ARCHBOLD BIOLOGICAL STATION

STATION FIRE MANAGEMENT PLAN

by

Kevin N. Main and Eric S. Menges

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Abstract:

Fire management planning at Archbold Biological Station attempts to balance diverse goals and provide temporal and spatial heterogeneity across the landscape. The goals are enhancing biological diversity, enhancing threatened and endangered species, mimicking natural processes, providing a diversity of research and educational opportunities, interacting with other fire management agencies, reducing fire hazards, and conducting safe burns. A mosaic of units of various sizes, burned at various fire-return intervals, should satisfy these goals. The system is built around five fire-return intervals, each of which is a range of years within which individual burn units are planned to re-burn. A key characteristic is the assignment of modal fire-return intervals to vegetation types (e.g. most sandhill will burn every 2-5 years, most rosemary scrub will burn every 20-59 years). Using fire-return intervals, rather than a fixed number of years, increases heterogeneity, provides research opportunities, and creates a plan with flexibility, including the ability to absorb most lightning-ignited fires. Initial burns in fire-suppressed areas are staggered to be burned over a time period corresponding to the modal fire-return interval. Heterogeneity is also provided by assigning units to intervals other than the modal one for the vegetation. We also seek to promote variation in timing of fires, fire patchiness, fire intensity, and size of burns. Recent Station fire management has increased the number of prescribed burns, shifted most burns to the natural ignition season, and used a range of fire sizes (<1 to 73 ha). A variety of fire-return intervals are also assigned to units containing critically-endangered species in order to provide research-based management information. Mechanics of the plan are described, including how burn dates are selected for burn units, how prescribed fires are conducted, pre- and post-fire monitoring, fire mapping, burn unit surveys, and burn day preparations. Policies for dealing with all fires (including lighting-ignited and accidental fires) provide information about acceptable prescription parameters, necessary safety equipment, crew training, maintenance of fire breaks, and archival of fire data.

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ACKNOWLEDGMENTS

This plan has developed through the efforts of many people over the past 20 year period. Special thanks go to Warren Abrahamson and Jim Layne for getting the process started with the first prescribed fire at the Station in 1977, and to Ron Myers, who wrote the first fire plan for the Station in 1984. Also involved are the many researchers (both on and off Station) whose work has provided important details that help to form guidelines for the plan. Thanks to Roberta Pickert for providing expert advice (and counseling) on the GIS generated maps. Thanks to all the people who reviewed this document and improved upon it, including Warren Abrahamson (Bucknell Univ.), Fred Adrian (USFWS), Geoff Babb (TNC), Mike Jennings (USFWS), Fred Lohrer (ABS), Dick Roberts (DEP), Paul Schmalzer (Dynamac Corp.), Robert Smith (Ichauway), and Hilary Swain (ABS).

I. GOALS OF FIRE MANAGEMENT AT THE STATION

This plan outlines fire management on the main property (see Fig. 2) at Archbold Biological Station (ABS, or, the Station)..

There are eight major goals of fire management at Archbold Biological Station, covering conservation, research, education, and safety concerns. No single goal takes priority over the others except for conducting safe burns, which is vital to the fire management program.

The major goals may not all be simultaneously met in all places; some may even conflict with one another at times. We exercise flexibility about which goals take precedence for any particular part of the Station and in any burn. Some burns may be expressly for research purposes, for example, while others may satisfy conservation objectives. We also continually evaluate our success in meeting burn-specific and general goals in a process of adaptive management. With this in mind, we expect to periodically update the Fire Management Plan to better reflect our understanding of our region's fire ecology, better utilize new technology, and find improved approaches to satisfy our objectives.

The goals are:

A. Enhance Biological Diversity
B. Enhance Threatened and Endangered Species
C. Mimic Natural Processes
D. Provide a Diversity of Research Opportunities
E. Provide Educational Opportunities
F. Interact with Other Fire Management Agencies
G. Reduce Fire Hazards by Managing Fuels and Fire
H. Conduct Safe Burns

A. Enhance Biological Diversity

The term biological diversity is interpreted broadly to encompass species diversity (species richness, the number of species, and equitability, or distribution of species dominances), landscape diversity (patches of various communities across space, including patches with varying fire histories), and species of special interest. Species of special interest include endangered and threatened species (at federal or state levels), unusual or significant populations, and keystone species.

We believe that biological diversity, in general, will be maximized by providing both temporal and spatial heterogeneity through our fire management program. With that in mind we have designed a plan that allows for variation in fire-return intervals, encourages patchy burns and variable fire intensities within individual burns, and avoids repetitive or fixed "rules" for the fire regime.

B. Enhance Threatened and Endangered Species

Florida scrub, and particularly scrub on the Lake Wales Ridge, is rich with narrowly-distributed plants and animals (Christman and Judd 1990). The Station is an important site for many of these species

(Menges and Salzman 1992, Deyrup and Franz 1994). Each individual burn unit prescription is evaluated with respect to specific endangered and threatened species. We evaluate the probable effects of each fire on endangered species, in part by consulting with experts on these organisms. We would like to move toward a more pro-active approach, where the mix of fire-return intervals and other aspects of the fire regime are considered for the most endangered species.

Besides our own desire to maintain listed species, the plan sets a framework for meeting state and federal regulations involving threatened and endangered species. While individual fires may temporarily reduce certain local populations of listed species, we believe an overall approach to habitat maintenance through fire management will ensure long-term viability of these species. Monitoring listed species populations is a key element of fire management at the Station. Results from long-term monitoring are used to refine the Fire Management Plan.

C. Mimic Natural Processes

One goal of Archbold's fire management is to mimic, to the degree possible, the natural range of variation in fire-return interval, fire intensity, fire behavior, fire effects, and other characteristics of the fire regime. While we would like to mimic the size range of presettlement fires, that is clearly not possible within our limited area. Nonetheless, within the constraints of the other goals, larger fires are seen as more characteristic of the natural fire regime. Most fire-burned area in presettlement times probably burned during droughts. We seek to burn some areas during droughts, but will be constrained by safety constraints and ecological goals from burning during extreme conditions. Head fires would have burned most of the area before European settlement. While we use many lighting techniques, including back fires, flank fires, strip head fires, and point-source ignition fires in conducting prescribed burns, we seek to burn the majority of many burn units with head fires to mimic presettlement fire intensities. Narrow prescription windows are necessary to insure control of these intense fires (see section VI). Safety constraints and other site-specific factors will limit the use of head fires in some burn units. We also seek to maintain other natural processes (e.g. hydrology, successional, metapopulation, dispersal, behavior) through proper fire management. In striving to mimic natural processes, we analyze our burn patterns not only across the Station, but in the context of fire management across the entire Lake Wales Ridge.

In addition, we plan for the occurrence of lightning ignitions so that some such ignitions can be allowed to burn in a controlled manner and, thereby, allowed to affect part of the landscape in a way similar to that which occurred before European settlement.

D. Provide a Diversity of Research Opportunities

This would include providing patches of various fire histories (fire frequency, time since last fire, fire intensity, fire patchiness, season of burn) for comparative research; as well as opportunities for studies before, during, and after single or multiple fires. Clearly, a diversity of research opportunities will include fires that do not necessarily mimic natural processes, nor maintain biological diversity, necessitating a balance among these goals.

In the past, fire managers at the Station have responded to research requests to burn or not burn individual research sites. We will to continue to do this, but increasing research pressure has often created conflicts between researchers' desires and management goals. By planning burns that may occur within five-year rolling windows, we can provide a broad spectrum of relatively predictable research opportunities for most scientists and visiting researchers working at the Station. This planning serves to integrate research and fire management in ways that are mutually beneficial.

E. Provide Educational Opportunities

Educational opportunities are maximized by maintaining biological diversity (so representative organisms are present), mimicking natural processes, and providing a diversity of research opportunities. Educational opportunities are also maximized by providing these goals in areas accessible to classes and individuals. Fire management can serve educational goals in teaching about fire ecology and management. Better understanding of the role of fire in natural ecosystems will engender sympathetic views among the general public about fire management.

F. Interact with Other Fire Management Agencies

We seek to interact with other fire managers and their agencies in conducting prescribed burns, sharing ideas and experience, and exchanging knowledge on fire management. Although the Station Fire Management Plan will not be entirely appropriate for other agencies, we hope our approaches and documentation can help to foster more informed fire management planning elsewhere.

G. Reduce Fire Hazards by Managing Fuels and Fire

Central Florida vegetation is inherently flammable, and long periods of fire suppression increase the difficulty of controlling accidental or lightning-ignited fires. Therefore, prescribed burning can manage these risks by reducing fuel levels and providing fire breaks in sensitive areas. The Fire Management Plan provides attention to units near buildings (both ours and our neighbor's), units having research equipment, and areas adjacent to public roads. In some cases, short fire-return intervals make control of an accidental fire easier. Careful burning in areas near buildings and research equipment, and careful coordination to avoid equipment being left in areas to be burned, are essential. Burning near developed areas adjacent to the Station must also be done with care to avoid problems with spot fires and smoky conditions.

H. Conduct Safe Burns

Proper training, effective equipment and supplies, informed decision-making, and careful planning are elements that need to be in place to ensure safety during prescribed fires and in controlling wildfires. The safety of the burn crew and control of the fire within the burn unit are the primary concerns when conducting prescribed burns. An increasingly important element of safety is smoke management. Liability and public perception associated with smoke may limit the conditions under which some burns can occur. We seek coordination with other fire management agencies to help us develop management techniques for conducting safe burns. We will burn with the utmost consideration for the safety and comfort of our neighbors.

II. FIRE HISTORY

A. The Florida Environment in the Late Wisconsin and Holocene Eras

Core samples of sediments from lakes along the Lake Wales Ridge, including lakes Annie, Buck, and Tulane (Fig. 1), show that repeated fires have occurred on the landscape for at least 50,000 years (Watts and Hansen 1988, 1994). During this time vegetative changes have reflected the frequency of fire (Table 1).

B. Presettlement Fire History

Southern Highlands County (Fig. 1), is subject to 100's of lightning strikes each year (Goodman and Christian 1993). Before urban and agricultural development of central Florida, lightning-ignited fires occurred at regular intervals, sometimes burning thousands of hectares before being halted by a natural barrier or rainfall (Myers 1990). Most areas were probably burned in early summer, in association with the first thunderstorms following the dry season (Robbins and Myers 1992). The largest acreage was probably burned by head fires during the day. Night-time head fires and day-time backing fires also occurred over large acreages, resulting in a spatially heterogenous burn pattern. Before fire suppression and anthropogenic landscape barriers were in place, the presettlement fire regime was probably characterized by large, landscape-scale fires (Table 2). Native Americans probably set fires during all parts of the year, but these fires probably did not dominate the fire regime before European settlement since the native America population is not generally thought to have existed at high enough densities.

C. Early Settlement Era (1880's - 1940)

When Europeans began settling in south-central Florida in the 1880's, a second era of fire history began (Table 2). Fires were probably still frequent and large, although the first attempts at fire suppression also began. A study of fire scars on trees on the southeast tract of the original Station Property, also known as "Red Hill" (Fig. 2) gave evidence of six fires between 1892 and 1927 (Myers 1985). There is an interesting account of the number of fires responded to by Alexander Blair (John Roebling's resident engineer, 1929-1941) and his crew, along with other local fire suppression agencies, between 1931 and 1937 (Blair, unpublished records; Table 3). Most recorded fires were in a "Fire Protection Area" (Fig. 3) which included the original Station property, the nearby town of Hicoria and the Sherman sawmill. (Fig. 3, Table 3). During that time 145 fires were reported. Most of these were accidental fires started by the railroad, campers on Lake Annie, or at the sawmill. Not all fires were recorded, only those that were actively fought. Fig. 3 shows rough locations for fires recorded by Blair between 1931 and 1934 (maps for 1935-1937 are missing). Fig. 4 is redrawn from a 1939 map (presumably done by A. Blair) of a wildfire that occurred west and north of the original property. Prescribed burning was used during this period to reduce fuels in pine plantations, "green-up" cattle grazing areas, and open up areas for hunting (Robbins and Myers 1992). Fuel reduction burns likely took place near developments. "The Brief History of Hicoria" (Wilson, unpublished) contains more information on the history of the Archbold area and the town of Hicoria.

