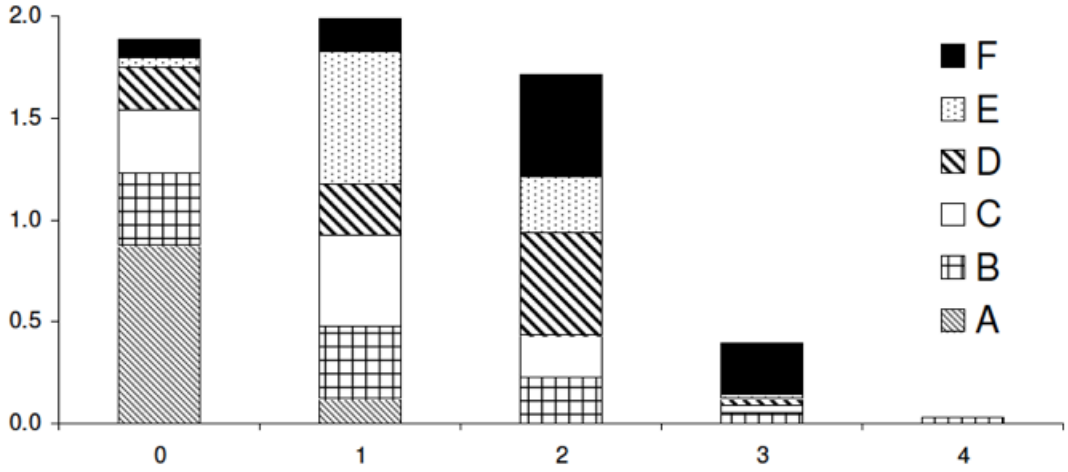


Figure 4.3. Proportion of all Cape Sable seaside-sparrow range-wide survey points that have held sparrows since 1989, and of these, those that have burned up to four times during the period of record (1989 – 2005), by population. Population A has the fewest burned points, whereas D and F have the greatest proportion of points that burned more than twice. From Lockwood et al. (2007). Figure originally produced by D. La Puma.

The average percentage of burned survey points per population was 69% and ranged from 13% of population A survey points to 95% of population E points. Excluding population A the proportions are more homogenous but still significantly different. When Lockwood et al. (2007) calculated the percentage of survey points burned in any given year, the proportion of points burned exceeded 5% in six out of the 16 years with the greatest proportion of survey sites burning in the 1989 Ingraham fire (29%).

Lockwood et al. (2007) show that sparrows occupy survey points at a significantly lower rate one-year post fire as compared to occupancy in unburned habitat (Figure 4.4). For all fire events, Lockwood et al. (2007) tested the influence of fire extent (Log_{10} hectares), fire type (human ignited, natural, management ignited), season (wet, dry), and soil depth at the survey point (meters) on site occupancy in the survey year immediately after a fire event. Following fire events, none of the four terms analysed were associated with significant trends in site occupancy. When Lockwood et al. (2007) tracked occupancy trends beyond the first year post-fire they saw that, following a fire event, average sparrow occupancy initially increased as the number of years without a fire increases (Figure 4.4). The change in sparrow occupancy with time-since-fire across a period of 17 (1989 – 2005) years is best modelled by a quadratic relationship (Figure 4.4).

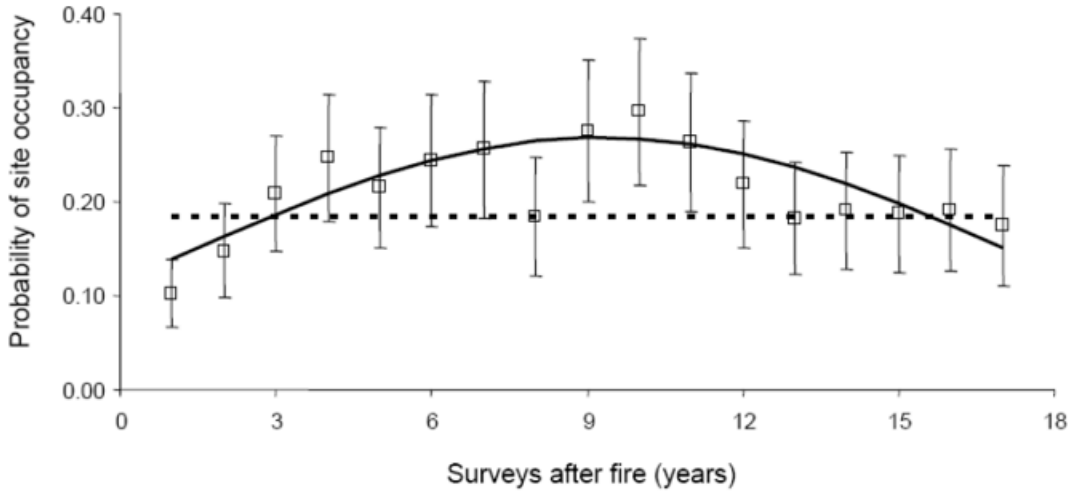


Figure 4.4. Probability of site occupancy by Cape Sable seaside-sparrows following known fire events during 16 years ranging from 1989 – 2005. Error bars around each estimate are +/- 1 standard error. The dotted line is the average site occupancy for all frequently surveyed points (i.e. those surveyed at least six times), which are known to have been occupied by sparrows (i.e. have had at least on sparrow detection) and have never burned during the study period. The fitted line is the logistic quadratic. From Lockwood et al. (2007). Figure originally produced by D. La Puma. (Chapter 5 also discusses the interpretation of this figure.)

In summary, the results of Lockwood et al. (2007) show that there is nothing unique about fire regimes within the habitat of the Cape Sable seaside-sparrow, as they report similar patterns and cycles over the past 16 years that have been previously reported by Gunderson and Snyder (1994) for the entire ecosystem for the 45 years prior. Moreover, Lockwood et al. (2007) provided evidence that even areas with the most sparrows have burned extensively during the span of our 16-year record. Thus, fire clearly is a regular driver of Cape Sable seaside-sparrow population dynamics and there is no reason to suspect that the subspecies has experienced any different fire regimes than have the rest of the inhabitants of the ecosystem. Nevertheless, the results of Lockwood et al. (2007) suggest that fire has a negative initial impact on sparrow occupancy followed by a recovery to post-fire levels by the second year post-fire. This result extends the evidence in favour of Scenario B in Figure 4.1, in particular extended our confidence in applying this model across the entire range of the Cape Sable seaside-sparrow.

Despite the evidence that sparrow numbers are reduced by fire, the analyses of Lockwood et al. (2007) show an apparent asymptote in occupancy at 10 years post-fire followed by a decline down to below the unburned average. This finding is consistent with the early research of Taylor (1983) and Werner (1975) and suggests a potential for vegetation in habitat to succeed into a sub-optimal state for sparrow

use after a long fire-free interval. This fire return interval is much longer than either Werner or Taylor's recommendation for a 4-year fire return interval. However, the recommendation of Lockwood et al. (2007) is congruent with the results of Gunderson and Snyder (1994) who show that episodic large fires occur on the order of every 10-14 years. Nevertheless, this conclusion must tempered with the realisation that the results of Lockwood et al. (2007) are correlational only. In other words, it is not possible to ascribe a mechanism to the lack of sparrows found in survey sites that have not burned in over 10 years. It is quite possible, for example, that these are the same sites that experience wetter than average conditions throughout the year, do not burn often because of higher average water conditions, and are suboptimal sparrow habitat because of the effects of water flow and not fire.

Although fire is clearly a part of the sparrow's evolutionary history, Lockwood et al. (2007) suggest managers employ extreme caution when couching their results in the context of Cape Sable seaside-sparrow management. Because of the sparrow's currently low population size, sparrow recovery is dependent on the exclusion of even relatively small-scale fire events, as these occurrences represent a threat to the persistence of the subspecies. Thus, at least over the near term, we cannot allow fire to run its natural course without imposing management safeguards to protect the subspecies. The type of safeguards required is dependent on the population under consideration. Lockwood et al. (2007) suggest that, while fires regularly occur within less-burned populations such as B and E, ample habitat likely remained after any given fire and this habitat may have provided refuge to displaced sparrows. This effect may continue into the future as long as fires are kept at a small spatial extent.

In populations D and F, however, the records presented in Lockwood et al. (2007) show that fires are burning at such a high frequency (every two to four years) that sparrows may be continually excluded from available habitat. These two populations have burned over 100% of their spatial extent since 1989. Unlike all other populations, F has burned more area in the dry season than in the wet, likely as a consequence of arson fires that start across the ENP boundary and readily spread into the park (and sparrow habitat) given the very dry conditions of the season. Population D, on the other hand, follows the general trend observed across sparrow habitat of burning predominately in the wet season, yet the extent to which it has burned still remains well above the mean for the populations within fire-prone regions of the park (i.e. excluding A). Lockwood et al. (2007) suggest that together these results argue for a role of fire in the decline and non-recovery of these small sparrow populations since they may not be of sufficient size to endure fires at the frequency and extent they have experienced in the recent past.



Figure 4.5. Fires burn off all the vegetation over extensive areas of the prairies.

Chapter 5

Long-term vegetation changes in populations C, E, and F.

Clinton Jenkins and Stuart Pimm

The long-term consequences of fires (or their absence)

The previous chapter explores the short-term consequences of fire on the sparrow's survival. A recurrent theme is whether fires, though harmful in the short term, might have a beneficial effect over long periods. Figure 4.4 suggests that sparrow numbers might peak a decade or so after fire and decline thereafter. We disagree with this interpretation. We agree that there is clear evidence that sparrow numbers are low immediately after fires. The mechanism for this is clear: there is little vegetation and fire scars are obvious on satellite images for this period. There after, whether the numbers actually decline is more contentious. There is considerable variability. In data such as these, there can be statistical artefacts that cause patterns similar to the figure. In data where values cannot be <0, then the more points there are, the more likely they will appear to bulge. There will generally be more in the middle of the data range, by chance, and fewer at the end where the averages tend to decline.

Whether there is a real decline in numbers after (say) a decade has important implications for management, of course. It might suggest the benefits of controlled burns to improve the habitat. We suggest there is no evidence to support such actions.

That said, we wish to explore long-term patterns in the vegetation related to fires. One possible mechanism for sparrow declines in habitats free for from fires for a decade or more is that frequent fires might prevent the spread of bushes and hammocks or remove the latter vegetation if it were established.

Comparing the Everglades from 1940 and 1990

To test this idea, we obtained digital versions of aerial photographs taken in 1940 — prior to the major damage done to the Everglades ecosystem by the dykes and levees the Army Corps of Engineers built over the following decades. We compare these images to those from 1994. The former are black and white, often scratched, of poor resolution, and show large changes in brightness due to the sun's position when taken. The 1994 images are very much better, of course. Some images were particularly difficult to compare.

The large differences in quality make the application of standard measures of change detection impractical. Consequently, we counted the number of bushes in each image and estimated the area of each one. This proved to be an extremely time-consuming task. To simplify it, we selected 15 samples across the prairies east of Shark River Slough of size 0.5 x 0.5 km (= 25 ha) We chose these areas according to their recent fire frequencies. Only since 1986 are compelling fire outlines available. Figure 5.1 shows the distribution of fire frequencies in the period since then and the location of the 15 sites. We chose 3 sites each from fire frequencies of 0, 1, 2, 3, and 5 attempting as best we could to sample from as wide a region as possible within each fire frequency.

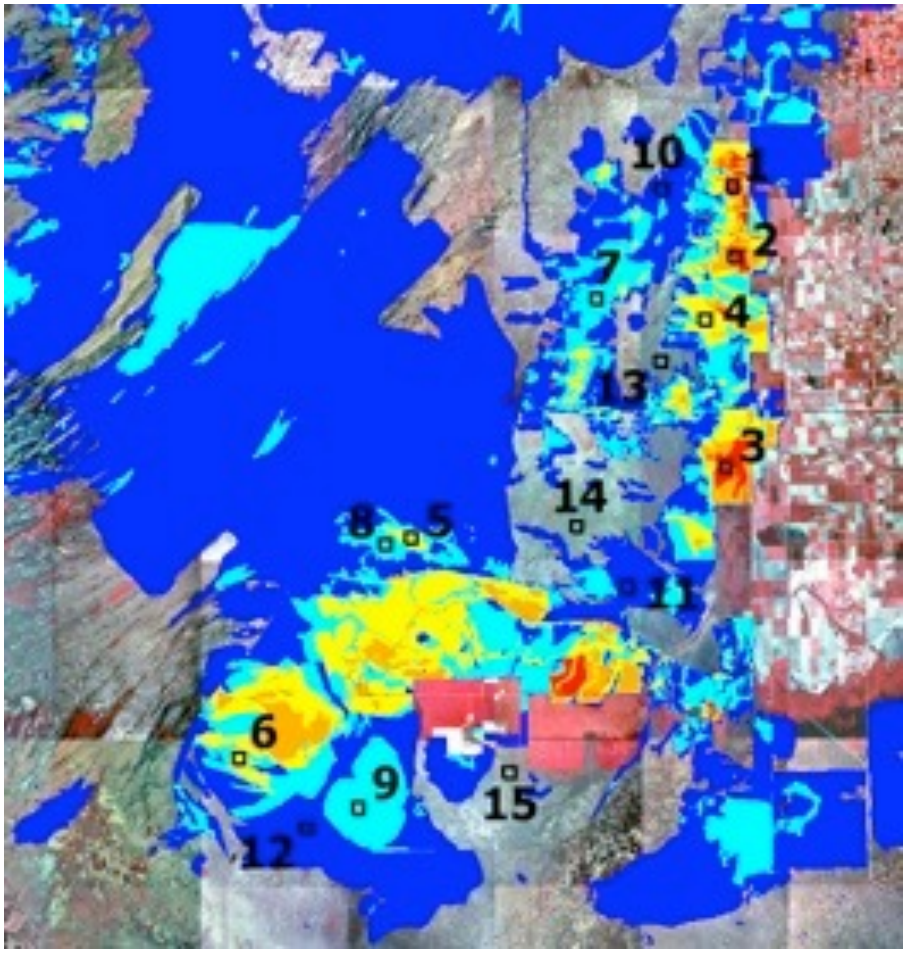


Figure 5.1 Fire frequencies from 1986 to 1994 in the eastern half of Everglades National Park. Colours range from blue (one) to orange red, (fifteen). The red-purple areas are green vegetation in this false-colour image, with tree islands obvious in Shark River Slough, the large areas of *Schinus* above the number 15, and the agricultural areas to the east of the Park. Numbers are the locations of comparisons of aerial photographs from the 1940s and 1990s.

Figures 5.2 through 5.16 provide the raw imagery of our analyses. Table 5.1 shows that, with some exceptions, the striking feature of these comparisons is how little

the vegetation has changed in >50 years. Only two sites have changed >1 ha in the area of their bush cover, only three more by > 0.5 ha, which may be within the error of our methods for detecting change.

Figure 5.10 (site 10) is not exceptional in showing an image where not only are the bushes in the same places, but odd-shaped bushes are readily seen not to have changed shape over the time interval.

The largest loss (site 1) appears to be due to the loss of a single large willow island, though inspection of this image motivates further examples to see if such changes are more widespread. (In other words, this is one of the largest changes and it is based on only one bushy area.) We are more confident about the increases in bushes in sites 5 and 8. Both are on the edge of Shark River Slough and show consistent and obvious increases in the area of bushes.

Apart from the ambiguous site 1, the other three most easterly sites (2, 3, 4) do not show consistent losses of bushes, despite being in the most fire-prone areas. In short, what is most striking is the lack of an effect of frequent fires. Clearly, many of the bushes are strikingly resistant to fires, even frequent ones.

			1940s		1990s		
ID	# Fires since 1986	Years burned	# of bushes	Area (ha)	# of bushes	Area (ha)	change
1	5	1998, 1994, 1991, 1988, 1986	7	1.81	1	0.34	-1.5
2	5	1998, 1996, 1994, 1989, 1987	3	0.05	0	0.00	0
3	5	1999, 1994, 1989, 1987, 1986	20	1.42	51	1.66	0.2
4	3	1996, 1990, 1988	15	0.75	15	0.31	-0.4
5	3	1995, 1989, 1986	14	0.57	100	4.01	3.4
6*	3	1998, 1989, 1986	0	0.00	19	0.37	0.4
7	2	1989, 1986	11	0.31	9	0.30	0
8	2	1989, 1986	7	0.22	53	0.83	0.6
9	2	1999, 1989	23	0.92	20	0.35	-0.6
10	1	1986	35	2.69	66	2.07	-0.6
11	1	1995	3	0.03	1	0.01	0
12*	1	1989	1	0.03	8	0.09	0.1
13	0		5	0.56	9	0.25	-0.3
14	0		13	1.06	31	1.55	0.5
15*	0		0	0.00	10	0.25	0.2

* indicates that the 1940s image is particularly difficult to interpret.

Table 5.1 Summary of bushes and fires in 15 selected sites (show in figure 5.1)

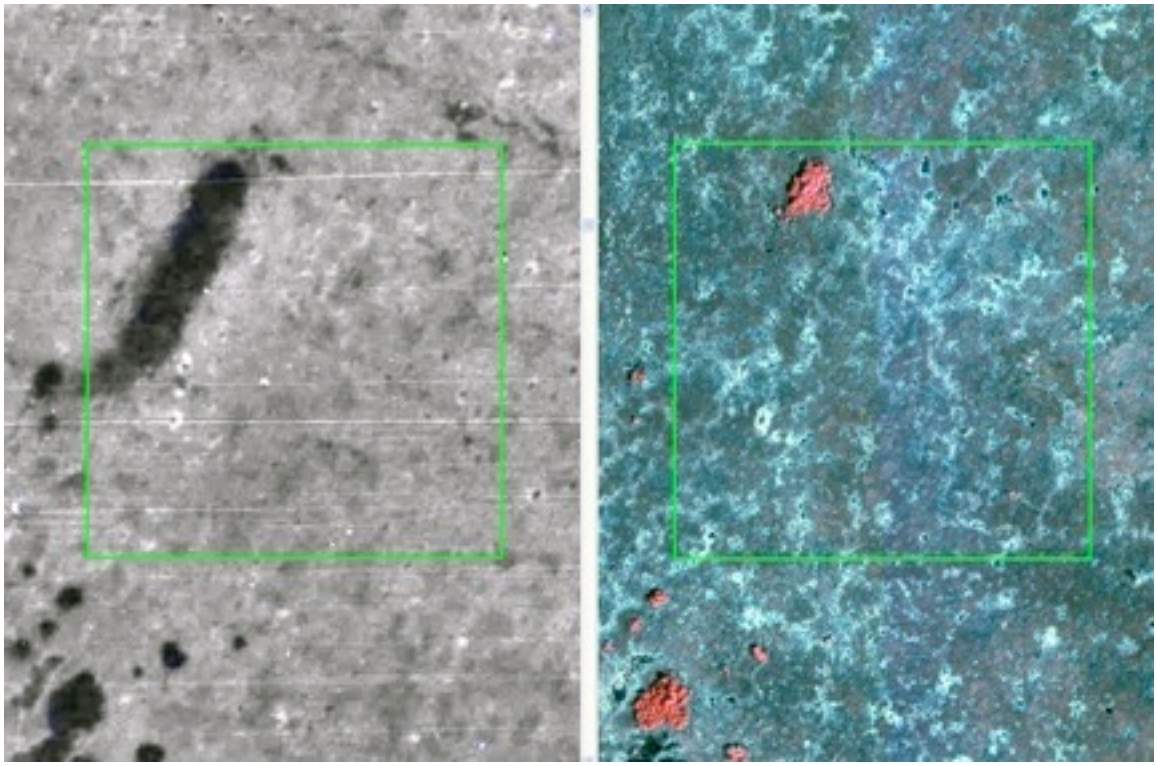


Figure 5.2 Site 1.

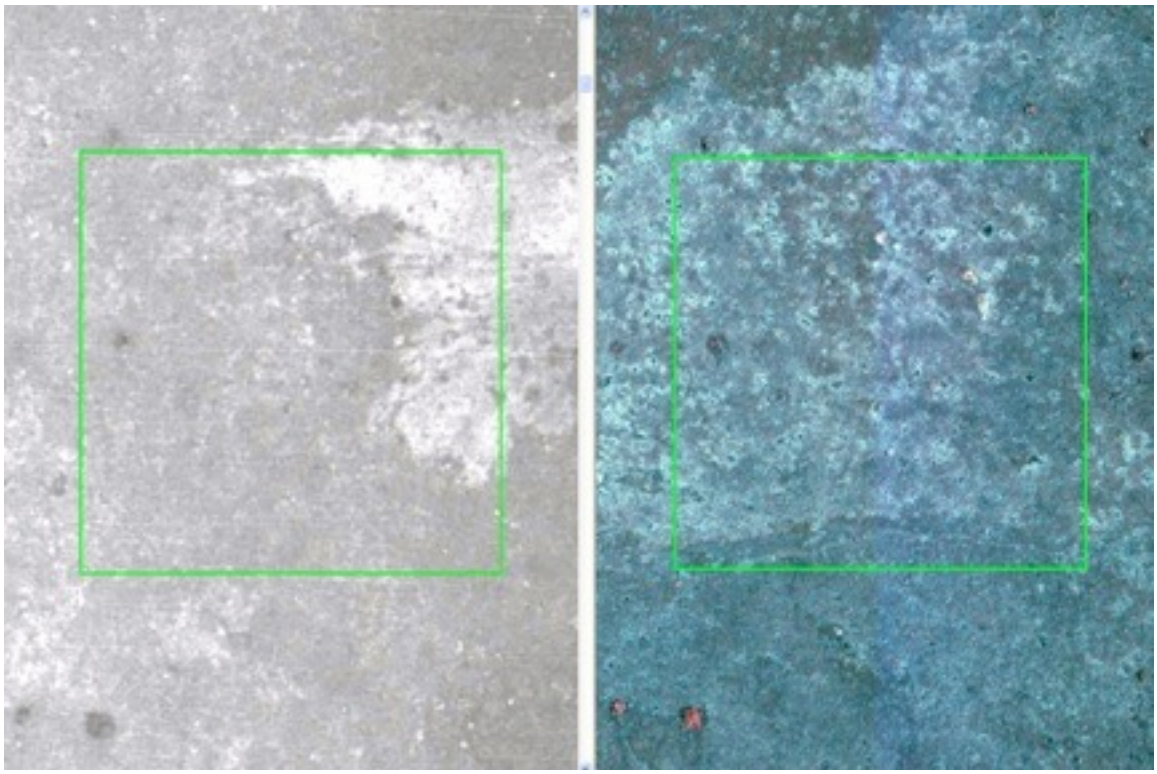


Figure 5.3 Site 2. An obvious fire scar is present in the 1940s image (left).

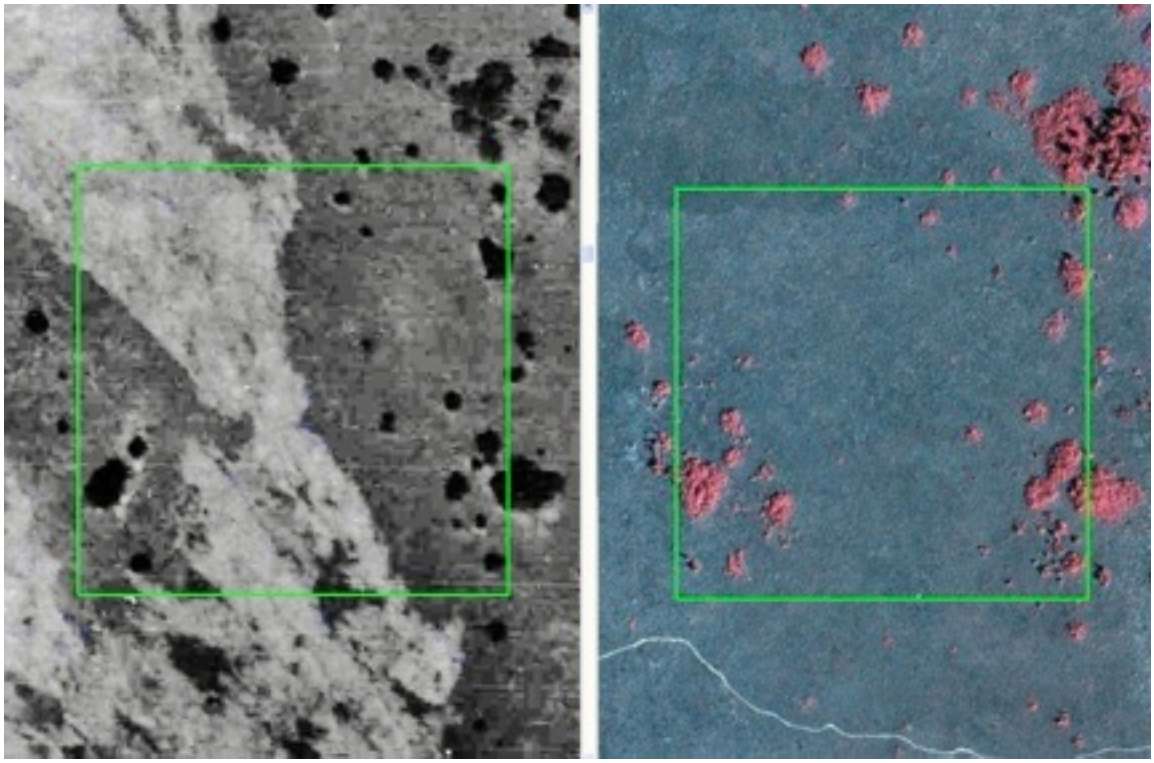


Figure 5.4 Site 3. An obvious fire scar is present in the 1940s image (left)

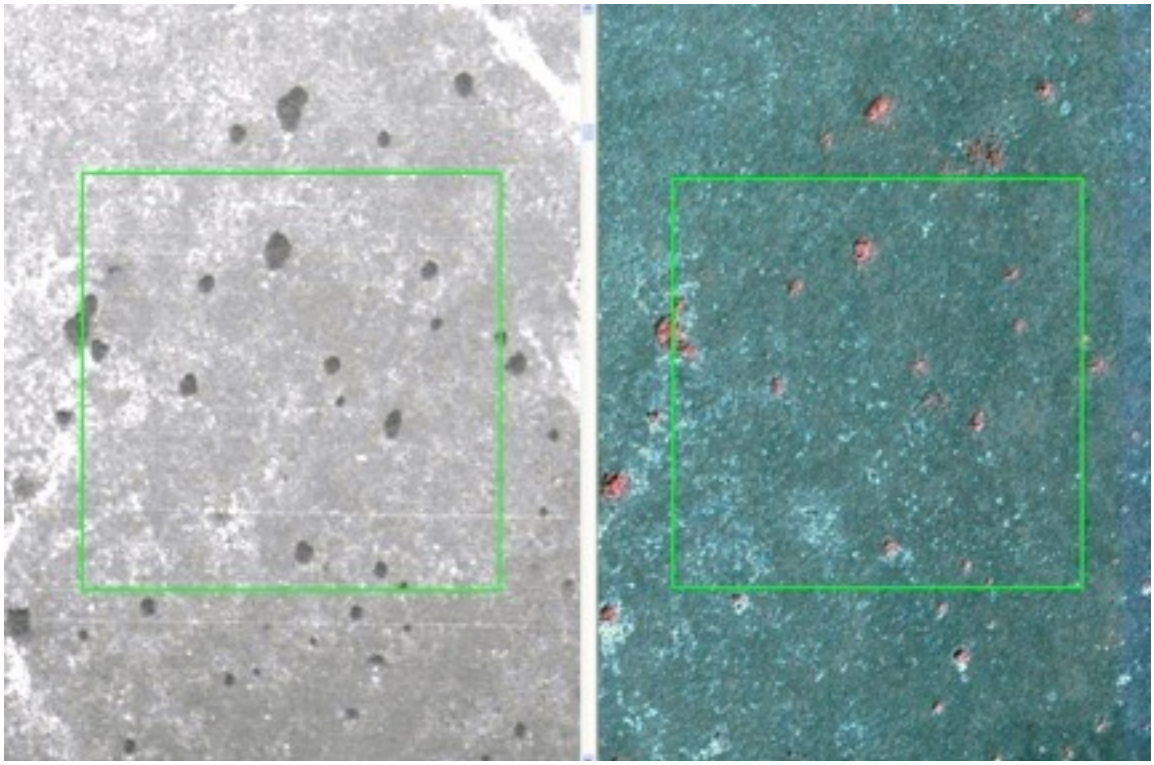


Figure 5.5 Site 4. As in other examples, the bush placements are strikingly similar.

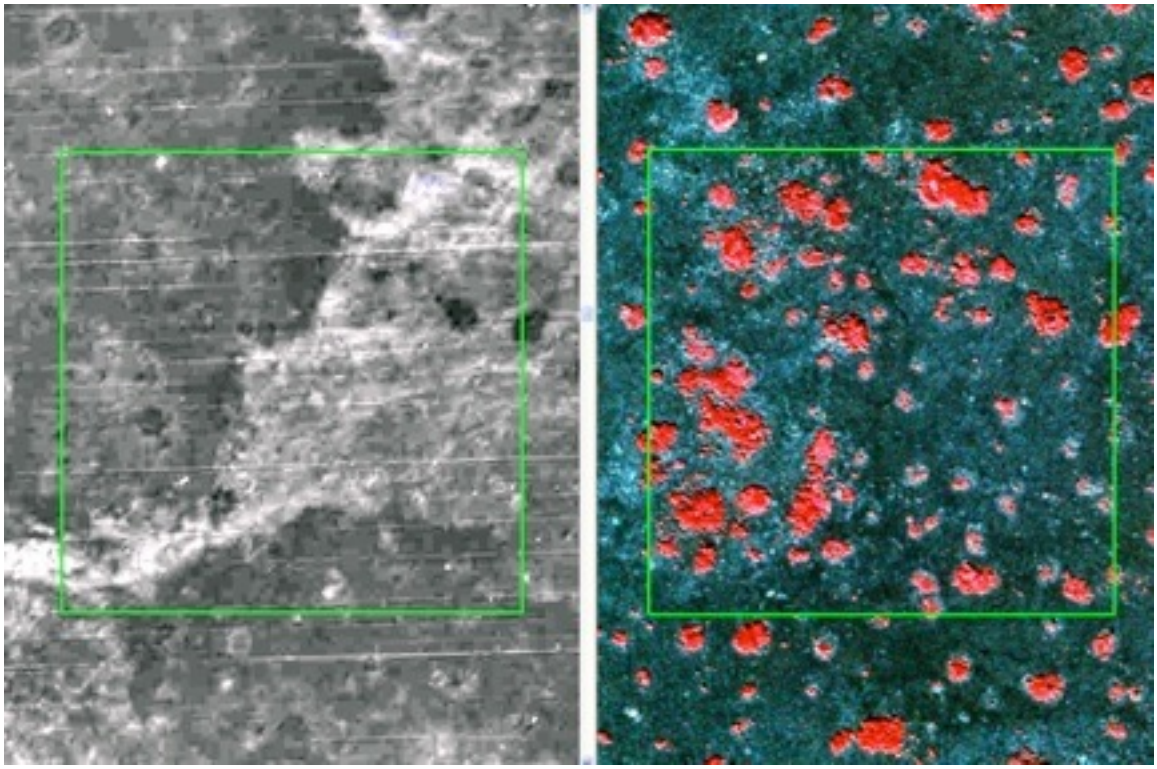


Figure 5.6 Site 5.

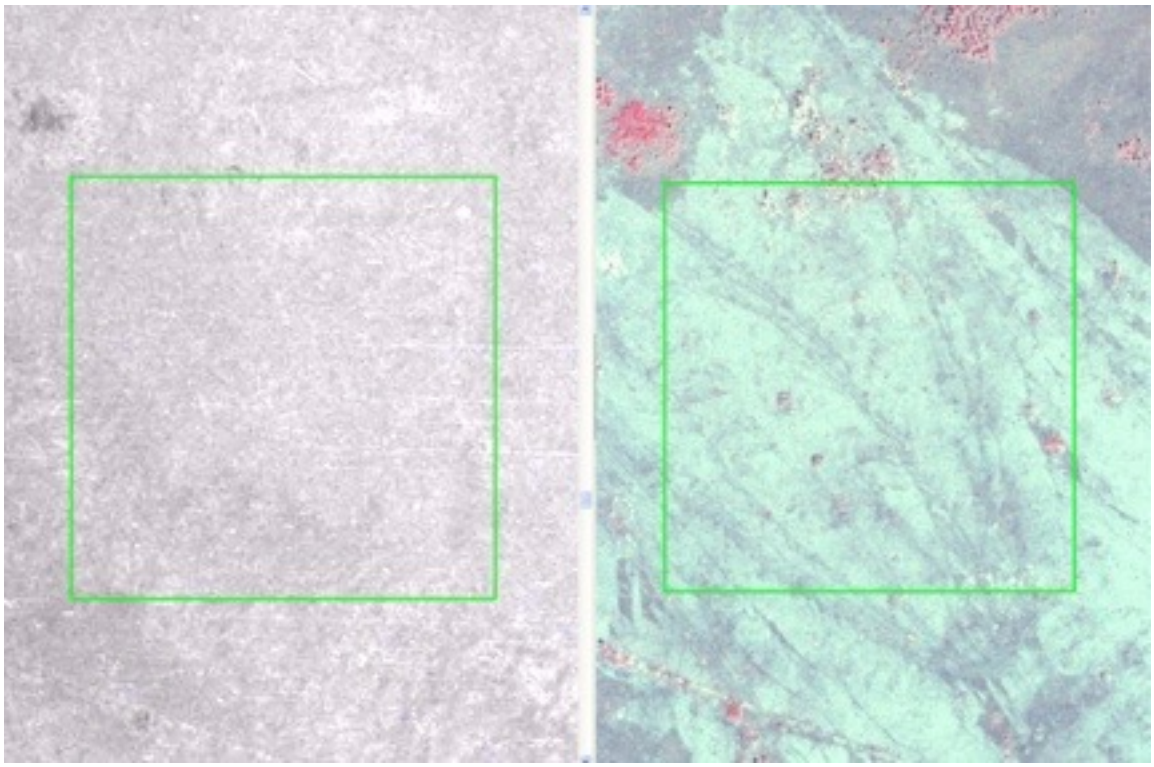


Figure 5.7 Site 6. An obvious fire scar on the right hand image.

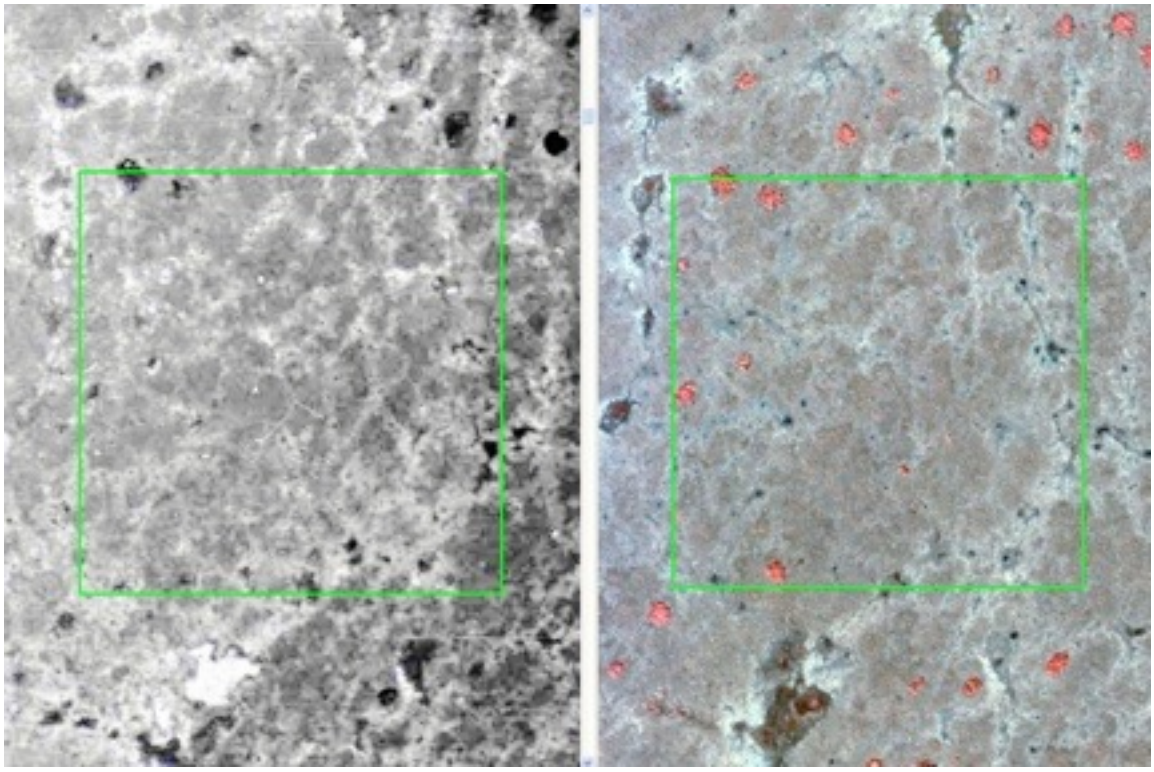


Figure 5.8 Site 7

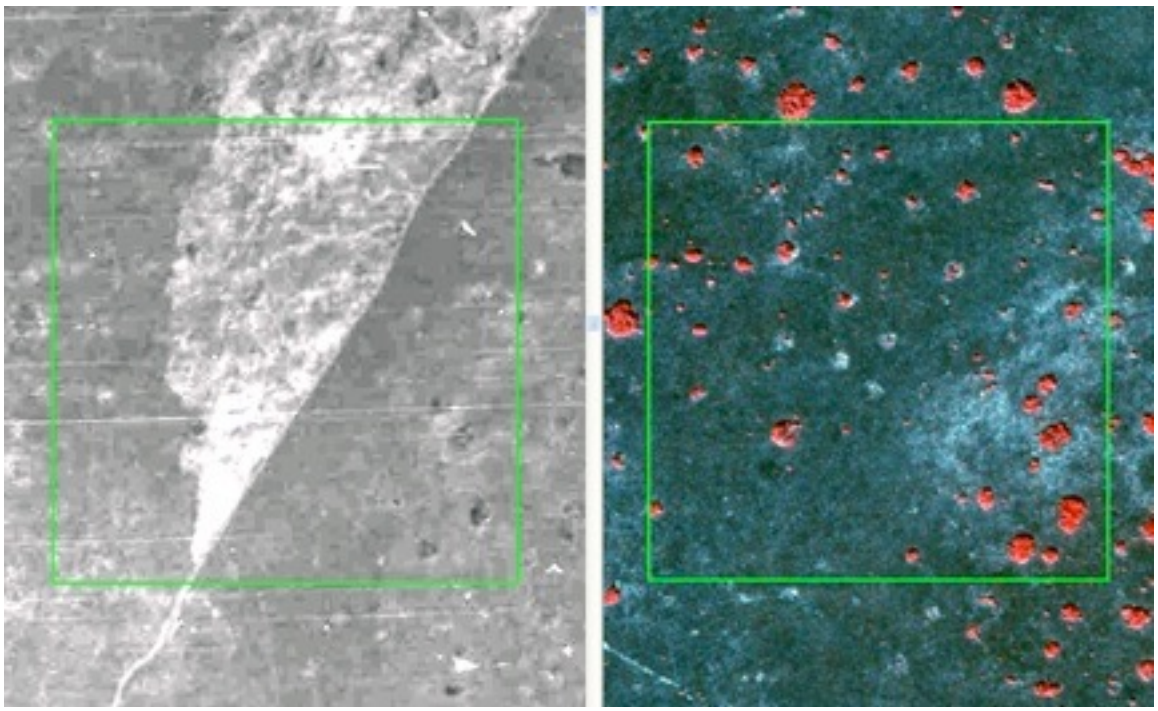


Figure 5.9 Site 8

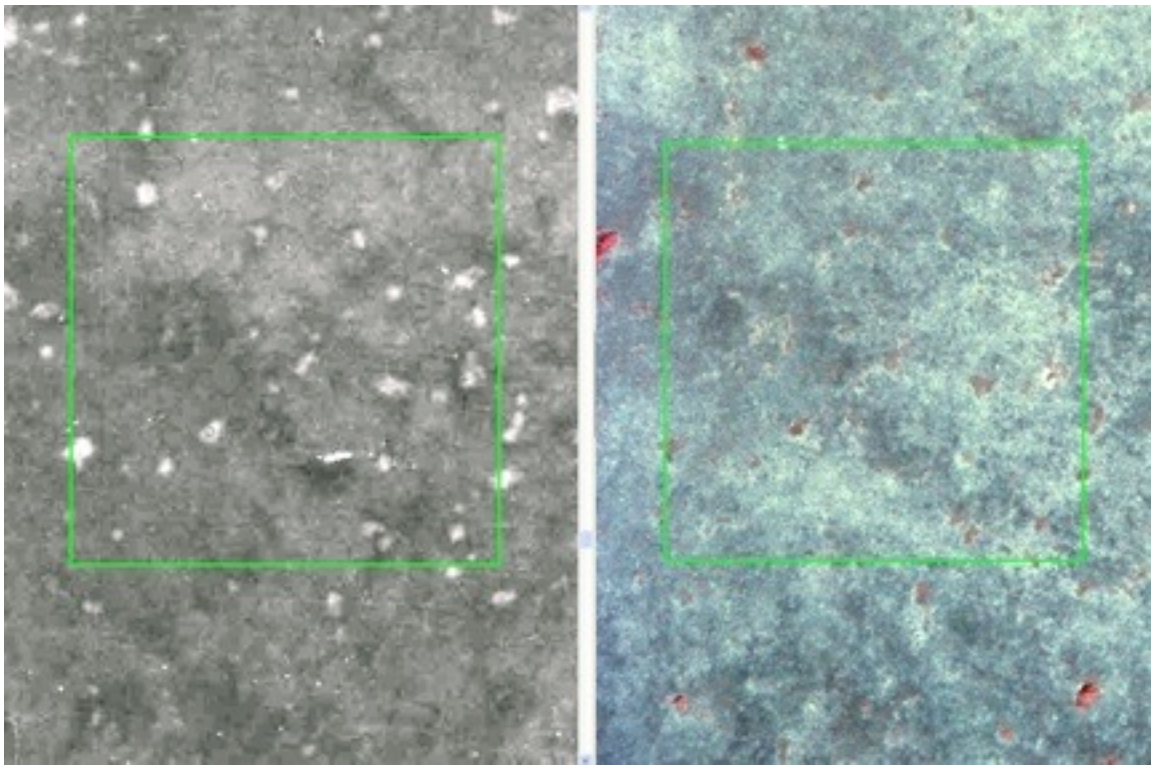


Figure 5.10 Site 9

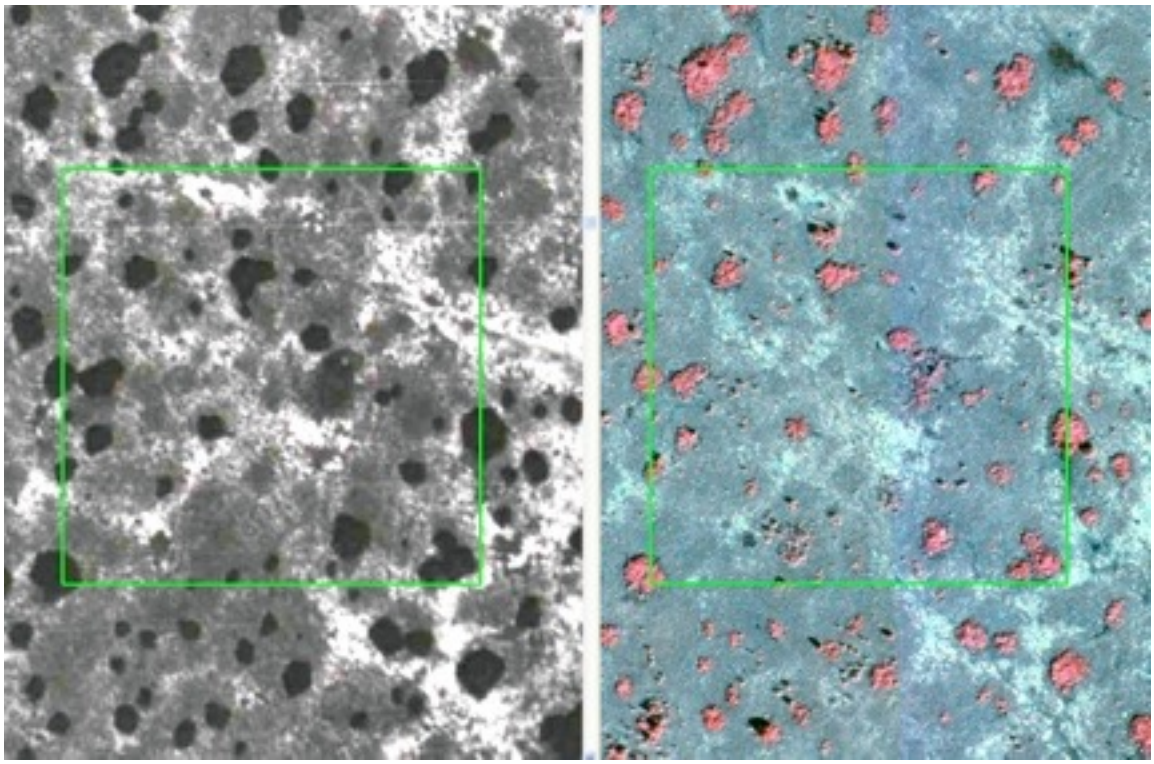


Figure 5.11 Site 10. Another example of strikingly similar bushes.

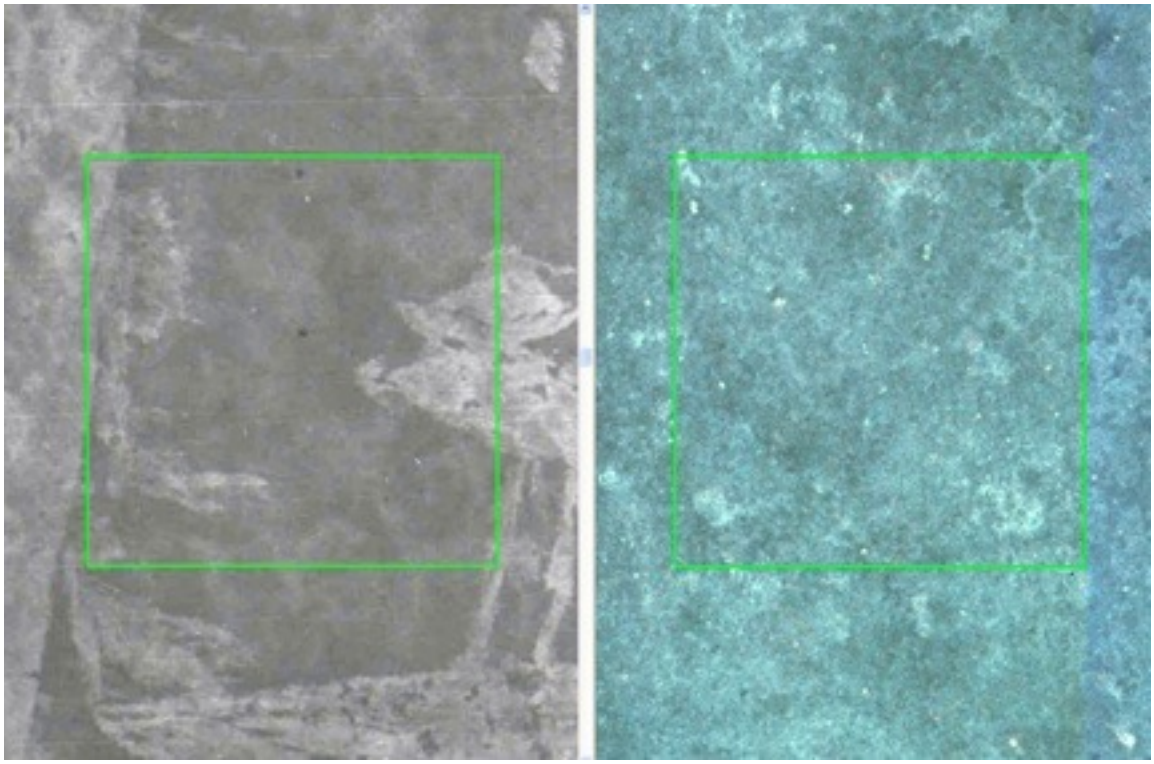


Figure 5.12 Site 11

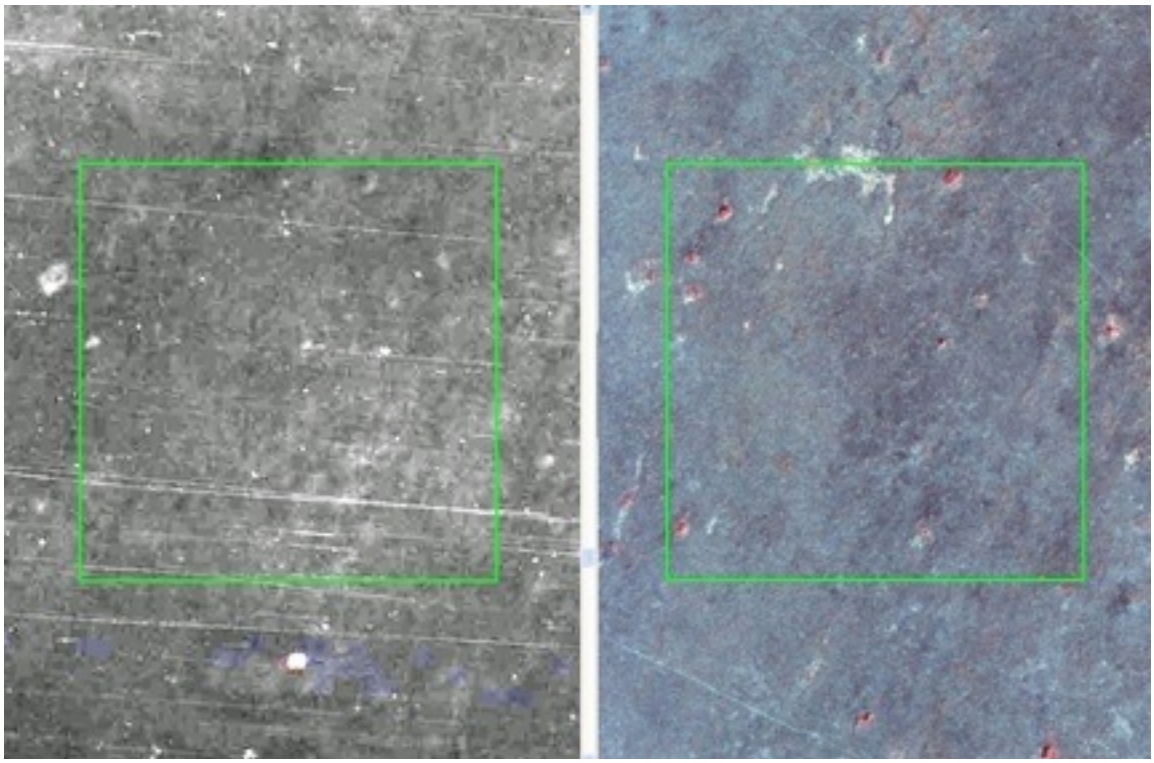


Figure 5.13 Site 12

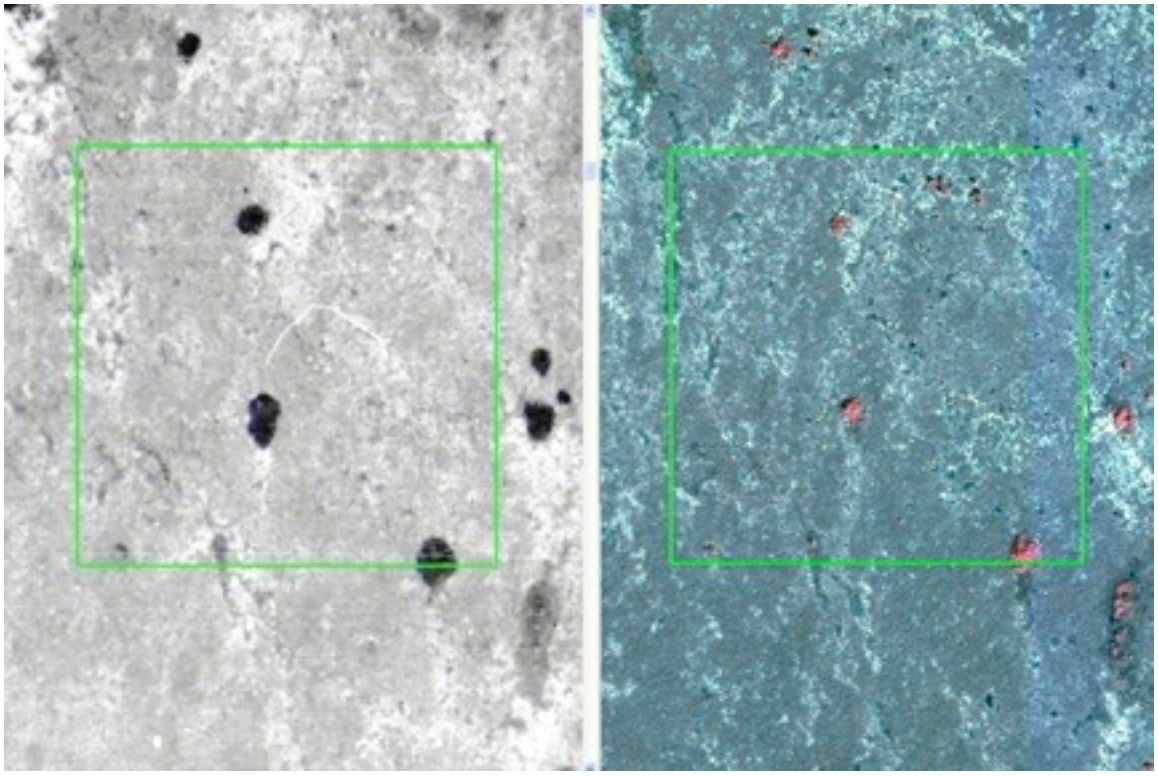


Figure 5.14 Site 13

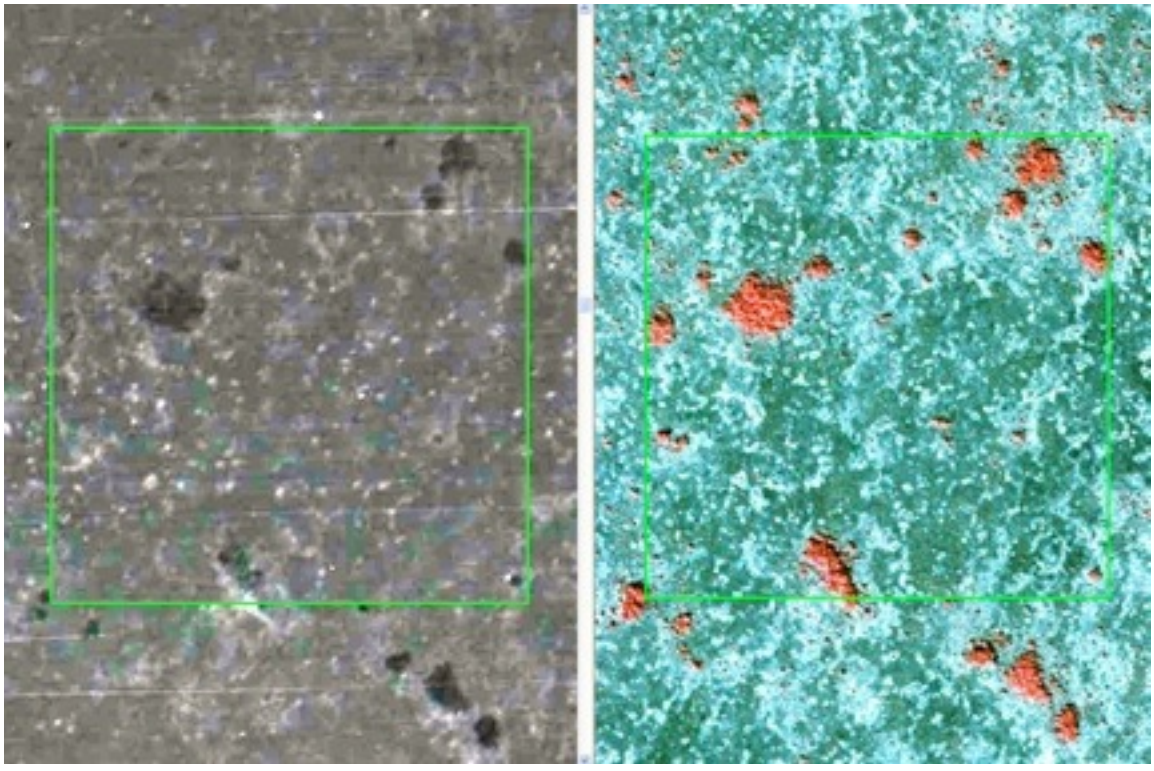


Figure 5.15 Site 14

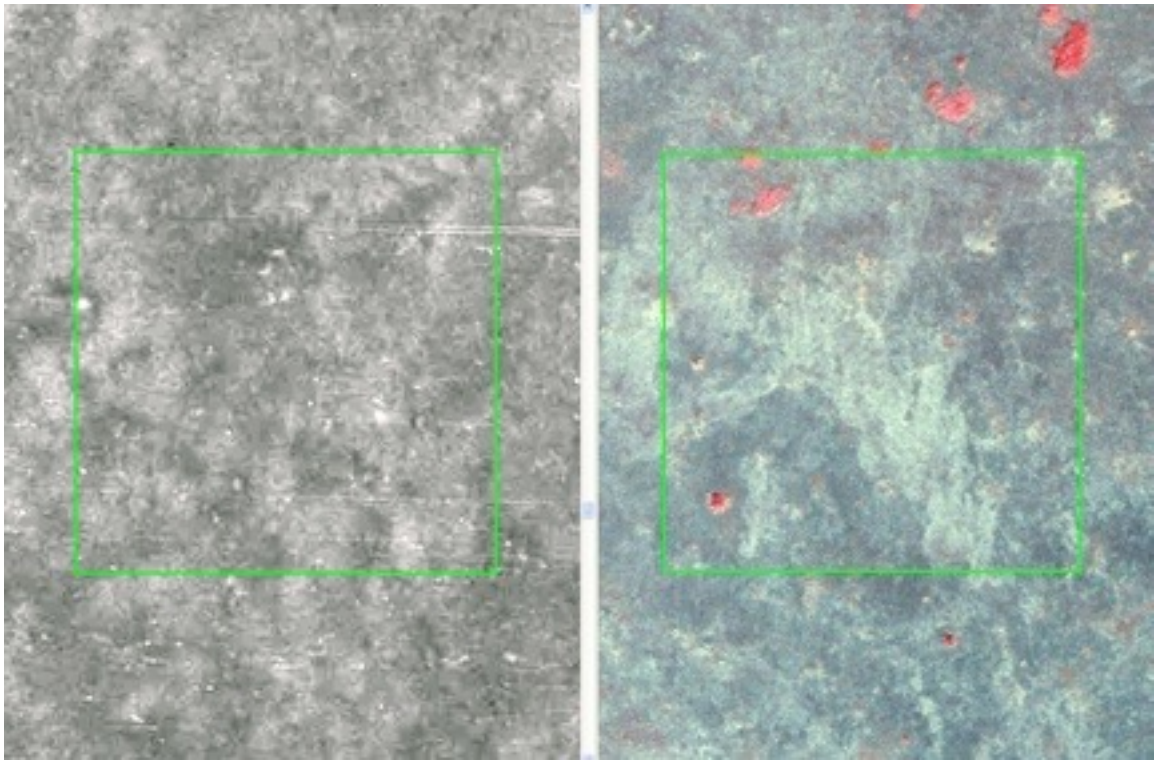


Figure 5.16 Site 15

Chapter 6

Dispersal

Kyle S. Van Houtan, Oron L. Bass, Julie Lockwood, and Stuart L. Pimm

This chapter was published as van Houtan, K. S., O. L. Bass, J. Lockwood, and S. L. Pimm (2010) Importance of estimating dispersal for endangered bird management. *Conservation Letters* 3: 260-266. It has been edited to avoid overlap with other chapters.

Abstract

Endangered species recovery plans are frustrated by small, spatially structured populations where understanding the influence of birth, death, and dispersal is difficult. Here we use a spatially explicit, long-term study to describe dispersal in the Cape Sable seaside-sparrow. Since 1990, this species declined >50%. It occurs as several geographically isolated sub-populations in the Florida Everglades. We characterise dispersal, recognising that our sampling, as well as the species' distribution, are spatially heterogeneous. The annual movements of juveniles and adults are statistically heavy-tailed. That is, while most individuals are recaptured locally, a significant portion exhibit long-distance dispersal. Individuals move between sub-populations to distances > 30 km. Not accounting for the spatial heterogeneity of sampling or the species range itself underestimates dispersal and can lead to ineffective management decisions. Recovery focused on translocation will be less successful than strategies that protect habitat and increase breeding.

Introduction

Population parameters of birth and death rates are essential elements in understanding the fates of species, especially endangered ones. However, population persistence is driven as much, if not more, by dispersal events as it is by births and deaths (Wahlberg et al. 1996, Van Houtan et al. 2007). Empirical studies of dispersal between sub-populations of endangered species are few. They demand marking efforts of individuals in the various sub-populations extensive enough in space and time to capture dispersal events between them. For endangered species, by force of circumstance, marking large numbers of individuals will generally be difficult. The statistical issues associated with modelling dispersal, especially the frequency of long-distance dispersal, are equally daunting (Clark et al. 1999, Hastings et al. 2005).

Most dispersals are local. For the small sample sizes involved with endangered species, one is likely to observe only such events. Using only these observations biases understanding population dynamics (Koening et al. 1996). Simple models severely underestimate the frequency of long-distance dispersal events. That is a concern given that such rare events may drive population dynamics (Nathan et al. 2003). The failure to represent dispersal correctly for threatened species raises important conservation issues, not merely statistical ones (Walters 2000). Management lies at the core of decisions made on behalf of endangered species. Clearly, the individual small sub-populations of an endangered species can have high risks of extinction. Indeed, they might not be self-sustaining and only persist through continued immigration. If such a sub-population becomes extinct, is it prudent to attempt to translocate individuals from another sub-population to rescue it? Or is it better to not intervene and focus resources on population centres?

The answer to these questions depends, in part, on the likelihood of long-distance dispersals. Here, we report a geographically extensive, long-term study of the Cape Sable seaside-sparrow (Lockwood et al. 1997, Curnutt et al. 1998, Nott et al. 1998, Lockwood et al. 2001, Pimm et al. 2002, Baiser et al. 2008, Boulton et al. 2009). We show that the statistical description of dispersal distances is heavy-tailed. That is, simple characterisations of movement will not describe long-distance movements well. Long-distance movements from large populations add individuals to smaller peripheral populations in sufficient numbers that likely prevent their foundering. When populations are reduced, their smaller satellite populations can become extinct as a consequence. This study aims to characterise dispersal to understand how it can affect the population dynamics of an endangered passerine bird. In answering these questions for the Cape Sable seaside-sparrow, we shed light on the broader issue of what role accurate estimates of dispersal distances play in core conservation management decisions for threatened vertebrates.

Everglades National Park and Big Cypress National Preserve in southwest Florida (Figure 6.1) hold almost all of the populations of the Cape Sable seaside-sparrow. The Florida Everglades is a subtropical wetland of global importance and was placed under protection as a national park in 1947 (Douglas 1947). In the early 1900s the ecosystem was regularly inundated by Shark River Slough, which swelled to 90 km wide, flooding large areas for 3–7 months annually. This changed in the 1950s when the Army Corps of Engineers built a vast infrastructure to manage water flow to the Everglades; keeping some areas unusually flooded and constricting water flow to other areas entirely.

This analysis addresses the following questions: (1) Does the Cape Sable seaside-sparrow show evidence of long-distance dispersal? (2) Do juveniles disperse further than adults?; (3) how does dispersal influence the spatial structure of the sub-populations?; and (4), what management actions follow from these results?

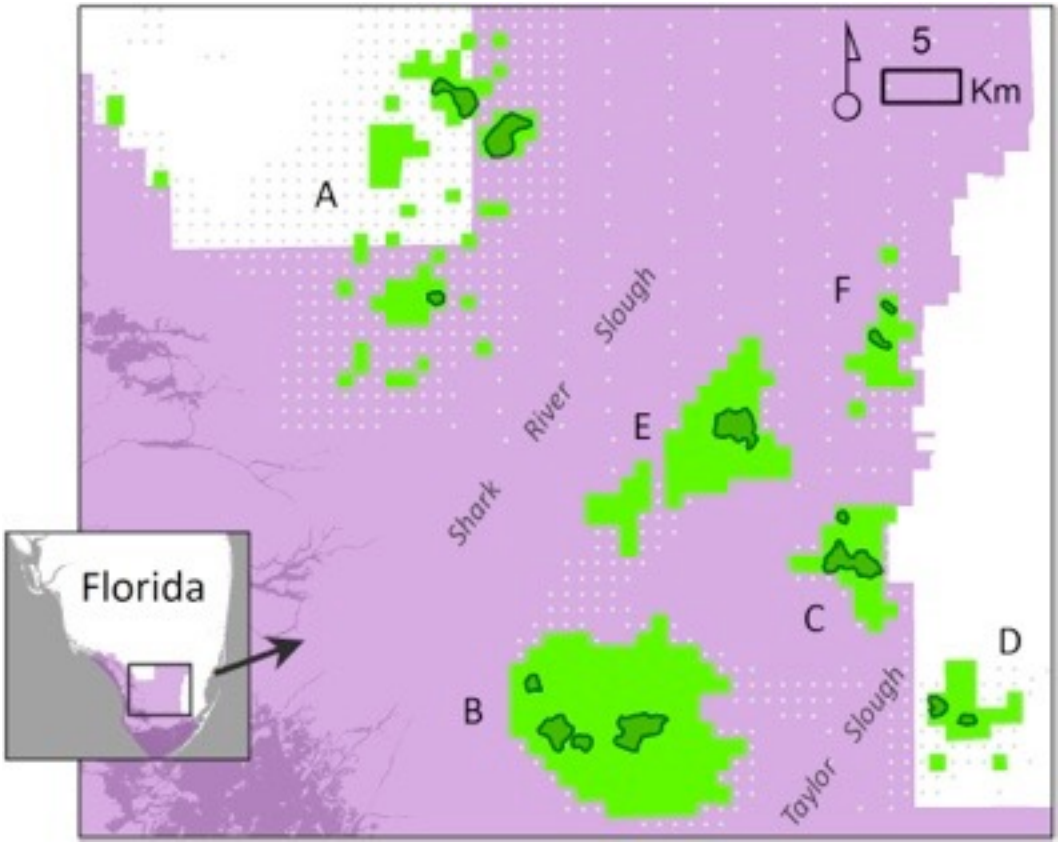


Figure 6.1. The 1994-2008 distribution of Cape Sable seaside-sparrows in Everglades National Park (purple) in south Florida. Light green cells are the 1 km^2 regions where sparrows were detected in point-count surveys during the period of record (grey circles are census points where sparrows were never detected during this period). Outlined dark green shapes are minimum convex polygons of intensive mark-recapture study sites. These sites are distributed across all six currently extant sparrow sub-populations A–F.

Methods

Study Area and Data Collection

In 1981, and annually between 1992-2008, Everglades National Park biologists conducted point count surveys to establish the Cape Sable seaside-sparrow's distribution (Jenkins et al. 2003b, Jenkins et al. 2003a). Surveys took place in April and May each year and occurred at intervals of 1 km in areas experts considered to be potential habitat - and in many adjacent prairie habitats that might possibly hold birds (Kushlan and Bass 1983). All birds detected within a 200 m radius of the survey location were recorded. From these surveys, the remnant population was classified into six sub-populations (Curnutt et al. 1998). From 1994-present, intensive capture-recapture studies took place at study plots where such sampling was logistically possible (Figure 6.1). (This still included some sites only accessible

by helicopter.) From April-June each year, researchers captured sparrows with mist nets and tagged birds with uniquely numbered aluminium bands (USGS provided) and installed additional colour bands to facilitate visual re-sighting. This combined tagging allowed both net recaptures and re-sights to provide 769 successive locations for sparrows after their initial release. Boulton et al. (2009) provide details.

Dispersal Kernel Analysis

We analysed census data from the point count surveys and capture-recapture effort to model dispersal. We used point count surveys to establish the known distribution of the species during the period encompassed by the capture-recapture effort (i.e., 1994-2008). This distribution is considerably smaller than the 1981 distribution and also reflects reductions in the number of occupied survey sites that occurred from 1981-1992, and again from 1993-1996 (Cassey et al. 2007). From the point count data we generated a grid of the species' occurrence with a 1-km^2 resolution. Each cell in this grid is centred on a census location and represents the detected presence or absence at that point in that year. The resulting map served as the greatest possible extent where the species was detected, after 1993. The capture-recapture database identifies 14 separate plots when minimum convex polygons consider locations within 750 m to be in the same plot.

We computed travel distances from capture locations, using two-dimensional data to derive a univariate quantity. A dispersal kernel is the probability density function that corresponds to the x and y distances. We seek the probability density function of the amplitude, r, or the distance from the origin to a successive location (x, y) using $r = (x^2 - y^2)^{0.5}$. We therefore model dispersal using amplitude kernels which are closely related to, but distinct from, dispersal kernels (Van Houtan et al. 2007). Having determined the species distribution, the areas sampled, and the distances travelled, we then considered different mechanistic models of dispersal.

The normal, or Gaussian, distribution describes an individual whose movement appears to drift randomly away from its place of origin. This random walk is the diffusion model and populations that diffuse through space will spread across landscapes slowly. The second model we considered was the negative exponential distribution. This model describes unidirectional movement with a constant probability of stopping at each step, or directional flight. This model has a slower decay than diffusion and will subsequently observe longer flights. In both the Gaussian and exponential models, long-distance movements are somewhat constrained. Heavy-tailed probability functions, can accommodate distances both near and far. This family of models assumes a combination of local and long-distance stochastic forces and expects that a few individuals fly long distances (Viswanathan et al. 1996). Heavy-tailed dispersal models describe populations that can spread relatively rapidly through space and time.

We described diffusion with the Rayleigh probability distribution:

$$g(r) = \left(\frac{r}{\alpha^2}\right)\exp\left(-\frac{r^2}{2\alpha^2}\right), \quad r \geq 0, \quad \alpha > 0 \tag{1}$$

where α is the scale parameter, or average dispersal distance.

For the negative exponential distribution, r is a special case of the gamma distribution. This distribution has the probability density function:

$$g(r) = \frac{1}{\alpha\Gamma(\beta)}\left(\frac{r}{\alpha}\right)^{\beta-1}\exp\left(-\frac{r}{\alpha}\right), \quad r \geq 0, \quad \alpha > 0 \tag{2}$$

where α is a scale parameter, β is a shape parameter of the kernel, and Γ represents the gamma function. In this instance, $\beta = 2$, for the gamma distribution takes the exponential form.

For the heavy-tailed model we used the log hyperbolic secant ("log-sech") distribution (Halley and Inchausti 2002). The amplitude kernel such that r has a log-sech distribution is:

$$g(r) = \frac{2/(\pi b r)}{(r/\alpha)^{1/b} + (r/\alpha)^{-1/b}}, \quad r \geq 0, \quad \alpha, b > 0 \tag{3}$$

where α is the scale, b is a shape parameter, and β is the tail index. Here $\beta = 1 + 1/b$ as the log-sech has the form $f(r) \approx (2/\pi b r)(\alpha/r)^{\beta}$ for large values of r. Unlike the previous models, the tail index parameter allows the rate of decay to vary more flexibly. When $\beta = 2$ the distribution reduces to the better-known Cauchy form, though β can lie anywhere in the range $(1,\infty)$.

Population occurrence and sampling is patchy (Figure. 6.1). Accurate characterisations of dispersal should account for sampling bias (Van Houtan et al. 2007) as well as the patchy distribution across a heterogeneous landscape (Smith et al. 2002). The probability of observing a recapture, $\Pr(r_i|c)$, depends on the model, $\Pr(c|r_i)$, and the spatial sampling effort at that distance, $\Pr(w_i)$. Using ArcGIS (ESRI 2008), we calculated $\Pr(w_i)$ as the area the mark-recapture plots sample divided by the species range area. We did this for each of the 14 plots, in 100 m annuli that radiate from each plot's centre. We weighted averages of values across all plots according to the number of observed recaptures in that plot. This provided a single value for each annulus of the amplitude data, $w(r_i)$, across the landscape. We incorporated this into a likelihood model that estimates model parameters given the data:

$$L = \prod_{i=1}^{n} \left[\frac{w(r_i)g(r_i)}{\int_0^{r_{\max}} w(r)g(r)dr} \right] \quad (4)$$

We used maximum likelihood methods to compare the Rayleigh, Gamma, and log-sech models using the corrected Akaike information criterion (AIC_c). An optimisation algorithm locates the parameters yielding the minimum AIC_c for each model. Although we considered all time intervals between captures, we derived dispersal curves using only movements between years as per its classic definition (Greenwood and Harvey 1982, Fahrig 2007). We furthermore made demographic distinctions, separating annual movements in the hatching year (natal dispersal) from those in successive years (breeding dispersal). We rank all models according to their δAIC_c values and Akaike model weights (Williams et al. 2001).

Results

Figure 6.1 maps the area of the known distribution of the Cape Sable seaside-sparrow from 1994-present. Light green grid cells are the extent of occurrence of the species determined from point count surveys. Dark green polygons are the 14 intensive study plots. Most populations are on the south or east side of the Shark River Slough, with the B sub-population being the most populous, and geographically contiguous, cluster.

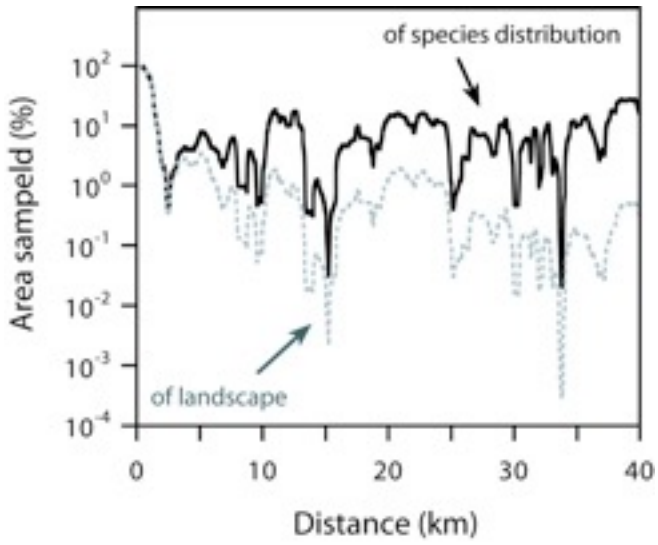


Figure 6.2. Spatial sampling effort was determined as a percentage of the current Cape Sable seaside-sparrow geographical distribution. Not all distances are equally

sampled, nor are they equally likely to contain sparrows. We thus calculated 100-m annuli from each plot centroid, determining the area sampled, area of the known distribution, and total area in each annulus. Data from all 14 census plots were added to achieve a single corrective value, Pr(w_i), of the sampled species distribution for fitting distance kernels.

Figure 6.2 shows the spatial sampling effort, displaying the area sampled by the recapture plots as a function of: (i) the species distribution, and (ii) the percentage of the entire landscape. Importantly, the sampling effort is not constant. If the sampled area is compared to the entire landscape, there is a steep and then fluctuating decay from the origin. If the sampled area is a function of the known distribution, the effort declines to 3 km, then gradually increases out to 40 km because the available habitat declines with distance. This latter calculation forms the $w(r_i)$ for the likelihood model.

Figure 6.3 compares three models of dispersal to the empirical observations of sparrow recaptures. Only the heavy-tailed log-sech distribution (red line) describes the empirical observations (black line) across the entire span of dispersal distances. The MLE fitting procedure, for the Rayleigh and Gamma models, in its attempt to accommodate the long distances in the data, grossly underestimates recaptures > 1 and < 5 km. This effect holds under a variety of circumstances – when the data are all lumped together, when only annual time steps are considered, and when juveniles and adults are considered separately.

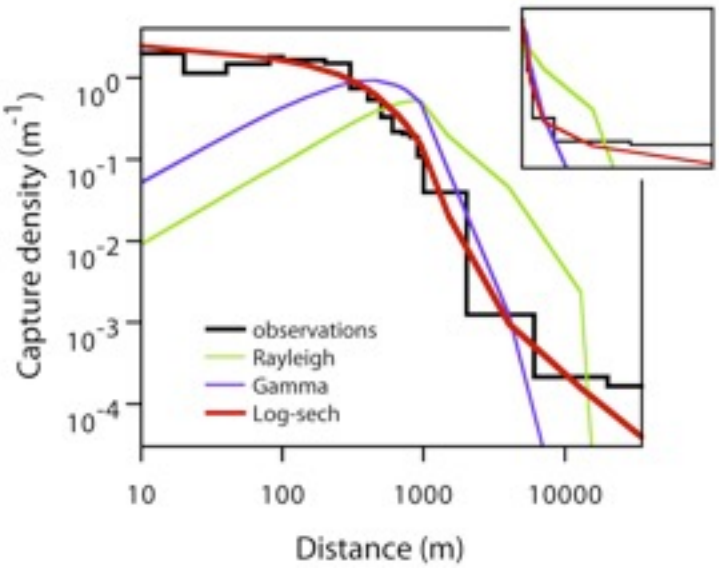


Figure 6.3. Heavy-tailed dispersal is the highest-ranked model in describing inter-annual movements of Cape Sable seaside-sparrows, and is the only model that accommodates both local and long-distance flights. This histogram is the recapture distances from all tagged individuals in comparison to the best fit for each of the three dispersal models we considered. On the log-log scale, recaptures have a

roughly constant density out to ~ 300 m and then decline roughly linearly. The *x*-axis is the distance a marked individual moved from the location of recapture to its previously known location. The height of each bar is the number of individuals observed in that interval divided by the width of bar, and thus the total area under the black line is the total number of individual recapture events (n = 769). The bin intervals for the histogram are chosen for visual clarity and affect neither model fitting nor model selection. Inset graphic plots the same figure on a log-linear scale, constraining the same axis limits.

Table 6.1 lists the parameters, δAIC_c values, and Akaike weights for all models. The log-sech is the highest-ranked model, in each case yielding a model weight of "1." In terms of the dispersal ability, there are nine instances of sparrow captures beyond 10 km, five beyond 20 km, and two beyond 30 km – the latter being almost the entire length of the species' global distribution. Eight individual birds flew to sub-populations where they were not born, and three of those individuals flew across Shark River Slough.

DATA CATEGORY	observations	AIC values			Log-Sech Parameters	
		Rayleigh	Gamma	Log-Sech	α	β
All data	769	13631	12231	**10692**	389	1.88
Juveniles (year	89	1485	1377	**1339**	1345	2.37
Adults (year step)	160	3762	2462	**2140**	211	2.29

Table 6.1. Full model results for the dispersal kernel analysis. A variety of metrics rank the log-sech model highest among the candidate models, no matter how the data are grouped. We constrained the time step between captures to one year to match the common time scales of population parameters. *K* is the number of parameters, *LL* is the log-likelihood, δAIC_c is the relative AIC_c among compared models, and ω_i is Akaike weight

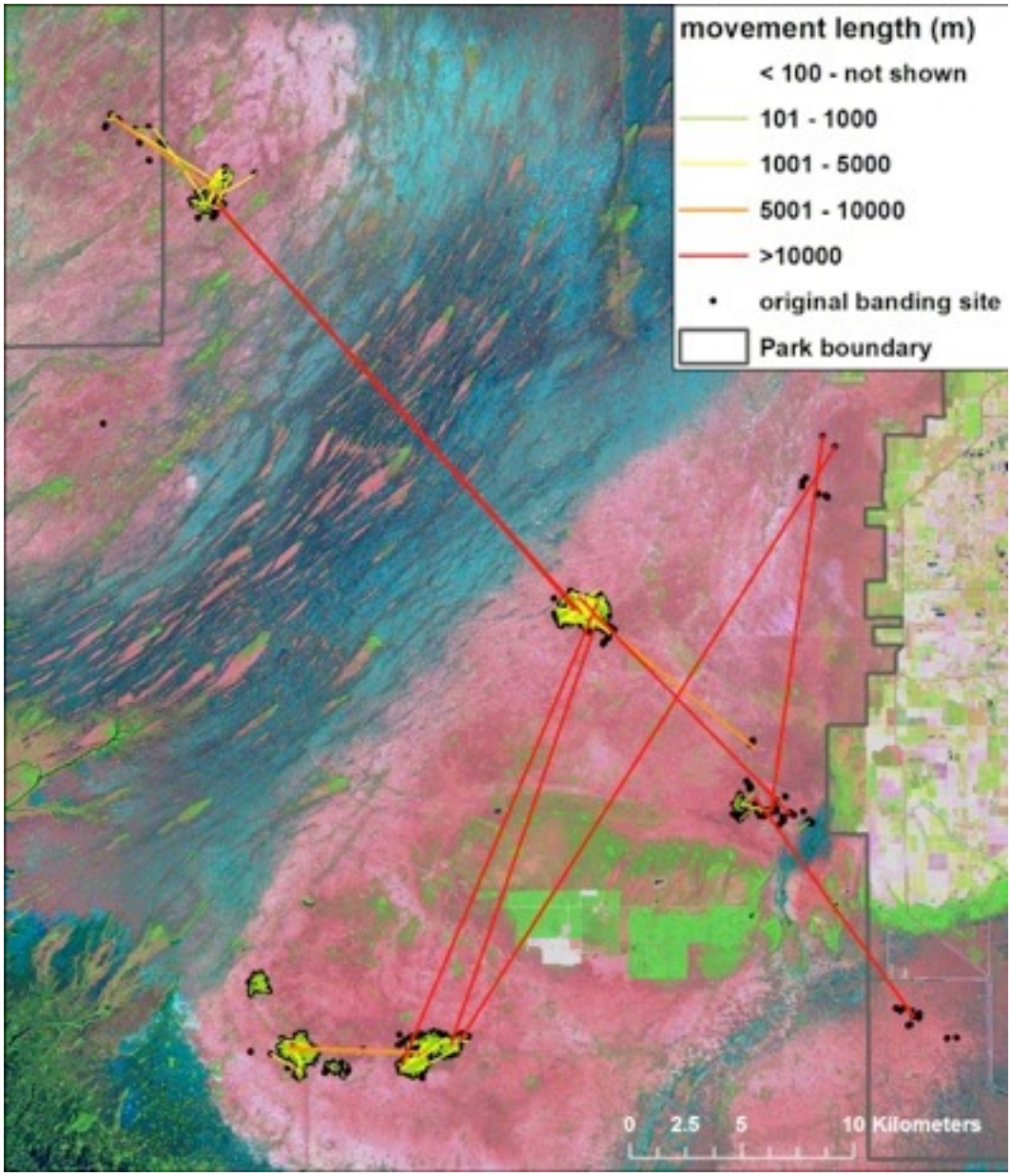


Figure 6.4. Movements of individual sparrows during the 15 years of sparrow banding efforts. Each line indicates the movement of one sparrow between its initial banding (black dot) and later re-sighting or re-trapping.

