THE FOOD HABITS AND NESTING SUCCESS OF WOOD STORKS IN EVERGLADES NATIONAL PARK IN 1974

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THE FOOD HABITS AND NESTING SUCCESS OF WOOD STORKS IN EVERGLADES NATIONAL PARK 1974

JOHN C. OGDEN
Research Department
National Audubon Society
Tavernier, Florida

JAMES A. KUSHLAN
U.S. National Park Service
Everglades National Park
Homestead, Florida

JAMES T. TILMANT
U.S. National Park Service
Biscayne National Monument
Homestead, Florida

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ABSTRACT

The Wood Stork (*Mycteria americana*) is a wading bird adapted to fluctuating water levels such as those found in the Everglades of Everglades National Park. The population of Everglades Wood Storks declined through the 1960s and they did not nest successfully from 1967 through 1973. This paper describes a study conducted in 1974 on the factors affecting food supplies and successful nesting of Wood Storks in Everglades National Park. Since Wood Storks nested successfully in 1974, this study provided the first opportunity in 7 years to obtain information necessary for the preservation of the species in Everglades National Park. As a result of this initial study, we recommend areas of future research required for proper management of the Everglades ecosystem.

Wood Storks began nesting in late January 1974 and the 2,000 nesting storks successfully reared 1,900 young. Since 1974 was a dry year, it continued the recent but unnatural pattern of storks nesting successfully in dry years, which began after the institution of water control in 1962. An important result of this year's nesting was that the time of nesting correlated with the rate of drying in the Everglades, substantiating a previously derived relation. The 1974 results proved that sufficient food can still be produced in the highly altered southern Florida environment to permit successful nesting of the remnant population of Everglades Wood Storks, although with loss of habitat and artificial impoundment of water, storks were forced to fly 130 km from the colony to feed young late in the nesting season.

Preliminary information was obtained on the abundance of Wood Stork prey in the southern Everglades and estuarine areas of the park. The first substantial understanding of food habits of Everglades Wood Storks also was acquired through collection of food items from nestling and adult storks. The diet of storks was composed almost entirely of fish and only a few species made up most of the food consumed. Storks fed where food was relatively concentrated and selectively consumed the relatively larger fish of those available.

The rapid population decline and changes in Wood Stork nesting success of recent years coincided with the institution of water control. Analyzing these changes, as well as deriving the proper management to preserve the natural Everglades ecosystem are complicated by diversion of surface water to the western part of the southern Everglades rather than through the natural drainage basin.

Cover photo Wood Stork in Typical Feeding Posture *by* Frank Mazzotti

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THE FOOD HABITS AND NESTING SUCCESS OF WOOD STORKS IN EVERGLADES NATIONAL PARK IN 1974

INTRODUCTION

This paper is a report on a study of the ecology of the Wood Stork (*Mycteria americana*) in Everglades National Park, conducted from September 1973 to June 1974. The Wood Stork is an important link in the food chains of the Everglades and estuarine ecosystems of southern Florida. It is adapted to the fluctuating water conditions which typify southern Florida (Kahl 1964). Its nonvisual feeding behavior (Kahl and Peacock 1963) requires high prey density (Kahl 1964). The rapid decrease in population over the past decades suggests that it is the wading bird species most susceptible to adverse alteration of natural ecological conditions. Because of wading birds' ecological importance, historically large populations, and adaptations to fluctuating water marshlands, understanding the ecology of the Wood Stork and of other less sensitive species is necessary for the management and preservation of the natural Everglades ecosystem.

The breeding status of the Wood Stork in Everglades National Park was especially critical at the start of this study. The last previous successful nesting season was 1967, and during the 1960s and early 1970s the breeding population fell from approximately 5,000 to 2,000 birds. Thus, the successful 1974 nesting season provided the first opportunity in 7 years to gather information necessary for the preservation of this species in Everglades National Park.

The background of the current program was a report by Kushlan et al. (1975) which attempted to discern historic relationships between surface water changes, fish populations, and the nesting success of Wood Storks in Everglades National Park. The results showed that before the completion of the levee system north of the park in 1962, Wood Storks nested successfully in those years of high water levels, high surface water discharge, and high rates of drying late in the nesting season. Kushlan et al. (1975) concluded that after 1962 the above pattern of water fluctuation no longer permitted successful nesting in the present, highly altered system and recognized that future management must be devised within the constraints imposed by the altered system. Considering information after 1962, Kushlan et al. (1975) found that nesting failed primarily because of desertion, which correlated with rising water levels, either a small water level rise early in the nesting season or a large rise at the beginning of the rainy season. They also found that the latter type of desertion resulted from late nesting and that, after 1962, early nesting occurred with rapid drying rates early in the dry season. They noted that since nesting by Wood Storks would be initiated and sustained only through adequate food supplies, the key to nesting success must lie in the production and timely availability of fish, about which little was known. Kushlan et al. (1975) hypothesized that freshwater fish may move long distances as water levels fell, emigrating ahead of progressively drying conditions and thereby increasing population densities and availability to Wood Storks.

In the present study, we attempted to further investigate the findings and test hypotheses that reducing surface water discharge into the southern Everglades, known as Shark River Slough, would increase drying rates and bring about earlier nesting of Wood Storks. To accomplish this, it was proposed that gates in the two eastern spillways that release water into the park be closed in November and December and water be diverted through two western spillways. Discharge through the western spillways apparently has little effect on the slough since it drains mostly to the southwest (F. A. Nix pers. comm.).

STUDY AREA

Everglades National Park is located on the subtropical southern tip of Florida (Fig. 1). The central feature and primary watershed of the park are the freshwater marshes of the southern Everglades, known as Shark River Slough. A dominant factor within the Everglades ecosystem is a seasonal rainfall pattern and the resulting seasonal fluctuation of water levels. Water levels are high in summer and fall and drop through the winter and spring.

FIGURE 1. Map of southern Florida.

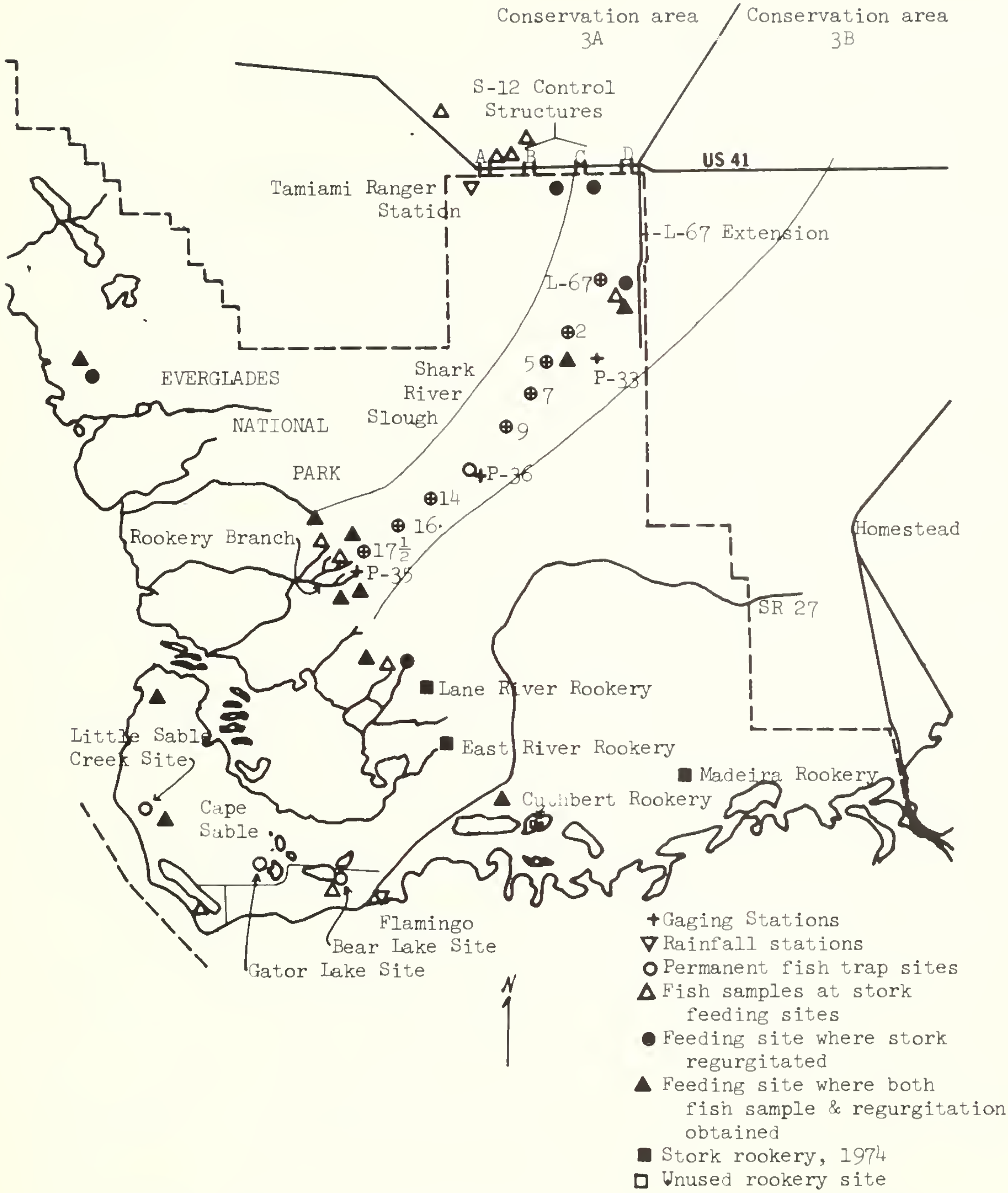


FIGURE 2. Location of fish samples and other sites in southern Florida.