The original Station property, 425 hectares (1,050 ac), including Red Hill, was purchased by John A. Roebling in 1929-1930. Just before the purchase of the property (probably 1927) a large fire occurred on Red Hill and burned most of the area. Active fire suppression began after this fire and continued until 1985. A fire truck was kept at the Station as early as 1932. Roebling was also gave fire trucks to the towns of Lake Placid, Sebring, and Avon Park.

Table 1. Summary of Paleoenvironments at Lakes Annie, Buck, and Tulane, Highlands County, Florida.

Years Before Present	Vegetation	Water Level	Inferred Climate	Fire Frequency
0-5000	pine woodland with swamps	high	as today	medium
5000-12000	oak forest or scrub with prairie	high after 8500 years before present	less precipitation and higher radiation	high
12000-14000	pine forest with herbs and mesic trees	very low, down 28 m	cooler than present and higher precipitation	low
14000-28000	pine woodland and herbs, fewer mesic trees	lowest: Lakes Annie and Buck dry	cooler than present and higher precipitation	very low
28000-50000	pine woodland, scrub, herbs abundant	low	windy, dry and some thunderstorms	high

From Watts and Hansen 1988.

Fig. 1. Location of Archbold Biological Station and the Lake Wales Ridge

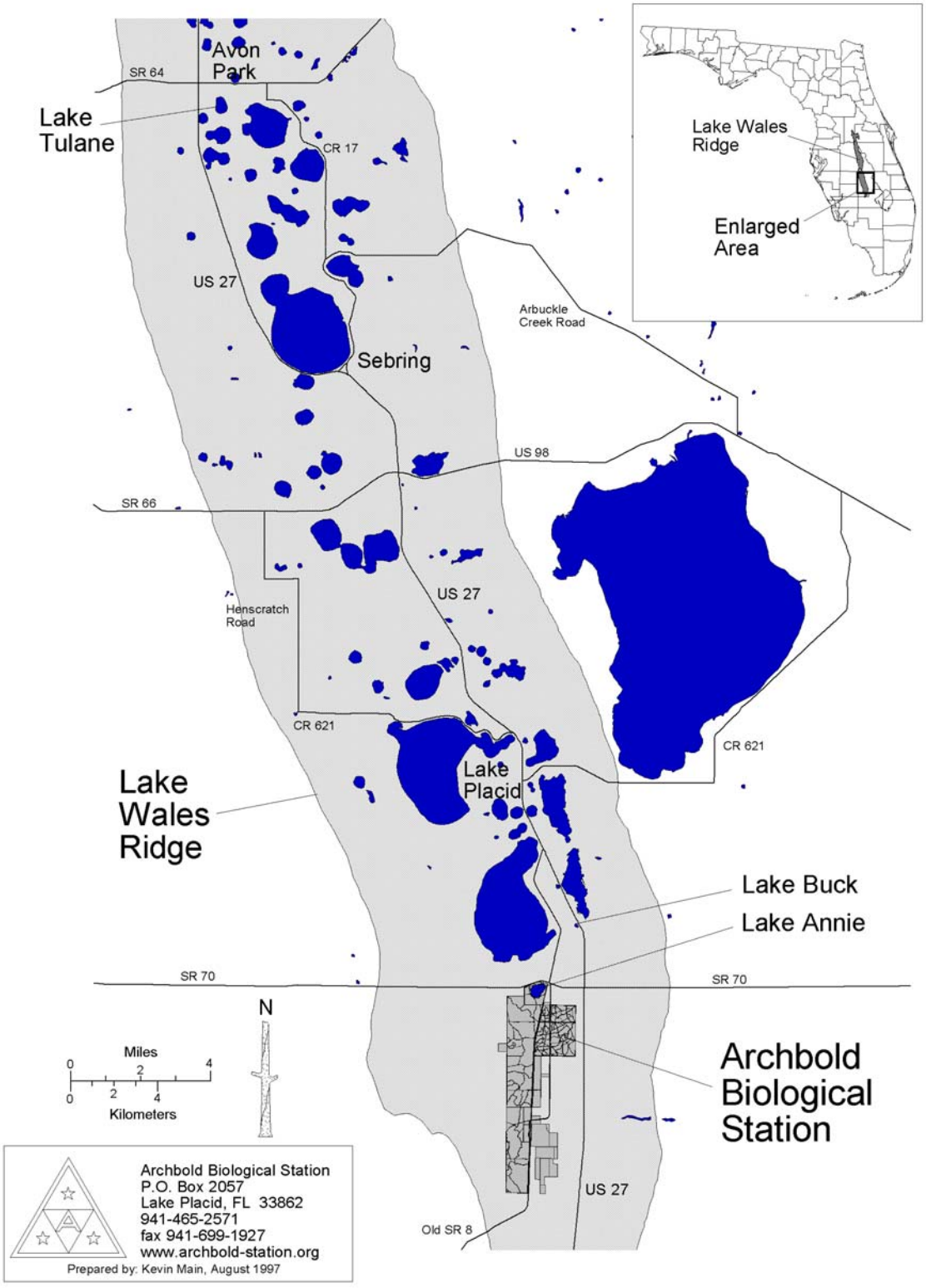


Table 2. History of Fire Management at Archbold Biological Station, Highlands County, Florida.

Time Period (and Fire Managers)	**Overall Management Approach**	**Primary Ignition Sources**	**Suppression Strategies**	**Notable Events**
Before Settlement	Not tightly managed by humans	Lightning, Native Americans	None	Landscape-scale fires
Settlement (ca. 1880) through 1940	Settlement, Fire Suppression	Lightning Accidental	Active suppression, constrained by logistics and equipment	Large fire in 1927
1941-1976 (Archbold, Layne)	Suppression (Original Property) Various ignition sources (West Section)	Lightning Accidental	Active suppression	Complete fire suppression in original property
1977-1981 (Layne, Abrahamson)	Fire Suppression, Experimental Research Burns	Lightning Prescribed (2 fires)	Suppression (Original Property), various approaches	Initial prescribed fires
1982-1987 (Myers)	Management Planning, Research Burns	Lightning Prescribed (4) Escaped (2)	Indirect control and active suppression	Several very large burns
1988-present (Menges, Main)	Flexible, Integrated Research and Management Planning	Prescribed (64) Lightning Escaped (3)	Indirect control and active suppression, pre-planned by burn unit	Increase in burn numbers; landscape heterogeneity

Fig. 2. Major Tracts of Land at Archbold Biological Station

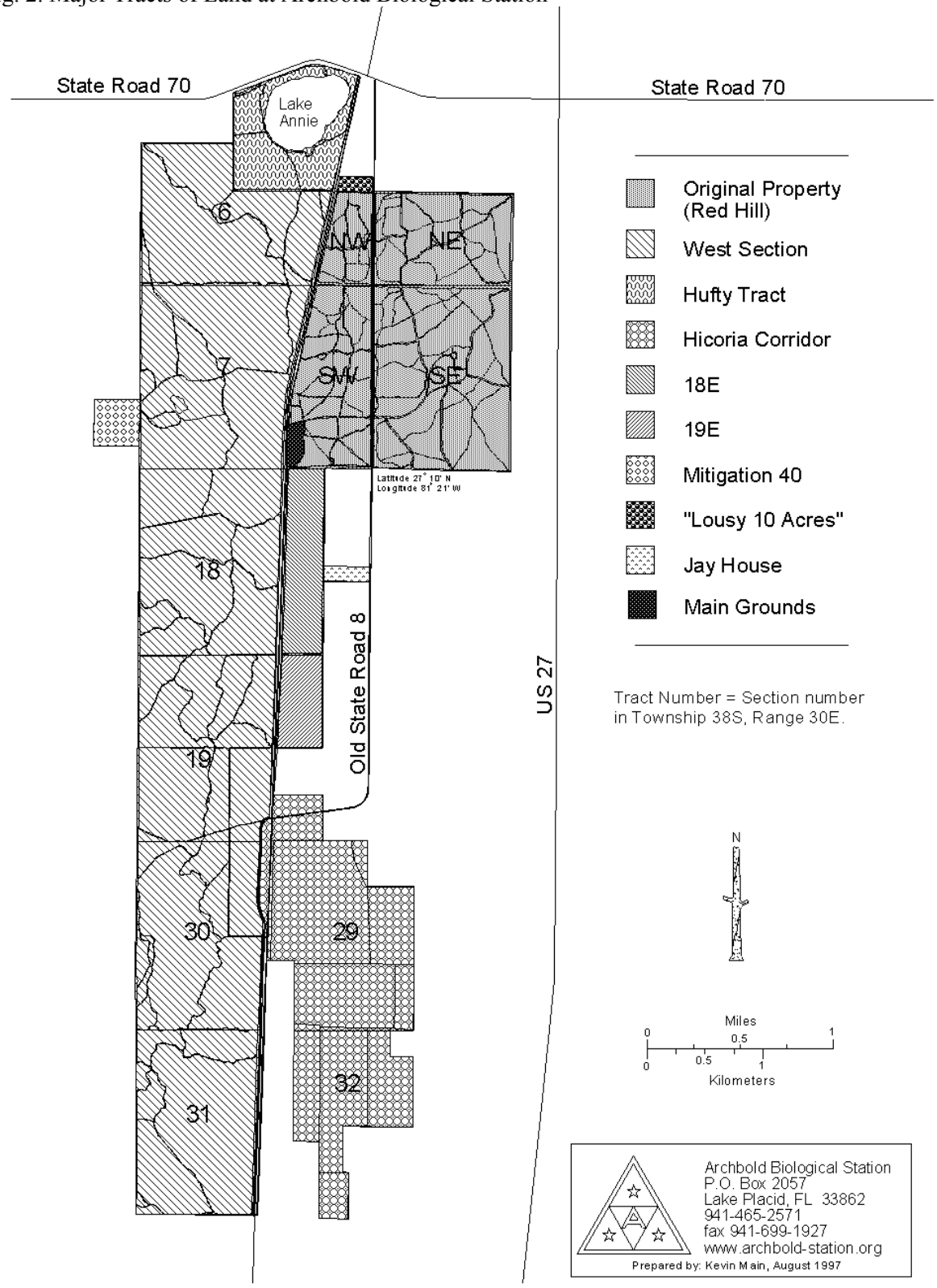


Table 3. Summary of Alexander Blair's Fire Records, 1931-1937, for the vicinity of Archbold Biological Station, Highlands County, Florida.