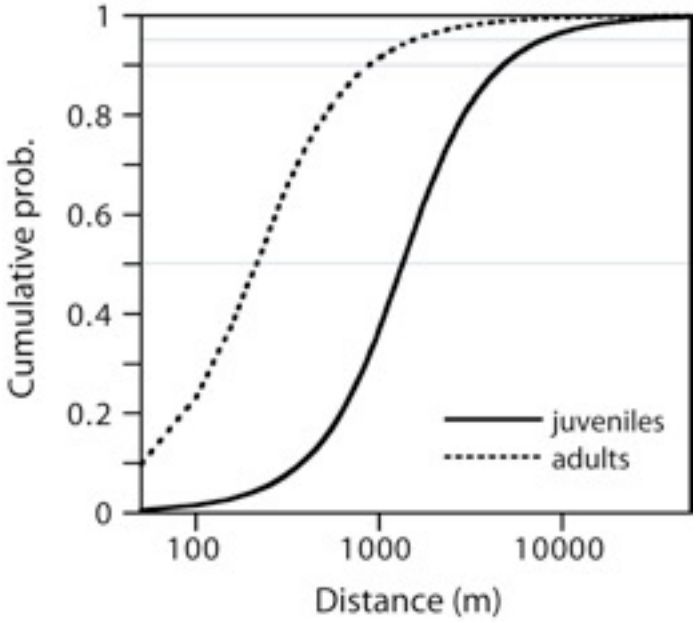


Figure 6.5. Natal dispersal of juveniles (n = 89) is to greater distances away from their original capture location (graph origin) than annual dispersals of adults (n = 160). The cumulative probability function was derived from the highest ranked dispersal model of the three we considered (log-sech, see text for details). Horizontal grey lines are the distances that capture 50, 90, and 95% of each demographic group. Our model estimated that half of juveniles would be captured beyond 1337 m, 10% beyond 4738 m, and 5% beyond 7658 m. Adults do not fly as far, with the respective distances being estimated at 211, 878, and 1508 m.

Figure 6.5 displays the cumulative dispersal probability for adults and juveniles, when the time between captures is constrained to contiguous years, i.e. annual dispersal. As expected, natal dispersal (annual movement in first year) is often to greater distances than breeding dispersal (annual movements by adults). The distances that capture 50, 90, and 95% of the recaptures are listed, showing that 50% of juveniles disperse almost 1337 m in their first year. In the same time frame, for adult birds, half of the individuals are recaptured within 211 m of their previous breeding location. These numbers indicate, especially for the juveniles, that the recovery of the Cape Sable seaside-sparrow is likely not limited by the species' ability to disperse.

Discussion

Our study shows that Cape Sable seaside-sparrows can disperse across Shark River Slough and between the several discontinuous sub-populations east of the Slough, including dispersing to distances beyond 30 km. Fitting dispersal models to these data views these observations in light of how likely we would be to capture sparrows moving these distances while taking into account the amount of effort we put into sampling the sub-populations as well as the known distribution of the

species. Our results provide new and important information for conservation management of this species and offer recommendation for population assessments for other threatened species.

Sparrow dispersal distances are heavy-tailed. There are few other empirical studies for comparison with other passerines, or for species thought to be sedentary, or for protected birds. This result, however, matches the conclusion that local dispersal generally underestimates how far individuals can travel and therefore will not accurately describe the species' ability to expand in space and time. This is a key aspect of population assessments and recovery plans for federally endangered species. Second, sparrow juveniles (who are predominantly banded in the nest) travel much further than individuals caught as adults (which are mostly banded on their breeding territories). We estimated that about half of all juveniles will travel more than 1.4 km, five percent flew more than 7.6 km, and some traveled almost the entire span of the species' known range (Figure 6.5). As we constrained the possible dispersal locations to the known distribution after 1993 (Figure 6.2), these figures are conservative.

How do these models match our field observations of the sub-populations over time? The largest sub-populations, B and E, average about 2500 and 500 individuals, respectively over the last decade (Pimm et al. 2002). About 40% of adults die each year (Boulton et al. 2009). At replacement rates, this survival rate implies that 1000 and 200 sparrows must be new territory holders in B and E, respectively. This provides some measure of the numbers of first-year individuals looking for new territories annually that settle successfully to breed. Perhaps even more individuals (adults dispersing after failed breeding attempts), will search for new territories too. Our results show that individuals can disperse between sub-populations and our models predict this will involve substantial numbers of juveniles and some adults each year.

This would have likely once been the case for sub-population A and the small and isolated Stair Step populations to its west (Figure 6.1). However, when sub-population A was reduced from >2500 birds prior to 1993 to <400 birds since 1999, the number of colonists it could have provided to the Stair Step population would likely have been reduced accordingly. The extinction of that population may well be a simple consequence of that reduced flow of colonists. If so, the population would not be viable without colonists and so not a candidate for birds to be translocated there.

Our results highlight the importance of estimating dispersal curves for threatened species. Contrast our results with a simple characterisation of the empirical dispersal data without considering the sampling effort, the species distribution, and using normal statistics. If we had lumped all the dispersal data together, the mean (μ = 583 m) and standard deviation (s = 2313 m) of observed dispersal distances would have provided confidence interval estimates suggesting 99.9% of individuals do not fly beyond 860 m. This distance is within most of the intensive study plots

and certainly within all of the sub-populations, which is predicted when a variety of functions is considered (Koening et al. 1996). Simple characterisations of the data underestimate the species' dispersal ability and might encourage management actions such as translocation efforts to reestablish previously occupied areas. Our estimation of dispersal that considers the patchy effort of sampling, the heterogeneous distribution of the species across the landscape, as well as demographic differences in dispersal indicates the Cape Sable seaside-sparrow disperses to long distances (Figure. 6.3) even across unsuitable habitat (Figure. 6.1).

There is nothing particularly unusual about this species' life history (e.g., non-migratory, socially monogamous, open-cup nest). Thus, our results documenting long distance dispersal adds important evidence that suggests, when properly modelled, long distance dispersal may be consistently found even in species considered to be poor dispersers. This insight is exactly what we found in a previous study of understory forest birds in the Brazilian Amazon (Van Houtan et al. 2007). To conservation biologists, our results suggest that even a species that has experienced a marked decline in abundance and occupancy across its entire range will continue to disperse over long distances.

The management implications cannot be overstated. Translocation of populations might be touted as a solution to recover sparrows, as it has for many other threatened species from areas where they were extirpated (Armstrong and Seddon 2008). Even though translocation can be a successful management strategy (Van Houtan et al. 2009) it might not always be warranted. Our analysis suggests translocations are not warranted as sparrows move between their main sub-populations in a non-trivial manner. Instead, the evidence indicates that efforts to boost population growth rates in existing populations should be emphasised. This refocuses attention on water management regimes and protecting critical sparrow habitat, both in the existing sub-populations and in unoccupied habitat.

Chapter 7

The wet season ecology of the Cape Sable seaside-sparrow.

Karla L. Balent, Katherine H. Fenn, and Julie L. Lockwood

Abstract

During the wet, or non-breeding, season the Cape Sable seaside-sparrow exhibit neither long-distance nor local migration within Everglades National Park. Individuals move an average of 277 m from the previous season's breeding territory. They show a microhabitat shift from open marl prairie to stands of sawgrass *(Cladium jamaicensus),* small tree islands and the edges of large hammocks. As the wet season progresses, observations of birds decrease until early February when males begin to establish breeding territories for the coming spring. Because there is no migration out of its breeding habitat, the Cape Sable seaside-sparrow depends exclusively on the marl prairies it inhabits year-round.

Introduction

One of the more enigmatic portions of the sparrow's life history has been its winter, or wet season, habits. Although Lockwood et al. (1997) reported some post-breeding activities of the sparrow, important information on wet season dispersal and habitat requirements are lacking. Data such as this brings full circle the requirements needed to build population models that will be applicable to management schemes. To provide this data, we conducted systematic surveys from June 1996 to March 1997 to determine the wet season distribution and habits of the sparrow.

Information on the wintering habits of most races of Seaside-Sparrows is sporadic (Quay et al. 1983, Greenlaw 1992, Post and Greenlaw 1994). Northern races are sometimes migratory (Quay et al. 1983, Post and Greenlaw 1994) and southern races are not believed to migrate at all (Post and Greenlaw 1994). The climate of the southern Florida peninsula is sub-tropical alternating between a wet and dry season with little variability in temperature. This climate is not only different from northern regions of the seaside-sparrow range, but also from regions in northern Florida. These climatic effects may or may not produce novel wet season (or over–wintering) adaptations. Cape Sable Seaside-Sparrows may remain within freshwater marshes

and become so secretive that observations are rare. They may move within their breeding range but outside the boundaries of our study areas. Since early sightings occurred during winter months within salt marshes (Howell 1919, 1932; Stimson 1956), the sparrow may still winter in these areas. For this reason, we did not limit the scope of our surveys and included all areas accessible on foot and by car or boat within Everglades National Park.

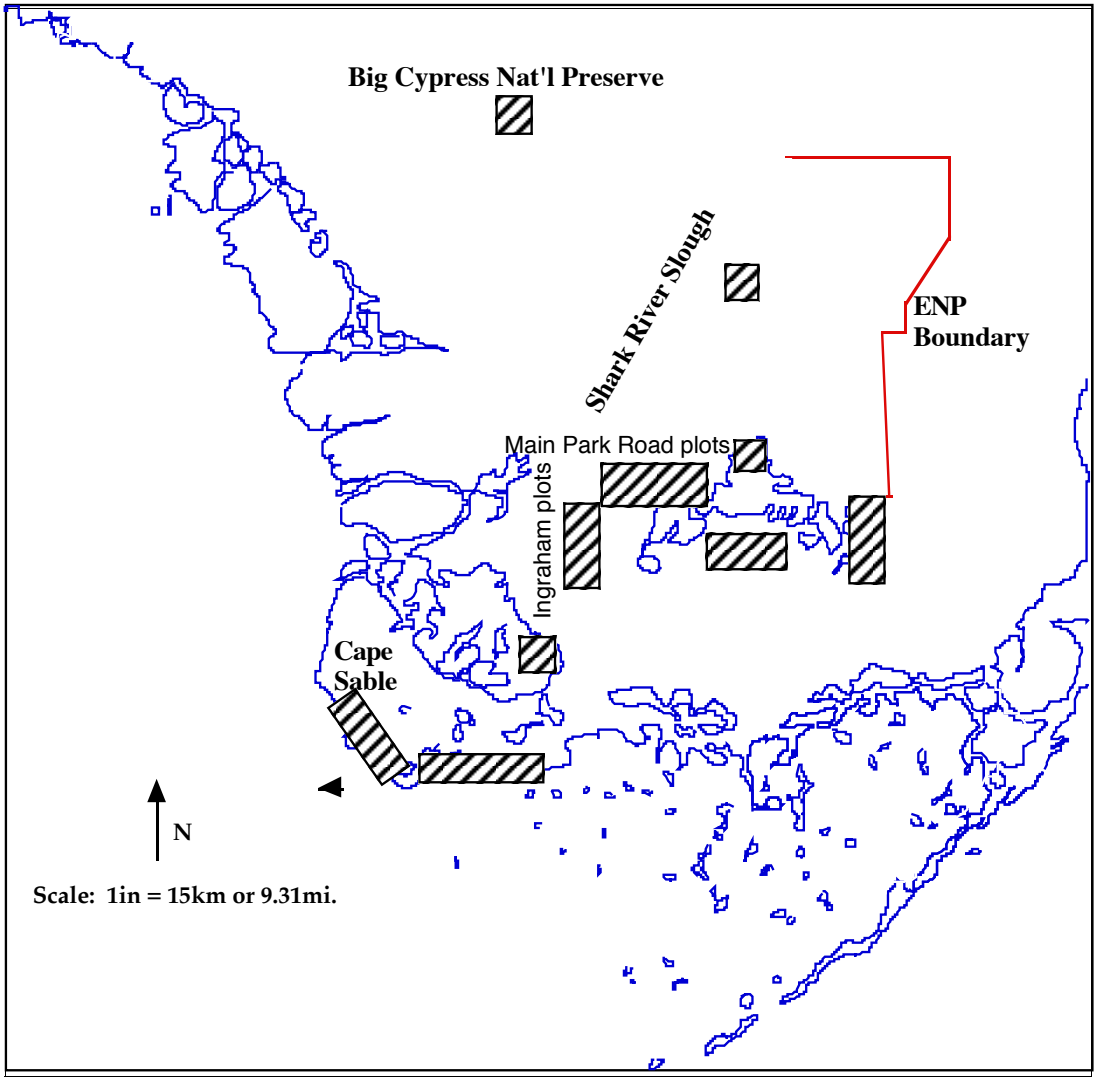


Figure 7.1. Areas surveyed for Cape Sable seaside-sparrows during the wet season of 1996 to 1997.

Methods

The Cape Sable seaside-sparrow exclusively breeds in marl prairies (Werner 1975, Bass and Kushlan 1982, Pimm et al. 1996, Lockwood et al. 1997). Marl prairies are dominated by *Mulenbergia filipes* interspersed with sawgrass *(Cladium jamaicensus)* stands and small tree islands. These prairies are flooded during the wet season, usually June through February. Several study plots established in the eastern sub–population have been under observation during the breeding season for the past four years. Within these plots 227 Cape Sable Seaside-Sparrows have been colour banded since 1994 (Pimm et al. 1997). Initially, we concentrated our efforts on these plots. Observations began immediately after the breeding season ended (mid–June 1996). We visited four of these established plots, each approximately 1000 m, from June 1996 to March 1997. Two plots (Alligator Hammock and Dogleg) were visited an average of three times a week. The remaining two plots (Old Ingraham North and South) were each visited once a month (Fig. 7.1).

As the wet season progressed we expanded the area of observation to include most of the southeastern portion of ENP, including Cape Sable. In order to determine if the sparrows migrate out of the marl prairies during the wet season, point count surveys were conducted in seven different habitat types found within ENP: marl prairie, coastal prairie, mixed prairie, dry prairie, pineland, dwarf cypress and mangrove (see Gunderson 1994 for detailed descriptions of habitat types). Other subspecies of Seaside-Sparrows have been found wintering in prairies in ENP, but no Cape Sable Seaside-Sparrows have been recorded in areas outside of their breeding habitats (O.L. Bass pers. comm.).

These seven habitat types are representative of ENP as a whole although most censuses were conducted in readily accessible areas (Figure. 7.1). Since there are no observations of Cape Sable Seaside-Sparrows during the wet season beyond that given by Stimson (1954) and Howell (1919), we chose not to narrow the search in any manner. However, we did budget our observations according to the habitat type in which we most often found sparrows (i.e., we spent the majority of observation time within the marl prairie habitat).

Following Gutzwiller (1991), we used an unlimited distance point count to survey each habitat type and identify all birds present. Count points were placed 200 m apart. Each count duration was determined by using the gain rate of species (Hutto et al. 1986) for each habitat, and compensating for the difficulty in detecting Cape Sable Seaside-Sparrows. For example, the gain rate for coastal prairie habitat was 5.5 min. Thus, after 5.5 min, 80% of all species eventually detected after 20 min had been counted. The average time to detect a sparrow was determined by recording the duration needed to identify one sparrow on two consecutive mornings during the non–breeding season (8 min.). This time was added to the gain rate resulting in a count duration of 12.5 min for coastal prairie habitats. We conducted all surveys between 0700 hours and 1000 hours, the time during which the sparrows are the most active (Werner 1975). To account for differences in survey effort throughout

the wet season, all results are expressed as the number of birds observed per observer per day. This number is calculated by summing the number of birds observed in each category per month then dividing that total by the number of observers reporting.

Water measurements were taken at fixed points within two marl prairie study plots throughout the season, and during point count surveys in all other habitats.

Using coloured flagging tape, we followed changes in sparrow distribution by marking all locations in which birds were found. Each re-sight of a banded bird was flagged with colours coordinated with its leg band combination. Otherwise, each location in which we sighted a bird was marked with white flagging. We used a Magellan Global Positioning System linked to a Magellan Differential Beacon Receiver (DBR), to record the locations of banded birds in UTM coordinates. The use of the DBR allowed a location to be specified to within 20 m. We used UTM coordinates taken during the 1996 and 1997 breeding season to calculate the distance re-sighted, banded individuals moved from the 1996 breeding season to the non-breeding location and/or to the 1997 breeding season. We used the CA-Cricket Graph III software program to map UTM coordinates on an X,Y graph**.** By scaling the graph in to equal increments on the X,Y axis (i.e., 100 m) we then calculated the distance each banded bird moved from its 1996 breeding territory to each non-breeding re-sight location, and where possible, to its 1997 breeding territory. This was only possible for banded birds, although positions of un-banded birds were recorded as well.

We also recorded the following data for each individual bird re-sighted: any behaviour observed (e.g., vocalisations, intra-specific interactions); the number of birds in the "flock"; status of tail and wing moult; and the microhabitat type in which the bird was found. Microhabitats were classified into categories (Table 1) based on vertical structure and species composition.

Fifteen behavioural classifications were established during the 1996 breeding season and we continue their use here (Pimm et al. 1996). For a detailed list of behaviours and vocalisations see Werner (1975). The number of birds observed exhibiting a particular class of behaviour was recorded per day. The frequency in which each behavioural class occurred was plotted from March 1996 to February 1997. These graphs allowed us to determine if particular behaviours were associated exclusively with the wet (non-breeding) season and to make better estimates of the beginning and end of the breeding season.

Results

Behaviour and Habitat Use

Figure . 7.2 shows the frequency in which we observed the various behavioural classes during one full year beginning just before the 1996 breeding season. Using such graphs, we classified each behaviour as breeding, non–breeding or

undetermined. These graphs indicated that several behaviours could be attributed to only the breeding season. Some of these behaviours were as expected, such as delivering and gathering food. Others, not necessarily expected, included singing while perched in open prairie and chasing another individual over open prairie. Only two behaviours can be attributed solely to the wet season. These are 'seep' calls and quiet chipping while perching in dense vegetation.

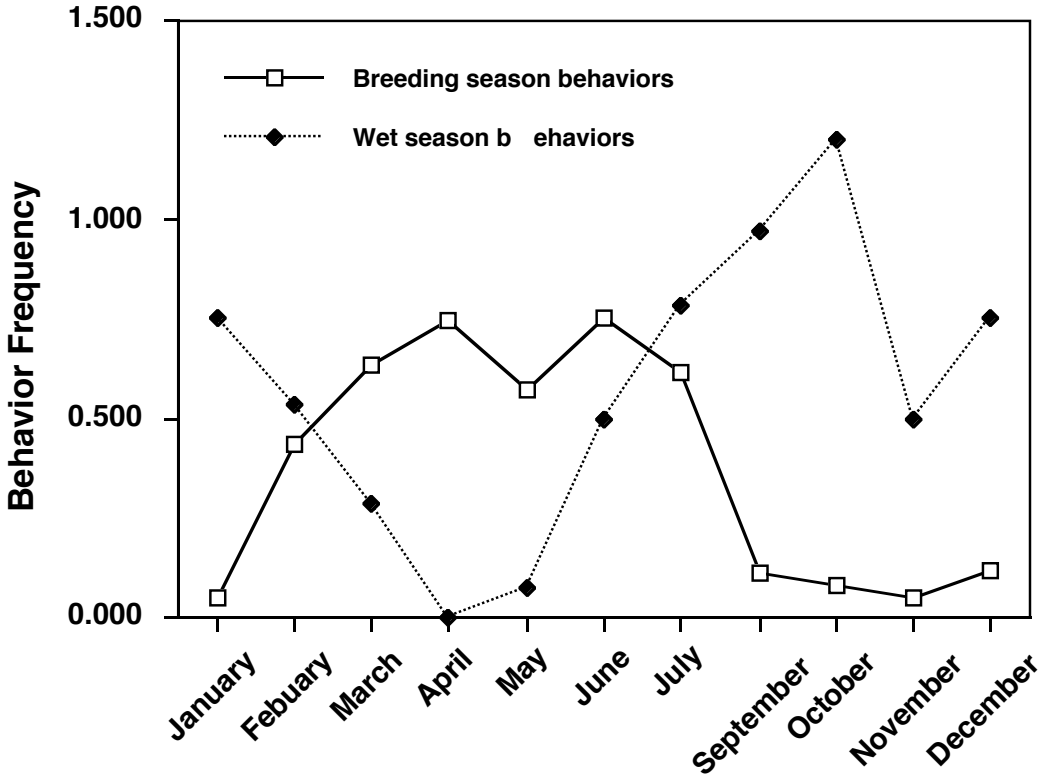


Figure 7.2. Observation frequency of various non-breeding and breeding behaviours (see text).

In addition, using only behavioural classes that can be clearly defined, we can illustrate when the breeding season ended and later began (Fig. 7.3). It is clear from Fig. 7.3 that the 1996 breeding season ended in early June and the 1997 breeding season began in mid–February. This supports observations of early and late nests found during the 1995, 1996 and 1997 breeding seasons (Lockwood et al. 1997, J.L. Lockwood and K.H. Fenn pers. obs.). Based on these graphs, we considered observations as 'wet season' if they occurred between 1 July 1996 and 15 February 1997. All results below reflect this decision.

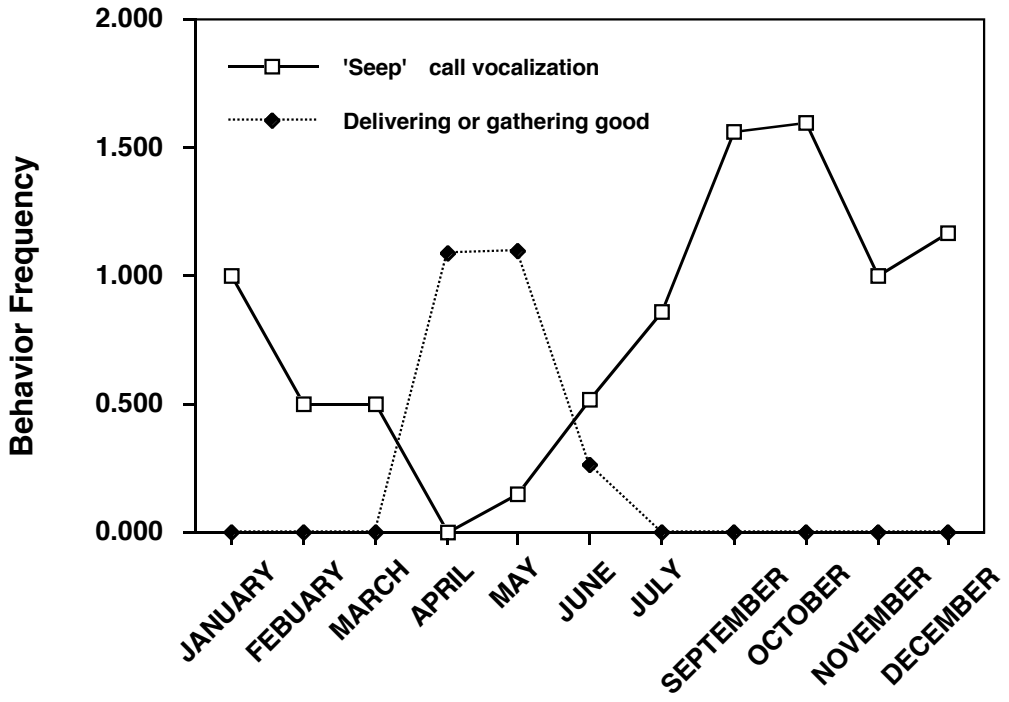


Figure 7.3. Examples of breeding and non-breeding behaviours

Similar to the behaviour witnessed by Werner (1975), immediately following the end of the breeding season we saw family groups of up to eight birds. Very often these 'flocks' consisted of one or two banded males and several un-banded individuals. We believe these are family groups as the un-banded individuals often gave a sub-song typical of juveniles (see Werner 1975 for description) and lacked the full length tail feathers of adults. Males did not sing during the wet season. These family groups broke down by September after which most observations were of two or fewer individuals.

The majority (80%) of detections throughout the wet season are of birds in sawgrass sways and sawgrass sways with small trees. Occasionally, we found sparrows perched in small trees within hammocks (all within the plot in which they nested), saw palmettos, or road–side vegetation. This behaviour is in contrast the breeding season activity when Cape Sable Seaside-Sparrows spend all of their time in the open prairie (Pimm et al. 1995, 1996). Through July, August and September some birds showed signs of moult. Moulting individuals remained within sawgrass sways presumably for cover.

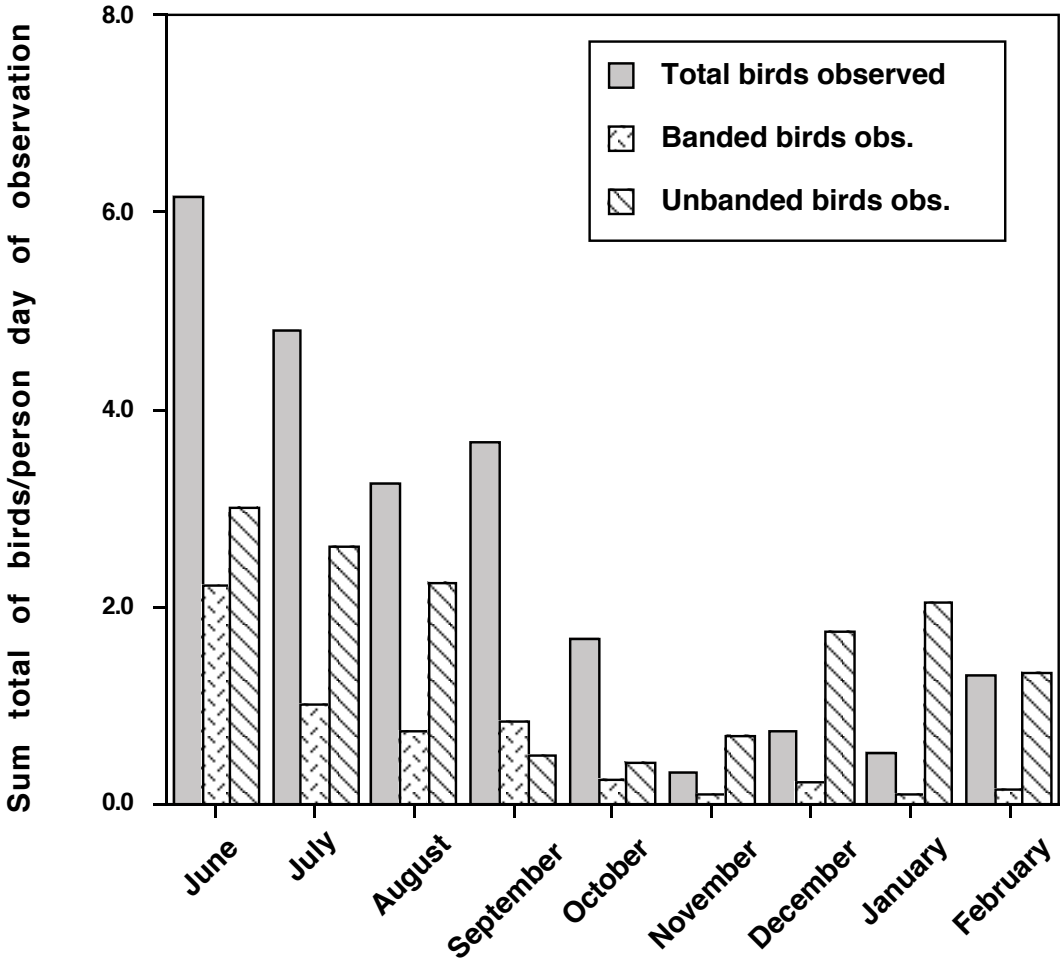


Figure 7.4 Sum total of birds seen throughout the wet season per person days.

Wet Season Distribution

Figure 7. 4 shows the sum total of birds (total, banded, and un-banded) seen throughout the wet season per observer per day. The total number of Cape Sable Seaside-Sparrows detected showed a steady decline beginning at the end of the breeding season in June. Detections reached a low of less than one bird seen per observer per day in November. Thereafter, the number of detections began to increase, until an average of two birds were seen per observer per day by mid–February. At this point, male sparrows were regularly observed singing from high perches within open marl prairie.

However, when banded bird detections are separated from un-banded bird detections, a different pattern emerges. Detections of banded birds decline steadily with no subsequent increase as the wet season progresses. Detections of un-banded birds, however, increase as the wet season ends (Fig. 7.4) and the breeding season begins. Thus, the increase in total number of birds detected late in the wet season

can be attributed entirely to the increase in detection of un-banded individuals.

A total of 51 hours of point count surveys conducted throughout ENP during the non- breeding season found no Cape Sable Seaside-Sparrows in habitats other than marl prairie. These surveys included the fringe prairies of Cape Sable and mixed prairies or dwarf cypress stands lying adjacent to the marl prairies where the sparrow breeds. Simply, we did not detect sparrows outside of their breeding range despite the fact that sparrow detections within their breeding range declined steadily throughout the wet–season.

Indeed, we observed little movement of Cape Sable Seaside-Sparrows. Marking the locations of banded birds allowed us to follow individual movements throughout the wet season. Twenty-one banded birds were re-sighted. Of these, 14 had all bands intact and could be positively re-identified. The remaining seven were either missing a colour band (two birds), or were not in visual contact long enough to be positively identified (five birds).

The 14 banded birds positively re-identified were found an average of 277 m (N=14, range=77 m to 986 m) from the spot where they were banded in the spring of 1995 or 1996. The majority of the all banded birds re-sighted (15 out of 21 birds) were only seen once. When locations of banded birds were revisited (sites were revisited at least once per month), the same individuals were not found again. The six individuals re-sighted more than once were usually found within a 10 to 20 m area of the initial re-sight spot.

For example, the bird banded WH/AL– YL/WH was re-sighted on three occasions. This bird was first re-sighted 250 m away from its breeding territory of spring 1996. This bird remained within 20 m of its initial re-sight location during the month of September. In early October, this bird moved North to an area 326 m away from its first re-sight spot (re-sighted 1 October) but only 115 m from its 1996 breeding territory. It was not seen again during the wet season, and was not re-sighted during the 1997 breeding season (Lockwood pers. obs.).

Only two birds were re-sighted in a study plot other than the one in which they were originally banded. One bird from Alligator Hammock plot was found in Dogleg plot, and vice versa. These plots are separated by Main Park Road, a distance of no more than 20 m. No birds from the Ingraham plots were found out of their original plot (i.e., where they were banded) despite the two Ingraham plots being separated by only 20 to 30 m. These observations are consistent with the high degree of philopatry observed between breeding seasons (Pimm et al. 1996, Lockwood et al. 1997). However, recent wet season telemetry studies have found 2 birds that traveled 6 km from the Ingraham study plots; they made no habitat change, but were subsequently found in marl prairie (T. Dean, pers. comm.). No birds have yet been found breeding in one plot one year, and a different one the next (Pimm et al. 1997).

Nine positively identified birds from the wet season survey were re-sighted during the 1997 breeding season (Pimm et al. 1997). They moved an average of 223 m from their wet season point (N=5, range=76 m to 460 m; UTM coordinates not available for all nine birds).

Five birds seen during the wet season were not re-sighted during the 1997 breeding season, despite the intensity of the observations and banding efforts during that time (Pimm et al. 1997). Conversely, 18 banded birds present in the breeding seasons of 1996 and 1997 were not seen during the wet season survey.

Conclusions

Our results indicate that neither long-distance nor local migration occurs in the Cape Sable Seaside-Sparrow. At least a portion of the Cape Sable seaside-sparrow population spends the winter in the same prairies in which they breed. This indicates that this sparrow may be completely dependent on the existence of marl prairies for their long-term survival.

They do, however, show a change in microhabitat use within those prairies. By the end of the 1996 breeding season, the birds began to move out of the open prairies and into small tree hammocks and sawgrass sways (see also Lockwood et al. 1997). These sawgrass sways likely provide cover and refuge during molt, and perhaps an increased food supply during the wet season.

For other wintering subspecies of Seaside-Sparrows, smooth cordgrass *(Spartina alterniflora)* provides an assortment of food, and these birds concentrate in these stands during the non-breeding season (Post and Greenlaw 1994). While feeding observations of the Cape Sable seaside-sparrow were rare during this study, a sparrow was observed eating seeds from a sawgrass seed head. Qualitative foraging observations of birds gathering insects for young show a preference for sawgrass stands (J. Lockwood and K.H. Fenn, pers. obs.), but whether these stands typically host more insects than open marl prairie is not known.

We do report a decrease in observations of sparrows throughout the wet season (October, November, December) and a subsequent increase in their numbers and activity by mid-February. This pattern is suggestive of a migration or movement out of the marl prairies. However, we may also attribute this to the birds' change in behaviour during moult and its choice of non- breeding microhabitat. This movement to higher (stem-wise), and more dense vegetation coupled with the birds' already secretive nature, confounds the ability of an observer to readily find these birds. The increase in detection by mid-February is clearly a result of male birds competing for territories for the oncoming breeding season. While banded bird observations decreased through the wet season and remained low as un-banded bird observations increased, those banded birds that were seen had not moved more than 1 km from their breeding territory.

In addition to protection during moult and food availability, sawgrass stands may

provide an escape, in the form of higher perches, from rising surface waters. Marl prairies usually stay inundated with water from June to March, and seeking higher "ground", the sparrows may move into sawgrass sways and tree islands to avoid the rising water. The 1996-1997 wet season, however, proved to be a particularly dry one. By mid-November, standing water had virtually disappeared from the marl prairies and did not return until late March (and then only during flash floods). Had the prairies remained flooded, the sparrows may have abandoned the marl prairies and moved into a drier habitat, such as coastal prairie. This possibility seems unlikely because we never observed an individual in any habitat other than marl prairie. Continuing to monitor the habitat use and distribution of the Cape Sable seaside-sparrow through several years, some inevitably wetter, could confirm or deny this possibility.

Chapter 8

The range-wide sparrow survey

Stuart L. Pimm and Oron L. Bass

Abstract

This chapter presents the results of the range wide survey in 1981 and from 1992 to the present. I present the survey results themselves, maps of where we heard each bird, and provide a discussion of the numbers. One of the two review committees to examine the sparrow research generated an extensive discussion of sparrow numbers and survey methods. This chapter includes that as an appendix.

The extensive survey

Methods

Bass and Kushlan (1982) surveyed the sparrow in 1981. Bass repeated the survey in 1992 and, with the increasing involvement of others, each year since then. Between 06.30 and 09.30 each morning, observers were dropped at sites across a 1 km grid. The number of sparrows seen or heard within a 10 min interval was recorded by each observer, before travelling via helicopter to the next site. Observers also collected data on dominant vegetation, surface water depth and the presence of trees or shrubs.

We took particular care to visit all the areas of marl prairies that might hold sparrows. Over the years, we explored many kinds of open habitat in the region, including sites both wetter and drier than where we ever found birds. This ensured that we did not overlook sites that might hold birds, even if we considered the habitat to be marginally or totally unsuitable. We did not observe birds at 80% of the sites we surveyed. Kushlan *et al.* (1982) established a non-random pattern of sampling sites from east to west through the breeding season (mid-March to May). This non-random drop pattern led to a confounding effect of time in the breeding season with location of sample site. We changed to a stratified random sampling method in 1995. We alternated between eastern and western populations among days.

Over the first years of the survey (1981 and 1992-1996) we used eight observers. Whenever possible, we dropped two observers at one site and compared their observations. From the small number of sites for which this was possible we could

not detect any differences between observers. Logistical problems prevented this for all observers and we resorted to an alternative calibration. We compared survey results at adjacent survey sites at the same time on the same day taken by different observers. There were no significant differences between observations made by different observers (one-way ANOVA: F= 0.74; d.f. = 470; P = 0.61). In later years, we used other observers, but principally Sonny Bass, Stuart Pimm, Lori Oberhoffer, and Mario Alvarado.

To estimate the actual numbers of sparrows present from the number we counted on our survey, it was necessary to use a correction factor. There were several, broadly comparable ways of doing this. First, Bass and Kushlan (1982) used a value of 15.87 (rounding it to 16) basing it on the range at which they could detect the sparrow's song and on the assumption that each singing male would be accompanied by one female. Second, we compared the number of birds recorded during the helicopter survey with the numbers known on the ground. As part of other sparrow studies, we had five study plots ranging in size between 0.25 and 0.6 km^2. We mapped all territories on these plots: they were large enough that it was possible to average the four nearest helicopter survey points for our calibration. We had up to four years of data for each plot, for a total of 15 separate calibrations

The ratio of average plot density divided by the average number of birds counted in the four adjacent helicopter survey points yielded a correction of 25. This number may seem at odds with the value of 16 proposed by Kushlan and Bass (1983). However, we could and did get zero values during the helicopter survey, but, by design, we picked our study sites to hold birds. The ratio was strongly right-skewed by occasional small totals of birds counted at the four adjacent survey points. (Theoretically, the ratio could be infinite if no birds were counted.) Moreover, we established several study plots because of their known concentrations of birds. This selection of high-density sites drives the correction factor higher than if our sites were more randomly distributed with respect to sparrow numbers One way to stabilise the right-skewed values of densities to birds counted was to take their reciprocals and then average these numbers over the 15 calibrations. Re-inverting this average yields an estimate of the correction factor of 18 - very close to Bass and Kushlan's estimate. Given the uncertainties, the factor 16 seems to be adequate.

Results

The results of the surveys are summarised in tables 8.1, 8.2, 8.3, 8.4 and figure 8.1.

Year	A	B	C	D	E	F
1981	168	147	27	25	42	7
1992	163	199	3	7	37	2
1993	27	154	0	6	20	0
1994	IN(5)	139	NS	NS	7	NS
1995	15	133	0	0	22	0
1996	24	118	3	5	13	1
1997	17	177	3	3	52	1
1998	12	113	5	3	57	1
1999	25	128	9	11	48	1
	12	171	4	NS	60	0
2000	28	114	7	4	65	0
	25	153	4	1	44	7
2001	8	133	6	2	53	2
2002	6	119	7	0	36	1
2003	8	148	6	0	37	2
2004	1	174	8	0	40	1
2005	5	142	5	3	36	2
2006	7	130	10	0	44	2
2007	4	157	3	0	35	0
2008	7	NS	3	1	23	0
2009	6	NS	3	2	27	0
2010	8	119	2	4	57	1
2011	11	NS	11	1	37	2
2012	21	NS	6	14	46	4

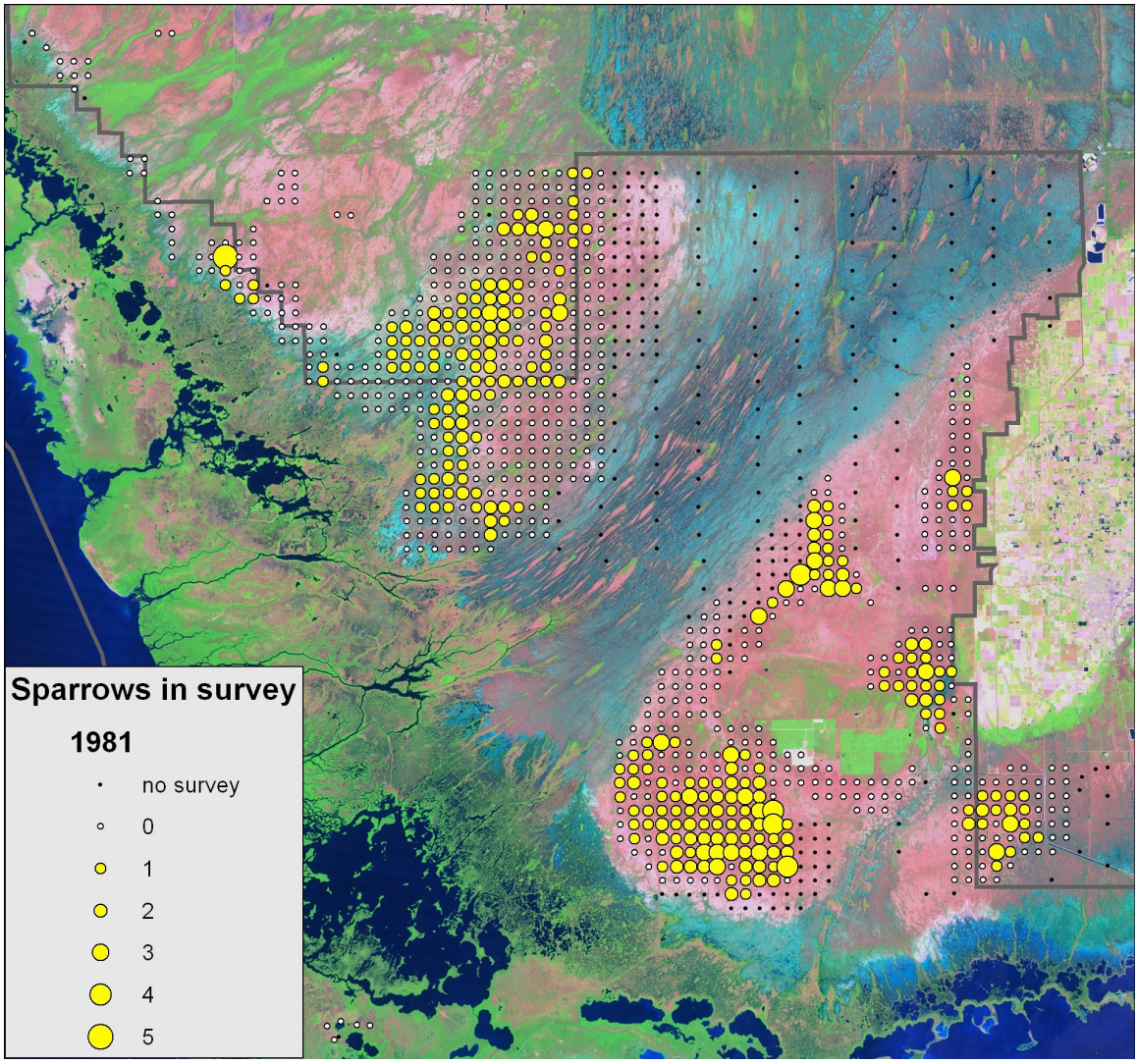
Table 8.1 The numbers of sparrows seen in each subpopulation in each year. NS means the population was not surveyed, IN that the survey was incomplete. The exact sites surveyed are shown in Figure 7.2 and they differ somewhat from year to year. We completed two surveys in 1999 and 2000. In 2003, 2004, 2005, and 2006 we also counted birds in selected areas on a 0.5km grid.

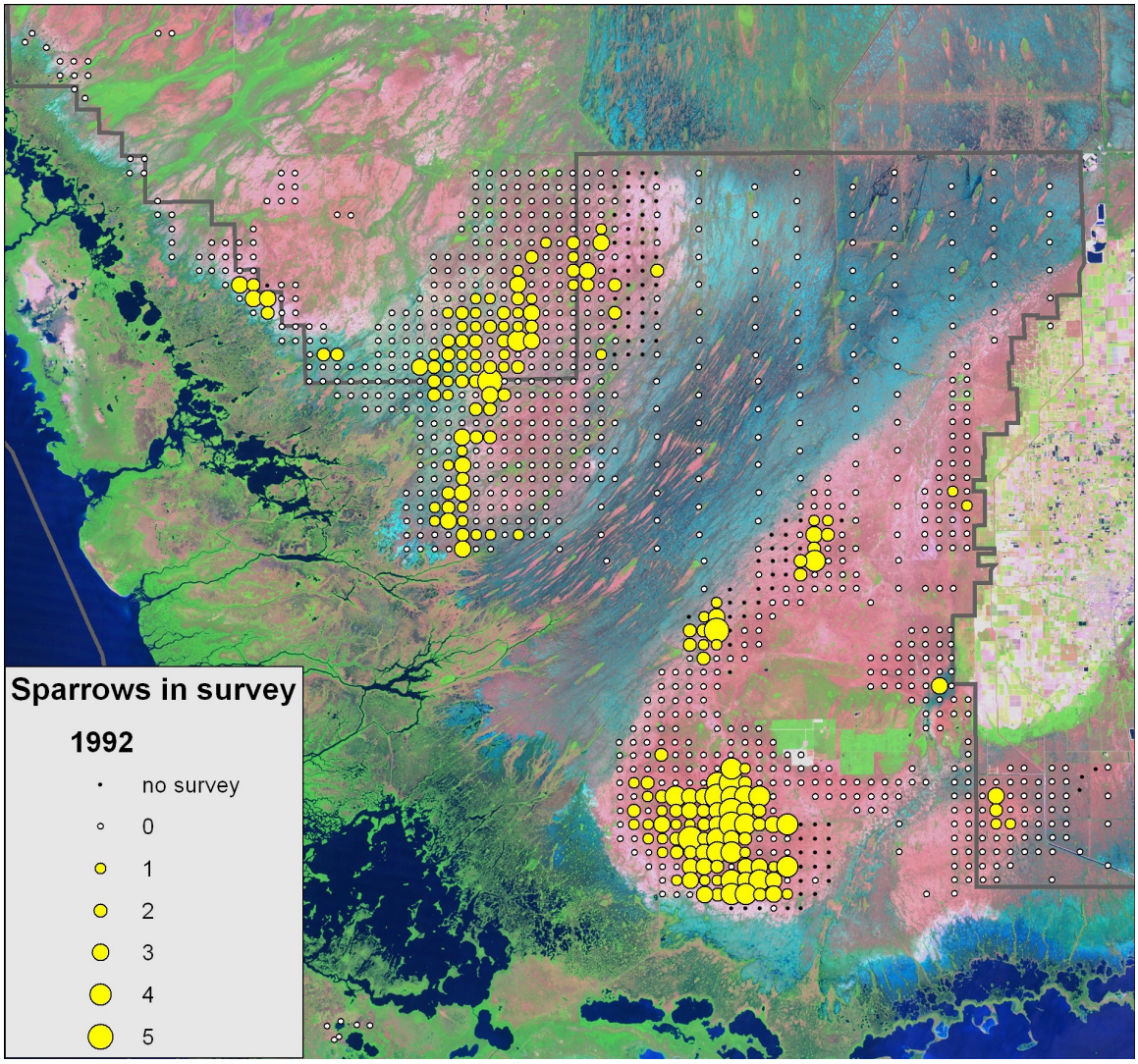
Year	A	B	C	D	E	F
1981	2688	2352	432	400	672	112
1992	2608	3184	48	112	592	32
1993	432	2464	0	96	320	0
1994		2224				
1995	240	2128	0	0	352	0
1996	384	1888	48	80	208	16
1997	272	2832	48	48	832	16
1998	192	1808	80	48	912	16
1999	400	2048	144	176	768	16
	192	2736	64		960	0
2000	448	1824	112	64	1040	0
	400	2448	64	16	704	112
2001	128	2128	96	32	848	32
2002	96	1904	112	0	576	16
2003	128	2368	96	0	592	32
2004	16	2784	128	0	640	16
2005	80	2272	80	48	576	32
2006	112	2080	160	0	704	32
2007	64	2512	48	0	560	0
2008	112		48	16	368	0
2009	96		48	32	432	0
2010	128	1904	32	64	912	16
2011	176		176	16	592	32
2012	336		96	224	736	64

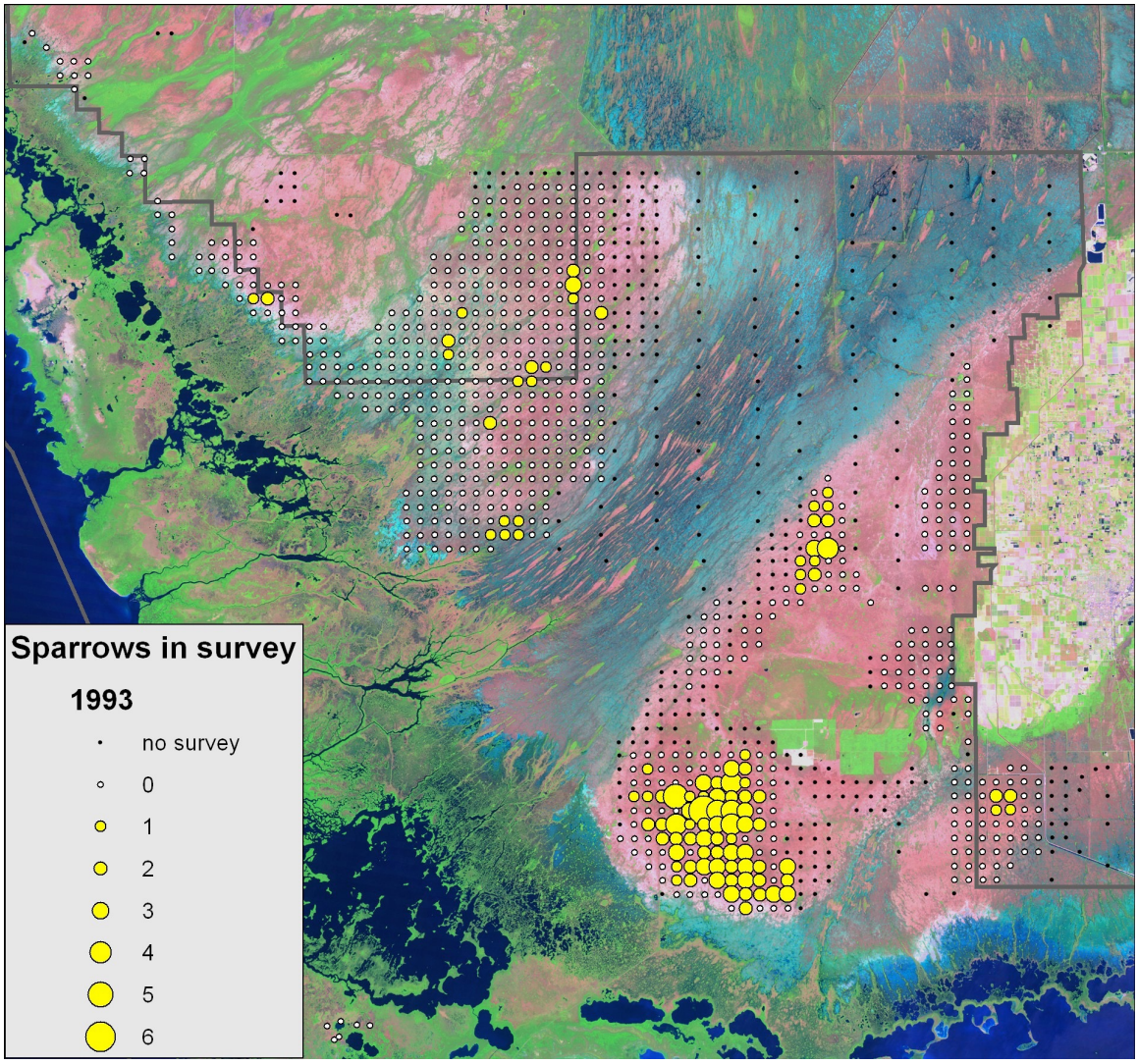
Table 8.2 Estimated numbers of sparrows seen in each subpopulation in each year. The exact sites surveyed are shown in Figure 7.2 and they differ somewhat from year to year. We completed two surveys in 1999 and 2000. These numbers are those in table 8.1 multiplied by 16.

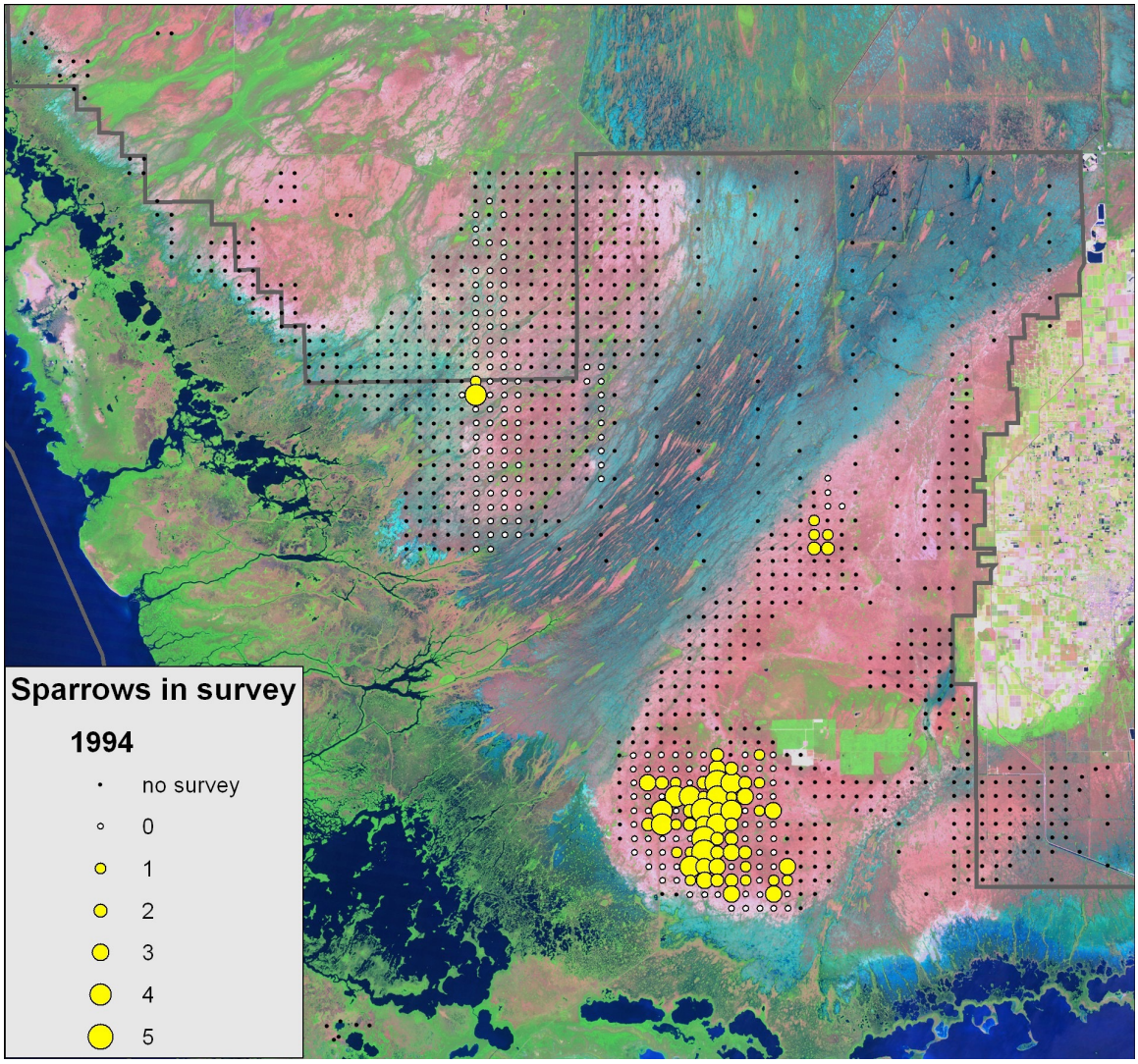
Year	A (total)	A (partial)
1981	168	52
1992	163	44
1993	27	8
1994		5

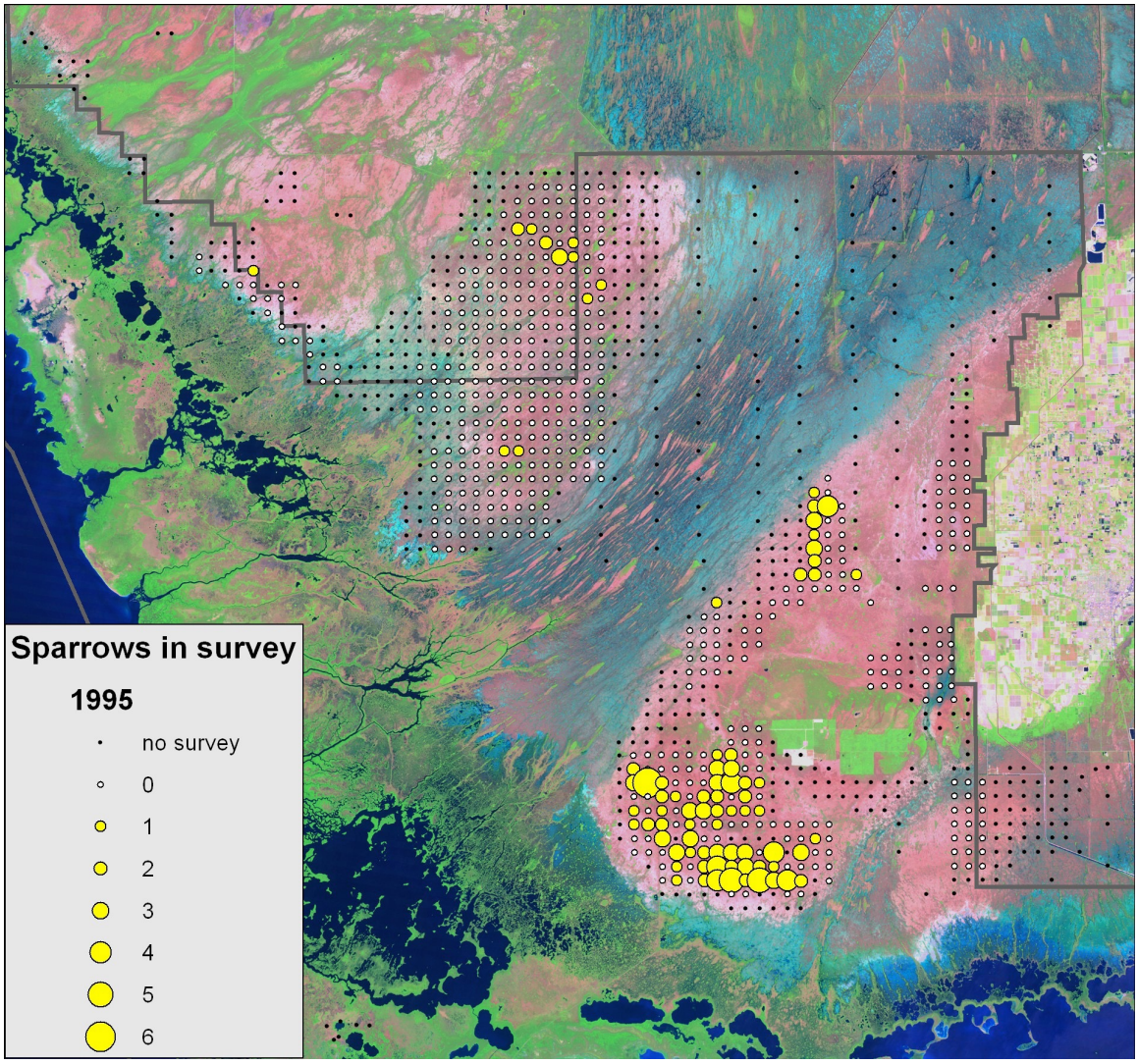
Table 8.3 Only a sample of the possible sites in A were counted in 1994; the totals for A (partial) are for those sites counted in all four years.