The Everglades is composed primarily of sawgrass marsh and marsh prairie. Water from the Everglades flows into the estuaries where mangrove swamps and coastal flats are the predominant habitats. The natural Everglades extended from Lake Okeechobee to the mangrove swamps of the southwestern coast. In the early 1960s the northern Everglades was impounded by levees to form three Water Conservation Areas (Fig. 1) and surface water discharge into the southern Everglades became controlled. Water is presently discharged into the park through spillways (called the S-12 structures) on the northern park boundary (Fig. 2). Water from the two eastern structures is conducted into the Shark River Slough through the marsh and along a canal (L-67 Canal) on the eastern park boundary (Fig. 2).

METHODS

Hydrologic data were collected by the U.S. Geological Survey (USGS) and park personnel. Water levels were measured at reference station P-33 (Fig. 2) and at staff gage stations along a transect down Shark River Slough (Fig. 2). Discharge was measured periodically at S-12 water control structures along the northern park boundary and total discharge through all the structures was then calculated by the USGS. Drying rate is defined as the rate of water level change from the highest water level in one month to the lowest level 3 months later as measured at reference station P-33 (*see* Kushlan et al. 1975 for details).

Two long-term fish trap sites used by the USGS from 1965-72 were reestablished. Monthly fish samples were taken with two 4.6 m^2 pull-up traps from November until the site dried in May. Our procedures followed those of the previous study (Kushlan et al. 1975) except that nets were left submerged in the water rather than exposed to air during the period between samples, and sampling was done during the day rather than at night. The latter change was justified because statistical analyses of data collected by the USGS showed no significant differences were detectable in numbers, weights, or kinds of fish caught between day and night trapping.

Nine other fish-trapping stations were also established along a transect down Shark River Slough and sampled at monthly intervals (Fig. 2). All but one were located next to permanent staff gage stations. Monthly fish samples along this transect were taken with 1-m^2 drop-traps or 1-m^2 throw-traps, unless a station was dry. Fish sampling stations also were established at three sites on Cape Sable (Fig. 2).

Food of Wood Storks was determined by obtaining regurgitation samples from nestlings in colonies and from adults at feeding sites. Nestling storks regurgitate readily when handled. We found that when we used a helicopter to fly close to feeding adult storks, they would regurgitate food onto the ground before flying away. We then landed to collect the regurgitation and took several drop-trap or throw-trap samples of fish at the same place where regurgitation samples were obtained (Fig. 2). Thus we were able to compare the species and sizes of fish available to those taken by storks. The data collected at feeding sites were combined for analysis into three habitats: coastal, mangrove headwaters, and Everglades.

Fishes collected during the study were preserved and later identified, counted, and measured for total length and dry weight. Aerial surveys, conducted two to four times per month, were used to locate feeding storks, follow storks from colony sites to feeding grounds, observe nesting colonies, census nests, and monitor stage of nesting. More detailed observations on the development of young, number of young in nests, survival of nestlings, and daily activity of adults were obtained by ground visits to the rookeries.

In addition to other aspects of the Wood Stork study, a color-marking and banding program was begun to obtain information on movements of storks outside the park and to gain vital information on mortality of nestlings and young.

RESULTS AND DISCUSSION

Hydrologic Conditions

During the 1974 hydrobiological year, 1 June 1973 through 31 May 1974, rainfall was 15% below normal at the Everglades reference station but 30% above normal at the coastal reference station (locations in Fig. 2). Figure 3 indicates the above normal rainfall for the year on the coast was due primarily to high rainfall in August and December. December was also a month of above normal rainfall in the Everglades. Rainfall between January and May was well below normal at both locations, only 19% of normal in the Everglades, and only 39% of normal along the coast. Thus, despite periods of high rainfall, the 1974 hydrobiological year was characterized, overall, by below normal rainfall.

Monthly calculated water discharge through the control structures into the park fell below the minimum annually scheduled amount from October through January. These low discharges were caused by low rainfall, gate manipulation, and nonacceptance by the park of makeup discharge from the U.S. Corps of Engineers. The two easternmost control structures were kept closed for 25 days in November and December resulting in only 81% of the minimum schedule discharge during that period.

Reporting the total discharge through all S-12 structures, as is presently calculated by the USGS (and presented in Fig. 4), does not show differences among individual spillways. Such information is critical because flows through different structures could have different impacts on Shark River Slough. Total flow cannot be used to show all effects of gate manipulation, and data on discharge through individual structures were not available. In an attempt to estimate individual flows, semimonthly USGS measurements of flow through each structure were used to determine proportional discharge at each structure. We applied these proportions to the total daily discharge calculated by the USGS and thus obtained an estimate of discharge through each structure. This estimate is especially inaccurate for periods when more than one gate change occurred

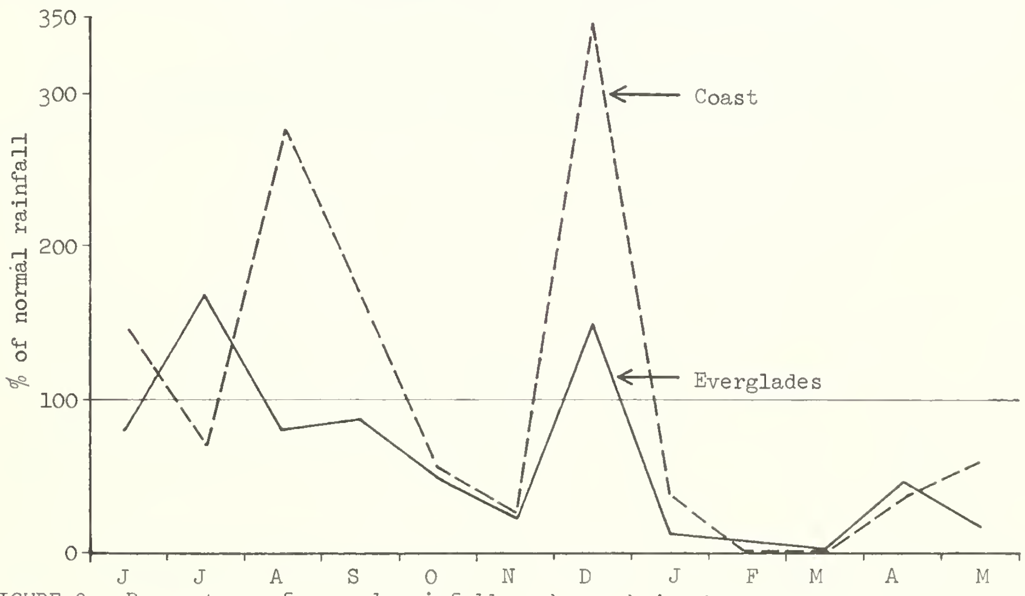


FIGURE 3. Percentage of normal rainfall each month in the Everglades and on the coast June 1973 to May 1974.

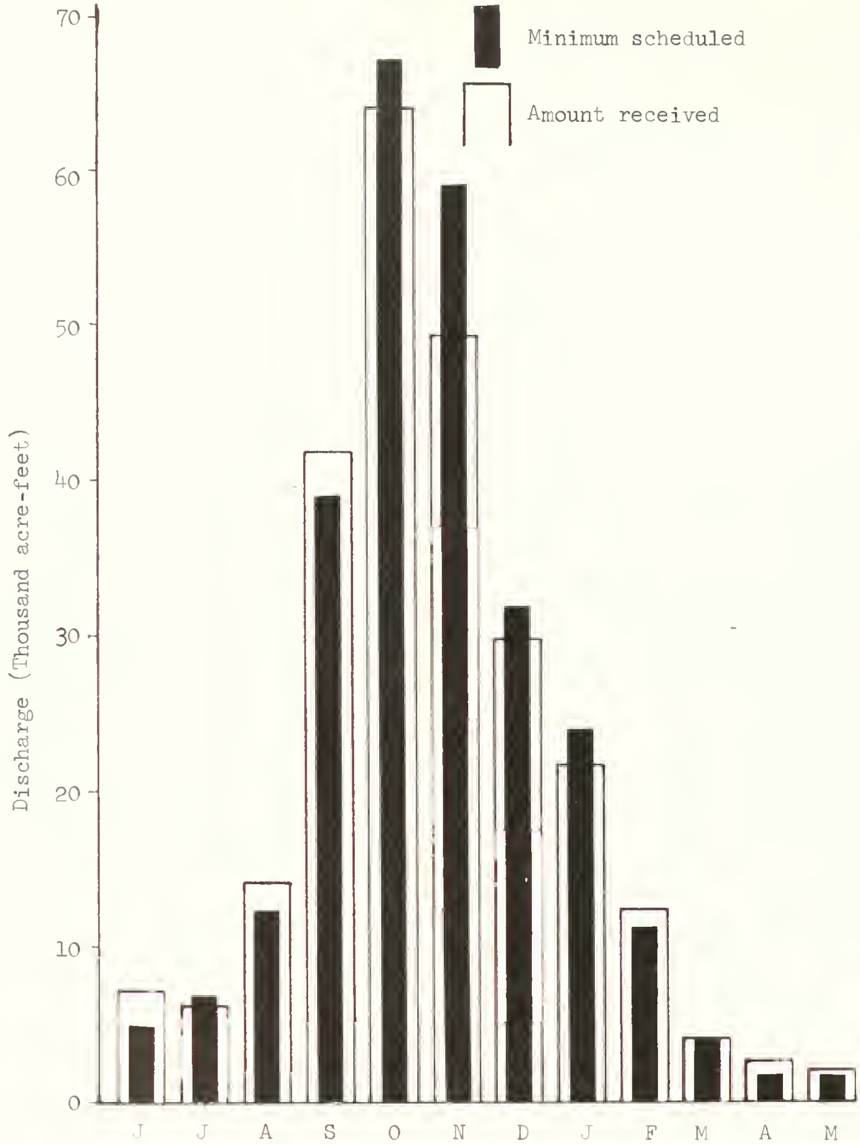


FIGURE 4. Total discharge through S-12 spillways in 1973-74.

between semimonthly measurements.