Year	Number of Fires	Notable Events	Fire Dates
1931	14	One fire had a line three miles in length, another was fought by a large crew over a period of several days at the "Yantz Muck Tract". Most likely all fires were accidental (many fire locations are near the railroad right-of-way or Lake Annie).	All fires in Oct., Nov., and Dec. - probably when record-keeping began.
1932	14	A fire destroyed part of the Sherman sawmill (at Hicoria) on May 12th of this year (mill was repaired). Most fires were accidental, although at least one fire was intentionally set "by men burning off Baseball Diamond".	All fires Jan-Apr. - missing the rest of the year or no fires because mill was not running?
1933	35	This is the only year in which several summer fires are recorded. Most of the summer fires were 2 hectares or more and were likely caused by lightning.	Seven fires in Jan-Apr., **20** fires in May-Aug., 8 fires in Sep-Dec.
1934	44	Several large fires are recorded (at least 4 over 40 hectares), all outside the normal lightning season. Most fires were probably accidental.	14 fires in Jan-Apr., one fire in May, then 29 fires in Oct-Dec. Missing summer fires?
1935	31	Several large fires are recorded (nine were 40 hectares or more, one was 400 hectares). Another fire destroyed part of the saw mill. Though the mill was rebuilt, it closed later in the year. Most fires were probably accidental. Map missing for this year.	28 fires in Jan-Apr., one each in May, Nov., and Dec. Missing summer fires?
1936	6	There is an interesting quote on one of the 1936 fires: "This fire was fought because the wind was blowing strong from the east and southeast and if it had not been stopped it would have developed into a dangerous fire." This may be good evidence that some fires were not suppressed or even recorded if they did not threaten developments. Map missing for this year.	5 fires in Mar-Apr., one in July. Missing the rest of the year?
1937	1	Fire recording may have been discontinued this year. Map missing for this year.	One fire recorded in Feb., rest of the year not recorded?

Fig. 3. Locations of Fires According to Blair, 1931-1934

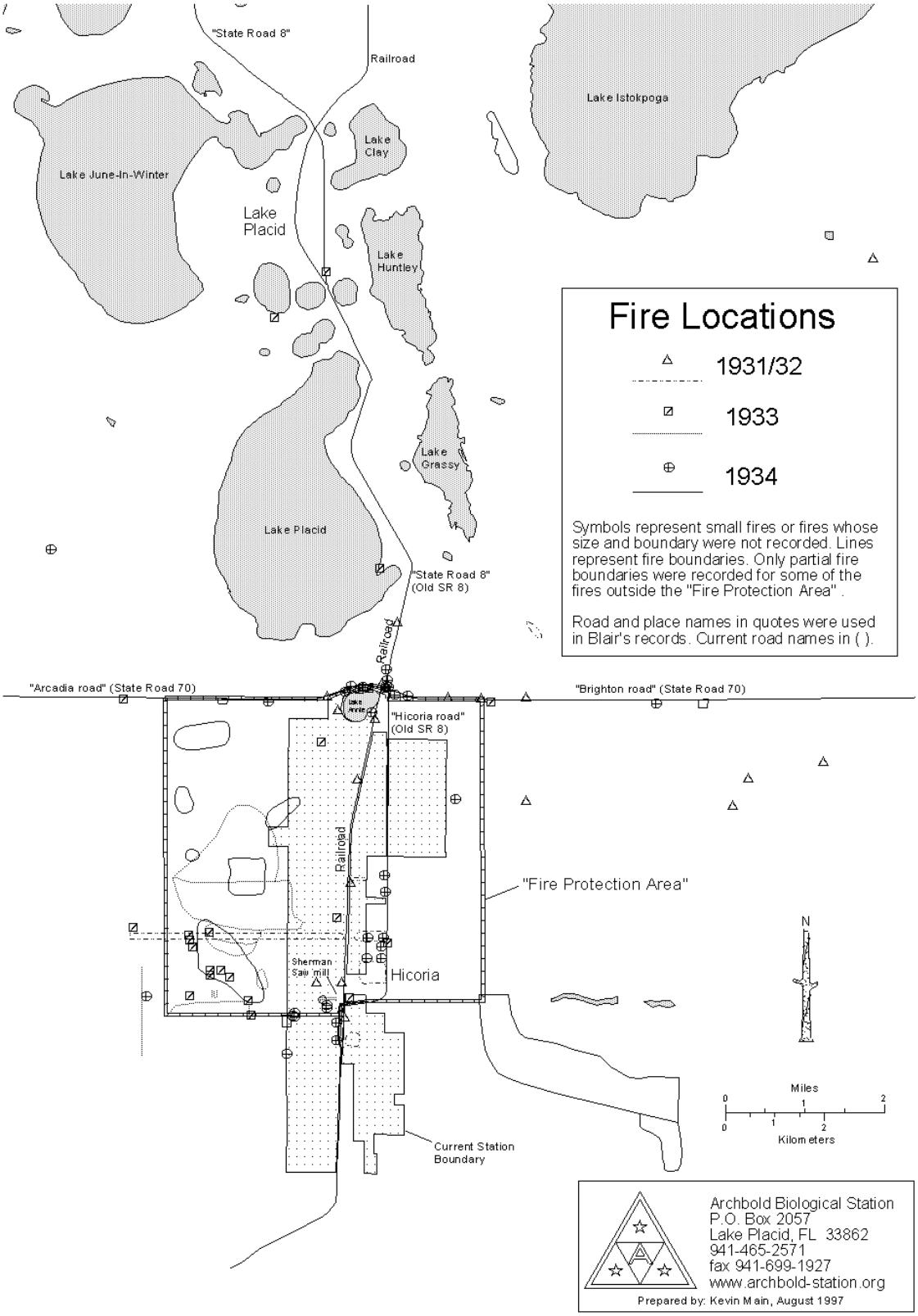
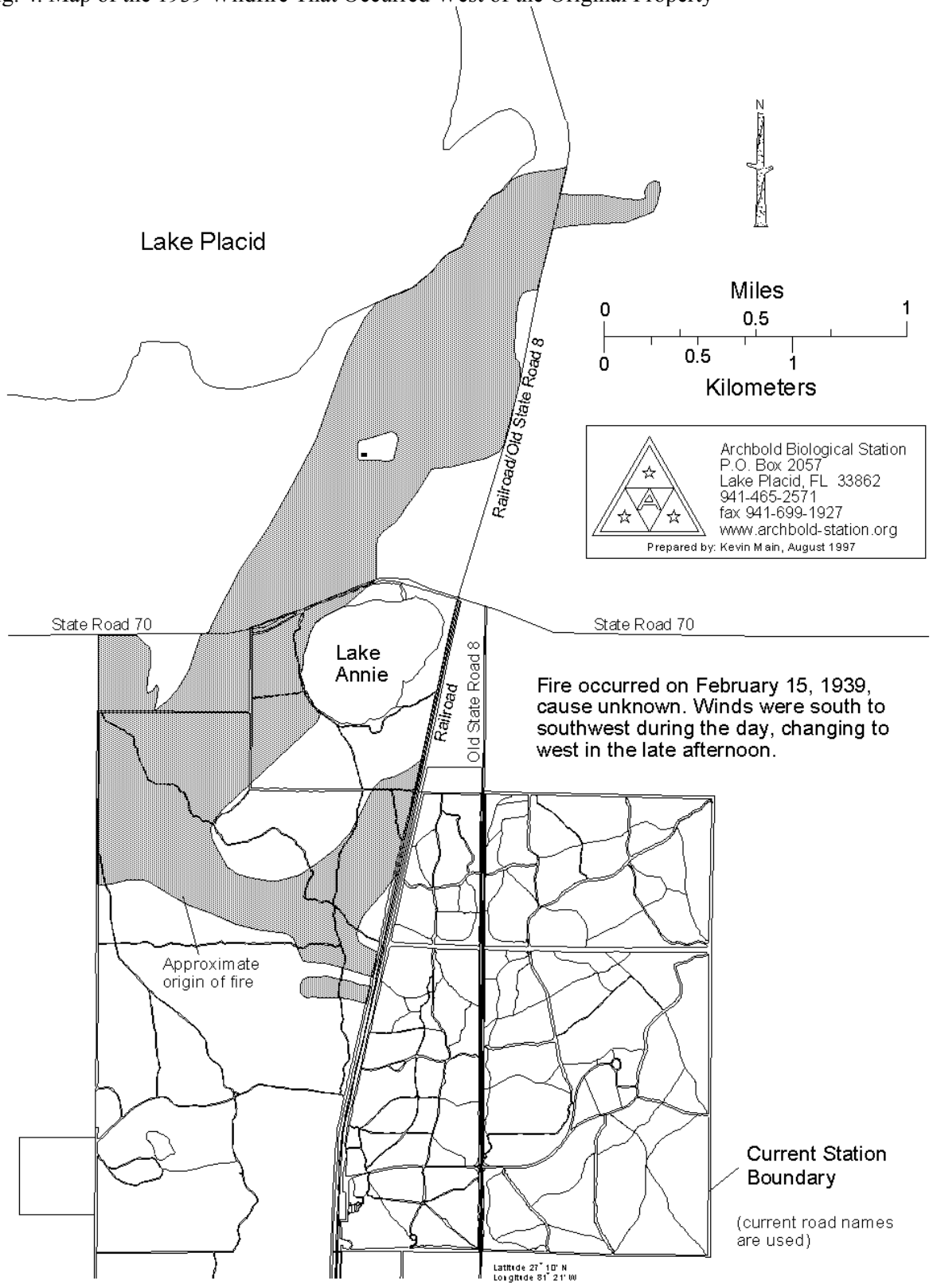


Fig. 4. Map of the 1939 Wildfire That Occurred West of the Original Property



D. Fire Suppression Era (1941-1976)

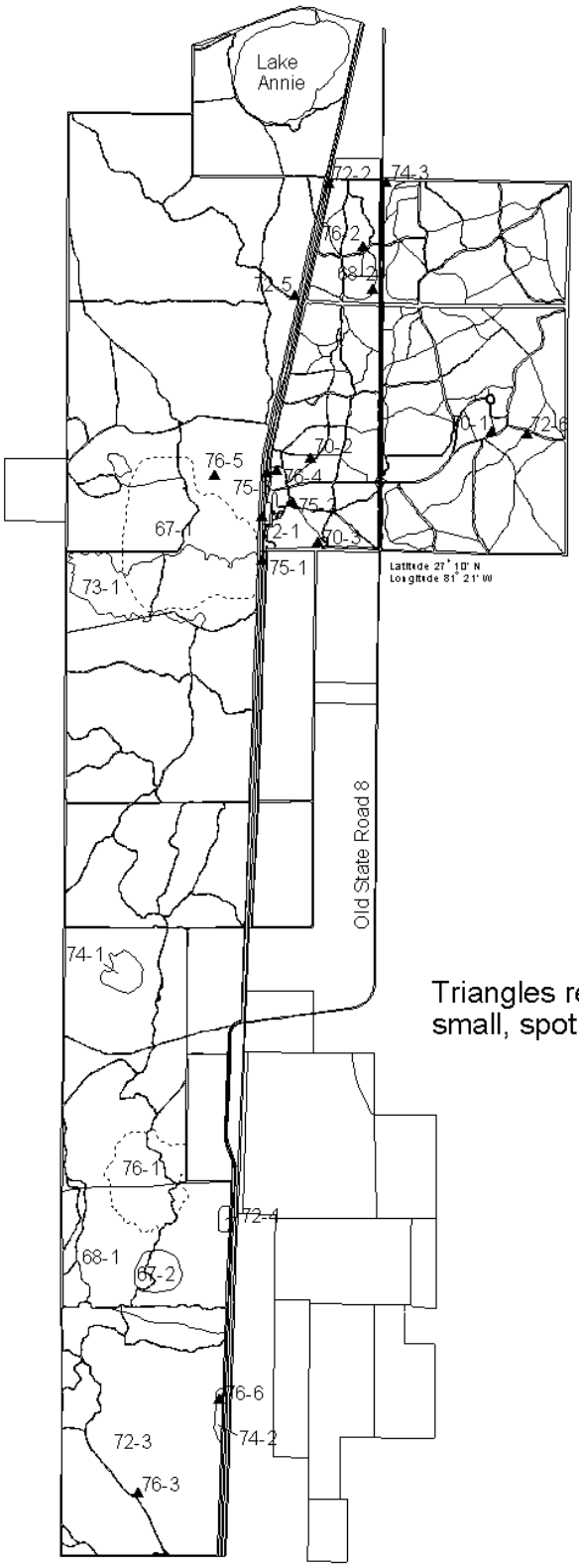
In 1941, Richard Archbold received the 425 hectare (1,050 ac) Red Hill Estate from Mr. John A. Roebling as a gift and founded the Archbold Biological Station (Fig. 2). Active suppression continued to be the rule for fires on the Station. Much of the land around the Station was developed into citrus groves or cattle ranches during this period, which probably reduced the overall number of wildfires in the area. Unfortunately, no records of fires or lightning strikes exist for this period. Wildfires must have been a continual threat, for in 1956 Archbold purchased a new truck (still in use today). Fires did occur on and near the Station during this period. The Station slide collection contains slides of a large fire that occurred in 1945 one mile east of Hicoria (slide numbers 97-108).