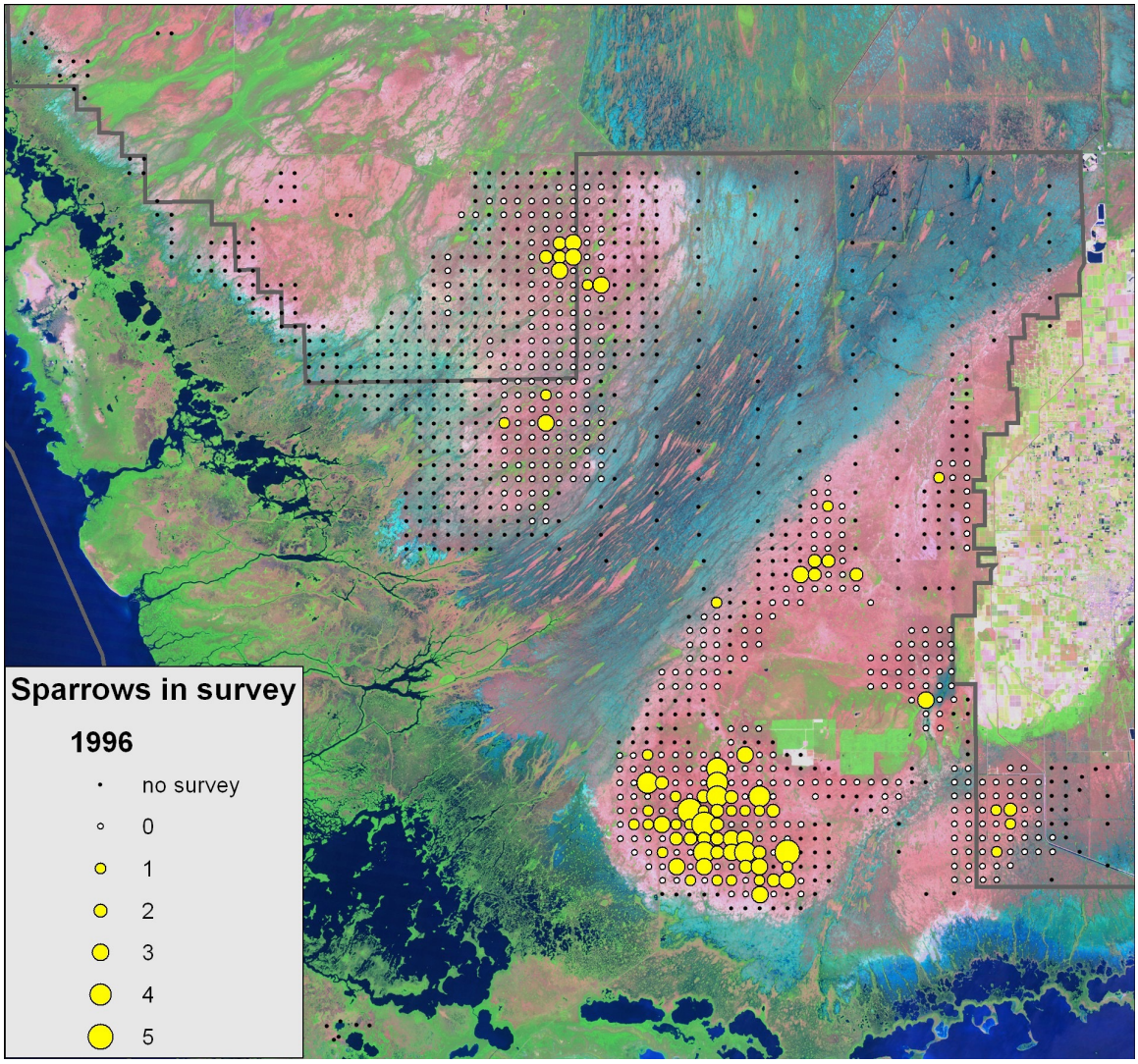

Sparrows in survey
1981
no survey
0
1
2
3
4
5

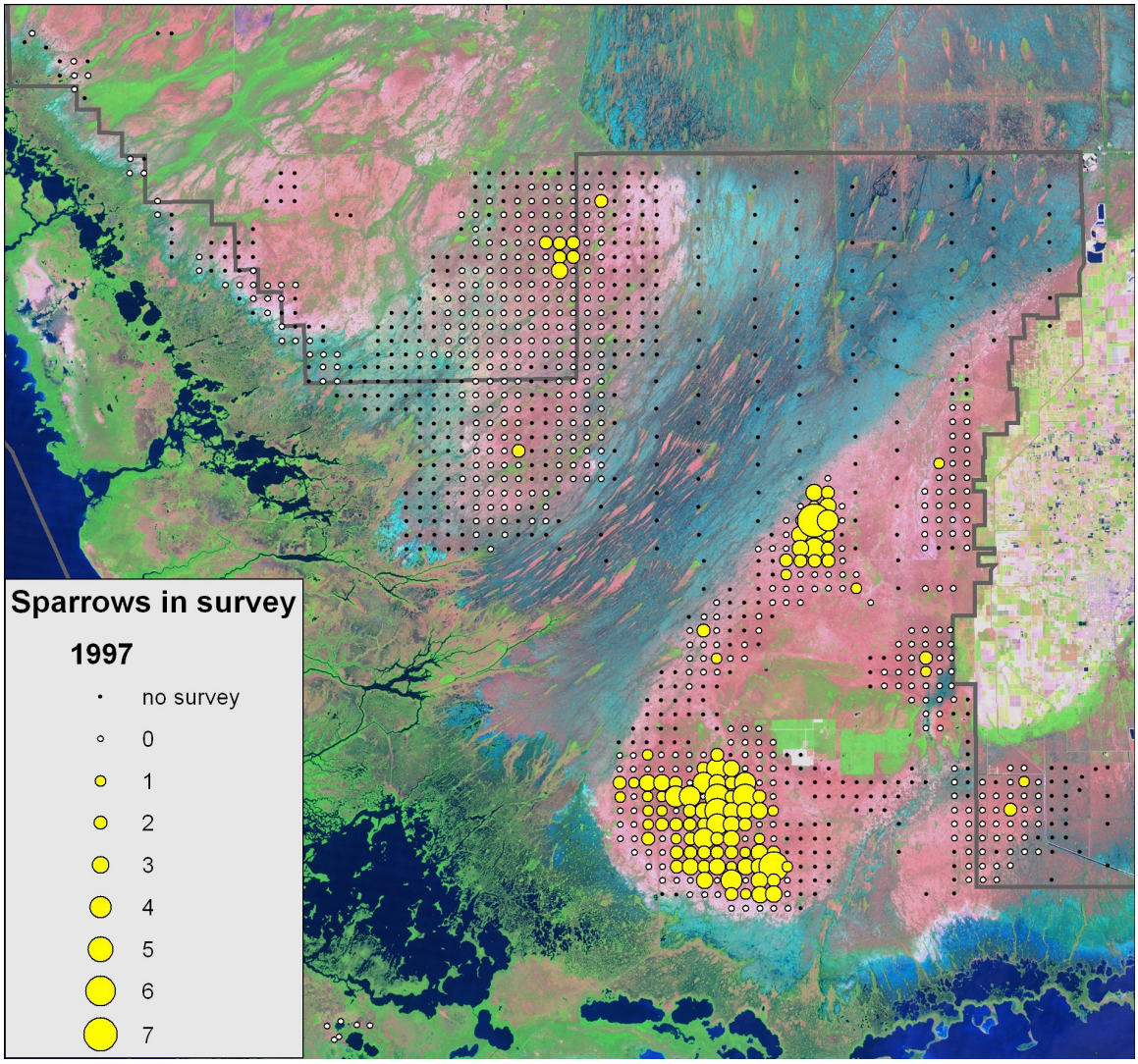

Sparrows in survey
1992
no survey
0
1
2
3
4
5

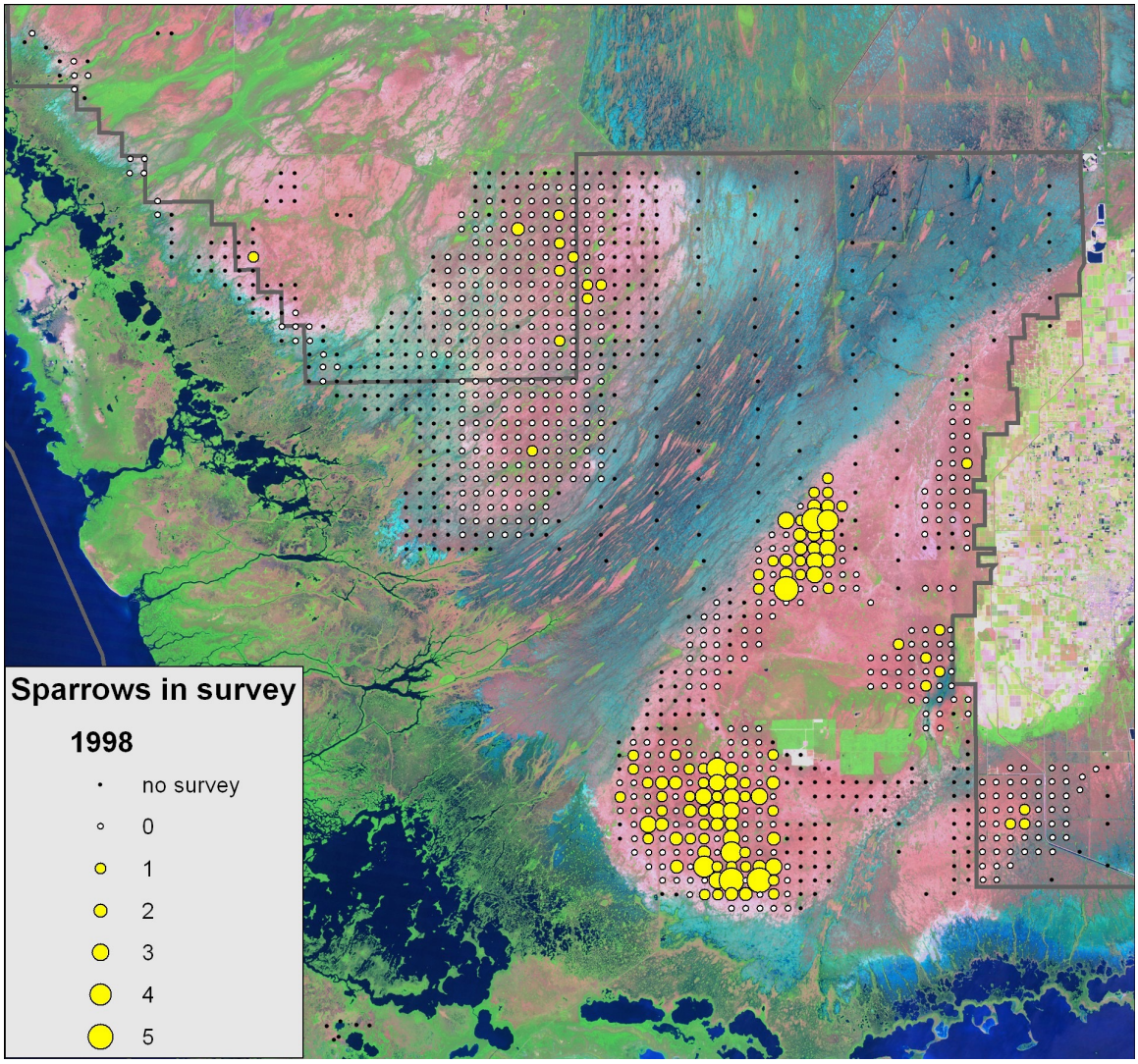

Sparrows in survey
1993
no survey
0
1
2
3
4
5
6

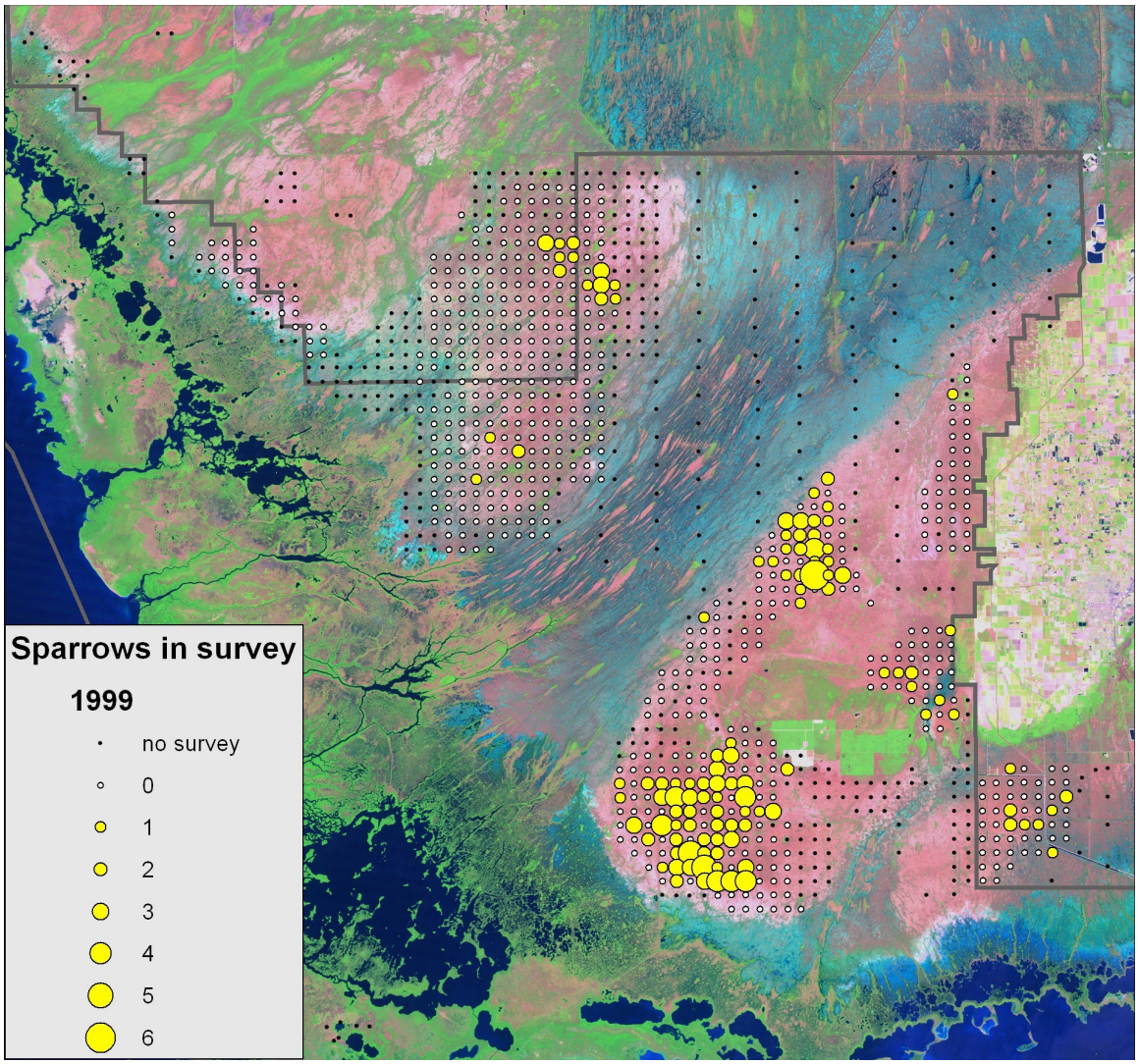

Sparrows in survey
1994
no survey
0
1
2
3
4
5

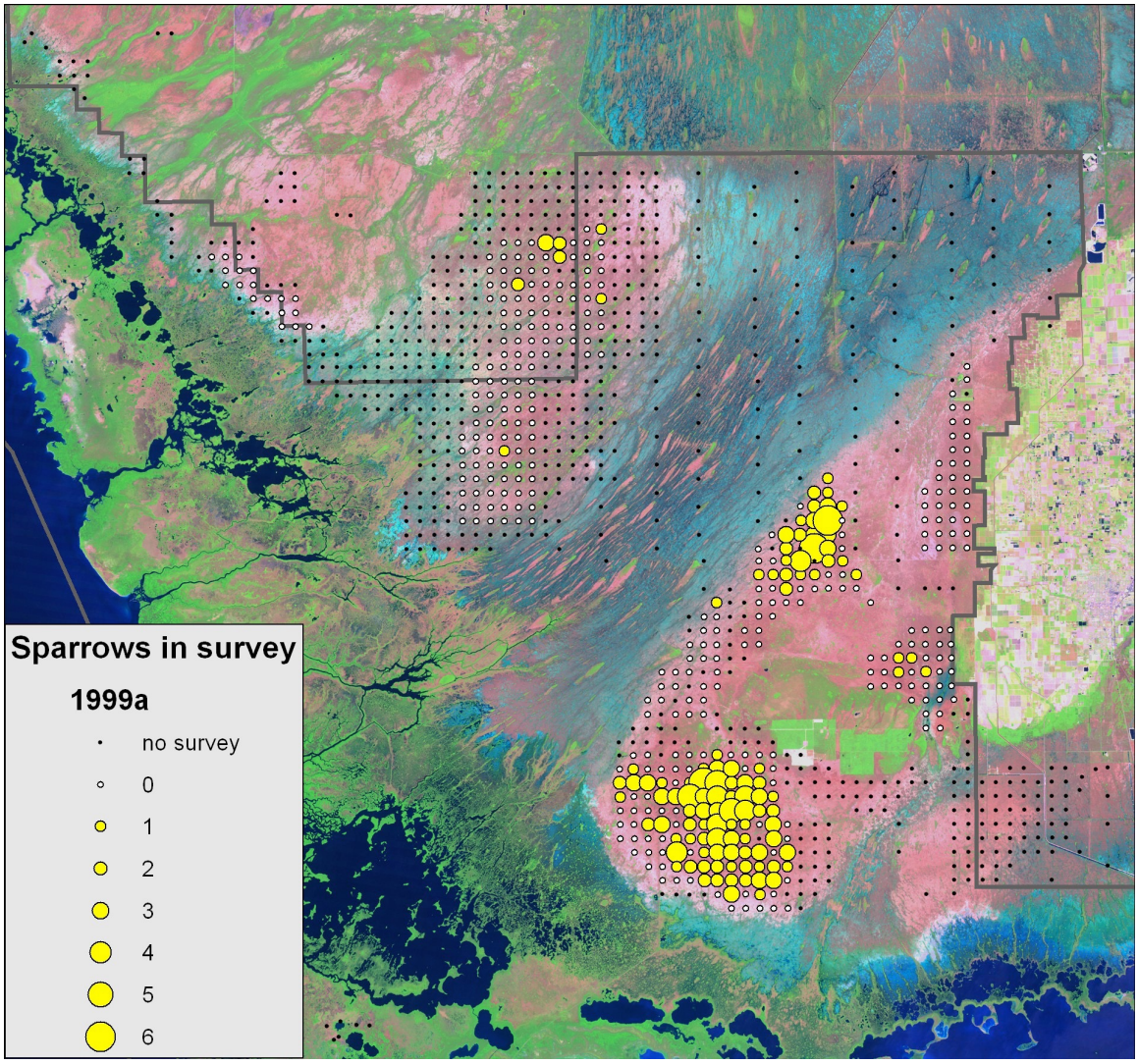

Sparrows in survey
1995
no survey
0
1
2
3
4
5
6


Sparrows in survey
1996
no survey
0
1
2
3
4
5

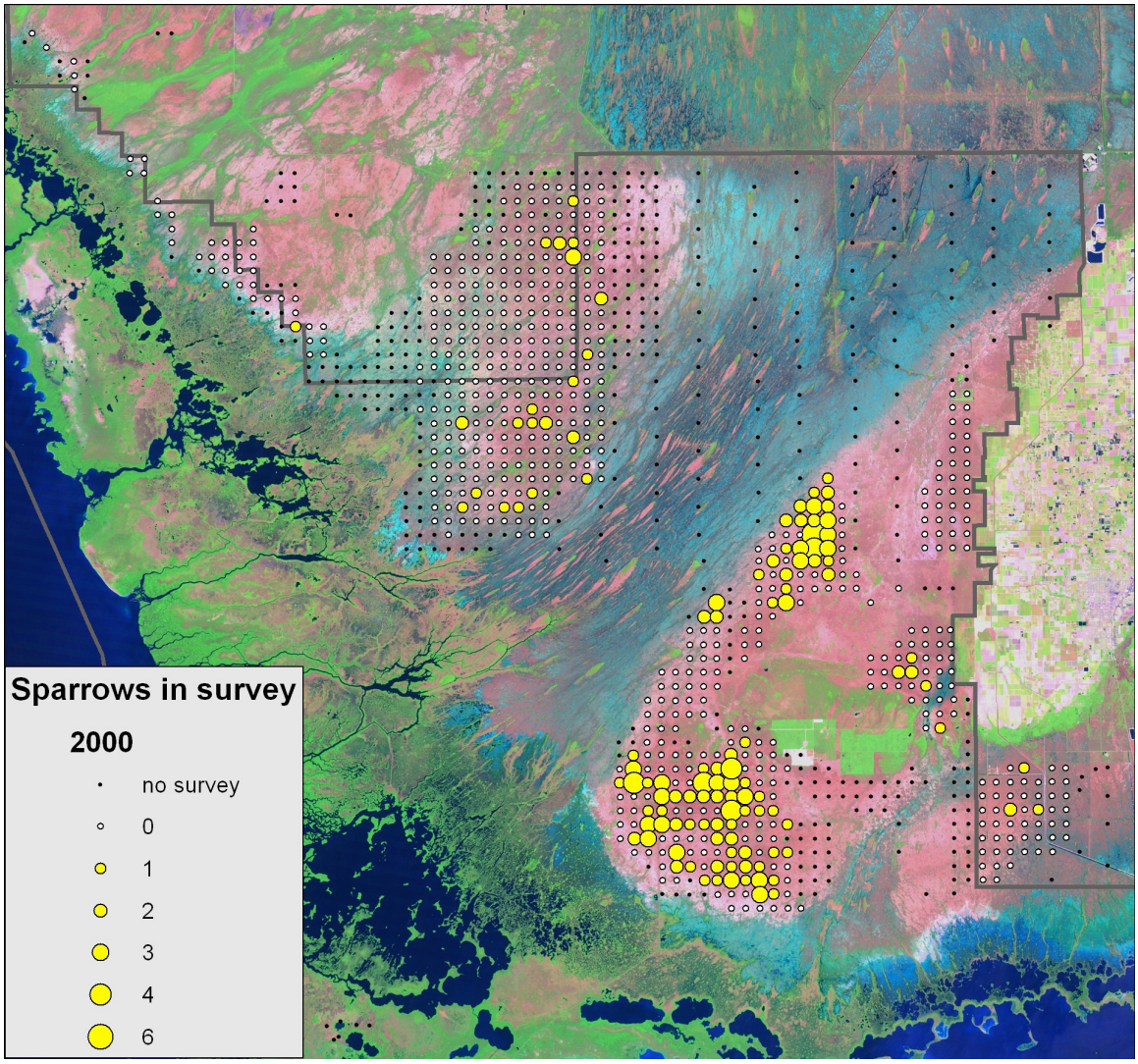

Sparrows in survey
1997
no survey
0
1
2
3
4
5
6
7

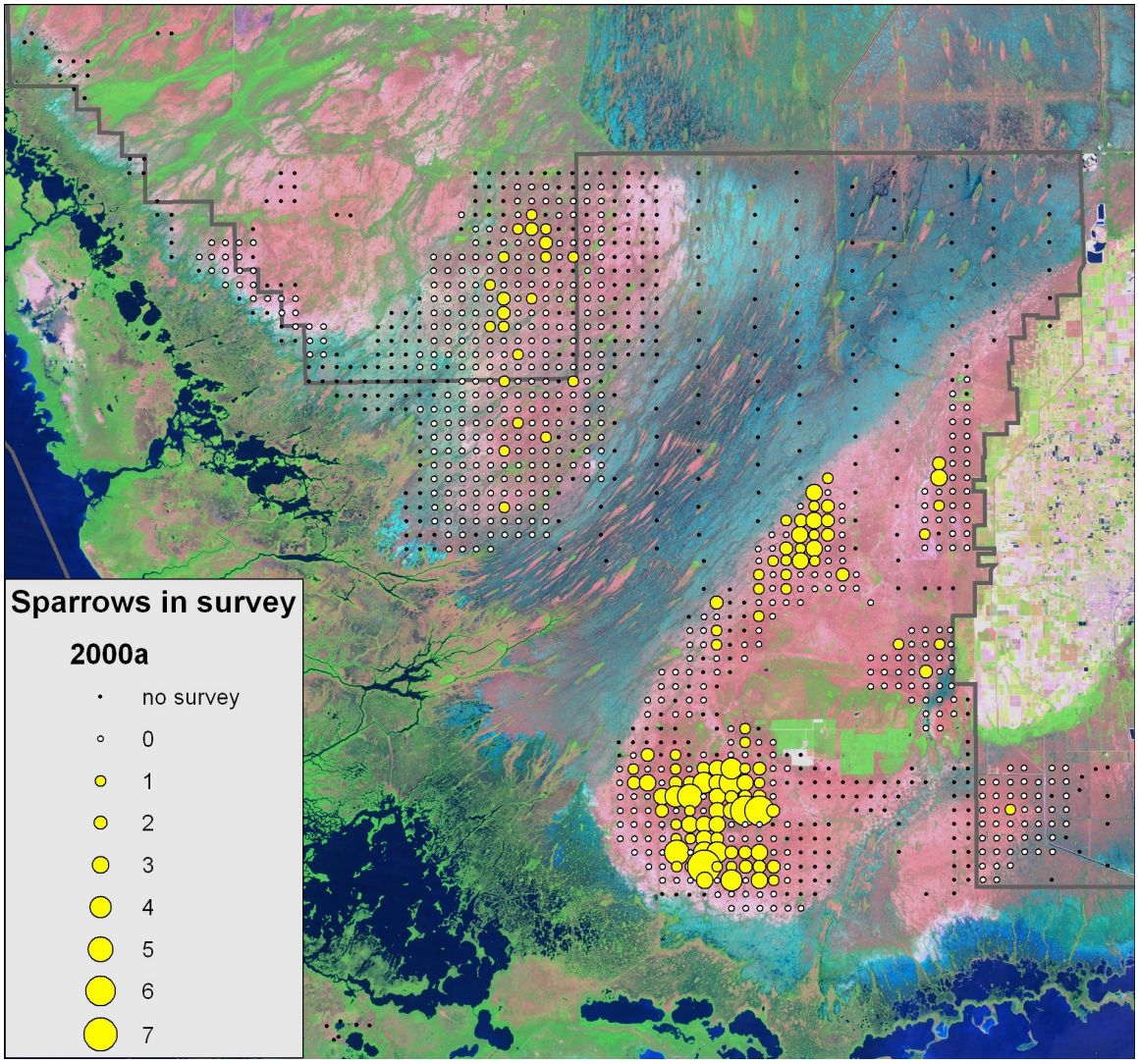

Sparrows in survey
1998
no survey
0
1
2
3
4
5


Sparrows in survey
1999
no survey
0
1
2
3
4
5
6

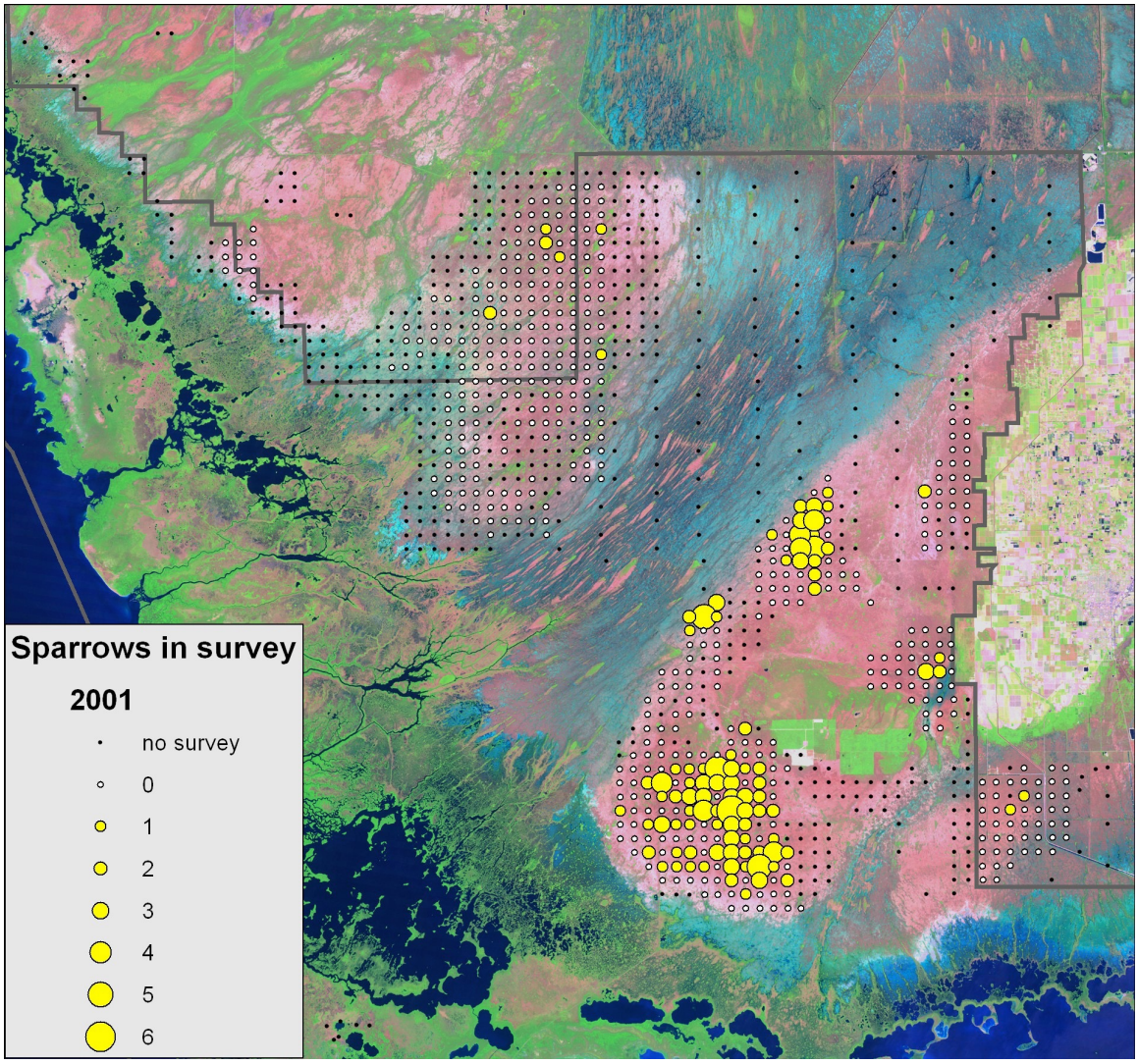


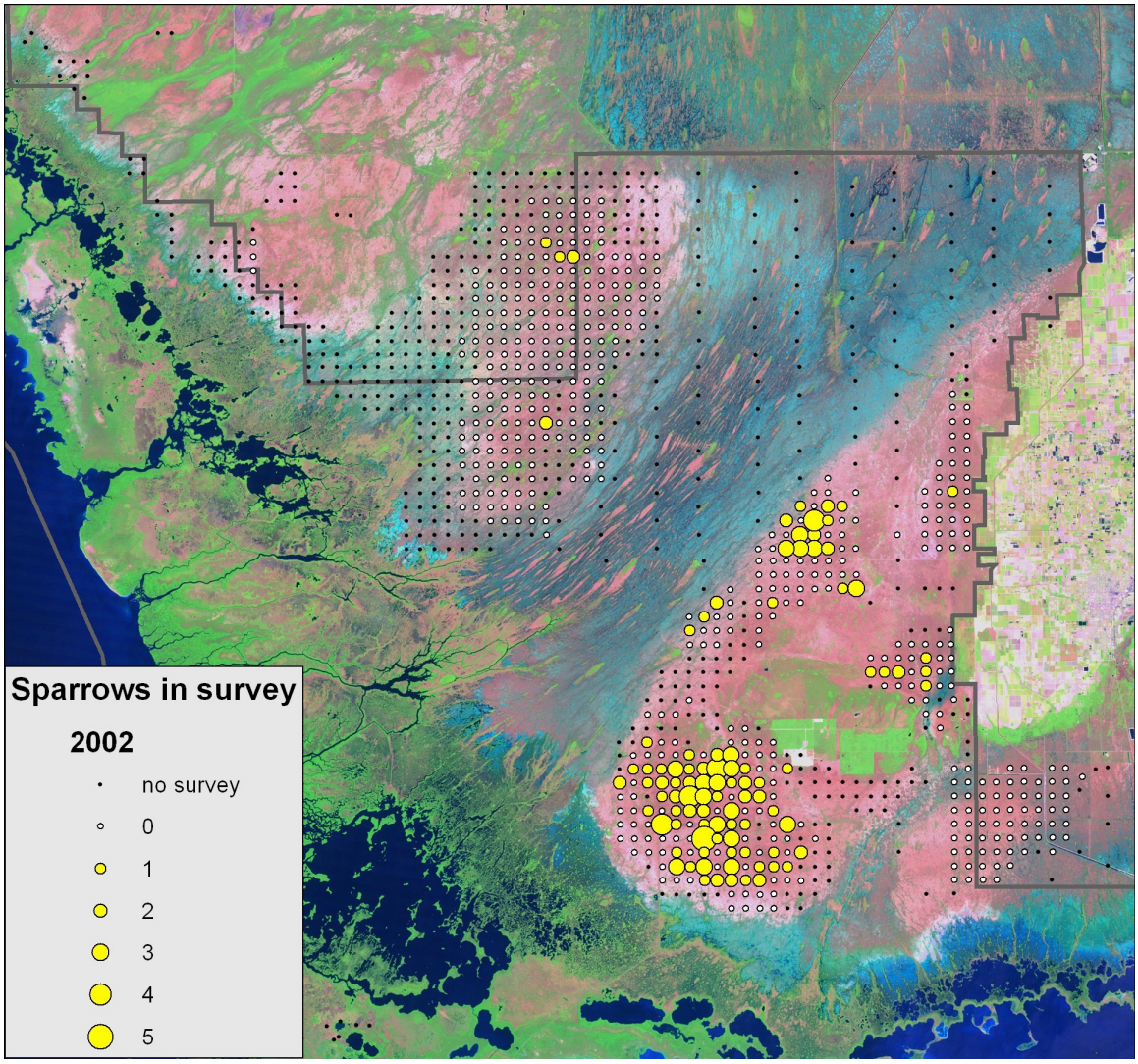
This survey took place relatively late in the breeding season and was an attempt to duplicate the earlier survey to address issues of repeatability.

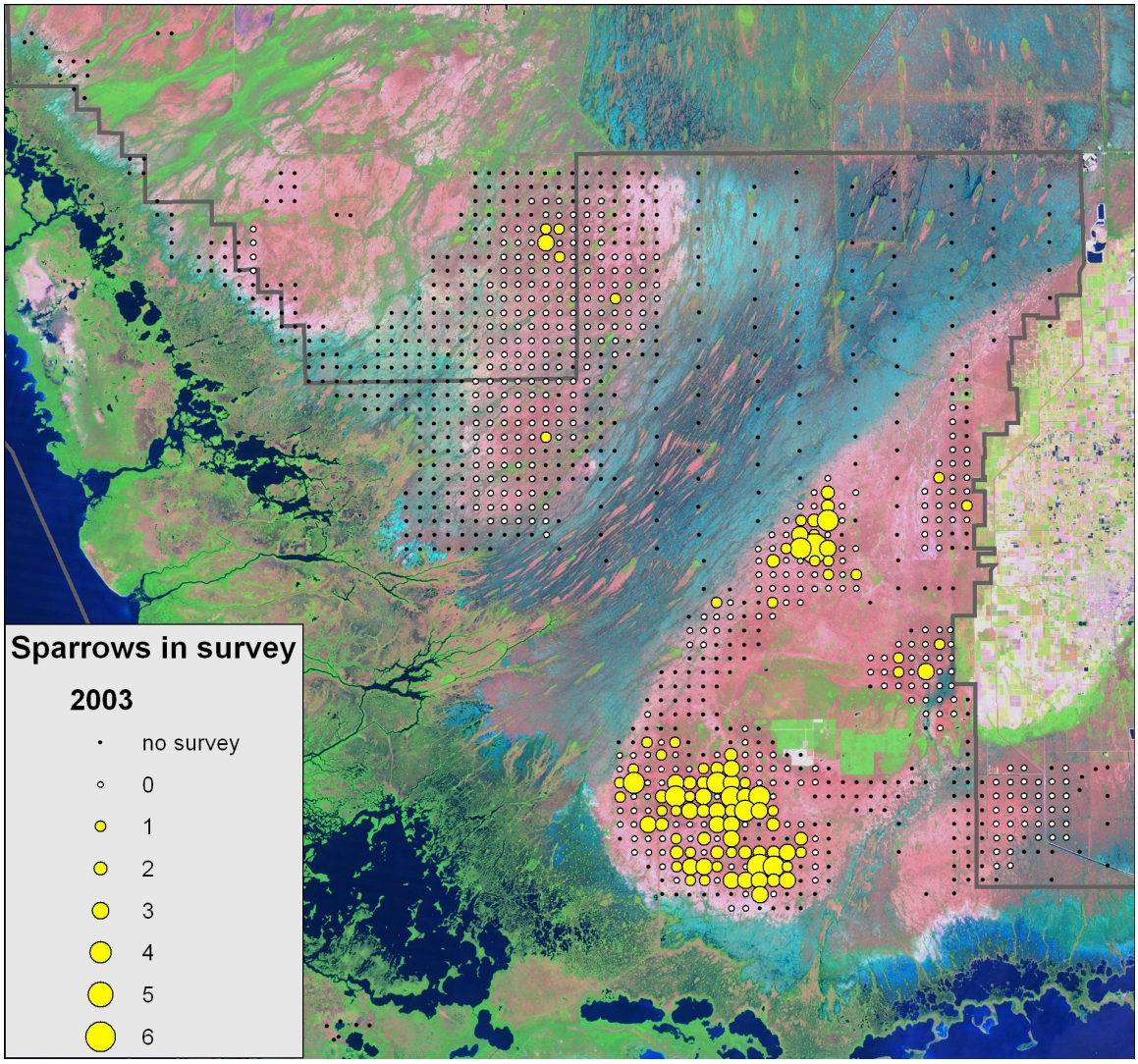

Sparrows in survey
2000
no survey
0
1
2
3
4
6

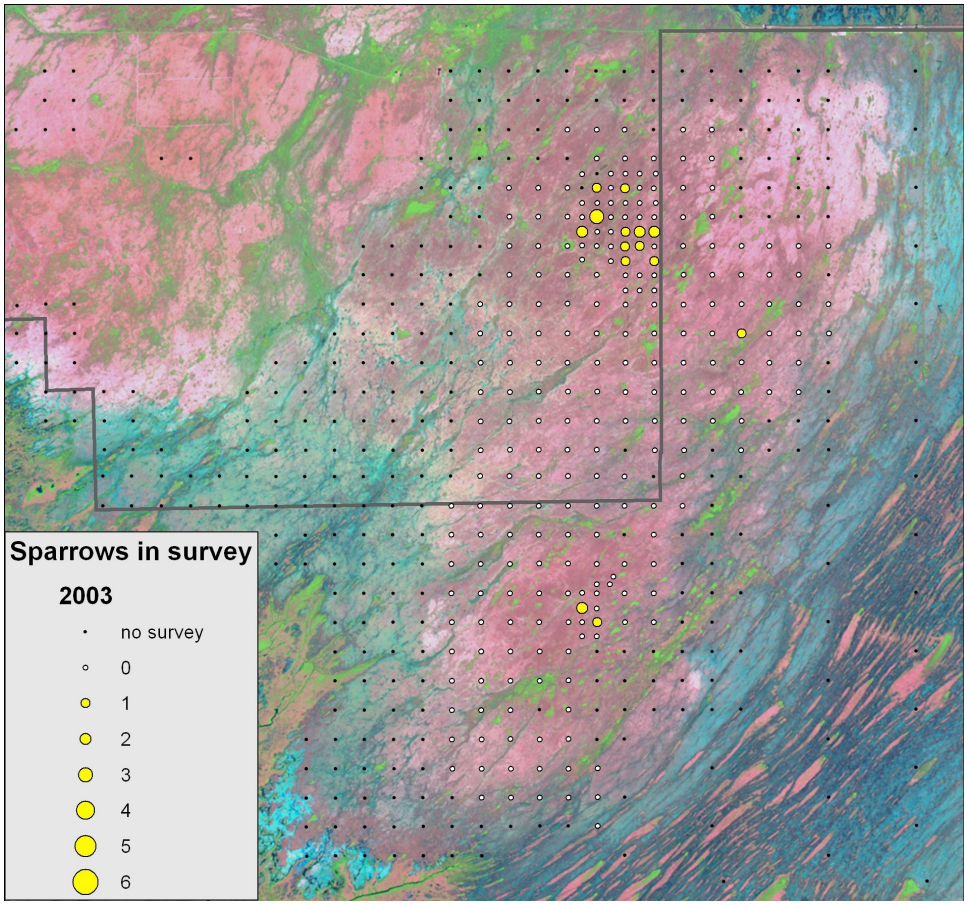


This was a second survey that involved a separate team of counters to establish how repeatable were the sparrow counts.

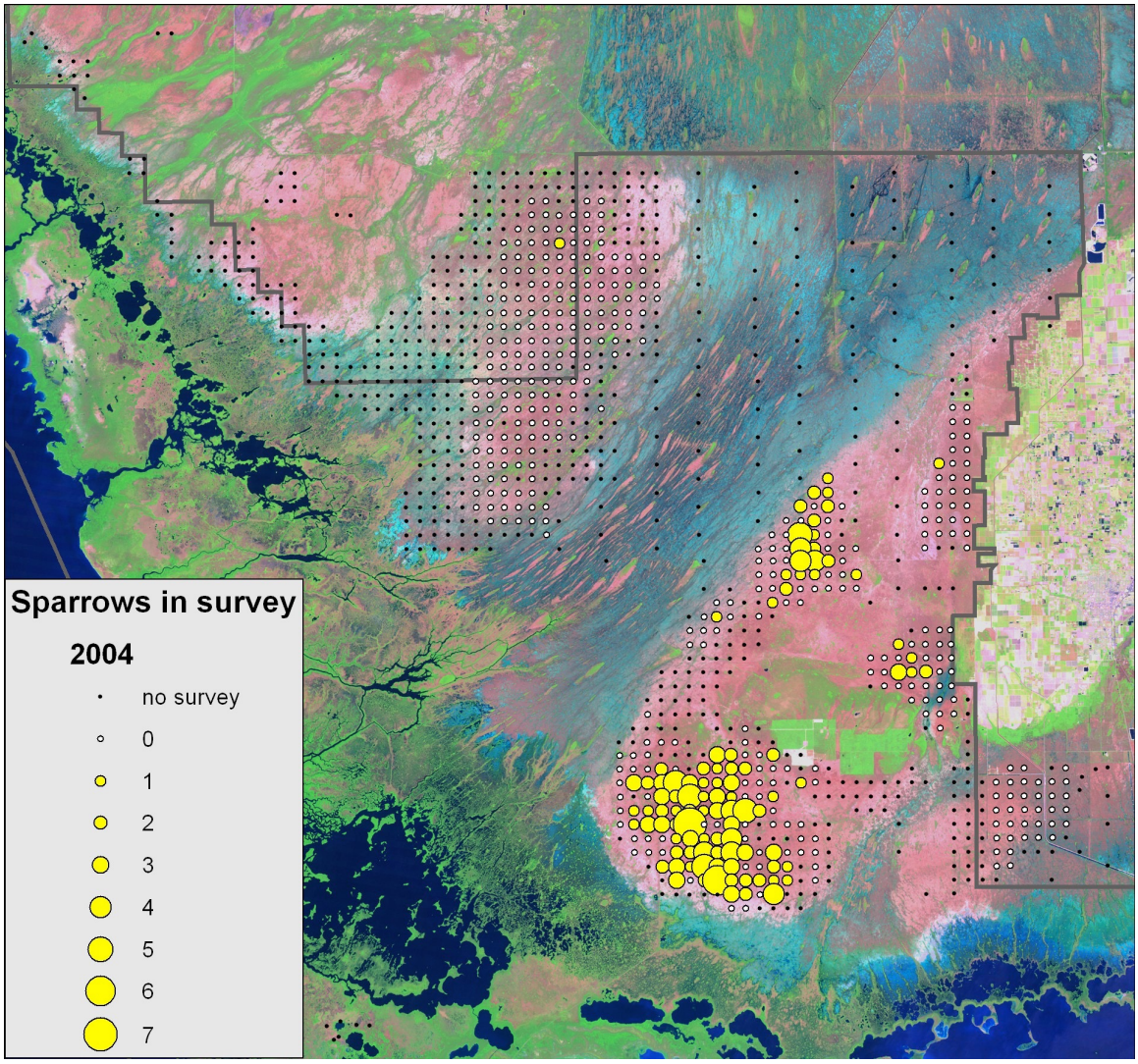

Sparrows in survey
2001
no survey
0
1
2
3
4
5
6

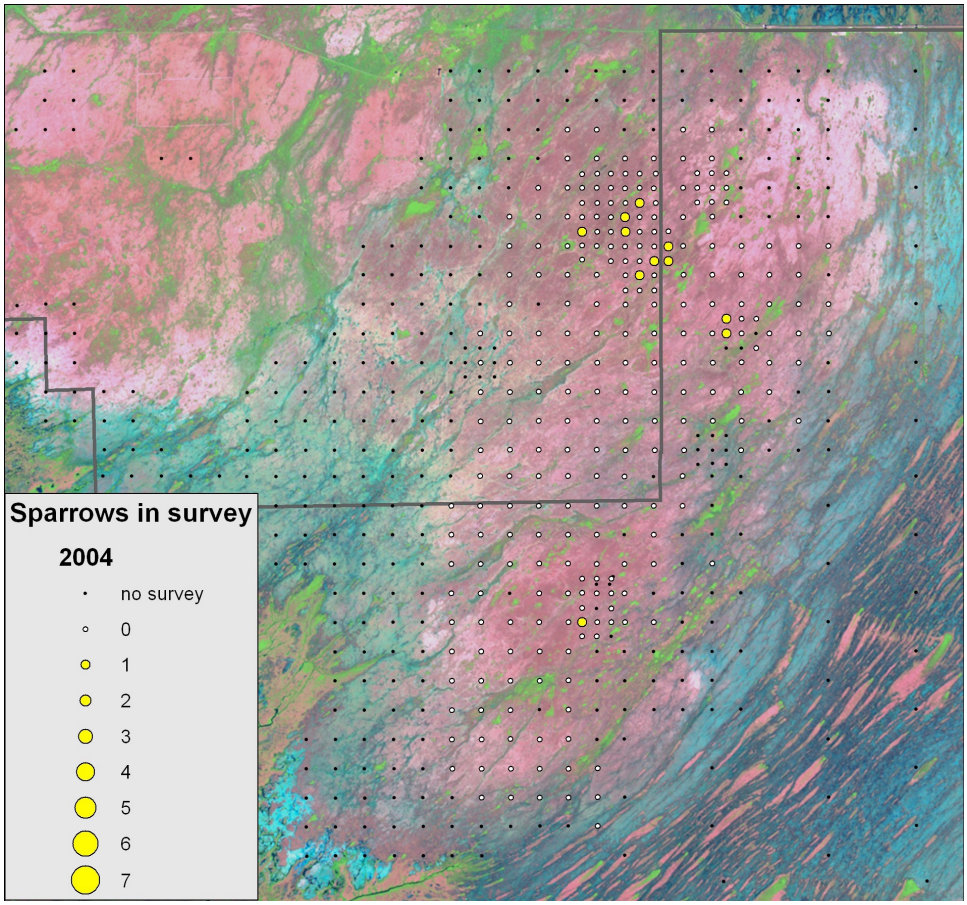

Sparrows in survey
2002
no survey
0
1
2
3
4
5


Sparrows in survey
2003
no survey
0
1
2
3
4
5
6

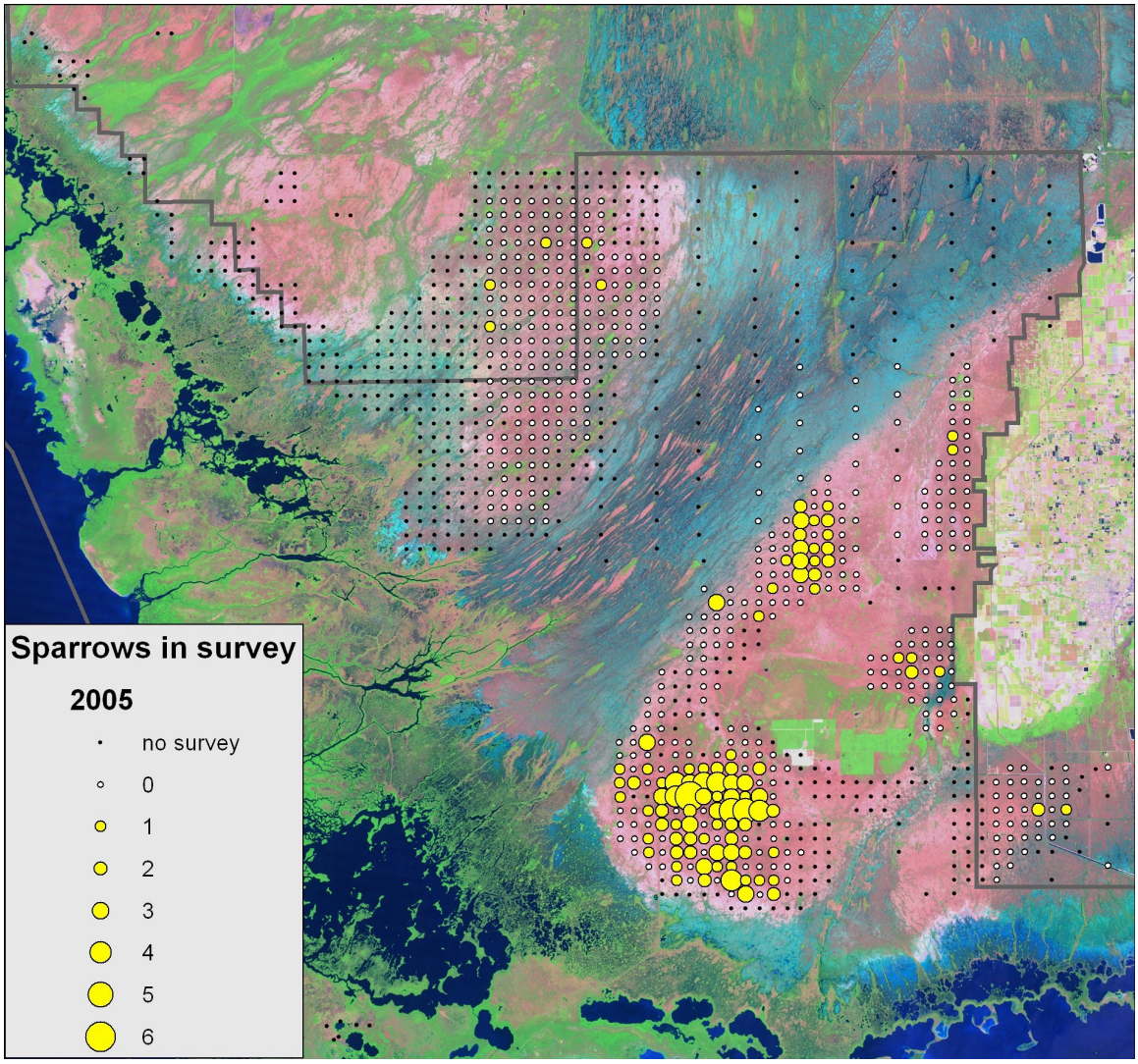


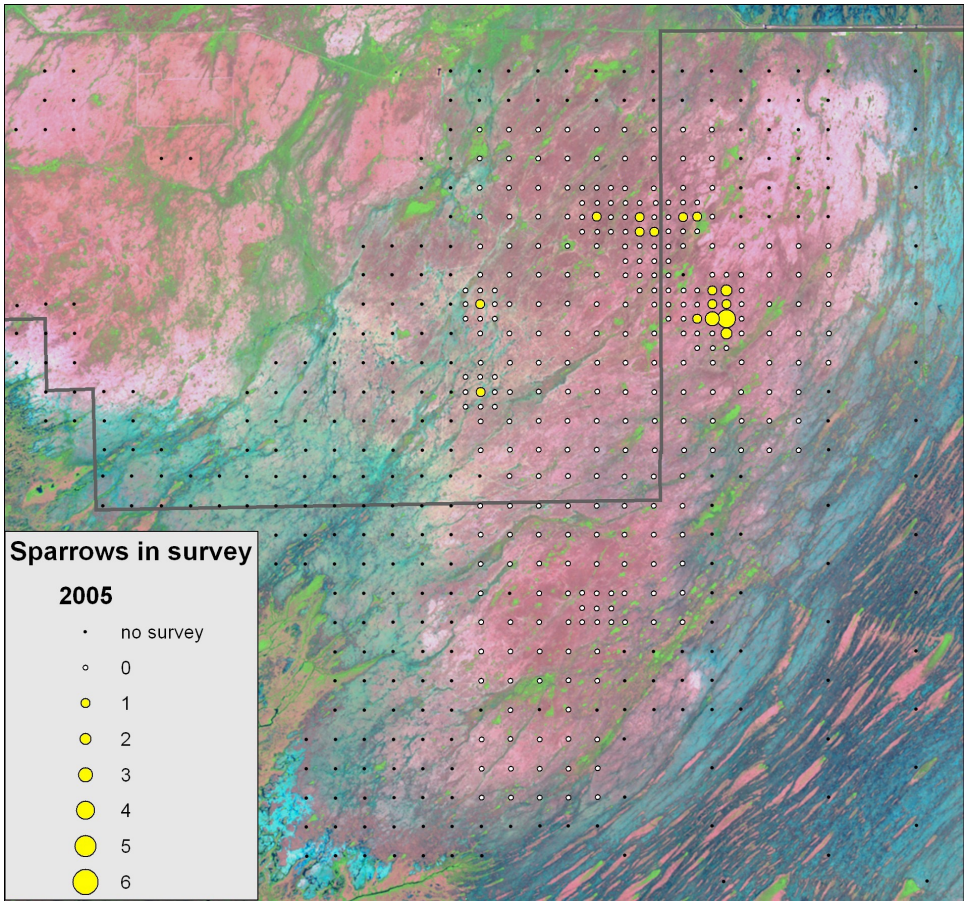
In 2003, we counted so few birds on the regular survey, that we decided to count key area on a 0.5 km grid, instead of the regular 1km grid. This increases the sample size by four in the areas so counted.


Sparrows in survey
2004
no survey
0
1
2
3
4
5
6
7

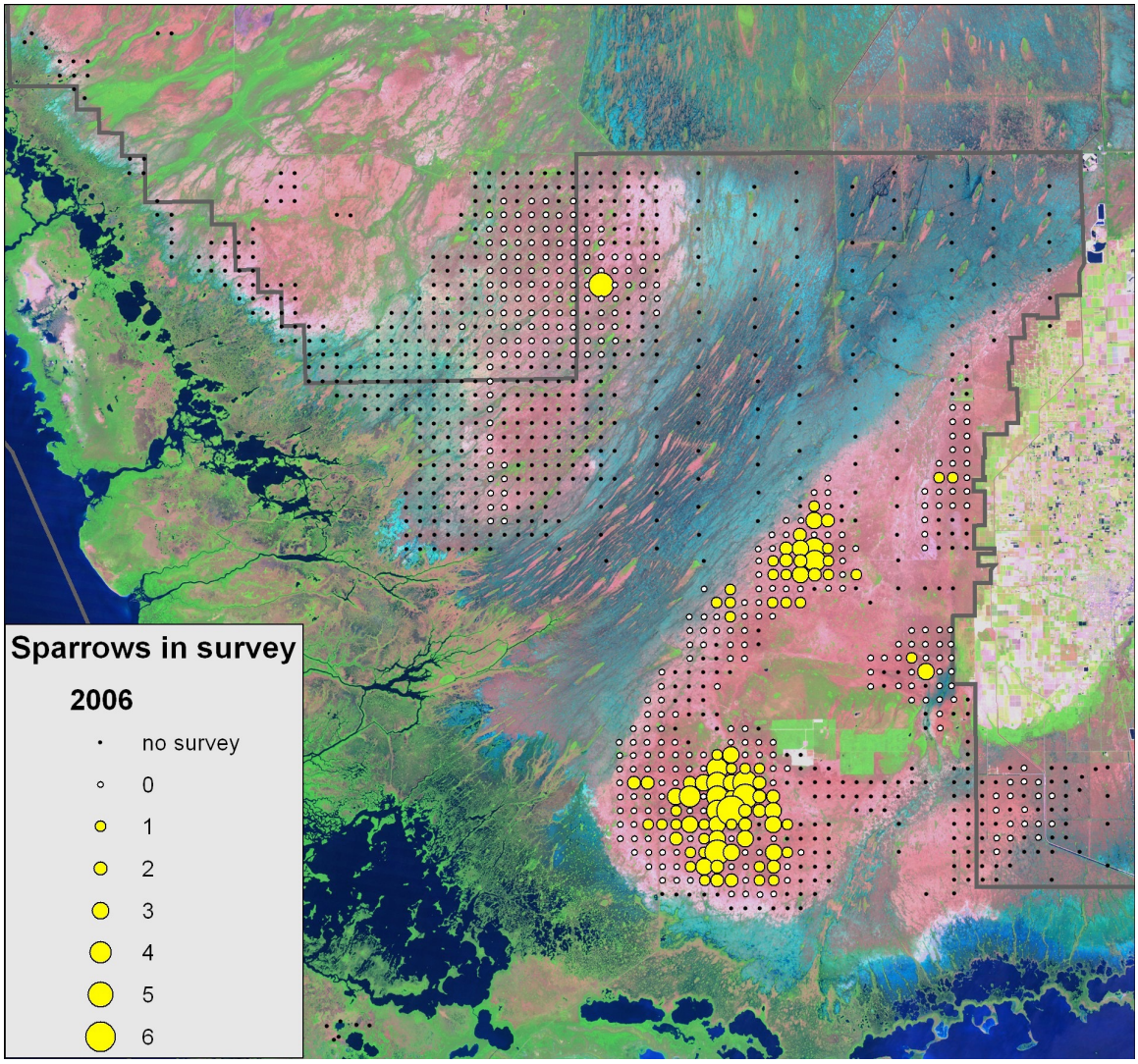


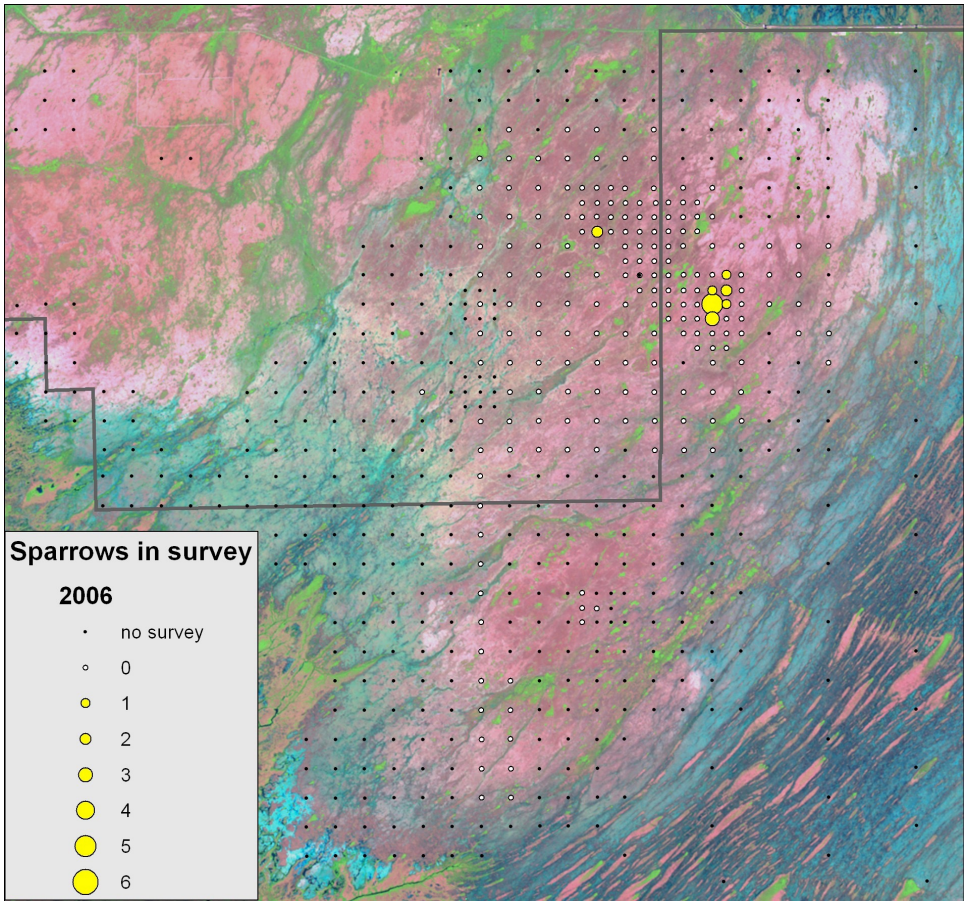
As in 2003, the small numbers of birds we counted on the regular survey — just one in this year — prompted counts on a 0.5km grid on key areas.


Sparrows in survey
2005
no survey
0
1
2
3
4
5
6



As in 2003 and 2004, the small numbers of birds we counted on the regular survey — just one in this year — prompted counts on a 0.5km grid on key areas.


Sparrows in survey
2006
no survey
0
1
2
3
4
5
6



As in 2003, 2004 and 2005, the small numbers of birds we counted on the regular survey — just one in this year — prompted counts on a 0.5km grid on key areas.

Figure 8.1 show the annual range-wide survey of the Cape Sable seaside-sparrow population for each year, including years of repeated surveys, and for 2003 to 2006, the half-km surveys of subpopulation A. Yellow dots indicate the number of singing males heard at a survey location. There were two surveys completed in 1999 and 2000 across most sites as a means to check the survey methods protocols. The underlying satellite image is not that for the year of the survey, but one we chose to best represent the potential habitat of the sparrows across all years.

Appendix. Response to the American Ornithologists Union review committee

Our work on this species has been the subject of two external reviews. The first (Orians et al. 1997) evaluated our conclusions about the effects of the high water levels of 1993 to 1995. The second was a more focused effort on the sparrow. It led to a review by the American Ornithologists Union. They raised many issues, while effectively silencing a large number of criticisms of our work. Of particular relevance here, are the recommendations the committee made about our surveying methods.

The American Ornithologists Union external peer review committee (henceforth, the AOU committee or AOU [1999]) recommended that we undertake a second count within a year to measure the accuracy and reliability of the method. Two surveys were completed in 1999 but one was much later than the other. (We did not receive the AOU's recommendations in time to do otherwise.) The later survey had fewer birds in populations where reproduction is poor (compatible with the suggestion that birds had abandoned territories after breeding). In the more productive populations, the second survey numbers were higher, raising the possibility that we were counting floating individuals from elsewhere (or even young birds of the year).

Two surveys were also completed in 2000, both within April and May across much the same range of dates, with two different survey crews, but using identical methods.

We feel that the AOU committee's concerns about the survey can be distilled into two questions: How repeatable (or consistent) is the survey? And how accurate are the population estimates based on the correction factor of counts times 16?

How repeatable is the survey?

The experience of 1999 illustrates the concern: the numbers on one count were quite different from those of the other. In the extreme, this must be the case: were we to count birds in (say) October, it is very unlikely that we would hear many singing. The second 1999 count lasted three weeks after the first and into the season when we knew many birds were not breeding. However, were there to be major discrepancies between two counts undertaken over the same interval during the peak of breeding, we could not easily explain differences except by a failure of survey method. There are very many reasons we should *not* expect the surveys to be replicates — and so, by inference, be concerned about the accuracy of the survey results in general. These include different observers and variation in the birds' propensity to call across the breeding season.

	0	1	2	3	4	5	6	7
0		30	11	5	2			1
1	28	10	8	6				
2	16	8	6	4		1		
3	7	4	4	4		2		
4			1		2			
5								
6		1						
7								

Table 8.A1: The frequency of numbers seen on the first survey (rows) compared to the second survey (columns).

Are the data we present above inconsistent with the each survey being a true replicate? For instance, should one be concerned that single birds were seen 28 sites on the first survey yet none at the same sites on the second? (There were 30 sites for which the converse was true.)

The nature of the survey means that only the statistically naïve would think that the counts would be identical on both surveys. Although we make every effort to land the helicopter in exactly the same location on each survey, the limitations of the GPS prevent that. (Until recently, GPS signals were scrambled to limit their accuracy.) Even if the signal were not scrambled, the birds move within their territories. These are roughly of 2 hectares; at its most compact, a territory might be a circle of 80 meters radius. The correction factor of 16 assumes that we will count all birds within 200 meters. Yet, a bird could be a mere 41 meters away on one count and at the other end of its territory, 201 meters away — and so out of range — on the next.

This suggests a statistical model for the distribution of sampling outcomes that has a long history in statistics. If the true density of territories is such that there are 1 per sampling area across the entire survey arena, then the distribution of counts of territories will have outcomes 0, 1, 2, … described by a Poisson distribution with mean 1. For example, suppose the true mean density were to be 1, then there is a 37% chance that no birds will be encountered, a 37% chance that 1 bird will be encountered, then 18% for two, 6% for three, 2% for four.

The standard deviation of Poisson outcomes equals the mean, so the standard error follows simply by dividing the observed mean by the square root of the sample size. Confidence intervals then follow in the usual way.

So is the model right?

One way to test it is to ask whether the number of birds seen on one survey is inconsistent with the number of birds on the other. The simple example just given allows us to calculate that the chance of seeing single birds on both surveys is (0.37 * 0.37 = 0.14), that is, 14%. There is the same chance of seeing no birds on both

surveys. And, in this particular case, there is a 28% chance of seeing one bird on one survey and no bird on the other or vice versa. There is a 4% chance of finding no birds on one survey and three on the other, or vice versa.

The point of this preamble is that this provides a model of how consistent the survey should be — and so the germ of a recipe for testing whether the survey fails that expectation.

This allows us to calculate how many sites would have (I,J) birds seen on the first and second surveys respectively, where I = 0, 1, 2, … and J = 0, 1, 2… when the true density is 0.5, 1.0, … At every density, of course, there are identical outcomes I = 1, J = 1, for instance. So the expected number of sites where one bird is counted on the first survey and one on the second, is the sum of the probabilities across all the true densities weighted by the frequency of those densities.

Summing these expected values across all possible outcomes leads to a small underestimate of the observed total because there is a fraction of sites where no birds are seen on the first count and none on the second but where the true density is not zero. (See the earlier example.) So we correct for that undercount, by multiplying the frequencies by the constant required to match the observed and expected counts.

This matrix sums to ~199 individuals (expected values need not be integers), but only 165 (=199 - 34) would be recorded because the 0,0 values do not appear. (165 is the observed total of sites with one or more birds counted during the survey.) One way to summarise these expected values is to sum the sites where the first and second counts do not differ, differ by 1, differ by 2, and differ by 3 or more

	0	1	2	3	4	5	6	7
0	34.25	22.67	9.34	3.36	1.17	0.40	0.14	0.05
1	22.67	18.68	10.07	4.68	2.02	0.83	0.33	0.13
2	9.34	10.07	7.02	4.04	2.07	0.99	0.44	0.18
3	3.36	4.68	4.04	2.76	1.64	0.88	0.43	0.19
4	1.17	2.02	2.07	1.64	1.10	0.65	0.34	0.16
5	0.40	0.83	0.99	0.88	0.65	0.41	0.23	0.11
6	0.14	0.33	0.44	0.43	0.34	0.23	0.13	0.07
7	0.05	0.13	0.18	0.19	0.16	0.11	0.07	0.03

Table 8.A2 Expected numbers of birds seen on one count versus numbers seen on the other

Difference	expected	observed
0	30.14	22
1	78.73	84
2	34.85	40
>3	21.64	19

Table A3: Comparison of expected versus observed differences. A difference of zero means that counts did not differ, 1 that they differed by 1, and so on. The colour-coding matches table 2

The differences between observed and expected are not significant (as tested by a χ^2 test.)

In sum, the differences between the two surveys are exactly what one expects given the nature of the sampling process. Given the large list of factors that could inflate the differences between the two surveys, this is a quite remarkable result.

How complete is the survey?

In the section that follows this one, “An analysis of detection probability” we present the results of an effort to replicate the helicopter survey count methodology on precisely fixed locations in areas where the number of neighbouring territories is know exactly. Much of what follows justifies the decisions we make on the helicopter survey. For instance, we do not count birds into June, late in the morning, when the wind picks up, and when it is misty. (In the last case, the helicopter cannot land.)

Amid the plethora of results that follow, is a consensus statement that under good conditions the chance of detection is "better than 60%." Does this mean that our survey consistently counts too few birds and so the population estimates are too small as a consequence?

The answers are "no" — and "not that it would matter if the answer were 'yes."

The second answer is the easier to explain. Even if the counts were underestimates, none of the inferences we have drawn (and on which the Fish and Wildlife Service’s Biological Opinions are based) would be altered. The damage done by releasing massive flows of water over the S12s, for instance, reduced the population to a mere 10% of its pre-1993 level. That statement — and the consequences that follow from it — are not changed if we multiplied the actual bird counts by 16 (as we do) or the first number that came into your head multiplied by the square root of e.

The first answer is rather more interesting. "Better than 60%" is nearly exactly what we expect on the basis of the Poisson model we employ. For a true density of one bird per 200 meter radius, the exact answer is 100 - 37% or 63%. Quite simply, birds move about their territories and — for reasons explained above — the birds present will not always been in earshot.

Here is a geometric example.

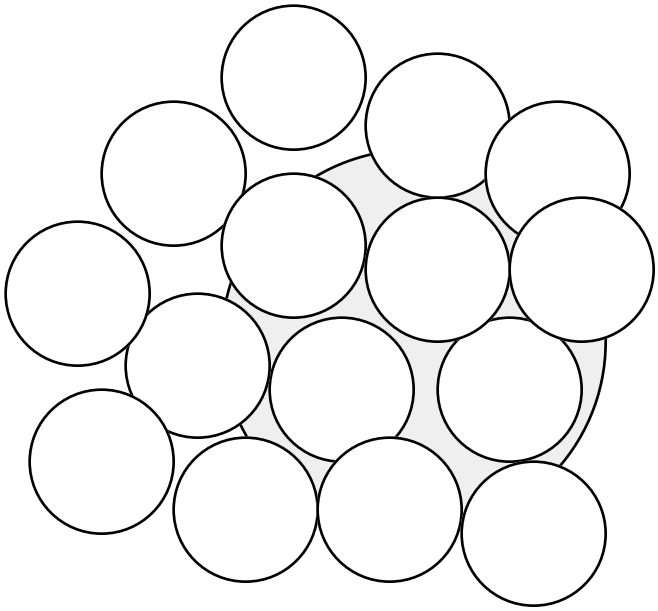


Figure 8.A2. An hypothetical example of territories (open circles) within a survey radius (stippled.) So how many birds will be encountered on average?

The small clear circles are territories (80 meter radius) and the larger, stippled circle is the 200 meter detection radius scale appropriately. These territories are packed unreasonably closely and real territories are not circular and so cannot be packed thus. But for an illustration, we ask: how many can be heard and how many birds must be heard if all birds sing during the survey. The answer is 11 and 3 respectively. On average, the numbers heard will be in between. If one takes the average as 7, and expresses it as a fraction of the maximum (11) it comes to 63%.

The point is that an unbiased, efficient survey should detect birds *only an expected fraction of the time* and our estimates are close to that expectation.

Of course, what we would still like to know is what fraction of birds with territories entirely within the survey radius were counted? (They should always be counted.) We do not have that information at present — it requires us to complete the GIS work presently underway (Lockwood, personal communication). On the other hand, the fraction cannot be too low or else the average detection fractions fall below values consistent with the survey results.

For the time being, we have no evidence to reject the hypothesis that our survey methods provide a true estimate of the sparrow's total numbers.

An analysis of detection probability

Detection probability — the chance that we will record a male sparrow during standard point counts — is influenced by a variety of factors (e.g., weather, observer, and species) all of which decrease the likelihood that a true count of individuals can be taken. This bias should be explicitly incorporated into estimate protocols to avoid inaccuracies in abundance calculations. In June 1999, we established a series of point count locations within our intensive study plots. Beginning in April of 2000, we visited these locations and mimicked the extensive survey procedures for counting resident males. By comparing the count results to detailed territory maps we can directly calculate detection probabilities. These probabilities can then be incorporated into error estimates for the extensive survey.

The correction factor of 16 is based on the fraction of total area sampled (a) and detection probability (p), such that $ap = 1/16$ (AOU 1999). Below, we directly calculate p, and variations in p, by conducting fixed-radius point counts within intensive study plots and then comparing these counts to the results from detailed territory mapping (see below for details). The mapping efforts represent the 'true' number of individuals within a 200m radius of the point count location. Once detection probability is calculated, a correction factor can be estimated under all conditions explored (e.g., wind speeds, density groups, and time of day).

Methods

We conducted fixed-radius point counts from 14 April to 17 July 2000. We located point count locations 400m apart within seven 600 X 800m plots. Six were within population B and one plot was within subpopulation E. Counts were made following the procedures described above (and in Kushlan and Bass (1982) and Curnutt et al. (1998). All individuals heard singing, or sighted, were recorded for up to 7 minutes after arrival at the point count station. We could not simulate the arrival and departure of a helicopter, however traveling by foot through a breeding area may have broadly similar effects on resident males. When generally disturbed (i.e. when not defending a nest), males will tend to perch atop sawgrass seed heads and sing. We varied our start times across study plots such that all times between sunrise and 11:00am were covered. During each count we recorded the observer, visibility, water depth, and wind speed. Wind speed was estimated using the Beaufort scale, with adjustments for use in marsh habitat. The Beaufort scale used ranged from 0 to 4 with each increase in scale indicating an increase in wind speed (Table 8.A4).

We began mapping the territories of banded and un-banded males on 25 March and continued to update these maps until 17 July 2000. A crew of two or more visited each plot at least one day per week for at least three hours. Observers located sparrows using spotting scopes or binoculars and the location of their territories were marked using coloured survey tape. Some territories were marked after a member of the resident pair was captured in a mist net. Territory location was recorded using a Global Positioning System (GPS) and subsequently recorded on an ArcView map. Point count locations were also recorded using GPS and these locations were overlaid onto the territory maps for each plot. We then counted the

number of territories within a 200m radius of each count location based on these maps.

Table 8.A4. Beaufort scale of wind speed modified for use in marl prairies, Everglades National Park.

Beaufort Number	Field Criteria
0	No wind.
1	Slight wind such that very tops of grasses were moving.
2	Wind such that entire stalks of grasses were moving.
3	Moderate wind such that leaves on trees in hammocks were moving.
4	Strong winds such that tree branches in hammocks were moving.

The total number of marked territories within 200m of a point count station represents the 'true' number of sparrows. The number of individuals detected during each point count is then scaled by this value. This proportion is considered the detection probability. It is possible for the observer to over estimate the number of sparrows within the 200m radius detection zone (e.g., birds not resident within 200m venture into the point count radius and are counted).

Thus, probability of detection can range from 0 (i.e. no birds were detected although some were mapped) to >1.0 (i.e. more birds were detected than were mapped).

Mean detection probability was calculated according to time of day, wind speed, water level, observer, plot, month, and density levels. Start times were categorised into four nominal categories. The first category included start times between 6:00am and 7:00am, the second category included start times between 7:00am and 8:00am, and so on. A final category included all starts after 10:00am. We compared the mean detection probability between these four starts times using ANOVA. Similarly, we compared mean detection probability between observers (seven), and months (four) using AVOVA. We looked for changes in detection probability with water level and wind speeds using simple linear regression and ANOVA. We measured water depth from soil surface. All water measurements were made at the point count station at the start of each count period.

It is possible that detection probability will change as sparrow abundance changes. To test this, we divided the point count locations into two density groups. Locations that held fewer than four territories within 200m of the point count station were considered low-density. Locations with more than five territories were considered high-density. We tested for differences in mean detection probability between the two groups using a t-test.

Results

Seven individuals made a total of 254 point counts between 14 April and 17 July 2000. The maximum number of birds detected during any one point count was eight, and the minimum was zero. The maximum number of territories mapped within a 200m radius of a point count location was nine, and the minimum was zero. Detection probability averaged 0.58 (standard error = 0.02) and ranged between 0 and 1.67. On 14 occasions (14/254 = 5%) more birds were detected than were shown on territory maps. Over-estimates occurred throughout the season and start times with no noticeable pattern. On 11 (4%) occasions, no birds were detected in areas that contained more than one mapped territory (i.e. a false negative occurred). The vast majority (95%) of errors in detection involved under-estimates. Visibility very rarely fell below 200m, twice falling to 150m and once to 60m. Thus, during 99% of the counts it was possible to easily see birds within a 200m radius of the count location. Wind speeds varied between zero and four with a modal Beaufort score of one. The earliest start time was 6:48am and the latest was 10:14am. Most counts (84%) were made between 7:00am and 9:00am.

Detection probability was not influenced by the depth of standing water according to ANOVA ($F = 2.4$, $df = 1$, $P = 0.12$). Water depths varied from zero to 17cm with a mean depth of 3.31cm (standard error = 0.30).

Detection probability varied significantly according to time of season (i.e. month), time of day, sparrow density, and wind speeds. Time of season (month) had a statistical influence on detection probability (ANOVA $F = 5.90$, $df = 3$, $P = 0.0007$). However, there was no obvious pattern to these differences. The highest mean detection probability recorded was among June counts (0.70, n = 65) and the lowest mean detection probability was in July (0.47, n = 41). April and May probabilities were 0.51 (n = 58) and 0.57 (n = 92) respectively.

Mean detection probability declined monotonically with time of day and higher wind speeds. Counts conducted after 10:00am produced the lowest mean detection probabilities (0.30, n = 4). Point counts that started at 9:00am and 8:00am had mean detection probabilities of 0.37 (n = 30) and 0.50 (n = 96) respectively. The highest mean detectability occurred during counts made between sunrise and 8:00 am (0.70, n = 114). These differences were statistically significant (ANOVA $F = 15.4$, $df = 3$, $P < 0.0001$). Detection probability and wind speed were negatively correlated ($F = 30.05$, $df = 2$, $P < 0.0001$). The correspondence of effects for wind speed and start time is not independent. Wind speed tends to increase as the morning wears on ($F = 43.80$, $df = 3$, $P = <0.0001$).

Finally, detection probability decreased as density increased. Count locations with three or more mapped territories had an associated detection probability of 0.61. Count locations with seven or more mapped territories had an associated detection probability of 0.49. These two means were statistically different ($t = 2.50$, $df = 1$, $P = 0.01$).

Discussion

The range of detection probabilities provided here provides advice to the extensive survey that has long been understood by that survey. Detection probability can be quite high depending on conditions. An early morning, low wind, count is often better than 60% accurate — what one would expect under the Poission model (see above). However, this probability drops by half as the morning progresses and the wind increases. To maintain a high rate of accuracy in counts, it is our recommendation that point counts are restricted to time periods before 9:00am and under wind conditions of a Beaufort scale of two or less. Although wind speed tends to increase later in the morning, this is not always the case. We encountered mornings when wind speeds remained low past 9:00am. Thus, discretion in applying this recommendation is necessary, as it may be possible to conduct accurate counts late in the morning on some occasions.

Detection probabilities also tend to vary by observer. The individuals conducting these point counts varied from those with several years of experience to those with none.

We could find no discernible pattern in detection probability during the typical time frame of the extensive survey despite observing significant differences in detection probability by month. We purposefully excluded juveniles in this calculation despite our recording flocks of juveniles regularly past mid-June. We observed some of these juveniles 'practicing' their song and thus they may be easily mistaken for breeding males by inexperienced observers. By late June, all observers were very familiar with sparrows as they had been finding and following nests since March. They could easily distinguish juveniles by site and sound. This may not be the case for personnel conducting the extensive surveys as they are typically not as intimately familiar with sparrow behaviour. Thus, it is our further recommendation that point counts are not conducted past the first weeks of June as observers may inadvertently include young of the year in their counts.

Because sparrows were absent in the western study population (i.e. the Shark Valley plot) during the 2000 field season (see section II), we can not judge differences across the spatial extent of the sparrow's range. However, there was a discernible difference in detection probability between low- and high-density locations. The low-density locations included here are comparable to densities observed in the Shark Valley plot pre-2000. This study plot is imbedded in what is now one of the most sparsely populated areas of the sparrow's range. In these low-density areas, detection probability was high (0.61) indicating that, if sparrows are present, they are likely to be counted. However, there also appears to be a saturation level beyond which observers have a difficult time distinguishing all resident males. Detection

probability dropped to 0.49 in locations that held five or more territories. This leads to the slightly counterintuitive result that the extensive survey is likely to under-estimate the number of males within densely populated areas as compared to sparsely populated areas.

Other relevant factors for the extensive survey

The AOU external review board also suggested the use of female departure calls as a method for surveying female sparrows. We observed what we believe to be departure calls made by the females of this subspecies under much the same circumstances as described in MacDonald and Greenberg (1991). However, the detection distance for this call is well within 50m of the nest and it cannot be heard given the slightest wind. This is in sharp contrast to departure calls given by other marsh nesting birds (Greenberg, personal communication). We find that counting females by listening for departure call is not practical in this context.

The AOU committee response to the repeated survey

In the winter of 2000/2001 three members of the AOU committee independently commented on our response to their earlier concerns about survey methods. In this section, we reproduce those comments and supply our response to them.

Reviewer 1

"In 2000, The CSSS research team added an assessment of detectability as part of its annual survey program. Following suggestions of the AOU review committee, the researchers conducted a number of point surveys in areas where the number of pairs of Cape Sable Seaside-Sparrows is known (based on colour banded birds). For me, this field exercise and analysis are much more powerful than the repeated survey analysis and I will focus my comments on this calibration."

We agree and, indeed, this is an important reason why we invest effort in maintaining colour-banded populations across in intensive study sites in the three main sub-populations.

Predictably, detection probability (sparrows counted on point survey/marked males with territories overlapping count circle) varied with time of day, time of year, wind speed, and sparrow density. Under "good' conditions detection probability was 0.6. We further argue that this is as high as can be expected if all singing males are detected, because no attempt was made to weigh the presence of birds in the 200 m circle by the portion of their territory within the circle. The conclusion is that correction factors can be incorporated based on the predictable changes in detection probability, however it is unclear as to when or if such correction factors will be applied.

"My main concern with this conclusion is that it is unclear from the document how many historical surveys were conducted under conditions that now require correction factors. My other question (having done a lot of this kind of survey work

in other regions) is whether enough days in the optimal season are available so that counting does not have to be done under poor conditions."

The expectation is that even under the best possible conditions that only roughly 60% of the birds will be detected stems from the assumption of a Poisson sampling distribution. The variation about this level — when conditions are not good — could be corrected in several ways. One might be using different correction factors under different conditions. In our experience, this is a poor solution when those factors can only be measured imprecisely. Our solution has been to only survey when the conditions are good. We survey for only 2 – 3 hours each morning (we are limited by helicopter range and fuel capacity), we do not fly when conditions are not good, and we stop early if, in particular, the wind starts to blow. We employ very few observers all of whom are very experienced.

"One interesting result is that detection probability declines with density. This has been found with other surveys and is apparently a result of people underestimating the number of singing birds when a number of birds are singing."

This is an interesting point. Its effect on the bird counts, however, is quite small. Almost all of the observations involve only 1 or 2 birds per site. If (say) sites with 5 birds were mostly sites with 6 birds, the estimated numbers of sparrows would increase only very slightly.

"It seems to me that there is much more information that can be derived from the type of calibration conducted. The analysis in this report has focused on determining the delectability coefficient. However, by presenting the data as a regression between the number detected and the "true" number of territorial sparrows and conducting some ANCOVA analyses, we could get a handle on the delectability at low densities (intercept), change in delectability with density (slope) and the reliability of the count (amount of scatter – correlation coefficient). Wind speed and time of day could be treated as covariates. It would be most interesting to plot out this regression for points conducted during the optimal count conditions. If territory maps are available, then one out to be able to estimate the proportion of territories contained in the 200 m circle. Along these lines, I wonder what can be learned from more information about the plot maps. For example, how many of the birds detected are unmated males and what is the origin of the males detected o surveys that weren't part of the territory maps."

While we are currently working on plot maps and birds detected by point counts on them, the main point is that we avoid those conditions that would affect the counts' accuracy.

"I have a couple of other more technical comments: What is the specific evidence that observer experience did not effect detection probabilities? Should some sort of program (such as DISTANCE) to correct for differences in the distance of the bird be used to convert detections into density estimates."

The evidence was overlooked by this reviewer; it appears earlier in this chapter. While it is possible (perhaps likely) that detection declines with distance to the bird, the "factor 16" correction includes this. We see no reason to change it.

"Finally, the confidence intervals and much of the arguments on the accuracy of the counts depend upon the use of a Poisson distribution. However, if the sparrows are patchily distributed can a Poisson distribution be invoked? I have yet to see actual territory maps or an analysis of the spatial distribution of sparrow territories. From comments in the report, I gather that such as analysis is in the works."

The Poisson distribution accepts that sparrows may live in patches, but it does require that the sparrow detections are statistically independent. (That is, there is nothing that prevents the expected value being (say) 5 detections per site or 2 detection per site, so long as the individual detections are not contingent. Were they to be contingent, then one would get too high a variance on repeated surveys. This is the point of the repeated survey analysis presented above. Were one to see (say) many locations were there were 10 birds on one count, then 0 on the next (and vice versa) then the Poisson assumption would not hold. This would be the case were birds to be in flocks. As the analysis shows, the numbers we encounter are entirely in accord with the Poisson assumption.

Reviewer 2

"The most exciting element of this chapter is the information on detection probabilities obtained by collecting census data on intensive study plots in which the population was known. One of the panel's primary recommendations with respect to research was to obtain such information. Even these initial results are interesting and informative. The overall detection probability was 0.58, whereas it has been assumed to be 1 previously."

Not so! The Poisson expectation is that the average number of detections matches the underlying true density. However, it recognises that (for instance) even when that true density is 1.0, no detections will be made in roughly 37% of the surveys. These omissions are counterbalanced by the times where more than one detection is made.

"Detection probability varied from 0 to 1.67 depending on observer, season, time of day, wind speed and population density. Knowing the effects of these factors will enable improvements in the census protocol, and indeed the authors suggest limiting counts to conditions meeting certain criteria based on their findings. Adhering to these criteria should reduce variance in detection probability and thereby enable more accurate population estimates."

We do indeed adhere to these criteria — and have already done so.

"The panel also recommended incorporating estimates of detection probability into the census, and using estimates of detection probability in calculating sampling error associated with population estimates. That detailed inferences about changes

in population were being made based on census data that lacked any variance estimate was a major issue in the panel review."

Again, this is not so. When we have made inferences, we have always assumed that the census data were Poisson distributed. For such data, the standard deviation equals the mean and so the standard error of the mean is the mean value divided by the square root of the sample size.

We disagree that the sampling error is our principal concern, in any case. What matters are the inferences we draw from them. Estimates with tiny sampling variances may not tell us anything of ecological interest — all populations fluctuate. Conversely, those with estimates greater statistical uncertainties may still be ecological informative when supplemental data are available.

"Perhaps data on detection probability are as yet too few, but still, it is disappointing that no attempt is made to determine the precision of the 2000 census data. Instead, the 2000 data are portrayed and discussed much like previous census data, despite the panel's criticism. Furthermore, two analyses are conducted to demonstrate the accuracy of the data, both of which the panel specifically discounted as useful approaches, replicate counts and application of the Poisson distribution. The panel noted that detection probability cannot be estimated well from replicate counts. The authors do not use their replicate counts for this purpose, but instead argue that consistency within replicates indicates that counts are accurate."

Our response contains two elements: an estimation of sampling variance (from the repeated surveys) and an estimation of detection probabilities. As explained in response to earlier comments, these have separate functions, ones this reviewer has misunderstood.

"The counts do not appear very consistent to me. For example, at the station at which the most birds (7) were detected during the first survey, none were detected during the second. As for use of the Poisson distribution, it addresses only one of the two components of sampling error (i.e., it does not address the component associated with detection probability), and even for this component it is better to use the actual distribution of count data rather than assume an underlying distribution (Walters et al. 2000)."

The reviewer's first comment is without any associated statement of probability. As explained in the analysis, across several hundred observations, the chance of seeing 0 birds on one count and 7 on the next, falls within broad expectations. Indeed, the example we provide could involve 0 birds being present on one count and 9 on the next.

"To provide just one example of the difficulties in interpreting count data in the absence of an estimate of variance, I turn to counts of population A in 1998, 1999 and 2000. The authors conclude from these data that population A has been constant in size during this period. However, the count in 1999 and 2000 was twice

that in 1998. Has population size changed? It is impossible to say without an estimate of sampling error."

Once again, we refer the reader to introductory statistics textbooks that would instruct him in how to calculate standard errors from Poisson distributed statistics. In this particular case, the answer depends largely on whether one expects the trend in numbers (in which case several years can be combined for inferences) or one must treat the samples without any prior inferences.

In response to this — and similar questions — this chapter now identifies each of the inferences we draw.

Reviewer 3

"The authors specify 2 quantities that they believed to have been of interest to the AOU committee: repeatability (consistency) and accuracy. I would have restated these as accuracy and precision, and I note that they are often combined into a statistic such as mean squared error that provides an excellent metric for evaluating estimator performance."

We are quite happy to call these repeatability and accuracy. The mean square error follows simply from the Poisson distribution assumption in the normal way.

"The exercise with the repeat counts for 2000 was difficult for me to follow, but I believe that the conclusion that emerges is that both counts can be described by a Poisson distribution with the same parameter. This would suggest similar detection probabilities for the two surveys if the population were closed between sampling periods."

Exactly so.

"That is nice, but a primary concern in the AOU review did not involve changes in detection probabilities within season, but from year to year and thus across water conditions. So I still believe it is important to try to incorporate efforts to estimate detection probability each year of the survey. Repeat surveys within a year are not useful for this purpose, and, in my opinion, the extra effort should instead be channeled into distance sampling, multiple observers, temporal removal modelling or some other approach for estimating the detection probabilities associated with point counts (the addendum to this chapter is yet another approach to detection probability estimation)."

As explained above, repeated surveys address one issue, estimation of detection probabilities quite another. The reviewers generally missed the efforts we expend in assuring that all the sampling is done by highly trained observers under optimal conditions. Simply, it is better to avoid differential corrections, than to estimate them.

"The discussion in the material addressing the question: "How complete is the survey?" includes the idea that underestimation of abundance is not necessarily a

problem in estimating rate of change. Certainly this is true, but the potential problem arises when detectability varies from year to year or from one set of environmental conditions to another. It is this year-to-year variation that is best dealt with by annual efforts to estimate detectability. In the absence of such estimation efforts, one must assume/hope that detection probability is constant over time, because temporal variation in detection probability will be confounded with true changes in abundance in the estimates of population change. This becomes especially important when changes in environmental conditions (e.g., water depths) are believed to influence true abundance but may also influence detectability."

We have no reason to expect that, under identical conditions, birds will be more difficult to detect singing in one year than another. There is a crucial point. Under conditions of high water, we rarely hear birds singing. That is because they are not singing, not because we do not detect them when they are. Why would birds sing when the only place for their nests is under a meter of water? What matters is not the number of birds alive in anyone year, but the number of birds that have the chance to breed. Our estimates are of breeding populations, not populations — as, in practice, are almost all estimates based on singing males.

"The addendum to this chapter was very interesting and goes directly to the kind of study that seems most relevant to me. It is clear that the author considered the AOU report recommendations seriously and designed a very interesting investigation of sources of variation in detection probability. Previous work using territory mapping suggests to me that this approach may not provide the best fix on "true" numbers of birds. Also, I am accustomed to estimating a detection probability that corresponds to the birds actually present at the time of the sampling (so you can't get estimates >1 unless you miscount), rather than one that includes a number of birds thought to "reside" in a sampled area. So I recommend considering other approaches for direct estimation of detectability."

Not so! Not only can one get estimates > 1, it is essential that one do so, in order for the Poisson distribution to work (see above). The reviewer's error here is to assume that observers and birds are completely fixed in space. Were this model to obtain, we would employ a binomial model, with p, the estimate of detection, given that a singing male is present. As explained, neither the surveyor is fixed (because of GPS considerations), nor are the birds fixed (they move around their territories). There will, indeed, be occasions when, by chance, birds will have arranged themselves closer to the observer than expected.

"Nevertheless, I like the basic approach of this work very much, and it may well turn out that use of territory mapping is the best that can be done. The results are not unexpected, as variation in detection probability was found to be associated with observers, time of day, wind speed, and true bird density. I believe that this kind of detailed work is excellent and that it should lead to the recommendation to try to estimate detectability directly every year of the survey (as opposed to the 2 alternatives of (1) hoping detection probability is the same every year, or (2) trying to identify every single factor that may influence detectability and to then control for

these factors or include them as covariates or develop models for them). Whether this estimation involves territory mapping, distance sampling, multiple observers, temporal removal, or another approach is best determined by those involved in the work.

Finally, I note that chapter 5 did not include an effort to estimate the variances of the population estimates. As noted in the initial AOU report, such estimates should include the components of variation associated with the estimation of detectability and the spatial variation in counts of animals. The previously noted asymmetry of effort devoted to data collection and analysis is worth mention again. The field work that went into this report was very expensive of time, effort, and real dollars, and such an effort should produce results that are accompanied by the standard measures of statistical precision. Such measures are not statistical fine points as they provide the information needed to permit the user to judge strength of inference. Thus, as a reader, I am provided no guidance about how seriously to view the estimates presented in Table 2, as my interpretation should be determined almost entirely by my understanding of the possible sources of bias (e.g., the manner in which detectability was incorporated) and by the associated measures of sampling variation (these are absent from this report)."

This reviewer's comment about "no guidance" suggests he misunderstands our statistical model. Once the Poisson sampling is established, the sampling variance follows in obvious ways that are explained in basic statistics books. However, we once again stress that the estimates of variance are means to an end and not one in themselves.

Chapter 9

The landscape and its ecosystems

Stuart L. Pimm and Clinton N. Jenkins

Abstract

This brief chapter introduces the landscapes in which the sparrows live and presents an extended series of satellite images for discussion elsewhere in the text.

Introduction

This brief chapter introduces the landscapes in which the sparrows live. Figure i shows where we counted sparrows between 1981 and 2006. Figure ii is a false-colour image of a larger area of south Florida that the sparrow occupies, but containing areas that determine its fate. Figure iii is a selection of the map supplied by Everglades National Park covering the relevant areas. Comparison of the former to Figure i readily shows that the areas in light yellow correspond closely, if not exactly, to the places where the sparrow nests.

The primary drainage in the southern Everglades is Shark River Slough. To the west lies the higher ground of the Big Cypress National Preserve and, to the east, the Atlantic coastal ridge. On either side of the Slough are expanses of marl prairie stretching from both sides of the slough's main drainage to these two modest ridges. These prairies are inundated seasonally with the overflow from the slough; historically, from 3 to 7 months per year (Olmsted et al., 1980). These prairies are the particular ecosystem on which the Cape Sable seaside-sparrow depends.

Defining this to the north is a series of striking rectangular shares, bordered on the south by an east-west line that is a road, Tamiami Trail. The S12s are structures that control the water flow from Water Conservation Areas (WCA) to the north. WCA3A and WCA3B form a square, with a pair of levees, the L67s, cutting off the southeast corner, to form WCA3B.

Figures i, ii, and iii and those that follow succinctly summarises much of what is wrong with the Everglades. With hubris, exceptional even for them, the Army Corps of Engineers, have moved the natural flow of water. It was from WCA3A to WCA3B and thence into the northeastern portion of Shark River Slough of Everglades National Park. Tamiami Trail forms a dam and water can only flow into the areas to the south across the S12s. Moreover, the images that follow clearly shows how wet is WCA3A and, generally, how almost completely dry is WCA3B. The 67s are an effective barrier — there are two of them and there was essentially no way for water

to flow across the eastern portion of Tamiami Trail. A very small, long-awaited bridge was opened in 2013.

As we shall see, not content with moving the famous “River of Grass” substantially to the west, the Army Corps also attempted to make it flow at the wrong time of year.

The larger of the two prairies is flanked by the slough’s eastern edge. It spreads southeast, encompassing the southern end of the Atlantic coastal ridge. It ends at the thin line of mangroves along the northeastern shore of Florida Bay. To the north, the marl prairies once extended in a long arm to central Broward County (Davis, 1943).

Over the last half-century, drainage and development has caused major changes in the vegetation and hydrology of the southern Everglades (Robertson and Frederick, 1994). Of the region’s ecosystems, the marl prairies may have suffered the most: there were once much greater expanses (Davis, 1943). Davis *et al.* (1994) estimate that their spatial coverage has decreased 24% since pre-drainage. Changes in hydrology affect what remains.

The pre-drainage Everglades system was inundated for longer periods and overland flow occurred across a broader expanse than at present (Fennema *et al.,* 1994). Currently, nearly all overland flow in the Shark River Slough drainage originates from the four S-l2 gated spillways at the northern boundary of Everglades National Park (Fennema *et al.,* 1994). In the past, most overland flow occurred toward the eastern edge of Shark River Slough. The S-l2 structures, however, are on the western edge — above and to the left of the words “Shark Valley Visitor’s Center” on the Park map. They permit flow across Tamiami trail, a road and associated barrier, that runs east-west across the map. To the north of Tamiami Trail are the Water Conservation Areas —3A to the west and 3B to the east.

Moreover, a barrier runs southwards from the Park’s northern boundary to restrict the flow of water from the west to the east. (This is the L-67 extension and is also visible in the satellite images.)

These changes mean that the eastern prairies are now flooded less often than under natural conditions. Furthermore, beginning in the late 1940s the federal government constructed an extensive series of canals obvious as usually red lines on the satellite images. These canals permitted the conversion of the eastern portion of prairies to residential and agricultural lands. Much of the remaining prairie, at and around the eastern boundary of Everglades National Park, is subject to over-drainage as a consequence. The consequences of this over-drainage may include woody shrub invasion (including exotic species such as *Melaleuca quinquenervia)* and an increased frequency of fires, which we will discuss later.

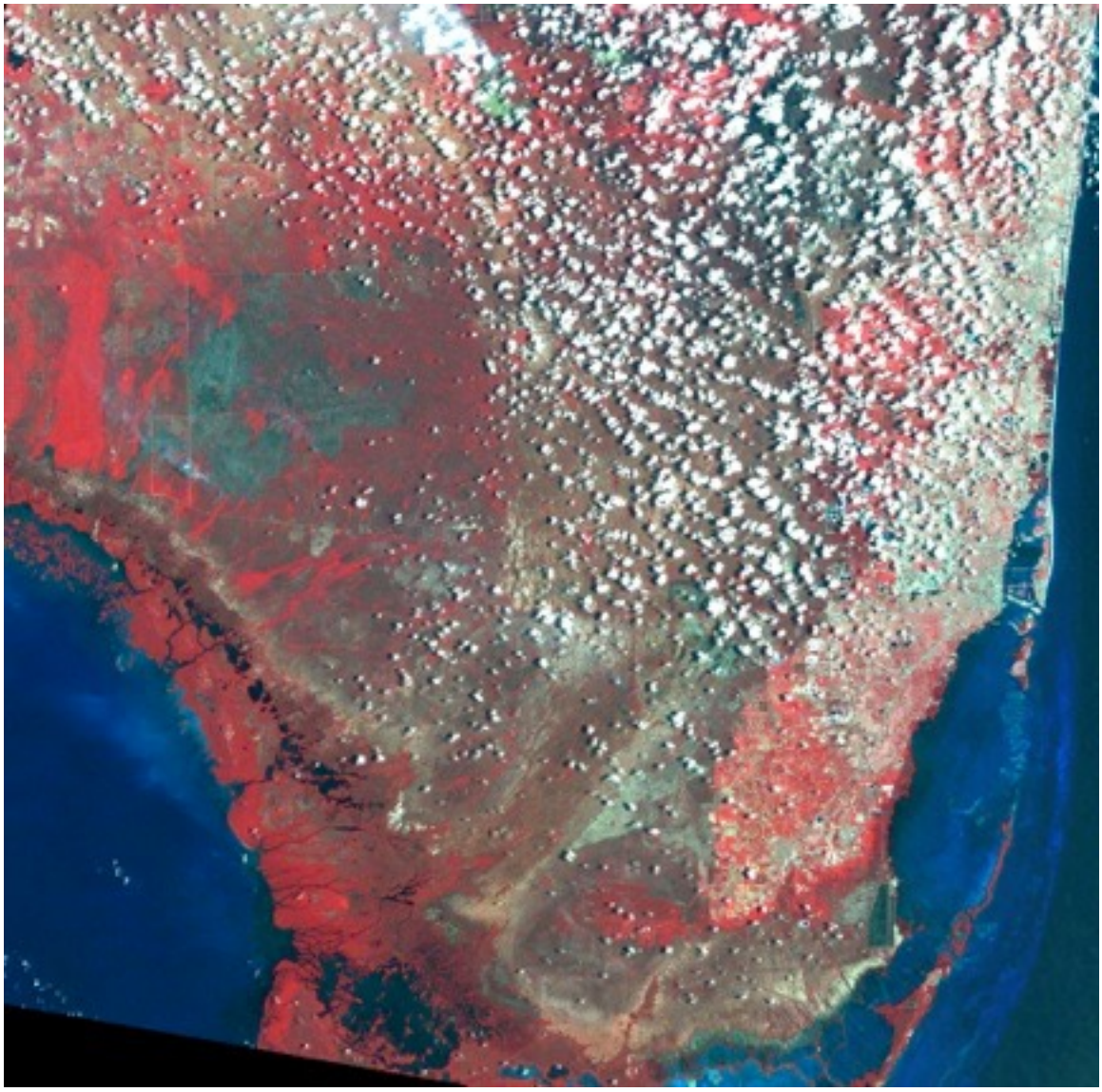
Depriving the prairies east of the Slough of its water simultaneously means adding that water to the prairies to the west. These are now subject to the vagaries of water releases from the S-l2 structures that we discuss in the companion paper.

In sum, the sparrow's habitat is greatly reduced and much of the unconverted areas is currently over-drained or fragmented. Half a century of anthropogenic changes has not protected the ecosystem on which the Cape Sable seaside-sparrow depends. It remains for us to determine the extent to which management practices have affected the remaining prairies.