Our calculated discharge through each S-12 structure from October through December 1973 is shown in Fig. 5. During the November-December manipulation, flow through S-12C ceased while flows through S-12A and B increased. S-12D remained closed. Thus, the below-minimum discharge of November and December was released through structures A and B and presumably most of it did not enter the slough.

Water level fluctuations monitored at the Shark River Slough gaging station P-33 (Fig. 6) declined rapidly through November, rose in December, and fell at an increasing rate through spring. Water at P-33 reached ground level in April and fell to a low of 0.9 m (3.0 ft) above mean sea level (msl) in May. Water level remained below ground surface until mid-June.

No conclusion is possible as to whether the short period of gate manipulation had any effect on the early drying rate. As noted above, discharge from October through January was below schedule, particularly so in November because of the manipulation (Fig. 4). Rainfall was also below normal in October and November (Fig. 3) and during this period water level fell rapidly. However, the high December rainfall (Fig. 3) raised water levels which decreased the overall November-January drying rate. Therefore, in 1974 below schedule discharges were not in themselves enough to provide a very high drying rate. The early drying rate (November-January) at P-33 was

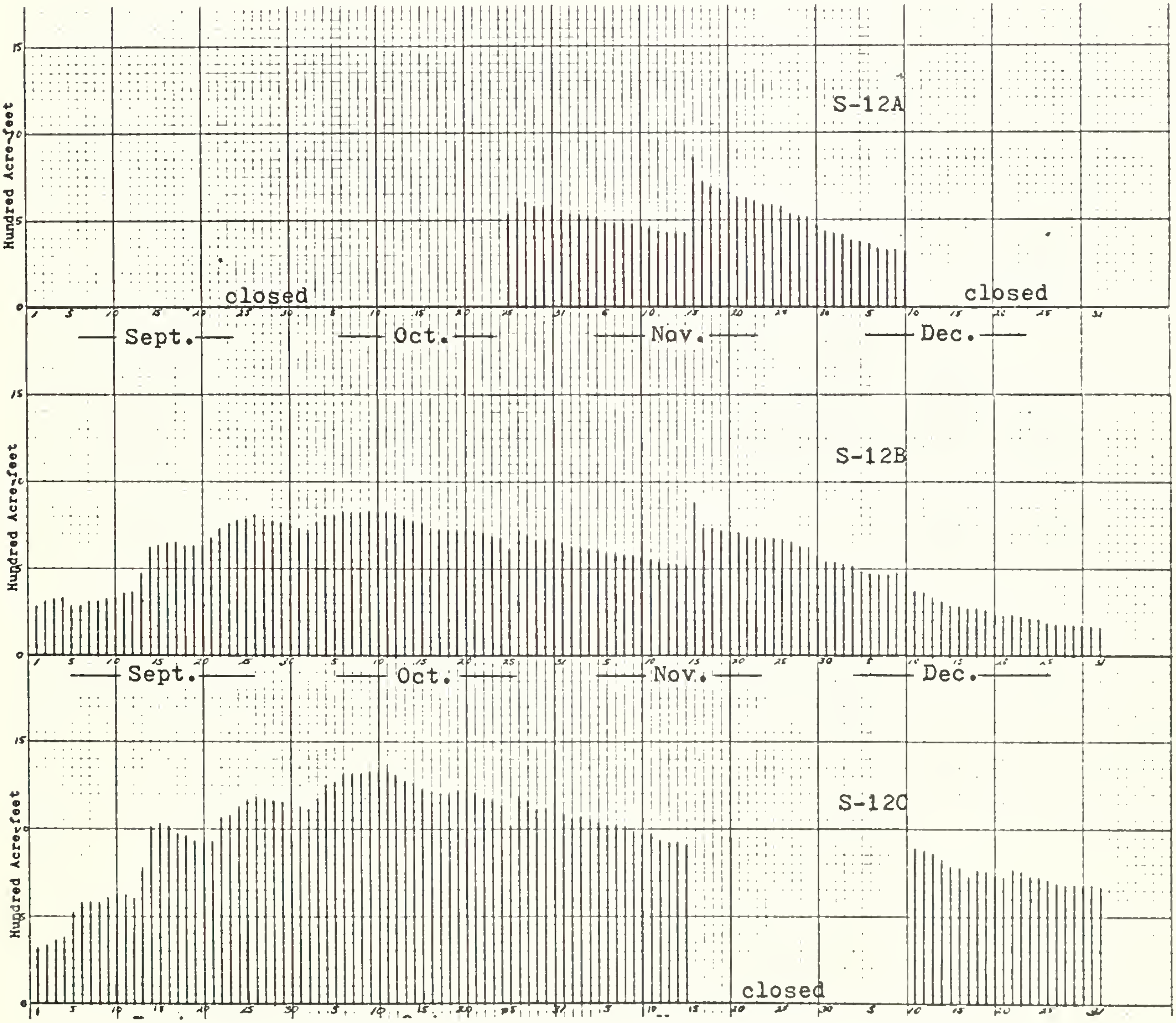


FIGURE 5. Discharges through each S-12 spillway from September through December 1973. (S-12D was closed with no discharge during this period.)

was 0.14 cm/day; the late drying rate (January-March) was similar at 0.15 cm/day.

Some information also was gathered on changes in water levels elsewhere in the slough. Figure 7 shows, to the best of current information, the general pattern of drying in the southern Everglades. In general, the slough first dried around its middle and then toward the northeast and southwest from this area. As the dry season progressed, these two tongues of water retracted until May when the remaining pools were northeast of Rookery Branch and southwest of the L-67 extension canal where water was continuously replenished through the spring by discharge through S-12D. This general pattern was derived from intermittent aerial surveys and is not precise in many details. More detailed information is required on the important questions of how the slough dried.

Two of the present study results are of interest in respect to the analyses and conclusions of Kushlan et al. (1975). First, drying rates observed are similar to those that, before 1962, were associated with failure of Wood Stork nesting. Successful stork nesting during the study year supports the conclusion that the Everglades system has changed in recent years. Second, the suggestion that early drying rate may be correlated with time of colony formation is strongly supported by the events of 1974. The regression derived by Kushlan et al. (1975) predicts that a drying rate of 0.14 cm/day would be associated with colony formation around 26 January, which is precisely what happened (*see* Nesting Success).

FIGURE 6. Water level changes at Everglades gaging station, P-33 from June 1973 through June 1974.

FIGURE 7. Pattern of surficial drying in Shark River Slough, 1973-74.

Movement Patterns and Feeding Areas

Most storks arrived in the park from northern summering areas between early November and early December 1973. Storks first concentrated on coastal feeding sites on the west coast and Cape Sable (Fig. 8). A maximum count of 1,568 birds on 4 December was nearly the exact count expected on aerial censuses based on estimated 1973 production and mortality. Based on nest counts, the 1974 breeding population was 2,000 storks (1,000 pairs).

Storks continued to feed in typical sites along the coast through December, with a gradual movement into mangrove headwaters. Storks in breeding condition were first observed in early December, but the unusually heavy rainfall and subsequent water level rise of that month were correlated with a dispersal of birds that apparently delayed rookery formation. Only 890 storks were counted on the early January survey and these were widely dispersed. By 24 January, storks had again concentrated at coastal feeding sites and two of the three rookeries were formed.

During February and March, high numbers of storks were feeding in lower Conservation Area 3A, with lesser numbers at feeding locations in mangrove headwaters and in Shark River Slough. Their preference for feeding in the Conservation Area rather than in the mangroves is not clear. At that time, we sampled higher densities of important prey species in drying creeks along mangrove fringes, particularly near Rookery Branch, than in Conservation Area 3A, and storks using the Conservation Area had to fly 50 km, many spending the night at the feeding area.

By early April, Conservation Area 3 was almost completely dry, and the major concentration of feeding storks shifted to the drying lower end of the Shark River Slough and adjacent mangrove fringes. A drying pool in Upper Shark River Slough was also used by feeding storks.

By May nearly all of the Shark River Slough and most of the mangrove areas had dried. Few feeding locations were apparently available in the park and storks made extremely long flights to feeding grounds well north of the park. Adult storks only returned to rookeries to feed young, remaining there an hour or less. Mid-May surveys located feeding storks in Conservation Area 2 (Fig. 1), 130 km north of the colonies, and lesser numbers on drying ponds and in mangrove swamps northeast of Everglades City, 75 km from the colonies.