In 1967 James N. Layne began mapping lightning strike locations and the boundaries of fires that occurred in the area west of the original property (the "west section", the Station did not purchase this area until 1973). Between 1967 and 1976, nine fires burned a total of 547 hectares (1350 ac) (Fig. 5). Three fires were caused by lightning, the others were reported as accidental fires (possibly caused by the railroad).

E. Experimental Fire Management Era (1977-1981)

A more proactive approach to fire management began in 1977, when, under the leadership of James N. Layne and Warren G. Abrahamson, the Station carried out its first prescribed fire. A second prescribed burn took place three years later. Both of these fires were conducted in the winter. The two fires totaled 122 hectares (303 ac). In addition to the two prescribed fires, there where 15 lightning-caused fires and 2 accidental fires recorded during the period (Fig. 5). Only two of the lightning fires were large {99 hectares (246 ac) and 48 hectares (120 ac)}. On the original property all fires continued to be actively suppressed during this period, although a more varied approach to fires was used in the west section, with indirect control used for at least one fire.

Fig. 5. Fires at Archbold Biological Station, 1967-1976



FIRE HISTORY, 1967 – 1976

FIRE #	DATE	CAUSE	AC	HA	KBDI
67-1	2 Jan	Accidental	161.0	65.1	596
67-2	30 Jun	Lightning	16.6	6.7	103
68-1	20 Mar	Accidental	205.5	83.1	556
68-2	4 Sep	Lightning	0.2	0.1	359
69-1	11 Aug	Lightning	0.2	0.1	330
70-1	21 May	Accidental	0.2	0.1	635
70-2	16 Oct	Lightning	0.2	0.1	558
70-3	16 Oct	Lightning	0.2	0.1	558
72-1	22 Mar	Accidental	0.2	0.1	646
72-2	22 Mar	Accidental	0.2	0.1	646
72-3	23 Mar	Accidental	382.0	154.5	649
72-4	5 Aug	Accidental	2.6	1.1	449
72-5	5 Aug	Lightning	0.2	0.1	449
72-6	27 Nov	Lightning	0.2	0.1	475
73-1	7 Nov	Accidental	113.0	45.7	447
74-1	Feb	Lightning	12.4	5.0	610
74-2	17 Jul	Lightning	3.3	1.3	100
74-3	22 Jul	Lightning	0.2	0.1	174
75-1	13 Feb	Accidental	0.2	0.1	578
75-2	8 Jun	Lightning	0.2	0.1	313
75-3	4 Aug	Lightning	0.2	0.1	311
76-1	27 Apr	Accidental	63.3	25.6	653
76-2	13 Jul	Lightning	0.2	0.1	157
76-3	Jul	Lightning	0.2	0.1	120
76-4	16 Aug	Lightning	0.2	0.1	228
76-5	16 Aug	Lightning	0.2	0.1	228
76-6	2 Sep	Lightning	0.2	0.1	300

Triangles represent small, spot fires.

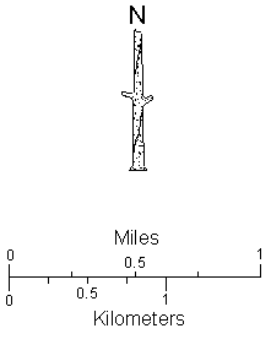


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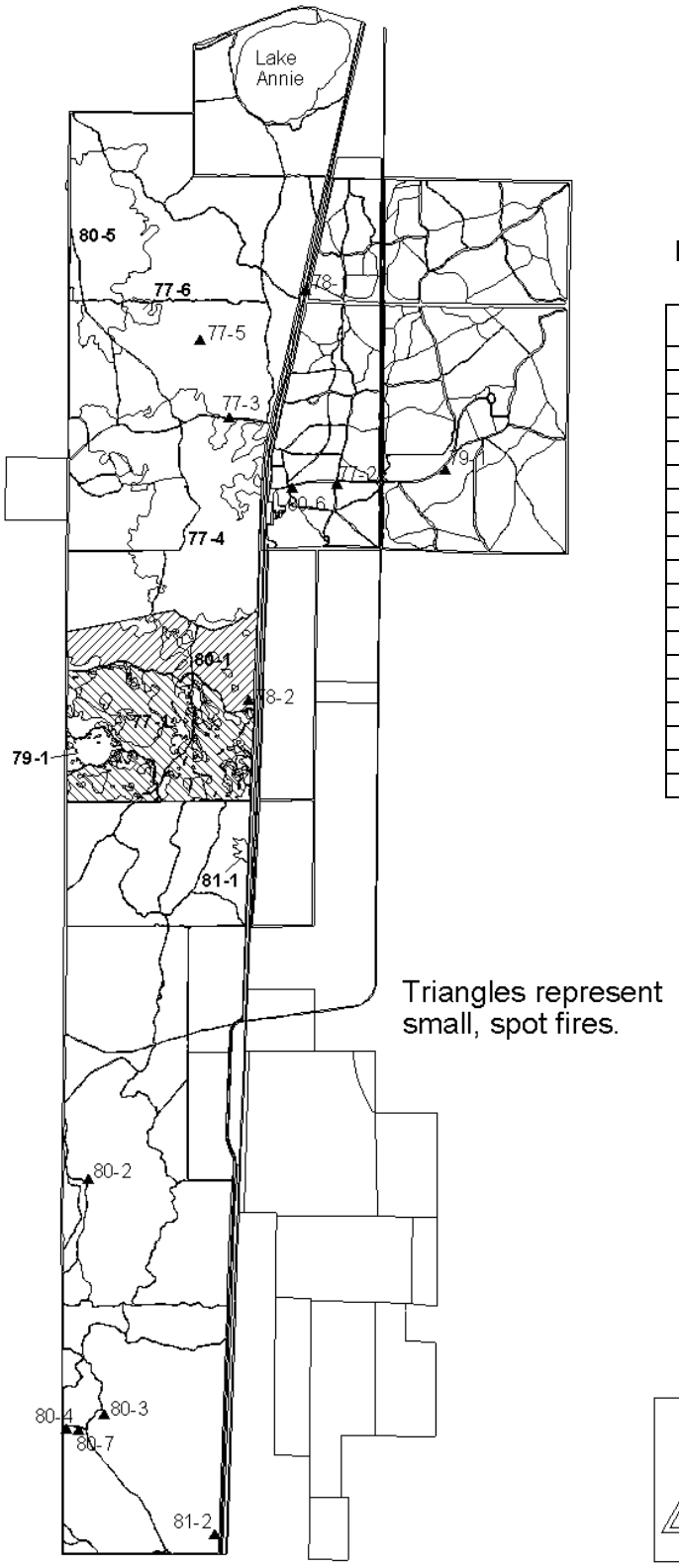
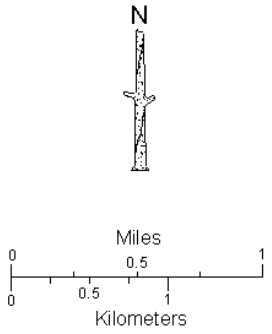
Fig. 6. Fires at Archbold Biological Station, 1977-1981



Triangles represent small, spot fires.

FIRE HISTORY, 1977 - 1981

FIRE #	DATE	CAUSE	AC	HA	KBD
77-1	21 Jan	Prescribed	202.3	81.8	507
77-2	26 May	Lightning	0.2	0.1	626
77-3	26 May	Lightning	0.2	0.1	626
77-4	26 May	Lightning	246.4	99.7	626
77-5	4 Jul	Lightning	0.2	0.1	475
77-6	26 Jul	Lightning	5.0	2.0	470
78-1	23 Mar	Accidental	0.2	0.1	194
78-2	Jul	Lightning	0.2	0.1	120
79-1	28 May	Lightning	14.9	6.0	418
79-2	30 Aug	Lightning	0.2	0.1	265
80-1	25 Jan	Prescribed	100.9	40.8	472
80-2	21 May	Lightning	0.2	0.1	613
80-3	21 May	Lightning	0.2	0.1	613
80-4	21 May	Lightning	0.2	0.1	613
80-5	7 Jul	Lightning	120.4	48.7	517
80-6	24 Jul	Lightning	0.2	0.1	273
80-7	Jul	Lightning	0.2	0.1	300
81-1	25 Apr	Accidental	4.9	2.0	679
81-2	23 May	Lightning	0.2	0.1	668



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F. Initial Fire Planning Era (1982 - 1987)

During the 1980's the first Fire Management Plan for the Station was created (Myers, unpublished document 1984). Specific plans and dates for burning units were set, though much of the planning was not implemented due, in part, to two large prescribed/escaped fires. The first prescribed fires on Red Hill also occurred during this period, though accidental and lightning fires were still suppressed on this part of the Station. Research for individual burns was sometimes planned with great detail, and effort was put into involving many scientists in different projects for each burn unit. Permanent vegetation plots, small mammal transects, and herp arrays were set up in some units. Some of these experiments were followed for several years post-fire (e.g., Johnson and Abrahamson 1990, Myers 1985, and Abrahamson 1995, W.G. Abrahamson and J.R. Abrahamson 1996, W.G. Abrahamson and C.R. Abrahamson 1996).

Although several prescribed fires were conducted during this era, burning was still not being used to the same extent as present. Prescribed fires were conducted with small crews, little safety equipment and limited training. There were 6 prescribed fires, 3 accidental fires and 15 lightning fires during the period (Fig. 6).