What the satellite images show

The images that follow reveal rich details in the natural history of the Everglades and the factors that threaten it. The first four images,1981, 1989, 1990, and 1991, cover a wider area than the ones that follow, which concentrate on Everglades National Park and Big Cypress National Preserve. Different satellites are involved in the earlier images and this alters the colour balance to some extent. The data below some images, indicate the height in feet at two monitoring stations, P34 and NP204 which will play a key role in discussion of later chapters. For convenience, we will refer to each figure by its date

Earth observations of southern Florida and the Everglades



May 18, 1981 (A close up on this image appears below)

P34	-0.41	NP205	2.69

We discuss the detail of this image below.



Landsat TM – May 21, 1989 (A close up on this image appears below)

P34 0.99 NP205 2.97

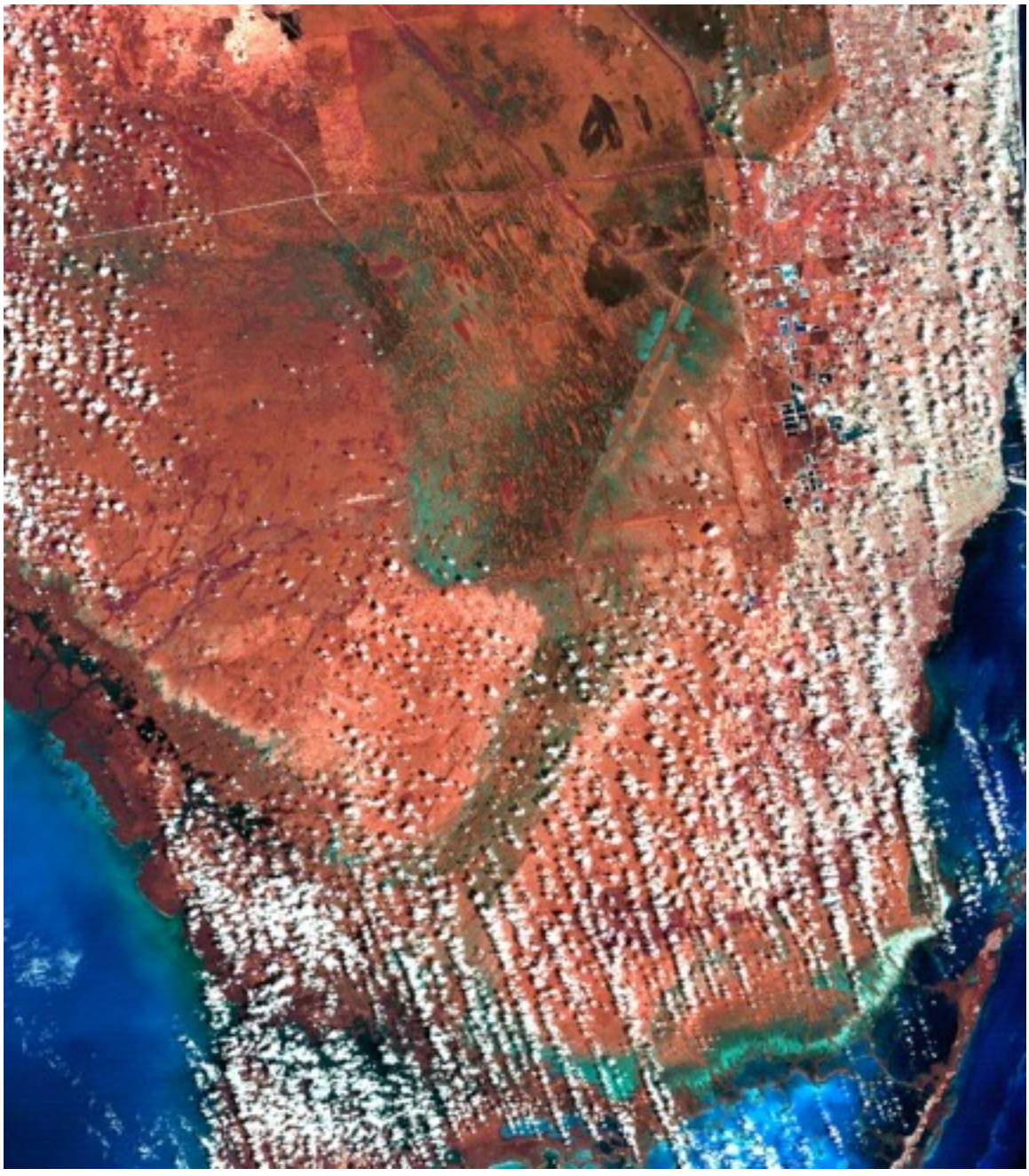
1989 is another particularly dry year. The only areas of standing water are in the southwest corner of Water Conservation Area 3A north of the park, and much further north at the southern end of Water Conservation Area 1A. We discuss this image in more detail below.



Landsat TM – April 06, 1990 (A close up on this image appears below)

P34	0.46	NP205	3.02

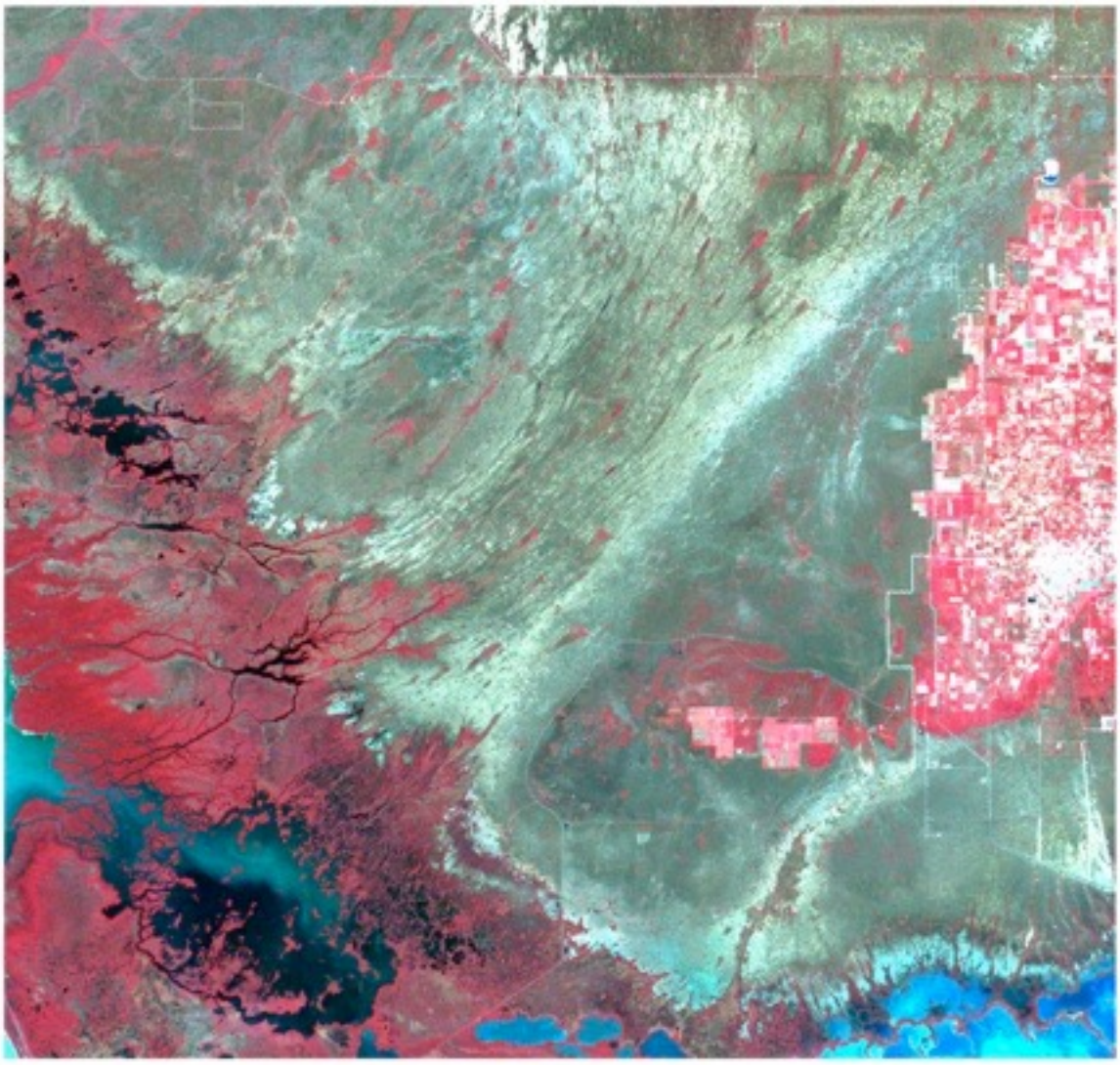
1990 is yet another dry year, one where there is more water in Water Conservation Area 3A, which is well defined by the water it contains. To its east, Water Conservation Area 3B is almost completely dry. The dark red streaks are the forests of tree islands and this image clearly shows that the natural flow path of water would be from 3A to 3B and thence into the north-eastern part of Shark River Slough within Everglades National Park.



Landsat TM – March 08, 1991

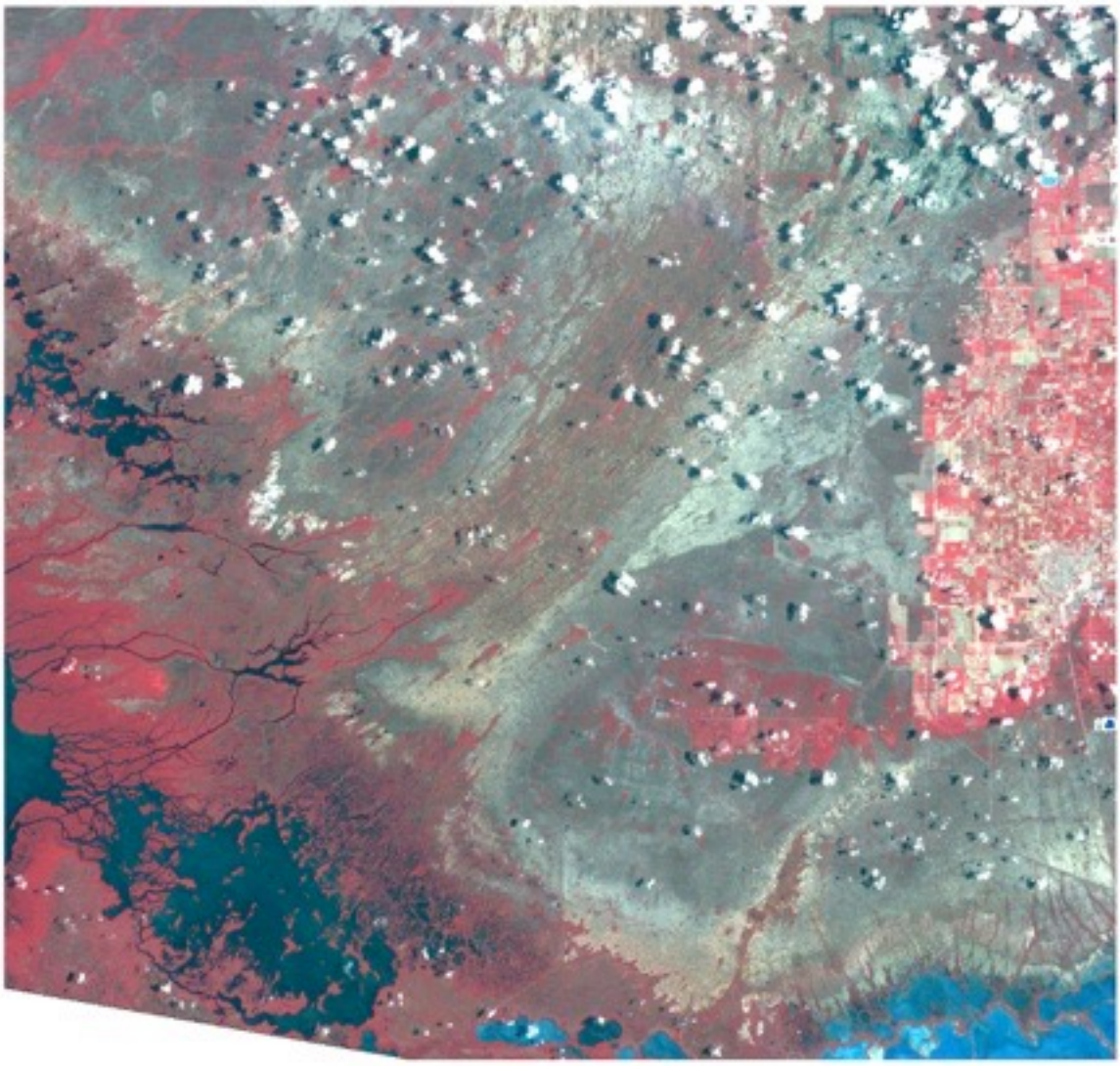
P34	0.83	NP205	3.82

1991 is an image taken earlier in the year than previous ones, with the expectation that there would be more water in the system. Water Conservation Area 3A clearly has more water than 3B, but Shark River Slough shows clearly in the image from the water it contains.



March 22, 1973

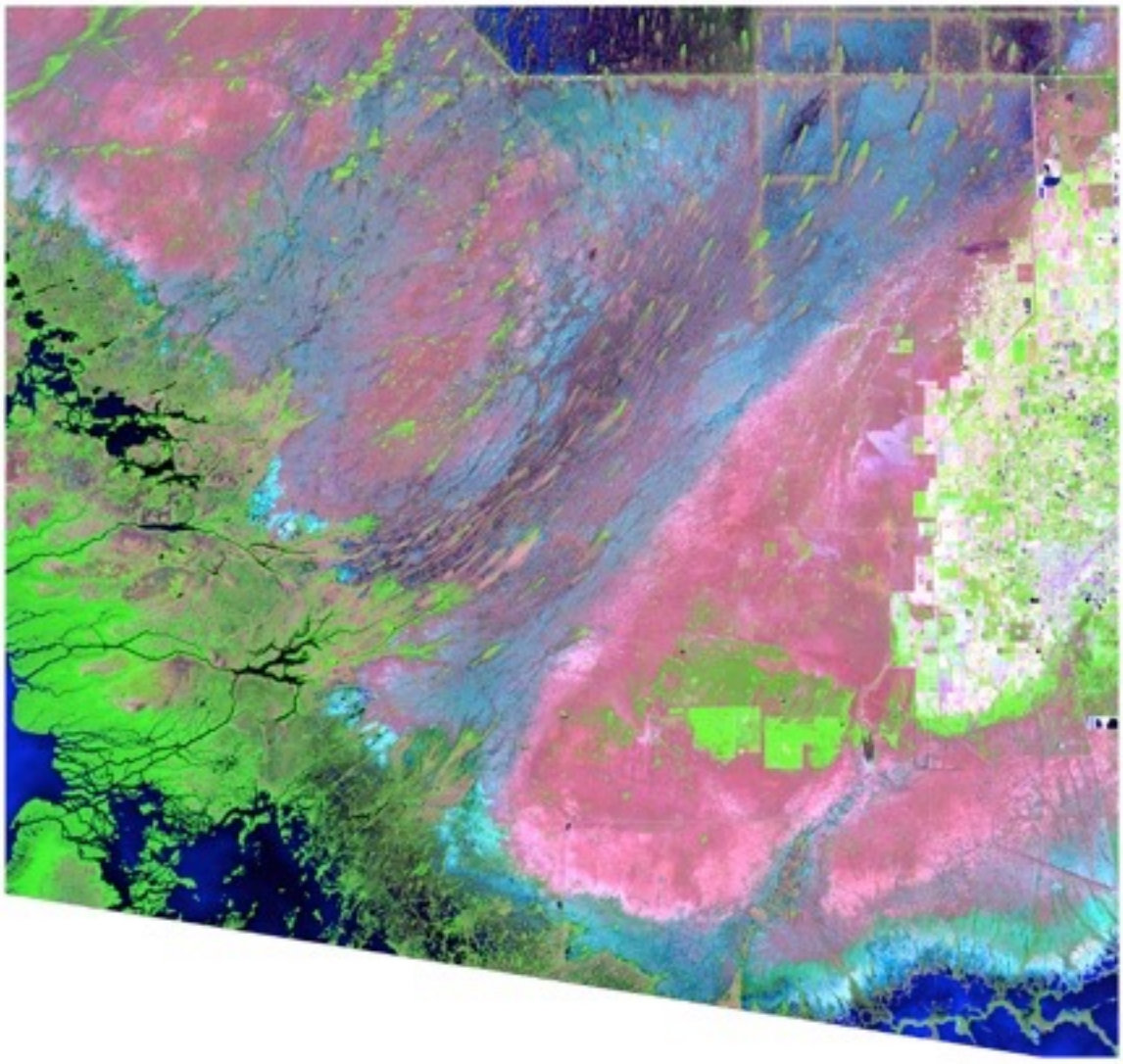
This is the earliest image we can find. The false colours show vegetation in dark red, while the prairies are in shades of grey. In the centre of Everglades National Park are pale pink squares — crops within an inholding that was eventually acquired by the Park. However, *Schinus* quickly reclaimed these areas and a massive restoration followed as a consequence of this unfortunate neglext.



May 18, 1981

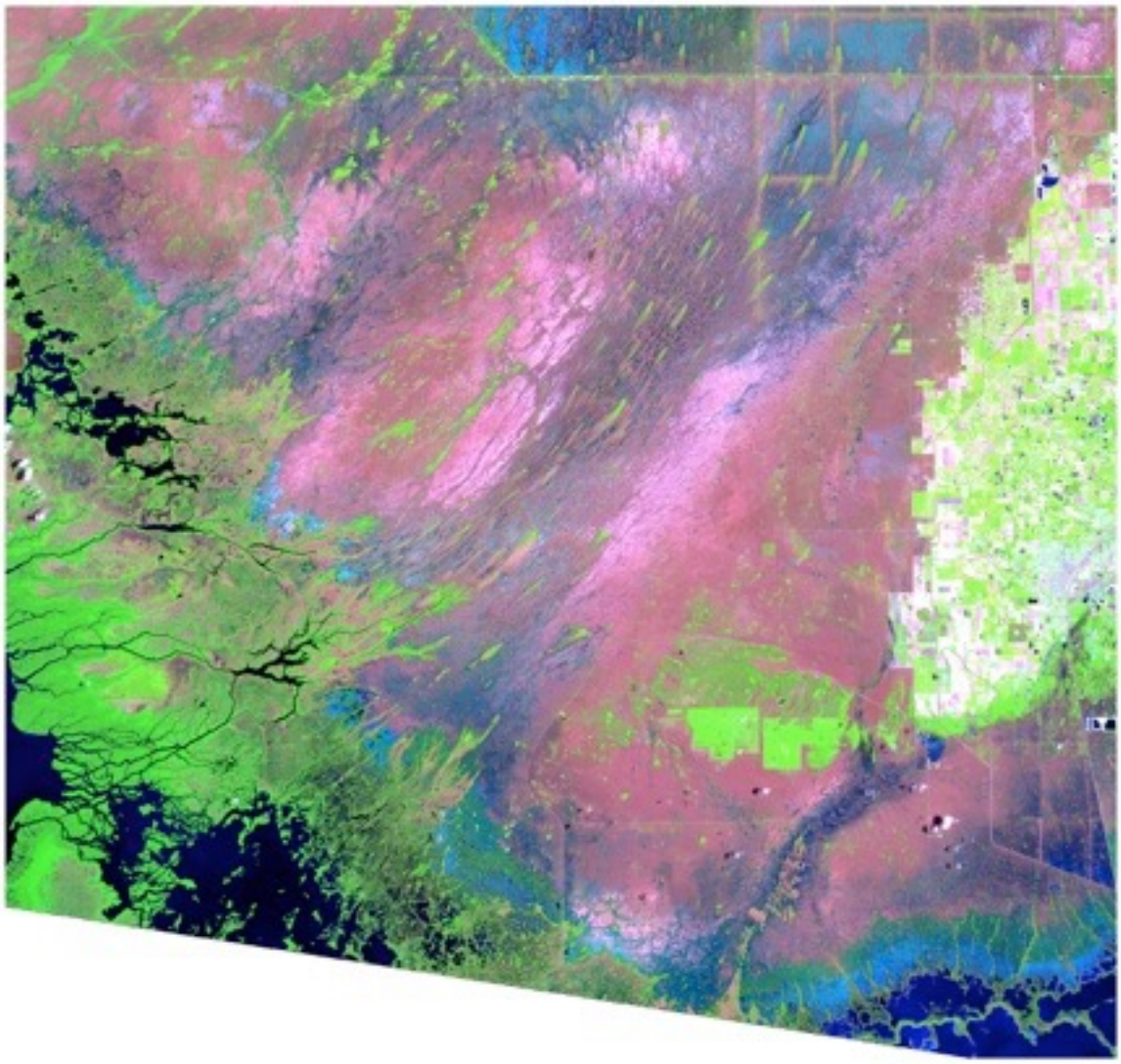
P34	-0.41	NP205	2.69

This is the year of the first sparrow survey. This was a particularly dry year and there are no extensive areas of open water within the park. The marl prairies show in brown and there is a large, triangle of pale buff, where population E is located (see figure i) that is a large fire scar.



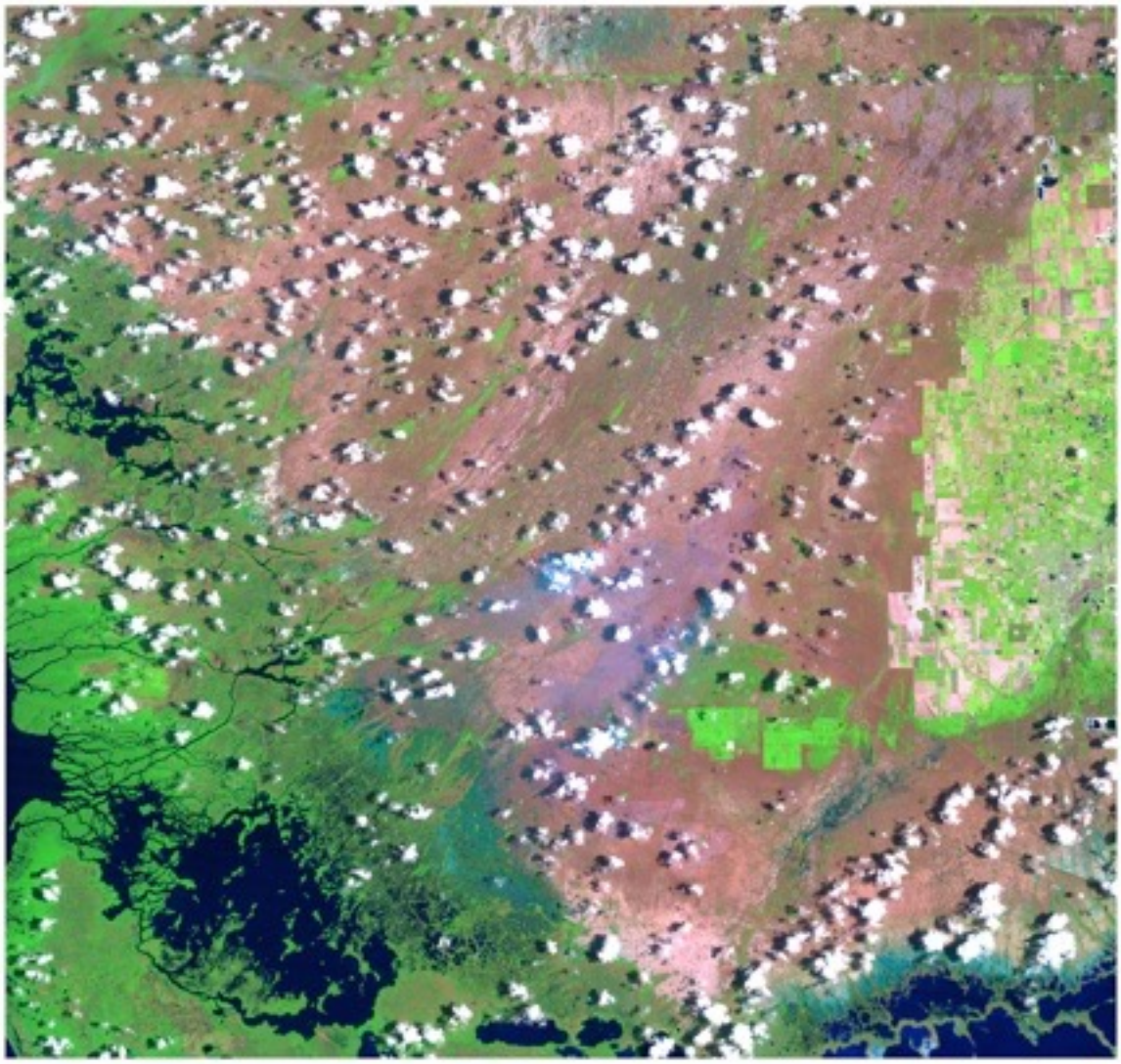
March 15, 1988

The sparrow habitat shows as pink, contrasting the blue of flooded areas. Even this early in the year, there are extensive areas of habitat west of Shark River Slough. WCA3A is deep blue, indicating deep water, but northeast Shark Slough is relatively wetter (bluer) than areas to its west.



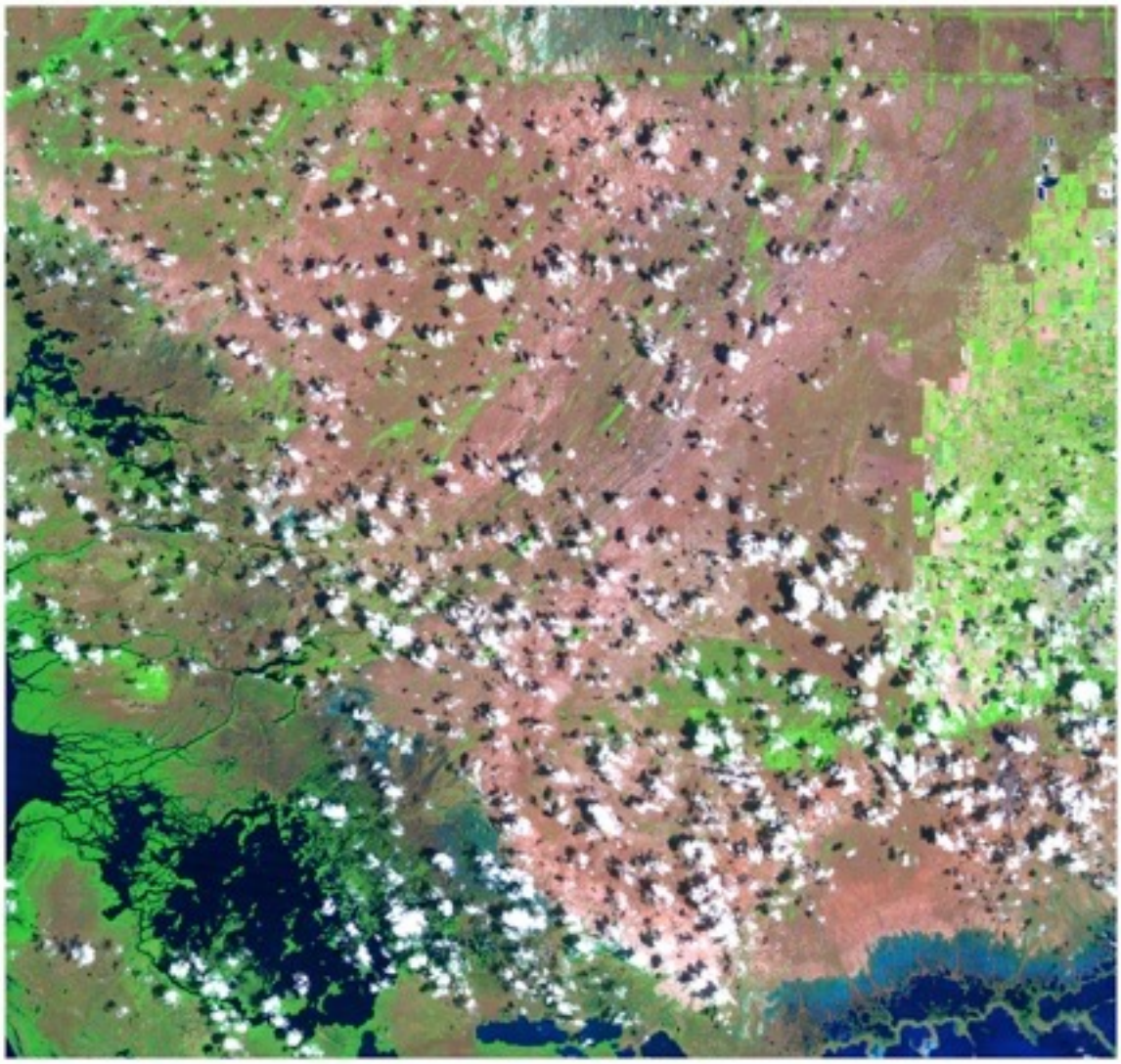
June 3, 1988

A image from late in the breeding season still shows extensive sparrow habitat (pink areas) west of Shark River Slough. Population D in the southeast corner is almost completely flooded.



May 21, 1989

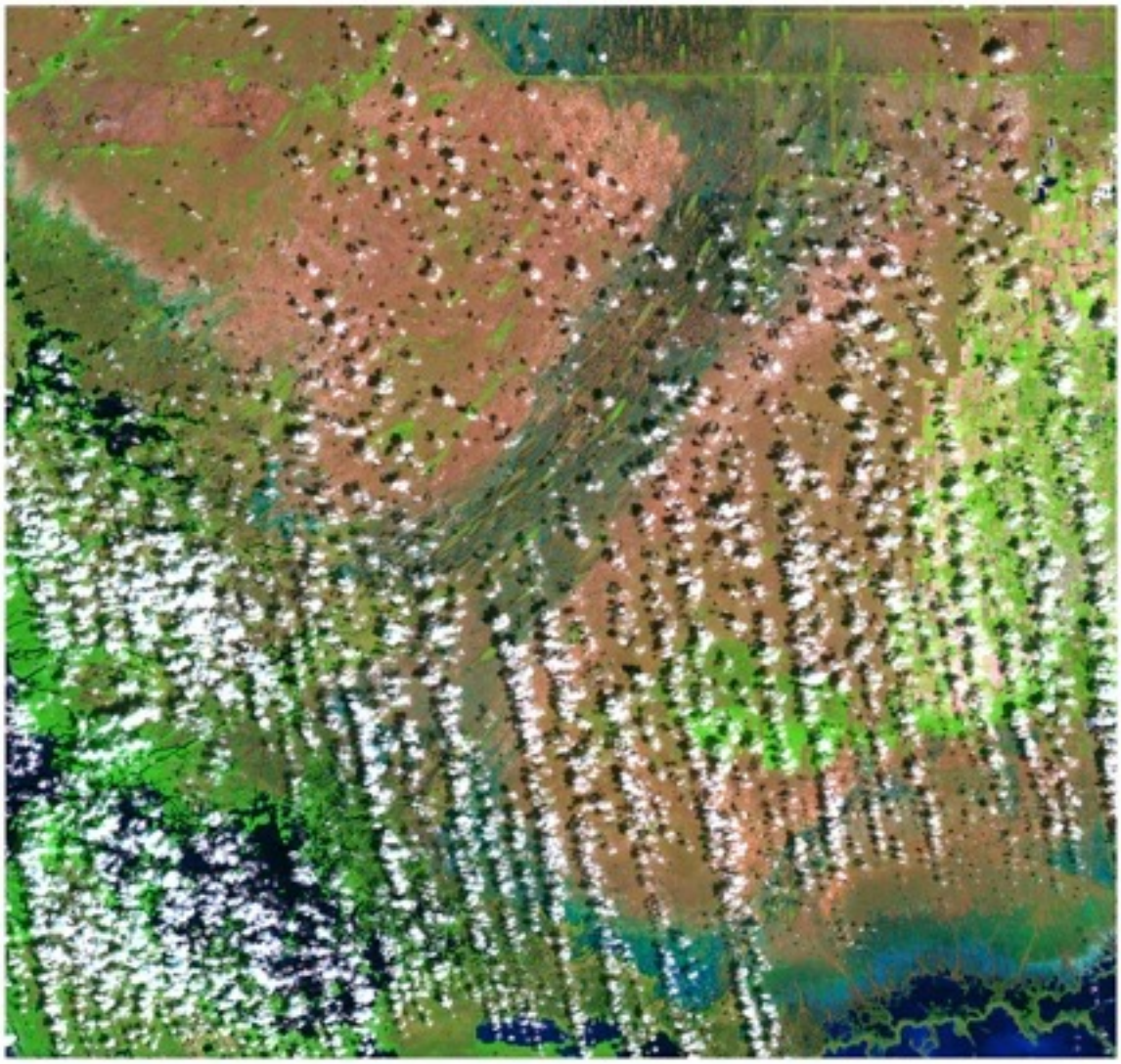
A very dry image, with almost no standing water. In the park itself, there is pale blue haze in addition to the obvious cumulus cloud. It is smoke and the start of a massive fire that burned larges areas of the park in 1989.



April 6, 1990

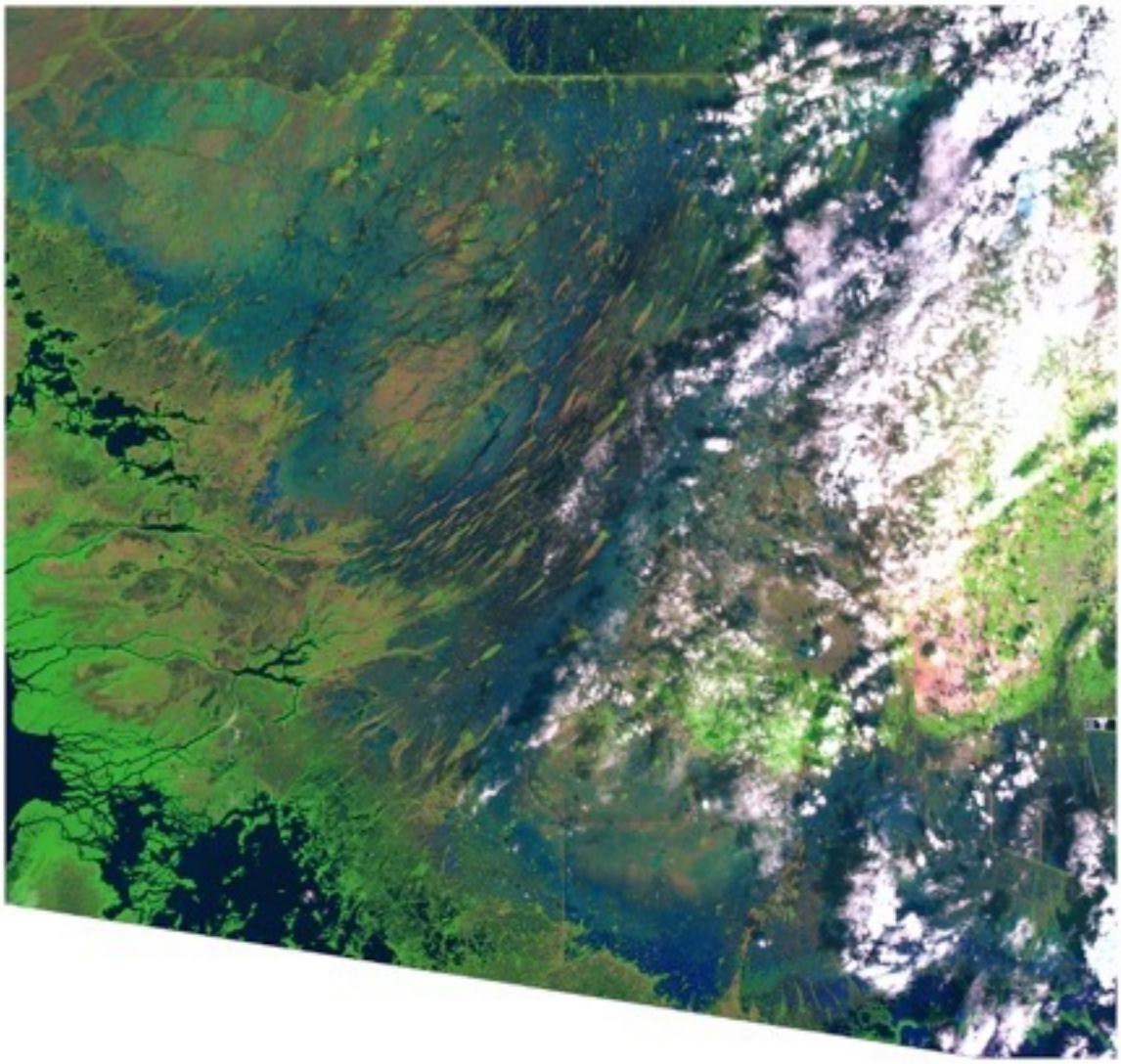
P34	0.46	NP205	3.02

Another very dry image, with no obvious standing water.



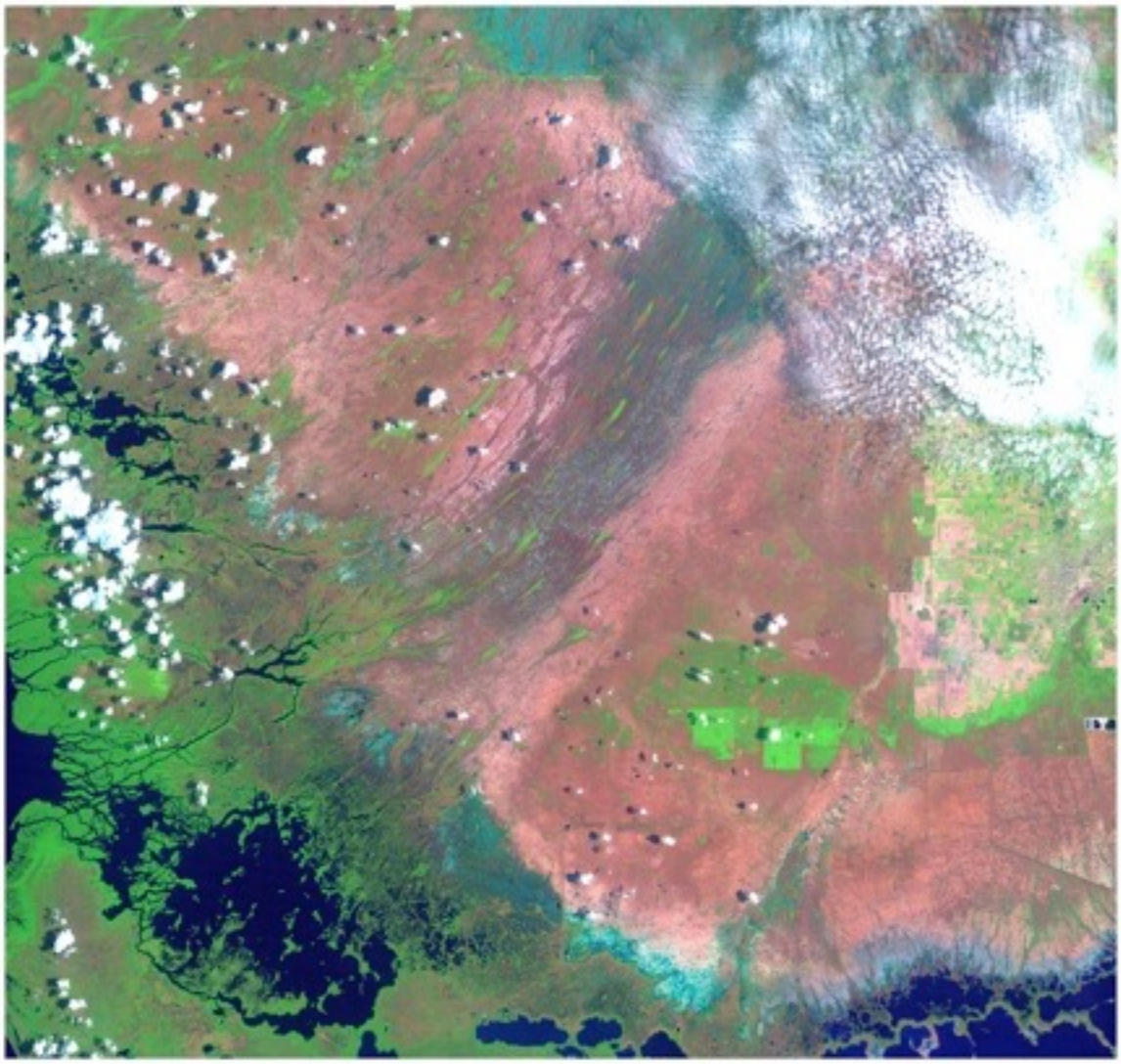
March 8, 1991

A wetter image than the previous two years, with water in Shark River Slough. The breeding areas west of the Slough are clearly dry, however, and would have afforded a long breeding season for the birds there.



October 17, 1991

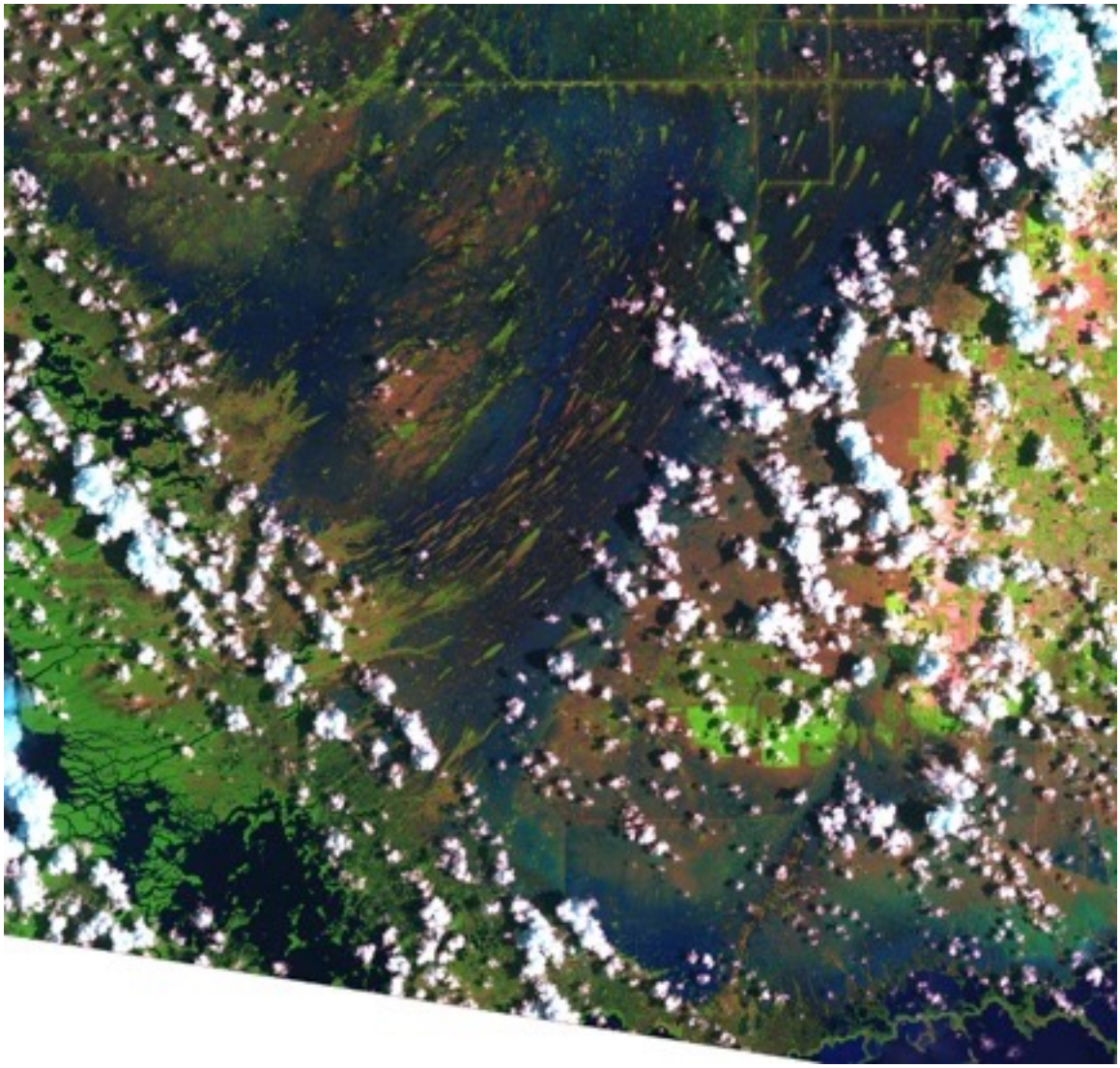
This is a wet season image that provides an interesting contrast to the dry season images shown previously.



May 13, 1992

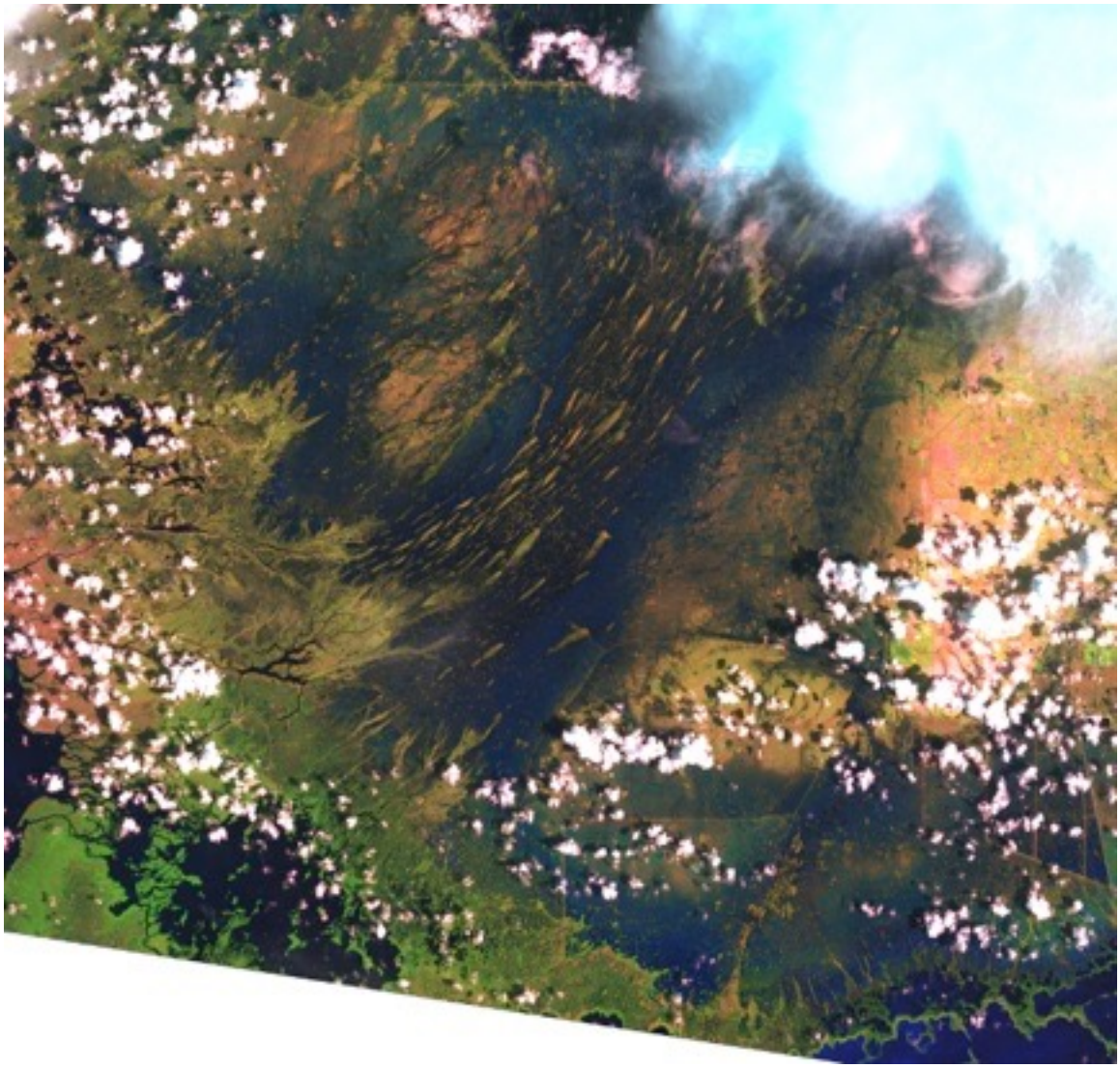
P34	-0.04	NP205	5.07

This is the year of the second sparrow survey. There are extensive dry areas across the region.



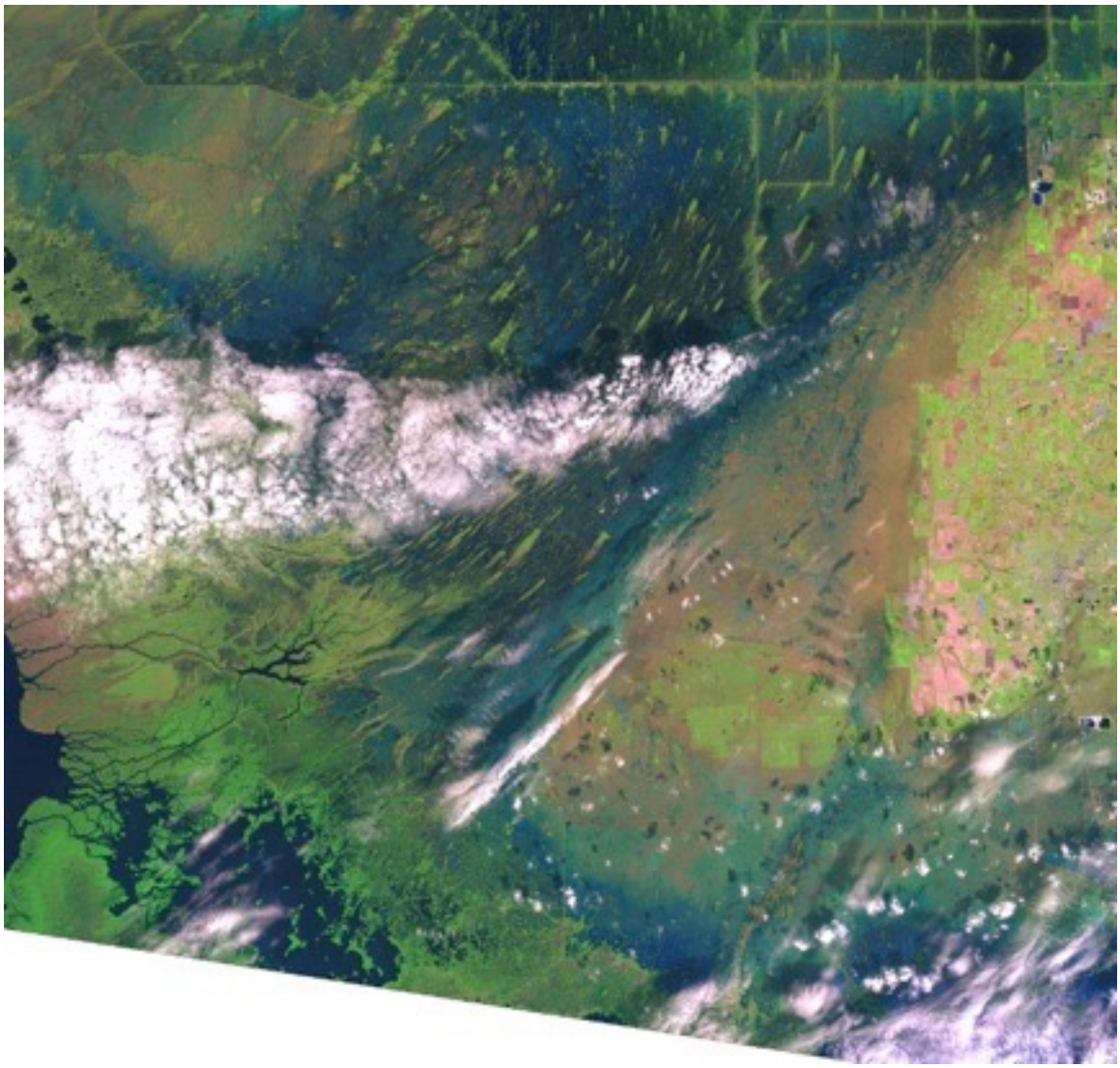
August 17, 1992

This early wet season image is just before Hurricane Andrew, which made landfall on August 24th. As one expect for this time of year, much of the region is flooded.



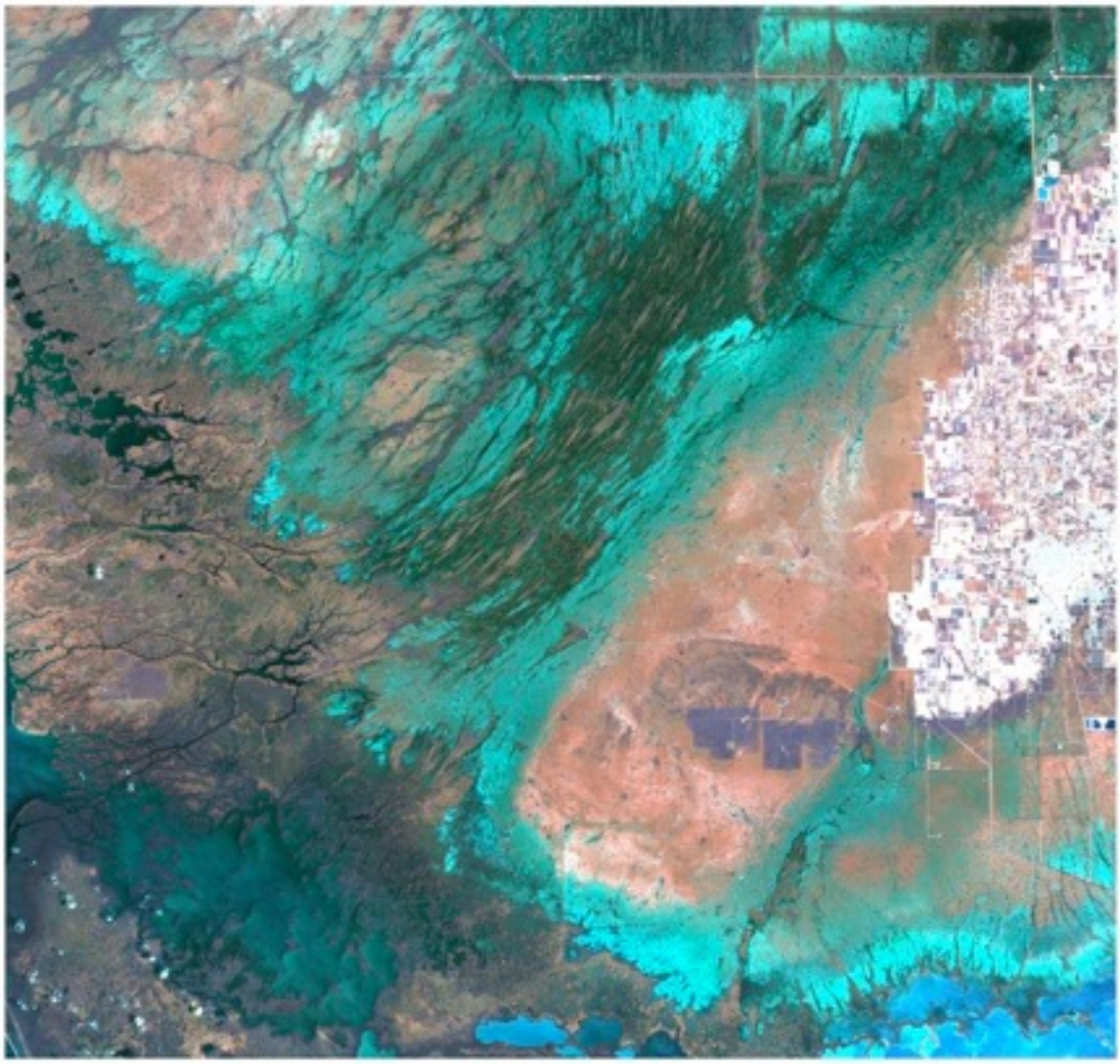
September, 2nd, 1992

Taken just after Hurricane Andrew, this extraordinary image shows most of the region in browns that reflect the near complete defoliation of the trees. Only an east-west strip across the south is green. These mangroves were south of eye wall.



October 20th, 1992

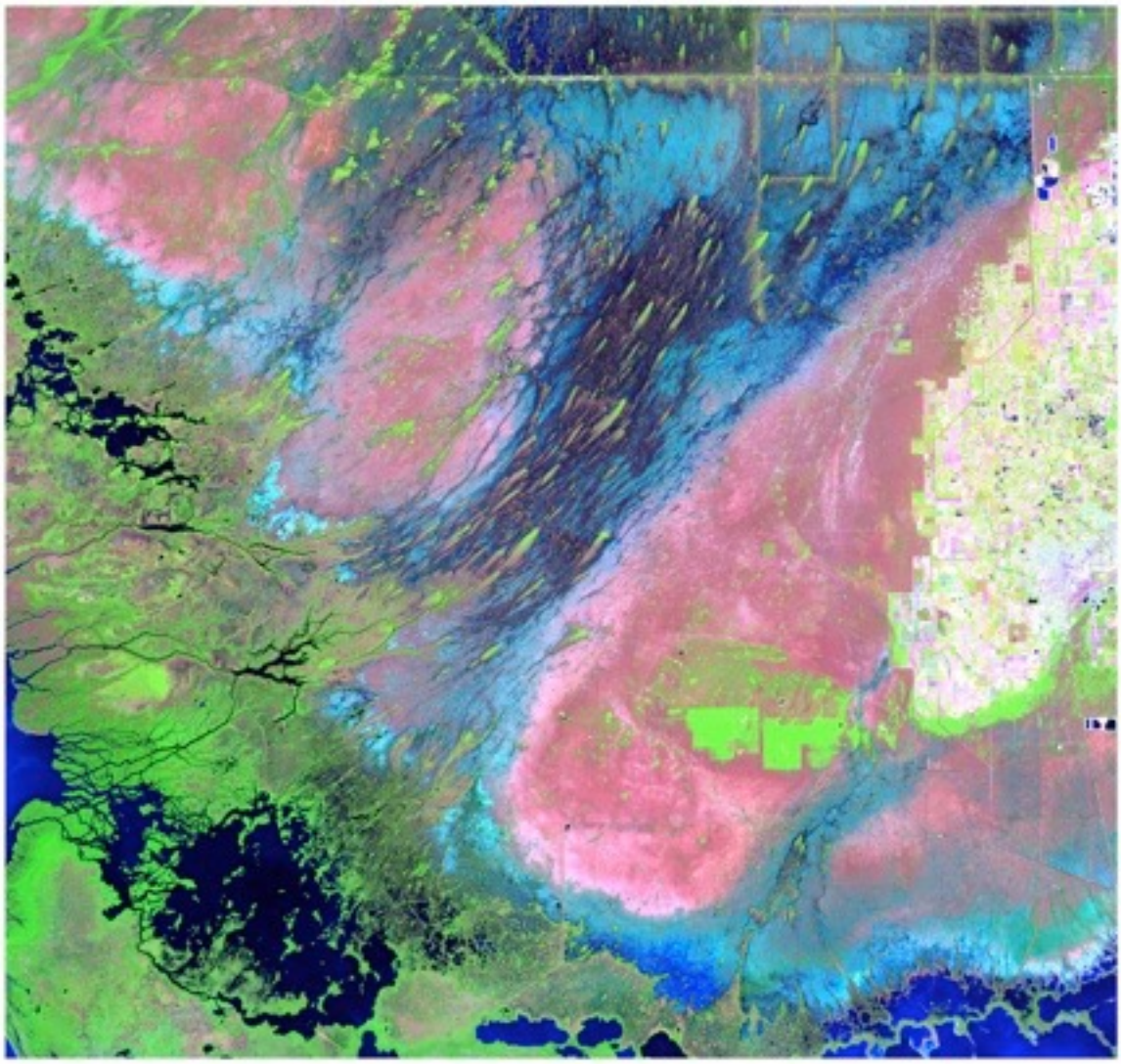
Two months after Hurricane Andrew, most of the trees had regained their leaves. An area of mangrove in the far west is still brown, however, in contrast to areas to the south.



April 14, 1993

P34 NP205 6.8

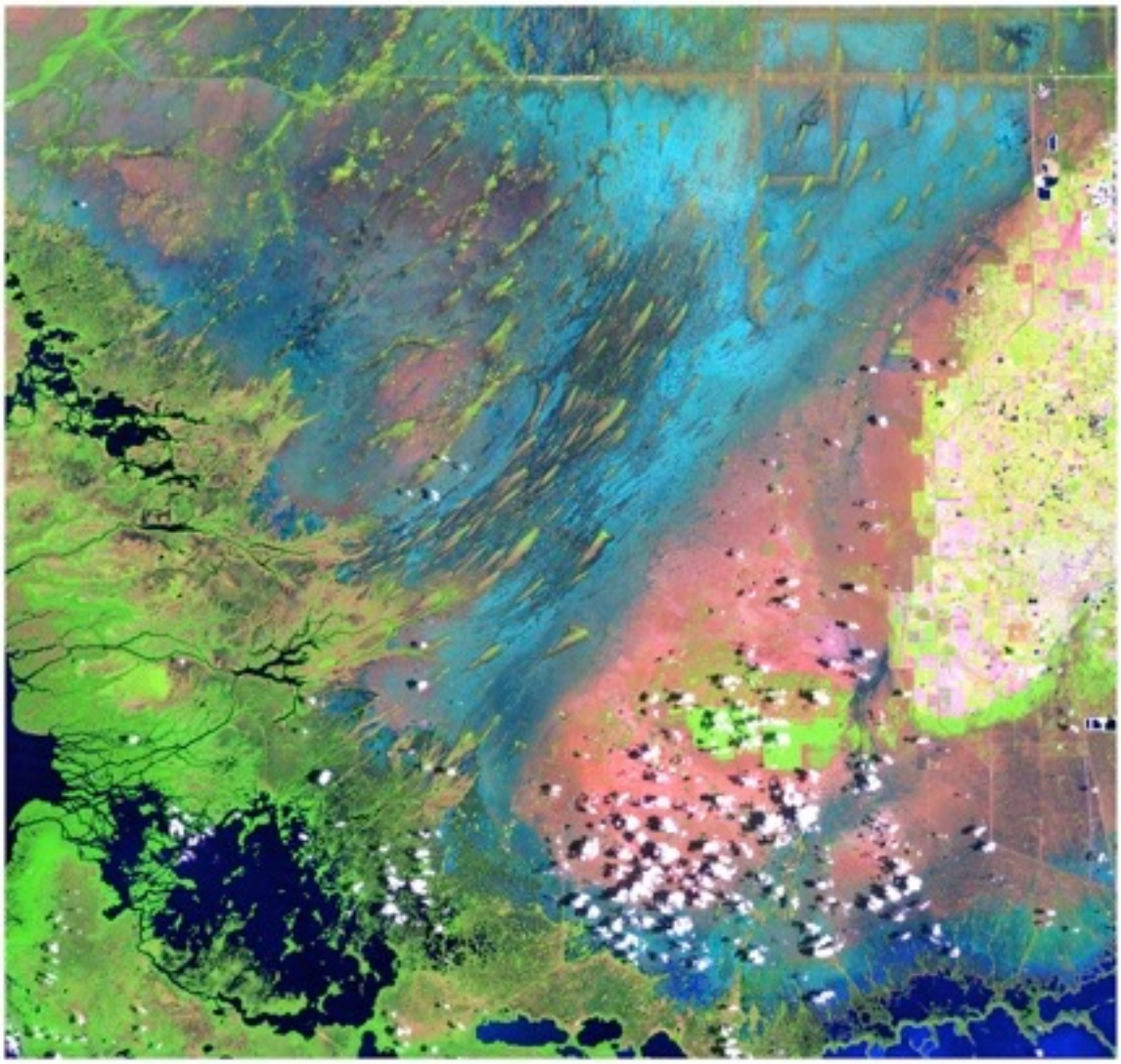
This is a different colour mix, to other images. Even so, 1993 is strikingly different from the previous images. Most obviously, there is very much more water and the previously dry areaswest of Shark River Slough are inundated. This had disastrous consequences to the sparrows and the survey results of the previous chapter testify. Taylor Slough, a smaller drainage, running slightly west of south in the southeast corner of the image is clearly visible in this image. The purplish coloured squares represent dense stands of the invasive tree *Shinus*. Restoration of these areas is visible on later images.



April 01, 1994

P34	1.74	NP205	6.36

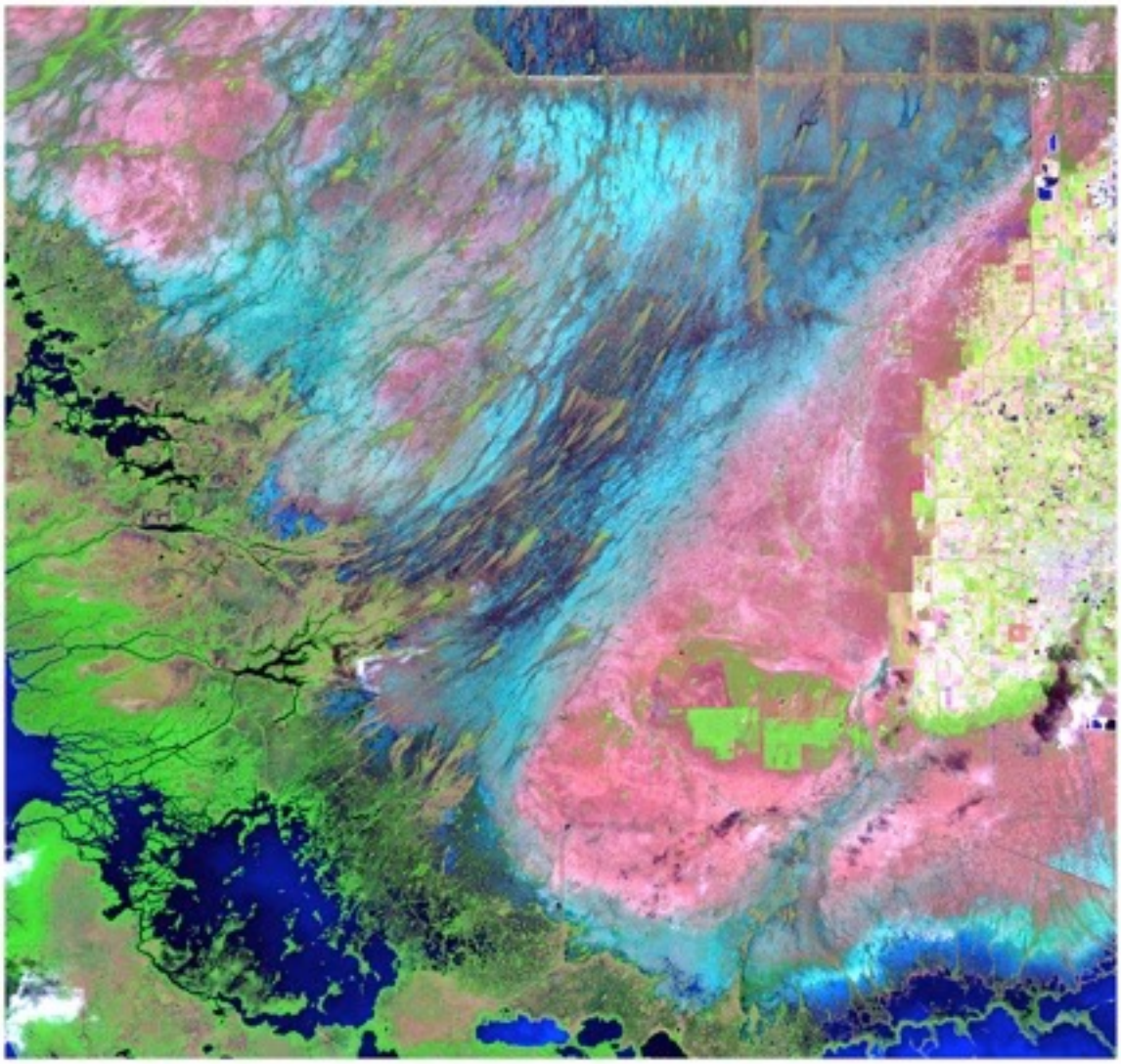
Again, a very wet image. Breeding season water releases across the S12s, were to make it even wetter in the weeks to follow. The areas of population D in the far southeast corner are flooded.



May 06, 1995

P34	3.59	NP205	6.94

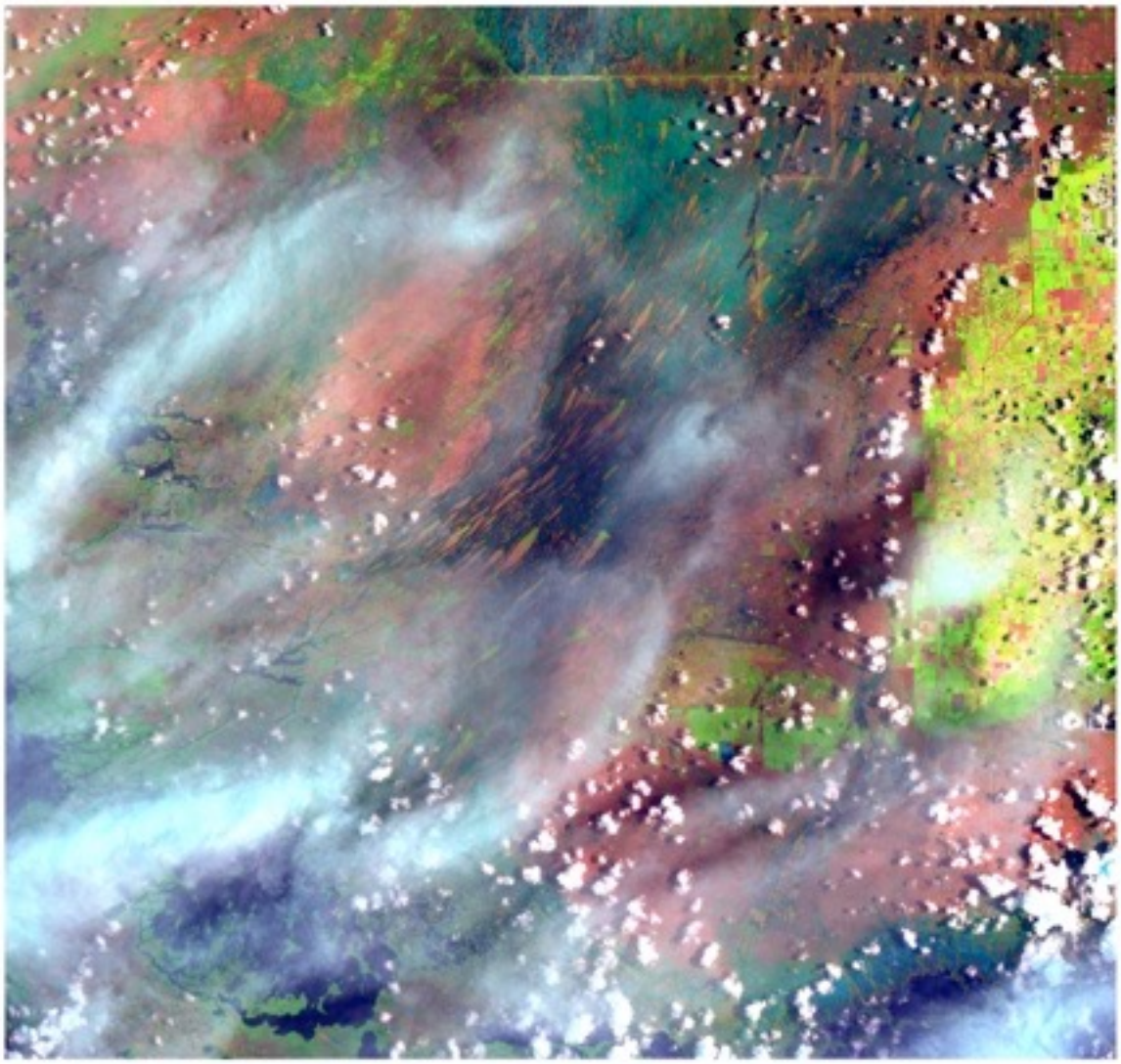
1995 was exceptionally wet, especially given that this was so late in the spring — May 6th. In these very wet images, the alignment of the tree islands — green streaks amid the blue water — is particularly clear. Their alignment indicates the natural water flow, clearly from the northeast in this image.



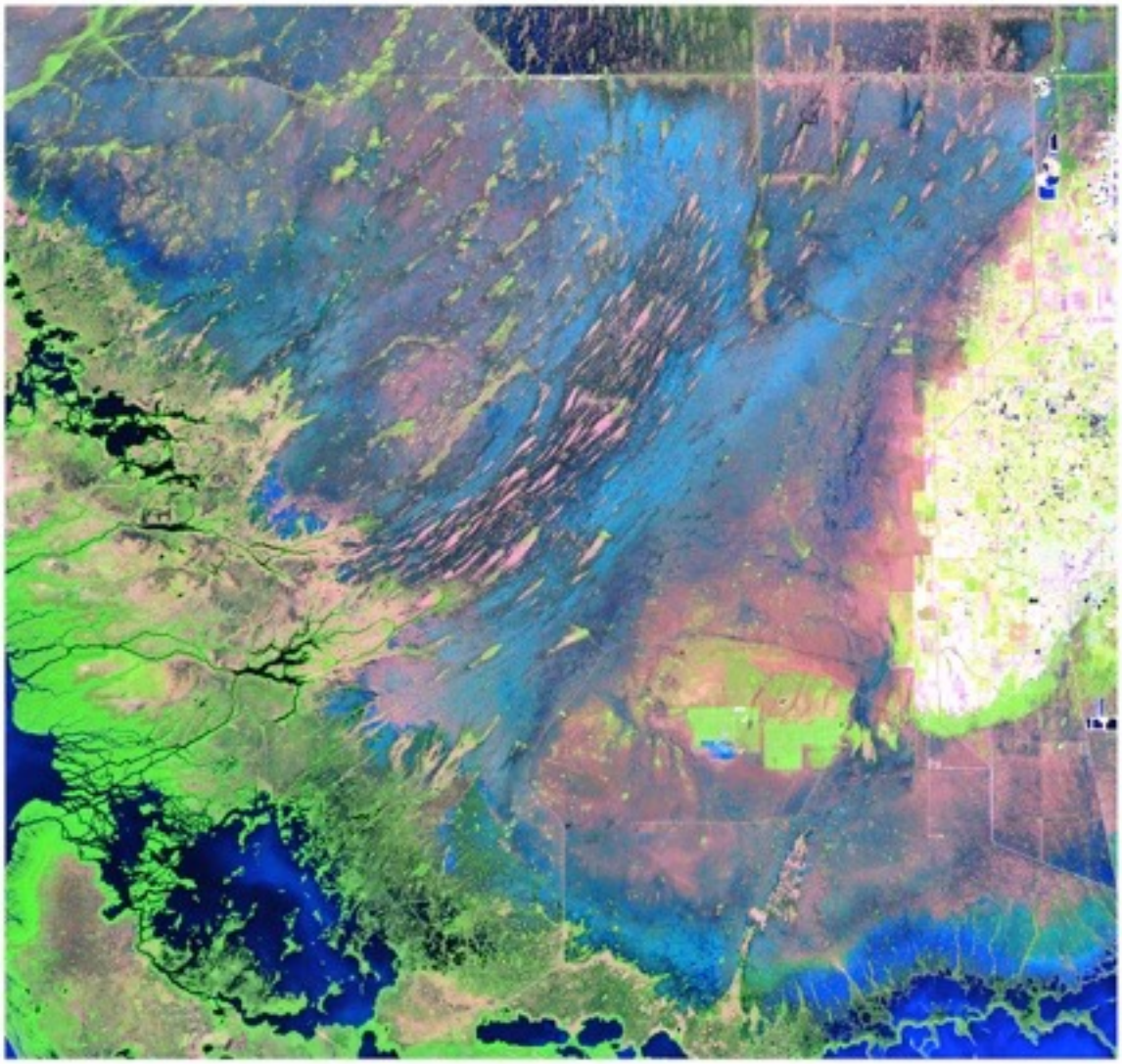
March 21, 1996

P34	2.7	NP205	6.44

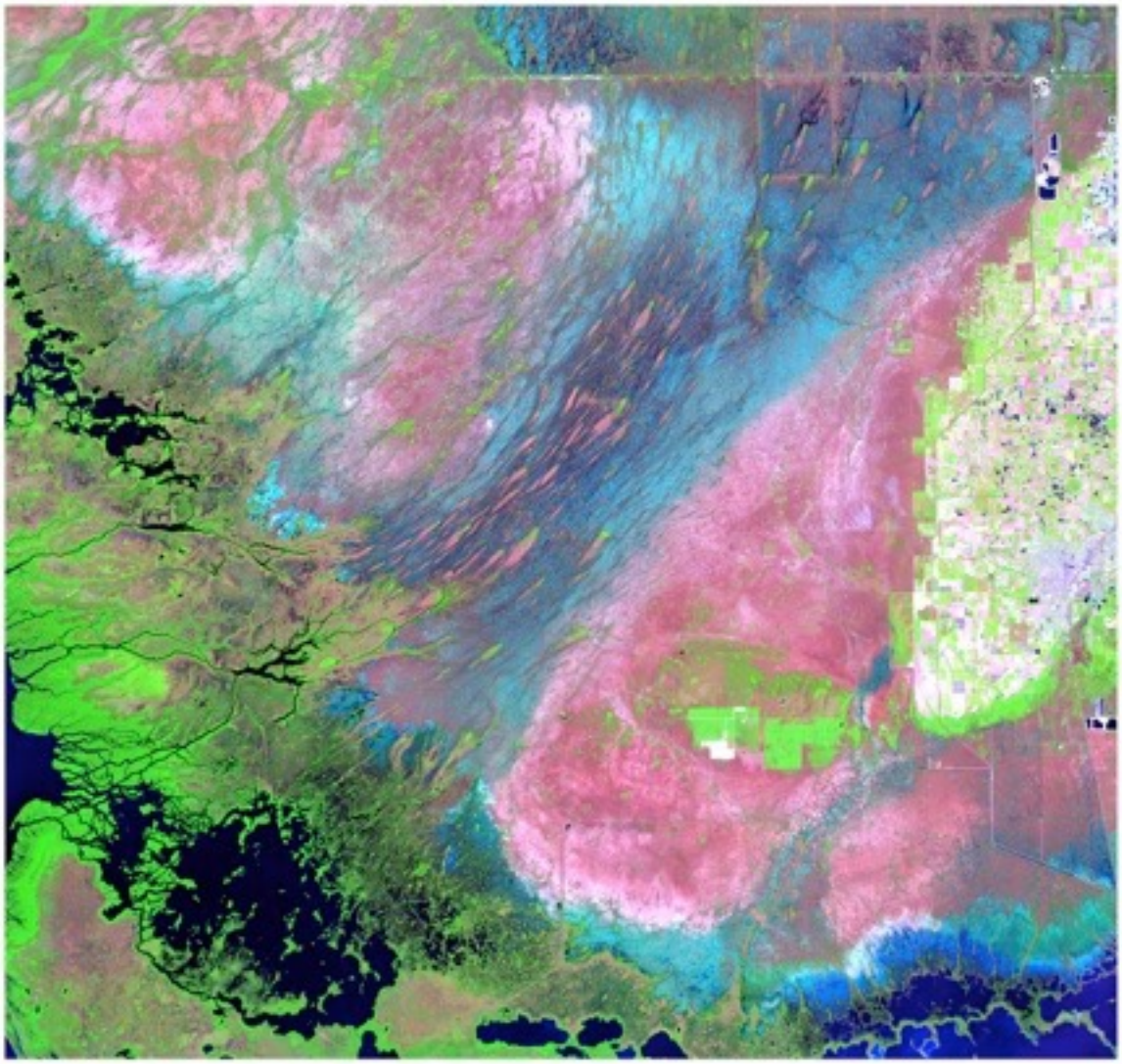
1996 is another wet image. Of particularly note, is that the water depth of NP205 (6.44 feet) is only just above what it was in 1994, (6.36 feet) yet the area of pink — dry prairie — is very much reduced. Field observations during the sparrow survey showed that all that remained of once extensive marl prairies was mud and periphyton — almost certainly the consequence of continuous flooding of this habitat from late summer 1992 until 1996.