Nesting Success

Three nesting colonies were established in the park in 1974 (Fig. 2). Lane River and East River rookeries formed between 15 and 24 January; Madeira Rookery formed during the first week of February. There were approximately 250 nests at Madeira (50 of which were deserted during incubation in late April), 150 at East River, and 600 at Lane River. A total of approximately 950 nests produced young. No storks nested on Cuthbert Island, an island often used by nesting storks in past years. East River Rookery has been much larger in past years. Storks and egrets, which park files show formerly nested at East River, are apparently shifting to the growing Lane River site, and it is possible that a similar shift has occurred in recent years from Cuthbert to Madeira.

Madeira was the most synchronized rookery, forming last and finishing by 27 May. Both East River and Lane River rookeries were relatively unsynchronized, with egg-laying at Lane River occurring over a 5-week period. It is not known why the synchrony differed in the colonies, but it may be the result of late-nesting birds merely being attracted to the largest colony. Fledging young remained in East River until the second week of June and in Lane River until the third week of June.

Counts early in the nesting season showed an average of 2.5 young per nest. Survival during the first month after hatching was not documented. Exact counts of older young that died prior to fledging showed that these losses were 0.25 young per nest at Madeira, 0.20 young per nest at East River, and 0.18 young per nest at Lane River. Overall, adults fledged about 2.0 young per nest, producing about 1,900 juveniles.

This production is a substantial recruitment to the previously decreasing population of Everglades Wood Storks. If nesting is considered at least marginally successful when production is sufficient to permit a stable population from one nesting season to the nest, 1974 was the first successful nesting in 7 years and only the third successful season since the institution of surface water control in 1962. A question of concern is the mortality of these young over the 6 months following fledging. If late nesting and a presumably lowered food availability during the last month of nesting resulted in the production of suboptimally nourished young, mortality could be severe. If normal mortality occurs, presently estimated to be 40% during the first year (Palmer 1962), aerial censuses of birds returning in the winter of 1974-75 should locate about 2,300 birds. A much lower return would suggest higher post-fledging mortality.

Three hundred nestlings were banded, tagged with red nasal saddles, and sprayed on the wing with yellow-gold picric acid dye. Five reports of marked birds were received later. The two most distant recoveries were one marked juvenile found dead in early June at Sebastian Inlet near Pelican Island National Wildlife Refuge in Brevard County, Florida, and one found alive on 1 July near Ft. Myers, Florida.

Everglades Wood Storks nested later in 1974 than any previous successful year and near the limit of having sufficient time to complete the nesting cycle. Nesting was completed successfully because of a late start of the wet season and an unusually slow rise in water level.

During most of the season, nestling storks appeared to grow normally and in many cases the usual brood of two to three birds survived until late in the nestling period. By 14 May, however, 7 nestlings 33-39 days old averaged 35% below the expected weight from Kahl's (1962) study, 20 nestlings 40-44 days old averaged 27% below expected weight, and 6 nestlings 45-47 days old averaged 20% below expected weight. It is believed nestling weights were subnormal late in the season because of lowered availability of food supplies as water levels began to rise.

The discovery that storks continued to forage and feed young despite slowly rising water levels in late May and June, and that they traveled over 130 km from the colony to find remaining pools of water is extremely important. A late start of the rainy season and the advanced stage of nesting in early summer made

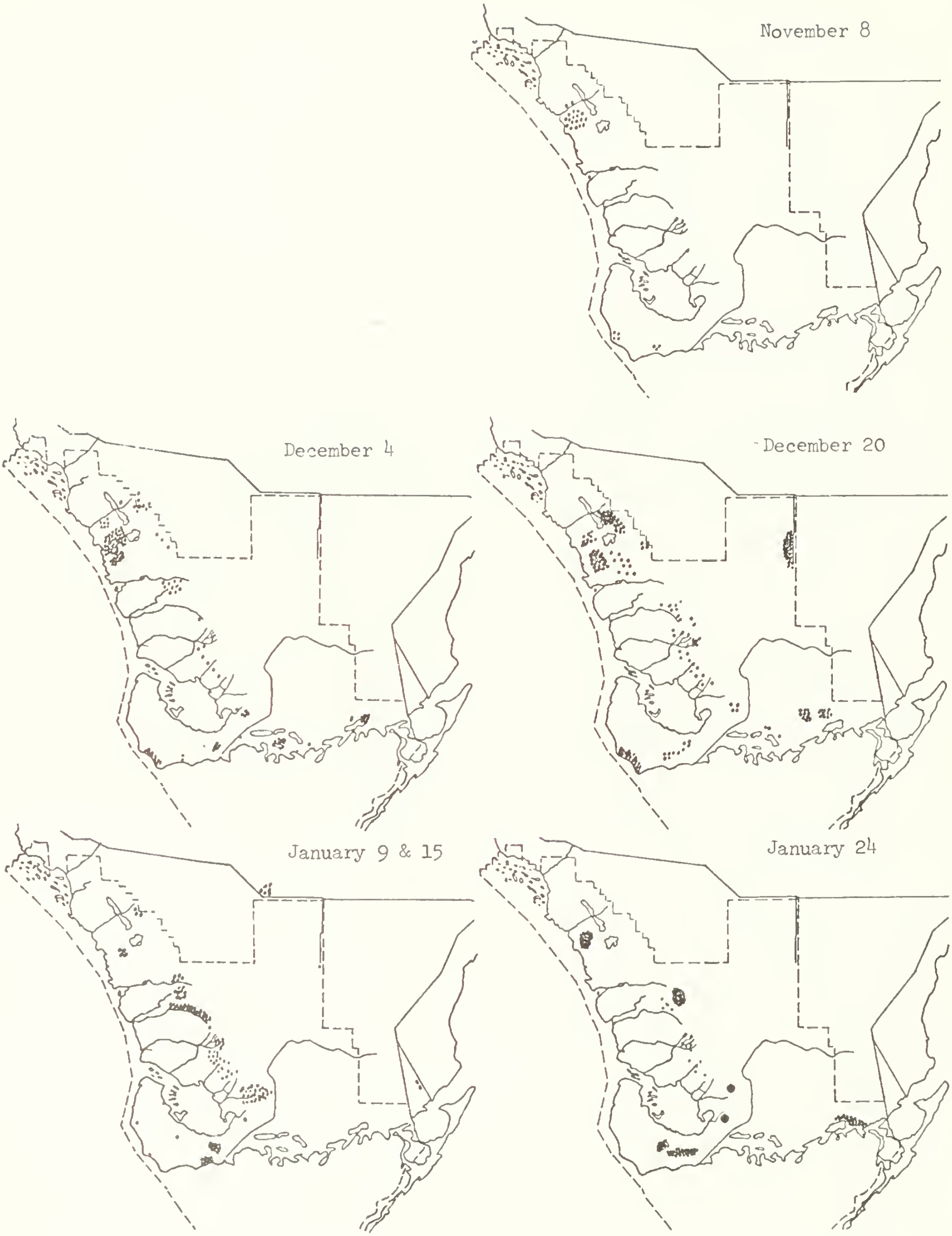
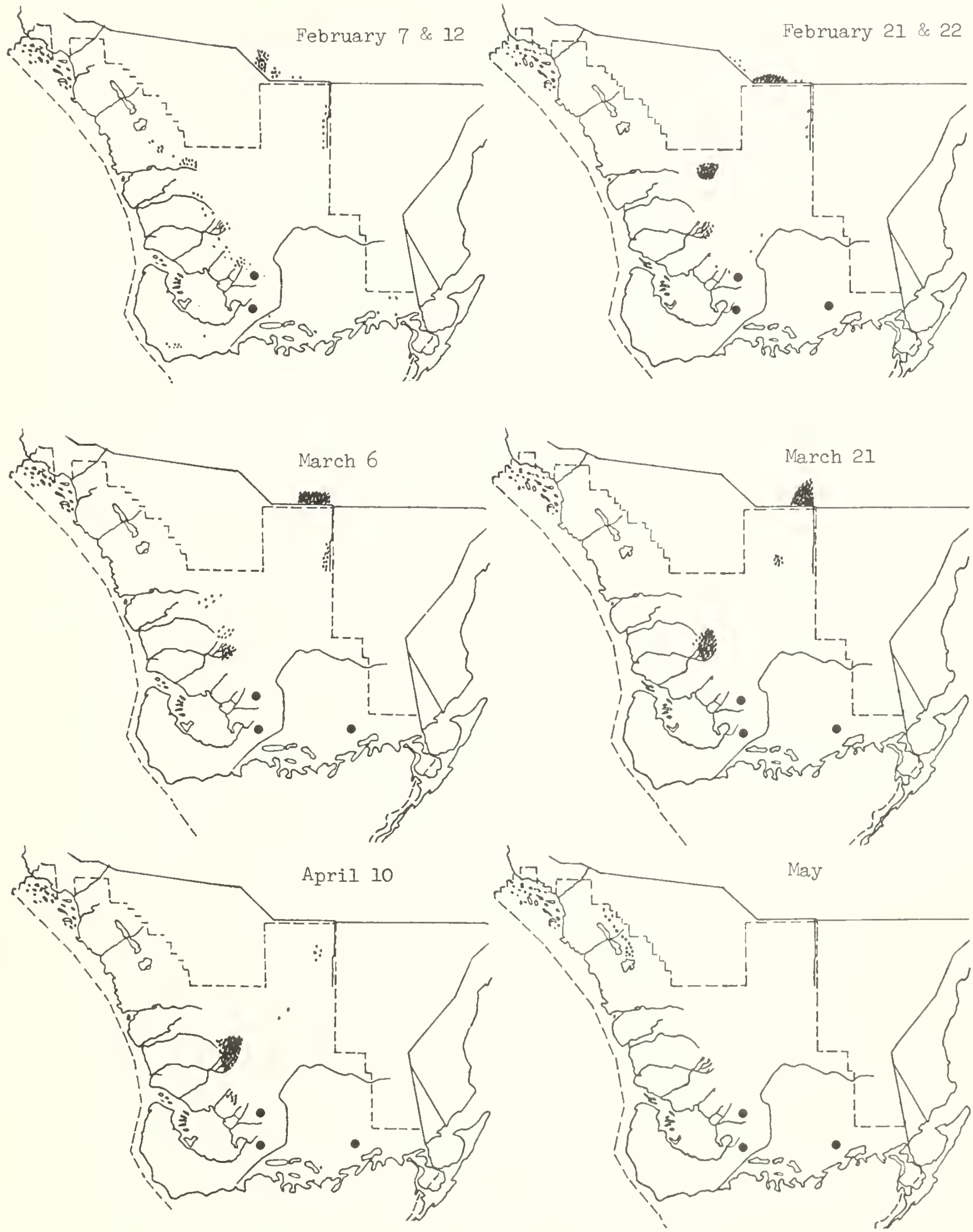