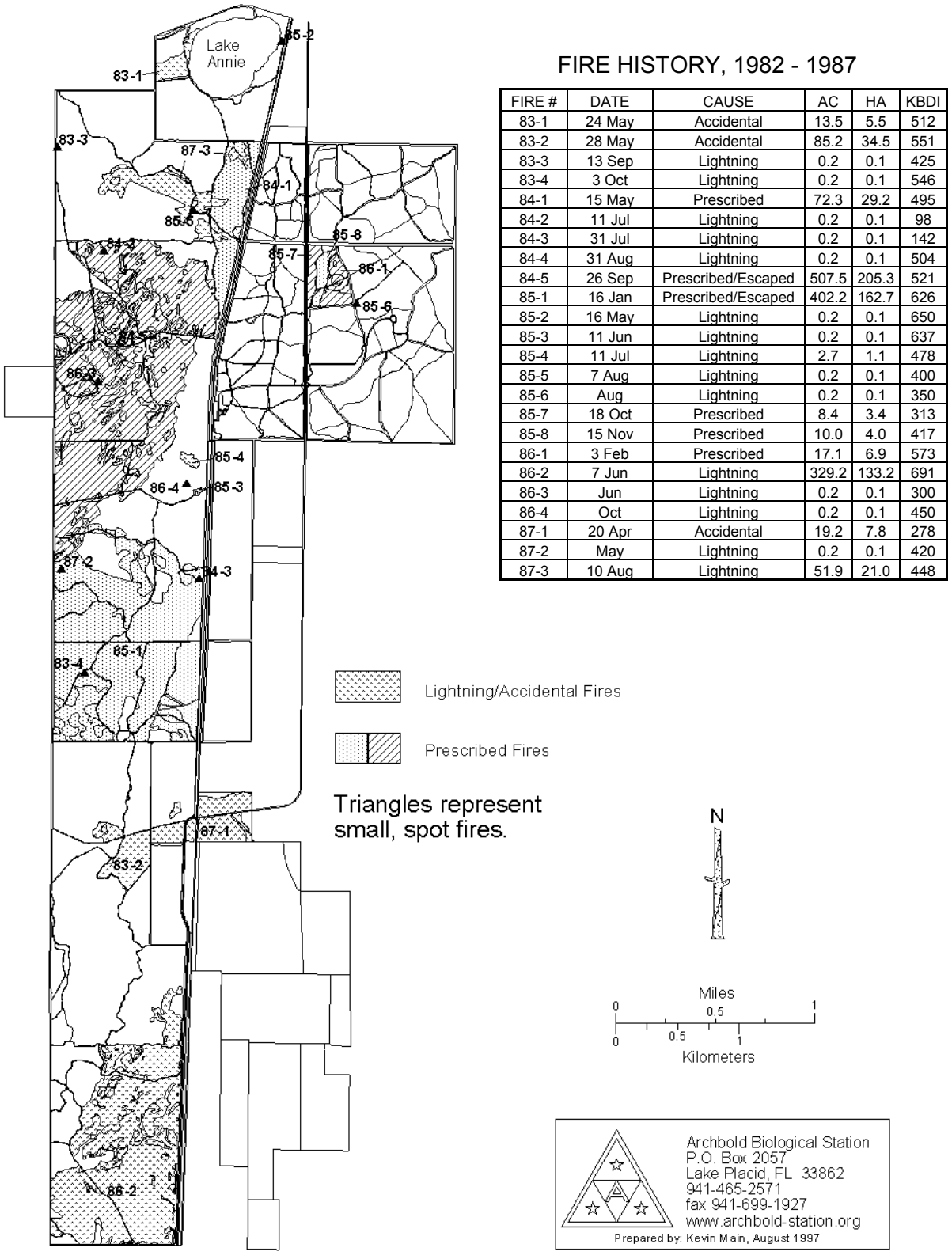
G. The Current Era (1988 - present)

At present, prescribed fires are used extensively for fire management at the Station. Though the plan leaves room for lightning-ignited fires, these seldom occur, due in part to the large-scale habitat fragmentation that now makes the Station an island surrounded by citrus groves and cattle ranches. Since 1967, only 5 lightning-ignited fires have grown to more than 20 hectares in size. This rate of burning is not sufficient to properly maintain the habitat. Lack of lightning-ignited fires may also be due in part to reduced fuel loads as a result of prescribed burning, making prescribed burning more critical to meeting goals.

Station staff have performed 64 prescribed fires between 1988 and 1996, burning 899 hectares (2,222 ac) (Fig. 7). Fire size ranged from less that one hectare to over 73 hectares (180 ac). Eric S. Menges and Kevin N. Main have performed most of the fire management planning for the Station in the 1990's.

Active fire management has greatly increased during the 1990's. Better safety equipment, more fire training, and improved lighting and holding techniques continue to benefit the fire program. Burn unit monitoring, both pre- and post-fire are an important part of each burn. Research on the effects of fire continues to be an important part of each burn. Details of fire management, planning and monitoring are the subject of the rest of this document.

Fig. 7. Fires at Archbold Biological Station, 1982-1987



FIRE HISTORY, 1982 - 1987

FIRE #	DATE	CAUSE	AC	HA	KBDI
83-1	24 May	Accidental	13.5	5.5	512
83-2	28 May	Accidental	85.2	34.5	551
83-3	13 Sep	Lightning	0.2	0.1	425
83-4	3 Oct	Lightning	0.2	0.1	546
84-1	15 May	Prescribed	72.3	29.2	495
84-2	11 Jul	Lightning	0.2	0.1	98
84-3	31 Jul	Lightning	0.2	0.1	142
84-4	31 Aug	Lightning	0.2	0.1	504
84-5	26 Sep	Prescribed/Escaped	507.5	205.3	521
85-1	16 Jan	Prescribed/Escaped	402.2	162.7	626
85-2	16 May	Lightning	0.2	0.1	650
85-3	11 Jun	Lightning	0.2	0.1	637
85-4	11 Jul	Lightning	2.7	1.1	478
85-5	7 Aug	Lightning	0.2	0.1	400
85-6	Aug	Lightning	0.2	0.1	350
85-7	18 Oct	Prescribed	8.4	3.4	313
85-8	15 Nov	Prescribed	10.0	4.0	417
86-1	3 Feb	Prescribed	17.1	6.9	573
86-2	7 Jun	Lightning	329.2	133.2	691
86-3	Jun	Lightning	0.2	0.1	300
86-4	Oct	Lightning	0.2	0.1	450
87-1	20 Apr	Accidental	19.2	7.8	278
87-2	May	Lightning	0.2	0.1	420
87-3	10 Aug	Lightning	51.9	21.0	448

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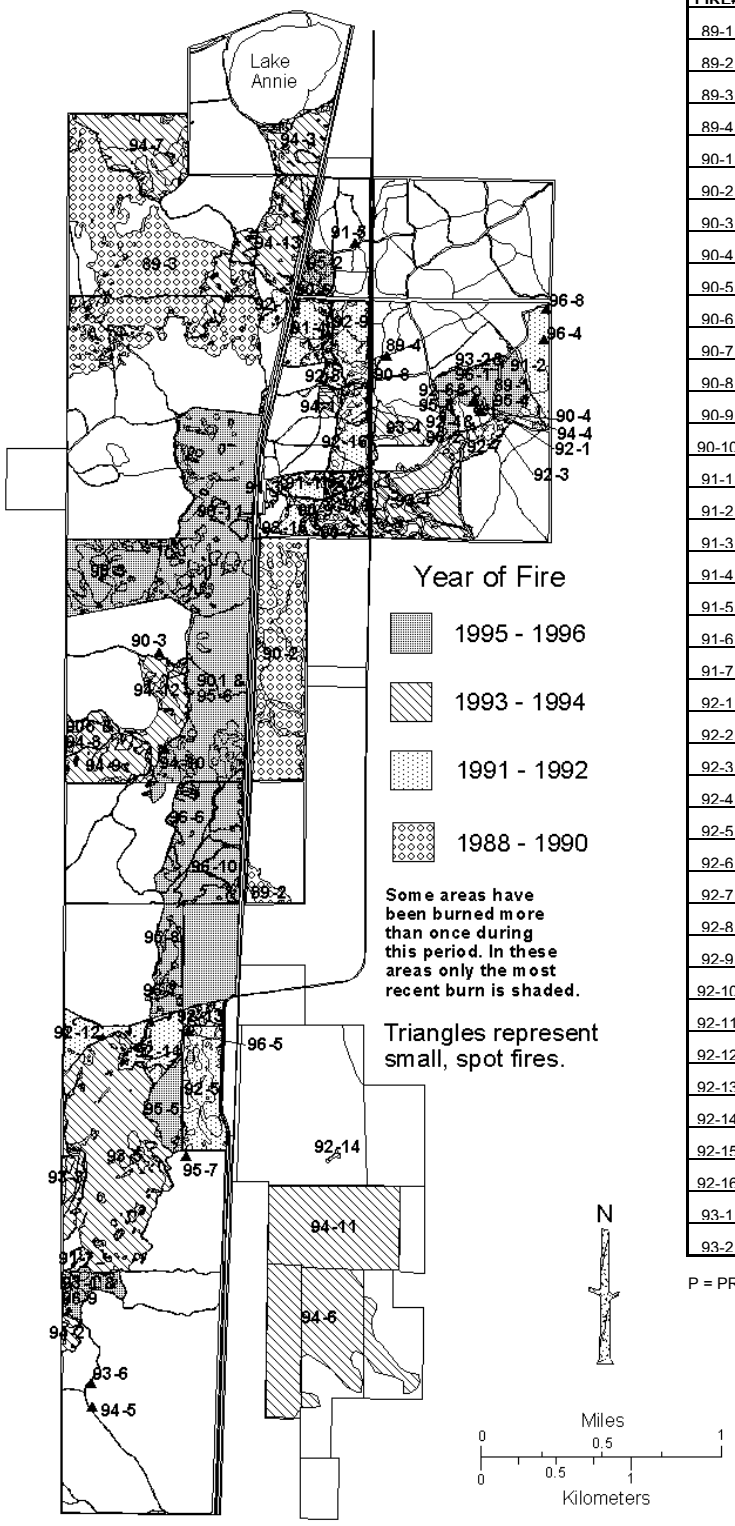
Fig. 8. Fires at Archbold Biological Station, 1988-1996



FIRE HISTORY, 1988 - 1996

FIRE#	DATE	CAUSE	AC(HA)		FIRE#	DATE	CAUSE	AC(HA)
89-1	13 Feb	P	4.5(1.8)		93-3	16 Feb	P	18.2(7.4)
89-2	15 Mar	A	10.2(4.1)		93-4	25 May	P/E	90.0(36.4)
89-3	22 May	L	325.4(131.6)		93-5	26 Jul	P	184.0(74.4)
89-4	14 Jun	L	0.2(0.1)		93-6	26 Aug	L	0.2(0.1)
90-1	26 Mar	P	123.4(49.9)		94-1	10 Feb	P	6.7(2.7)
90-2	28 Mar	P	136.5(55.2)		94-2	11 Feb	P	6.0(2.4)
90-3	25 Jul	L	0.2(0.1)		94-3	22 Feb	P	36.2(14.6)
90-4	27 Oct	P	0.2(0.1)		94-4	24 Mar	L	0.2(0.1)
90-5	28 Oct	P	15.8(6.4)		94-5	18 Apr	L	0.2(0.1)
90-6	29 Oct	P	3.8(1.5)		94-6	10 Jun	P/E	120.0(48.5)
90-7	29 Oct	P	5.8(2.3)		94-7	21 Jun	P	30.0(12.1)
90-8	30 Oct	P	1.0(0.4)		94-8	27 Jun	P	16.7(6.8)
90-9	6 Nov	P	8.8(3.6)		94-9	6 Jul	P	34.8(14.1)
90-10	11 Nov	P	2.0(0.8)		94-10	7 Jul	L	1.0(0.4)
91-1	9 Apr	P	12.5(5.1)		94-11	8 Jul	P	128.0(51.8)
91-2	1 May	P	58.8(23.8)		94-12	1 Aug	P	35.0(14.2)
91-3	4 Jun	P	1.6(0.6)		94-13	4 Aug	P/E	80.0(32.4)
91-4	17 Jul	P	25.5(10.3)		94-14	15 Dec	P	18.4(7.4)
91-5	26 Jul	L	0.2(0.1)		95-1	9 Jan	P	3.0(1.2)
91-6	28 Oct	P	14.0(5.7)		95-2	10 Jan	P	10.9(4.4)
91-7	29 Oct	P	8.0(3.2)		95-3	10 Mar	P	2.7(1.1)
92-1	8 Jan	P	2.2(0.9)		95-4	17 May	P	19.5(7.9)
92-2	10 Feb	P	10.0(4.0)		95-5	24 May	P	25.0(10.1)
92-3	12 Feb	P	2.2(0.9)		95-6	15 Jun	P	129.0(52.2)
92-4	12 Feb	P	3.7(1.5)		95-7	Jul	L	0.2(0.1)
92-5	13 Feb	P	57.0(23.1)		95-8	14 Sep	P	31.0(12.5)
92-6	11 May	P	5.0(2.0)		96-1	25 Mar	P	26.0(10.5)
92-7	13 May	P	10.7(4.3)		96-2	6 May	P	5.0(2.0)
92-8	19 May	P	7.2(2.9)		96-3	7 May	P	68.0(27.5)
92-9	20 May	P	29.5(11.9)		96-4	12 May	A	2.0(0.8)
92-10	10 Jul	L	7.9(3.2)		96-5	3 Jun	P	2.0(0.8)
92-11	20 Jul	P	27.5(11.1)		96-6	14 Jun	P	37.0(15.0)
92-12	22 Jul	P	21.3(8.6)		96-7	1 Jul	P	25.0(10.1)
92-13	23 Jul	P	9.6(3.9)		96-8	3 Jul	P	1.0(0.4)
92-14	17 Aug	L	0.2(0.1)		96-9	12 Jul	P	20.0(8.1)
92-15	7 Dec	P	15.0(6.1)		96-10	17 Jul	P	60.0(24.3)
92-16	9 Dec	P	30.1(12.2)		96-11	18 Jul	P	175.0(70.8)
93-1	29 Jan	P	19.2(7.8)		96-12	26 Jul	P	90.0(36.4)
93-2	2 Feb	P	15.0(6.1)					