May 27, 1997

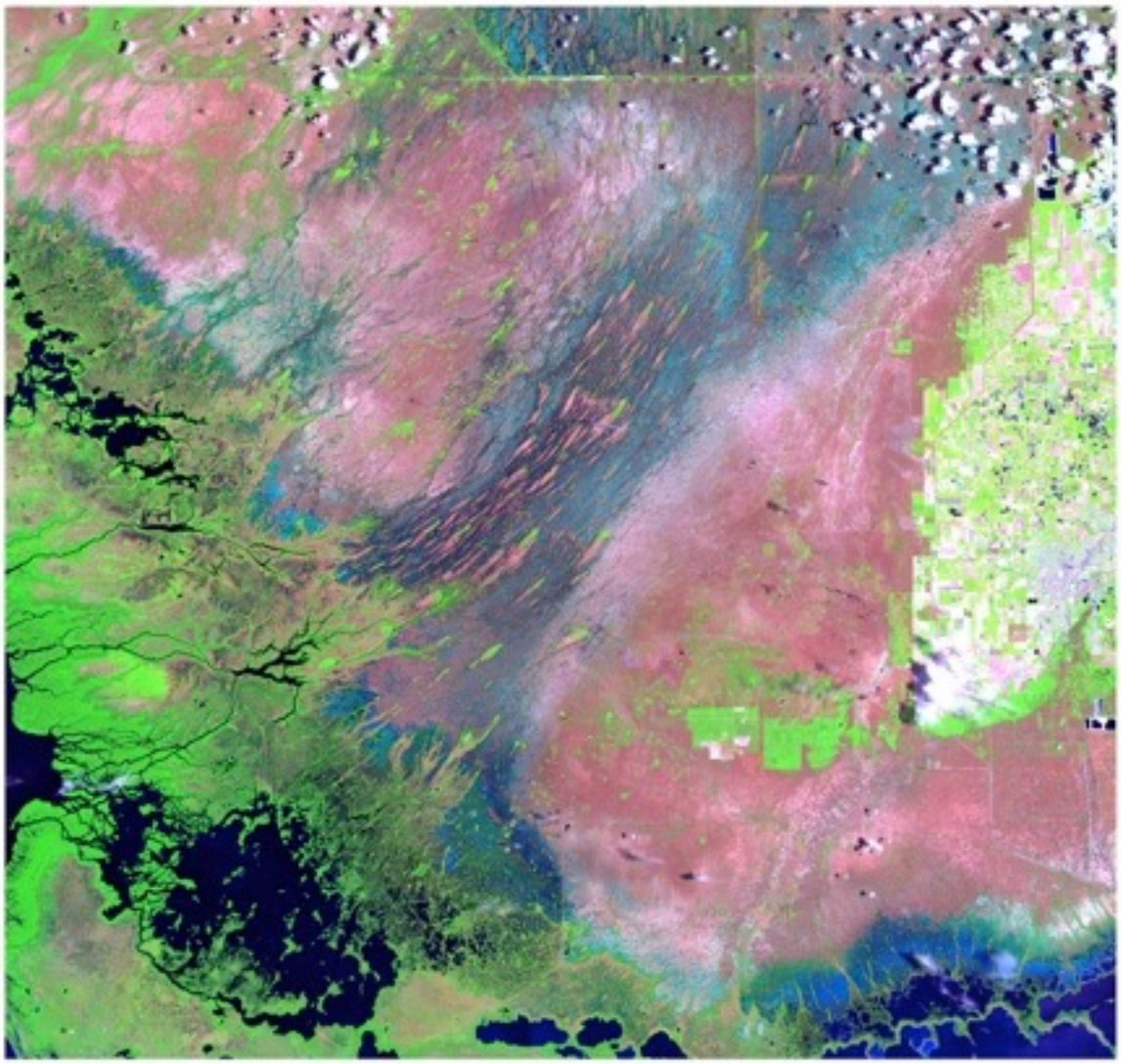


March 11, 1998



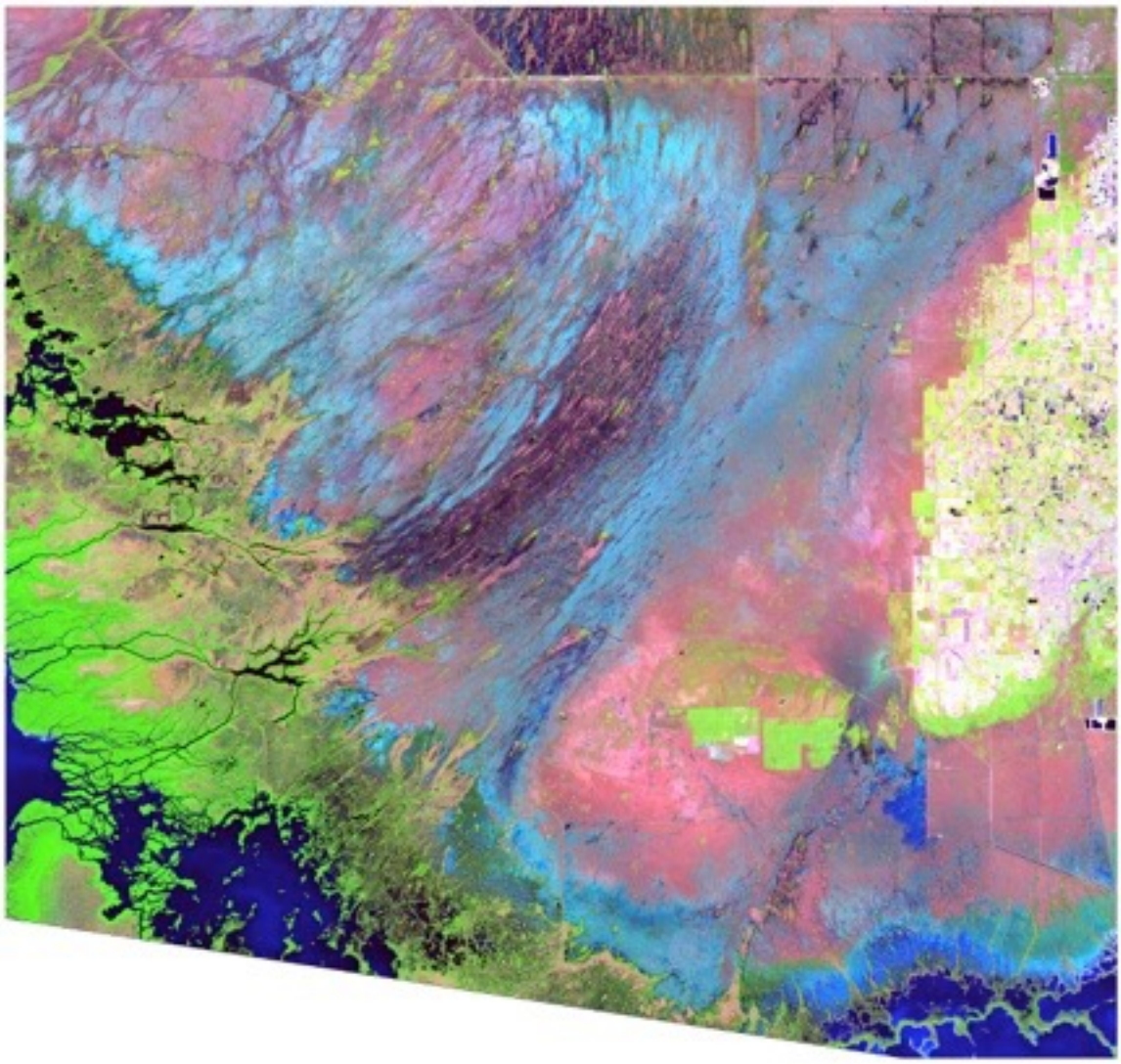
May 14, 1998

P34	2.21	NP205	4.85



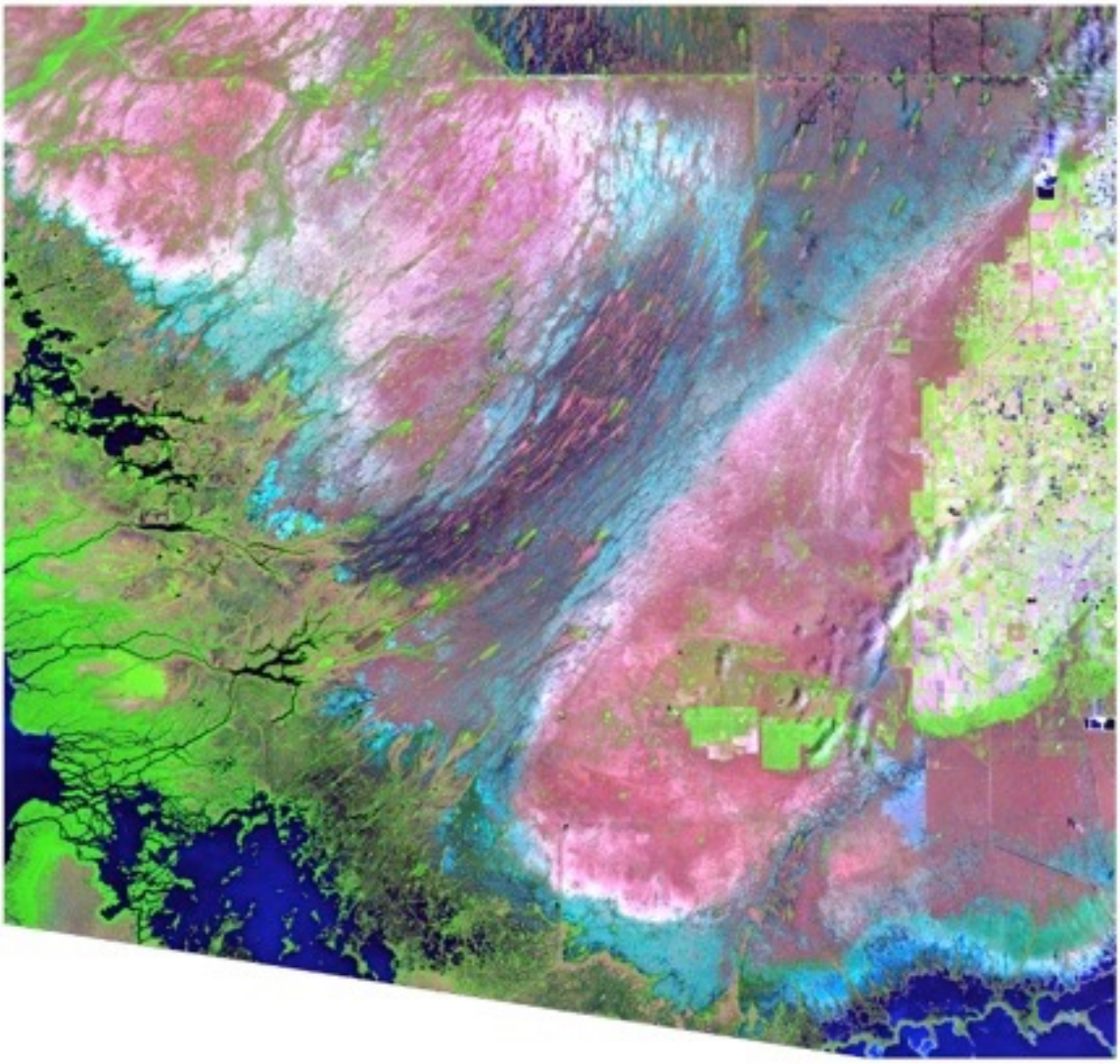
May 17, 1999

P34	2.05	NP205	5.37



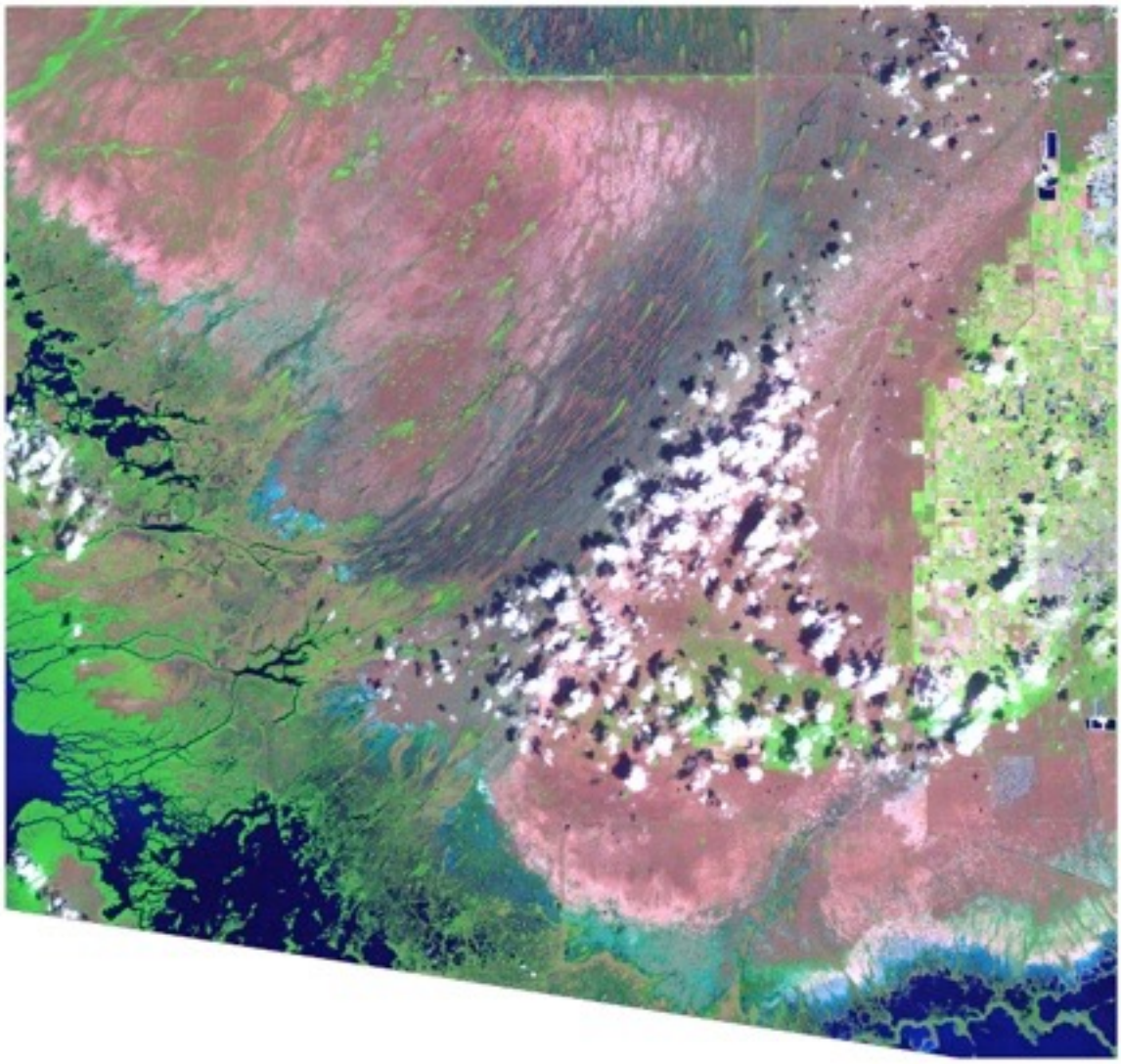
February 21, 2000

This is before the breeding season. The dark blue area in population D, east of Taylor Slough indicates a fire in the previous year. In burning the vegetation, the image detects shallow open water when flooded.



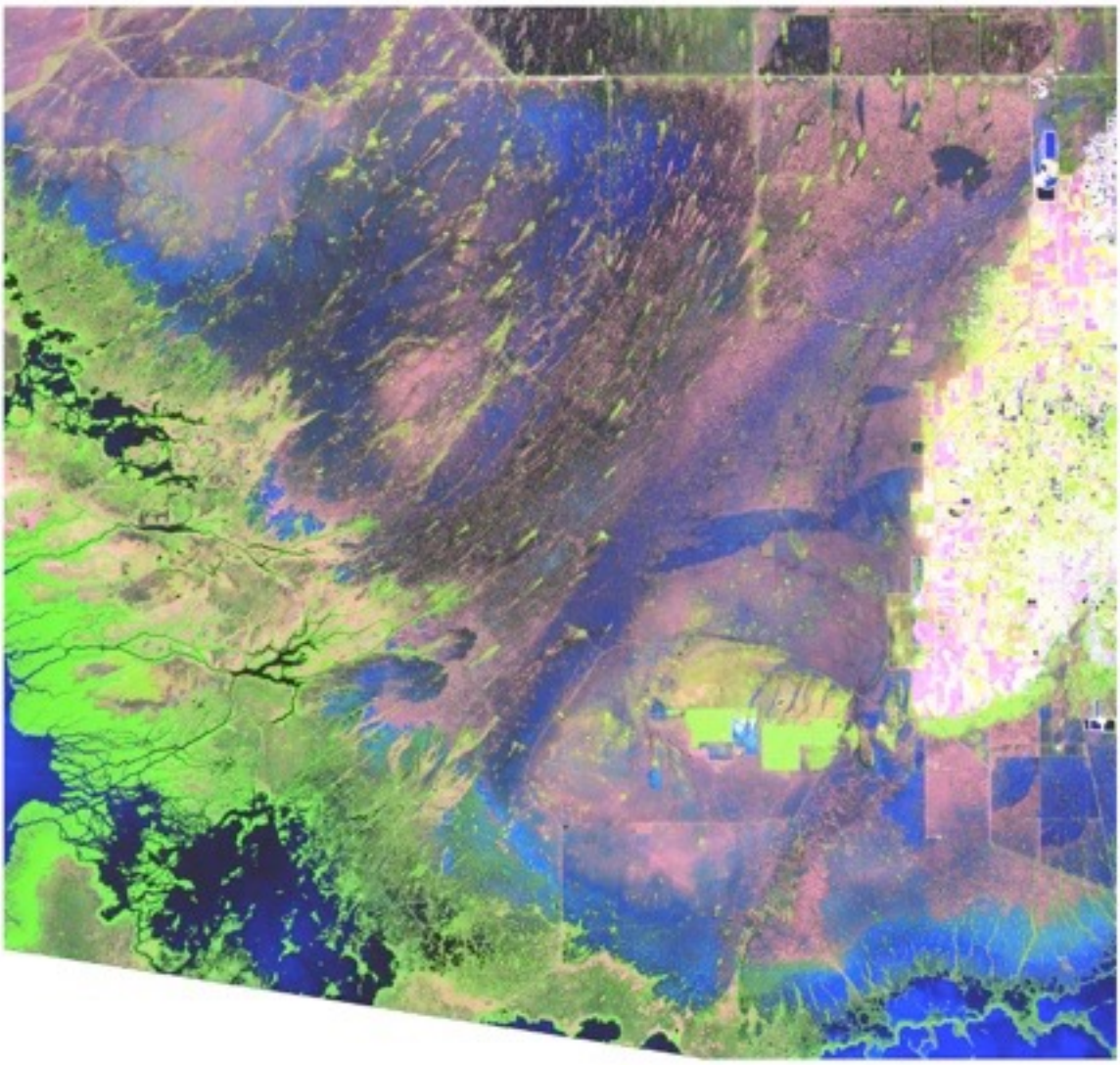
April 9, 2000

Six weeks after the previous image, this is a drier one. The effects of flooding in population D are less evident.



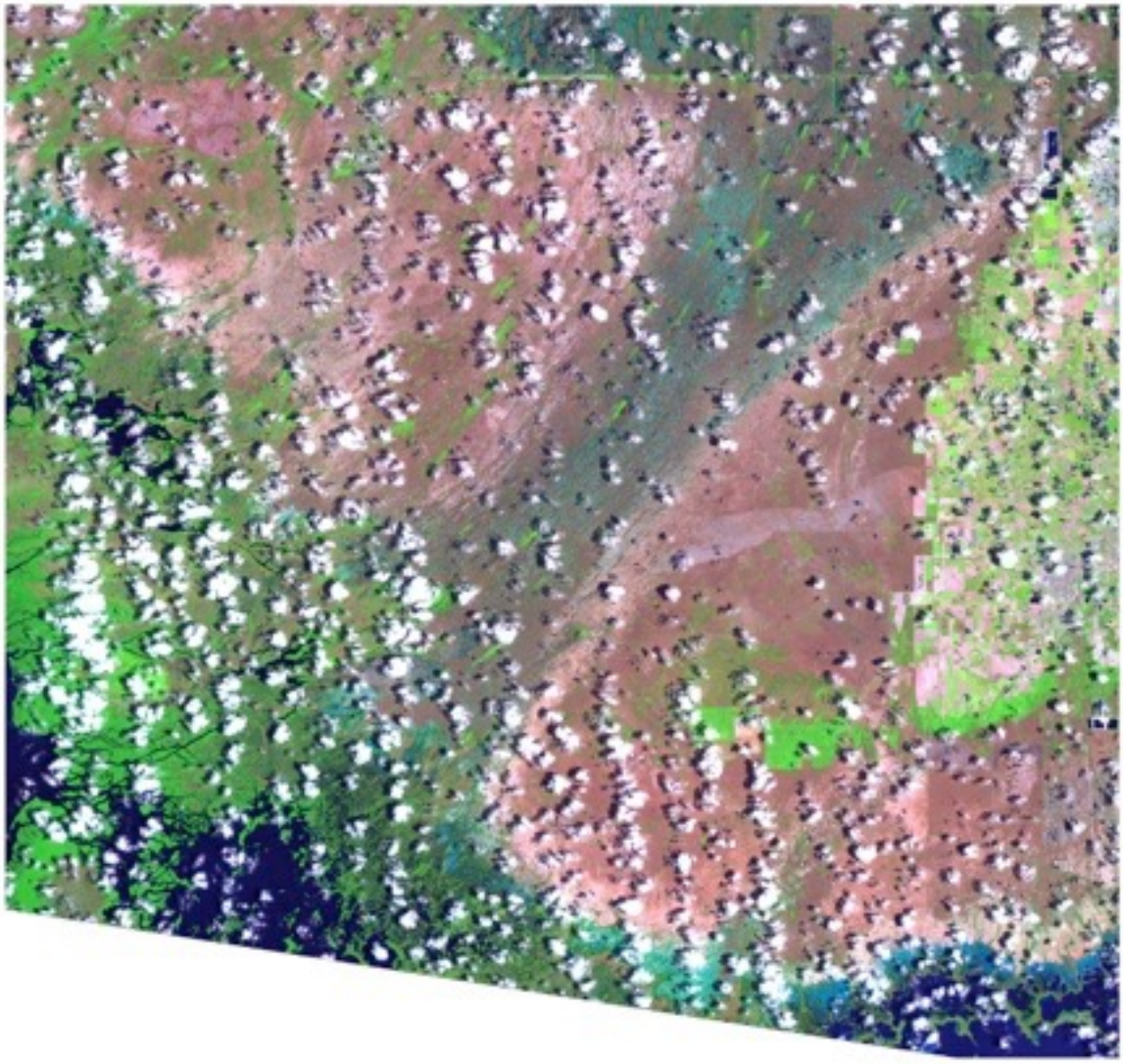
March 11, 2001

The burned areas in population D now show as a pale fire scar.



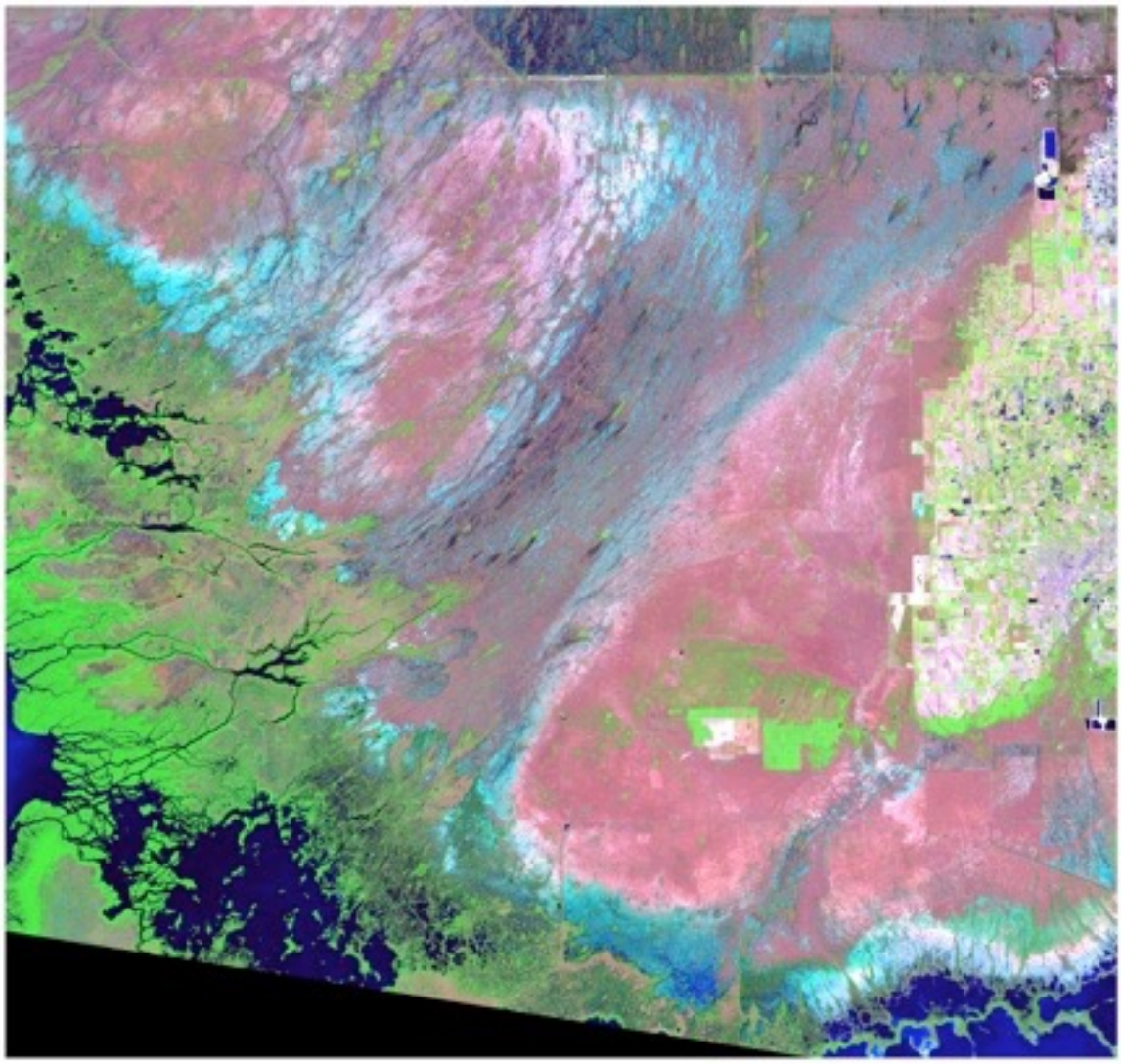
November 6, 2001

This is well after the breeding season. The dark blue area in populations D and E, show extensive fires in the previous year. The fire in E that spread westward towards Shark Slough — the Lopez fire — allowed the detailed investigations of fire on sparrow breeding that Chapter 4 documents.



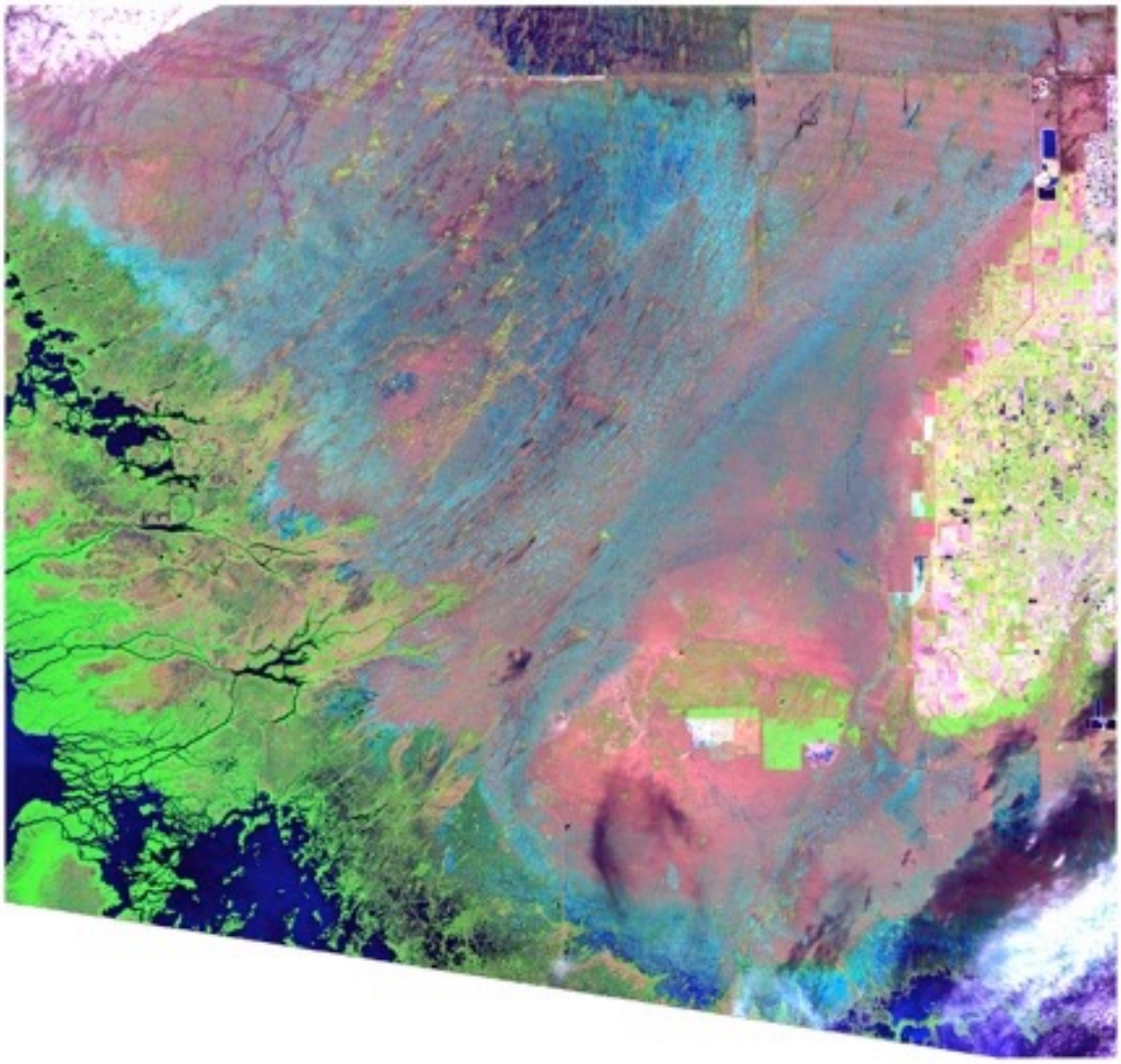
May 1, 2002

The burned areas in populations D and E now show as a pale fire scar.



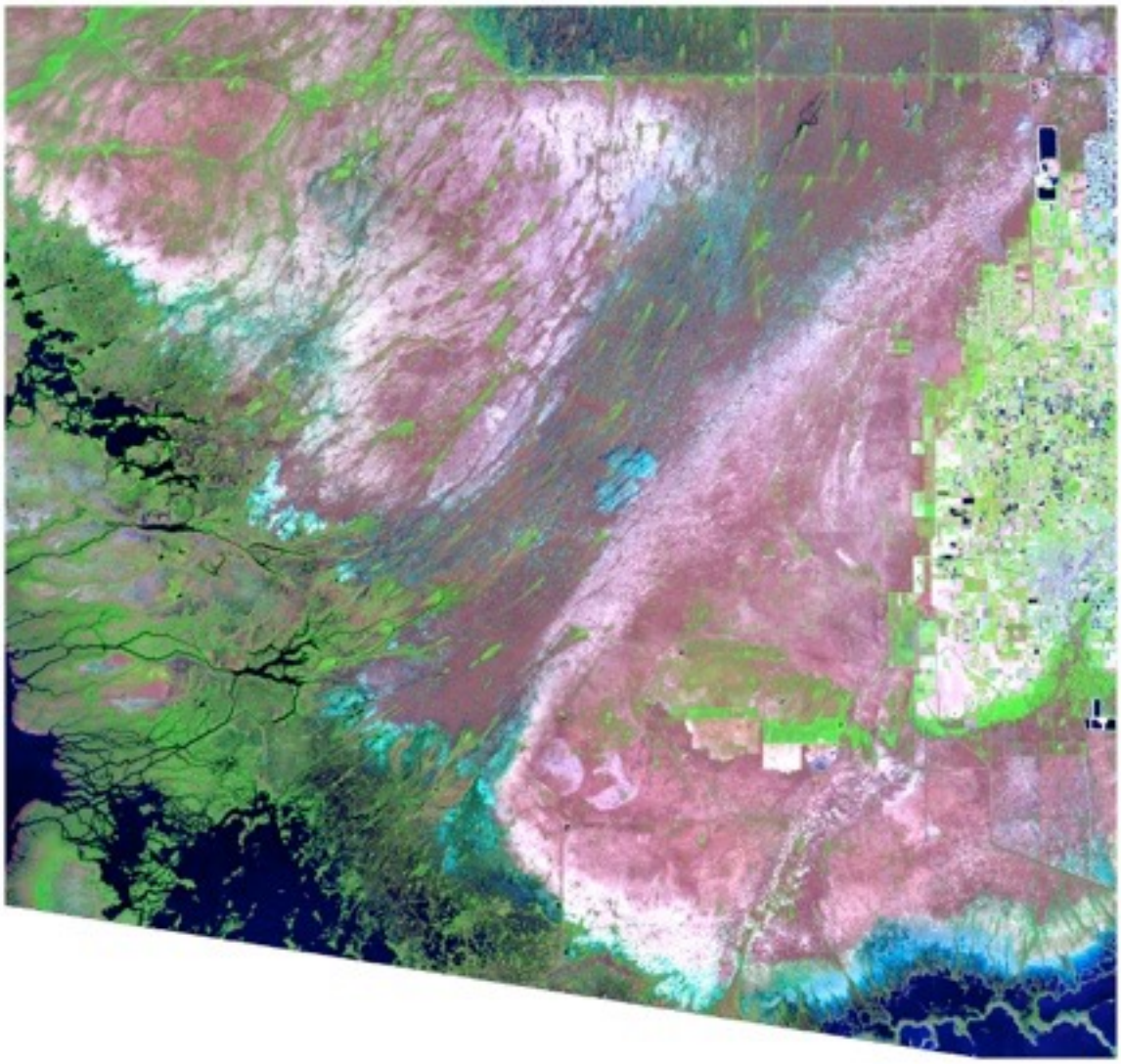
February 13, 2003

The burned areas in population E are still visible as a pale fire scar, but it is much less distinct.



January 7, 2004

Some of the former bright green squares of *Schinus* — the farm visible in the 1973 image — are now white. Restoration efforts scraped off this invasive species leaving behind the bare, coral bed rock visible.



May 4, 2006

Small moon-shaped fire scars are visible in population B. Like the Lopez fire of 2001, these allowed us to investigate how many breeding pairs of birds the fire eliminated and for how many years it did so.

Chapter 10

Demonstrating the destruction of the habitat of the Cape Sable seaside-sparrow

Clinton N. Jenkins, Robert D. Powell, Oron L. Bass Jr., Stuart L. Pimm

This chapter is from Jenkins, Clinton N, R. D. Powell, O L. Bass Jr., and S. L. Pimm. 2003. Demonstrating the destruction of the habitat of the Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) *Animal Conservation* 6, 29–38. It has been edited to reduce overlap with materials presented in other chapters. The model predictions of sparrow habitat that follow as an Appendix were not included in the original paper because of cost.

Abstract

The Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) is Federally protected under the Endangered Species Act of the United States of America. This legislation prohibits direct or indirect take — the killing or harming — of the protected species. In 1993 and 1995, the opening of floodgates into Everglades National Park during the normal dry season resulted in a direct take of the sparrow. The argument was also made that there was indirect take through destruction of the habitat upon which the sparrow depends. Using a combination of fieldwork and satellite image analysis, we show that the floods did damage the habitat of the sparrow. Moreover, they did so for a period longer than the actual flooding, further increasing the sparrow's extinction risk. Recovery of the sparrow population to pre-flood levels will require an adequate and stable amount of habitat. We now have a technique for monitoring that habitat and ensuring that poor water management does not threaten it. More broadly, this technique has the potential for monitoring the habitat of many other species and avoiding another situation such as the sparrow faces.

Introduction

Countries differ in the vigour to which they protect biodiversity and in the particular laws they pass to do so. In the United States of America, one of the most effective laws is the Endangered Species Act. It prohibits direct take — the killing or harming — of Federally-listed endangered species. From its inception there has also been the implication that it prohibits take indirectly — through the destruction of the ecosystems on which species depend. That provision was challenged in a legal case, Sweet Home versus Babbitt, argued in front of the Supreme Court of the United States, on February 17th 1995. In the particular context of the Spotted Owl, an Oregon group challenged the responsible cabinet member, Secretary of the Interior Babbitt, arguing that only direct take violated the law and not habitat destruction. In a brief of Amici Curiae scientists, one of us (Pimm) among others (Cairns et al. 1995) argued that habitat destruction is most often the cause of species endangerment and extinction.

The Supreme Court agreed with that position. In doing so, they raise a scientific question that transcends national boundaries: how are we to demonstrate that human actions harm the habitat on which a species depends? In the case of the owl, the action — extensive logging of the old growth forests on which the birds depend — was obvious. Of course, it need not be.

Our particular concern is the Federally-listed Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) a bird found only within the seasonally flooded marshes in the Everglades of South Florida. In other chapters, we demonstrate that unnatural flooding of its breeding habitat directly caused its precipitous decline in the western half of its range (Curnutt et al. 1998, Nott et al. 1998). The flooding resulted from diversion of the area's drainage, Shark River Slough, to the west of its natural path and a change in the timing of its seasonal ebb and flow. Because sparrows nest near the ground, flooding results in increased or total nest failure both by drowning nest contents and by increasing losses to predators (Lockwood et al. 1997, Lockwood et al. 2001). Floods also do indirect harm by causing sparrows to cease courtship activities and further nesting (Lockwood et al. 1997, Lockwood et al. 2001). Concomitant with those changes, areas in the east became over-drained and more susceptible to anthropogenic fires. Those fires also harm the birds and when too frequent eliminate sparrows from the area (Chapter 4).

Here, we address the possibility that flooding and fires also damage the habitat and so the birds as a consequence. In this paper, we demonstrate that flooding has indeed altered the habitat in which the sparrow occurs, done so in a way to preclude the bird's use of the habitat, and over a period longer than the flooding itself.

The paper proceeds in two stages. The first explains how we predict sparrow habitat. In brief, by precisely locating the nests of sparrows during the breeding season, we identify the "spectral signatures" of their territories on satellite images. (The signature of each pixel in an image is a six-element vector, each element representing a "colour"— a wavelength within or beyond visual detection.) The combination of these spectral signatures for a sufficient sample of territories

produces a prediction of the habitat available to the sparrows on the date of the satellite image.

The second stage is an evaluation of those predictions. It has three parts. The first shows we can predict habitat in years before we began intensive fieldwork and thus have no nest locations. It includes both ecological reasons and empirical evidence supporting our methods. The second is an analysis of the habitat predictions. It links water management decisions to their effects on the habitat. The third part is a detailed technical analysis of the errors in our predictions. We identify these errors using the annual range-wide surveys of the sparrow's abundance and distribution. Some of these errors are failings of the predictive model; we argue that many more are errors the birds make for one reason or another. We discuss this analysis in the chapter that follows.

We will present two key results.

(1) Across the eight years of the study, large year-to-year fluctuations in predicted habitat confirm the culpability of water managers. Flooding in 1993 and 1995 greatly reduced the habitat predicted to be suitable for the sparrow compared to 1992. This is a formal, technical demonstration of the figures presented in Nott et al. (1998), inferring dry prairies in 1992 and extensively flooded prairies in 1993 and 1995, from the colours of the published images.

(2) The predicted suitable habitat west of Shark River Slough was at a low ebb in 1995 and has recovered slowly, but consistently, since then until 1999. This formal, technical demonstration matches exactly the subjective opinion expressed by Bass and Pimm from their visual inspections during the annual surveys of the sparrow population. By 1999, the predicted suitable habitat had not yet recovered to its pre-flood state. The habitat is recovering faster than the slowly recovering bird populations. It is the repetition of precisely such a scenario that we predict could lead to the species' extinction (Chapter 13).

Neither of these results are surprises, for they were suggested by our previous papers (Curnutt et al. 1998; Nott et al. 1998). Nonetheless, we consider the details presented here to be important in both a national and broader context. Importantly, our data conclude that water management practices have damaged huge areas of vegetation across Everglades National Park, have done so for extensive periods of time, and in a way that jeopardises the survival of a Federally listed species. This constitutes a take. Moreover, it is one that is independent of, and lasts longer than, the direct affects of flooding. Crucially, these data are independent of — and so additional to — all other conclusions that we have drawn in previous papers (Curnutt et al. 1998; Nott et al. 1998).

More broadly, we have used satellite imagery to predict potential habitat, its fluctuation from year to year, and calibrated these changes against known bird numbers. This is a singular result with few, if any, precedents.

Stage I: Predicting the habitat

To produce a map of a species' habitat using satellite imagery, we need to incorporate all the features of a species' natural history that are identifiable on the image. For the sparrow, our field experiences suggest a minimum of three features: vegetative structure, proximity to bushes, and patch size.

Our first stage is to identify what spectral responses correspond to suitable sparrow habitat. Different vegetative structures give different spectral responses or *signatures*. The images of Chapter 9, clearly show that it is possible to distinguish between the wetter vegetation in the central part of Shark River Slough and the drier prairies on either side. At a finer resolution, it is possible to distinguish many other more subtle vegetative features.

We located 261 nests using a Global Positioning System (GPS) and then matched each of these nests to their corresponding pixel on the satellite images. The resolution of these images — the pixel size — is 29 by 29 meters. These pixels form the basis of the prediction of potential sparrow habitat.

The second stage involves the proximity to bushes. Predators, such as Red-shouldered Hawks (*Buteo lineatus*), perch on bushes and shrubs when looking for prey, such as the sparrow. Nesting close to bushes likely exposes sparrows to an increased risk of predation. So we ask: how close to bushes do the birds nest? After answering that question, we eliminate areas that are too close.

In the third stage, we eliminate patches that are too small to hold a breeding territory (~2 ha).

Predicting habitat 1: Obtaining the spectral signatures

This stage has three parts. First, we correct the satellite images so our GPS data will match up correctly with the image. Second, we make spectral signatures of suitable sparrow habitat using the nest pixels. Last, we apply these spectral signatures to the image to map the habitat.

Images and rectification. We use Landsat Thematic Mapper (TM) images taken during the breeding seasons of 1992 through 1999. When possible, these are from April or May, the months of peak breeding activity. In 1996, no cloud free image was available in April or May and we used one from March 21. In 1997, all images in the breeding season were cloudy.

Landsat TM images consist of seven spectral bands ranging from blue (0.45-0.52 mm) to thermal (10.4–12.5 mm). Using the thermal band reduces the accuracy of our results because the prairie is essentially at thermal equilibrium. We eliminate it from our analyses.

We first defined a set of 66 control points that we could unambiguously identify both on the satellite image and on the ground or accurate maps. We recorded the coordinates of these using a GPS accurate to <2 m in accessible areas and 1:24000 quadrangle maps in inaccessible areas. We use these to correct for misalignments and distortions in the satellite images. This process, known as rectification, smoothly stretches the image to produce a least square fit to the control points. The difference between the predicted positions of the control points and their true values had a root mean square error of 2.9 meters, that is, 10% of the linear dimension of each pixel.

Making spectral signatures. Using the differentially corrected GPS, we took coordinates for 261 nests from 1996 through 1999. We eliminate nest locations judged to be of questionable accuracy and those closer than one pixel (29m) to a road. Presence of a road within a nest pixel contaminates the spectral signature. This leaves 232 usable nests. For each year, we discard nest locations if they fall on clouds, shadows or other features corrupting the image.

Using only the nest pixel provides no information on the spectral characteristics of the surrounding habitat within the territory. Sparrows defend homogenous territories of about 2 hectares (Werner 1975, Lockwood et al. 1997, 2001). In an ideal world, we would have precise maps of sparrow territories and build our spectral signatures from those. However, in most cases we have only the nest location and must work from that. Therefore, we need to select pixels that adequately represent the true territory. To select those pixels we tried two methods.

The *central place foraging method* assumes sparrows place their nest in the centre of their territory. This would minimise the distance flown to feed nestlings and the distance to defend territory boundaries. We use the 25 nearest pixels (2.1 ha) that are not obviously unsuitable (i.e., bushes or water). (25 produces a compact, if not quite circular pattern, with the nest location centrally located.)

The *minimum spectral distance method* assumes sparrows place their nest in a typical part of the territory. We select the 25 contiguous pixels having the minimum Euclidean spectral distance from the nest pixel over all spectral bands. We define contiguous pixels as those touching along one of the four sides, but not diagonally.

Our field experience, including mapped territories that were irregular in shape and had nests near their boundaries, suggested this second method should be the better one. Indeed, our results support this. In direct comparisons of the first and second methods, the latter classifies more habitat in areas with birds and less habitat where there are none. In what follows, we only use the minimum spectral distance method.

Making and summing classifications. For a particular nest and its associated 25 pixels, we calculate the minimum and maximum value within each of the six spectral bands. This produces a six-dimensional box within which we deem all enclosed pixels to be predicted habitat. This is one sparrow's opinion of suitable habitat.

Clearly, we can do this for all the available nests and territories and combine those opinions.

We can combine those opinions in a large variety of ways. Samples based on few nests will likely perform less well than those based on large samples. Moreover, in some years we have no nests at all. To get the largest samples we could combine nests from different years. This runs the risk of combining years where the birds placed their nests in different places because of different water conditions, for instance. To resolve these difficulties, we need to compare and contrast the predictions they produce. This we will do, but first we must explain the final two stages.

Predicting habitat 2: The bush layer

We find that sparrows do not nest near bushes, presumably because of increased predation risk. Using aerial photography of the intensive study plots, we measured the distance of 235 nests and 235 random points from the nearest bush. Figure 10.1a shows the frequency distribution of these nests and points and Figure 10.1b their cumulative distributions. The distribution of nests is shifted away from bushes when compared to what one expects for randomly selected locations. Very few nests are within ~29m of a bush (or one pixel on the satellite image. There are fewer nests within 58m and 87 m (two to three pixels) than one would expect, though there are some. As a compromise between excluding too sparrow habitat and including too many areas too close to bushes, we eliminate classified habitat within 2 pixels (~58 m) of a bush.

Bushes are high in chlorophyll — they are green — compared to the buff tones of the prairie grasses. The satellite images capture these visually obvious features. Because of the large spectral differences between bushes and other prairie vegetation, we use the ISODATA algorithm (Jensen 1996) to automatically find signatures corresponding to bushes. Accuracy assessment with aerial photography shows this algorithm has an error rate of 8% for commission errors and 29% for omission errors. It detects most large bushes and clusters of smaller bushes, but misclassifies areas with only a few small bushes.

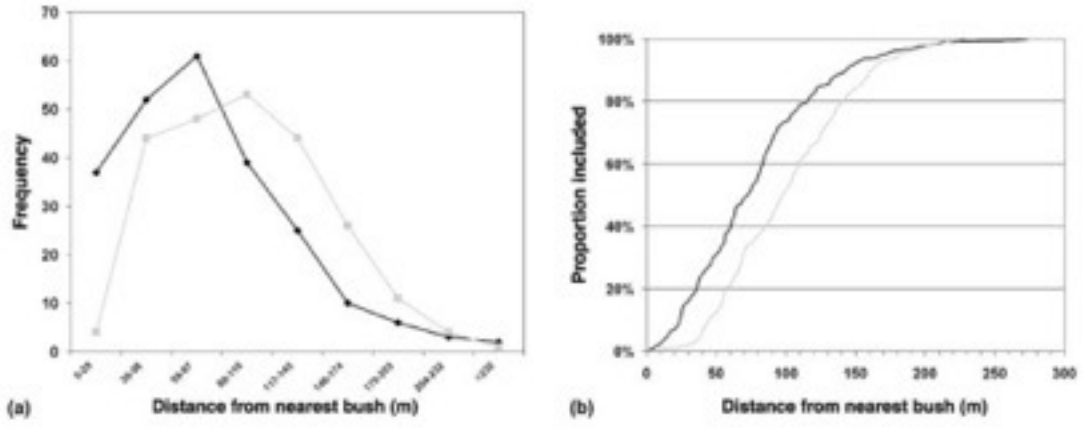


Figure 10.1 – Distance from nests and random points to the nearest bush. Each curve shows the percentage of sparrow nests (black) or random points (gray) occurring within a given distance of the nearest bush. For example, 20% of the random points occur within 26 meters, but only 3% of sparrow nests do. Sparrows begin to randomly distribute their nests after approximately 40 meters from a bush. In each study plot, we generated random points equal in number to the number of nests. A Kolmogorov-Smirnov test shows the distributions to be different ($p<0.0001$).

Predicting habitat 3: eliminating small habitat patches

Because sparrows need enough suitable habitat for a breeding territory, we eliminate patches of habitat smaller than 25 pixels (~2 ha) from the predicted area of habitat. We use 25 pixels to be consistent with the territory size used in making signatures.

Stage II: Evaluating the predictions

Any attempt at prediction begs two questions: "of what?" and "by what?" The first answer is simple — bird distributions. It is the second that is more subtle. Certainly, we could predict distributions of birds in each population in each year from nest locations in each population and in each year. But prediction usually seeks efficiency. Ours is the ability to predict distributions in all populations in all years from a sample of nests that are from only the more accessible populations and only from some of the years. The first part of the evaluation stage explores how accurately we can do this.

The second part is an analysis of the habitat predictions within each of the populations. It links water management decisions to their effects on the habitat and the population.

The third part is a detailed and technical analysis of the errors in our predictions. We defer discussion of this to a companion paper (next chapter).

Each of these components uses the annual range-wide surveys of the sparrow's abundance and distribution. Tests in the intensive study areas indicate an observer can hear a singing sparrow up to 200 meters away — an area of about 13 hectares (Pimm and Lockwood 2000). We calculate how much predicted suitable habitat is within a circle of 200-meter radius about the survey point. If the model predictions are good, then the survey should find birds more often in areas where the model predicts more habitat. In a graph of sparrow presence versus amount of habitat predicted (Figure 10.2a) there should be few sparrows below a minimum threshold for predicting presence and many sparrows above the threshold. We use the size of a breeding territory (2 ha) as the threshold.

Predicting habitat in years without enough nests

We only have nest locations from 1996 onward and 1996 and 1997 have too few nests for good results. However, we need to predict habitat from 1992 onwards. An inefficient solution would obtain if there were large variation in nesting habitat from year-to-year. If sparrows did nest in very similar places each year, then a nest in 199x would not likely be within a territory in 199y. An efficient solution would be to use nests from *all available* years on *every* year's imagery. This provides a large sample size and allows predictions in every year. Both ecological and empirical evidence support this alternative.

The ecological evidence is the consistency of habitat within our study sites. They are primarily in areas that have not flooded or burned since 1992. A criterion for originally selecting these locations was that they had a consistent sparrow population and thus suitable habitat. Therefore, we posit that areas in which sparrows nested during the detailed surveys, 1996 through 1999, were also suitable habitat in prior years. Sparrows nest in very similar places each year, so a nest in 199x would almost certainly be within a territory in 199y.

Figure 10.2 (b-d) shows the empirical results supporting our assumption. These graphs compare using nests from 1998, 1999 and from all years on various years' imagery. (We have too few nest locations in 1996 and 1997 to separate them out.)

Ideally, we would get a graph comparable to figure 10.2a, showing a positive relationship between habitat predicted and probability of finding birds. Below some threshold amount of habitat (the vertical line), there would be insufficient habitat to hold birds. Should we find birds in such areas we would have an *omission error*. (Our model errs in omitting places where birds occur.) Above this threshold, we should find birds and, were we not to do so, we would have a *commission error*. Ideally, both omission and commission errors would be small, and there would be a sharp transition about the threshold. In reality, the graphs are more variable, but the relationship still holds.

Figure 10.2b shows the results of using 1998 nests to make signatures and predict habitat on 1998 imagery. It gives a strong, but variable, increase in the proportion of survey points with birds as the amount of predicted habitat increases, as we expect. When using 1998 nests on non-1998 images a similar pattern occurs. Thus, 1998 nests predict habitat just as well in other years as they do their own. Using 1999 nests on the 1999 image and other years gives a similar result (figure 10.2c). Thus, 1999 nests work as well.

We offer no formal tests of what we mean by predictions "working well." For one prediction to be better than another it would have to predict a smaller proportion of sites holding birds when there was only a small area of classified habitat and a larger proportion when there was a large area of classified habitat. Inspection of the figures shows that the lines cross repeatedly, with no tendency for within year predictions (1998 nests on 1998 image, 1999 nests on 1999 image) to be consistently better. Indeed, to the extent we might claim any consistency it is for nests from all years to predict a given image better than the nests from its year. (Thus for the 1999 image, (figure 10.2c) using nests from all years predicts fewer sites with birds when there is less classified habitat and more sites with birds where there is more classified habitat than do the 1999 nests alone.)

Figure 10.2d shows a summation of results from using 1998, 1999, and all nests to map sparrow habitat. Again, none of the curves differs substantially or consistently from each other. These results indicate the year of the nest does not alter the efficacy of the predictions. Likely, nest locations are consistently good habitat, at least within the time span of this study.

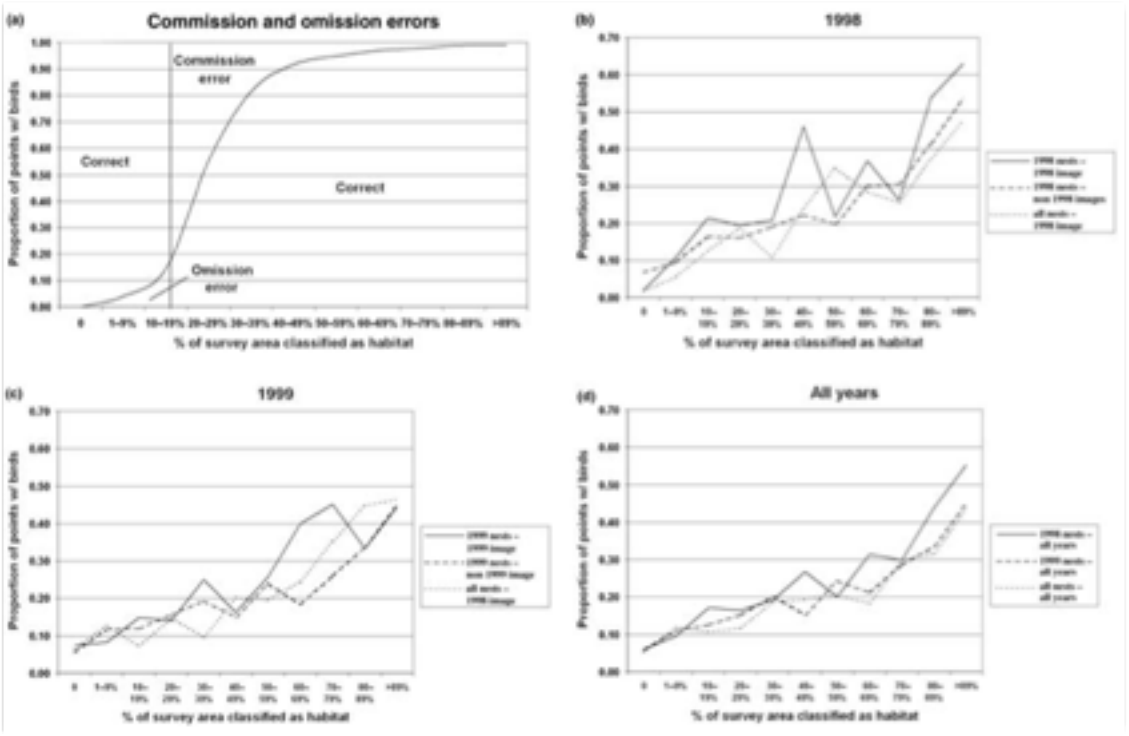


Figure 10.2 – The proportion of survey sites where one or more birds were encountered versus the percentage of the area predicted to contain suitable sparrow habitat based on different sets of nests. (a) Ideally, there will be a threshold below which we do not find birds and above which we do. In this case, we use the size of a breeding territory (2 ha or 16%) as the threshold. (b-d) In reality, the results have noticeable variability, but do show a positive relationship between the prediction of habitat and the presence of sparrows. Each line corresponds to a combination of nests (1998, 1999, or all) used as seed pixels and years of imagery analysed (nest year or non-nest year). All years is a summation of the results from every year's imagery using a given set of nests.

We conclude that nests from one year are usable for making habitat signatures in other years. To gain the maximum sample size we use all nests to map habitat in each year. This provides the opinions of the most sparrows' and thus predicts the most habitat.

Habitat analysis

To estimate the total potential habitat, we combine the final habitat classifications for all years. Looking at the six populations together, we estimate 459 km^2 held potential habitat in one or more years. Among the populations, A and B have the most with 138 km^2 (30% of the total) and 116 km^2 (25%) respectively. Population E is third with 82 km^2 (18%), and C, D and F have 31 km^2 (7%), 54 km^2 (12%) and 38

km^2 (8%) respectively.

Not all of these areas will be suitable habitat each year. In any given year, floods, fires and other environmental factors reduce the potential habitat, leaving a subset that is currently suitable. Looking at the average amount of this suitable habitat reveals a different pattern than looking at only potential habitat. Overall, the habitat suitable for the birds each year averages 240 km^2 (52% of the potential). Population A averages only 38 km^2 (28%) of its potential, reflecting the large amount of habitat destroyed by floods in 1993 and 1995 and the slow recovery thereafter. Population D, also affected by flooding, averages just 20 km^2 (37%). Populations B and E are relatively constant and have the highest average amount of habitat with 85 km^2 (73%) and 54 km^2 (66%) respectively. Populations C and F average 19 km^2 (61%) and 23 km^2 (61%) respectively.

How much of this suitable habitat do the birds occupy in a particular year?

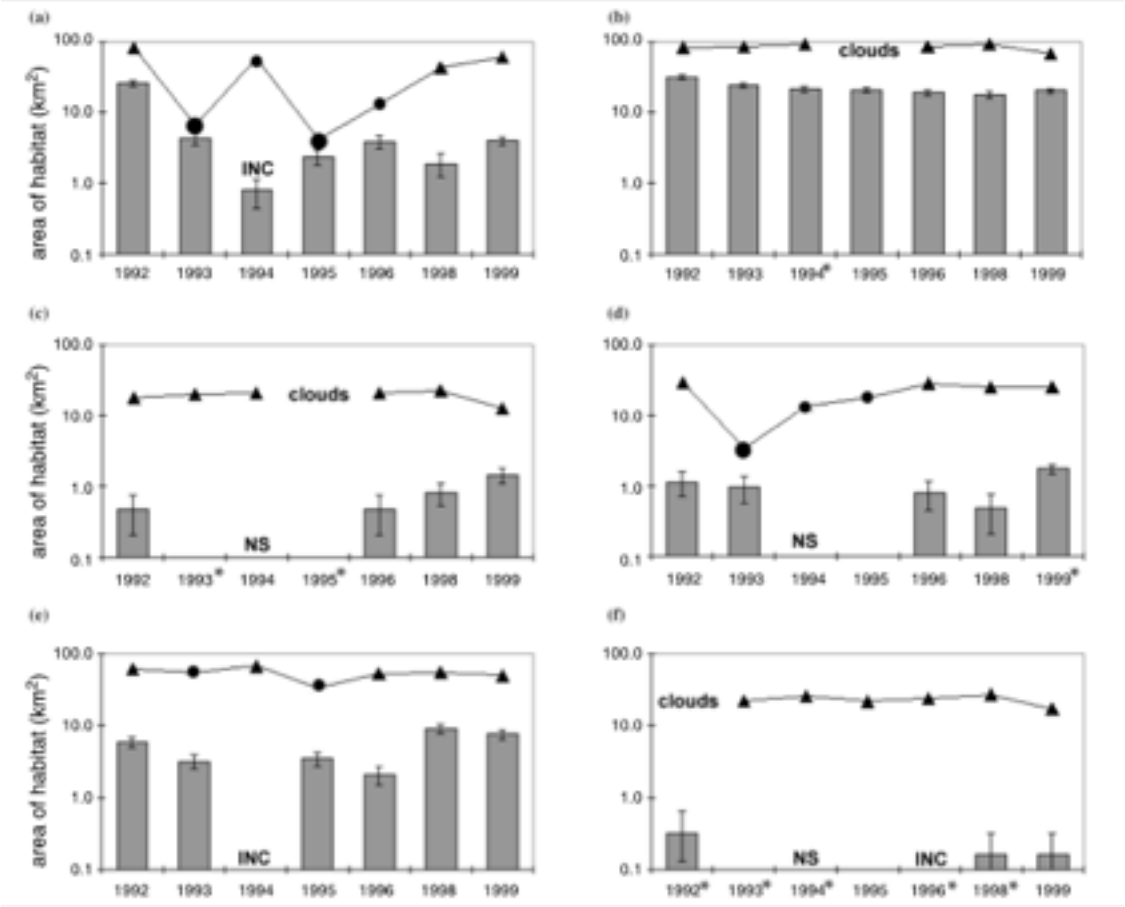


Figure 10.3 – Area (km^2) occupied by sparrows (columns) and area of suitable habitat (lines). We calculate the occupied area by multiplying the number of birds counted in the survey (table 1) by 8 to estimate the total number of breeding territories, equivalent to breeding males. Each territory is 2 ha or .02 km^2. The y-axis is a logarithmic scale. Bars are +/- one standard error. Triangles = no flooding. Large

circles = extensive flood. Small circles = moderate flooding. * = year with fire(s) in that population. 'NS' means there was no survey and 'INC' means the survey was incomplete.

Figure 10.3 shows the predicted amounts of suitable habitat and their variation from year to year as well as estimates of the area occupied by sparrows. To calculate these numbers, we take the number of birds heard on the survey in each population (table 10.1), multiply by eight territories (for the survey counts only one territory in eight — see above) and then by 2 ha, the average size of a territory. For example, in 1992, we counted 163 birds in population A, and estimate the population size as 163 x 8 = 1304 territories, that should occupy 2608 ha = 26.08 km^2. The predicted suitable habitat for that population in that year was 82 km^2.

Figure 10.3 hints at an important and plausible pattern, though one about which our small sample size (6 populations) precludes drawing strong inferences. Populations with frequent disturbances support fewer birds. Populations A, B, D and E demonstrate this relationship with respect to floods (circles in figure 4). Populations A, D and E suffer varying degrees of flooding and support few sparrows, whereas B is not flooded and supports many sparrows. In populations C and F, fire (asterisks in figure 4) is the dominant influence. Our habitat estimates do not reflect fire's influence, but the relationship to sparrows is clear. Sparrows do not live in areas that burn frequently.

Population A has the largest fluctuations in habitat (figure 10.3). Flooding reduced habitat from 82 km^2 in 1992 to 7 km^2 in 1993, a 91% decrease. Simply, most of the area was underwater. In the same years, the area occupied by sparrows declined from 26 km^2 to 4 km^2. In 1994, the water level was lower than in 1993. As a result, the habitat rebounds to 58 km^2, 71% of pre-flood levels. However, most of this habitat was again flooded soon after the image date and sparrow breeding again failed (Nott et al. 1998). The occupied area stayed extremely low at less than 1 km^2. The 1995 flood reduced the suitable habitat to just 9 km^2.

In 1996, the water level at the image date was almost the same as in 1994 (< 4 cm higher). Yet, the predicted habitat in 1996 was only 25 km^2 compared to 80 km^2 in 1994. Our personal observations explain the large difference. Even though the area was not flooded, plant cover was very sparse and a thick layer of periphyton covered much of what had been sparrow habitat. The thick mat was a consequence of nearly 3 years of constant inundation.

In the following years, the water remained low and a slow recovery of sparrow habitat ensued. This suggests the prairie was able to quickly recover from the single flood in 1993, but three sequential years of unnatural flooding caused long-term damage from which the habitat has yet to fully recover. The sparrow population shows little recovery with occupancy in 1999 of only 4 km^2 of the 60 km^2 available. There appears to be a significant lag time between habitat recovery and population

increases.

Population B is the only population that has a relatively constant amount of habitat and number of birds. It is largely unaffected by flooding and is not subject to high fire frequency.

Population C shows a relatively constant amount of habitat, but few birds. In 1981, it had 4 km^2 of occupied habitat. Then, between 1990 and 1995 nearly the entire area burns one or more times. Consequently, the population dropped to an undetectable level by 1993 and was not detected again until 1996. Since then, the population increases slightly but is still at a precariously low level.

Population D suffered a large decline in habitat because of flooding in 1993, going from 30 km^2 in 1992 to 3 km^2 in 1993. It then experienced moderate flooding until 1996. Since then, the amount of habitat has been relatively constant but the location has varied by year. This population had high occupancy in 1981 but relatively few birds in 1992, possibly because of a large fire in 1990. The floods from 1993 to 1995 depress the population even further. Since 1996, the population remains small.

Population E had a small decrease in habitat from the 1993 flood, and the 1995 flood caused a decline from 68 km^2 in 1994 to 34 km^2 in 1995. The occupied area stayed relatively low from 1992 to 1996, ranging from 2 to 6 km^2, likely due to the flooding in 1993 and 1995. In 1998 and 1999, the occupied area increased to 9 and 8 km^2 respectively. This higher occupancy may result from the consistent level of habitat since 1996.

Population F shows a small, but constant amount of habitat. However, this area has burned every year from 1981 to 1994 and again in 1996 and 1998. As a result, sparrows never occupy most of the habitat.

Conclusions

Species do not survive in isolation to their environment. They need a healthy ecosystem containing sufficient habitat to maintain their populations. If we are to preserve species, we must identify changes in ecosystems that lead to habitat losses and link them to particular causes.

For the Cape Sable seaside-sparrow, water management caused direct harm by opening the S-12 floodgates in 1993 and 1995 before the birds west of Shark River Slough had time to rear their first clutch of young. The inability to breed in those years resulted in a rapid decline in the population.

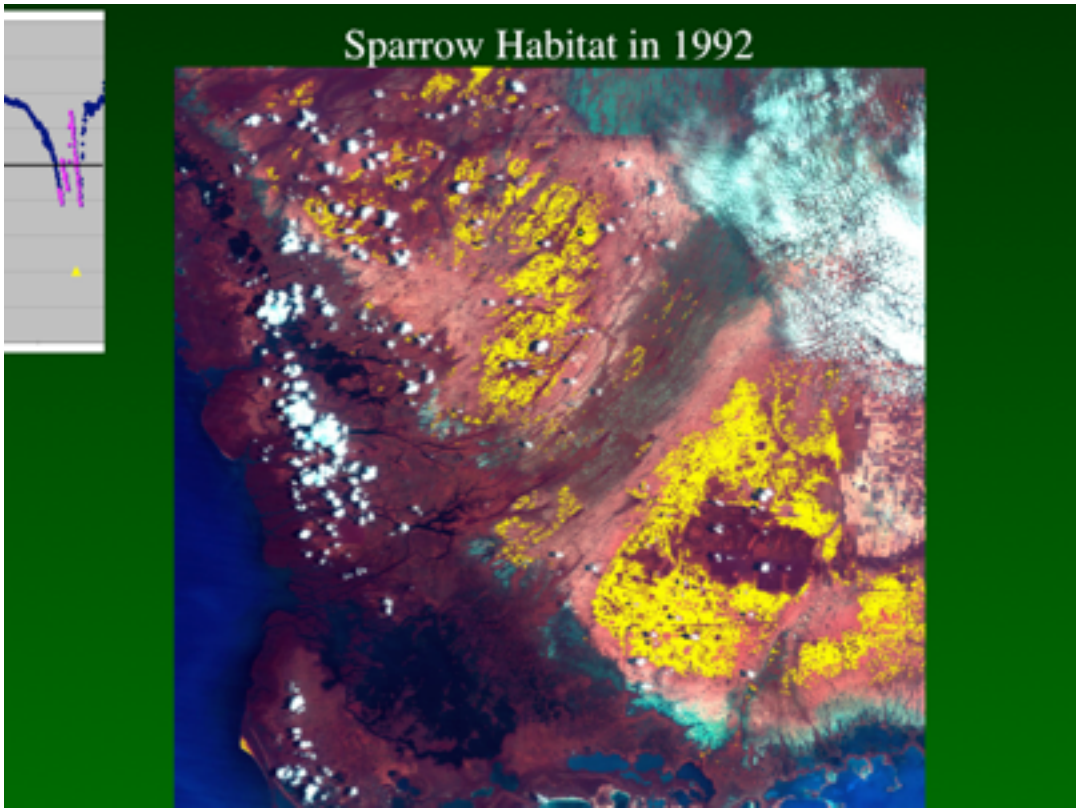
However, the damage was even more extensive. This flooding indirectly harmed the birds by destroying their habitat, and it did so for a period longer than the actual flooding. During the floods, suitable habitat declined dramatically, especially in the west, and was at a minimum in 1995. Since then, it has recovered slowly, but had not returned to pre-flood levels by 1999. As long as suitable habitat is not consistently available, we cannot expect the sparrow population to recover from its flood-induced crash. Indeed, the population has yet to show any significant increase.

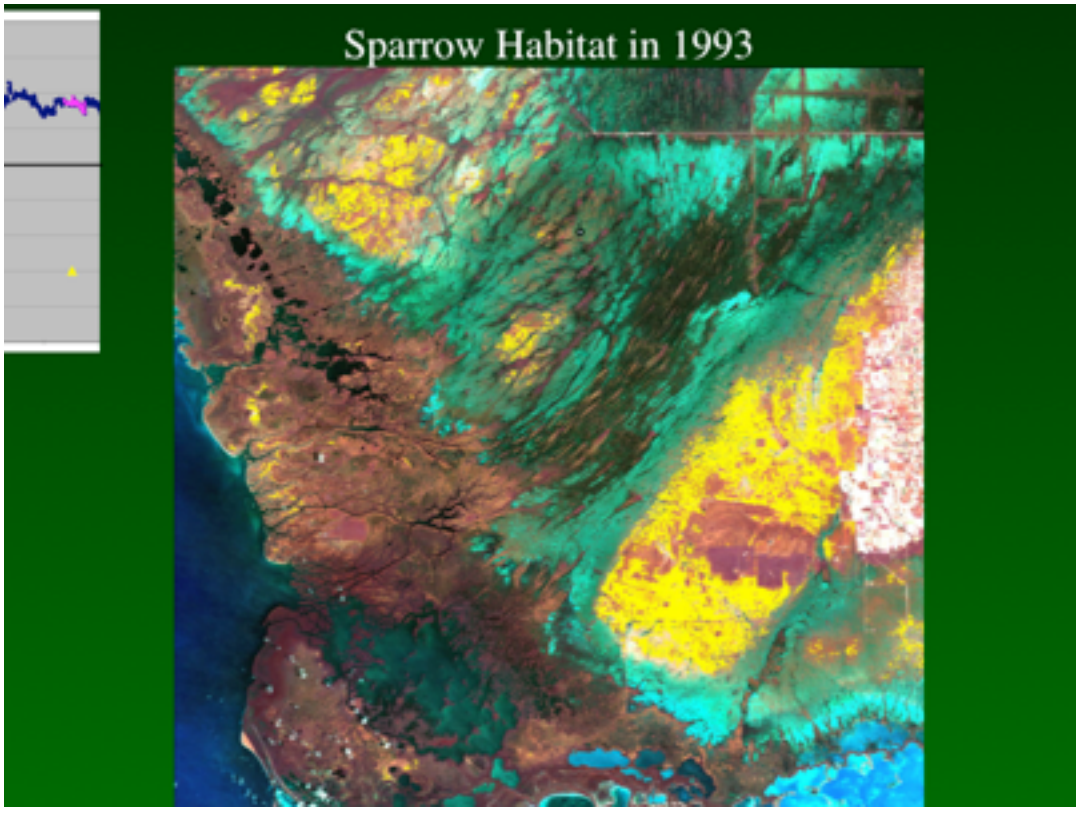
The sparrow clearly cannot cope with ecosystem changes such as those imposed by water managers in 1993 and 1995. One of the two main populations is already at a dangerously low level. Another year of flooding could result in extinction of this population. Moreover, the species' long-term survival is now dependent on a single large population (B). If this population experiences a catastrophic event, such as a fire, then the entire species would face extreme risk of extinction.

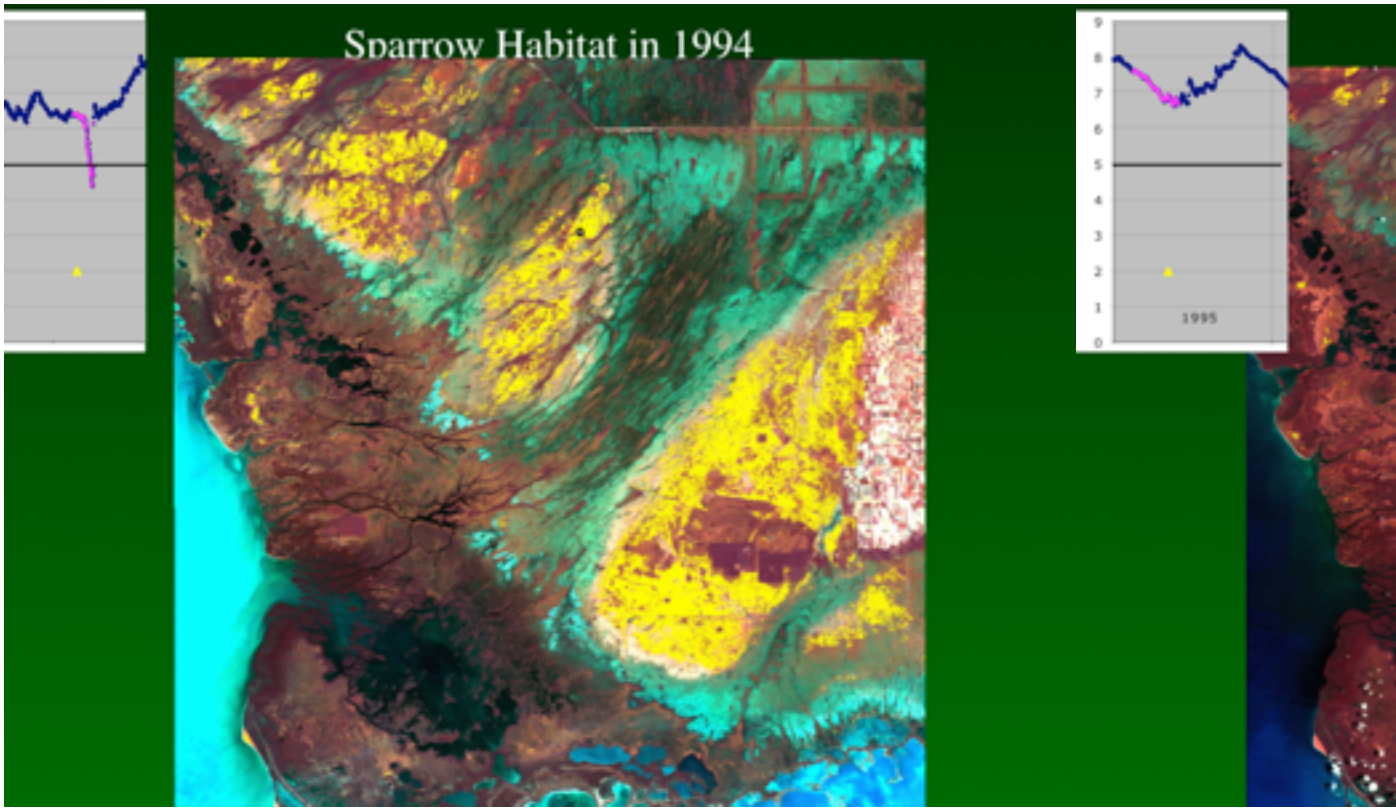
It is vital that we manage the Everglades in a manner that will enable recovery of the western population. This recovery cannot happen without an adequate and stable amount of habitat. We now have a technique for monitoring that habitat and ensuring that poor water management does not threaten it. More broadly, this technique can potentially monitor the habitat of many other species and avoid another situation such as the sparrow faces.

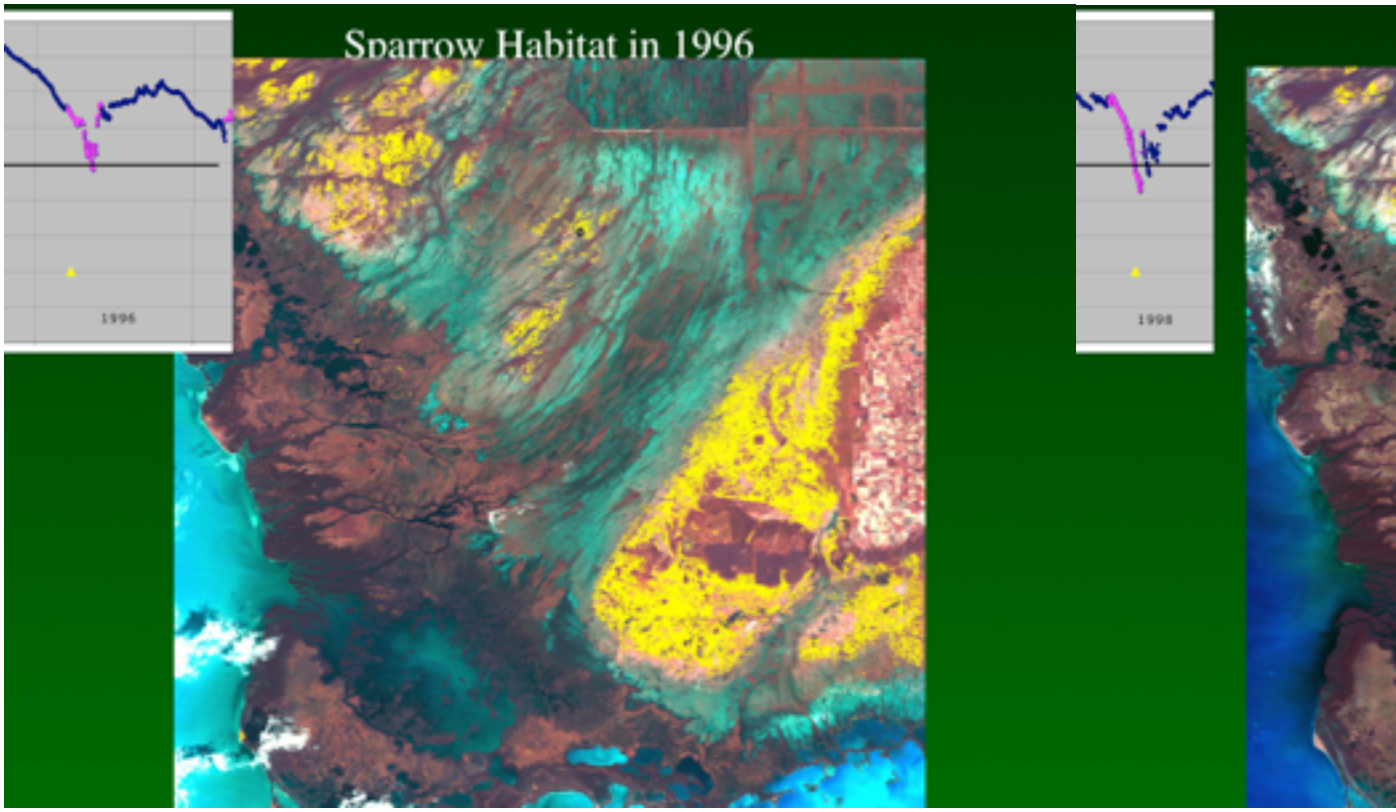
Appendix

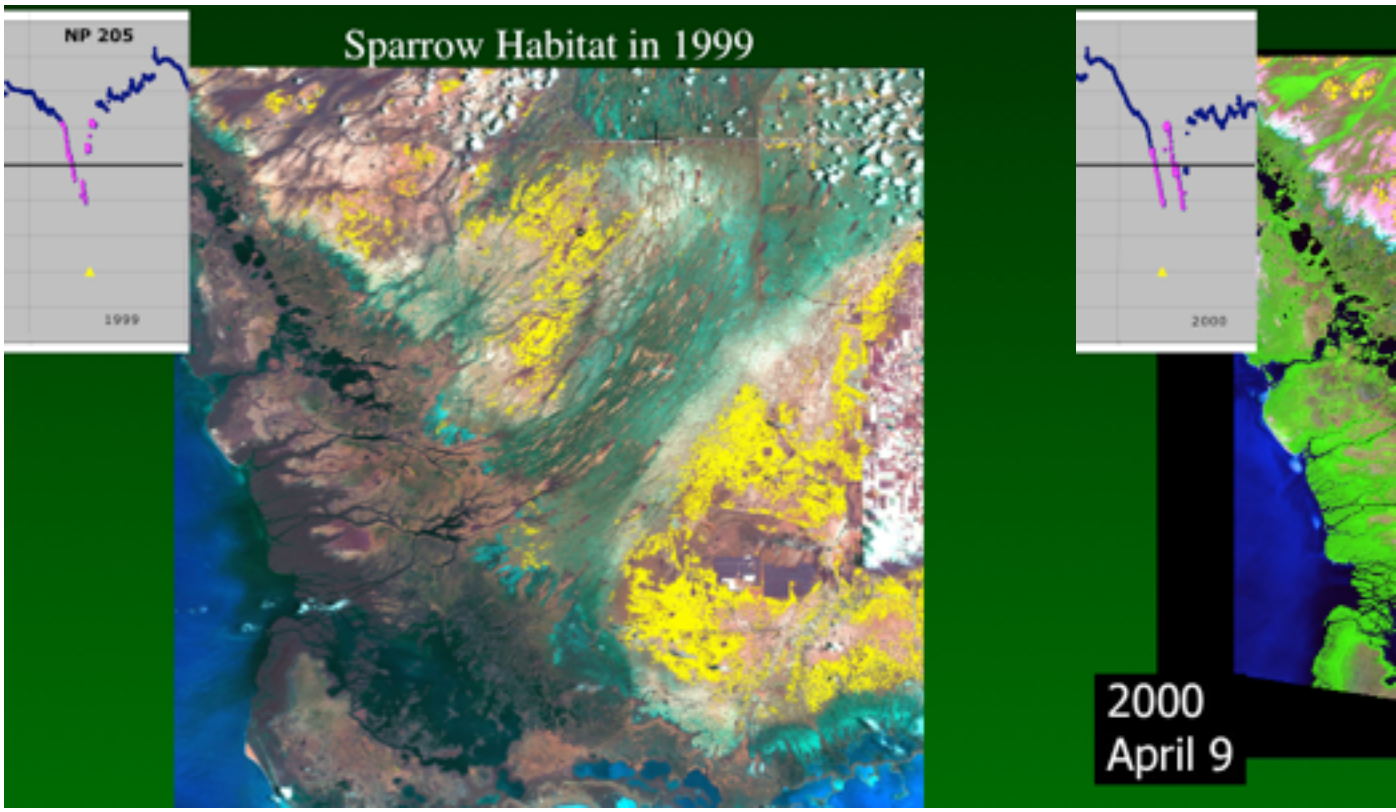
The images that follow implement the models we discuss above and show the predicted habitat in yellow. The insets at the left shows the water depths at NP205 in blue (outside the breeding season) and purple (inside the breeding season). Broadly, unless there was a sufficient number of days when NP205 was below a reference level (shown as a horizontal black line) there flooding prevented successful breeding.