FIGURE 8. Feeding sites of Everglades Wood Storks in 1973-74. Each dot represents five storks.


February 7 & 12
February 21 & 22
March 6
March 21
April 10
May

continued nesting possible. The eventual success of nesting proves that sufficient food can still be produced in the highly altered south Florida environment to permit reproduction. Prior to this study, it was suspected that this might not be the case. Perhaps it is not so much the food supply that runs out at the end of the dry season, but time in which to locate it. It remains probable, however, that the overall fish production in the southern Florida ecosystem had declined in recent years due, at least, to loss of habitat. Before 1962, successful stork nesting occurred in high water years, suggesting that there was a greater total biomass of fish available then than now, assuming that similar fish densities were necessary for stork feeding under such high water conditions.

Fish Populations

Reestablishment of previous USGS monitoring stations provided an opportunity to compare fish densities in 1974 to those from the period of 1965-72. Figure 9 shows changes in fish populations in the Everglades as indexed by the two monitoring sites. Populations of fish and prawns were generally high in 1973-74. Maximum recorded fish density was higher than that of 1967, the last year when Wood Storks nested successfully.

Fish densities in other parts of the slough and on Cape Sable were measured monthly at the permanent drop-trap stations shown in Fig. 2. Two trappings per month at Cape Sable sites were too variable to statistically detect small changes in density. With a mean density of 16.8 fish/m^2, there were no significant differences in fish density at the three Cape Sable sites (analysis of variance, $P>0.05$). Similarly, no significant differences were discerned among trappings in Shark River Slough during November and December (analysis of variance, $P>0.05$). This indicates that within the resolution of the trapping technique fish were distributed homogeneously throughout the slough prior to January, except for station 17½ which had higher densities (studentized range test, $P<0.05$), probably because of its location on the edge of a stream. Excluding station 17½, the average density in the slough during this period was 6.9 fish/m^2.

Changes began to appear in the slough in January (Fig. 10). Average January fish density of 9.0 fish/m^2 in the upper slough was similar to previous densities. However, density in the lower slough had decreased significantly to 3.6 fish/m^2 (comparisons by t-test, $P<0.05$). This difference continued through February. No samples were taken in March. By April, the lower slough had dried, and densities at the two intermediate stations in the upper slough were higher than previous levels while the other two still-flooded stations were unchanged. The high mean values of 71.0 and 35.3 fish/m^2 for the intermediate stations could only have come about by movement of fish into these trap sites. All trap sites were dry in May.

The sampling program in the Shark River Slough detected increases in two stations late in the dry season, which reflect fish movement, but was not sufficiently sensitive to detect changes at lower fish density. This shortcoming and lack of sampling in March preclude any quantitative statement on fish movements in the slough. In addition, it should be noted that the pattern of drying in the slough (Fig. 7) suggests that fish movement is much more

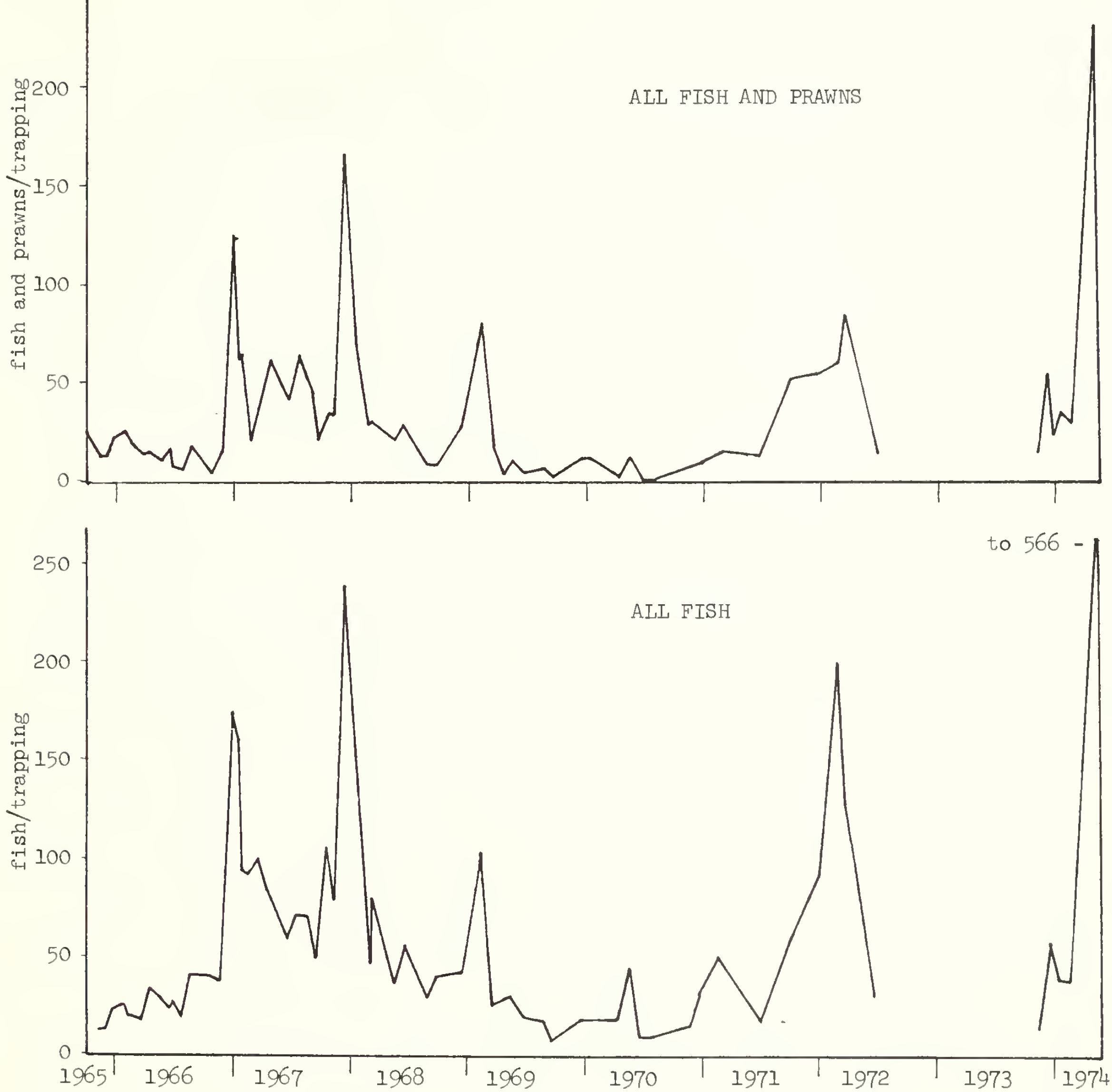


FIGURE 9. Long-term record of fish populations in Shark River Slough showing how conditions during the current study 1973-74 compared to previous years.

complex than would be shown adequately by a single transect. The program (which, because of few previous attempts at this sort of study, must be considered a preliminary one) did show that the methodology used can detect tenfold changes in density. However, detecting differences among the low densities of fish that prevail in the Everglades for most of the year will require the development of more sensitive sampling procedures.