P = PRESCRIBED, P/E = PRESCRIBED/ESCAPED, L = LIGHTNING, A = ACCIDENTAL

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H. History of Burn Seasons

Fires have occurred in every month at the Station since records were kept in 1967 (Fig. 9). Lightning fires have occurred during every month except December and January, although the vast majority of the area burned by lightning-ignited fires has occurred in May through August. Large areas burned during several lightning-ignited or prescribed/escaped fires, especially in the mid-1980's (Fig. 9), accounting for an erratic pattern of area burned across the months. January, March, May, and July have seen the greatest areas burned.

In the last few years, nearly all the burned area has resulted from prescribed fires (Fig. 10). Total area burned has been greatest in July, May, and June. Prescribed burn area has been greatest in July (Fig. 11). Very little area has been burned in April or November. The distribution of burned area (mainly from prescribed fires) across the seasons since 1989 closely mimics lightning-caused acreages burned in south Florida, suggesting that the prescribed fire program now mimics the natural seasonality of lightning fires (Robbins and Myers 1992).

Fig. 9. Number of Fires by Season and Ignition Source, 1967-1996, at Archbold Biological Station, Highlands County, Florida.

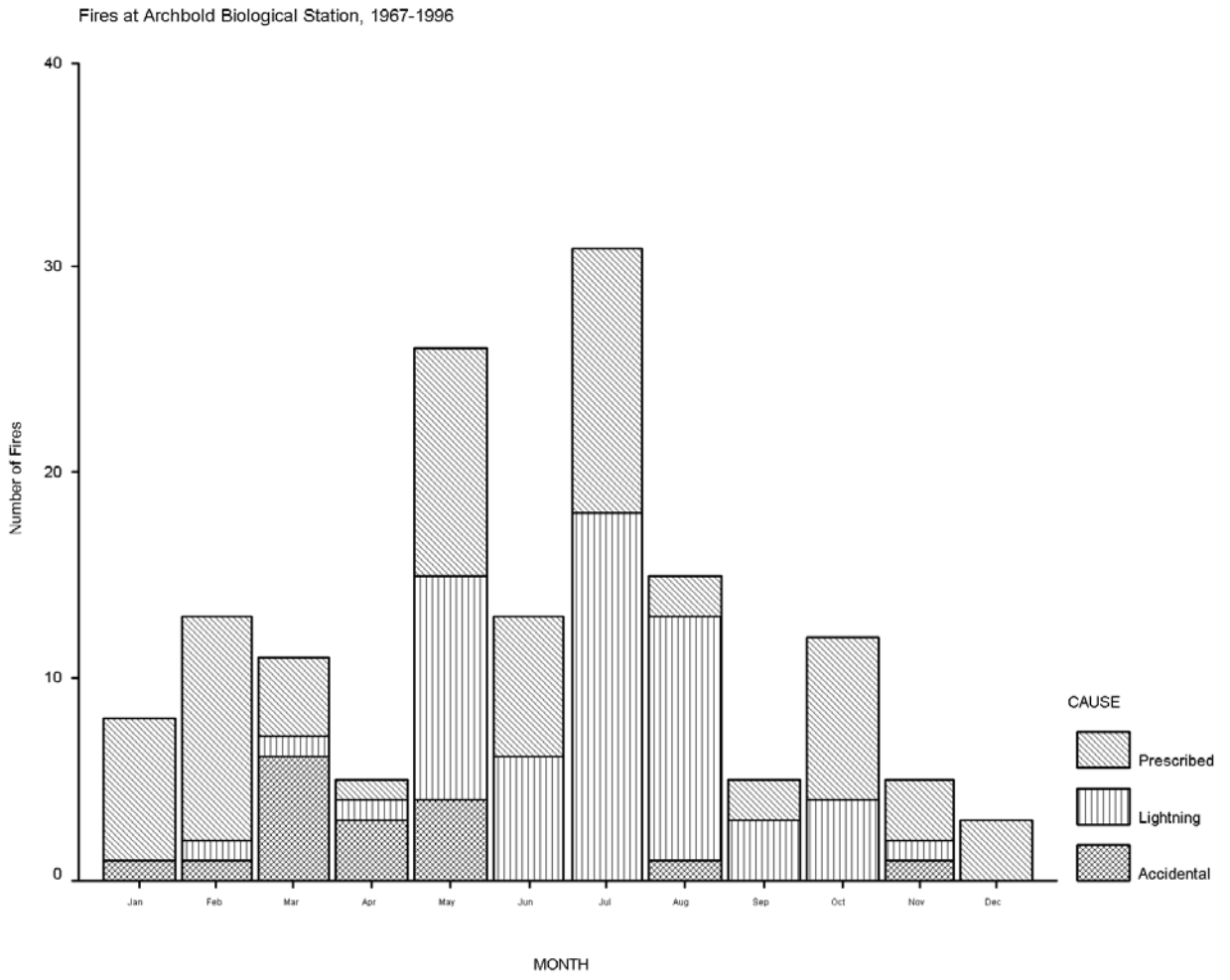


Fig. 10. Area of Fires by Season and Ignition Source, 1967-1996, at Archbold Biological Station, Highlands County, Florida.

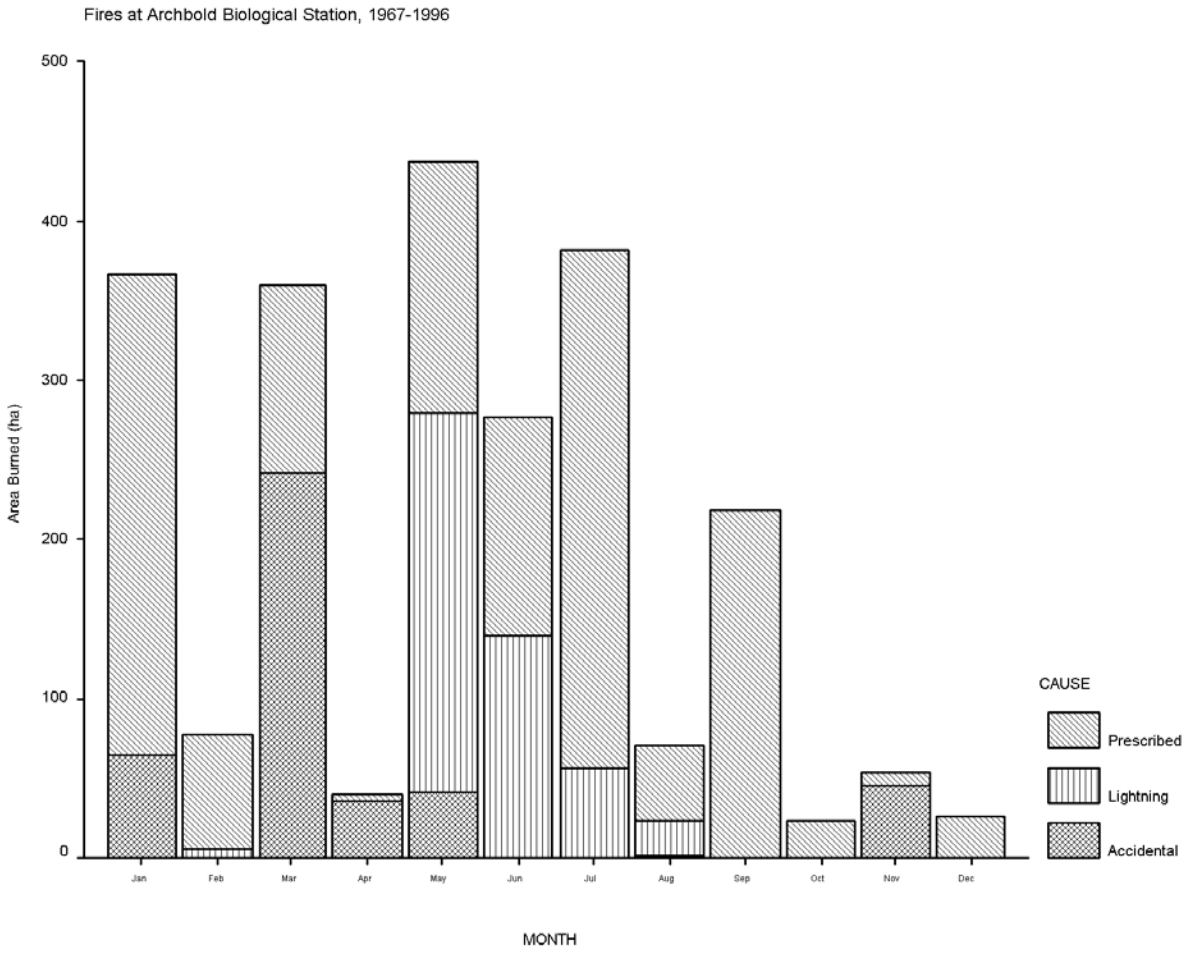
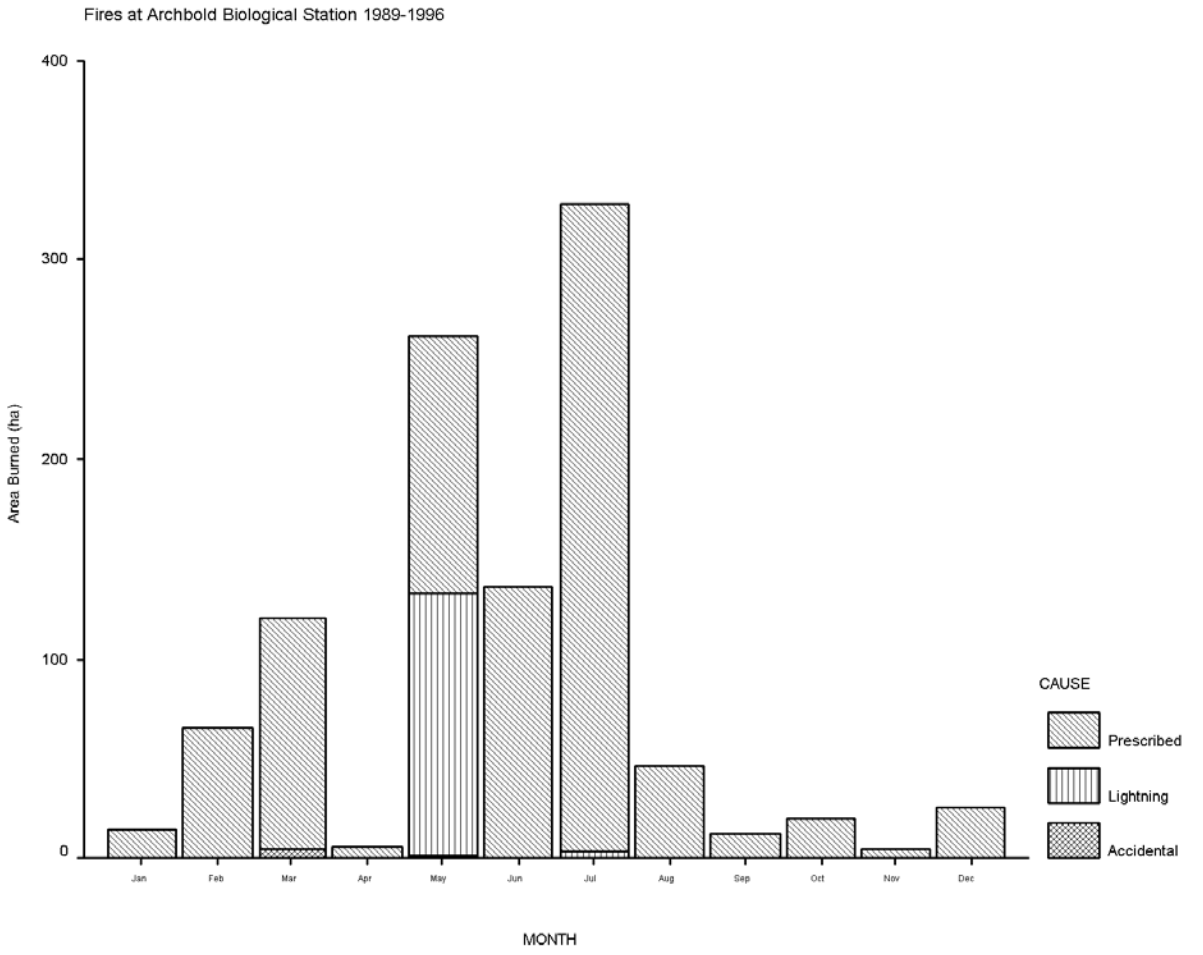