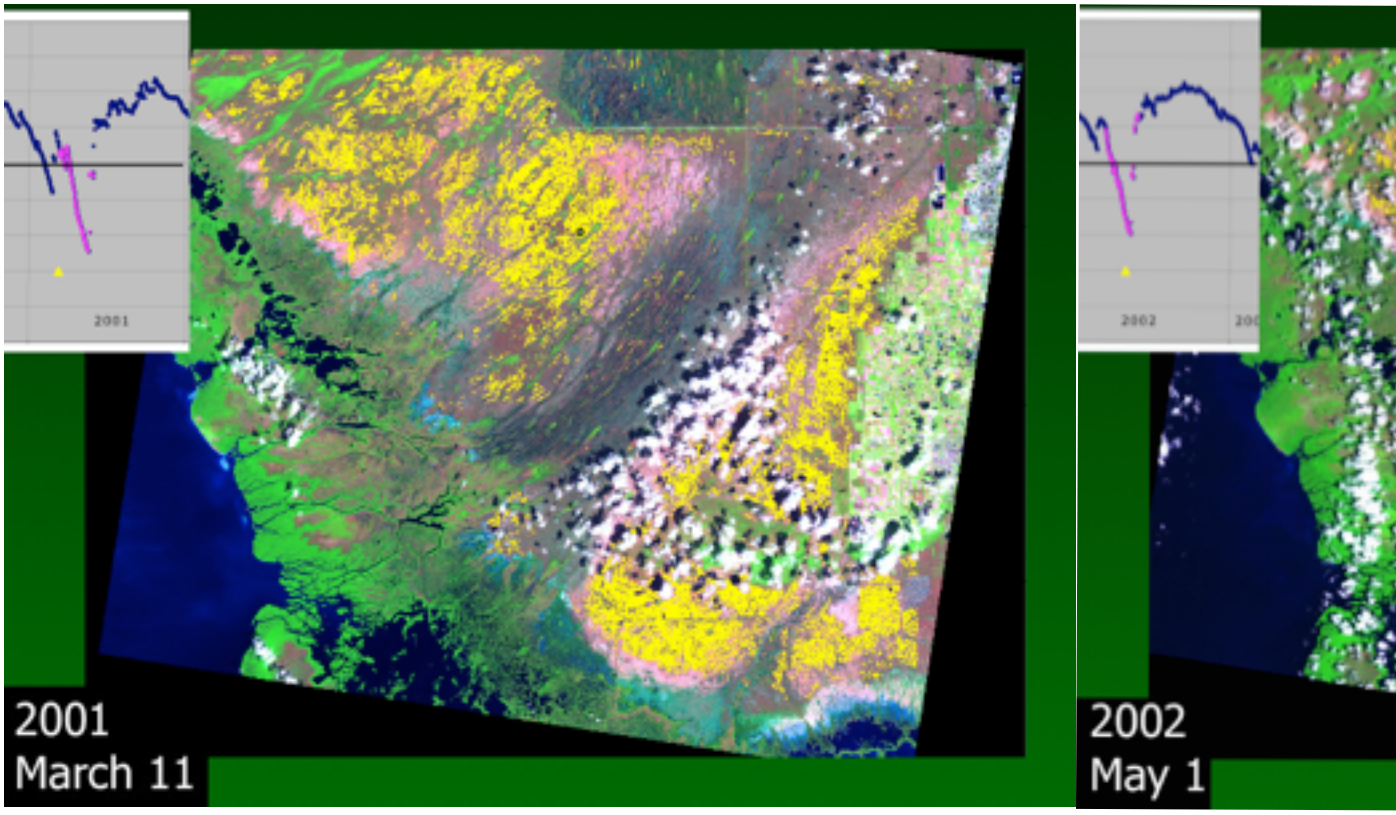

Sparrow Habitat in 1992


Sparrow Habitat in 1993


Sparrow Habitat in 1994
1995


Sparrow Habitat in 1996
1996
1998


NP 205
Sparrow Habitat in 1999
1999
2000
2000
April 9



Chapter 11

When good birds make bad choices

Clinton N. Jenkins, Robert D. Powell, Oron L. Bass Jr., Stuart L. Pimm

This chapter is from Jenkins, Clinton N, R. D. Powell, O L. Bass Jr., and S. L. Pimm . 2003. Why sparrow distributions do not match model predictions *Animal Conservation* 6, 39–46. It has been edited to reduce overlap with materials presented elsewhere.

Abstract

Chapter 10 describes the mapping of Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis*) habitat using satellite imagery. In general, those maps are

correct. However, testing against an independent survey of the sparrow population does identify errors. Those errors fall into two categories, model errors and bird errors. The model errors result from genuine problems with the model. More interesting for conservation are the bird errors, which are more numerous. They are of two types. 1) Commission errors - Some suitable habitat does not contain birds. These are areas where prior events have depleted sparrow numbers, but because of the sparrows' reluctance to disperse long distances, they cannot occupy it quickly. 2) Omission errors - Some birds remain in unsuitable habitat that was formerly suitable. This results from the sparrow's very high site fidelity. Often, they will not leave an area even when it is no longer suitable. The consequences of these bird errors are that some habitat and some birds are not contributing to the species' survival. Thus, an estimate of only the amount of habitat or only the population of sparrows may present an overly optimistic view of the sparrow's plight.

Introduction

Chapter 10 uses satellite imagery to produce maps that are predictive models of the habitat of the Cape Sable seaside-sparrow. Each year, a survey of the entire sparrow population by helicopter records all the birds encountered within a 200 m radius of the observer. In comparing the model's predictions to these surveys, we expect to find birds more often in areas where the model predicts more habitat. The companion paper confirms the overall predictions, but there are errors.

With *errors of omission*, we encounter birds, but the model fails to predict sufficient habitat. In *errors of commission*, the model predicts sufficient habitat, but the survey finds no birds. The purpose of this paper is to examine the causes of these errors. We will separate those errors due to the model from those due to inappropriate choices the birds make. We then ask, why do birds make bad choices?

These bird errors have important consequences for conservation. Quite generally, if organisms are not occupying suitable habitat, then that habitat is not contributing to the population's survival. Thus, measuring the amount of habitat alone may give an overly optimistic view of the species' plight. Similarly, organisms that are in unsuitable habitat do not contribute to the population's survival because they are unlikely to successfully produce offspring. Thus, population numbers alone may also give an overly optimistic view.

If we are to prevent the sparrow's extinction, we need to know both the amount of habitat and how much of it the sparrows will actually use. The companion paper tackles the former question. The errors in those predictions can help answer the latter. The first step in analysing those errors is to separate their various types and causes.

We shall show that about a quarter of the errors of omission are model failures. More interesting are the errors we attribute to the birds. The remaining three-quarters appear to be birds occupying unsuitable habitat either at the edge of densely populated areas or else remaining in areas that were suitable in a previous year but are no longer so. Of the commission errors, about two-thirds appear to involve suitable habitat that the birds cannot occupy because prior events have depleted their numbers and they cannot move into it quickly enough.

Before discussing these errors in more detail, we must first explain how we identify them.

Error causes

Of the 4645 survey points over 8 years, 663 have held one or more birds. The model successfully predicts that 499 (75%) should have held birds, leaving 164 (663 - 499) omission errors. Of the 3982 survey points without sparrows, the model successfully predicts 2486 (62%) should not hold sparrows, leaving 1496 (3982 - 2486) commission errors.

Both omission and commission errors have five potential causes: bird errors, model errors, survey errors, image errors and threshold errors:

1. Birds may make mistakes in their choice of territories, placing them in inappropriate places or not placing them in suitable ones.

- The model may incorrectly predict the habitat.

- Surveyors may make errors when surveying the sparrow population, missing birds that are present or recording birds by mistake when they are absent.

- The satellite image may not capture an important event affecting the habitat.

- Our threshold for predicting presence, 2 hectares, may be incorrect.

Threshold errors are a dilemma. Increasing the threshold increases omission errors while reducing commission errors and vice versa. We use the size of a territory (2 ha) because it is the lower limit of what the threshold can be and it is ecologically defensible. Sparrows need at least 2 ha but we do not know how much more they might need. We prefer to risk overestimating habitat than risk missing important areas. We will not discuss these errors further.

We must now try to assess the relative frequency of the remaining errors and to do this requires a "field guide" to their distinguishing characteristics.

Omission errors: where the model omits birds from places where they actually occur

Bird errors. Birds may make two kinds of omission errors, temporal and spatial. The first is where birds are in a suitable area that becomes unsuitable from one year to the next, but they remain there. Cape Sable seaside-sparrows rarely move more than a few hundred meters between years (Chapter 6). A diagnostic of this error is the presence of birds in predicted unsuitable habitat when, in the previous year, birds were present and the model judged the habitat suitable. For example, in figure 11.1a we successfully predict the presence of sparrows in 3 of 4 sites in 1992 (yellow dots). In 1993 (figure 11.1b), two of these sites still contain birds but we predict no habitat because of the flooding (red dots). These birds are remaining in the area even though suitable habitat has disappeared.

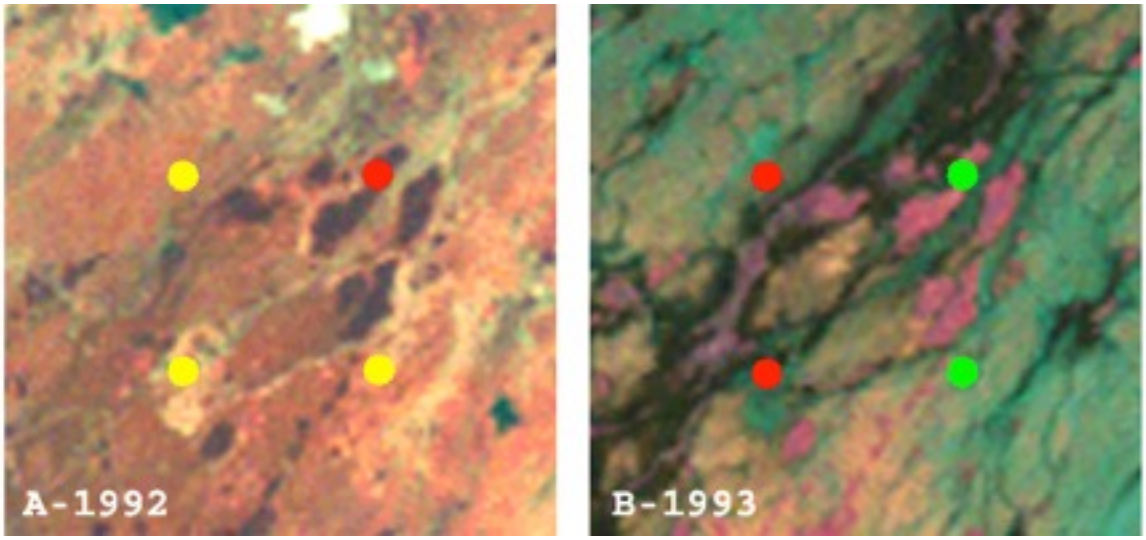


Figure 11 – Examples of *temporal bird errors* and a *bush model error*. The Landsat image in (A) is of the northern portion of population A in 1992. (B) is a 1993 image of the same area. These images are in false colour and employ three spectral bands, 5, 3 and 2 for red, green and blue respectively. In 1993, the prairies were flooded and water absorbs much of the mid-infrared light (band 5) leaving a bluish-green colour. Yellow dots are survey points where our model predicts birds and they are present. Red dots are survey points where the model does not predict sparrows, but they are present. Green dots are where the model does not predict sparrows and they are not present. In 1993, two sites that had birds in 1992 still contain birds even though flooding has destroyed the habitat. The red dot in 1992 is a bush model error. Although the location appears in the middle of a tree island, the helicopter would have landed near the trees, not within them. Our model does not predict enough habitat within a 200 m radius of the survey point (all habitat < 60 m from tree islands and other bushes are excluded), but nonetheless, one or more birds were counted here.

Spatial errors occur when birds in densely populated, productive habitat force other birds into adjacent marginal habitat. A diagnostic is the presence of birds in habitat the model predicts to be unsuitable with birds present in at least one adjacent point with habitat the model predicts to be suitable. These areas must also have a history of two or fewer sparrow occurrences during the study period and be near a large, presumably full population. For example, figure 2 shows the southern portion of population B in 1994. We successfully predict most of the sparrows, but fail to predict three sites along the southern margin.

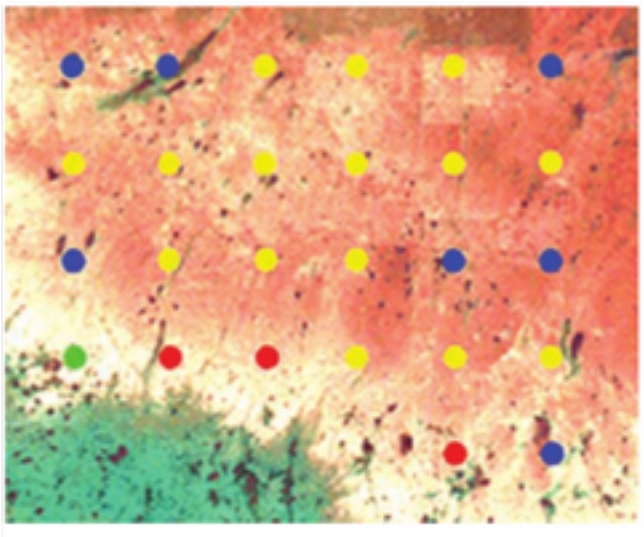


Figure 11.2 – Examples of *spatial bird errors*. A 1994 image of the southern portion of population B. This population is the largest and is densely populated with birds. Yellow dots are sites with birds that the model successfully predicts. Blue dots have no birds but the model predicts they should have birds. Green dots have no birds and no habitat. Red dots are sites with birds that the model does not predict should have birds. The three red dots occur in an area that usually does not hold birds and is flooded in some years. The bluish-green area in the southwest is water and the white areas along its edge are mostly periphyton, sparse vegetation, and exposed limestone.

Model errors. Our model does not always successfully predict suitable habitat. Two sets of criteria distinguish these model omission errors from bird omission errors. (1) *Bush model errors*: The model eliminates the area because it identifies it as having too many bushes, but it consistently has birds. This can happen when the helicopter lands outside a tree island when the correct coordinate would be within it. The actual survey point can then be closer to sparrow habitat than the model would predict. Figure 11.1a shows an example of a *bush model omission error*. (2) *Prairie model errors* are areas that consistently have birds (≥3 times) but where we see no evidence of fires or floods making the habitat unsuitable. Figure 3 shows a prairie model error. The central red dot is a site that consistently holds birds, the area around it consistently has suitable habitat with birds, but the model rarely classifies this area as suitable for reasons we do not understand. A large number of errors from population A in 1992 are also in this category. In that case, we have no signature of the sparse sawgrass habitat that occurred in A in 1992 and thus misclassify it as unsuitable. We explain this in detail later in the paper.

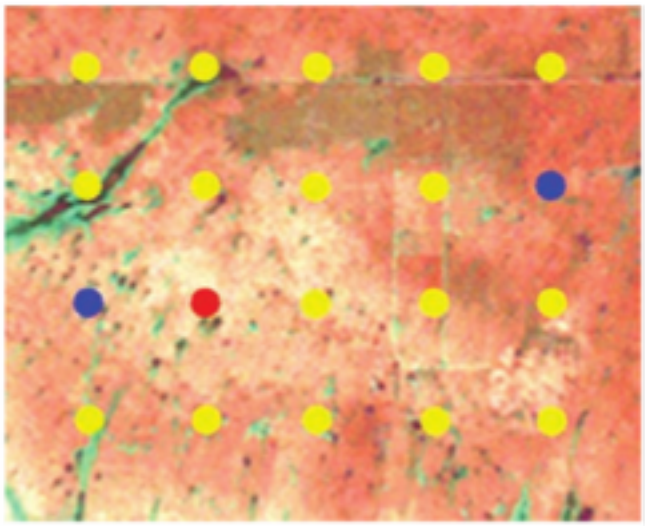


Figure 11.3 – Example of *prairie model error*. A 1993 image of the southern part of population B. Yellow dots are survey sites successfully predicted to have sparrows. Red dots are errors where sparrows are present but the model does not predict habitat. Blue dots have habitat but no sparrows. The red dot is a site that has birds in every year of the study. The area surrounding it has habitat occupied by birds. Yet, the model does not classify the area as suitable in 1993 or most other years, and there is no evidence of floods or fires.

Survey errors. Survey omission errors involve false detections of sparrows. They would appear as birds in locations unusual for sparrows, likely as single birds, and occurring only in single years. We have no examples of these errors. Surveyors only count sparrows if they sing and they are very familiar with the sparrow's song from years of experience. In addition, no other bird in the prairie has a similar song. We will not discuss them further. (The very distant songs of red-winged blackbirds and meadowlarks can sometimes fool the inexperienced and we give no guarantees that others who count the sparrows for other projects do not make mistakes.)

Image errors. Image omission errors occur when image problems cause a suitable area to be classified as unsuitable. They have two sources. Clouds in the satellite imagery may obscure suitable habitat in a survey area, causing an omission error. Therefore, before our analyses we remove any survey point that is cloudy in the satellite image. It is also possible that the habitat suitability will change between the image date and survey date. For example, if an area is underwater on the image date, the model will not classify it as suitable. However, if the water recedes before the survey it may become suitable and we will have an omission error. The reverse could happen as well. Evidence of flood between the survey and image dates identifies these errors. To avoid such errors, all of the images in this study are during or within three weeks of the survey dates. We find no image errors and will not consider them further.

Commission errors: where the model predicts birds in places where they are absent

Bird errors. Bird commission errors stem from the sparrow's limited dispersal. Fires or floods can eliminate sparrows from an area and damage the habitat. Thereafter, the habitat may recover, but the birds may take several years to reoccupy it. Areas of predicted suitable habitat that appear in one year, and then become occupied by sparrows in future years, confirm this type of bird error. So, too, do areas that had habitat and sparrows in the past, have predicted suitable habitat now, but the birds do not occupy them. Figure 11.4 shows an example from an area in population E. In 1996, only 4 sites (yellow dots) held birds while most of the predicted habitat was unoccupied. By 1998, the sparrows had expanded to occupy 11 additional sites.

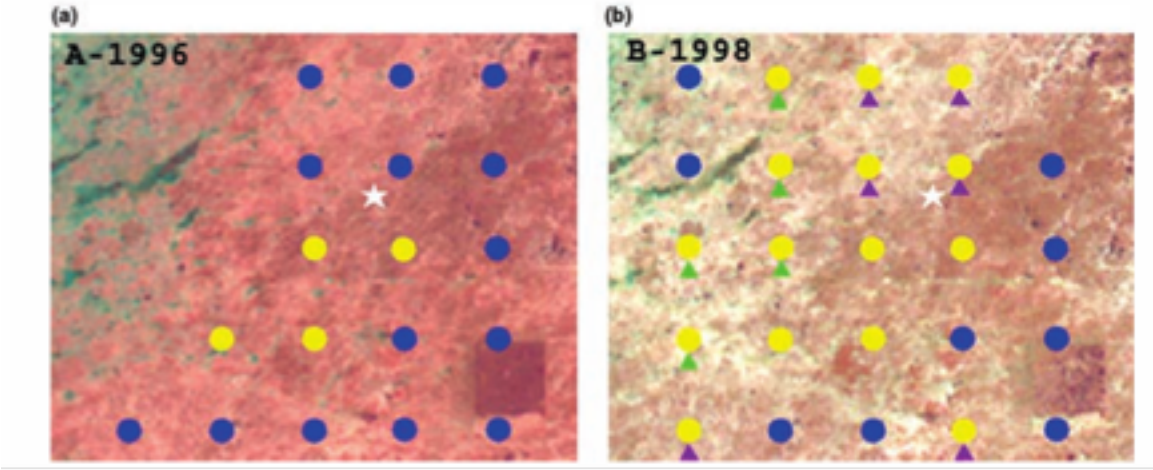


Figure 11.4 – Examples of *bird commission errors* and *bush model commission errors*. Landsat images from 1996 (A) and 1998 (B) of the northern part of population E. Yellow dots are sites with predicted habitat and sparrows present. Blue dots have predicted habitat but no sparrows. Fires in 1989 and flooding in 1993 and 1995 reduced this population to only 4 sites in 1996. As the floodwaters receded the habitat recovered, but a large amount remained unoccupied in 1996. By 1998, the population had rapidly expanded into 6 new sites predicted to be habitat in 1996 and 1998 (purple triangles). In addition, as the western area dried out, the habitat recovered and the sparrows have been expanding westwards (green triangles) into areas that were flooded, and so unsuitable, in 1996. Intensive fieldwork at one of our remote camps (white star) supports these results. This site is very densely populated and has the highest nest success rate of the three populations we monitor (Lockwood et al. 2001). The blue dots in the easternmost column are *bush model commission errors*. Bushes fragment the area too much to support sparrows, but the model fails to exclude it. The square feature in the southeast corner is from an abandoned tomato field dating from the mid 1970's. The ploughing and fertiliser permanently changed the area from prairie to shrubs.

Model errors. In model commission errors, the model predicts there should be birds, but the survey finds none. These errors have four causes. (1) *Bush model errors*

result when the area has too many bushes, but we cannot detect them with the satellite imagery. We identify these using the qualitative vegetation records from the extensive survey and aerial photography when available. (2) *Fire model errors* result when the area burns too frequently. We calculate the burn frequency using fire maps from 1980 to 1999. Sites burning in the previous year or three or more times during the previous ten years identify fire model errors. (3) *Data model errors* result from insufficient data to rule out model error when it may be a bird or survey error. (4) The cause may be unknown. The absence of sparrows at a survey point and in most adjacent survey points in every year distinguishes these from bird commission errors. Because the sparrow population has only been monitored for a short period, some suitable areas may never have had sparrows simply by chance. Thus, we are likely to overestimate model commission errors.

Figure 11.5 shows examples of *bush* and *fire model commission errors*. In the bush example (A), we regularly classify an area in population E as suitable habitat but it rarely has birds. A search of the vegetation records from the helicopter survey shows that 11 of the 16 sites in error contain vegetation that renders the area unsuitable. In the fire example (B), the model classifies most of population F as suitable. However, this area has a much higher fire frequency than elsewhere in the park, which renders it unsuitable for sparrows.

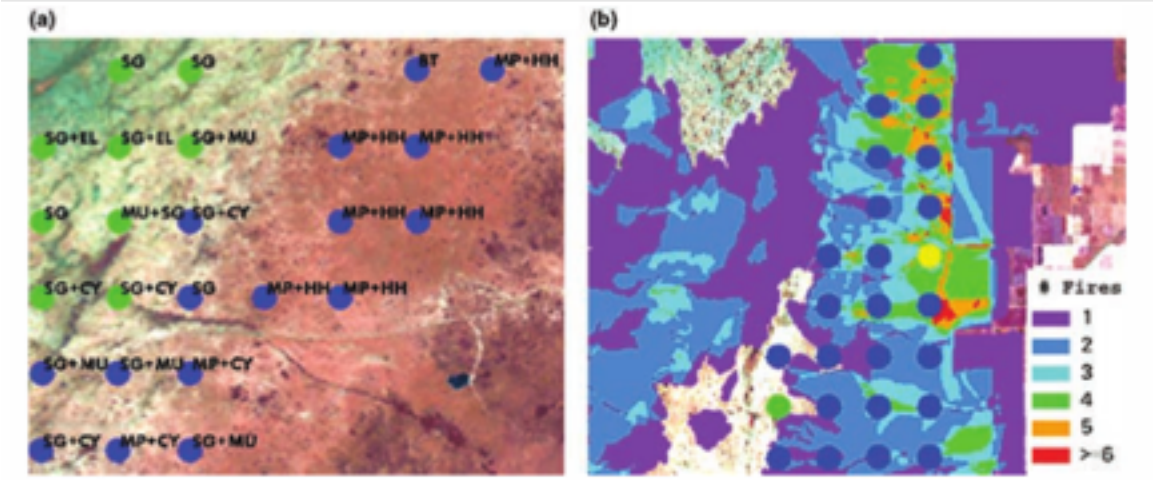


Figure 11.5 – Examples of *model commission errors*. (A) The southwestern portion of population E in 1998. This area rarely has any birds, yet the model classifies it as suitable habitat in every year. Inspection of the vegetation records from the survey show that many of these sites contain hardwood hammocks or cypress trees, which render the habitat unsuitable for sparrows. In particular, scattered cypress trees do not appear on the Landsat images (pixel size 30m by 30m) though they do show up on more finely resolved aerial photographs. SG= *Cladium jamaicens*e (sawgrass), EL= *Eleocharis cellulosa*, MU=*Muhlenbergia filipe*s (muhly), CY=cypress trees, MP=mixed prairie, BT=*Schoenus nigrican*s (black-top sedge), HH=hardwood hammock. (B) Population F in 1998 with fire frequency overlain. Population F has had very few birds throughout the study period, yet the model consistently classifies it as habitat. However, this area has had a much higher fire frequency over the past 20 years than

the rest of the park. Most of the survey sites in population F, which cover all areas potentially holding sparrows, have a fire frequency of 3 or higher, compared to 2 or less for most of the park. Because the model does not include fire, it fails to account for its effect on the sparrow population.

Survey errors. The survey does not always detect birds when they are present. The principal explanations are 1) the birds do not always sing and 2) birds move about their territories and will sometimes be beyond detection distance when we are surveying. When this happens, and the model classifies the habitat suitable, we get a commission error. These errors are indistinguishable from other commission errors because we do not know which survey points really had birds. If we did, then we would correct these errors.

By comparing the results of two coincidental surveys in 2000, we were able to estimate that birds were likely present at 34 sites in addition to the 165 sites at which we actually detected them (Pimm 2000). Scaling this proportion to the previous years suggests that birds should have been present at 800 sites [= (199/165) *663] and so missed at 137 of them. With this correction, there should have been only 3845 sites without sparrows, and the model prediction of 2484 sites leaves an error rate of 35% versus our original 38%. Given the small number of these errors relative to bird and model commission errors, it is unlikely they alter any conclusions. We will not discuss them further.

Image errors. Image commission errors result when habitat changes from suitable to unsuitable between the image and survey dates or vice versa. This may happen because of fire or flood damage. Evidence of fire or flood between the survey date and the image date identifies these errors. We find no image commission errors.

Results of Error Analysis

The 164 omission errors

Table 11.1 lists the classification of omission errors by year and by type, noting in which population the majority occurs.

Temporal bird omission errors have their highest proportions, relative to the number of points with birds, in the flood years of 1993 and 1995 and are primarily in population A, 52 of 79 (table 11.1). Population B has the second highest absolute number (12), but very few relative to the number of survey points with birds (364). Population D has 8 and is the second highest relatively (22 points with birds).

Flooding directly causes the high error rates in 1993 and 1995. Most of the errors are in population A, 19 of 24 and 10 of 15 respectively. In both years, opening of the S-12 flood control structures during the breeding season floods potential habitat in the western portion of the park. Related flooding also causes 4 errors in population D in 1993.

Table 11.1 – The three types of omission errors each year and the corresponding

number of points where birds were encountered. Numbers in parentheses indicate the population that contains the majority of the errors.

	Bird errors (temporal)	Bird errors (spatial)	Model errors	Total	Points with birds
1992	14 (12 in A)	4 (4 in B)	42 (41 in A)	60 (53 in A)	164
1993	24 (19 in A)	10 (9 in B)	1	35	99
1994	0	4 (4 in B)	0	4	60
1995	15 (10 in A)	5	1	21	48
1996	9 (8 in A)	3 (3 in B)	0	12	75
1998	1	6	0	7	108
1999	16	6	3	25	109
Total	79 (52 in A)	38 (27 in B)	47 (41 in A)	164 (95 in A)	663

Spatial bird omission errors are almost entirely in populations B and E, 27 and 7 respectively from a total of 38. This is not surprising, as these two populations have had most of the birds since 1992 (table 1 in companion paper). We find these bird errors typically along the southern and western edge of population B, and the northern portion of population E. These areas are where there is a sharp division from the dry prairies to wetter slough habitats dominated by sawgrass.

Model omission errors are only in populations A and B. Most of these errors, 41 of 47, are in population A in 1992, and most of them are in the western half of the population. The 1981 survey also found birds in this western area. Flooding in 1993 causes these birds to disappear. The most likely explanation for birds being present, but the model failing to classify the habitat, is that the habitat is genuinely different from what we find after the floods. The vegetation records from the 1992 survey support this conclusion. In 1992, 72% of the error points in population A have sparse sawgrass (*Cladium jamaicensis*) as their primary vegetation. In all of the intensive study sites, muhly grass (*Muhlenbergia filipes*) dominates or it is a mixed prairie with no dominant species. Thus, we can get no spectral signature for the sparse sawgrass habitat type.

If we compare the points that have birds and sparse sawgrass in 1992 to their vegetation in 1999, we find that this area has changed significantly from its pre-flood condition. *C. jamaicensis* now dominates only 18 of the 41 sites and most of those also have long hydroperiod species such as *Eleocharis cellulosa*. *E. cellulosa* is the dominant species in 12 other sites. In addition, the average percent ground cover increases from 62.8% to 87.8% ($p < 0.01$). This suggests that flooding has changed the overall vegetation to the detriment of the sparrow. Moreover, the birds we do see in later years do not occur in the western area but only in the eastern half where the model does predict habitat.

Population B has eight errors, but also has 55% of the total survey points with birds.

It is also the best-studied population because it has many birds and easy access. Thus, it is the easiest place to identify model errors.

The 1496 commission errors

Table 11.2 shows the number of commission errors by year and type, noting the populations in which the greatest number occurs.

Bird commission errors are relatively low in the flood years of 1993 and 1995 (table 2). They have the fewest errors while having the highest number of survey points without birds, and thus potentially in error. The incomplete survey in 1994 makes it artificially low. The floods primarily reduce suitable habitat, and thus bird commission errors, in populations A and D (figure 4 in Jenkins et al. this issue). The highest proportions of bird commission errors are in dry years after the floods recede, 1996, 1998, and 1999. This reflects the lag time between recovery of the habitat in A and D, and recovery of the sparrow population.

In 1993 and 1995, population A has 2 and 4 errors respectively, indicating an absence of open habitat. In 1994, there is a significant recovery of habitat (28 commission errors), but after the 1995 flood the habitat recovery is much slower. Thereafter, a steady upward trend is evident, going from 4 survey points in 1995 to 63 in 1999.

	Bird errors	Model errors	Total	Points without birds
1992	139 (39 in B, 39 in D)	158 (101 in A)	297	654
1993	131 (51 in B)	80 (25 in A)	211	753
1994	92 (55 in B)	59 (44 in A)	151	425
1995	87 (25 in B, 25 in D)	65 (21 in F)	152	688
1996	144 (59 in B)	60 (17 in E)	204	403
1998	161 (52 in B)	66 (22 in F)	227	510
1999	159 (63 in A)	95 (45 in A, 22 in F)	254	549
Total	913 (318 in B)	583 (258 in A, 110 in E)	1496	3982

Table 11.2 – The two types of commission errors each year and the corresponding number of points where birds were not encountered. Numbers in parentheses indicate the populations that contain the most errors.

The 1993 flood causes a large decrease in open habitat in population D, going from 39 bird commission errors to 6. The 1995 flood apparently had little impact with 25 error points, close to the average of 24. From the satellite images, it is clear that while the 1995 flood was more extensive around population A than the 1993 flood, it was less extensive in the region around population D. This may be due to less

movement of water down the L-31W and C-111 canals, which flow into population D.

The other populations have a higher elevation, protecting them from flood damage. Population B consistently has a high number of bird commission errors, but it is also the largest amount of habitat.

Model commission errors show both temporal and spatial biases. They are higher in 1992 both in raw number (158) and proportionally (24% of survey points w/o birds) than any other year. This high error rate is entirely accountable for by population A. In 1992, population A has 101 commission errors whereas the average for other years is only 26. However, this is likely an overestimate. Some of them may be bird commission errors. We propose two possible explanations.

The first explanation stems from a lack of data before 1992. For many places, 1992 was the only year of the study that they potentially had suitable habitat because of the 1993 and 1995 floods. If the model predicts an area suitable only in 1992 and it has no birds, we cannot tell if it had birds in previous years or would have had birds in the absence of flooding in the following years. Thus, an area may be good habitat and had birds for the last 10 years, and by chance had no birds in 1992. However, all we know is that it has no birds in 1992, and thus it is impossible to rule out model error.

The second explanation is that the sparrows were using the sparse sawgrass habitat in the west rather than the muhly and mixed prairie habitats in the east. Because the sparse sawgrass habitat no longer exists, we have no data to indicate if it may have been more suitable, and thus favoured by the sparrow. If that were the case, we would expect the sparrows to occupy most of the sparse sawgrass habitat before they expanded into the muhly and mixed prairie habitats.

Population E has a high number of model errors concentrated in the centre region. The model consistently finds the area suitable but we never find sparrows. However, in 1981 sparrows from the main northern population did extend farther southwest into this habitat than in 1992 and later years. In addition, a small population of sparrows occurs near the southwestern end of this “mis-classified” habitat in 1992. A possible explanation for this split population is a very large fire in 1989. This fire burned much of population E, but left the far northern and southern portions of the range intact. In addition, 1989 was a drought year, which could mean a lower food supply and thus higher sparrow mortality. Then in 1993, flooding eliminates the southwestern sub-population. The combination of the 1989 fire and 1993 flood may have left population E with only a small northern sub-population. Without survey data during this period, it is impossible to confirm this scenario and thus rule out model errors. Thus, this area may be suitable, but sparrows have yet to re-colonise it.

Population F, and to a smaller extent population C, has many commission model errors because of high fire frequency. Fires exclude sparrows in two ways. One, frequent fires prevent the vegetation from becoming thick enough to support a

sparrow nest, supply adequate food resources, or provide adequate cover from predators. Two, fires during the breeding season interrupt nesting, reducing total fecundity. The model captures some fire effects via vegetation changes that are visible in the satellite image. However, the lack of an explicit fire component causes the model to predict habitat in areas unable to support a sparrow population.

Conclusions

We find that our model is an accurate tool for understanding the dynamics of Cape Sable seaside-sparrow habitat. The model error rates are low, 7% for omission errors and 15% for commission errors. Moreover, these are likely overestimates. Most of the omission errors result from an inability to map the sparse sawgrass habitat that existed in population A in 1992. We know of no other occurrence of this habitat. Excluding population A in 1992 leaves a model omission error rate of just 1%.

Two factors reduce the model commission error rate. First, many commission errors are also from population A in 1992. We suspect the birds preferred the sparse sawgrass habitat in the west and used it before using the habitat we find in the east. The lack of survey data before 1992 makes it difficult to confirm this scenario. Second, we undoubtedly miss some birds in the survey for reasons described earlier. Considering these two factors reduces the model commission error rate to 10%.

Most errors result from water managers forcing conditions on the sparrow to which they are not adapted. This is because of the sparrow's strong site fidelity and its inability to quickly occupy newly available habitat (Lockwood et al. 1997, Dean and Morrison 1998, Lockwood et al. 2001). These "bird errors" demonstrate that the sparrow cannot cope with the habitat variability that resulted from floods in 1993 and 1995.

Bird omission errors result primarily when floods destroy habitat from beneath the sparrow. Because of the sparrow's strong site-fidelity, it will stay even when the habitat disappears. This means they have little chance of survival unless the habitat returns quickly. Such was not the case for population A where floods in 1993 and 1995 caused damage that had yet to fully recover by 1999.

Bird commission errors are a direct measure of the open habitat into which the sparrow population can grow. As no organism is 100% efficient in occupying its habitat, we would expect there to always be some open habitat. Indeed, most of the populations have a relatively constant amount. However, the 1993 and 1995 floods meant there was essentially no open habitat in population A. Simply, there was not enough habitat to support the sparrow population and it declined dramatically. Thereafter we see a steady increase in open habitat. However, the sparrow's low

population growth rate means it will take another decade, under optimal conditions, for this population to return to pre-flood numbers.

The poor water management decisions made during this study have resulted in the effective sparrow population and amount of suitable habitat to be lower than they first appear. The consequence is that a species we already knew to be threatened with extinction is actually in a more perilous situation than we previously thought. As long as water management such as occurred during this study period continues, the Cape Sable seaside-sparrow faces an unnaturally high risk of extinction. To prevent the sparrow's extinction, water managers must ensure that suitable habitat is both present and that the sparrows are able to occupy it.

Chapter 12
Changes in sparrow numbers and their causes
Part 1: Chance, hurricanes, and fires

Stuart L. Pimm and Oron L. Bass

Abstract

The Cape Sable seaside-sparrow (*Ammodramus maritimus mirabilis)* has disappeared from its only known breeding areas episodically since its discovery early this century. Systematic surveys across its range in the southern Everglades find the sparrow's range to be fragmented into six subpopulations. The sparrow population decreased by 58% between 1992 and 1995, with the near extinction of the western half of the population and the temporary local extinction of some eastern populations. Other similar grassland sparrows have populations that vary considerably from year to year. Yet the decline in the western subpopulation and the local extinction of some of the peripheral populations cannot be explained by natural variability alone. Hurricane Andrew passed over several subpopulations prior to the particularly poor year of 1993. However, the geographical and temporal patterns of subpopulation decline are not consistent with what would be expected following a hurricane. Frequent fires prevent successful breeding as does flooding during the breeding season. Better management can prevent frequent fires and episodic flooding. However, the long-term survival of the sparrow depends on managing the unanticipated risks that attend its small, fragmented population.

A summary of the extensive survey results

In 1981, Bass and Kushlan (1982) estimated a total of 6600 birds in six subpopulations; two core populations (A, B) that held most of the sparrows, and four peripheral populations (Table 8.2 Figure 8.1). Core population A inhabited the marl prairies west of Shark River Slough, interlaced between drier shrub-dominated areas and wetter areas dominated by sawgrass *(Cladium jamaicanese).* It extended into Big Cypress National Reserve, and in small numbers up a northwest strip between mangroves and the mixture of forest and open prairies. Combined, these areas held an estimated 2688 individuals. Core population B held 2352 individuals near the centre of Everglades National Park. Peripheral subpopulation E, just north of B, held 672 sparrows, while C and D, located along the park's eastern boundary, held about 400 individuals each. F was the smallest subpopulation (at 112). The

survey covered a few possible breeding sites on Cape Sable, but found no birds there.

Bass repeated the survey in 1992, with one day's help from Stuart Pimm, exploring many wetter sites in Shark River Slough (and elsewhere) in case the bird was more widely distributed than expected. It was not and the numbers in 1992 closely mirrored those in 1981 (Table 8.2 Figure 8.1). (Similarly, in 1996, we searched for possible sparrow habitats in openings among the mangrove-dominated areas to the west of area A. No birds were found there either.)

Population A

Population A decreased by 84% from 1992 to 1993 — a decline from nearly 2700 birds to just over 400 birds. In 1994, technical difficulties led to the surveying of only ~25% of the sites of population A (Figure 8.1). Table 8.3 shows the counts for the four years are these sites. Some 52 birds were counted there in 1981, 44 in 1992, but then only 8 birds in 1993 and 5 in 1994.

In 1995, the second year for which we have complete survey data for this area after Hurricane Andrew, we found that the population further decreased to nearly half of the 1993 abundance (Table 8.1, Fig. 8.1). Numbers have remained low ever since. In the 18 years, from 1995 onwards, the population has only once exceeded 400 birds, and has remained below 260 — 10% of its 1981/1992 levels in 13 of those years. Figure 8.1 shows that those birds are clustered in the northern area of the once more continuous range, and where we established West Camp as a consequence. The small populations to the northwest held a few birds in 1993, but only one (in 2000) ever since.

Population B

Since 1992, population B has held the majority of the sparrows. (In 1981 area A held more birds.) While there is some inter-annual variation in population B, overall there is no obvious trend.

The smaller populations —C, D, E, and F

Population C declined to 11% of its 1981 value by 1992. After an apparent three-year absence, we estimated 48 sparrows in this area in 1996. It has held small populations ever since. As we shall explain later, the southern portion of this population is downstream from a water pumping station. These birds disappeared after 1981, for reasons we will discuss later.

Population D declined from 1981 to 1992 and was not counted in 1994. We found no birds here in 1995, but estimated the population in 1996 to be 80 birds. As we shall discuss later, this population has been hard hit by fires and floods and its recent high estimate of 224 in 2012 likely a consequence of much improved conditions.

Since 1993, population E has held the second largest numbers of birds. The lowest numbers were in 1993, 1995, and 1996 — years of high water levels. This

population has two clusters of birds — a northeastern and a southwestern. Birds are absent from the later in those years of high water.

Population F has very few birds and, in some years, we do not detect it there at all.

We now consider what might cause these changes. Four factors are leading candidates: (1) Natural fluctuations in numbers, (2) Hurricane Andrew, which came after the 1992 breeding season and so just before the precipitous decline in numbers in population A in 1993, (3) fires, and (4) floods.

Chance fluctuations in numbers

This section is extracted from Curnutt, J. L., A. L. Mayer, T. M. Brooks, L. L. Manne, O. L. Bass, Jr., D. M. Fleming, M. P. Nott and S. L. Pimm. 1998. Population dynamics of the endangered Cape Sable seaside-sparrow. *Animal Conservation* 1:11–20.

All populations fluctuate from year to year (Pimm, 1991), grassland sparrow populations fluctuate considerably, and populations at the edge of the species' range are the most variable (Curnutt *et al.,* 1996). Before we point the accusatory finger at some specific explanation, we should be sure that this sparrow's declines and local extinctions are sufficiently unusual events.

The one-year decline in population A to 16% of its 1992 level is atypical. For instance, in the extensive, long-term population monitoring of British birds, unusually so (Pimm, 1991). The most severely affected species — small-bodied insectivores — declined to ~ 50% of their 1962 levels. The causes of this much larger decline in population A clearly require investigation.

More problematic are the other populations. Small, peripheral populations of abundant, widespread species fluctuate considerably (Curnutt *et al,* 1996). Their local extinctions are commonplace and need not elicit special concern. How long should populations be absent locally before we express concern?

Methods

Curnutt *et al.* (1996) used North America Breeding Bird Survey (BBS; Robbins, Bystrak and Giesler, 1986) data to analyse the spatial and temporal population variability of 10 species of grassland sparrows. Their distributions typically consist of one or more areas of high density and relatively low variability surrounded by peripheral low-density populations that are highly variable. The Cape Sable seaside-sparrow population appears to behave in much the same way.

With two assumptions, we could apply these analyses to the Cape Sable seaside-sparrow. We wished to estimate the probability that it would be absent from an area for a specified period. The first assumption was that *its dynamics were typical of other, non-endangered grassland sparrows.* There was little variation between the 10

species of sparrows Curnutt *et al.* (1996) analysed and it seemed reasonable to assume that this sparrow's dynamics might be comparable.

The second assumption rested in the correspondence of BBS data and the extensive sparrow survey (Bass and Kushlan, 1982). Each BBS consisted of 50 observation points at least 0.8 km from each other where participants recorded all birds heard or seen. Observations for the Cape Sable seaside-sparrow survey were similar, though the distance between sites was exactly 1 km. As in the BBS, no observations did not necessarily mean an actual local extinction. But if not, then the apparent absence represented a fall in the numbers to some small and comparable level. (Recognising this possibility, we will not preface each use of the word 'absent' by 'apparent' for simplicity's sake.)

We determined the probabilities of sparrows being continuously absent from a BBS route for 1-12 years - the maximum length of an absence that could appear in our Cape Sable seaside-sparrow data. We combined the data for all 10 grassland species and selected all BBS routes that had continuous data from 1970 to 1989. We only used routes where birds were present in the first and last years of record *(n* = 284**)** to exclude areas where the species might be lost from long-term habitat changes. For each route, we calculated the mean abundance over 20 years and tallied the number of occurrences that a species was absent one year, two consecutive years, three consecutive years, etc. We grouped routes by their mean abundances (in increments of 10) and determined the proportion of occurrences for each length of absence. We expressed these rates as proportions to determine probabilities (Figure 10.1).

Results

The populations A, B and E have consistently held sparrows over all survey years (198 1 and 1992-1996). In contrast, populations D, C and F have apparently dropped to zero on one or more occasions (Figure 8.1). For these areas we can compare the survey results with our probability model to determine whether we would expect these absences to be due to chance.

In typical years, there are 70 survey sites within the area of population D, 43 sites in area C and 38 in area F. We assume that these numbers are close enough to the 50 sites of a BBS route that we can make direct comparisons with them. That is, a zero count from one of these areas is equivalent to a zero value in the BBS data set. Survey data for both populations C and D are incomplete for 1994.

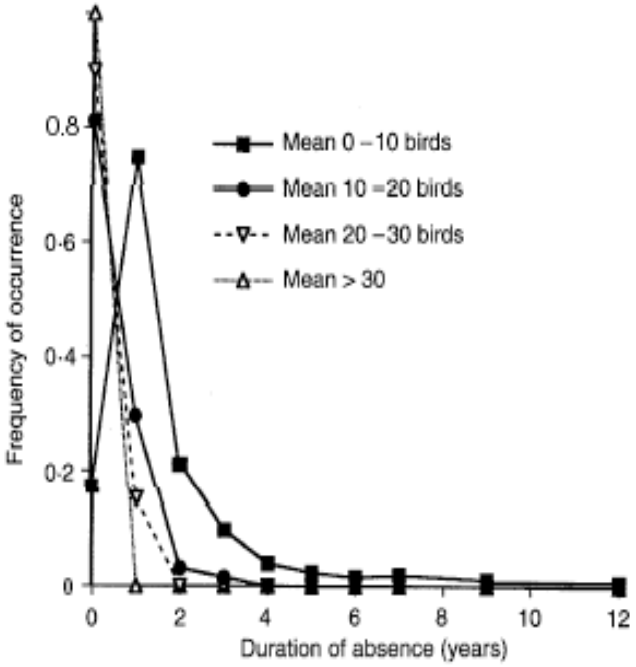


Figure 12.1. The frequency of occurrence of consecutive zero counts of 10 species of grassland sparrows on BBS routes for different overall mean abundances.

We counted 25 birds in population D in 1981; birds were absent for one year (1995) and could also have been missing in 1994. For BBS routes with between 20 and 30 birds counted on average, the probability of a single year absence is 0.15 (Figure 12.1). On its own, we should not consider this one-year absence to be unusual. If there were no birds in D in 1994, then a two-year absence would have been highly unusual (Figure 12.1). Population C occupies the upper reaches of Taylor Slough - formerly prime sparrow habitat, where Werner (1975) conducted much of his work. Here, as late as 1981, sparrows were relatively plentiful (27 birds). This population was absent for either three consecutive years (1993-1995) or twice for one year, depending on the unknown value for 1994. In the BBS data, three-year absences are unknown for populations that average more than 20 birds. They occur less than 5% of the time for those that average more than 10 birds.

The area of population F holds only 38 sites so we should be cautious in applying the BBS-derived model to our survey data. The area is bounded to the east by agricultural fields and is surrounded by habitat unsuitable for sparrows, primarily due to high densities of native and exotic shrubs. We can assume, therefore, that the survey results represent the entire population of the area, and that zero values are comparable to BBS zeros. We counted seven birds in 1981, two in 1992, and no more until we saw one in 1996. The sparrows could have been absent for a maximum of three consecutive survey years. The probability of a population averaging seven birds being absent for this length of time is 9% —a low, but not statistically significant probability.

We conclude that chance fluctuations is not a sufficient explanation for the declines

First, in the west, the drop in population A from 1992 to 1993 is highly unusual and it requires explanation. Second, in the east, if 1981 represented an average year for its subpopulations, then the likely three-year absence of the birds from population C, and the possible two-year absence from population D, are unusual events. Population F is so small that such absences might occur in roughly one in 10 comparable data series. Taken together, the declines in these three, peripheral, eastern populations are sufficiently unlikely to require our searching for specific causes.

Hurricanes

This section is also based, in part, from Curnutt, J. L., A. L. Mayer, T. M. Brooks, L. L. Manne, O. L. Bass, Jr., D. M. Fleming, M. P. Nott and S. L. Pimm. 1998. Population dynamics of the endangered Cape Sable seaside-sparrow. *Animal Conservation* 1:11–20.

In this century, 80 hurricanes and other tropical storms passed close enough to south Florida to affect the Everglades (Duever *et al.,* 1994). The official hurricane season lasts from June to November with September being the most frequent month of occurrence. Hurricanes could have a variety of effects on sparrows. They normally fall outside of the main sparrow breeding season of March to early June (Lockwood *et al.,* 1997) and thus are unlikely to kill nesting birds. When hurricanes do strike, the high winds could kill birds directly. Hurricanes and tropical storms can drop up to 25 cm of rain. Thus, a storm early in the storm season could result in flooding and the termination of nesting, since most nest are within 15 cm of the ground (Lockwood *et al.,* 1997). Wet storms that occur as late as October or November could prolong a high wet-season water table (Duever *et al.,* 1994). In turn, this could delay the period of 'drydown' the following spring and so delay the onset of nesting.

We know of two hurricanes that have affected the sparrow. In 1935, a hurricane temporarily flooded Cape Sable with salt water. It caused subsequent changes in vegetation that made Cape Sable unsuitable for the sparrow. Previous to the hurricane of 1935, the Cape held large expanses of prairie dominated by cordgrass *(Spartina bakerii)* (Holt and Sutton, 1926). By the 1970s many of these prairies had converted to mangroves, bare mud flats, and halophytic forbs (e.g. *Batis* sp. and *Borrichia* sp.) as a result of the substrate deposited by the storm (Kushlan *et al.,* 1982).

Werner (1975) and Bass found sparrows on Cape Sable until 1978, but not since (Bass and Kushlan, 1982). We speculate that the habitat remaining on the Cape became too small to support a viable population of sparrows. This scenario suggests a hurricane-mediated extinction but in the long term, through habitat changes, rather than directly because of the storm itself. In August 1992, Hurricane Andrew

scored a near direct hit on the Cape Sable seaside-sparrow, its eye and eye-wall encompassing almost the bird's entire range (Figure 10.3; Armentano *et al,* 1995).

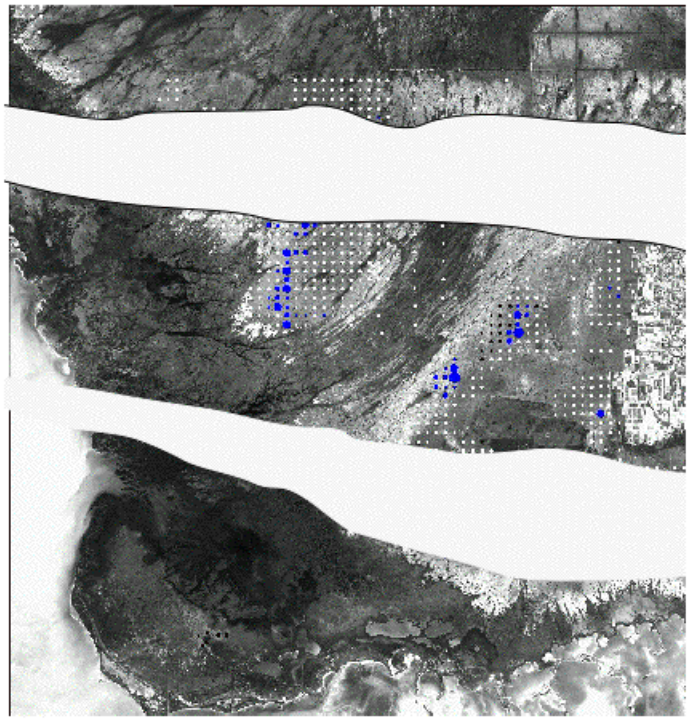


Figure 12.3. The path of Hurricane Andrew across sparrow habitat. The two white bands are the estimated paths of the eye walls, where winds would be expected to be strongest.

Hurricane Andrew's effect was most obvious in the hardwood hammocks and pines within its path. Figure 10.4 and 10.5 show satellite images taken on August 17th, 1992, just before the storm, and September 2nd, just after it, for population A and populations B and the southern part of E, respectively Flying over these areas in late August, one had the sensation of winter having come to the Everglades in late summer — all the vegetation appeared dead and brown as in a northern winter. Figure 10.4 makes this point vividly. In August, the tree islands are green amid the flooded prairies. Two weeks later, the tree islands and the prairies are the same dull colour.

The same pattern is true for population B, but the most obvious changes are in the dense stands of *Schinus* that reclaimed former agricultural fields. These show as bright green squares in August, but were completely defoliated by the storm.

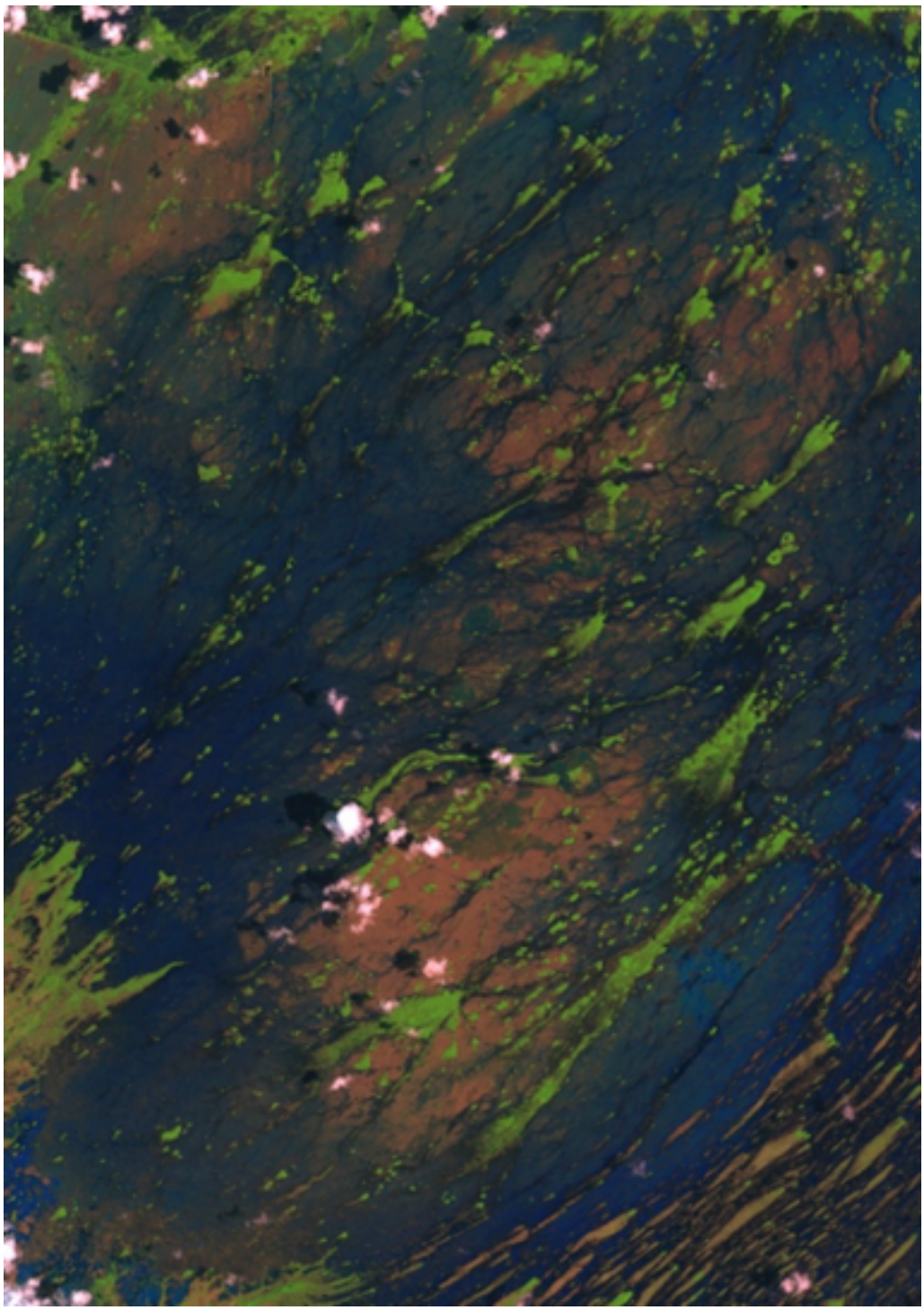


Figure 12.4 (a) August 17th, 1992, Population A.



Figure 12.4 (b) September 2nd, 1992, Population A.

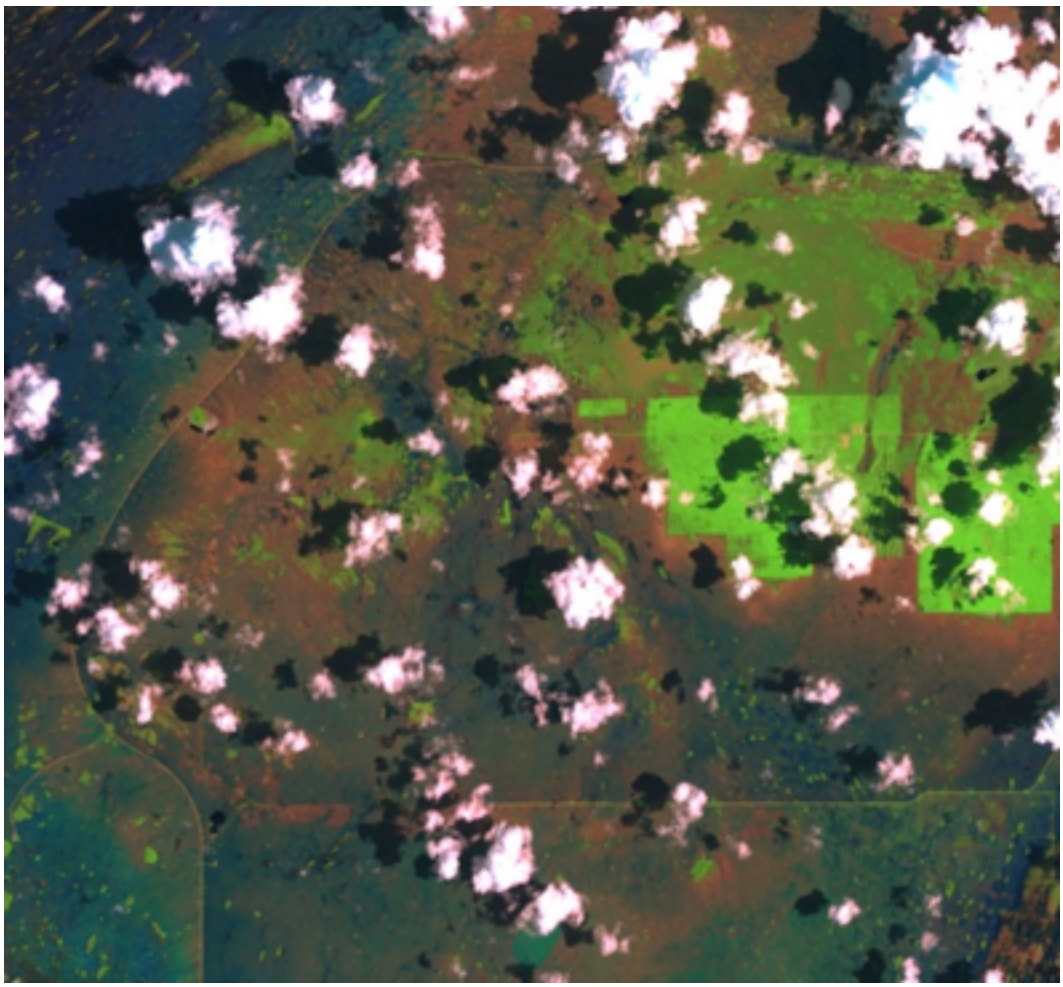


Figure 12.5 (a) August 17th, 1992, Population B.

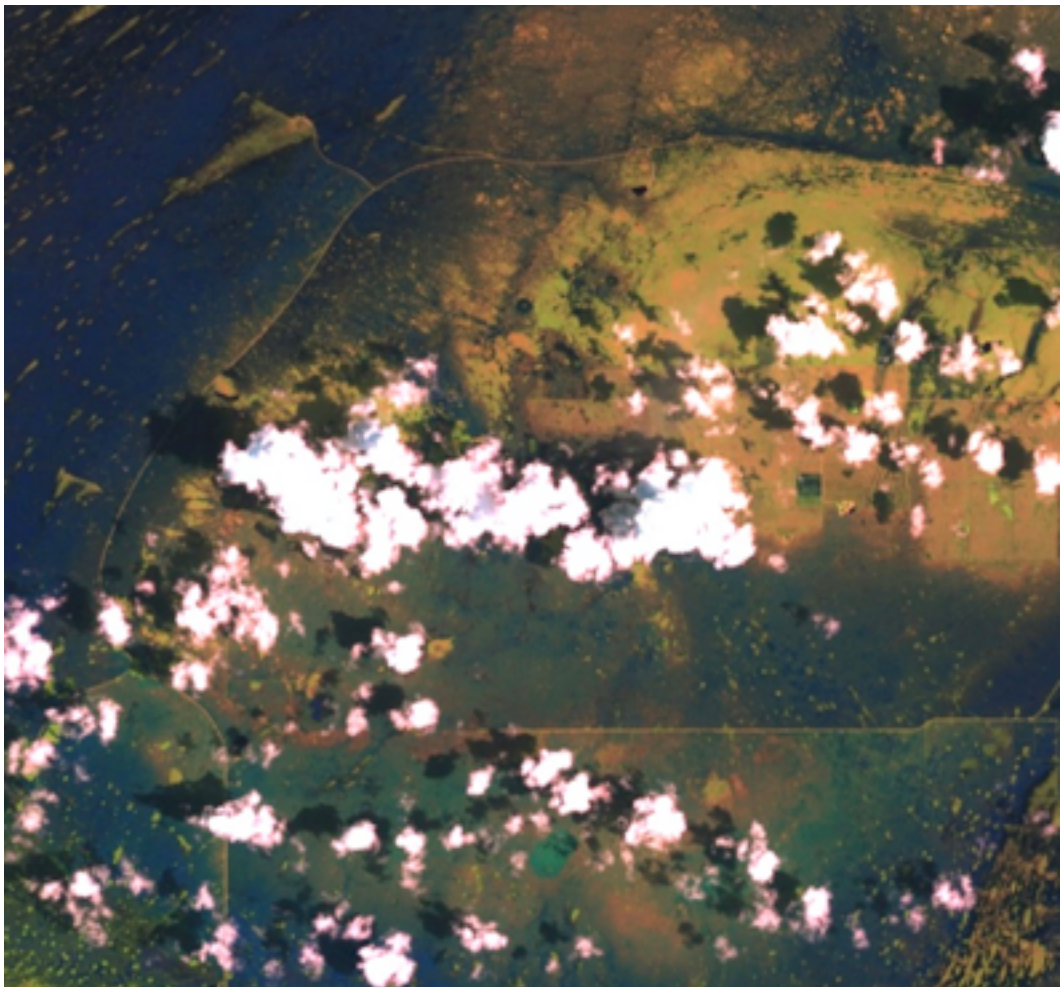


Figure 12.4 (b) September 2nd, 1992, Population B.

Changes to the prairies were less obvious (Pimm *et al.,* 1994). There is no evidence that hurricanes cause direct mortality of sparrows, although surely the sustained winds of 242 km/h of Hurricane Andrew were lethal to at least some of them. We did not count the birds immediately after the storm, nor indeed, can we count them outside of any breeding season. The complete defoliation of the forests, however, combined with the massive physical damage to the trees, initial suggested Andrew might have been the principal cause of the sparrows' decline from 1992 to 1993.

Closer inspection, however, let is to conclude that despite the overall declines in areas A and E from 1992 to 1993, Andrew was not their major cause. In area A, the numbers outside the eye, but within the northern eye-wall, declined dramatically. The numbers in population B in the southern eye-wall did not. The decline in area E was entirely within its southern part. The numbers in the northern part of area E,

though also within the storm's eye, actually increased. We might expect population A to recover from a short, sharp mortality were habitat conditions suitable. In fact, it declined further and has remained at low levels since. Numbers in populations B and E remained high or even increased. We must look elsewhere for the massive decline in population A.

Fire

Chapters 4 and 5 have considered fire both in the detail of its affects on sparrow breeding ecology and on the long-term effects (or lack of them) it has on the mix of bushes and prairies within the Everglades ecosystem. The question remain is whether these fires are extensive enough to alter sparrow numbers significantly. There is abundant evidence that they do from the populations closest to the park's eastern boundary where fire frequencies are highest (figure 5.1).

Population D

Subpopulation D has not had a large number of birds since the original 1981 survey, when it had an estimated 400 birds. In 1992, it held only an estimated 112 birds. Figure 12.5 shows that a major fire in 1990 burned where the birds had been in 1981, providing one explanation for the birds absence. (There could have been other factors in the interval, of course.)

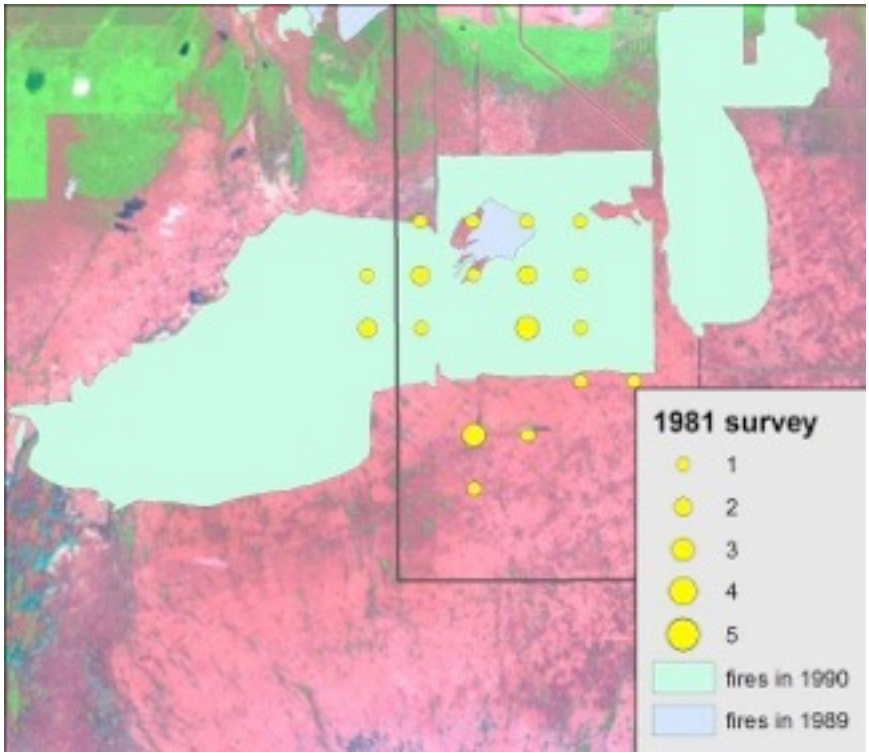


Figure 12.5 – Subpopulation D with overlay of 1981 survey results and fires layers for 1989 and 1990.

The population remained low and we counted no birds in 2002, 2003, 2004, 2005, and 2007. Inspection of the satellite images of Chapter 9, shows the area to be flooded in 1994, 1995, 1996 and 1998. In 2000, 2001, 2003, 2004, and 2006, the extensive blue areas on the images show just how extensive were the fires in this subpopulation. Figure 12.6 shows a detail from November 2001.

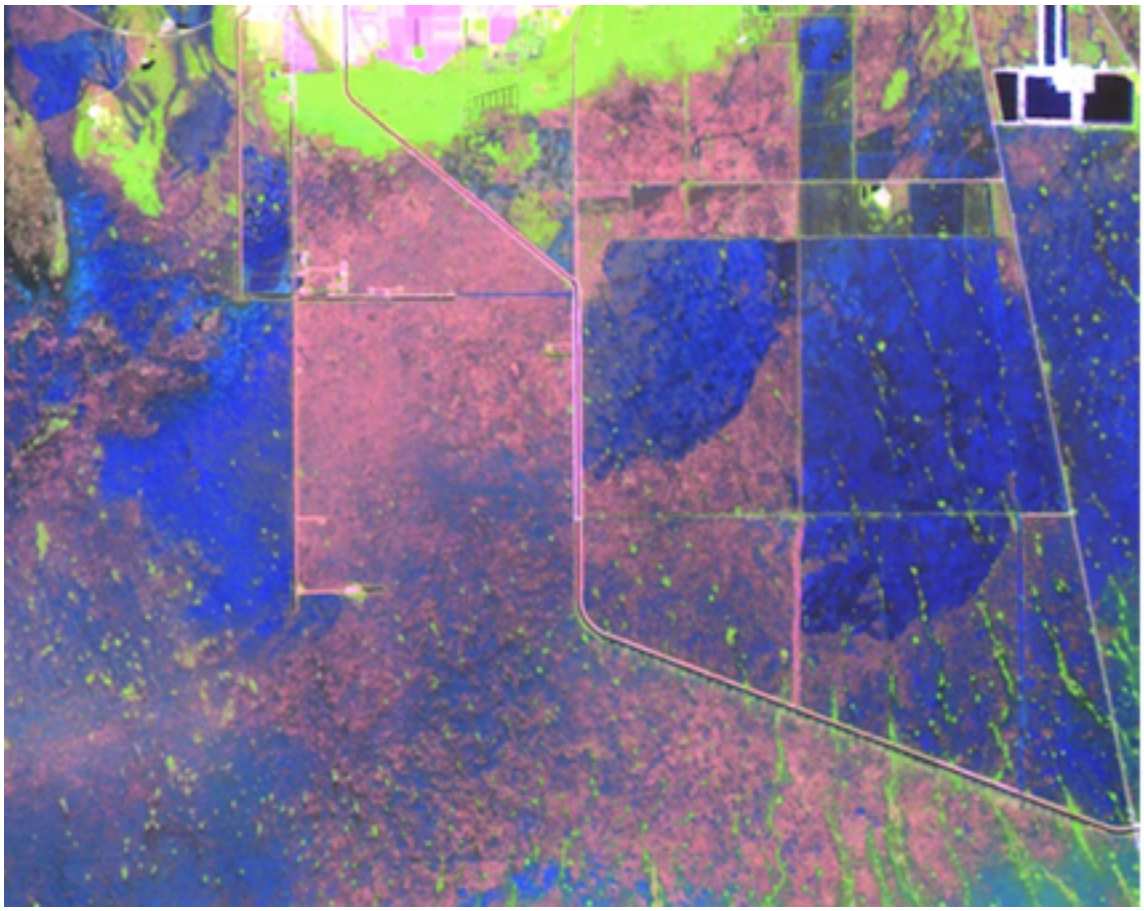


Figure 12.6. Population D in November, 2001.

Now, we expect the area to be wet in November, of course, but these extensive areas of blue indicate a continuous sheet of water, almost certainly the consequence of the vegetation having burned off by fires earlier in the year.

Now, this population is close enough to both populations C and E that immigration is possible if conditions improve. (See Figure 6.4). Indeed, in 2012, we estimated 224 birds here, the second largest count. Clearly, properly managed, this population can recover.

Population C

Subpopulation C was approximately 400 birds in the 1981 survey but had declined to fewer than 100 by the next survey in 1992. The specific cause of the decline is unknown, although fires in 1990 and 1991 burned about a third of the area (Figure 12.7). Since at least 1996, there has been a small but persistent population in this area. However, in both 2007 and 2008 the survey detected only 3 birds. Continued problems of flooding and fire prevent this population from recovering. In particular, the pumping station into Taylor Slough floods part of the population that was formerly dry. (We discuss this below.) As well, there is the continuing risk of anthropogenic fires. This was highlighted most recently in 2007 when the Frog Pond fire escaped into the park, burning a substantial amount of sparrow habitat (Figure 12.8).

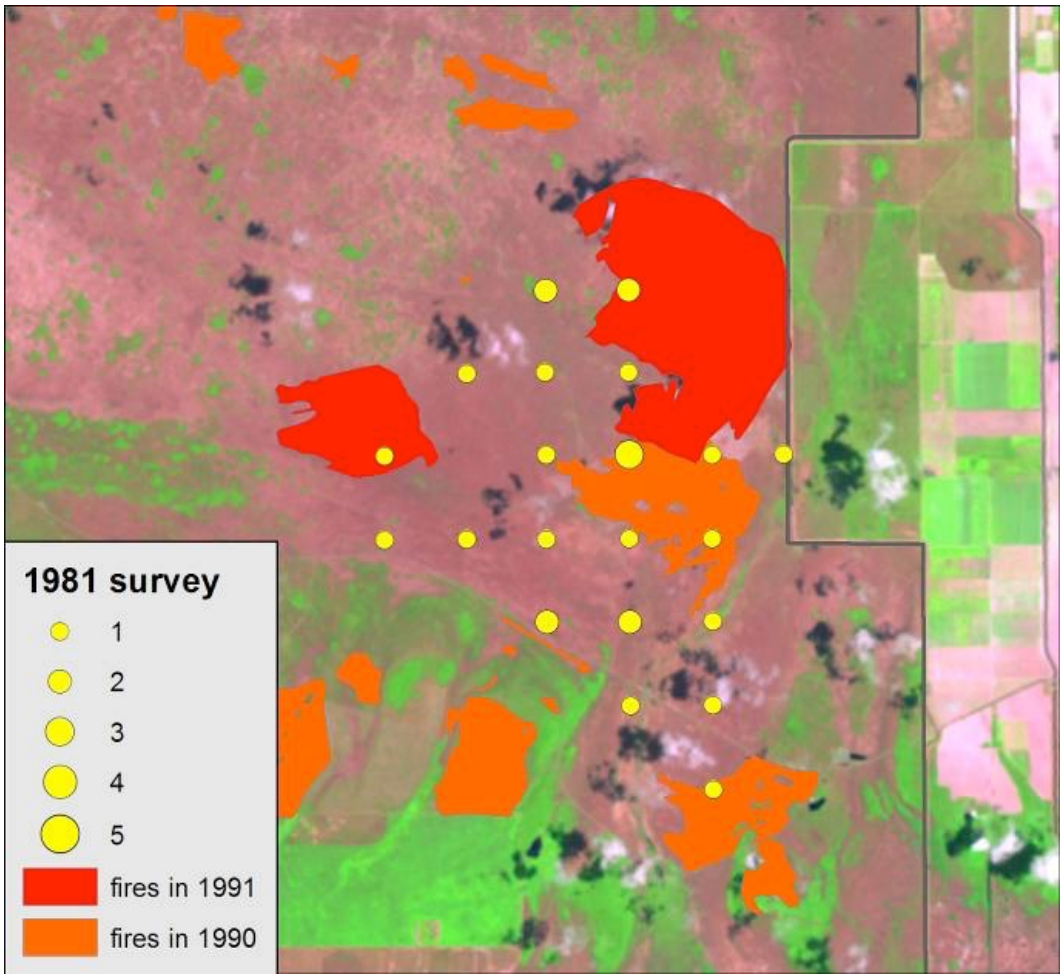


Figure 12.7 – Population C with overlay of 1981 survey results and fires layers for 1990 and 1991. Sparrow numbers here were greatly reduced in 1992 as a consequence.

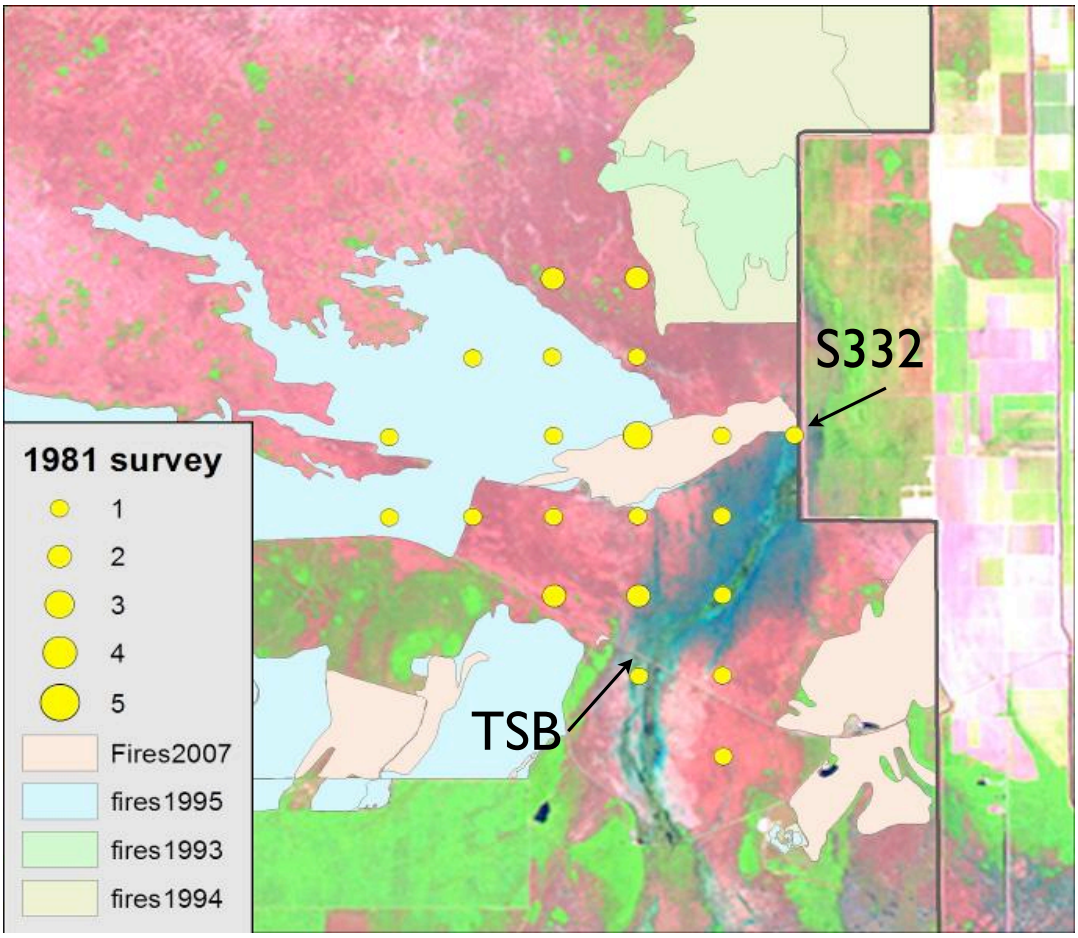


Figure 12.8 Population C with overlay of 1981 survey results and fires layers for 1993-95 and 2007. A pumping station at the Park's eastern boundary (S332) floods the prairies to its south. As the next chapter will discuss, the increase of its capacity lead to substantial changes in the downstream vegetation and the consequent loss of sparrows. TSB, Taylor Slough Bridge, is a water monitoring station.

Population F

This population has never had many birds in a survey, and in 2007 to 2009 we did not detect birds. The few birds detected in the field surveys in recent years are possibly dispersing in from other areas, although it is difficult to be certain. The cause of F's decline is mostly a result of anthropogenic fires, with the added pressure of invasion by exotic woody plants into formerly suitable areas.

Population E

Only two significant fires have burned subpopulation E in the last twenty years, the Ingraham fire in 1989 and the Lopez fire in May 2001. The outline of the Lopez fire

shows particularly well in the November 2001 satellite image as a continuous blue sheet of water in contrast to adjacent areas with generally the same depth of water obscured by vegetation.

Figure 12.9 shows the consequence of this fire to the sparrow numbers we counted on the survey. The birds disappeared from burned areas the following year (2002), there were birds on its edge, in 2003, and by 2004 the birds had re-colonised the area again. This timing closely follows the recovery of the vegetation as judged by the satellite images we show in chapter 9. The predictions of sparrow habitat from satellite images (Chapter 10 and its appendix) also correctly show this area as being unsuitable.