Prey Density

There was a sharp contrast between fish densities at permanent sampling sites and at locations where storks actually fed. Both in the slough and on Cape Sable fish densities were higher at locations where

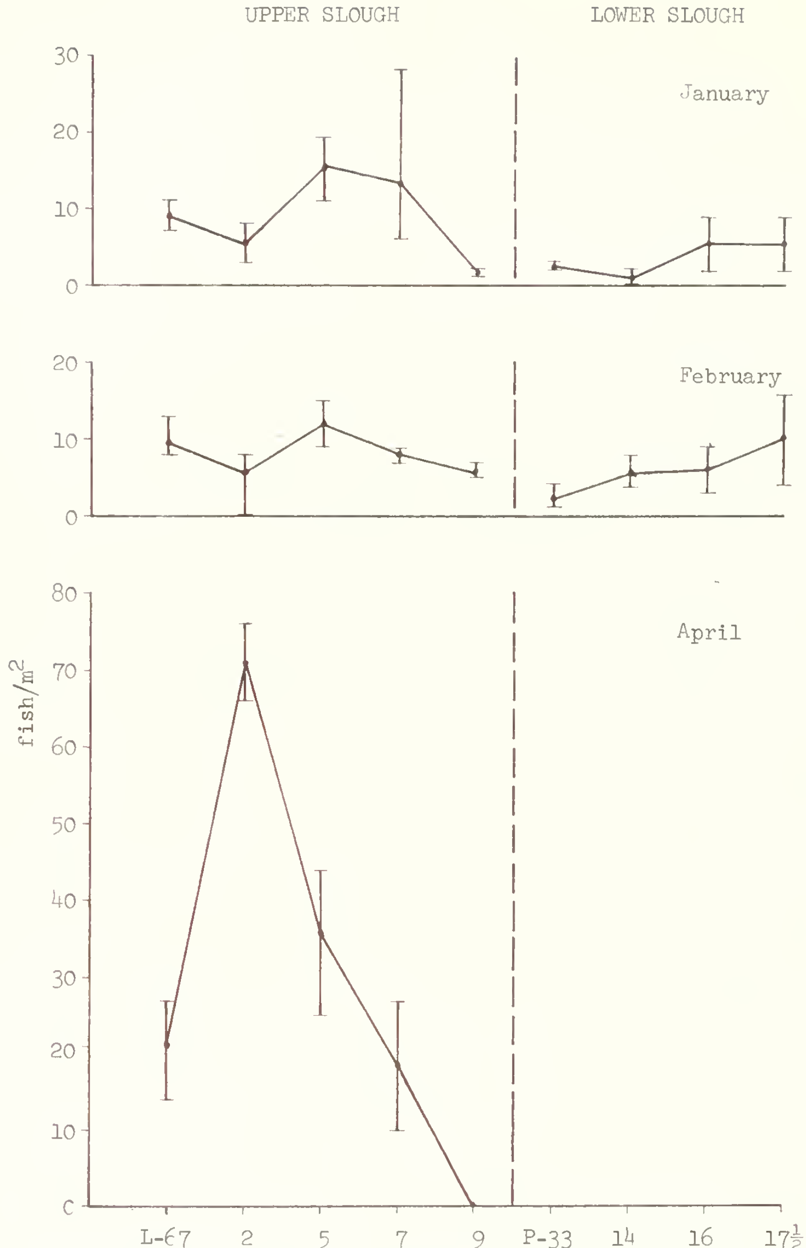


FIGURE 10. Fish density at stations on northeast to southeast transect down Shark River Slough (Fig. 2). Means are plotted. Ranges are indicated by vertical lines.

storks fed (t-tests, $P<0.05$). Along the coast, average density was 40 fish/m^2 as contrasted with 16.8 fish/m^2 at permanent trap sites. In the Everglades, average density at feeding sites was 141 fish/m^2 as contrasted with 10.3 fish/m^2 at the permanent sites. These data of fish density quantify and extend to the Everglades and coastal habitats Kahl's (1964) finding that storks in the Big Cypress Swamp feed on high densities of fish and, furthermore, show that storks foraged in locations where fish densities were relatively high.

A notable exception occurred in the northern Everglades. Fish densities at feeding sites in Conservation Area 3A were lower than in Everglades marshes within the park (means 12.2 vs. 144.5 fish/m^2).

Despite this, there was heavy use of Area 3A by storks. More information from the Conservation Area is essential, especially since storks attracted to this area in March were passing up high concentrations of fish closer to the colony. Although there were no significant differences in the mean fish densities among coastal, mangrove, and Everglades feeding sites (t-test, $P>0.05$), the trend of increasing mean density 48.8, 82.9, and 144.5 fish/m^2, respectively, suggests that storks fed on higher densities later in the season.

Food Studies

Little was known previously about food consumed by Wood Storks in southern Florida or elsewhere. Kahl (1963), who summarized all existing information on food of Wood Storks, reported on stomach contents of seven southern Florida storks that had been examined, including two he collected in the Big Cypress, one found dead in the Big Cypress, and four collected at Cape Sable Gator Lake in 1924. All seven contained only fish. Thus, other than four 50-year old specimens from Gator Lake, no data was available on food of Everglades Wood Storks. Previously, our understanding of foraging relationships of Everglades storks was extrapolated from Kahl's study. Samples of adult and nestling regurgitation and data on fish availability collected in this study provide important information on this previously little known aspect of stork ecology.

Table 1 lists the prey taken by Wood Storks in three foraging areas and food brought to nestlings at two colonies. (All scientific names of prey are also shown in the table.) Fish comprised practically all of the Wood Stork's diet in extreme southern Florida. Overall, 27 species of fish were consumed by Wood Storks. However, only a relatively few kinds of fish made up most of the total. Flagfish, sailfin mollies, marsh killifish, and the combined species of sunfish accounted for 83% of the individuals and 72% of the biomass. One additional species, the yellow bullhead which made up less than 2% of the individuals, comprised 12% of the biomass. Thus, these five groups of fish made up 85% of the number and 84% of the biomass of fish consumed by Wood Storks.

The only vertebrates other than fishes were one red-spotted newt, three tadpoles, and one adult frog. Seven freshwater prawns were found among the 3,000 food items analyzed. This is surprising in view of the extemely high densities attained by this minnow-sized crustacean, as can be seen by comparing the two graphs of Fig. 9, one of which includes the prawn. Even though densities of prawns at stork feeding sites reached 1,242 prawns/m^2, they were not taken in any quantity. It is highly probable that most of the prawns were ingested secondarily by storks because prawns are also eaten by fish, especially sunfish, and some of the specimens were found in the mouth of such fish disgorged by storks.

Collections of regurgitation from nestling storks were made at Lane River Rookery on 17-18 April and at Madeira Rookery on 24 April. Food brought to nestlings was similar to the two colony sites studied (Table 1), with two notable exceptions. Sailfin mollies were more important at Lane River. There was a significant difference in the size of food brought to young at the two rookeries (t-test, $P<0.05$). Fish from Madeira Rookery averaged 4.1 cm

TABLE 1. PREY CONSUMPTION BY WOOD STORKS

		Percentage of Prey Items						Percentage of Biomass					
		Coastal	Mangrove	Everglades	Madeira Rookery	Lane River Rookery	All Samples	Coastal	Mangrove	Everglades	Madeira Rookery	Lane River Rookery	All Samples
Fish													
Florida gar	*Lepisosteus platyrhincus*	0	0	0.4	0	0.4	0.2	0	0	9.2	0	3.2	2.8
Bowfin	*Amia calva*	0	0	0	0	0.1	<0.1	0	0	0	0	0.3	0.1
Chain pickerel	*Esox niger*	0	0	0	0	0.1	<0.1	0	0	0	0	0.3	0.1
Golden shiner	*Notemigonus crysoleucas*	0	0	0	0	0.3	<0.1	0	0	0	0	0.4	0.2
Taillight shiner	*Notropis maculatus*	0	0.4	0	<0.1	0.4	0.2	0	0.2	0	<0.1	<0.1	<0.1
Yellow bullhead	*Ictalurus netalis*	0	0	1.8	0.8	4.2	1.7	0	0	8.5	11.5	16.4	11.8
Tadpole madtom	*Noturus gyrinus*	0	0.4	0	0.3	0.3	0.2	0	0.2	0	0.2	0.1	0.1
Sheepshead minnow	*Cyprinodon variegatus*	18.1	6.7	2.0	0.5	0.7	4.1	18.2	4.8	1.0	0.2	<0.1	2.7
Golden topminnow	*Fundulus chrysotus*	0	0	1.5	1.7	1.8	1.3	0	0	1.6	1.8	0.4	0.8
Marsh killifish	*Fundulus confluentus*	7.5	28.0	25.1	18.4	17.4	18.0	8.9	31.7	22.0	14.9	5.2	10.7
Seminole killifish	*Fundulus seminolis*	2.7	1.8	0	0.3	0.1	0.7	15.2	22.6	0	0.8	0.4	3.1
Flagfish	*Jordanella floridae*	0	22.7	46.2	41.1	34.0	32.0	0	9.3	11.0	15.6	4.0	7.0
Bluefin killifish	*Lucania goodei*	0	0	0	0.3	0	0.1	0	0	0	<0.1	0	<0.1
Rainwater killifish	*Lucania parva*	0.2	4.4	0	0	0	0.3	<0.1	0.9	0	0	0	<0.1
Rivulus	*Rivulus marmoratus*	0.2	0	0	0	0	<0.1	0.1	0	0	0	0	<0.1
Mosquitofish	*Gambusia affinis*	16.4	3.1	2.8	4.7	4.8	6.3	0.7	0.5	0.2	0.7	0.4	0.5
Least killifish	*Heterandria formosa*	0	0	1.8	0.6	0.1	0.5	0	0	<0.1	<0.1	<0.1	<0.1
Sailfin molly	*Poecillia latipinna*	54.4	23.1	8.3	21.4	1.8	19.8	50.9	14.0	5.4	12.9	0.5	10.6
Brook silverside	*Labidesthes sicculus*	0	0	0	0	0.3	0.1	0	0	0	0	<0.1	<0.1
Tidewater silverside	*Menidia beryllina*	0	0.4	0	0	0	<0.1	0	0.2	0	0	0	<0.1
Sunfish													
Bluespotted sunfish	*Ennescanthus gloriosus*	0	0	0.8	0.2	2.2	0.8	0	0	0.9	0.3	1.5	0.9
Warmouth	*Lepomis gulosus*	0	3.1	2.5	2.1	12.3	4.8	0	11.6	21.9	21.5	38.8	27.2
Bluegill	*Lepomis macrochirus*	0	0	0	0	1.1	0.3	0	0	0	0	1.4	0.7
Redear sunfish	*Lepomis microlophus*	0	0	0	0.6	7.2	2.3	0	0	0	3.1	9.4	5.4
Spotted sunfish	*Lepomis punctatus*	0	0	4.5	0.8	6.7	2.8	0	0	17.3	8.7	9.3	8.7
Unidentified sunfish	*Lepomis spp.*	0	4.4	1.5	3.4	2.7	2.5	0	4.0	1.0	2.3	0.6	1.0
Total Sunfish		0	7.5	9.3	7.1	32.2	13.5	0	15.6	40.2	35.6	61.0	43.9
Largemouth bass	*Micropterus salmoides*	0	0	0	0.2	1.0	0.3	0	0	0	3.6	7.2	4.4
White mullet	*Mugil curema*	0.4	0	0	0	0	0.1	6.0	0	0	0	0	0.8
Other													
Freshwater prawn	*Palaemonetes paludosus*	0	0.4	0.2	0	0.3	0.2	0	<0.1	<0.1	0	<0.1	<0.1
Red-spotted newt	*Diemictylus viridescens*	0	0.4	0	0	0	<0.1	0	0.1	0	0	0	0.1
Bullfrog	*Rana grylio*	0	0	0	0.5	0	0.2	0	0	0	1.7	0	0.4
Total Number/Weight		518	225	398	1,150	907	3,198	249.4	63.2	245.2	415.2	978.8	1,952