Fig. 11. Area of Fires by Season and Ignition Source, 1989-1996, at Archbold Biological Station, Highlands County, Florida.



III. FIRE PLANNING

A. Approach to Fire Planning.

Fire planning at Archbold Biological Station involves the translation of the eight general goals into plans for (1) when each unit will be prescribed burned, and (2) the likely response to wildfires in each burn unit. The goal is a system that is built around using fire to enhance biological diversity (goals A and B) and mimic natural processes (goal C), but is also flexible to particular research needs (goal D), and the needs to provide educational opportunities and interact with other fire management agencies (goals E and F), reduce hazards (goal G), and conduct burns safely (goal H).

The system is built around fire-return intervals, which are a range of years between fires within which individual burn units are planned to re-burn. Using a range of years introduces variation and provides flexibility to meet other goals and to incorporate wildfires into the process.

The fire-return interval assigned to each unit is mainly a function of its vegetation. For each vegetation type at the Station, a modal fire frequency is assigned (see section III.B.). Variation around the modal fire frequency is provided by deliberate variation in the fire-return intervals for specific burn units, and by the nature of the vegetation. Because most burn units contain several vegetation types with different modal fire-return intervals, minority vegetation types within each unit will be burned at non-modal fire-return intervals. The application of the entire range of potential fire-return intervals to some area of each type of vegetation is a key part of the Station's approach to fire management (Table 4).

Most burning will be done during the natural fire season. Most presettlement ignitions at the Station were due to lightning. Although we have had lightning-ignited fires documented 10 months of the year (except December and January, Fig. 9), most of the area burned by lightning-ignited fires was between May and August (Fig. 9). May is clearly the modal time of year for large-scale lightning fires. Therefore, most prescribed fires will occur between May and August, with many in the month of May. However, a diversity of dates for prescribed fires will be retained. Winter burns, in particular, will be used in areas where fuel reduction is the primary goal, for training, and for specific research purposes.

The assignment of fire-return intervals to each vegetation type and to individual burn units does not address one problem: the Station is clearly behind schedule in its burn program. The many decades of fire suppression on the original property leave many hectares of land overdue for burns; in other words with longer intervals since the last fire than the maximum value for the assigned fire-return interval. In order to preserve a diversity of years since fire, we will not rush ahead to catch up. Rather, initial burns in overdue units will be phased in over a period of time corresponding to the normal fire-return interval. Therefore, when we do "catch up", we will have a full range of fire-return times within the assigned fire-return interval.

Table 4. Guiding Principles for Fire Management Using Modal Fire-return Intervals at Archbold Biological Station, Highlands County, Florida.

Component	**Rationale**
Use **range** rather than single return interval.	Avoid regular intervals. Maintain flexibility.
Apply **entire range** of fire-return intervals to each vegetation type, including very seldom burned.	Provide research and educational opportunities. Increase landscape diversity.
Burn majority or plurality of vegetation at **modal fire-return intervals**.	Manage most of land using evolutionarily and ecologically-relevant fire-return intervals.
Apply **lightning-season ignitions** to burn units when possible.	Manage land using season of natural ignitions.
Use **non-lightning-season ignitions** to reduce fuels and for research.	Effectively and safely burn areas with large fuel accumulation, promote research.
Move to **larger burns** and aggregated burns as feasible.	Increase the spatial grain of burns to favor wide range of species, burn more cost-effectively.
Tolerate **heterogeneity in fire intensity** including unburned patches.	Produce burns with realistic within-burn patchiness, provide research opportunities.
Maintain **flexibility** with regard to prescribed burn planning and wildfire control.	Provide greatest opportunities for future research and management.
Balance management for biodiversity and ecological processes with consideration of research and safety needs.	Dual missions of Archbold Biological Station, opportunities in basic and management-related research.

Although our emphasis is on fire-return intervals that are keyed to vegetation types across the Station and predominant in individual burn units, this is not the only criterion for assigning burn units to particular fire-return intervals. Among the other criteria, the most important may be endangered species management. We will attempt to manage most of the actual and potential occurrences for the most endangered species at appropriate fire-return intervals, with some variation for research purposes. These individual species considerations will modify some assignments based on vegetation.

We emphasize that the main points of using fire-return intervals, rather than a fixed number of years, is to increase heterogeneity, provide research opportunities, and create a plan with flexibility (Table 4). Heterogeneity is also provided by burning some areas of vegetation at intervals other than the modal interval. Research that can contrast the effects of different fire regimes will then be used to modify fire regimes to better accomplish our goals. We also seek to promote variation in timing of fires, fire patchiness, fire intensity, and size of burns. The fire management plan is also intended to provide for flexibility and to balance management for biodiversity and ecological processes with consideration of research needs. We summarize our approach in Table 4.

B. Defining Modal Fire Frequencies by Vegetation Type

Modal fire-return intervals are defined by vegetation types, based on Abrahamson et al.'s (1984) classification and accompanying maps. Additional information on vegetation types found at the Station can be found in Abrahamson 1984a,b (several types), Myers 1985 (sandhill and sand pine scrub), Myers and White 1987 (sandhill), Myers 1990 (sandhill and scrub), Johnson and Abrahamson 1990 (rosemary scrub), Abrahamson and Hartnett 1990 (flatwoods and scrubby flatwoods), Blanchard 1992 (sand pine scrub), Schmalzer and Hinkle 1992, 1996 (oak-palmetto scrub), Stout and Marion 1993 (several types), Menges et al. 1993 (several types), Guerin 1993 (sandhill), Ostertag and Menges 1994 (scrubby flatwoods), Menges and Kohfeldt 1995 (rosemary scrub and scrubby flatwoods), Greenberg et al. 1995 (sand pine scrub), Abrahamson and J. R. Abrahamson 1996 (sand pine scrub), Abrahamson and C. R. Abrahamson 1996 (scrubby flatwoods and flatwoods), Hawkes and Menges 1996 (rosemary scrub), Menges and Hawkes 1997 (several types), Menges 1997 (scrub), and Halpern and Menges submitted (scrubby flatwoods and flatwoods).

The vegetation at the Station is mainly scrubby flatwoods, flatwoods, and seasonal ponds (Figures 12 and 13). These occur primarily in the large West Section and in the Hicoria corridor in a complex mosaic. Hickory-dominated scrub (hickory-phase of southern ridge sandhill; Abrahamson et al. 1984) occurs in several areas of the Station, especially in tracts near Old State Road 8. Sand pine scrub dominated by oaks and typical sandhill are concentrated in the original property. Rosemary scrub occurs as scattered islands within the mosaic with scrubby flatwoods (Quintana-Ascencio and Menges 1996), and is significant beyond its areal extent because it supports many endangered plants.