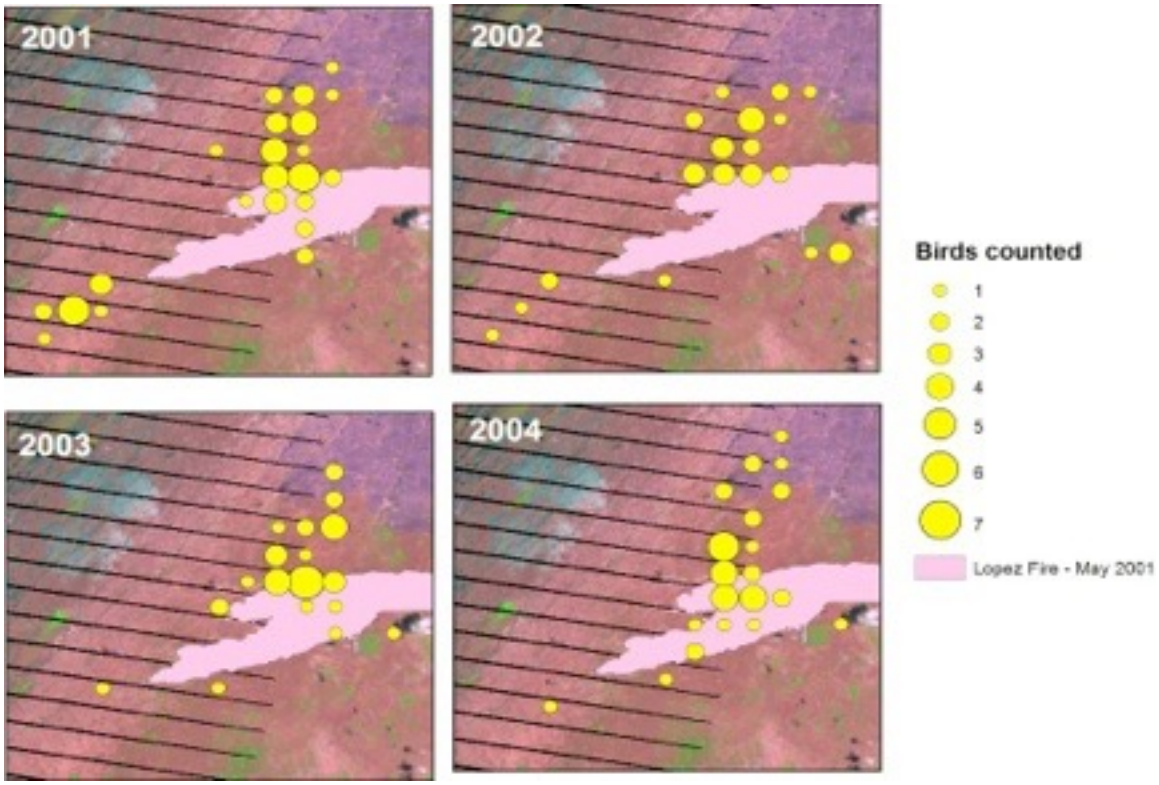


Figure 12.9 – Extensive survey results for subpopulation E showing the effect of the Lopez Fire, which occurred in early May 2001. The fire excluded sparrows in 2002 and 2003, but most burned areas were reoccupied by 2004.

In sum, these examples show that fires eliminate most and often all of the breeding populations within them and do so for about two years post-fire. Fires are not only intensive enough, but extensive enough to remove birds from large areas. Fires, in short, are a major threat to the sparrows presence in the areas adjacent to the Everglades' eastern boundary.

Chapter 13

Changes in sparrow numbers and their causes.

Part 2: Floods

Stuart L. Pimm and Oron L. Bass Jr.

Abstract

The most extensive changes in sparrow numbers follow deliberate changes to the water deliveries to the Everglades. These are most extensive in population A, for which deliberate flooding in the 1990s nearly eliminated the bird from the area where it had once been most numerous and did eliminate in from 75% of that area. Similar changes also occurred in population C, which given its close proximity to the main park road allowed detailed study of both birds and vegetation.

We discuss the changing water levels and their causes that led to these consequences.

Taylor Slough: population C

This section is based, in part, on Nott, M. P., O. L. Bass, Jr., D. M. Fleming, S. E. Killeffer, N. Fraley, L. Manne, J. L. Curnutt, T. M. Brooks, R. Powell and S. L. Pimm. 1998. Water levels, rapid vegetational changes, and the endangered Cape Sable seaside-sparrow. *Animal Conservation* 1:21–29.

In chapter one, under "Investigation," we recount the surprise discovery of the sparrow, east of Shark Slough, in the very accessible prairies on either side of Taylor Slough, along the main Park road. Taylor Slough is a much smaller drainage than Shar River, is in the eastern marl prairies and flows roughly southwards to Florida Bay (figure ii and iii). The agricultural and urban areas to its east are drained by an extensive network of canals. After the western population (A), the largest decline of the sparrow has been in population C, which includes this drainage (see the previous chapter).

The accessibility of Taylor Slough means that in addition to the extensive sparrow survey, we have longterm data on both bird and plant community composition. Werner established a 150 ha study plot in 1974 on the east side of Taylor Slough (Werner, 1975). The site was centered on Taylor Slough Bridge (see Fig. 12.8). In 1992, John Curnutt established a permanent study plot in the south-west corner of Werner's site measuring 66 ha. The population of sparrows increased from 11 singing males in 1974 to 21 in 1975 (Werner, 1975). In 1981, on the extensive

survey, we heard one male singing at each of three points suggesting. In 1993, Curnutt found no sparrows in Taylor Slough. There have only been sporadic sightings of sparrows in this general area on the survey in the years since (Chapter 8). So what caused the sparrow populations to disappear from this area?

The results of our extensive surveys (Chapter 8) the sparrow is found almost exclusively in marl prairies. These prairies are either dominated by muhly grass *(Muhlenbergia filipes),* or are mixed prairies with no dominant grass species. Mixed prairies are often diverse and include muhly, sawgrass *(Cladium jamaicense),* and black-top sedge *(Schoenus nigricans).* The sparrow avoids prairies dominated by sawgrass and spikerush *(Eleocharis* spp.), which have longer hydroperiods.

The studies in Taylor Slough show that prolonged flooding altered the vegetation in the area and prevented the birds from breeding. These vegetational changes were quite rapid but they have longer-term consequences to the sparrow than the ephemeral flooding.

Table 13.1 compares the floral composition of Taylor Slough in 1995 and 1996 with that of Werner's study in 1975. Werner found muhly grass and sawgrass to be the dominant species in this area. However, in the 21 years between our surveys, the relative dominance of these two species has switched. The area has changed from a diverse, muhly-dominated prairie to a less-diverse, sawgrass-dominated prairie.

Parameter	1975	1995/1996
Square meters sampled (N)	50	16
Mean No. of species / square meter	9.9	4.1
Muhly dominance by % cover	82%	21%
Sawgrass dominance by % cover	14%	77%

Table 13.1. A comparison of the vegetation of Taylor Slough between the years 1975 (from Werner 1975), 1995 and 1996. We determined species dominance for the 1995 and 1996 data by scaling percentage coverage measurements per square meter to percentage coverage of all live plants after Werner's method (From Nott et al. 1998.)

Further support for these changes comes from a detailed vegetation study of Taylor Slough by Armentano *et al.* (1995). Across 10 plots in a transect just north of Werner and Curnutt's plots, muhly cover averaged 61% in 1980 but only 9% in 1995. Armentano *et al.* (1995) suggested that the changes may not have happened gradually. In a transect placed within both Werner and Curnutt's study plot, muhly

increased in abundance from 35% cover in 1980 to 54% in the dry year of 1992. By 1995, its cover had declined to only 25%.

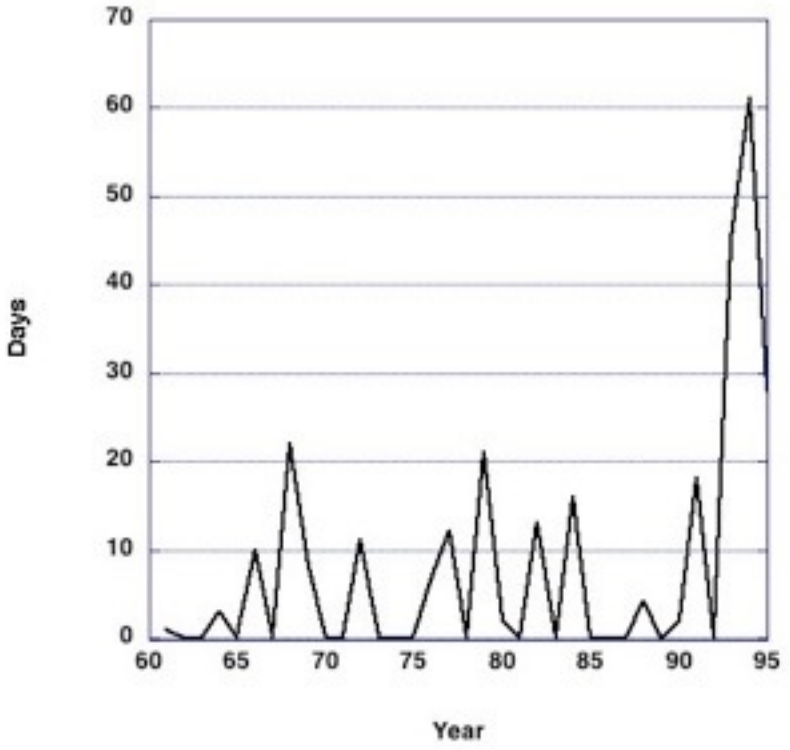


Figure 13.1. The number of days there was standing water at the Taylor Slough Bridge monitoring station (see figure 12.8) during the 90 days following March 15th each year.

The conversion of this area from a muhly grass to a sawgrass-dominated prairie indicates a lengthening of the hydroperiod. The placement of a pumping station (S-332) at the boundary of Everglades National Park and Taylor Slough in July 1980 altered the hydrology of the downstream drainage of the slough. Interestingly, Kushlan *et al.* (1982) correctly predicted a change from muhly grass to sawgrass dominance in the plant community directly downstream of the station. Figure 13.1 shows the number of days the water level at the monitoring station at Taylor Slough bridge was above ground level for the 90 days following 15 March. The area was typically dry for most of the sparrow's breeding seasons up until 1992. Almost certainly as a consequence of increased pumping from S-332, the area since 1993 has been much wetter than the 20 years prior to the pump's operation.

West of Shark River Slough: population A

By far the most severe loss of sparrow occurred in population A in 1993 and the following years. The details are chapter 8 (where we present numbers and maps), Chapter 9 (where we show satellite images), and Chapter 10 (where we use models to predict the habitat). Figure 13.2 is a summary of the distribution of the sparrows in 1981 and 1992, then in two seven-year periods that followed.

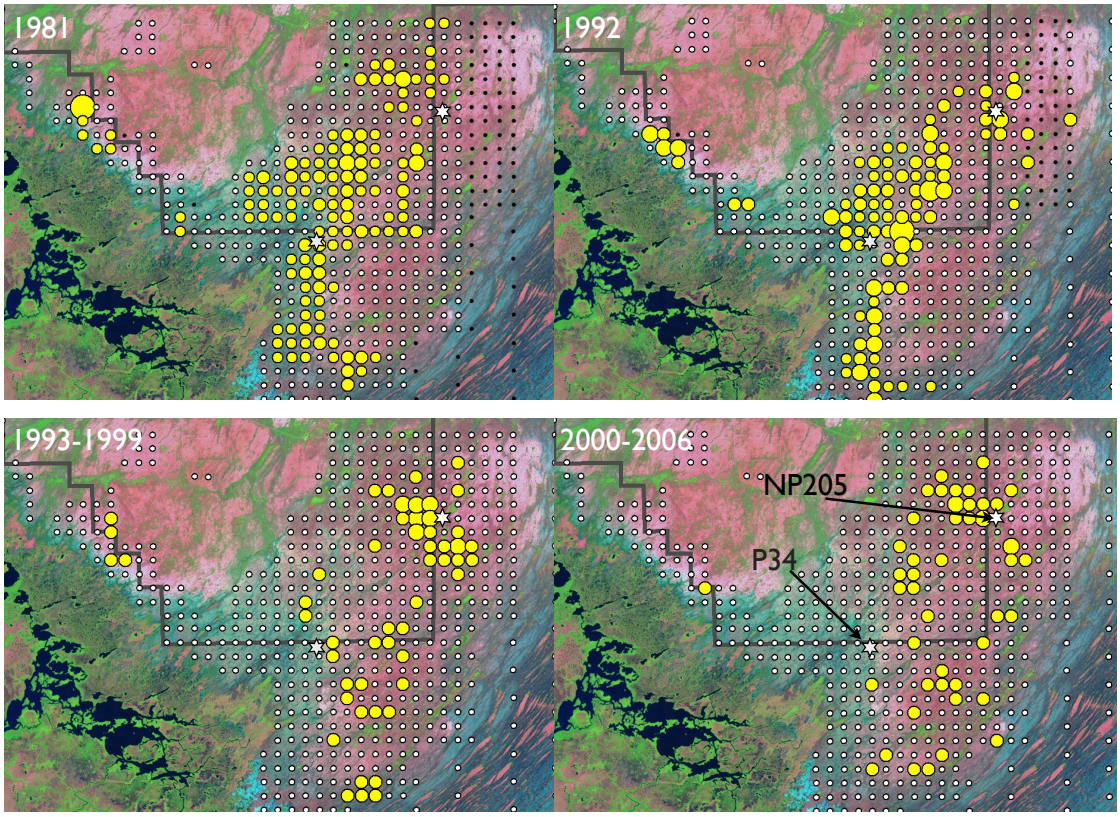


Figure 13.2 Sparrow numbers and distributions in population A. White stars are the two water monitoring stations NP205 and P34. Note that 1981 and 1982 are for single years, where the maximum number of birds seen are both 5. The bottom two figures are for totals over seven years each and the maximum number of birds seen is 10. The grey line is the boundary between Everglades National Park (to the south and east) and Big Cypress National Preserve (to the north).

We will address three features of these numbers. First, notice that the small population to the far west — along the "stair step" boundary between Everglades National Park and Big Cypress National Preserve. These population disappeared

after 1992 apart from sporadic sightings. They were always small and isolated. In chapter 6 we argued that immigration from the larger population to their east maintained them. When this population declined, they were no longer viable.

The second feature we address is the catastrophic decline in the population after 1992. Table 13.1 shows the total counts of birds across the area. Birds numbers dropped to a single individual counted on the regular survey in 2004 — an estimated population of 16 birds. In 2003, 2004, 2005, and 2006, we also counted birds at selected sites on a 0.5 km grid to obtain better estimates of the now tiny population. That suggest a population size of 40 birds, but still a massive decline from the estimates of 2688 and 2608 in 1981 and 1992 respectively.

The third feature is that the declines are not uniform. We consistently found birds near the water monitoring station NP205 after 1992 in smaller numbers than in 1981 and 1992. The temporary station "West Camp" we established was near NP205 and allowed us to study and band this small population. As the maps of figure 8.1 show, this was where we counted the birds on the 0.5km grid.

Year	N sub-total	total
1981	48	168
1992	42	163
1993	9	27
1994	0	(5: but an incomplete survey)
1995	13	15
1996	19	24
1997	15	17
1998	10	12
1999	21	25
2000	10	28
2001	5	8
2002	4	6
2003	7	8
2004	1	1
2005	4	5
2006	5	7
2007	4	4
2008	6	7
2009	2	6
2010	4	8
2011	9	11
2012	10	21

Table 13.1 shows the sub-total count for northern sites and the total for population A repeated from table 8.1.

Table 13.1 also shows sub-totals of birds from sites where birds were counted in the northern 10 kilometres of the survey — that is all sites north of 3 kilometres south of NP205. These birds constitute the majority (and sometimes the entirety) of the birds seen from 1995 onwards. Certainly, their numbers are much smaller than those we counted in 1981 and 1992, but the decline in relatively smaller than for the population as a whole.

The other side of this — and what is most striking — is the declines in numbers to the south. Apart from sporadic sightings, the birds have been entirely lost from about two hundred square kilometers broadly centered on the water monitoring station P34. As table 13.1 shows, this was where 75% of the birds once lived.

Figure 13.3 shows the stage levels at NP205 and P34 for March through June inclusive each year. At the top is the entirety of the record, while the bottom shows just 1980 to the present — essentially the interval for which we have sparrow counts. At both monitoring stations 1993,1994 and 1996 were unusually wet, while 1995 was unprecedented. The effect of this is evident in the satellite images (chapter 9) are our modelling of sparrow habitat (chapter 10): the deliberate flooding prevented nesting over most of the area and destroyed habitat. We shall show below that the habitat changes were long term.

Figure 13.3 has other interesting features. While breeding season water levels dropped at NP205 after 1997, we see no periods such as those in the early 1970s and mid- to late 1980s when there were several years when the water fell below 1.5 metres.

P34 provides the most significant changes, however, and it has a longer time series. Before 1993, it was rarely above 0.5 metres, and dropped below ground level in 17 years our of the 39 years before 1993. From 1993 onwards *it was rarely below 0.5 metres.*

We have emphasised the previous statement with italics, because it is surely this book's most important result, for it explains the extermination of the sparrow over the 75% of its range in population A. Importantly, this change in water level is not seen in the NP205 data. Rather, the figure suggests a quick marked break in relative heights of the two stations.

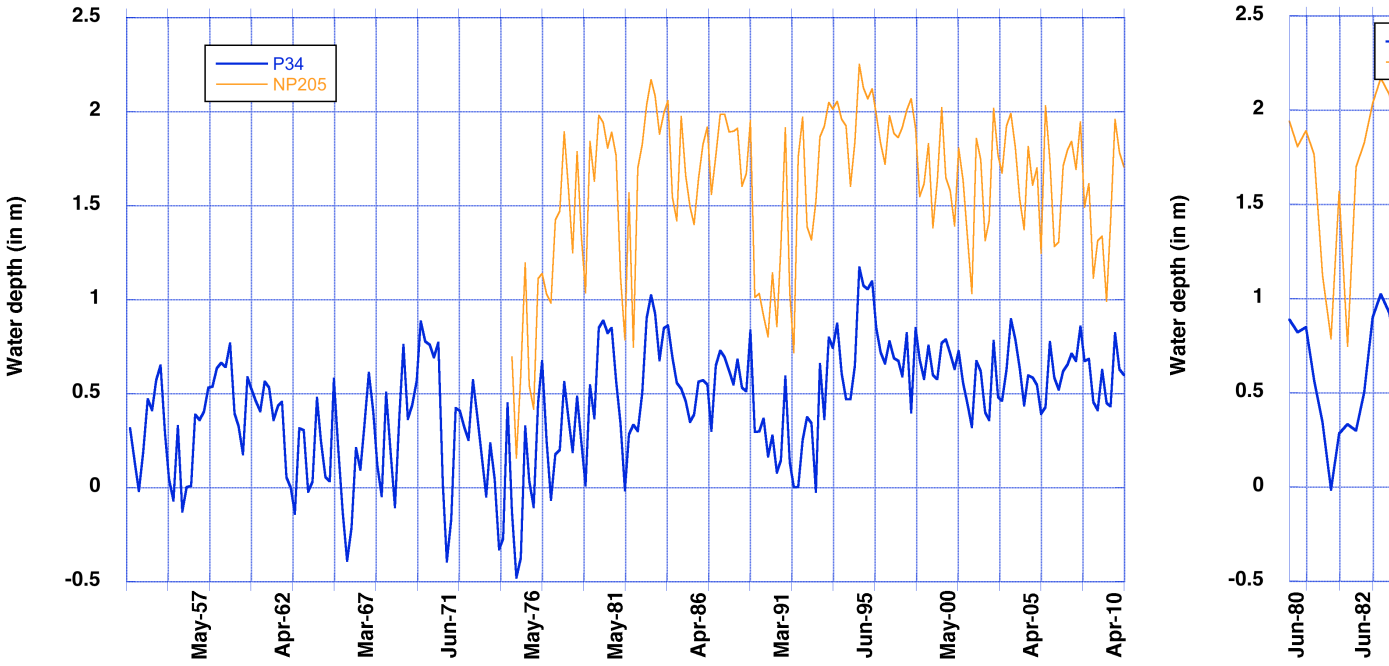


Figure 13.3. Water levels at two monitoring stations. Only data from March, April, May, and June each year are displayed. The top figure shows all the years available, while the bottom show just 1980 to the present.

This rapid shift in the relative levels is best seen in Figure 13.4, where we plot the values of NP205 versus those at P34. As expected, there is a strong correlation. Also as expected, NP205 can drop further, because it is higher and so has further to go. But what is remarkable is the relationships between the data before (shown in blue) and after 1993 (shown in orange). There is very little overlap, with the post-1993 data showing much the same ranges of values as in earlier years, but shifted about 0.25m higher

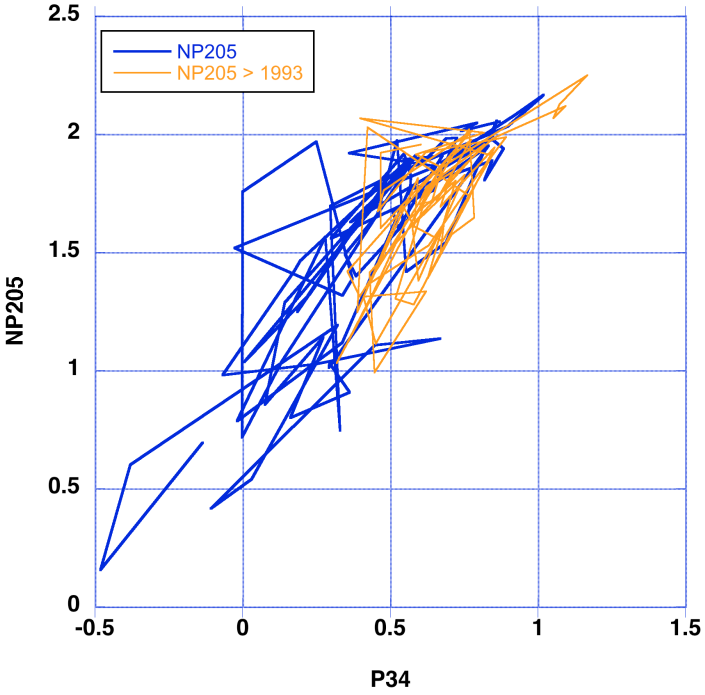


Figure 13.4. Relative water depths.

Monthly averages, such as those shown, do not show daily detail that can be vital to the sparrow's survival. In particular, individual storm events can drop substantial amounts of rain within a few days and especially if managers permit emergency releases of water, flood extensive areas of the park.

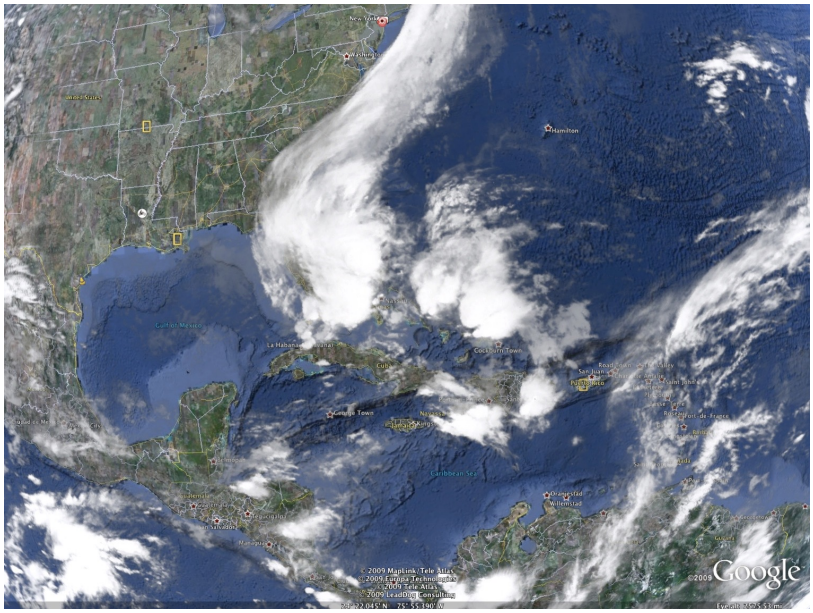


Figure 13.5 shows a storm on May 19th, 2009. It raised the stage level of NP205 by 44 cm in three days.

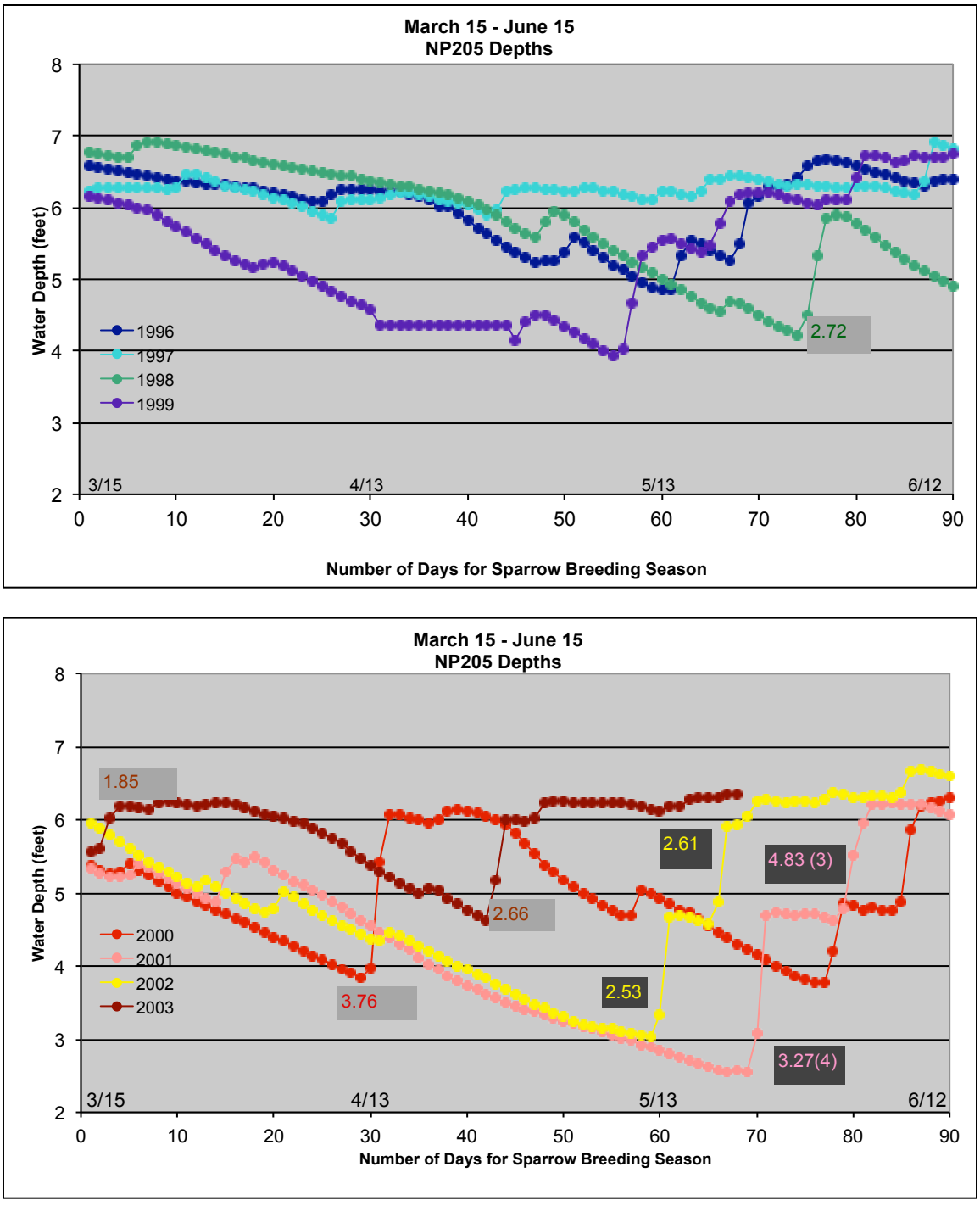


Figure 13.6. Water depths (in feet — 3.28 feet = 1m) for NP205 for 90 days in each of 8 years 1996 to 1999 (top) and 2000 to 2003 (bottom). Numbers on the lines indicate two days (or more if indicated) rainfall totals in inches. (1 inch = 2.54cm)

NP205 water levels

Figure 13.6 shows daily stage levels of NP205 for eights years from 1996 to 2003. As figure 13.3 attests, some years such as 1996 and 2003 were very wet years, where high water precluded breeding across all or most of population. Even in relatively dry years, sparrows were vulnerable to sporadic storm events that raised water typically by 2 feet (60 centimeters). Thus, by April 12th, 2000, water levels had dropped to their lowest level on that date since 1992, then a storm dropped nearly 10cm of rain in two days and water levels rose over 60 cm. In short, high water levels are in themselves damaging to the sparrows' breeding success, but high water levels mean that rainfall events are much more damaging than when water levels are much lower.

Figure 13.7 shows the daily water water flows across the S12s over the period of record (from 1965) at the top, then below a detail of the period since 1991. The much greater flows of water since late 1992 are apparent as are the historically unprecedented flows in 1994 and 1995. Flows above 2000 units were exceptional before late 1992, but have been annual events since. Figure 13.8 shows that total annual flows above 20 billion cubic feet occurred in only 10 years from 1962 to 1991. Only two years since failed to achieve that total.

The detail also shows that from late 1992 onwards, flows did not cease during the breeding season until in 1999 they were stopped because of the Biological Opinion on the sparrow (see Chapter 15).

In short, the deliberate flooding of the sparrow's breeding sites by water managers caused these declines. Not content with moving the water flows from predominantly through northeast Shark Slough to much further west via the S12s, managers chose to flood extensive areas of sparrow habitat from 1993 onwards with historically unprecedented flows across the S12 in the sparrow's breeding season.

Based on our results, USACE 2002 C-111 GRR Supplement, Section 5.1: Planning goals and objectives, stated as a target: " a minimum of 50 to 60 consecutive nesting days, preferable 80 consecutive days, in all years until the sparrow numbers have increased in to at least 1000 individuals."

As these figures attest, not year achieved that, despite the seasonal closures of the S12a.

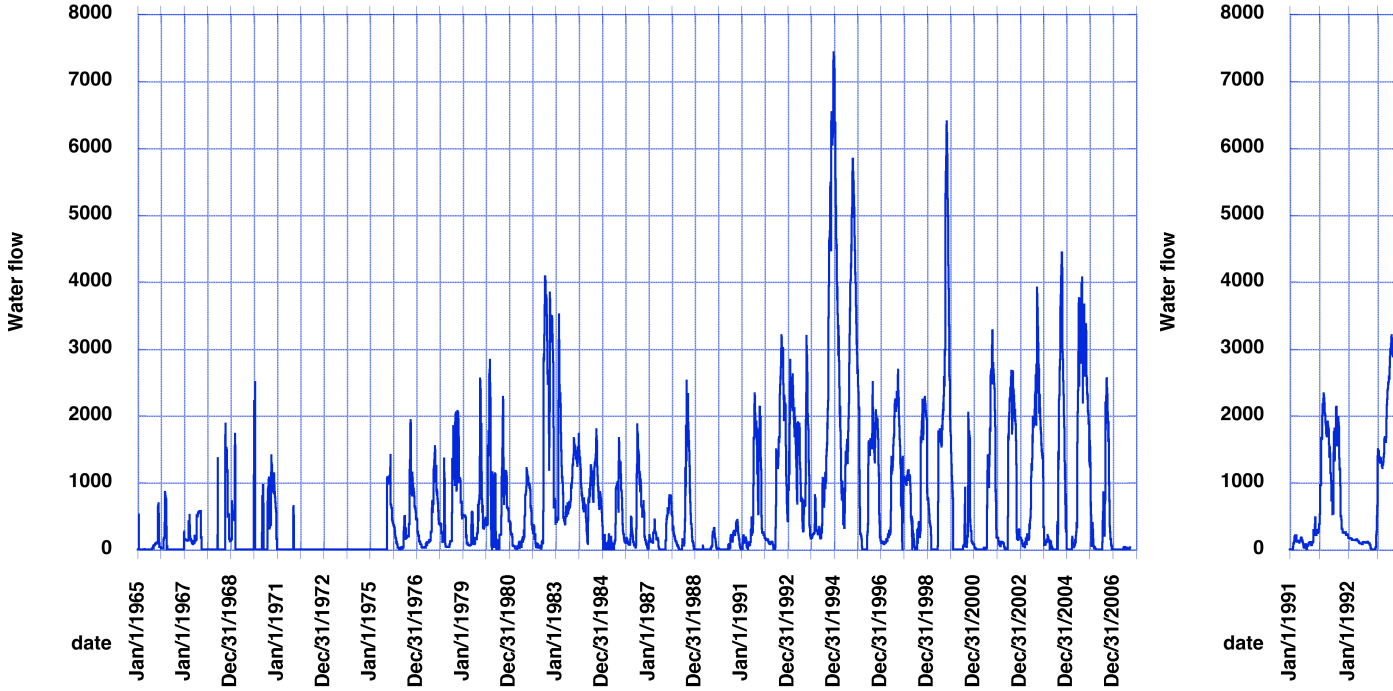


Figure 13.7. Daily flows, measured in cubic feet (0.028 m^3) across the S12s for the period of record (top), then to show detail, from 1991 onwards (bottom).

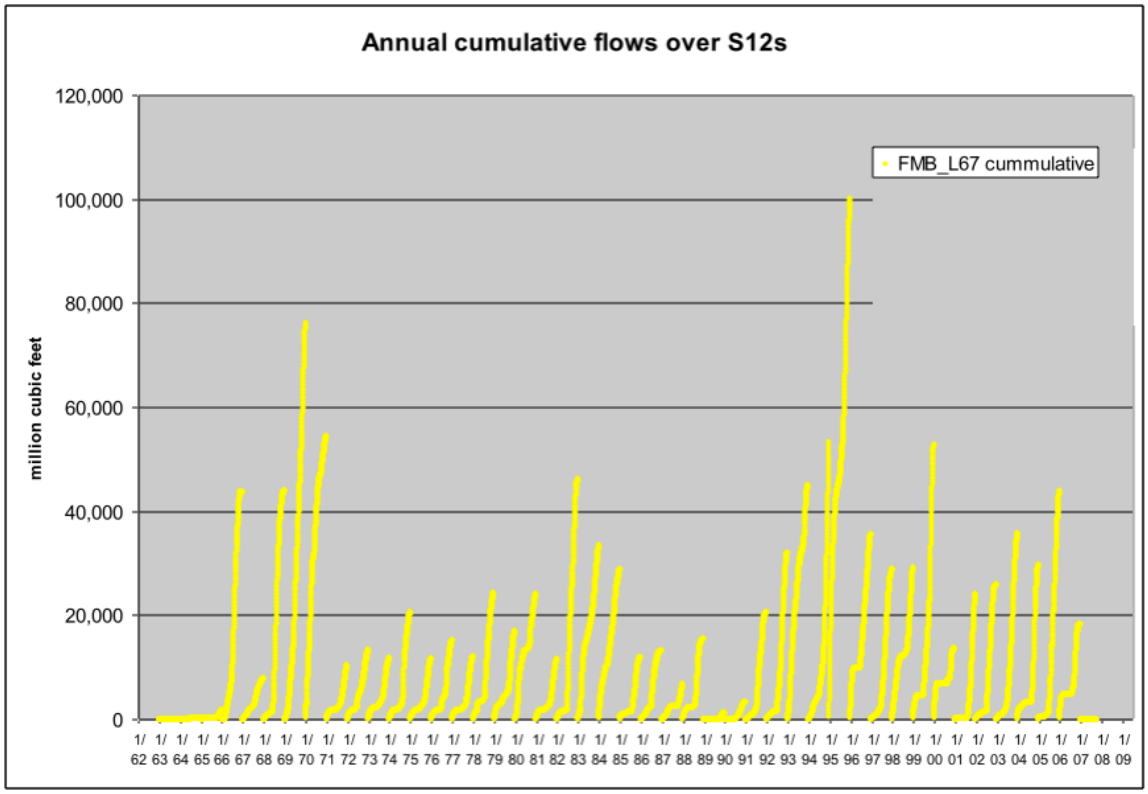


Figure 13.8 – Total flows across the S-12s, expressed as annual accumulation curves for the periods from 1962 to 2008.

P34 water levels

The greatest decline in sparrow numbers has occurred near P34 in sub-population A. As figures 13.3 and 13.4 show, beginning around 1994, water levels at P34 appear to have shifted to a higher level relative to the NP205 gauge, which is upstream and on higher ground. The implications are significant, for much of the water management for subpopulation A is linked to the water levels at NP205 under the assumption that water levels in other parts of A closely correlate to those at NP205. We can confirm that this is not always the case for the area around P34.

Figure 13.9 plots the water level at P34 versus the water level at NP205 for each day since 1 January 1980. Blue dots represent dates from then until the end of 1994, then pink dots dates thereafter.

We also show linear regressions through the two subsets of data. These are not compelling fits to such highly non-linear relationships. *Inter alia*, the data show a clear discontinuity at about 6 feet for NP205, which is the point at which it becomes flooded. Nor does P34 depend on NP205 in any simple, functional way. Nonetheless

the regressions suggest a simple characterisation that P34 is now higher relative to NP205.

More usefully, we plot the pre-1995 “blue” data *on top of the* later “pink” data. This means that blue points will cover pink ones, and so areas of pink points have no comparable blue points. The extensive set of pink, post 1994 points above the blue points indicates substantial higher water levels at P34 for comparable water levels at NP205.

In contrast, the presence of lower, blue points is not in itself informative, since they could be hiding pink points.

Is this change unique to the P34 area? Were this a special case of the area around P34 being wetter, then gauges in other areas (Figure iv) should not show the same pattern. Their relationship to water levels at NP205 should be consistent both before and after 1995. Alternatively, perhaps more water is flowing through East Slough, and so gauges in the flow path to P34 would show a similar pattern of higher water post-1995.

Our analyses indicate that this change is not unique to P34 and may actually be the prevalent pattern in the subpopulation A area. The LOOP1 gauge is the first gauge in East Slough with a sufficient record prior to 1995 for meaningful analysis (records start in 1st January 1984). It displays a pattern similar to that of P34, with water levels post-1995 shifted higher by about the same relative amount as NP205 (Figure 13.9). There are no other gauges in East Slough with a sufficient record prior to 1995 to make meaningful comparisons.

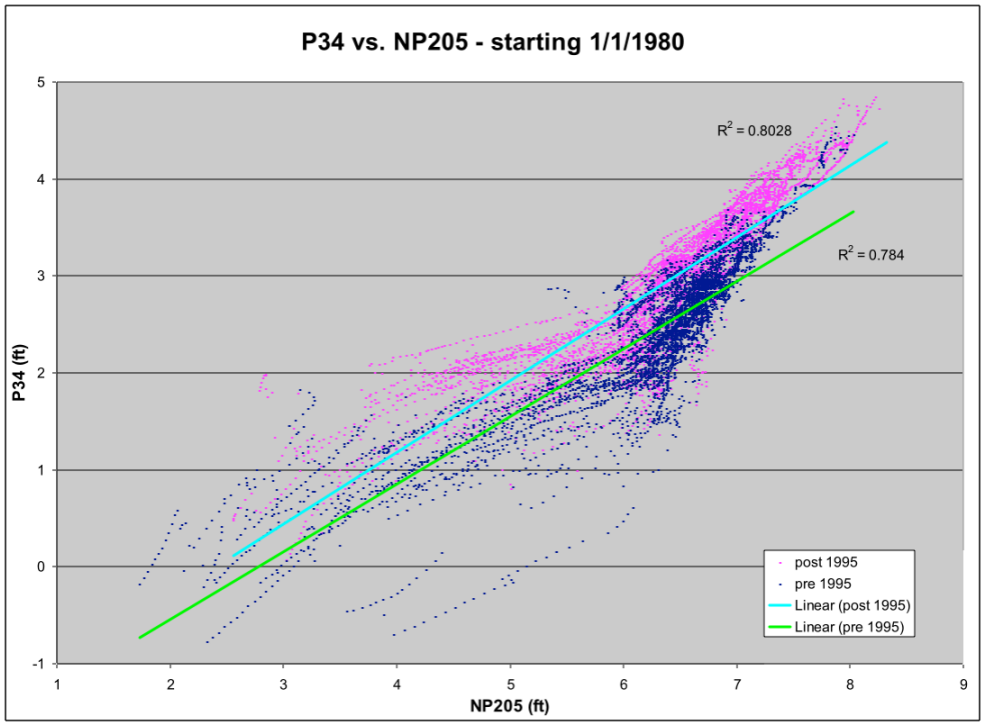


Figure 13.9 – Water levels at P34 versus water levels at NP205 for two periods (1980 - 1994 and 1995 - 2008). Data pre-1995 are plotted on top of data post-1995.

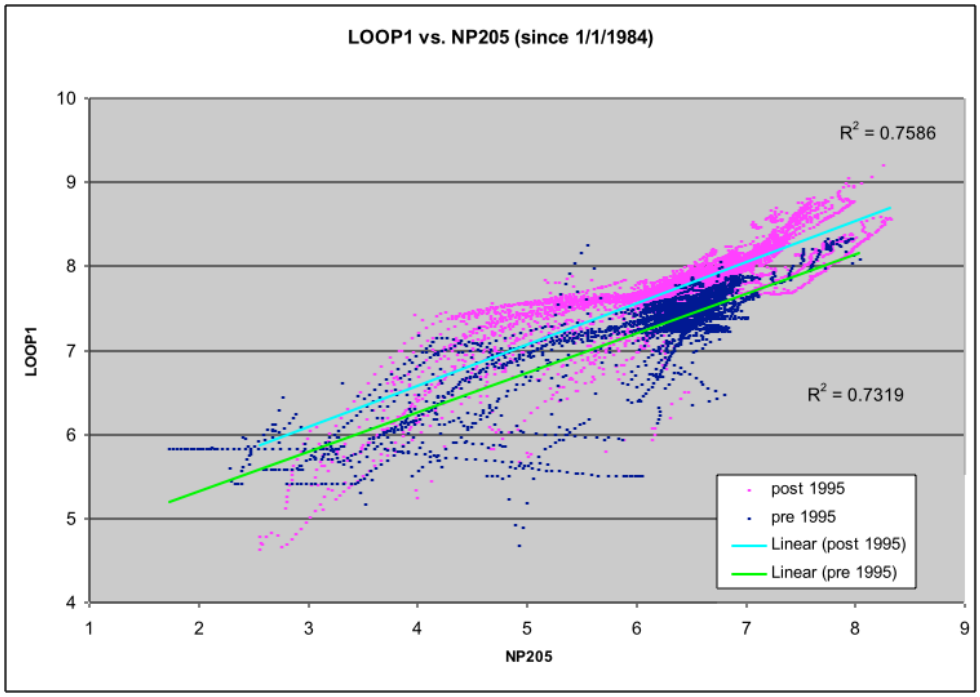


Figure 13.10 – Water levels at LOOP1 versus water levels at NP205 for two periods (1984 - 1994 and 1995 - 2008). Data pre-1995 are plotted on top of data post-1995. LOOP1 started recording data on 1st January 1984.

What about to the east, in Shark River Slough? Four gauges are available for making comparisons, going from north to south (NP201, NP202, NP203, and P36). To simply all the possible combinations, we present just two more that are typical. Figure 13.11 shows that these the two most southerly stations closely correlate.

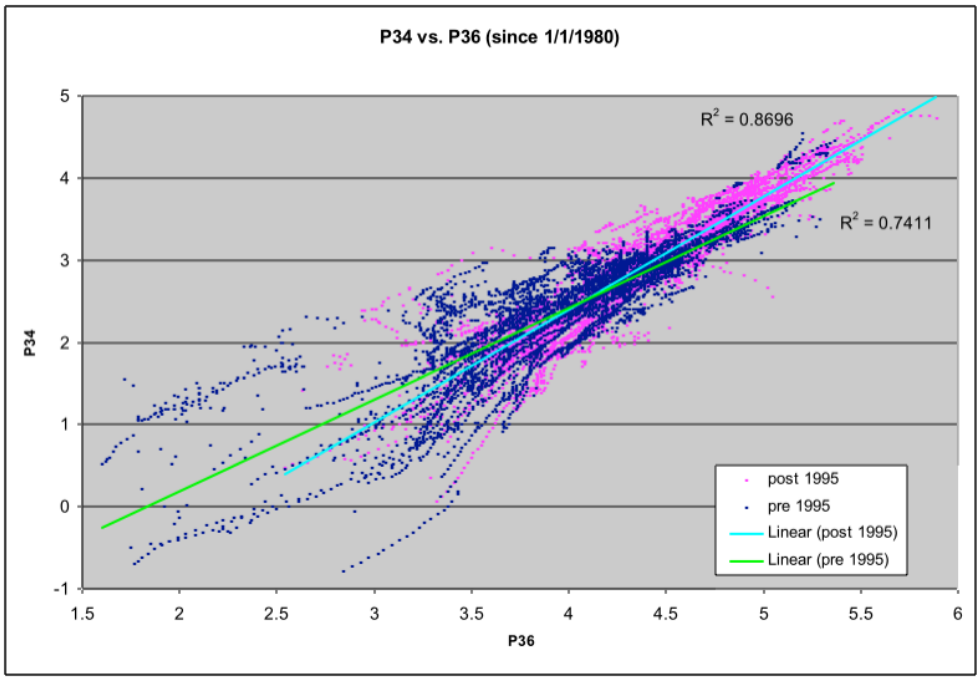


Figure 13.11 Water levels at P36=4 versus water levels at P36 for two periods (1984 - 1994 and 1995 - 2008). Data pre-1995 are plotted on top of data post-1995.

Finally, figure 13.12 compares NP205 to NP 203 in Shark River Slough. It too, shows the post 1994 period to have relatively higher levels at NP203. The comparisons of NP205 to NP201 and NP 202 are broadly similar.

The crucial question is: Why does there appear to be extra water at the non-NP205 stations since 1995 and where is it coming from? If this were simply a case of the entire system being wetter, then NP205 should have become wetter too, in a pattern consistent with other places. We have three hypotheses to explain the oddity.

(1) Sea level could have risen, essentially raising the floor for freshwater around P34 and other low areas, but not strongly affecting NP205 because of its higher location.

(2) More water could be flowing through East Slough from Big Cypress National Preserve, bypassing the NP205 area and leaving it drier.

(3) Water management actions to keep NP205 dry have forced water into other areas.

(1) *Sea-level*. We can dismiss the first hypothesis, sea level rise. It would be a gradual effect, not the sharp change we see occurring in 1994/1995. As well, sea level is only rising from 1 to 2 mm per year, with a ~10cm rise recorded since 1940 at Key West (Maul and Martin 1993). At this rate, the 0.4 foot (122mm) increase that we see in the Everglades would take 60 to 120 years.

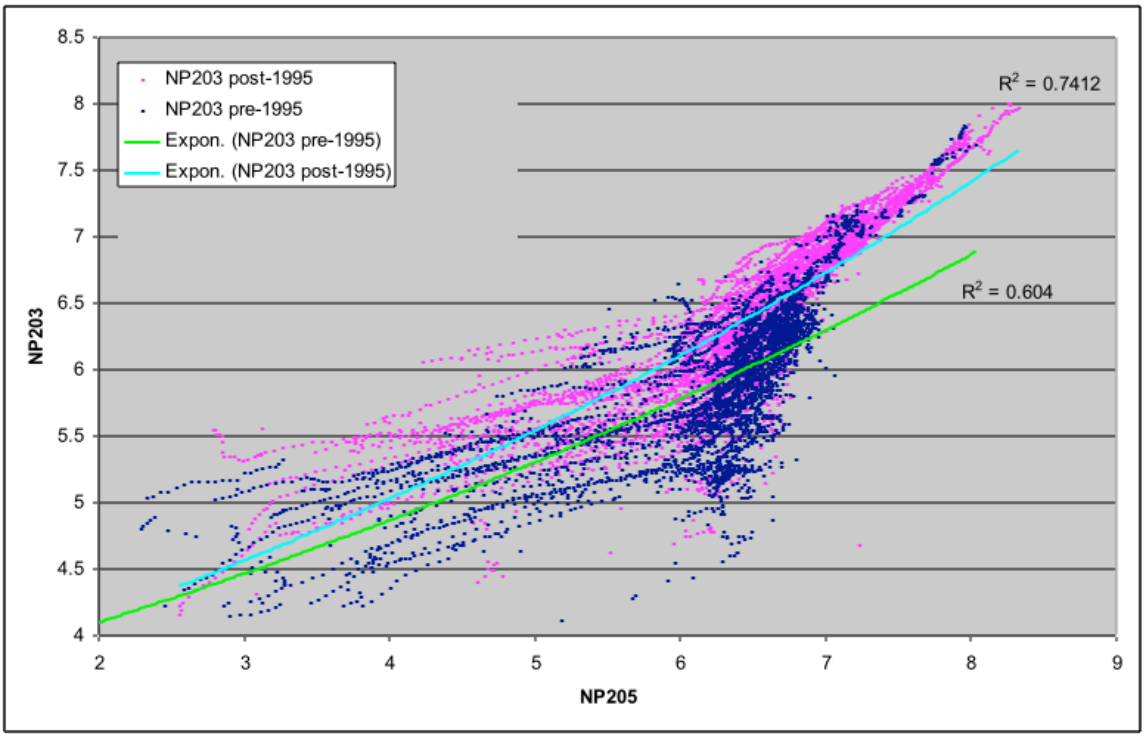


Figure 13.12. Water levels at NP203 versus water levels at NP205 for two periods (1980 - 1994 and 1995 - 2008). Data pre-1995 are plotted on top of data post-1995.

(2) *The water comes from the west.* The second hypothesis, water entering through Big Cypress, is complicated. Were this happening, then the extra water could bypass the higher areas of subpopulation A, raising water levels at P34 while not appreciable increasing them at NP205. To raise water levels in Shark Slough, that extra water would have to either go around the north side of A and into the slough, or go around the southern end of subpopulation A. It is not clear if either is likely or even possible.

The potential sources of additional water flow into East Slough are the S343A, S343B, and S344 water control structures along the L-28 levee (Figure iv). While these three structures were cut into the L-28 levee between 1983 and 1985, our analysis of available water data indicates little or no water flowing through them until late 1994 and early 1995.

To identify water from Big Cypress as the cause of high water at P34, via the S-343A/B and S-344 structures, then two things need to be true. One, water flow through the S-343A/B and S-344 structures must have increased post-1995 relative to pre-1995. Analyses of gauge data from Everglades National Park show that either essentially no water flowed through these structures prior to 1995, or the available data are incomplete. Most of the entries in the water database prior to 1995 are "null." Conversations with park staff also indicate that little or no water was flowing through the structures prior to 1995.

After 1995, there is clear evidence that large amounts of water — on the order of billions of cubic feet — flowed through the structures each year (Figure 13.13). As a reference point, these flows are ~10% of what flows through the S12s per year (Figure 13.8). Since 2000, most of the water has flowed across the L28 between July and October of each year.

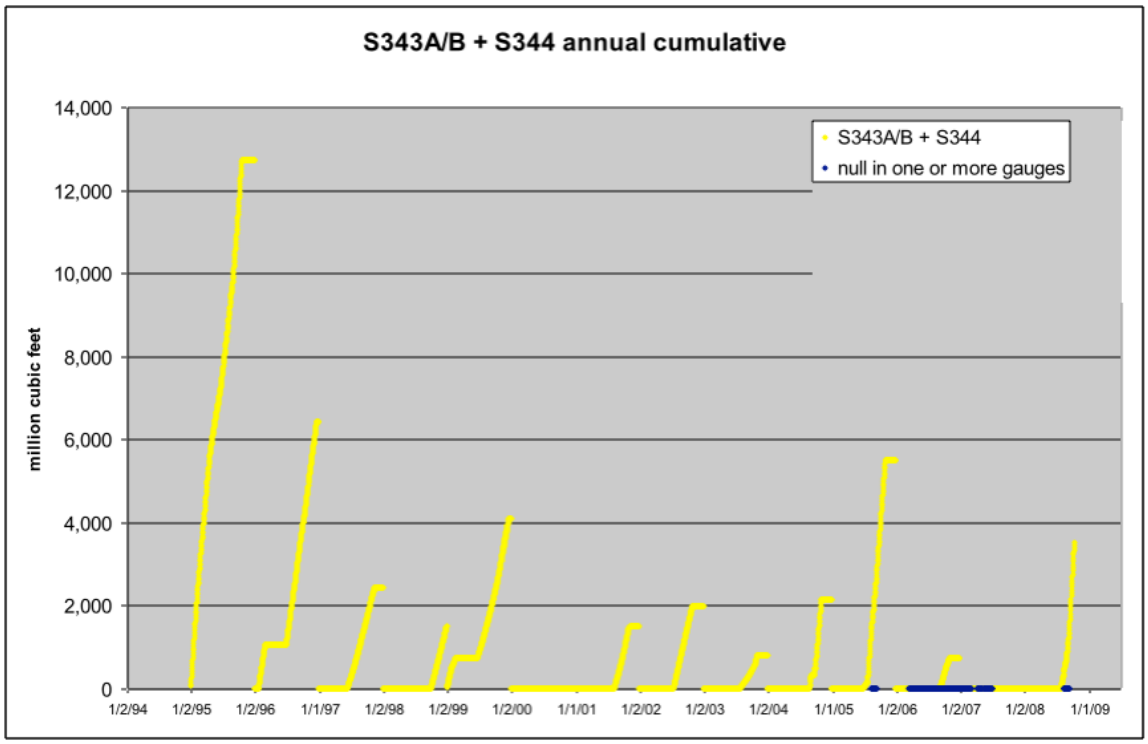


Figure 13.13. Cumulative flows across the S343A, S343B, and S344.

If this second hypothesis were to be true, we would expect a close correlation with the stage levels at LOOP, just downstream of the control structures on the L28s and P34 about 30 km to the south. Figure 13.14 shows a very strong correlation, indeed, with the highest values post 1994.

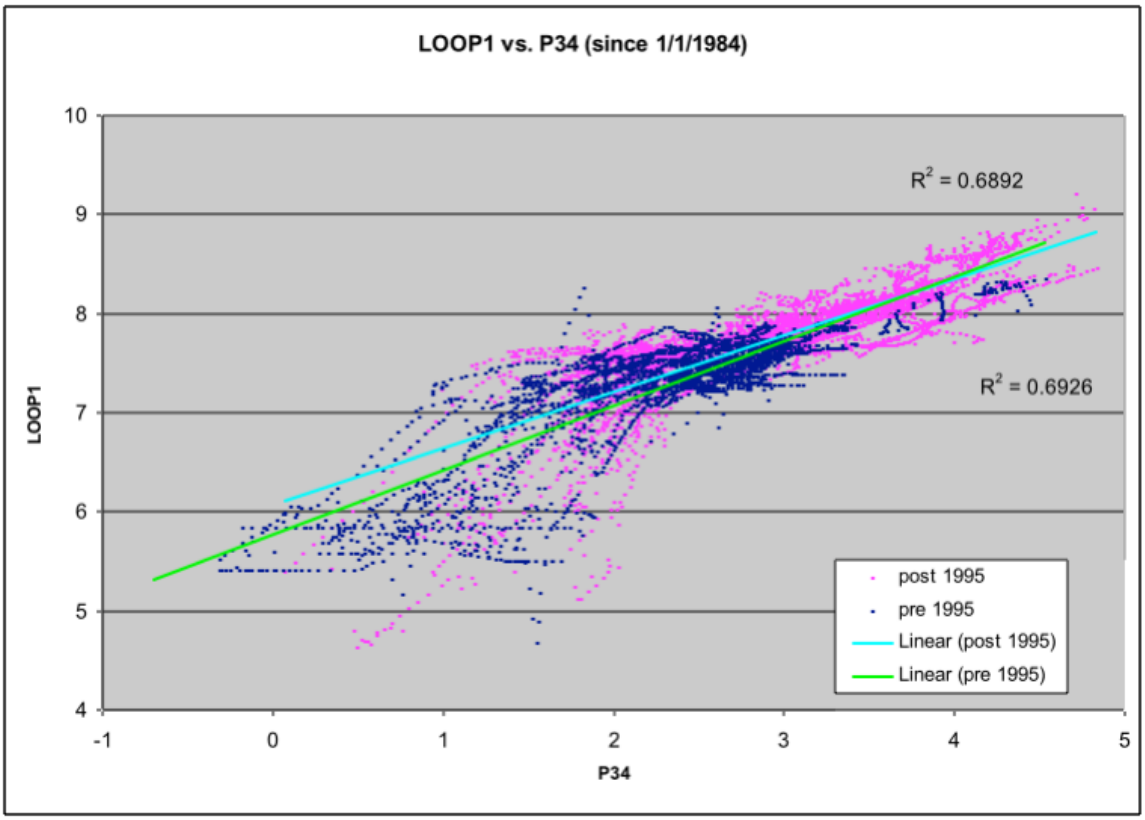


Figure 13.14. Water levels at LOOP1 versus water levels at P34 for two periods (1980 - 1994 and 1995 - 2008). Data pre-1995 are plotted on top of data post-1995.

(3) *NP205 has been keep drier.* The third hypothesis is that management actions keep NP205 relatively dry. Certainly, from 1999 onwards, managers stopped flows during the sparrow breeding season. Indeed, if there is more water in the system overall since 1995, but NP205 is to be kept dry, then the extra water must go somewhere. It is our possible that managers sent this water through East Slough and the eastern S-12 structures. The result is that more water enters the park, but partially goes around NP205 and so avoids flooding it.

This has both positive and negative consequences. The most obvious positive is that NP205 was kept drier, allowing the possibility of that the sparrows would persist in the northern part of subpopulation A. They did. Failure to have done so would certainly have resulted in the extirpation of that subpopulation because of flooding.

The negative consequence of this extra water is that low-lying areas are flooded, such as around P34 and the edges of Shark Slough. This likely reduces the potential of sparrow habitat developing in these areas. Such effects would only be noticeable in subpopulation A because the sparrows areas on the east side of Shark Slough are

significantly higher than the actual slough, thus requiring a massive increase in water levels in Shark River Slough for them to become flooded.

Chapter 14

Range-wide Risks of extinction

Stuart L. Pimm and Oron L. Bass Jr.

This chapter is based on Pimm, S. L. and O. L. Bass, Jr. 2002. Range-wide risks to large populations: the Cape Sable seaside-sparrow as a case history. Pages 406-424 in S. R. Beissinger and D. L. McCullough (eds). *Population Viability Analysis.* The University of Chicago Press. As with other chapters, we have edited this to avoid overlap with material presented elsewhere.

Abstract

Very small populations usually go extinct quickly. More surprisingly, larger populations that occur across wider ranges can also become extinct quickly. Understanding the fate of these species is the difficult challenge that this paper will address. The species of concern is the Cape Sable seaside-sparrow. We explore two methods of calculating the sparrow's risk of extinction. The first employs the idea that one can characterise the natural limits of population size fluctuations over time on the basis of past experience of the species of concern or some similar species. So armed, one can predict whether the lower limit will encompass such low levels that rapid extinction will be probable. This method failed spectacularly when applied to a situation where it would seem entirely appropriate. The second method identifies the underlying causes of the sparrow's population fluctuations. In particular, we consider the factors that cause its range to shrink and determine its ability to recover from such shocks. By understanding the mechanisms underlying population fluctuations, we conclude that poor water management choices could exterminate the bird.

Introduction

The reasons for populations numbering a few to a few dozen breeding pairs going extinct quickly are well understood (Pimm 1991). Such populations suffer the problems of finding suitable mates, of many individuals dying before the next breeding season from different causes, loss of genetic variability and its deleterious consequences, and other unavoidable vagaries of birth and death. The importance of these chance factors diminishes quickly as populations become larger. Nonetheless,

experience teaches us that much larger populations can also become extinct quickly. Indeed, we know that vertebrate populations numbering in the low thousands of breeding pairs are too rare to enjoy a secure future (Collar et al. 1994, Baillie and Groombridge 1996, Mace 1996). Understanding the fate of these species is the much more difficult challenge that this paper will address.

Large populations may be composed of many smaller partially isolated subpopulations constituting a metapopulation. If so, the balance between frequent local extinction and re-colonisation from surviving populations determines the species' long-term fate (Hanski 1998. In such cases, insights from studies of very small populations are of value (Pimm et al. 1993, Pimm and Curnutt 1994). In other cases, an inexorable decline in numbers, perhaps driven by a readily observable reduction in habitat, leads to a clear prediction of a species' demise. Yet other species may be at risk because of the high year-to-year variability in numbers that typify many natural populations (Pimm 1991). In nature, many individuals die from the *same* causes, e.g., bad weather. Such natural population fluctuations can prove terminal for a species that is more geographically restricted than in the past.

The case history we present may be typical in requiring answers to all the questions implied by the last paragraph. What is the spatial organisation of the population? Are any of its geographically determined subpopulations sufficiently small to warrant concerns over unavoidable vagaries of birth and death? What are the unnatural causes of population decline? How will these causes affect the population in the future? What are the natural causes of population fluctuations and how can we anticipate the low levels to which they will drive the population in the future?

We explore two methods of calculating the sparrow's risk of extinction. The first employs the idea that one can characterise the natural limits of population size fluctuations over time from the study of time series data. So armed, one can predict whether the lower limit will encompass such low levels that rapid extinction will be probable. This is a familiar recipe. It characterises the papers in Brook et al.'s (2000) meta-analysis of the predictive accuracy of "population viability analysis." One of us has devoted considerable thought to it (e.g., Pimm 1991). This method failed spectacularly even though the Cape Sable seaside-sparrow case would seem entirely appropriate. The second method identified the causes of the sparrow's population fluctuations, in particular, its range contractions and its ability to recover from them. By understanding the mechanisms underlying population fluctuations we deduce an altogether bleaker picture of the bird's future.

Risk analysis 1: a phenomenological approach

What is the likelihood that this bird will become extinct? Other things being equal, populations that are highly variable in their numbers from year to year are more likely to go extinct than less variable ones (Pimm et al. 1988, Pimm 1991). The causes of population variability are diverse. They include population factors (birth

and death rates), features of the food web in which the species is embedded (e.g., whether it is a trophic specialist or generalist), and fluctuations of the host ecosystem. These factors operate at different scales (Pimm 1991). Estimating the population variance (or, equivalently, the variance in birth and death rates) and dissecting out underlying causes is a critical step in answering the key question about a species' fate. So how do we estimate this variability?

Data-rich, long-term studies to assess population variability directly will be a luxury afforded very few conservation biologists. For example, Sæther et al. (2000) have provided statistically rigorous dissections of the key population variables, their variances, and their time dependence for various species. In the example quoted, they utilised a 20-year record along a 60 km stretch of the dipper's (*Cinclus cinclus*) riverine habitat, a large fraction of the population was colour-banded, and the bird is widely distributed, relatively common, and conspicuous.

For many endangered species, infrequent estimates of population size will often be the only information available. For many species, we lack even this information. The urgency of the problem, however, does not allow us to request 20 years of intensive field effort before returning an answer. We might have access to long-term data on surrogates —species that are closely related or at least ecologically similar. Using one, or at best a few, estimates of abundance and a surrogate estimate of year-to-year variability, we may be able to predict risk of extinction. This is a familiar tactic (Brook et al. 2000).

As for many other threatened species, there are no long-term data on year-to-year changes in Cape Sable seaside-sparrow populations, or indeed on other seaside-sparrows. There are, however, substantial long-term records of grassland sparrow numbers in the Breeding Bird Survey (BBS). BBS data are obtained from point counts—a method very similar to the survey method we employ—and grassland sparrows from prairie states are broadly similar in their life history characteristics.

Curnutt et al. (1996) used BBS data on 10 North American grassland sparrows to explore how populations behave simultaneously in space and time. Two well-known relationships guided this exploration. The first is the power law relating variance of population abundance over time to average abundance across a species' geographic range (Maurer 1994). The second relationship examined the increase in a population's variability at a single location over time (Pimm and Redfearn 1988). Curnutt et al. (1996) asked how abundance, variability, and increase in variability change over a species' geographic range and with respect to one another.

For all but one of the species they analysed, variability increased more slowly than expected with increasing abundance across the species' range. If relative variability were independent of abundance, the slope of the logarithm of standard deviation versus the logarithm of abundance would be unity. Most of the species had slopes of ~ 0.7. This means that where a species is least common—typically at the edge of its range—its population fluctuations will be relatively more variable. To put this average slope into more accessible terms, a sample of 10 observations will span

values encompassing approximately ± 1.5 standard deviations of the mean for a normally and independently distributed (statistical) population.

First, consider one of the larger subpopulations of Cape Sable seaside-sparrows (A or B) and suppose we had counted 200 birds (log 2.3), leading to an estimate of 3,200 individuals. The log of the standard deviation of this population would be 0.7 x 2.3 = 1.6, and so the standard deviation would be ~41. A range of plus or minus 41 x 1.5 (= 61) would have the population varying between 140 and 260 counted birds or between an estimate 2,240 and 4,160 birds. This approximates a two-fold span of values over a sample of 10 points, that is, over a decade. This hypothetical situation fits comfortably with the experiences of those who count common birds over such intervals.

Now consider a site where the species is much rarer: say a mean count of 10 birds and so an estimate of 160 birds. Using the same logic, it would have a standard deviation of 5 and so abundances would span from 18 (an estimate of 288 birds) down to a count of two (an estimate of 32 birds). This is a much greater span of values than in the previous example (i.e., a factor of nine, versus a factor of about two). It is large enough that local extinctions might occur naturally, by chance, at least intermittently over the span of a decade or two. Mean population counts below 10 should experience regular periods when the birds would not be counted—and where they might indeed be locally extinct.

We have not missed the significance of the assumptions of normal and independently distributed population sizes in the previous analysis. The population count in one year is likely to be dependent, probably strongly so, on that of the previous year. As a consequence, for most populations, estimates of the variability of population abundances increase with increased length of record (Pimm and Redfearn 1988).

This was also the case for the grassland sparrows. Curnutt et al. (1996) found that of the seven species with at least 10 sampling locations of continuous data over 20 years, six showed significant increases in variability over all time periods. These increases in variability over time would mean that not only would we expect a sample of 20 years to encompass a wider range of standard deviations than the samples of 10 years exemplified above, but that the standard deviation itself will be larger.

We will not discuss how large the envelope of population fluctuations is with the added complication of increasing variability over time, for this has been done elsewhere (Lande 1993, Ariño and Pimm 1995). Incorporating these details—or formalising the mathematics—does not alter the general conclusions about the Cape Sable seaside-sparrow: (1) The two largest subpopulations are large enough that given normal year-to-year variability seen in other grassland sparrows, we should not expect dangerously low populations within a century (or indeed a much longer interval). (2) In contrast, the smaller subpopulations might well fall below levels where we likely could not count them, and where unavoidable vagaries of birth and

deaths may well doom them to at least local extinction.

Thus, local subpopulations may become extinct, but at least one of the three larger subpopulations (A, B, or E) should be available to naturally re-stock them. This is an entirely comforting conclusion. It stems from a rough-and-ready estimate of risk, but one certainly appropriate to the amount of information at hand.

This conclusion, however, was rudely shocked in April 1993. The western subpopulation (A), for which the preceding calculation suggests might vary two-fold over a decade, declined to one-seventh of its 1992 abundance in the spring of 1993. It has remained at low levels ever since. Subpopulation D in the southeast corner of the species' range nearly disappeared and the subpopulations in the northeast (C and F) also declined. Curnutt et al. (1998) provided a detailed analysis to show that these declines were statistically highly improbable given what we know about year-to-year variation in other sparrow populations.

The result was particularly discouraging to one of us (Pimm), because he had spent much of the previous decade cataloging and analysing natural year-to-year variation in population sizes for conservation ends (Pimm 1991). Moreover, he was a founding partner, with John Lawton, (Ascot, United Kingdom) of the effort to provide a catalogue of more than 2,000 long-term time series (now available at <http: // www.sw.ic.ac.uk/cpb/cpb/gpdd.htm>). A central objective of this compilation was to provide conservation biologists an accessible set of estimates of natural population variability for population risk assessments.

Worse still was that the assumption of natural variability seemed a particularly sensible one. The Cape Sable seaside-sparrow is found almost entirely within Everglades National Park and Big Cypress National Preserve. These adjacent protected areas are very large by the standards of the hemisphere. Only about twenty national parks in Central and South America are as large or larger (Mayer and Pimm 1998). If the method of using natural variability to calculate risk of extinction should apply anywhere, this bird in these National Parks would seem to be a good candidate. Why did this approach fail?

Risk analysis 2: a mechanistic approach

Our surveys showed that the Cape Sable seaside-sparrow population on the western side of Shark River Slough declined dramatically since 1992. It has declined similarly since 1981 in the northeast and southeast of its range. Only two subpopulations have remained more or less constant. According to Curnutt et al. (1998), Nott et al. (1998) and Lockwood et al. (1997), there are three reasons. (1) The massive decline in the western subpopulation is the consequence of the inundation of the breeding habitat during the dry season by managed flows over the S-12 structures in 1993, 1994, and 1995. (2) The decline in most of the northeastern subpopulations is due

to the very high fire frequencies in these areas over the last decade or more. We erect the plausible hypothesis that the high fire frequency is due, in part, to the high incidence of unplanned human ignitions in the areas adjacent to the park. Moreover, we suggest that unnaturally low levels of water permit high fire frequencies during the breeding season. Water that should have naturally flowed through northeast Shark River Slough to seasonally flood the eastern populations has been diverted to the west through the S-12s. Moreover, the water was prevented from flowing back to the east by a barrier to water flow called the L67-extension. (3)The decline in the lower part of subpopulations C and in D was due to changes in the managed water levels that have locally converted the seasonally flooded prairies that favour the birds to nearly continuously flooded, sawgrass-dominated marshes that the birds avoid.

The next step is to combine the variable area of suitable habitat with a simple demographic model of the sparrow. Such a model needs extensive data on the bird's birth and death rates. This is a time-consuming effort given the bird's rarity and inaccessibility. (All but one of the sub-populations are reached only by helicopter.) In recent years, we have banded over about 100 individuals per year and find as many nests. The central feature of our model of risk assessment was the availability of suitable breeding habitat. Our studies show this varies considerably from year to year. For this step in risk assessment, we postpone the longer-term changes in vegetation effected by changes in hydrology and fire frequencies.

Lockwood et al. (chapter 3) report on the sparrow's demographic parameters. This chapter is based on the best estimates of parameters available at the time it was published. In brief, the sparrows laid an average of 3.2 eggs per clutch, a number that varied little from year to year or from place to place. About half of the eggs fledged young and that fraction varied considerably. In particular, it depended on whether the clutch was laid earlier in the year and was almost certainly a first clutch, or whether it was laid later and was likely a second clutch. Rising water levels, which are common later in the year, terminate clutches. There were far fewer second clutches than first clutches, and known third clutches were so few and fledged so few young that they contributed little, if anything, to the population size of the next generation. Maximum likelihood estimates of banded birds showed that 66% of territory-holding males survived from one year to the next. Lockwood et al. (in prep.) combined the best estimates of these parameters and inferred others, including the survivorship of females and first year birds. They came to the conclusion that the overall growth rate of the population was, plus or minus a few percent, close to replacement. Those "few percent" are a measure of the rigour of our procedures for these data are derived from a population that has not changed perceptible over the years during which we collected the data. That is, we estimate parameters consistent with the birds replacing each other and they have obliged us by doing so.

For a typical PVA we would devote considerable effort to estimating the bird's demographic parameters. We do not. While we applaud rigour and the best possible

procedures, we now ask whether tight confidence intervals applied to some parameters make any difference or, worse, obfuscate the critical issues. Perhaps the most important parameters that we need to know, only serendipity will give us. How quickly do birds die when evicted from their homes by fire and flood? And how quickly does the population recover thereafter? These are inherently rare events for which our detailed estimates are merely a guide, however small the confidence intervals about them.

How quickly do birds die when conditions are bad? Even under the best conditions, 34% of the males are lost from their territories from one year to the next. We have smaller sample sizes for females that suffer the extra stress of producing and carrying eggs. We see only about a quarter of the fledged young the following year, but this must be an underestimate of their survival for some move to areas away from our extensive network of study sites. Almost certainly, however, young do not survive as well as territory-holding adults. A much greater fraction of birds will likely die under the worst conditions—prolonged, deep flooding of the habitat (which occurred from 1993 to 1995 in the western subpopulation) or extensive fires (such as that which burned most of the eastern subpopulations in 1989).

We do not have survival estimates during these conditions and think that few studies will ever satisfactorily estimate parameters during rare events—even those that befall common species. We assume conservatively that adult survival (males and females alike) is 66% even in bad years. We assume that 50% of young survive from their hatch year to the next—a number that we feel is almost certainly too high.

How quickly can birds recover when conditions are favourable? Obviously, long-term estimates of parameters give means not maxima. There are, however, some obvious limits on those maxima. First, suppose every pair in a sub-population laid two clutches a year. (We have never seen anything like every pair laying a second clutch even when the conditions remain dry enough, long enough, for them to do so.) Second, suppose that the best fledge rate ever observed in a given year (60% of eggs) applied to both clutches. (We have never seen second clutches fledge the same fraction of eggs as first clutches.) Combined with the optimistic survival rates of the last paragraph, a population could increase at 61% per year. We then assume that these birds could fill up the area available for nesting without any additional mortality during their dispersal. We label this "the wildly optimistic scenario. "The best fledge rate ever sustained for a few years in a row at a particular subpopulation was 53%. This was in subpopulation E, where numbers have steadily increased in the last few years. Even there, second clutches were less frequent and less successful than first clutches. Assume that 60% of birds with available habitat lay second clutches and their success was the same as the first attempt. This leads to a potential growth rate of 34% per year. This is still "very optimistic"—we label the scenario as such—for second clutches have never been observed to be so frequent or so successful. Reducing the 60% to 50% leads to a maximum growth rate of 24% per year. We label this case "plausible."

Certainly we can change other parameters. Reducing the survival of the hatch year birds—a parameter for which this and many other studies estimate imprecisely—has the same effect as reducing the number of young that fledge. What matters is the relative rates of increase between years; 1.61 for the "wildly optimistic" case, 1.34 for the “optimistic” case, and 1.24 for the "plausible" case. We now see which of these are consistent with our observations and what are the implications for each subpopulation's risk of extinction.

The Subpopulation West of Shark River Slough (A)

This subpopulation is situated on a low ridge that is particularly vulnerable to flooding. Water depths of more than a few centimetre prevent breeding or terminate it if it has already started (Lockwood et al. 1997). Nott et al. (1998) calculated the extent of available breeding habitat for each of the last 20 years, classifying areas into those that remain dry enough for just one brood to be raised, and those that could produce two (assuming birds were physiologically capable of doing so). We then estimated the number of sparrows produced each year from the breeding and survival parameters scaled by the available habitat under the various scenarios described in earlier chapters. The sparrow numbers start with a guess of 2,000 birds in 1977 and follow deterministically thereafter, with the observed previous 20-year sequence of water levels repeated cyclically into the future. This starting point in 1977 allows the subpopulation to increase to its estimated 2,500 birds by the time of the 1981 survey.

The model caps the subpopulation at 3,500 birds—an estimate of carrying capacity that doesn't strongly enter into the model's results because water levels so rarely allow the birds to breed across the potential range. We determined the cap based on the maximum available habitat and typical maximum observed densities. The estimates of actual habitat conditions show, for example, that in 1977 all 2,000 birds had the chance to raise one brood, but only 11% of them were in places dry enough to raise a second, even had they been fit enough to do so.

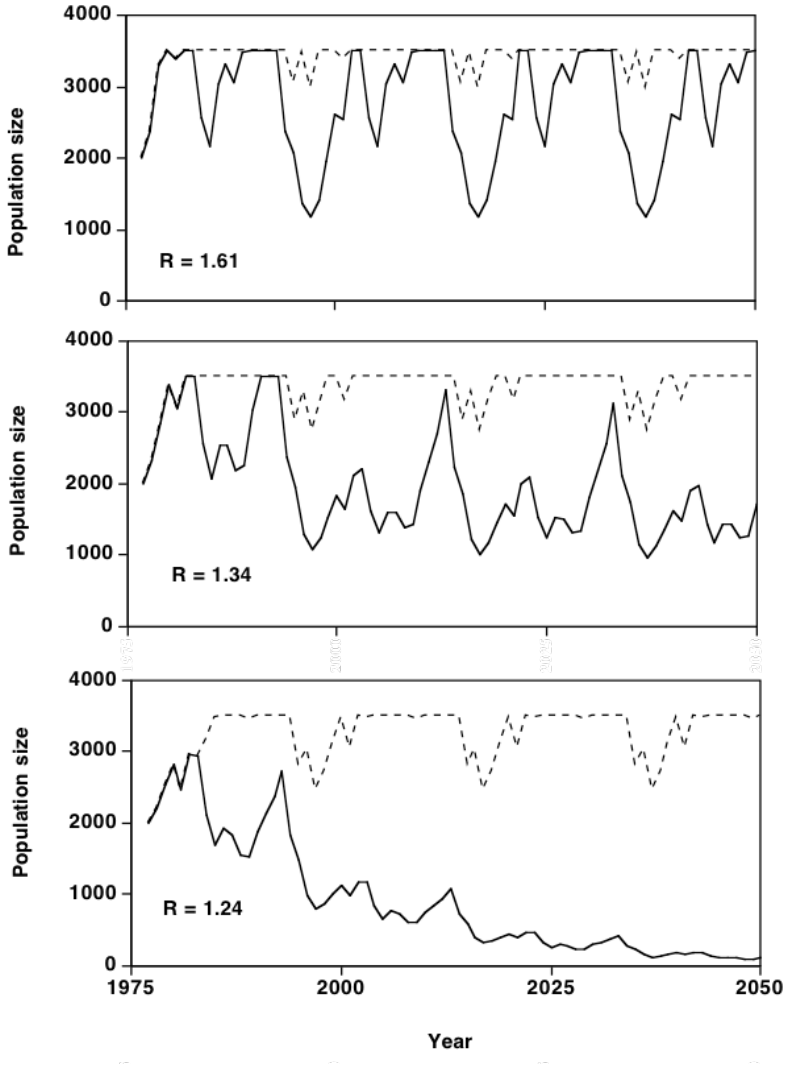


Figure 14.1 Three deterministic simulations of a model described in the text for the sub-population west of Shark River Slough. The proportional maximum change from one year to the next (R) varies from 1.61 ("wildly optimistic"; at top), through 1.34 ("optimistic", middle) to 1.24 ("plausible" bottom). The solid line uses the known extent of available breeding habitat available for first and second clutches over the 20 years prior to 1997. It then repeats the same pattern. This extent is driven by managed water flows. Were massive, dry season releases prevented, more habitat would be available for second clutches (dashed lines). As the text discusses, only the "plausible" model is consistent with the known population estimates in 1981, 1992 and subsequent years.

Two of the three scenarios in Figure 14.1 (“wildly optimistic” and “optimistic”) allow the subpopulation to persist. However, both optimistic scenarios fail to match two features of the range-wide survey of the birds. First, whereas both optimistic scenarios suggest an increase in numbers between 1981 and 1992, the subpopulation in 1992 was estimated to be 7% lower that it was in 1981. Unfortunately, there were no surveys in intermediate years including some when substantial areas suffered prolonged flooding. Second, these models do not recreate the drop in subpopulation that followed the wet years of 1993 to 1995 inclusive, when the subpopulation estimates fell to fewer than 400 birds. The “plausible” model predicts fewer birds in 1992 than 1981, but even it optimistically predicts ~800 birds after these wet years.

An additional validation of the model and its parameters requires the sparrows to persist in the absence of these unnatural events. Were the sparrows predicted to decline, then we might suppose the model erred in not allowing the birds to recover quickly enough. A second set of models runs this “what if” alternative. If, during the catastrophic years, the sparrow's habitat had not been flooded early in the season and if 100% of the habitat had been available for one brood, then the subpopulation would have thrived even under the "plausible" scenario. Indeed, it would have often reached the model's subpopulation ceiling of 3,500 birds.

Thus calibrated, we run our models for more sets of 20 years. They re-cycle the exact patterns of habitat availability, whereupon, the subpopulation declines towards extinction within fifty years in the "plausible" scenario. It even goes to extinction in the “optimistic” one. What if water were not released? The subpopulation dips below its population ceiling periodically, but persists indefinitely even in the plausible scenario.

The catastrophic years of 1983, 1984, 1986, 1987, 1993 and 1995, were not *naturally* bad years. They resulted from deliberate, massive dry season releases of water through the S12s into Everglades National Park (Nott et al. 1998). The contribution of rainfall to the water levels is relatively small in comparison.

So we conclude that repeating managed water flows with the pattern of the last two decades will drive this endangered species to extinction in the area that once held the largest number of birds. The survey data we have collected since 1997 confirms this speculation. The population has remained under 500 birds and it is restricted to a few square kilometres of habitat.

The Subpopulations to the North and East of Shark River Slough (C, F)

Managed high water levels are not an issue in the other sparrow subpopulations; indeed, it is the shortage of water that is the problem. Here, frequent fires burn the prairies. Birds are not found in areas that are burned as often as once every two years (Curnutt et al. 1998). We see little point in running risk analyses of these subpopulations. In total, they number a few hundred birds scattered across a wide area that fires burn, in some cases, annually. Thus, the birds are already scarce and the threats to them are self-evident. More important is the question of whether fires that start in this area might spread southwards to burn the only area where more than 1,000 birds remain—the south-eastern subpopulation.

The South-eastern Subpopulation (B)

Small portions of this area burn every year often as consequence of fires that burn out of the pinelands to its north. Yet in 1989 nearly half of it burned as a consequence of a massive, dry-season fire. Probably all of sub-population E burned, perhaps explaining why it is still recovering. Such fires can burn many hundreds of square kilometres in the Everglades. This size dwarfs the sparrow's range: the population in the southeast occupies only about 60 square kilometres. The policy of Everglades National Park is not to allow major fires to cross the park roads that divide this population into three parts. Nonetheless, fires of this size are hard to control in practice.

We model this area's population using the "plausible scenario" calibrated above. We "set" small fires ($1/40^{th}$ of the available habitat) every year in 20% of that habitat. Birds within these areas cannot breed successfully that year, but do not suffer any direct mortality. We do not know how many adult birds die in fires, but it surely more than we have assumed. In the year after fire, we assume that 50% of the birds can breed in an area, 75% the year after that, and 100% the following year. Curnutt et al. (1998) show that sparrow populations increase for five or more after fires, so these estimates are also optimistic. Finally, we vary the frequency of severe fires — those that burn 90% of the bird's habitat.