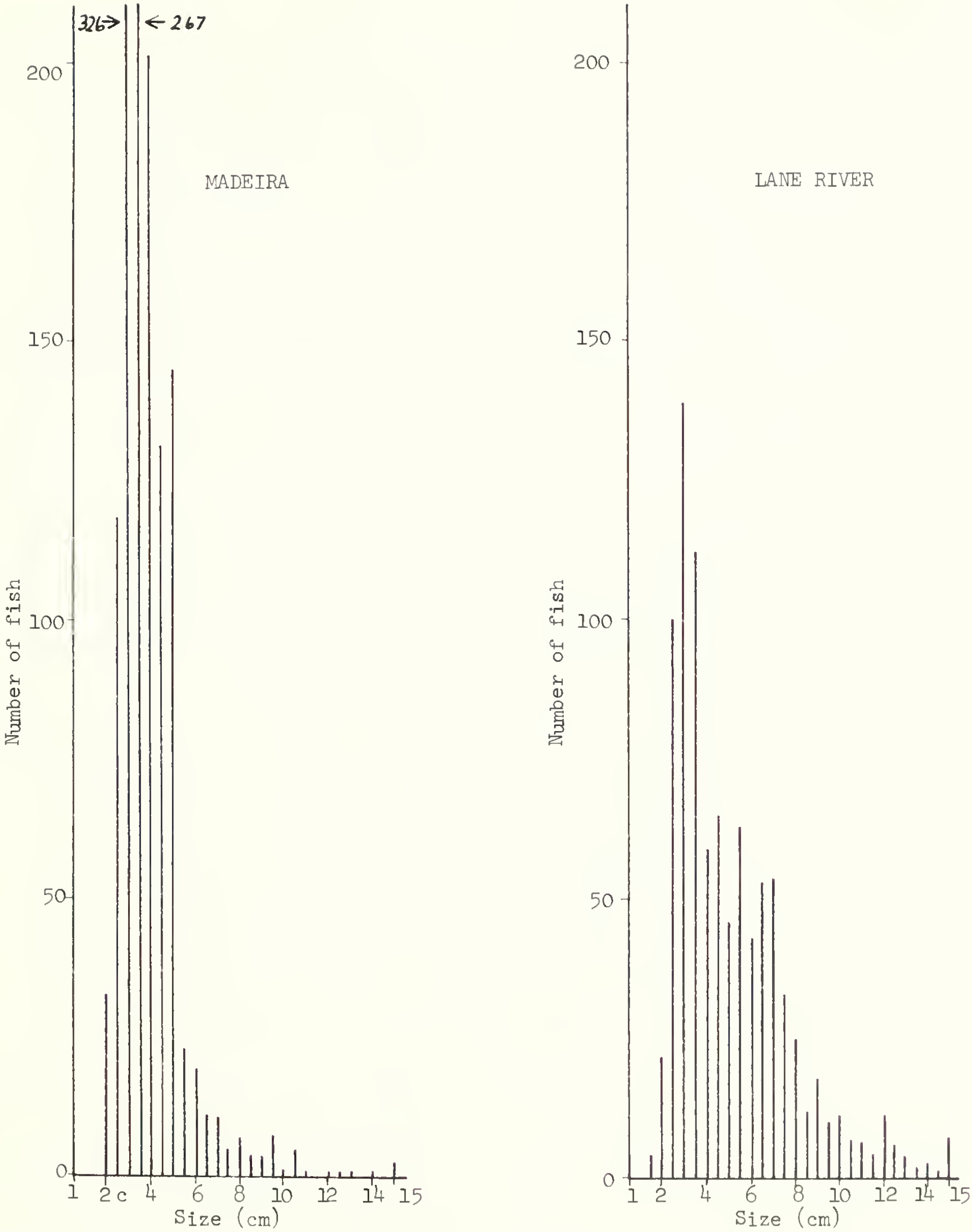


FIGURE 11. Size frequency distribution of fish from nestling Wood Storks at two colonies.

compared to 5.4 cm at Lane River Rookery (Fig. 11). The difference was due to a greater proportion of larger fish species 5-9 cm) obtained in the Lane River samples (Table 1) and not to differences in size of similar species.

Nestlings consumed larger fish on the average than did adults (t-test, $P<0.05$). The differences were not great (4.6 cm vs. 4.3 cm) and may not be meaningful.

To determine whether there were any differences in the size of fish fed to different-aged young, regurgitation samples from nestlings were broken down by nestling age classes. There were no consistent differences in size of fish fed to young of various ages. In fact, the second largest fish found in this study, a 22-cm bass, was from a stork less than 20 days old. These results do not confirm the observation of Kahl (1962) that smaller fish were brought to younger storks.

Prey selection by Wood Storks is passive in that storks do not visually select and pursue prey but rely on nonvisual foraging behavior (Kahl and Peacock 1963). Particular species consumed may be captured selectively because of availability (i.e., density), size, behavior, or other characteristics. The relationship between availability and prey actually taken can be quantified by a selectivity (electivity) index:

$$E = \frac{e - a}{e + a}$$

where e is the proportion of a species or length of fish among all prey eaten and a is the proportion of a species or length of fish available to foraging Wood Storks as determined by the samples taken at stork feeding sites. This index, proposed by Ivlev (1961), quantifies prey preference by a number ranging from +1 to -1. A prey with an index near +1 is consumed selectively in much greater proportion than it is available. A prey with an index near zero is consumed in proportion to its availability. A prey with an index near -1 is consumed below its relative abundance in the environment.

Figure 12 shows the relative abundance of various species of fishes, their relative importance in the diet of Everglades Wood Stork, and selectivety of storks for each species of fish. Of the more important species in the diet, sunfish, marsh killifish, sailfin mollies, and sheepshead minnows were highly selected. The mosquito fish, abundant in feeding areas, was underrepresented in food samples obtained. Similarly, bluefin and least killifish, although relatively abundant, are seldom taken by storks.

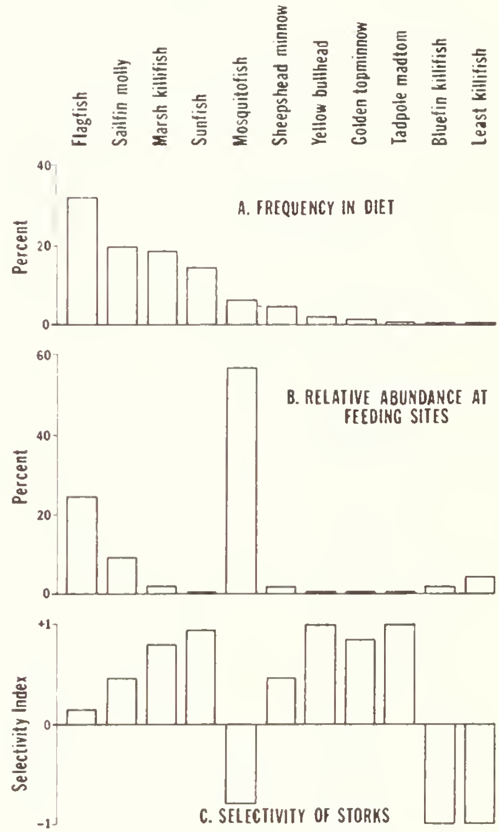


FIGURE 12. Relative abundance of various species of fish, their frequency in the Wood Stork diet, and the selectivity of storks for each species.

Selectivity by storks for various sizes of fish can be measured in the same way as selection for species, by calculating selectivity indexes for various length classes, as shown in Fig. 13, for all samples. Selectivity was zero for fish about 3.5 cm in length and rose rapidly for larger sizes. This pattern was similar in all three habitats. This means that relative to the available sizes of fish, Wood Storks selectively consumed the larger fish, generally those over 3.5 cm. Other aspects of prey selectivity of Wood Storks are discussed elsewhere (Ogden et al. 1976).

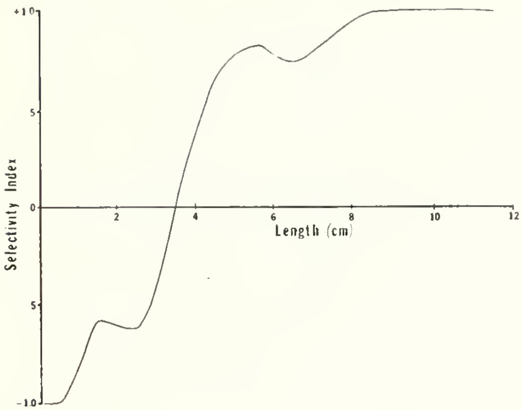


FIGURE 13. Selectivity of Wood Storks for different sizes of prey.

SUMMARY AND CONCLUSIONS

Rainfall was below normal during most months of the 1974 hydrobiological year. Discharge into Shark River Slough was below the scheduled minimum from October through January because of low rainfall, management diversion of discharge west of the slough in November, and nonacceptance by the park of make-up discharges. Thus, the 1974 hydrobiological year was one of low water supply to the park. However, high rainfall in December dispersed feeding Wood Storks and delayed the initiation of colony formation. The drying rate, which is one way of quantifying the pattern of water level decline, was rapid despite the December rainfall, and the overall drying pattern for this year was similar to years before 1962 when Wood Stork nesting failed. Nonetheless, 1974 turned out to be a successful one for the Wood Storks, strengthening the conclusion of Kushlan et al (1975) that successful nesting years after 1962 do not follow the historic pattern. These authors also derived an empirical relation between drying rate in the Shark Slough and the time of colony formation using data from 1962 through 1973. If this relation continued to hold in 1974, Wood Storks should have begun nesting around 26 January. In fact, storks began nesting between 15 and 24 January. This extremely close agreement with the previously derived relation strongly supports its validity.

Because of the relatively small amount of water manipulation, by closing of S-12 structures, no conclusions are possible on impact of such actions on fish populations of the Everglades. Since no significant water manipulation took place, the most important contribution of the present program was the detailed study of the food ecology of Everglades Wood Storks. This information is basic to understanding the ecological relationships of this species and provides a step toward management of the Everglades ecosystem.

The study showed fish populations were high in the Shark River Slough in 1974 and that movement of fish did occur as the slough dried, although details of such movement remain obscure. Wood storks fed on relatively high densities of fish except, apparently, in Conservation Area 3, where much future study needs to be directed. The Wood Storks in the coastal, mangrove, and Everglades regions of southern Florida ate fish almost exclusively, consuming 27 species. However, marsh killifish, sheepshead minnows, flagfish, sunfish, and yellow bullhead made up 84% of the diet. Some of these species were highly selected by Wood Storks and consumed far in excess of their relative abundance at feeding sites, whereas others were less highly selected. Abundant potential food species such as mosquitofish, least killifish, and freshwater prawns were insignificant in the stork's diet. Wood Storks also selectively consumed fish over 3.5 cm, the relatively larger fish and therefore larger species among those available. Thus, these data show that the Wood Stork is a highly selective feeder despite its nonvisual, tactile hunting technique.

The ecological implications and management applications of the results of this study are considerable. It is believed stork nesting in recent years has failed primarily because nesting began too late. Previously, no nesting had succeeded which began after December. Nesting began this year in late Janary, near the latest date at which nesting could successfully finish before the rainy season. The attempt to initiate early nesting by water management was inconclusive. However, nesting would probably have begun earlier if water levels had not risen in December.

It is apparent from this year's data that the general rate of water decline at the P-33 reference gaging station does correlate with time of colony formation, but why it does is not clear. It appears that storks were not feeding in the area which is most probably influenced directly by small changes in the discharges at the S-12 structures during the early drying period and that less than scheduled water deliveries did not in themselves provide a rapid drying rate this year. It is possible that relatively small manipulation of dry season discharge may have little impact. However, it remains unknown how S-12 discharges affect water levels either at P-33 or elsewhere in the slough. As noted by Kushlan et al. (1975), the value of P-33 may be as an index of the pattern of drying over the entire region, including areas where Wood Storks are feeding during colony formation. Thus, water level relations at P-33 are probably a valid indication of water conditions in relation to Wood Storks, but the relation between P-33 and S-12 discharge remains unquantified in any way applicable to management. It is reasonable to suspect that high discharges in the drying season might prevent rapid drying. Thus it remains reasonable that manipulation of early dry season discharges may indeed affect drying. However, without more detailed information on the amount of discharge through each structure and the impact of such discharge on water levels throughout the slough, it is not possible to predict the effect of such manipulation.

Since Wood Storks consume predominantly a small array of species, it is the production and availability of these few species, as opposed to the availability of the whole array of species, which probably determines whether sufficient food is available for successful nesting. In addition, storks consume primarily larger fish, the ages of which are not presently known. This information is important because if the fish are the result of production during the current hydrobiological year, the biological and physical conditions which control their availability may be relatively straightforward. If they are in fact over one year old and have survived a previous dry season, the situation becomes more complex. Unfortunately, little is known about the productivity, growth, or ecology of these species or of the aquatic communities of which they are a part.

The general nonpredictability of successful Wood Stork nesting after 1962 continued. It is particularly notable that successful years prior to 1962 were wet years while the 3 successful years after 1962 were dry years. However, other recent dry years and also recent high-water years were unsuccessful. The breakdown of predictability coincides with the institution of water control, although other concurrent environmental changes are undoubtedly in part responsible. Both the analysis of such changes and the proper management of the Everglades ecosystem are confounded by the delivery of surface water discharge to the western part of Shark River Slough rather than through its natural drainage east of the park. It seems highly probable that the breakdown of the historical pattern of wading bird nesting may only be rectified if the historic pattern of water delivery to the entire slough is again realized.

RECOMMENDATIONS

This project provided a beginning toward an urgently needed and long overdue study of the Shark Slough ecosystem. We strongly recommend that a unified research program be initiated to continue investigating the biological and hydrological dynamics of this vital but failing ecosystem, *the* central feature of Everglades National Park. We specifically recommend the following program as the first stage in the needed studies.

Hydrology--Data on monthly discharge through the S-12 structures should include daily discharge for each structure as a necessary requisite of future management decisions regarding this discharge.

A program to determine the pattern of drying in Shark River Slough and adjacent areas of importance to wading birds should be established.

Fish Studies--A program should be undertaken to determine the distribution, community structure, breeding cycles, longevity, movement, food, and productivity of fish populations in the southern Everglades. A necessary first step in this program must be further refinement of the sampling technique used to measure low densities of fish. Studies of the abundance and productivity of fish in Shark River Slough should then be contrasted with similar information from the Conservation Areas and eastern Everglades to determine the impact of water management on fish populations and their availability to higher levels of the food chain. These studies should be part of an overall effort to develop a systems model of the Everglades region which will provide the basis for management of these ecosystems.

Studies should also be undertaken to determine productivity and the environmental determinates of prey availability in the estuarine habitats which serve as the primary feeding site of Wood Storks in early winter.

Sampling should be continued at the two previous USGS trap sites reestablished this year in order to perpetuate this long-term record of fish populations in Shark River Slough.

Wood Stork Studies--The present study obtained information on the distribution, movements, food, and prey selectivity of the Wood Stork in the Everglades. Studies now should be undertaken to examine more closely its nesting biology, foraging behavior, and parental care in the Everglades while expanding the study of its ecology and biology to other parts of its range so that the environmental factors that lead to successful production in different habitats can be compared and general patterns uncovered. In addition, banding and marking programs in the park and elsewhere should be continued to provide information on mortality and distribution in the nonbreeding season.

Wading bird studies should be expanded to include more precise information on the movements, food habits, and populations of other wading bird species. Surveys should give better coverage of important feeding areas for wading birds outside the boundaries of the park, especially in the Big Cypress Swamp, the Conservation Areas, and eastern boundary area.

Alligator Studies--Preliminary studies (Kushlan 1974, 1976) have shown the importance of this species and its role in providing foraging habitat for wading birds and survival ponds for fish. A program should be begun to study the ecology of the American alligator in the southern Everglades, specifically in relation to water levels, fish populations, and wading bird predation.

Future Considerations--Hydrobiological research in the southern Everglades should have as its ultimate goal determining whether the current discharge structures and discharge schedule adequately reproduce the natural hydrologic cycle in the Shark Slough watershed and, if so, whether this has maintained the natural biological system. An effort should be undertaken to determine if surface flow should be restored to the entire Shark Slough basin.

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