Figure 14.2 provides two sample simulations with severe fires every 10 years and every 20 years. In the former case the subpopulation quickly goes to extinction; in the latter case it persists. These simulations are typical. With fires on average every 10 years, only 5% of the simulations allowed the subpopulation to increase over a 50-year period. From their original start of 2,000 birds, 50% of the simulations resulted in the subpopulations dropping below 1,000 birds and 15% fell below 500 birds. Given enough years, all of the model runs encountered a series of fires that drove the subpopulation to extinction.

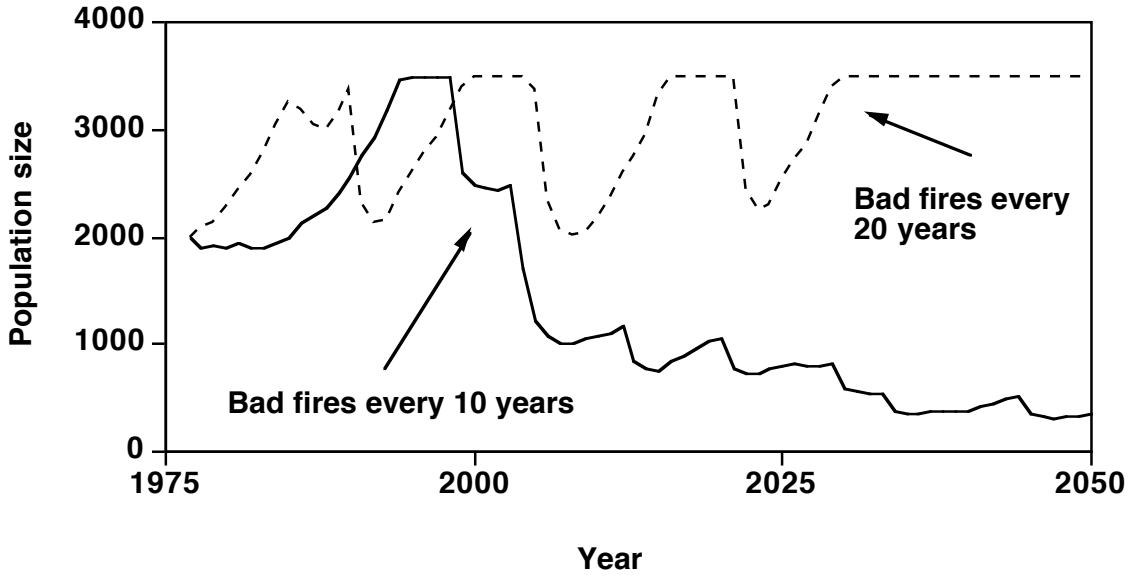


Figure 14.2 . Examples of stochastic simulations of a model described in the text for the largest remaining sub-population. Twenty percent of the habitat is burned each year, on average, plus there are "bad" fires that burn an average of 90% of it. Such fires every 20 years allow the population to persist, those every 10 years do not.

In sum, the south-eastern subpopulation is in danger of extinction from extensive fires that occur as frequently as one in ten years. Given that we have observed such fires in or near this subpopulation at that frequency, we conclude that this subpopulation is also at severe risk of extinction.

Conclusions

We predict that the Cape Sable seaside-sparrow subpopulation west of Shark River Slough will decline to extinction if the pattern of managed flows over the S-12 structures for the last 20 years is repeated. If these unnatural breeding season flows over the S-12s are stopped, this subpopulation should flourish. The subpopulations in the northeast have already declined to near extinction. These declines will continue unless the fire regimes are changed. On its own, the subpopulation in the southeast runs the risk of extinction because of episodic, large-scale fires. The fate of subpopulation E (now the second largest subpopulation) is interesting because it may illustrate a population that was burned to oblivion in 1989 and is still recovering.

Our models omit some obvious features. We have not included the effects of prolonged inundation or of frequent fires on the vegetation. These processes alter

the vegetation in ways that preclude the birds' use of areas for several years (Curnutt et al. 1998, Nott et al. 1998). Incorporating these impacts would likely lead to even greater concerns about the sparrow's future.

The predictions of our models arise from our knowledge of the bird's breeding biology and of the area's water and fire regimes. They are not "curve fitting" exercises to the census data. Importantly, the results predict the timing and magnitude of the changes in those data. This confirms that the models are both sensible and sufficiently complete to capture the essential features.

The predicted decline to extinction of the southeastern subpopulation is a prediction of future events and thus one not confirmed by our short-term data. Notice a subtle problem: if the currently least-affected population is doomed, why does it hold so many sparrows? Should it not have gone extinct earlier? There are two non-exclusive answers. First, it, too, is affected by episodic fires—such as the fire in1989—that might be relatively recent phenomena brought on by management changes, and likely to be outside previous experience. Second, the sparrow has become locally extinct on occasion and then been re-colonised from other subpopulations. This possibility makes good sense. Years of naturally high water west of Shark River Slough would harm the subpopulation there. Concomitant flooding in the northeastern subpopulations would suppress the frequency of natural fires there, and, consequently, the possibility of the fire's spread to the southeastern subpopulations. In contrast, in dry years, the population west of Shark River Slough would be expected to flourish, even if the eastern subpopulations ran higher than average risks due to fires. Simply, a high-risk year west of the slough would be a low-risk year east of the slough, and vice versa. A complete exploration of these possibilities will require a combined water and fire model.

Nonetheless, we offer the following tentative conclusion: the Cape Sable seaside-sparrow will only survive if it has at least three healthy subpopulations. To implement this requirement, the breeding areas west of Shark River Slough must not be flooded in the breeding season, and water levels should be raised in the northeast of Shark River Slough to reduce the incidence of fires.

The general conclusion for conservation is that species even within one of the hemisphere's largest national parks—and possibly its best funded—are not immune to massive anthropogenic impacts from outside. Everglades National Park is not large enough for calculations of risk based on natural population fluctuations to be sensible. Such calculations demonstrably gave the wrong answer for the Cape Sable seaside-sparrow.

Critics may counter that this is a special case. The species occupies a wetland and perhaps wetlands are uniquely vulnerable to the vagaries of water flows upstream. Perhaps, but we are not convinced. Other large parks have unique problems that cross their boundaries. Fire, and our inclination to suppress small fires and so risk catastrophic ones, is an example that comes to mind for many parks in the western United States, for example. We argue that even for the largest

protected areas we must develop mechanistic models of what causes populations to decline. Unless we do so, we will not be able to adequately predict future risks.

Chapter 15

Law, Policy, Politics, and Ecology in Florida's Everglades

Stuart Pimm

Abstract

The history of the modern Everglades is a case study in how federal agencies work. It shows how the regulatory, administrative and legislative processes impact so many decisions that affect biodiversity and ecosystems, as well as water supply and quality and land use planning. It shows how difficult that work can be in such a complex ecosystem. More specifically, the history of the attempts to address the decline of the Cape Sable seaside-sparrow and the broader Everglades ecosystem demonstrates that the fate of the Everglades and our responses to it has always been entangled in the maze of federal, state and local laws, rules, regulations, practices, program statements, guidance documents, and policy manuals that drive the government. This chapter will survey the associated federal interventions — who did what, when, and why — and to relate them to the science. These interventions drove the scientific work which of course, in turn, caused various actions. Without a close examination of the government record, one cannot really understand what has happened to the Everglades and its biodiversity. Without that careful review, one cannot properly learn how to save the Everglades.

Part I: From the C&SF Project to Snail Kites

An appropriate starting point is the late 1940's. At the end of that decade, President Truman enacted two major federal actions that forever impacted the Everglades. The first was the dedication of Everglades National Park in December 1947. The second was the enactment of the law that authorised a water project that substantially changed the hydrology—and ecology—of the Park and broader ecosystem: the Central and South Florida Flood Control Project (the C&SF), enacted in 1948 [Flood Control Act of 1948, Pub. L. No. 80-858, 62 Stat. 1171, 1175 (1948)]. Indeed, commentators have noted that "[i]ronically, while President Truman protected part of the Everglades with his action, he fundamentally altered the ecosystem with" the other (Rizzardi 2000 at 352).

The C&SF channelized the Kissimmee River and other waters for flood control and water supply for agriculture and human consumption. The authorisation for this C&SF project attached to the Flood Control Act. It was one of the bills that became the precursor to the Water Resources Development Act (WRDA). This is the biannual water projects bill that authorises the Civil Works program of the Army Corps of Engineers. Over the years, bills amending the Flood Control Act, the 19th century Rivers and Harbors Act, and other water infrastructure-related bills were merged

into one omnibus water projects authorisation bill—WRDA. It is on WRDA, and, in years when WRDA was not enacted, certain appropriation bills, that most of the legislative story of the Everglades saga is written.

Two decades later, C&SF was largely constructed. As part of the "creep westward" provisions of the 1968 Flood Control Act (The Flood Control Act of 1968, P.L. 90-483, Sec 203, 82 Stat. 731, 740-41) increased flood control protection and provided water supply for agricultural uses in Dade County (Rizzardi 2000 at 353). Note, again, more infrastructure was authorised to meet the needs of the South Dade Conveyance System expanding population and agriculture (Rizzardi 2000).

This taming had the effect of altering—even ending—the natural sheet flow that had characterised the region's hydrology and ecosystem. Rather than a thin sheet of water meandering through the grasslands and sloughs, the C&SF was—or rather, intended to be—an ordered, managed, engineered system—or at least that was how it was conceived. The impacts of this change to the hydrology and ecology were soon becoming apparent.

Early Restoration Efforts

By the early 1970's, there were warning signs about how much water was being diverted from what would be its natural end point in the Park to other places and to other needs, often in the name of flood control, but just as often in the name of water supply for agriculture, industry, and drinking water.

This, of course, was also the time when the environmental movement was reaching its prime and Congress enacted the National Environmental Policy Act or NEPA, the Clean Water Act, the Clean Air Act and the Endangered Species Act. At this time, both parties wanted to be seen as green. In true bipartisan fashion, Republican President Richard Nixon, working with a Democratic-controlled congress, signed and enacted these laws.

This green movement did not escape the Everglades. Of course there is a conservation history regarding the Everglades going back to the bird feather craze of the early 20th century and in many ways, that movement was the precursor to the citizen-activists that formed the core of the movement to save the Everglades in the last quarter of the last century (Grunwald 2006 Chapter 8).

Congress authorised the Minimum Water Deliveries Schedule, requiring the Corps and South Florida Water Management District to use the C&SF project to deliver a minimum of 315,000 acre feet of water to Everglades National Park as a fixed monthly allotment (Public Law 91-28, River Basic Monetary Authorization and Miscellaneous Civil Works Amendments, Section 2 (1970)). Though this monthly allocation was not nearly enough to address the problem, the Minimum Water Deliveries Schedule is still a significant milestone. Congress expressly authorised the C&SF to assist the ecology of the Park, rather than just more infrastructure for flood control and other uses.

It is important want to note here that Congress began its involvement in reviving the Park much earlier than is generally realised—the problem was that the Minimum Water Deliveries simply did not provide adequate water to the right places at the right time. Nearly three decades would pass before comprehensive restoration was enacted into law.

The early 1980's saw some of the most serious scientific efforts to carefully study the changing hydrology of the Everglades and impacts on water quality inside and outside the park, and of course, impacts to species. In particular, the 1980s were exceptionally dry years, with a fire in 1989 burning large areas of the Park.

Congress's next major action was to authorise the Experimental Water Deliveries Program on the Supplemental Appropriations Act of 1984 (P.L. 98-181, Sec. 1302 of Supplemental Appropriations Act of 1984). This program authorised the Corps to go a step further from the Minimum Water Deliveries previously in place. Specifically, it was to deviate from the minimum delivery schedule for two years to conduct experimental programs. The hope was that an improved schedule for water deliveries to the Park based on actual rainfall amounts over the southern Everglades watershed and improved distribution of these flows would follow. It was clear eventually that little ecological progress was made in the Park and it was ultimately terminated nearly 15 years later.

This law was put on an appropriation bill—and a 'supplemental' appropriation bill. This was because there was only one WRDA enacted during the 8 year Reagan Administration—1986 WRDA that introduced major changes to the Corps' Civil Works water projects, including significant cost sharing with state and local entities for many projects.

This is important because Everglades' restoration was often hostage to legislative politics, timelines, and manoeuvrings. Indeed, restoration advocates had to attach important legislative actions to bills other than WRDA throughout the process. At one point, even the final Comprehensive Everglades Restoration Plan (CERP) was nearly attached to an agriculture appropriations bill to avert a final collapse of negotiations in 2000 (Grunwald 2006 at 349).

Everglades Expansion Act of 1989

Even before 1989, it is clear that Congress had noticed that the Florida Everglades were changing for the worse and that situation was unacceptable. The local and national press were covering the rapid and discernible decline of the ecosystem. Of course, a major local and national constituency was emerging to save the Everglades, one that produced colourful and passionate heroes like Art Marshall and Marjory Stoneman Douglas.

That constituency's first major federal legislative victory was the enactment of the Everglades Expansion Act of 1989 [Pub. L. No. 101-229, 103 Stat. 1946 (1989]. Sponsored primarily by Representative Dante Fascell in the House of

Representatives and Senator Bob Graham in the Senate, it added much of Northeast Shark River Slough to Everglades National Park so that historic flows could return there. The Act also authorised the Modified Water Deliveries (Mod Waters) project, which authorised alterations to Tamiami Trail, to allow for more natural sheet flow —a tremendously important project to this day.

(Parenthetically, I hear Senator Graham at an Everglades Coalition meeting tell the story of how E.F. (Tom) Coe had, until the last minute refused to sit on the platform with President Truman and the Park's dedication in 1947. He was incensed by the boundaries drawn for the Park, excluding as they did the area of Northeast Shark Slough. The Expansion Act acquired a key missing piece — see Figure 14.1

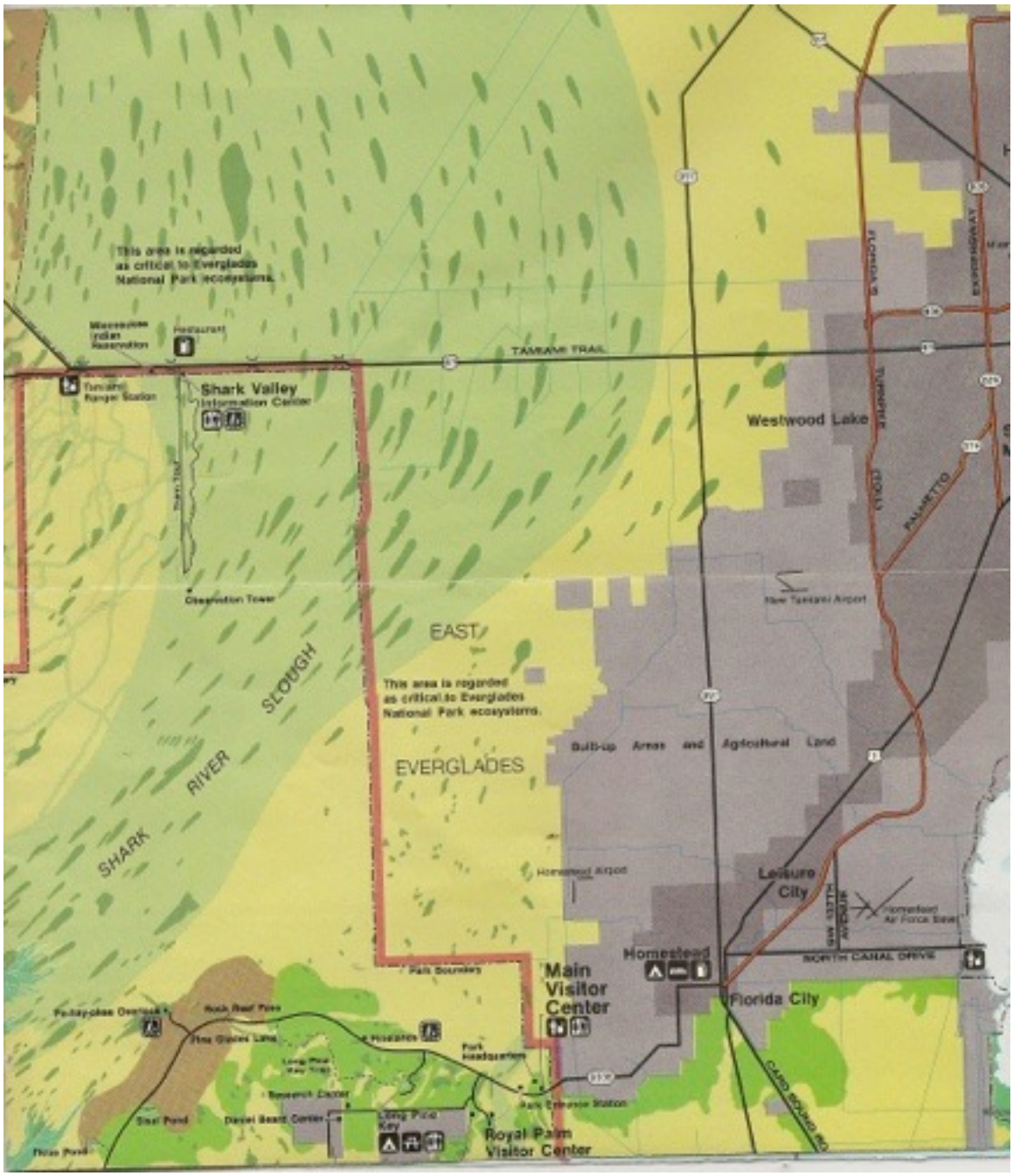


Figure 15.1. Old maps of Everglades National Park show the area of Northeast Shark Slough labelled as "this area is regarded as critical to Everglades National Park ecosystems. Contrast the Park boundaries with those in figure iii, a more recent map.

The legislation was also notable for stating that the construction costs of the modifications envisioned by the project "are justified by the environmental benefits to be derived by the Everglades ecosystem in general and by the park in particular and shall not require further economic justification." (Section 104 (a)(3)). That language would help the project, which was extremely costly, survive the economic justification requirements of earlier laws, including the 1986 WRDA reforms—

requirements that could have fallen short given that much of what was envisioned was ecological restoration rather than 'merely' protections to property and related values.

The Everglades Expansion Act was very significant for the restoration of this ecosystem. One of the primary infrastructure project devoted to restoration—Mod Waters—was legislatively conceived on that law. The Act also proved an essential step on the road to 'comprehensive' Everglades restoration: a step built upon later in the 1992, 1996, and the 2000 WRDAs.

Bureaucratic Differences

Of course, the details of implementing these projects fell to federal agencies — including the Department of the Interior's Fish and Wildlife Service and National Park Service and the Department of Defence's Army Corps of Engineers.

Each of these agencies has different obligations and purposes and are governed by different laws and regulations. They each must act in accord with those laws and regulations and purposes.

The Park Service must protect the resource of the park for the purposes stated in the organic act of the National Park System and of the specific park it manages.

The Fish and Wildlife Service must evaluate, protect and conserve threatened and endangered species and their habitat.

The Army Corps of Engineers must provide and maintain navigation ways, construct flood damage reduction projects, and restore ecosystems. Additionally, as the mission of the Corps has grown or even ballooned—largely due to congressional authority—over the decades, it can do a myriad of other things including provide water supply, recreation, and even beach re-nourishment.

Not surprisingly, these three agencies and their statutes, missions, and purposes clash—even when one would think that their missions would be complimentary. Moreover, this says nothing about State laws and agencies and local and regional authorities, including public water managers.

Coming after the significant moment that was the Everglades Expansion Act, the 1990's was to prove rather contentious and even acrimonious when it came to Everglades issues. Indeed, the Act precipitated the first controversy.

Snail Kite Controversy

The south Florida "water wars" of the 1990's demonstrated this more than at any other time. Not long after the enactment of the Everglades Expansion Act, there is the first in a series of interagency conflicts. It quickly became very messy.

Recall that the Everglades Expansion Act did more than just expand the boundaries of the park—it included a significant water infrastructure project authorisation: the Modified Waters Project (Mod Waters). Mod Waters' express purpose was to alter Tamiami Trail and begin the process of restoring a more natural flow into Everglades National Park.

Doing this, however, would greatly affect water levels in the Water Conservation Areas (WCA), particularly, WCA 3A—and affect the habitat of the apple snail, and with that, a listed species—the snail kite, whose diet depends on them. Some biologists at the Fish and Wildlife Service monitoring the Snail Kites were concerned. That worry began one of the first major inter-agency Everglades battles, in this case between the Fish and Wildlife Service and the Park Service (Levin 2004).

Specifically, the Fish and Wildlife Service in its February 1990 Biological Opinion, found that the Mod Waters project and its attempts to restore natural flow by altering the WCAs would jeopardise the continued existence of the Snail Kite. This opinion would grind the project to a halt just as major Everglades' restoration was beginning.

The staff at Everglades National Park was livid and intensely frustrated by this. It had long been seeking more water for its drying resource and wanted to see more natural, less regulated water flow returned to Park boundaries. Further, it disagreed with the Service's conclusions about the impacts on the Snail Kite. And it did not want to see a biological opinion prop up massive water infrastructure.

Frustration at the Park reached a fever pitch—staff there was so frustrated over the biological opinion that it attempted to "sidestep" it, drafting legislative language explicitly exempting Everglades restoration from the ESA (Levin 2004 at 79). Though this attempt was unsuccessful, such action is indicative enough of how awry the ecology—and management—of the Everglades had become.

The divide between the two agencies was huge at this moment. But it largely subsided as the Fish and Wildlife Service "revised" its understanding of Kite populations, seeing them as more fluid, and thus, that the proposed restoration actions would not jeopardise the Snail Kite (Levin 2004 at 79, quoting scientist Rob Bennett).

It is surely self-serving, but I believe a key step in this rapprochement was a National Audubon Society panel, convened to mediate the dispute (Orians et al. 1992). Organised on identical lines to a National Research Council report, it heard evidence and wrote its recommendations. As one of its authors, I shared in the criticisms that the Fish and Wildlife Service has defined its Biological Opinion too narrowly. Restoration of water flows to Northeast Shark Slough might reduce snail kite numbers in WCA 3A (the geographical scope of the Opinion), but would surely improve its numbers elsewhere as a direct consequence.

The controversy over the Snail Kite was but an overture to a much bigger problem facing Everglades resource management. Indeed, the Park staff had a much more difficult problem regarding another ESA-listed species with entirely different habitat and water management needs—the Cape Sable seaside-sparrow (the sparrow).

As the Audubon committee finished its work, the Park staff asked me if I would help them with that assessment. Initially, I declined, stating that the species was too abundant and that I preferred to concentrate on more critically endangered species. Then the high water levels of 1993 and subsequent years cut the numbers in half. One need not have a background in theoretical ecology to understand that if the Army Corps of Engineers could wipe out half an endangered species in one year, then they could probably wipe out the other half in another year.

Part II: Sparrow Wars

As previous chapters show, the early 1990's was the beginning of more intensive research in the Everglades' ecology, biodiversity, and hydrology. The Cape Sable seaside-sparrow had been a listed species for decades but a significant decline occurred in the early 1990's.

Initially, the authors of this Report believed that the enormous hurricane of late August 1992, Hurricane Andrew, might have been responsible for the declines in sparrow populations. As we learned more about the sparrow's habitat, nesting and breeding behaviour and most important, its disbursal among several distinct populations, we began to see other causes as being predominant (Pimm et al. 2002). Specifically, studies showed the catastrophic population drop was not related to Hurricane Andrew, but rather to major disruption of its breeding habitat due to unnaturally high water levels west of Shark River Slough.

Van Lent's hydrological studies demonstrated how much the C&SF has changed the natural hydrology of the Everglades and the Park (Van Lent 1996). His papers and presentations proved invaluable to Park managers and other decision-makers. His reports also noted the increased risk of fire to sparrow breeding habitat. Fire risks also increased in certain areas without regular, natural hydration. These hydrological and fire risk studies, combined with population and ecological papers prepared by other experts at the Park and in academia contributed greatly to our understanding of how the water infrastructure built up over the previous four decades were causing major declines for the Sparrow.

The October 1995 Jeopardy Opinion

Much of this science informed the decision-making of the field staff at the Fish and Wildlife Service. With this information, the Service, as part of an ESA Section 7 consultation of the Experimental Water Deliveries program—specifically, the 7th test iteration of water deliveries—issued a "jeopardy opinion" under the Endangered Species Act in October 1995. [Letter from Noreen K. Clough, U.S. FWS, to A.J. Salem, Planning Div., Jacksonville Dist., U.S. Army Corps of Eng'rs 9 (Oct. 27, 1995)

(regarding Test Iteration 7 of the Experimental Program of Water Deliveries to the Park)]. This action meant that the Army Corps was obligated to work with the Fish and Wildlife Service on implementing Reasonable and Prudent Alternatives (RPA) to this project.

The jeopardy opinion mandated additional, comprehensive research and monitoring of water levels at particular times of year. But most important was an RPA that "[w]ater flows through the S-12 Structures should be distributed in a manner that restores and maintains" the needed shorter hydroperiod on sparrow habitat to the west of Shark River Slough. (Ibid at 20). These water levels were necessary to allow the Sparrow's narrow nesting and breeding season.

Taken together, the October 1995 jeopardy opinion and the RPA required what became the Remedial Action Plan (RAP). Much of the next two years were spent in coordinating meetings and discussions, in which much data and information were exchanged among agencies as there was an attempt to make the Experimental Water Deliveries Program work appropriately—including for the Sparrow's continued existence.

The 1995 jeopardy opinion represented the opening shot of what was to be a bureaucratic battle among agencies over water flow, as the jeopardy opinion also required the Corps to work with not only the Fish and Wildlife Service, but with the Park and the South Florida Water Management District.

Congressional Action

The 1989 Everglades Expansion Act was but the beginning of congressional involvement in Everglades restoration. By the mid 1990's, it was clear that much political will had grown for increased involvement in major Everglades restoration and that such restoration was becoming a national priority. Florida was becoming a much more competitive state in presidential elections. The year 1996 was only the third time since Harry Truman in 1948 that a Democrat had won the rapidly growing state (Grunwald 2006). Hence, both political parties were determined to keep Floridians happy by showering them with attention.

I will discuss the CERP authorisation process in Part III of this chapter. For now, it important to state that both Democrats and Republicans supported increased federal involvement in Everglades restoration, including a significant feasibility study authorisation on the 1996 Water Resources Development Act (WRDA), the first step toward congressional authorisation of a major water infrastructure project. Specifically, it was the "Restudy" of the C&SF project, requiring the Corps to submit a plan to Congress to change the existing project and restore the Everglades.

The Interagency Conflicts between 1997-1999

Particularly for the legal analysis presented in this section, I have relied on a law review article by Keith Rizzardi: Everglades in Jeopardy (Rizzardi. 2000). It is a review of much of the legal and policy controversy of this time.

Congressional comity on WRDA—a not infrequent bipartisan event—was only part of the story. While the Corps was conducting its feasibility study, all the agencies—federal, state, and municipal—had to contend with the ecological realities of a declining Everglades and major disruptions to the species that depend upon it.

The Fish and Wildlife Service, charged with conducting science and protecting endangered species, and the Everglades National Park, charged with protecting and preserving the park found itself in a paper war with Corps, charged with, among other things, providing flood control protection to the suburban and urban populations.

The record has many toughly worded letters among the agencies—particularly and not surprisingly from the seemingly much aggrieved Fish and Wildlife Service. These were often fraught with warnings about legal issues—even the occasional threat of legal action—if certain actions were or were not carried out. The letters, together with formal ESA Section 7 consultation documents form a record illustrating the story [See generally: Consultation History, U.S. FWS, FINAL BIOLOGICAL OPINION FOR THE U.S. ARMY CORPS OF ENGINEERS: MODIFIED WATER DELIVERIES TO EVERGLADES NATIONAL PARK, EXPERIMENTAL WATER DELIVERIES PROGRAM, CANAL 111 PROJECT 23 (Feb. 19, 1999)].

Indeed, during the projected El Nino years of 1997-1998, for which all concerned were attempting to prepare, the controversy over the sparrow reached its most difficult period yet.

Fears of excessive rains due to this event impacting the Park and its wildlife, but also the entire water infrastructure and the lands—and people—it attempted to protect spurred flurries of action. Much of the attention was on the Corps, which had control over the S-12's and the S-333 features and hence considerable control over how much water entered into the Park—and most critically, *where* it entered the Park.

The Corps, concerned about the ESA liability of accumulating too much water in the Water Conservation Areas and affecting other listed species, such as wood storks and snail kites, wanted to open the S-12s and send excess water directly into core—and currently, dry—breeding habitat for the sparrow during nesting season. Obviously, Everglades National Park and the Fish and Wildlife Service were rightly worried about the impacts of such an action on the Sparrow for the reasons we have explained elsewhere.

Letters between the agencies illustrate the controversy brilliantly: In particular the correspondence between Stephen Forsythe, State Supervisor of the Fish and Wildlife

Service and Colonel Joe Miller, Commander of the Jacksonville District of the Corps of Engineers.

On Christmas Eve 1997, Mr. Forsythe sent a letter to Col. Miller, expressing his concerns about the Corps' plan for the S-12 during this significant rain event:

> "At this time continued regulatory releases would exacerbate the current flood conditions and would likely preclude the possibility of a successful 1998 nesting season. As stated earlier, faced with the sixth consecutive nesting season with little to no breeding by birds in the western core population, the Cape Sable seaside-sparrow faces extinction. As you no doubt can see, these are very serious issues for a species that is as close to extinction as the CSSS. In the view of the FWS and the NPS, the current condition in western Shark River Slough represents a condition requiring immediate and corrective action….The NPS and the FWS cannot concur with actions that increase the risk of an unsuccessful nesting season…" [Letter from Stephen W. Forsythe, State Supervisor, U.S. FWS, to Col. Joe Miller, Jacksonville Dist. Commander, U.S. Army Corps of Eng'rs (Dec. 24, 1997)].

Undoubtedly noting the legally-loaded words 'cannot concur,' the Corps promptly kept the S-12's closed. That naturally affected water levels in the WCA's. The Corps' action, which was essentially to comply with the Service's advisement to keep the S-12s closed to protect sparrow habitat, now risked adversely affecting other wildlife, particularly the snail kites and their staple, the apple snail.

The Service believed that the Corps had other options for managing the excess water throughout the entire water management system in south Florida. The Corps' approach, a January 1998 letter from Forsythe stated,

> "places the entire burden of water management on the natural systems, with adverse effects on the numerous species that rely on different portions of the natural system to survive; this approach requires us to choose which portion of the natural system will suffer the greatest harm. We have never recommended actions that protect the endangered Cape Sable seaside-sparrow at the expense of other portions of the historic Everglades ecosystem. Despite suggestions to the contrary, we have consistently maintained that all beneficiaries of the C&SF project, including private lands, should share the adversity created by high water levels in South Florida. We believe your agency currently has options to share the adversity that are not being used, such as using the S-333 structure to deliver flows to northeast Shark River Slough." [Letter from Stephen W. Forsythe, State Supervisor, U.S. FWS, to Col. Joe Miller, Jacksonville Dist. Commander, U.S. Army Corps of Eng'rs (Jan. 15, 1998)].

This letter demonstrates the problem in miniature—and so much was on the line for both sides.

On the one side were the Fish and Wildlife Service and Everglades National Park. They, and especially the Park, were arguing that the openings of the S-12s under the current regime were causing—and would continue to cause—damage to Sparrow habitat just when it needed water levels in Western Shark River slough to be lower. In short, it wanted much less water—if any—to be sent to West Shark River Slough during nesting and breeding season. Additionally, it urged more monitoring of water levels and impacts on sparrow breeding habitat.

On the other side, the Corps had additional responsibilities. It was warned about potentially incurring ESA liability for water levels being too high in the Water Conservation Areas and could cause problems for wading birds, such as the Wood Stork, and of course, the snail kite. There was considerable concern about the potentiality of flooding private property.

The Service and Park were essentially arguing that the water should be spread around more equally among the various water areas. The problem for the Corps was that such an action would have increased the flood risk to human populations, including and especially to those who lived in the 8.5 Square Mile Area, an especially difficult political problem in a year with a gubernatorial election in Florida.

Sensing the Corps' delay, the Service essentially threatened the Corps with legal action under the ESA.

> [T]he Corps has not implemented any of the actions recommended by [FWS] to reduce adverse impacts to listed species resulting from the Corps' emergency actions. When, during an emergency consultation under section 7 of the ESA, an action agency (the Corps in this case) does not implement [FWS]'s recommended measures for minimizing adverse effects of emergency actions, or partially implements [FWS]'s recommended measures, [FWS] is obliged to advise the action agency that any take resulting from such incomplete implementation does not meet the requirements for exemption from the taking provisions of Section 9 of the ESA. We believe such advice is pertinent to the sparrow situation. [Letter from Stephen W. Forsythe, State Supervisor, U.S. FWS, to Col. Joe Miller, Jacksonville Dist. Commander, U.S. Army Corps of Eng'rs (Apr. 7, 1998)]

Although the Corps did execute a cooperative agreement allowing more water to be sent from sparrow habitat to the Atlantic coast via the South Dade Conveyance System, it was clear that the Service and Park's frustration with the Corps was very high.

Years of science related to hydrology in the Park and the breeding and nesting cycles and behaviour of the sparrow cumulated in the Fish and Wildlife Service's 1999 Jeopardy Opinion for the Sparrow. The Service concluded that the Corps' operations, including the Experimental Deliveries program, were jeopardising the continued existence of the Cape Sable Seaside-Sparrow. This jeopardy opinion essentially "kills" the Experimental Program.

It also contained a Reasonable and Prudent Alternative to be implemented over the next few years. First for 1999, between March 1 and July 15, the Corps was required to maintain a minimum of 45 consecutive days of water levels not to exceed six feet at NP 205 in the Park. The Corps was also required to fund additional fire prevention and management operations. It is worth noting that the RPA contained a fairly flexible exception as long as certain factors, largely beyond the Corps' control, were met.

Finally, according to the RPA, in subsequent years, the periods for maximum and minimum water levels were to be extended, again with the intent to provide the sparrow with enough time to nest and breed. Over all the intent of this RPA was to increase water flow into Shark River Slough by May 1999 and then manage the levels in sparrow habitat to allow it to nest and breed over a four year period.

Between February 1999 and December 1999, there were numerous interagency meetings and conference calls between the Corps, Service, ENP, and SFWMD to discuss the implementation of the FWS's 1999 Biological Opinion. The Corps found itself in a tangle, simply appearing to not even follow the Service's Reasonable and Prudent Alternative to alter water flows.

Indeed, in March of 1999, the Corps essentially took matters into its own hands, relying on emergency regulatory authority—and announced that it would take steps to keep water levels down in sparrow breeding and nesting habitat, but not in accordance with the RPA's requirements.

The staffs of the Fish and Wildlife Service and of Everglades National Park were having none of that, firing off letters in March of 1999 stating that the Corps' emergency proposals were insufficient for the sparrow and the broader ecosystem. Additionally, the Service indicated that this new proposal was substantial enough to trigger *another* Section 7 Consultation under the ESA—essentially, needing to send everyone back to the drawing board despite the enormous efforts put into the February 1999 Jeopardy Opinion and accompanying RPA.

Further, the Service pointed out that only the Fish and Wildlife Service has the authority under regulation to declare an Endangered Species emergency—not the action agency, in this case, the Corps. (I have been told that there might be some legal ambiguity on this matter.)

Nevertheless, in an April 1999 letter the Corps claimed to have based its decision making, at least in part, on what was

> "discussed under the auspices of the Southern Everglades Restoration Alliance…[The actions discussed] have been modified based on input from all agencies to address any concerns that have been identified. This, while not providing formal notification, was the vehicle we hoped could be used to develop a consistent response to conditions that exist in the sparrow's western habitat. Nonetheless, we will consider any suggestions you have on

> the actions we have taken….They were taken with due regard to all previous information you gave us on the sparrow, and in my opinion will have no adverse impact on any listed species." Letter of Deputy District Engineer Richard E. Bonner for Colonel Joe Miller to Stephen Forsythe, dated April 6, 1999

In a very tersely-worded response, State Supervisor Forsythe scolded the Corps by an April 29, 1999 letter for

> 'equat[ing] discussions of an issue with concurrence on an issue. I believe we need to keep the distinction between the two quite clear. Finally your letter seems to imply that we are not trying to work with your agency to protect the Cape Sable seaside-sparrow since we do not think there is any emergency. That is far from accurate, and if the Corps had consulted with us when we first suggested you do so, the perceived need for any ESA emergency operations would have been precluded (emphasis original).

Although there was a fight over the implementation of the RPA, the Corps itself indicated that the initial goal of the RPA had been met regarding keeping water levels at NP 205 at 6 feet or less—indeed it exceeded the 45 day minimum and attained the 60 day target scheduled under the RPA for following year in 2000. Yet all sides seemed at an impasse on how to proceed.

Indeed in June, Forsythe sent another letter to the Corps indicating that

> "it is clear that the March 9, 1999 proposed action is so similar to Test 7 in both the nature (flooding some habitats while overdrying others) and extent (resulting in potential jeopardy to the species) of its effects on the [sparrow] and other listed species that it fails to meet the regulatory criteria for reinitiation of consultation (50 CFR 402.16). Therefore, the effects to listed species of this, and any other water management scenario having similar impacts, have already been analyzed by the Service and all such proposals must conform the Service's February 19, 1999 final biological opinion.

That letter's penultimate paragraph concludes ominously:

> Through the existing biological opinion, the Service has already provided the Corps with the only available RPA and the maximum possible amount of incidental take coverage short of jeopardy. Therefore given the current state of our knowledge on this subject, *any action that would cause a failure to meet the RPA targets and/or would exceed the anticipated amount of incidental take would be an ESA violation that cannot be remedied by further consultation.* [Letter from Stephen W. Forsythe, State Supervisor, U.S. FWS, to Col. Joe Miller, Jacksonville Dist. Commander, U.S. Army Corps of Eng'rs (June 18, 1999]. [Emphasis added].

The issues were so contentious —and comprehensive Everglades restoration such a priority for both the Clinton administration and Florida congressional delegation in advance of the 2000 presidential election—that "meetings were elevated to the White House Council on Environmental Quality (CEQ) to obtain guidance on National Environmental Policy Act (NEPA) coverage for emergency operations and to facilitate negotiations on points of disagreement between [Interior] and Corps." [See generally: Consultation History, U.S. FWS, FINAL BIOLOGICAL OPINION FOR THE U.S. ARMY CORPS OF ENGINEERS: EVERGLADES RESTORATION TRANSITION PLAN, PHASE 1 (NOV. 17, 2010)].

Eventually resulting in the Interim Structural and Operational Plan (ISOP), it was essentially a placeholder in anticipation of the enactment of CERP.

One issue that needs further analysis is whether the rainfall in these expected El Niño years cooperated and made the decisions easier for all concerned.

The Corps: Stuck in the Middle

Compared to the Fish and Wildlife Service, the record contains strikingly far fewer letters of correspondence. This is at least partly explained by the missions of the agencies, which will be reviewed again below. It is also obvious that the Corps was in a tight spot, at least in part because of engineering decisions made decades ago—and also because of politicians tend to respond most to the concerns of human populations, rather than wildlife—especially when the matter seemed one of protecting life and property.

In reviewing the agency, legislative and political history of the Everglades as part of the analysis of the last 40 years of Everglades restoration lead Rizzardi (2000) to have some sympathy with the Corps.

Initially, the Corps was involved in creating and maintaining the interstate navigation ways of the United States. But that role had changed over the years, as water quality issues regarding the navigable rivers and harbours led to new missions of environmental quality as early as the 19th century. The Corps was also called up to help address what was considered South Florida's public safety threat due to flooding—the initial chief mission of the Central and South Florida project.

Regulations and even often statutes govern each of these missions. These include the Flood Control Act. So the Corps has a whole host of laws, regulations, rules, program statements, and regional procedures to follow—it has a number of responsibilities, obligations, and duties, very often to beneficiaries—direct or indirect—with very different needs. The most politically explosive of these, at least potentially, is the Corps' mission to provide flood protection to human populations and their property.

With the responsibility under these statutes comes legal liability—liability that only raises the stakes for the Corps' decision-making. This perhaps explains, at least in part, the Corps' hesitance to act in accord with the Service's recommendations.

When these concerns over public safety are coupled with the water management decisions that could 'take' one (or more) endangered species while attempting to protect another, it can almost look impossible.

Hence, Rizzardi argued, while it is easy for critics to say that the Corps was not abiding by the Endangered Species Act by not implementing reasonable and prudent alternatives from the U.S. Fish and Wildlife Service. The Corps had a defence—it could not cause flooding or the likely flooding of people's property when that was explicitly against the mission of the Corps and the Flood Control Act—the statutes it was obligated to follow (Rizzardi 2000).

Part III: CERP

Introduction

The politics of the Everglades reveal themselves more than ever in the development of, and debate over, the Comprehensive Everglades Restoration Plan (CERP).

The water wars of the 1990's demonstrate the challenges and the problems facing the relevant regulatory agencies. CERP was originally environed as an attempt to rectify the Everglades' ecosystem, while meeting the needs of an expanding human population in south Florida, continuing to provide for agricultural, and protecting the public from flooding.

While Mod Waters was deemed helpful (assuming its construction and implementation would occur), but insufficient without improvements to or at least changes to existing flood flows and plans and flood infrastructure. The western populations simply would not benefit from Mod Waters as it had been currently authorised. This, of course, anticipates issues with CERP.

One observation from the outset of this discussion is that legislation and project proposals generally mentioned restoration of the South Florida ecosystem rather than of Everglades National Park. This could envision other public lands such as Big Cypress National Preserve and state and local parks. Its broader 'South Florida ecosystem' could include the human element of the ecosystem as well, including agricultural needs and human public health and safety.

Additionally, much of the criticism that CERP has received from some commentators, especially in the environmental community, is that Everglades National Park itself does not as much water when and where many believe necessary. Perhaps most people associate the Park (and Big Cypress) with the Everglades and would naturally expect most of the conservation and restoration benefits to have fallen to it, rather than the broader South Florida ecosystem, but broader language was authorised.

The Restudy Authorisation Process

As noted earlier, CERP and the authorisations leading up to CERP were not the first time Congress had engaged the Everglades—the Experimental Deliveries program and most significantly the Everglades Expansion Act demonstrates this. About a year later, the 1990 WRDA authorised a feasibility study on altering the Kissimmee River, the first major legislative step that moves a project toward authorisation. After authorsation, the project could then receive appropriations.

The 1992 WRDA proved even more significant [Pub. L. No. 102-580, 106 Stat. 4797 (1992)]. First, it authorised construction of the Kissimmee River Ecosystem Restoration project (Ibid § 101(8)]. As stated in a law journal by two House legislative counsels and policy professionals, who played a significant role in the authorisation process, the authorisation is the first "major Corps project whose sole purpose is to improve the environment through ecosystem restoration" (Grumbles and Kopocis at 10382). The authors go onto to describe the project and its historical significance for the Corps and water infrastructure policy.

> The Kissimmee River restoration project, authorized in WRDA 92 § 101(8), significantly modifies the existing Kissimmee River project by removing certain features in the interest of improving the environment. Combined with the existing Kissimmee River headwaters revitalization project, WRDA 92's provisions represent a commitment of nearly $520 million from federal and state sources to improve the ecosystem of the Kissimmee River.
>
> The Kissimmee River's restoration will undo the channelization that occurred in the 1960s. The existing project, coupled with basin development and upland drainage practices, reduced wetlands habitat and degraded water quality. The result has been significantly reduced populations of fish and wildlife species and a decline in wetlands acreage from 35,000 acres to 14,000 acres.31 The proposed project will fill in about 29 miles of the current river channel, allowing the river to resume its meandering course south to Lake Okeechobee. Other structural changes to the existing project will allow the river to reclaim its former course.
>
> This project may be the best example yet of the new, greener Corps and how its engineering skills can be put to use to improve the environment. Of course, the restoration would not be necessary if the original, environmentally detrimental project had not been constructed, but the project is there, and the restoration of the area must be viewed under current circumstances with an operational project. The fact that the Corps would ever commit to study, recommend, and construct a project of this magnitude, which has only environmental benefits, is a major new direction and accomplishment of a greener Corps." (Grumbles and Kopocis 1993)

In addition to authorising construction of the Kissimmee River Ecosystem Restoration project, it began the process of more ecosystem-wide restoration. Specifically it authorised the Corps to 'review' the Central and South Florida project

> …with a view to determining whether modifications to the existing project are advisable at the present time due to significantly changed physical, biological, demographic, or economic conditions, with particular reference to modifying the project or its operation for improving the quality of the environment, improving protection of the aquifer, and improving the integrity, capability, and conservation of urban water supplies affected by the project or its operation. (106 Stat. at 4802.)

The 1996 WRDA went even further [Pub. L. No. 104-303, 110 Stat. 3658 (1996)]. It authorised the "Restudy," requiring the Corps to issue a final report by July 1, 1999 on a

> "proposed comprehensive plan for the purpose of restoring, preserving, and protecting the South Florida ecosystem. The comprehensive plan shall provide for the protection of water quality in, and the reduction of the loss of fresh water from, the Everglades. The comprehensive plan shall include such features as are necessary to provide for the water-related needs of the region, including flood control, the enhancement of water supplies, and other objectives served by the Central and Southern Florida Project. (PL 104-303, Section 528).

It also established the South Florida Ecosystem Restoration Task Force, comprised of cabinet secretaries and representatives from the South Florida Water Management District, the Miccosukkee Tribe, and the State of Florida (Id. at Section 528 (f)). In establishing the Task Force, congress clearly recognised that in order to create the largest ecosystem restoration project the world had ever known, it needed consensus and input from local interests. That is what happened over the next few years leading up to the final Chief's Report and the authorisation of CERP.

The WRDA 1996 Restudy authorisation began the lengthy technical, hydrological, ecological and engineering work that led to the Chief's Report, the ultimate stage.

CERP Development

In the run up to the incumbent-less 2000 presidential campaign, Everglades Restoration was huge political issue. Florida had emerged as a critical state after Bill Clinton became the first Democratic candidate to carry Florida since Jimmy Carter in 1976. Indeed only Florida and Arizona switched to President Clinton during his re-election bid—both sunbelt states. It was obvious that Florida would be critical in 2000.

Given the importance of environmental protection to many Florida voters, both parties saw 'saving' the Park while ensuring water supply for domestic use and agriculture and flood control as important. CERP attempted to be all things to all people—and to some wildlife and the natural ecosystem too. The CERP process particularly articulated benefits to direct human public health, safety and economic needs.

In brief, CERP was a massive collection of projects, covering 16 counties and over an 18,000-square-mile area ("CERP: The Plan in Depth - Part 1." CERP: The Plan in Depth - Part 1. N.p., N.d. Web. 28 Mar. 2013). It was estimated to take roughly 30 years to complete the 60 project elements. Initially cost-estimated at $7.8 billion, the cost estimates have increased dramatically over the year. An October 2009 estimate indicates CERP will cost $13.5 billion ["CERP Report to the Public2009-2010 UpdatePage 3 - From Concept to Completion: CERP Project Development." CERP 2009-2010 Report to the Public. N.p., n.d. Web. 01 Apr. 2013].

Together, the multiple components of CERP would move and store water from the north and redirect it into different storage areas, to be redirected to target areas. Some of this would flow to key areas of the Everglades National Parks—most would flow to water needs for human consumption and agriculture.

While some channelization and infrastructure would be removed (eventually) or at least mitigated, very much more new infrastructure would also be built, including underground storage areas. In short, the vision of the restoration of natural sheet flow was hardly realised here. Given the stated diverse goals of CERP—and the number of interests needed to be pleased—it would be very difficult to achieve that without losing the political support needed to make the project happen.

CERP Concerns and Criticism

These concerns were crystallised when a distinguished group of biologists sent a letter to Secretary of the Interior Bruce Babbitt on January 28, 1999 stating that there were “serious failings in the plans being considered…deep systemic problems, one unlikely to be overcome by tinkering with the existing alternative.” [Letter from Stuart Pimm, et al., to Secretary of the Interior Bruce Babbitt, (January 28, 1999)]

My letter was co-signed by Paul Ehrlich, Gary Meefe, E.O. Wilson, Gordon Orians, Peter Raven, and E.O. Wilson. It specifically asked for additional scientific review, including peer review, preferably by the National Research Council (id.). The letter criticised the plan for its various wet-dry weeks differences in certain areas of the Everglades as not being ‘natural’ despite the model name. It mentioned the requests of the staff of Everglades National Park for reduced water infrastructure and water management and for increased uses of natural water storage through wild marshes.

Finally, it expressed concern that the new and expensive technologies envisioned for implementing CERP may not work for restoration, particularly the use of Aquifer Storage and Recovery (ASR), one of the principle approaches planned for the massive water move and storage.

ASR envisioned using wells to store and then pump over a billion gallons of water into the aquifer beneath Florida’s surface—water that could eventually be ‘recovered’ and reused. The scientists were worried about the untested nature of this technology—especially since so much of CERP was dependent on its successful operation, as well as water quality issues that could come from the mixing of fresh and brackish water.

It was our notion that the problems were so deep that the plan could not simply be 'tinkered' that undoubtedly caused the public relations uproar. The letter started a media—and agency—storm. *The New York Times* placed the controversy on its front page with this ominous-sounding headline: Everglades Restoration Plan Does Too Little, Experts Say [Stevens, William K. "Everglades Restoration Plan Does Too Little, Experts Say." The New York Times. The New York Times, (22 Feb. 1999) (Web. 29 Mar. 2013)].

Pressure was put on the many environmental groups in support of the Restudy. A coalition of groups put their support of the plan in writing, sending a letter to Secretary Babbitt backing up the existing scientific basis for the currently-proposed Restudy. It also expressed their "united position that delaying the conceptual restudy until completion of a comprehensive peer review process is unnecessary and would seriously jeopardize the restoration of the Everglades by the significant delay such review would require." (February 12, 1999 letter). It concluded asking Secretary Babbitt to "stay the course." Having been engaged for, in some cases, decades in building a political consensus for the Everglades, these groups did not want to lose the alliances they helped put together.

(In contrast to the majority of the environmental groups, Sierra Club agreed with the concerns we expressed. There is considerable e-mail correspondence on the likelihood that some environmental leaders were hopeful of positions in a Gore administration and did not want to rock the boat. I have chosen not to expand on this subject here.)

Within days of the letter from the scientists, Secretary Babbitt invited the signers of the January 28, 1999 letter to meet with him and his team, including Assistant Secretary of the Interior for Water and Science, Patricia Beneke. (February 3, 1999 Letter of Bruce Babbitt to Stuart Pimm, et al). The invitation letter indicated that representatives of the Corps would also be there (Id.). Indeed, the day before the Babbitt letter was sent, the Corps sent a letter to the same scientists defending the Restudy. It contained several pages addressing or attempting to address some of the concerns laid out in the letter. For example, the Corps indicated that hydrologic model it used for its plan had been peer reviewed by Dr. Daniel P. Loucks of Cornell University.

The meeting between the scientists and the Interior Secretary was positive and constructive, according to both sides. As I had hoped, it resulted in the announcement of a scientific review panel to advise federal agencies on implementation of CERP. Indeed, the scientists themselves, who had initiated the criticism were to be involved in this approach.

In a press release following the meeting, both sides praised the development. Secretary Babbitt declared himself "deeply gratified that this distinguished group of scientists will be helping us," and "Dr. Pimm" stating that he and his colleagues were "absolutely delighted" that their request for "an on-going, independent group of advisors" was being met (February 21, 1999 Press Release from the Department of

the Interior). As if to quell the uproar from the front page New York Times story, the by-line in the press release left no doubts reading: “Leading Scientists Endorse Approach.”

Ultimately, the final bill authorising CERP contained the following language establishing the review panel.

> Section 601(j) of the Water Resources Development Act of 2000 (Public Law 106-541) requires the establishment of an independent scientific review panel to review the Plan's progress toward achieving the natural system restoration goals of the Plan. Specifically, the law requires:
>
> "(j) Independent Scientific Review. -
>
> (1) IN GENERAL. - The Secretary, the Secretary of the Interior, and the Governor, in consultation with the South Florida Ecosystem Restoration Task Force, shall establish an independent scientific review panel convened by a body, such as the National Academy of Sciences, to review the Plan's progress toward achieving the natural system restoration goals of the Plan.
>
> (2) REPORT. - The panel described in paragraph (1) shall produce a biennial report to Congress, the Secretary, the Secretary of the Interior, and the Governor that includes an assessment of ecological indicators and other measures of progress in restoring the ecology of the natural system, based on the Plan."
>
> On June 14, 2004 an agreement was signed among the Department of the Army, the Department of the Interior, and the State of Florida to provide an independent scientific review panel for the Comprehensive Everglades Restoration Plan (CERP). The review will be accomplished by the National Academy of Sciences (NAS) and will produce biennial reports on the progress of CERP to Congress.
>
> NAS will convene an Independent Science Review Panel composed of a diverse team of internationally recognised experts in restoration science. The panel will produce biennial reports to Congress, which will include an assessment of ecological indicators and other measures of progress in restoration of the Everglades.

I contend that this review process has provided more than a decade’s worth of sound science and feedback to the restoration process.

Final Enactment

In April 1999, after public comment and other agencies had reviewed it, the Plan was finalised, officially signed and dated by the Corps’ Chief of Engineers as the “Chief’s Report” on June 22, 1999. After the plan was submitted to the White House on July 1, the lengthy process of enactment began—a political process in which the congressional process of hearings and ‘mark-ups’ saw politicians discussing and

even debating the Plan. (For more detailed analysis of the political process leading up to enactment see Grunwald, Chapters 16, 17, 18).

Ultimately, enactment of CERP survived the passing legendary advocate Marjory Stoneman Douglas, who died in 1998. It survived the death of John Chafee, the moderate Republican—and CERP supporting—Chairman of the Senate Committee on Environment and Public Works, who died in 1999. (I had testified to a committee he chaired, shortly before he died and greatly admired his grasp of environmental issues.) It survived the new conservative Chairman of that Committee, Bob Smith, who came to be a major supporter of CERP, and a huge inter-chamber squabble on the eve of final passage of CERP about what kind of water projects belonged in WRDA—that final blow nearly killed CERP until last minute manoeuvring allowed final opposition to crumble.

Just days before the 2000 election, it was passed by both chambers, and on December 11, 2000, President Clinton signed CERP into law. CERP proved by no means to be the last Everglades controversy of competing needs. Indeed, it was to play a significant role in the most recent major Everglades fight—one that again featured the Cape Sable seaside-sparrow and its hapless habitat and conditions.

Part IV. Critical Habitat

Introduction

The most recent controversy over the Everglades and the Sparrow concerns the decision over the last several years to alter critical habitat for the species. (See Appendix B for chronology of the events related to this decision-making). Considerable litigation over the designation of critical habitat for the Sparrow has ensued as a result of these decisions (or lack thereof) over the years. A review of this history demonstrates the same pattern of controversy seen with many other elements in the history of the Everglades.

Background

Through the Endangered Species Act, Congress granted the Fish and Wildlife Service the authority to designate critical habitat for listed species {See ESA Section 4 (a) (3)}. Specific authority is also given to "as appropriate, revise such designation." {Id. at 4(a)(3)(B)}.

The Fish and Wildlife Service designated Critical Habitat for the sparrow in 1977. From the start, scientists believed that the initial designation was insufficient, at least in terms of the locations of the designation. Eventually, even the agencies seemed to concur with this.

The 1999 Multi-Species Recovery Plan (MSRP), which included the Sparrow and remains the recovery plan for that species, stated that the "[p]resently designated critical habitat does not adequately encompass the areas occupied by core populations," and that critical habitat "should, at a minimum, *include habitat west of*

Shark River Slough that supports one of the two core subpopulations." (my emphasis added.)

In the same year as the MSRP, the Biodiversity Legal Foundation submitted a petition to revise the critical habitat designation and, in July 2000, in a response, the Fish and Wildlife Service issued a 90-day finding that revision may be warranted. This launched a series of lawsuits aimed at prodding the Service to act on its petition, and finally, in November 2003, the Service notified the court that a proposed rule to revise Critical Habitat would be submitted to the Federal Register by October 2006 and a final rule would be completed within 12 months of the publication of the proposed rule.

At first, the Service seemed to follow this appropriately. On October 31, 2006 the Service published its Proposed Rule (FR 63980) revising critical habitat for the sparrow to a total acreage is 156,342. It included 59,892 acres in Unit 1 (for sparrow subpopulation A on marl prairies) and 11,402 acres in Unit 2 (for sparrow subpopulation A on cordgrass marsh) and included land in Western Shark River Slough. (The original designations are in acres, so I have followed those units here. There are ~2.2 acres to a hectare.)

It relied on widely-accepted scientific literature and conclusions — essentially all the work presented in earlier chapters up to that time. That included the American Ornithologists' Union's 1999 review that "concluded that the best available means to reduce the risk of extension of the sparrow is to retain and recover sparrow subpopulation A." F.R. 63990.

In designating the habitat in Western Shark River Slough, the Proposed Rule referenced the sparrow population decline and, specifically, the "hydrological management."

> From 1993 to 1995 the sparrow population in this area declined precipitously from an estimated 2,608 individuals 1992 to 240 individuals in 1995. (Pimm et al. 2002, 70). This decline apparently resulted from hydrologic management within the area immediately upstream of the area, just north of ENP. During these years, sparrow habitat remain flooded for extended periods, sometimes deeply flooded. Since then, measures have been implemented by the US Army Corps of Engineers and South Florida Water Management District water managers to prevent further damage the sparrow subpopulation in the area resulting from excessive water levels and duration of inundation, but the subpopulation has not recovered. *Water management plans continue to have the potential to result in damage to sparrow habitat in these areas and special management of hydrologic conditions is necessary.*

This section is very important. It indicates that the Service not only identified the importance of the region historically and currently for the sparrow, but why the sparrow has declined there—habitat degradation due to water management plans. It even states that it is "necessary" to manage the hydrologic conditions. (Id.)

Scientists largely applauded this proposed revision, and the Service quickly began action. On November 13, 2006, the Corps and the Service agreed via a conference call that the proposed Sparrow Critical Habitat would *not* be adversely modified or destroyed by the proposed continuation of the IOP. This is *very* important both for the Sparrow's critical habitat and for Everglades' restoration. And it is particularly relevant given what was about to happen next.

Just one year later, on November 6, 2007, the Service—or really the Department of the Interior—reversed course. On that date, the Service published its final rule in the Federal Register revising its proposed critical habitat designation for the CSSS downward to a total of only 84,865.

Most importantly, it excluded all Sparrow habitat west of Shark River Slough from the designation. The final rule eliminated designations for subpopulation A—a loss of more than 70,000 acres from the Proposed Rule of October 2006. The Final Rule reduced the total area of designated critical habitat for the species by more than 60%.

The natural question here is, given the years of the Service's own support for such a designation, what happened?

My public response to the decision pointed to the scientific arguments for excluding subpopulation A, belongs elsewhere, but it included:

"The two critical ecological arguments are fabricated. That is, the conclusions that FWS draws from them are not supported by the scientific data presented. I use the term "fabricated" carefully. Were these conclusions presented by a university colleague, I would be honour-bound to report them to the university's committee on misconduct for further analysis.

Finally, FWS appear to have seriously violated Federal standards on reviewing. Two of the five reviewers have financial conflicts of interest.

In sum, the final CH ruling on the Cape Sable seaside-sparrow ignores substantial peer reviewed science, it fabricates two conclusions from data that do not support them, and employed a review process that I believe violates Federal standards. That the proposed and final rulings were so different raises disturbing questions about what happened in the year following to cause FWS to so dramatically changes its mind."

Litigation

In brief, the legal explanation for the shift is that the Secretary of the Interior was exercising his discretion under the Endangered Species Act to exclude areas from critical habitat designation that otherwise qualify to be critical habitat as long as the exclusion does not jeopardise the continued existence of the species in question. This is known as an ESA Section 4(b)(2) exclusion.

Section 4(b)(2) of the Endangered Species Act reads:

> The Secretary shall designate critical habitat, and make revisions thereto, under subsection (a)(3) of this section on the basis of the best scientific data available and after taking into consideration the economic impact, and any other relevant impact, of specifying any particular area as critical habitat. **The Secretary may exclude any area from critical habitat if he determines that the benefits of such exclusion outweigh the benefits of specifying such area as part of the critical habitat, unless he determines, based on the best scientific commercial data available at the failure to designate such area is critical habitat will result in the extinction of the species concerned.** (Emphasis added).

After such a major revision—especially since a significant conservation goal dating back more than 30 years had been seemingly achieved—litigation naturally ensued. In April 2010, the Center for Biological Diversity, (CBD) the organisation that had used the petition process to pressure the Interior Department to increase critical habitat for the Sparrow, filed a Motion for Summary Judgment in its favour, requesting the United States District Court for the District of Columbia remand the rule-making to the Service and direct it to revise its designation "lawful[ly]". (Plaintiff's Motion for Summary Judgment, 4.)

CBD's principle complaint was the Service's "disregarding three decades of scientific evidence, ignoring a long string of consistent findings by the agency as well as the agency's recent representatives to other courts, and flouting this Court's prior rulings, in its Final Rule the Service has excluded all of the Sparrow habitat west of Shark River Slough from the designation." (Plaintiff's Memorandum, 2 emphasis original). CBD then noted that though it had sought to increase the Sparrow's habitat designation through the ESA process, the final Rule actually "makes matters worse" as it reduced the Sparrow's "designated critical habitat by more than 60%" (id. emphasis original).

The brief attacks Interior's argument that despite the Service's "consistently-held opinion—until the Final Rule at issue here—that properly-designed and implemented Everglades restoration projects were a necessary part of protecting the Sparrow's western habitat and saving the species from extinction." It jabbed at the irony of the Service admitting that removing the critical habitat protection explicitly to allow CERP plans to destroy that habitat despite saying—repeatedly and for many years—that this particular habitat was essential for the species' survival.

In short, CBD argued, in undoing the proposed Critical Habitat revision, the Interior Department was allowing the destruction of the habitat west of Shark River Slough "under the auspices of Everglades restoration activities" (Id. 2-3). Such changes in position, it argued, were arbitrary and capricious and the kind that are prohibited by the Administrative Procedures Act, the main law governing the federal rule-making and regulatory process.

The Interior Department acknowledged at the outset that the Fish and Wildlife Service "is in a difficult position in this case: the agency is charged with implementing the ESA with respect to all species." (Interior's Brief, 3, emphasis original). It argued for the broad discretion of the Secretary of the Interior as provided by the ESA itself.

Specifically, Interior cited Section 4(b)(2) of the ESA exercising the Secretary's discretion to exclude areas from critical habitat designation that otherwise qualify as critical habitat as long as the exclusion does not jeopardise the continued existence of the species. Interior's brief is explicit stating that

> "it does not matter if an area considered for exclusion is occupied, unoccupied, or essential to the conservation of the species; indeed, by definition, any area that qualifies as critical habitat and is subject to exclusion under Section 4(b)(2) is 'essential to the conservation of the species' (cite omitted) So long as the Secretary determines that the benefits of exclusion outweigh the benefits of inclusion, the only limit on the secretary's discretion to exclude an area from critical habitat is if exclusion will result in extinction of the species. (Interior's brief at 16).

One issue that was not taken up in this litigation is to whom the benefits of exclusion run—to the species, or other species, to the broader ecosystem, to public health or safety, or to economics. An examination of this matter is outside the scope to of this Report, but further clarification from the agencies may be of some help. The statute's language is not clear on this matter, again erring on the side of giving broad discretion to the Secretary to exclude designation.

Interior further cited the House Committee Report, the official legislative history of the Endangered Species Act Amendments of 1978. In setting limits to critical habitat designation, the Secretary 'shall' consider "[e]conomics and any other relevant impact." H.R. Rep. No, 95-1625, at 16-17. The report goes further: "The Committee expects that in some situations, the resultant critical habitat will be different from that which would have been established using solely biological criteria. In some situations, no critical habitat would be specified." Id. At 17.

To support its contention that excluding the areas west of Shark River Slough would not lead to the Sparrow's extinction, Interior cited 'ample support' as stated in its Final Rule, namely that the Sparrow's range is on Federal and State lands managed for conservation purposes, 90% of which is Park Service land.

It further cited existing management plans, the protections of Section 7 consultations, the 'key oversight role' that the Interior Department will play in CERP, and that "the area excluded has supported less than four percent of the sparrow population over the past five years, and it is completely with the boundary of lands managed by NPS." (Id. At 34, citing 72 Fed. Reg. 62760-61).

I find this last justification ironic, given that it had deemed the area so important to allowing the population to grow and given the importance the area played historically. Most ironic is that the decline has occurred within Park boundaries all along—despite that fact, and the considerable resources spent studying and attempting to protect the Sparrow, the Sparrow has declined because of the hydrological changes to the broader Everglades ecosystem and that would have had far stronger protections if the critical habitat designation occurred in west Shark Slough.

The issue with this of course is that the for the greater part of forty years, water management decisions made by agencies outside of the Park have so greatly altered the hydrology and ecology of the Park that the Park scientists and staff were running out of options to prevent the species' extinction. The Park Science staff would argue that just because the Sparrow dwelled in Park managed-lands does not protect it given the water management and alterations—a fact argued for years by the Interior Department.

Interior cited precedent for courts granting the Secretary wide discretion over these decisions. It further argued that agencies change their positions frequently and that the APA is not designed to prevent such policy changes from being made. Indeed, one of the primary points of the public comment process is for the rule-making agency to receive and consider new information to better adjust and tailor its regulatory decision. In this case, Interior argued that in the judgment of the Secretary, all species, including the Sparrow, would ultimately benefit from Everglades restoration through CERP and that as long as the exclusion did not jeopardise the continued existence of the Sparrow, the Secretary's judgment should not be overturned.

In the end U.S. District Judge Rosemary M. Collyer, in part relying on the Administrative Record and the enormous discretion given the Secretary under the ESA itself ruled in favour of the Interior Secretary. She granted Summary Judgment for the defendant-agency and denied CBD's motion. Her 41 page Memorandum of Decision lays out the "very complexity of these issues [that] shows that more than one reasonable conclusion could be drawn; under such circumstances, the Secretary is entitled to exercise his discretion" (Opinion at 40).

The Interior Department, thus, won that legal battle, convincing federal district court judge successfully on the broad discretion given the Secretary of the Interior in the ESA under Section 4(b)(2).

Notice that Interior did not defend the science on which they had based their opinion. I find this tantamount to admission that my accusation of scientific misconduct — data "fabrication" (see above) is correct. Interestingly, the Fish and Wildlife Service are repeat offenders. Appendix C is Greenwald et al. (2012), where we showe that the Service consistently ignores scientific advice to achieve political expediency.

So what does this mean for the Everglades? A critical habitat designation in the Western Shark River Slough would have provided strong protections that would have ensured appropriate measures to maintain proper water levels would be maintained for the sparrow—and it would have done so in a way that no other law or policy had been successful at in more than twenty years. That opportunity appears lost for the time being.

Conclusion

As complex as the Everglades' natural ecosystem can be, equally Byzantine can be the various laws, policies, regulations, and missions of the most important federal agencies—to say nothing of the requirements of state and local governments and economic interests. When all of these collided the conflict that has been at the centre of south Florida's history since the 1940's emerges.

As federal budget battles loom over the coming years and decades, Everglades restoration may very well be harmed. Not that Florida will lose its political clout in federal elections for president and congress. But rather that many politicians that had once sought to demonstrate their support for Everglades restoration may be more willing to demonstrate their budget-cutting prowess instead.

Is there opportunity in this? Can conservationist actually see their goals met—perhaps even exceeded—by this opportunity? Can CERP be 'redeveloped' to emphasise less infrastructure-based techniques and allow more natural flow—perhaps even more of a return to millennia-old sheet flow?

If anything this case study demonstrates to planners and resource managers the peril of reengineering natural system—or at least the pretence of control. It shows how letting nature run its course—while often fraught with risk—can often lead to more manageable results than upsetting the natural system through engineering.

The most memorable quote I heard in the quarter century of working in the Everglades was from Stuart Appelbaum, Chief of Planning and Policy Division, Army Corps of Engineers, who told a colleague "we can keep the Everglades on life-support forever — we can make it just like Disney World."

Appendix A

Water Deliveries Timeline and Brief Discussion of Issues and Controversies Related to Everglades Restoration Efforts Since the 1970's

The following is a timeline of major decisions, authorisations, controversies and other events regarding water deliveries to Everglades National Park. It includes a few issues that are discussed in the second timeline regarding critical habitat designation decisions and controversies for the CSSS. This timeline primarily weaves the US FWS' process into the development, authorisation, construction, and implementation of these projects. It mostly describes how the overall projects have evolved since the mid-1990's to avoid jeopardising the continued existence of the CSSS. Note the separate timeline regarding decisions about critical habitat designation for the CSSS.

The primary sources of this information are biological opinions and other consultation documents of the Fish and Wildlife Service and Army Corps of Engineers public information documents, including this 2010 Everglades Report on Everglades Restoration to Congress. Secondary sources, including two law review articles and a National Research Council report also contributed to this information.

1947 On December 6, in a ceremony in Florida, President Harry Truman dedicates Everglades National Park.

1948 Congress authorises the Central and Southern Florida Project, For Flood Control Purposes (C&SF), as part of the Flood Control Act of 1948, P.L. 80-858, 62 Stat. 1171, 1175 (1948).

1968 The Flood Control Act of 1968, P.L. 90-483, Sec 203, 82 Stat. 731, 740-41 (1968) makes improvements to the C&SF as part of the South Dade Conveyance System. It increases flood control protection and provides water supply for agricultural land owners in southwestern Dade County.

1970 Congress authorises Minimum Water Deliveries Schedule (P.L. 91-28) requiring that the Corps and SFWMD use the C&SF to deliver a minimum of 315,000 acre feet of water to ENP as a fixed monthly allotment— many experts said that this monthly allocation was not enough.

1984 Experimental Water Deliveries Program (P.L. 98-181, Sec. 1302 of Supplemental Appropriations Act of 1984).

--authorised the Corps to deviate from the minimum delivery schedule for 2 years to conduct experimental program

--it allows for an improved schedule for water deliveries to ENP based on actual rainfall amounts over the southern EG watershed and improved distribution of these flows.

-N.B. the monthly schedule in the Minimum Deliveries Act was suspended for the duration of the Experimental Program

-- little ecological progress was made in the Park and in 2000 the Experimental Program was terminated when the Corps implemented a water management plan to protect the CSSS.

1989 The Everglades Expansion Act of 1989 (P.L. 101-229) is enacted. It included the acquisition and inclusion of much of Northeast Shark River Slough into Everglades National Park so that historic flows could be restored there. The Act also authorised Modified Water Deliveries (Mod Waters), which authorised alterations to Tamiami Trail, to allow for more natural sheet water flow.

1992 The Water Resources Development Act (WRDA) of 1992 authorises the Kissimmee River restoration project to 'dechannelize' major portions of the River to improve the ecosystem and broader environment. It also authorises the Corps to 'review' the C&SF project "with a view to determining whether modifications to the existing project are advisable at the present time due to significantly changed physical, biological, demographic, or economic conditions, with particular reference to modifying the project or its operation for improving the quality of the environment, improving protection of the aquifer, and improving the integrity, capability, and conservation of urban water supplies affected by the project or its operation."

1993-1995 Biological and hydrological studies show increasing threats to the CSSS (including a catastrophic population drop) and its habitat due to unnaturally high water levels west of Shark River Slough.

1995 October 27th, original FWS jeopardy opinion for CSSS finding that Test 7 of the Experimental Program is likely to jeopardise the continued existence of the CSSS. Beginning of major Everglades controversies between the FWS, ENP, and the Corps (as well as other stakeholders—e.g., South Florida Water Management District (SFWMD).

1996 The Water Resources Development Act (WRDA) authorszed the "Restudy" of the C&SF project, requiring the Corps to submit a report to Congress on restoring the Everglades (P.L. 104-303, Sec. 528(b)(1)(A)(i); 111 Stat. 3657,8 (1996)).

The C-111 Spreader Canal is also authorised to improve water flows to Florida Bay via Taylor Slough.

1997-1999 Many letters and meetings between FWS, ENP and the Corps related to the scientific findings of water levels in key habitat areas for the Cape Sable Seaside-Sparrow.

1999 FWS Bi-Op concluded that the Corps' C&SF project was jeopardising the continued existence of the Cape Sable seaside-sparrow (Bi-Op at 77). This Bi-Op essentially "kills" the Experimental Program. Between February 1999 and December 1999, numerous interagency meetings and conference calls were held between the Corps, Service, ENP, and SFWMD to discuss the implementation of the FWS's 1999 bi-op.

1999 December—Meetings are elevated to the White House Council on Environmental Quality (CEQ) to discuss and resolve key disagreements between agencies within the Department of the Interior and the Corps, resulting in the development of the Interim Structural and Operational Plan (ISOP).

2000 Corps implemented the ISOP emergency deviation. Comprehensive Everglades Restoration Plan (CERP) enacted into law.

Since January 2000 interim water delivery plans

2001 Corps implements ISOP 2001 emergency deviation.

2001 August, due to the conflict resolution process a collaborative agreement between the Corps, FWS, ENP, and District was reached on a new Alternative, the IOP.

2001 October Corps issues draft Supplemental EIS for IOP.

2001 December SFWMD withdrew its support for the IOP, citing flood control concerns. Other federal agencies continued to refine the IOP alternative to satisfy the SFWMD's concerns. They have discussions on the final recommended plan in February 2002.

2002 Amended Biological Opinion—On March 28, 2002, the FWS issued a final bi-op amending the February 1999 bi-op that found jeopardy for the CSSS. Specifically, this amended bi-op was on the IOP-Alt.7R, which "includes features that address each of the concerns that led the Service to conclude that the ISOP and draft IOP EIS alternatives would not likely meet the requirements of the February 19,1999 biological opinion RPA for the sparrow." (March 2002 bi-op at 32). "The IOP-Alt. 7R will provide for water deliveries that mimic more natural water flow conditions across the sparrow's nesting habitat. Therefore, the Service anticipates that these conditions will provide for the frequency of nesting opportunities and maintenance of nesting habitat necessary for the sparrow's long-term viability." (Id. At 34-35)

FWS also explicitly stated that this IOP Alt.7R must be "implemented in combination with all other RPA components contained in the February 19, 1999 biological opinion with the exception of component #6." (Id. At 35).

"Consequently, the Service hereby amends the February 19, 1999 biological opinion to include IOP-Alt.7R as a second RPA option in terms of water management requirements." (Id.)

2002 July 3, Corps signed a Record of Decision (RoD) for the IOP.

2002 June and July Interim Operational Plan (IOP) begins, providing a minimum breeding window for the western CSSS population. An additional interim management program—the Combined Structural and Operational Plan (CSOP) will replace the IOP.

2006 January 25, the Corps signed the ROD to raise the Tamiami Trail (US Highway 41), the principle component of the Mod Waters project.

2006 November 13, the Corps and the FWS agree via a conference call that proposed CSSS Critical Habitat (published the Federal Register at October 31, 2006; FR 63980) would not be adversely modified or destroyed by the proposed continuation of the IOP.

2006 November 17, FWS issues a bi-op on the continuation of IOP finding that "[t]he continued operation of the Op for 4 years is expected to remain consistent with the RPA in the Service's 1999 bi-op. Accordingly, we anticipate reduced water levels during sparrow nesting season to a level that will allow adult sparrow pairs to complete one or two successful clutches in most years. This level of nesting is sufficient to main Subpopulation A for the remains of IOP. Rainfall events are expected to continue to affect the hydrologic conditions within Subpopulation A during nesting season, but IOP protections are sufficient to minimize the detrimental effects of these rainfall events on sparrow reproduction over the period. IOP operations are also expected to maintain hydrologic conditions to support suitable sparrow habitat within portions of Subpopulation A that are sufficient to maintain the subpopulation. Large increases in the number of sparrows within Subpopulation A or large improvements in the condition of habitat in the area are not expected to occur under IOP. However the continued operation of IOP, designed to avoid jeopardy of the CSSS, is anticipated to sustain Subpopulation A, which is necessary for overall population health." (November 17, 2006 Bi-Op at 73).

2009 The Everglades Restoration Transition Plan, Phase One (ERTP 1) will replace the IOP when the ROD for the ERTP-1 is signed. The purpose

of ERTP-1 is to define operations for the constructed features of the Mod Waters and C-111 projects until those projects are fully completed and a Combined Operations Plan is implemented. The proposed ERTP-1 is a modification of the IOP and operations if the IOP structures ad impoundments in the C&SF Project under the 2002 IOP Alternative 7R plan, including operation flexibilities to improve or maintain hydrological conditions to benefit multiple listed species and other resource values in the project area. The ERTP1 is anticipated to provide water management flexibilities by emphasizing an east-to-west distribution of water, while maintaining the C&SF Project purposes (flood control and water supply). ERTP is intended to cover operations until full implementation of the Combined Operational Plan (COP), which is currently scheduled to be completed in 2013 when all the remaining Mod Waters and C-111 features are anticipated to be constructed. (November 2010 Bi-op at 13)

2010 November FWS issues its bi-op that "the action, as proposed, is not likely to jeopardise the continued existences of the CSSS…and is not likely to destroy or adversely modify CSSS…designated critical habitat." (November 2010 bi-op at 181).

Appendix B

Critical Habitat for the Cape Sable Seaside-Sparrow: Timeline of Major Federal Actions and Decisions

1967 The Cape Sable seaside-sparrow (CSSS) listed as "Threatened" under the Endangered Species Protection Act

1969 CSSS added to list protected by the ESCA of 1969

1973 CSSS added to the Endangered Species List under the ESA

1977 August 11 Critical Habitat (CH) designated for (42 F.R. 40685)

1977 September 22 Critical Habitat designation corrected (42 F.R. 47840) encompassing approximately 197,260 acres (79,828 hectares)

1983 April Recovery Plan released.

1995 March 2, Army Corps seeks to move forward with Test 7 of the Experimental Program. It asks FWS to rescind constraints established in a June 3 1994 BiOp on Test 7. The Corps concluded that Test 7 would have no effect on the CSSS.

1995 April 19, FWS respond to the Corps indicating that it could not concur with the Corps' determination of no adverse affects and FWS requested additional information about Test 7.

1995 June 22, After a meeting with representatives from the Corps, ENP, and the FWS, the FWS determined that the proposal was likely to adversely affect populations of the CSSS (as well as the wood stork) and adversely affect the CSSS' critical habitat. At this time, the FWS requested initiation of formal consultation under Section 7 of the ESA.

1995 October 27, FWS issues its bi-op for the CSSS finding "that Test 7 of the Experimental Program is likely to jeopardize the continued existence of the Cape Sable seaside-sparrow" (October 27 1995 Bi-op at 20). It also says that while Phase I of Test 7 is not likely to appreciably improve critical habitat conditions, Phase II should help reverse the degradation of the critical habitat for the CSSS—therefore, FWS believes the proposed action is not likely to adversely affect critical habitat for the CSSS. (Id.) The bi-op included reasonable and prudent alternatives to preclude jeopardy.

1999 Multi-Species Recovery Plan (MSRP) is issued and included the Sparrow; the MSRP remains the recovery plan for the Sparrow. It includes a statement that "[p]resently designated critical habitat does not adequately encompass the areas occupied by core population," and that critical habitat "should, at a minimum, include habitat west of Shark River Slough that supports one of the two core subpopulations." MSRP at 4-368.

1999 February 19 Biological Opinion is issued by FWS concluding that the Experimental Program is likely to jeopardise the continued existence of the CSSS and adversely modify its habitat. FWS also issues a RPA for precluding jeopardy.

1999 Biodiversity Legal Foundation submits petition to revise CH designation

2000 July 90-day finding that revision may be warranted (65 F.R. 42316)

2000 December 20, a lawsuit was filed in U.S. District Court for the District of Columbia alleging that the FWS had not complied with the ESA by failing to issue a 12 month finding as to how it planned to proceed with the petitioned revisions to CH and that the revisions was withheld or unreasonably delayed under the APA.

2001 October 12-month Finding that revision of CH may be warranted as a result of detailed new info about sparrow distribution and ecology that had been obtained since CH was originally designated. New areas would likely need to be added and some removed from CH designation.

2003 The Court ruled that that the FWS complied with the ESA by issuing the 12-Month Finding and was exercising reasonable discretion in postponing developing a postponed rule to revise CH. However it ordered the FWS to specify a date on which work would commence on a rule to revise CH for the CSSS and estimate how long it would take.

2003 November 23, FWS notified the court that a proposed rule to revise CH would be submitted to the Federal Register by October 24, 2006 and a final rule would be completed within 12 months of the publication of the proposed rule.

2006 October 31, FWS publishes its Proposed Rule on October 31, 2006; Federal Register 63980) revising Critical habitat for the CSSS. Total acreage is 156,342. It included 59,892 acres in Unit

1 (for sparrow subpopulation A marl prairies) and 11,402 acres in Unit 2 (for sparrow subpopulation A cordgrass marsh).

2006 November 13, the Corps and the FWS agree via a conference call that proposed CSSS Critical Habitat would not be adversely modified or destroyed by the proposed continuation of the IOP.

2007 November 6, FWS publishes its final rule in the Federal Register (FR 62736) revising its proposed CH designation for the CSSS downward to a total of only 84,865. It excluded all Sparrow habitat west of Shark River Slough from the designation. The final rule eliminates CH designations for subpopulation A—a loss of more than 70,000 acres from the Proposed Rule of October 2006. The Final Rule reduced the area of designated critical habitat for the species by more than 60%.

2010 Litigation over the revised, final critical habitat designation ensues. Federal district court upholds the FWS' Final Rule and critical habitat designation, citing broad discretion and the ESA's authority for excluding areas that otherwise may appropriately be designated as critical habitat (Endangered Species Act, section 4(b)(2) exclusion).

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