Fig. 12. Vegetation Map of Archbold Biological Station

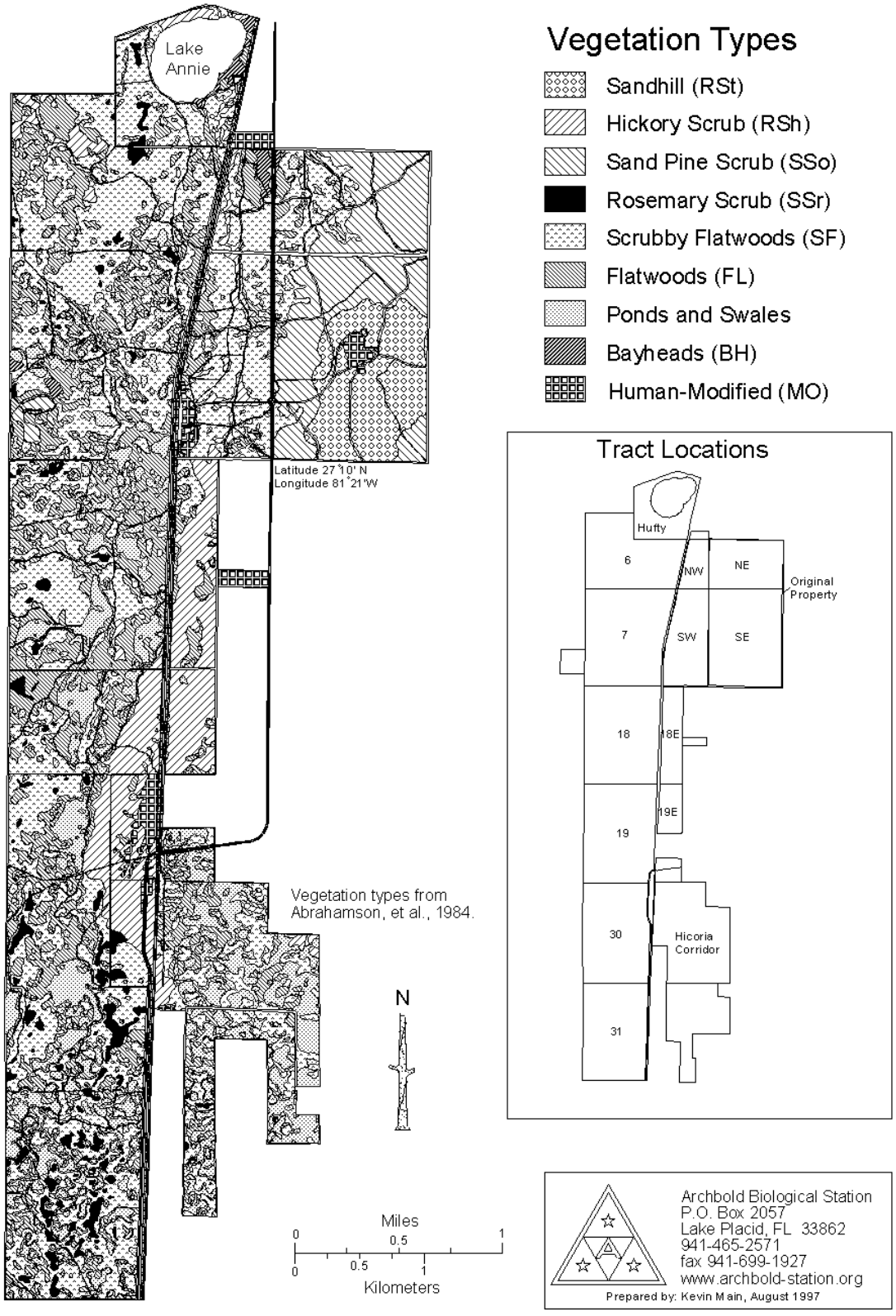
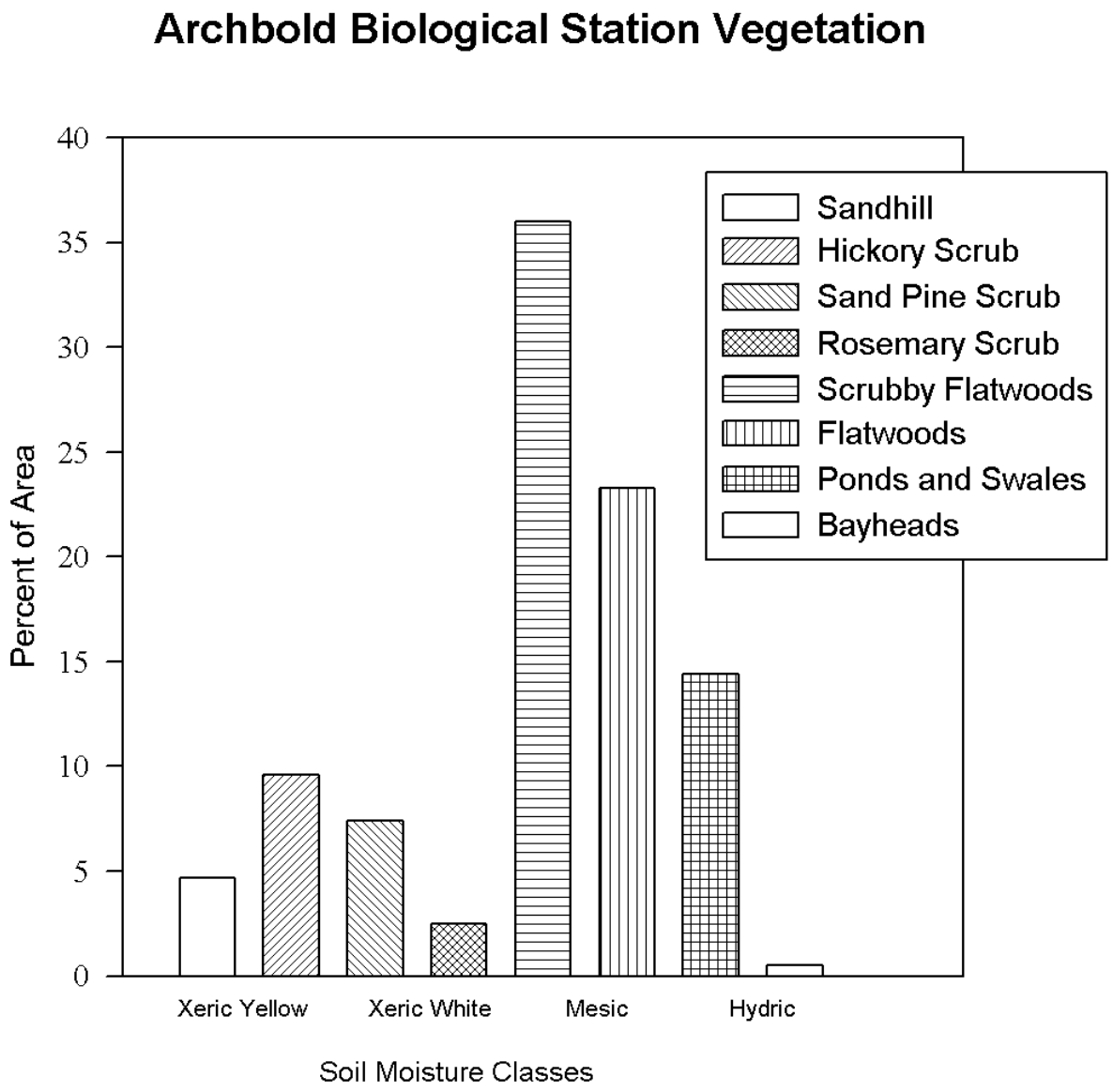


Fig. 13. Percent of Area of in Major Vegetation Types at Archbold Biological Station, Highlands County, Florida.



The Abrahamson vegetation maps (Abrahamson et al. 1984) have now been digitized into an Arc-Info Geographic Information System (GIS), and additional mapping of recently acquired tracts has followed the Abrahamson scheme. Although the original vegetation mapping is now over a decade old, most vegetation types are fairly stable (Peroni and Abrahamson 1986). The major changes are probably successional change in fire-suppressed areas, as bayheads have invaded seasonal ponds and wet flatwoods and scrub plants have continued to invade sandhill (Givens et al. 1984, Peroni and Abrahamson 1986, Menges et al. 1993). Vegetation sub-types within seasonal ponds also do not appear well-mapped today.

Modal fire-return intervals are defined by vegetation type (Table 5). These intervals were determined by scientific understanding of the natural fire-return intervals, found in the literature (summarized in Table 5) and by discussions with staff and other scientists. Nonetheless, because complete fire histories do not exist for our area, natural fire-return intervals are mainly inferred by studies of life histories of component species, fuel characteristics as a function of fire-return interval, and fire behavior observations in different fuels. Our inferences of natural fire-return intervals are presumed to represent evolutionarily relevant fire frequencies to which many organisms are adapted. Thus, burning the majority of a vegetation type at that modal fire-return interval will help us meet our goals of enhancing biological diversity and mimicking natural processes. Providing variation away from these modal intervals should protect us against mistakes due to ignorance of the true fire-return intervals and our inability to apply fire at a landscape scale.

Five fire-return intervals are used in the Archbold Biological Station Fire Management Plan (Table 5). The shortest interval is 2-5 years and is the modal fire-return interval for turkey-oak dominated sandhill (RSt), swales, and cutthroat-dominated flatwoods (FLc). A 6-9 year fire-return interval is modal for other flatwoods, seasonal ponds, and some scrubby flatwoods. The intermediate fire-return interval (10-19 years) is modal for the remainder of scrubby flatwoods and hickory scrub (RSh). For sand pine scrub (both oak and rosemary phase), the modal fire-return interval is 20-59 years. Other oak-dominated sand pine scrub is in the infrequently burned 60-100 year interval, along with all bayheads.

It should be emphasized that the evidence for determining modal fire-return intervals varies; and there may be controversy over some intervals. For example, life histories of the Florida scrub-jay (*Aphelocoma coerulescens*), Florida rosemary (*Ceratiola ericoides*), and sand pine (*Pinus clausa*) are a large part of the basis for determination of modal intervals for scrubby flatwoods, rosemary scrub, and oak-dominated sand pine scrub, respectively (Table 5). Fire-return intervals for sandhills and bayheads appear to enjoy general agreement. In contrast, we know little about hickory-dominated sandhill (RSh), which has floristic similarities to frequently burned sandhill but structurally seems to respond to fire as a scrub, and contains specialist species (e.g., *Dicerandra frutescens*) that may not be adapted to frequent fire. In this case, the intermediate modal fire-return interval is partly a matter of bet-hedging. Our assignment of flatwoods to mainly a 6-9 year fire-return interval rather than to the shorter 2-5 year interval reflects the fact that the Station landscape is dominated by scrub, whereas other flatwoods in marsh matrices or that dominate large areas may tend to burn more frequently.

Table 5. Fire-return Intervals by Vegetation Type at Archbold Biological Station, Highlands County, Florida.

Fire-return Interval (years)	**Modal for These Vegetation Types**	**Key Species and Groups (Fire-return Interval)**	**Citation(s)** **(Fire-return Interval in parentheses)**
2-5	Sandhill (RSt)	Grasses, Forbs	FNAI 1990 (2-5), Myers 1990 (1-10), Stout and Marion 1993 (LLP: 1-3), Menges and Hawkes 1997 (1-10)
	Swales (SW)	Graminoid	FNAI 1990 (1-5)
	Cutthroat Flatwoods (FLc)	Cutthroat	TNC 1989 (1-10), Bacchus 1992 (3-4)
6-9	Flatwoods (FL)	RCW (1-3; not at ABS)	FNAI 1990 (mesic: 1-8; wet: 3-10), Stout and Marion 1993 (LLP: 1-3)
	Seasonal Ponds	Graminoids	FNAI 1990 (basin marsh: 1-10), Kushlan 1990 (3-5)
6-9 and 10-19	Scrubby Flatwoods (Oak Scrub; SF)	Scrub-jay	FNAI 1990 (8-25), Fitzpatrick et al. 1991 (10-20), Menges and Hawkes 1997 (5-20)
10-19	Hickory Scrub (RSh)	Scrub mint (?5-?20)	
20-59	Rosemary Scrub (SSr)	Endemic Herbs (?<20)	Johnson 1982 (10-40), Menges and Hawkes 1997 (15-100)
20-59+ 60-100	Sand Pine Scrub (SSo)	Sand Pine	Abrahamson et al. 1984 (>30), Richardson 1977 (20-40), FNAI 1990 (20-80), Myers 1990 (10-100)
60-100	Bayhead (BH)	Trees (?>30)	FNAI 1990 (baygall:50-100)

(Vegetation codes from Abrahamson et al. 1984)

C. Designing Individual Burn Units

The actual boundaries of burn units are relatively fixed, being largely determined by permanent firelanes and primitive roads (Fig. 14). Some boundaries, especially between units that differ by a letter within a number (e.g. 2A vs. 2B), are set by trails. These trails will always need additional mowing or other pre-fire preparation before they can serve as firebreaks. In many cases, these units can be combined to accomplish larger burns. In a very few cases, units are divided by soft breaks, such as mown or wet lines that may vary in placement from fire to fire.

D. Assigning Fire Frequency Classes to Individual Burn Units

The translation from general principles and modal fire-return intervals to a map of fire frequency classes for individual burn units is a complex and iterative process. It is based primarily on assigning modal fire-return intervals to each burn unit based on what the majority or plurality vegetation type is in the unit. Because most burn units have several vegetation types, this creates some variation in fire-return intervals for each vegetation type. This variation is augmented by deliberately choosing some non-modal fire-return intervals for certain burn units. In particular, infrequently burned intervals (60-100 years) were assigned to several units so that major vegetation types all had representation in this "long-unburned" category.

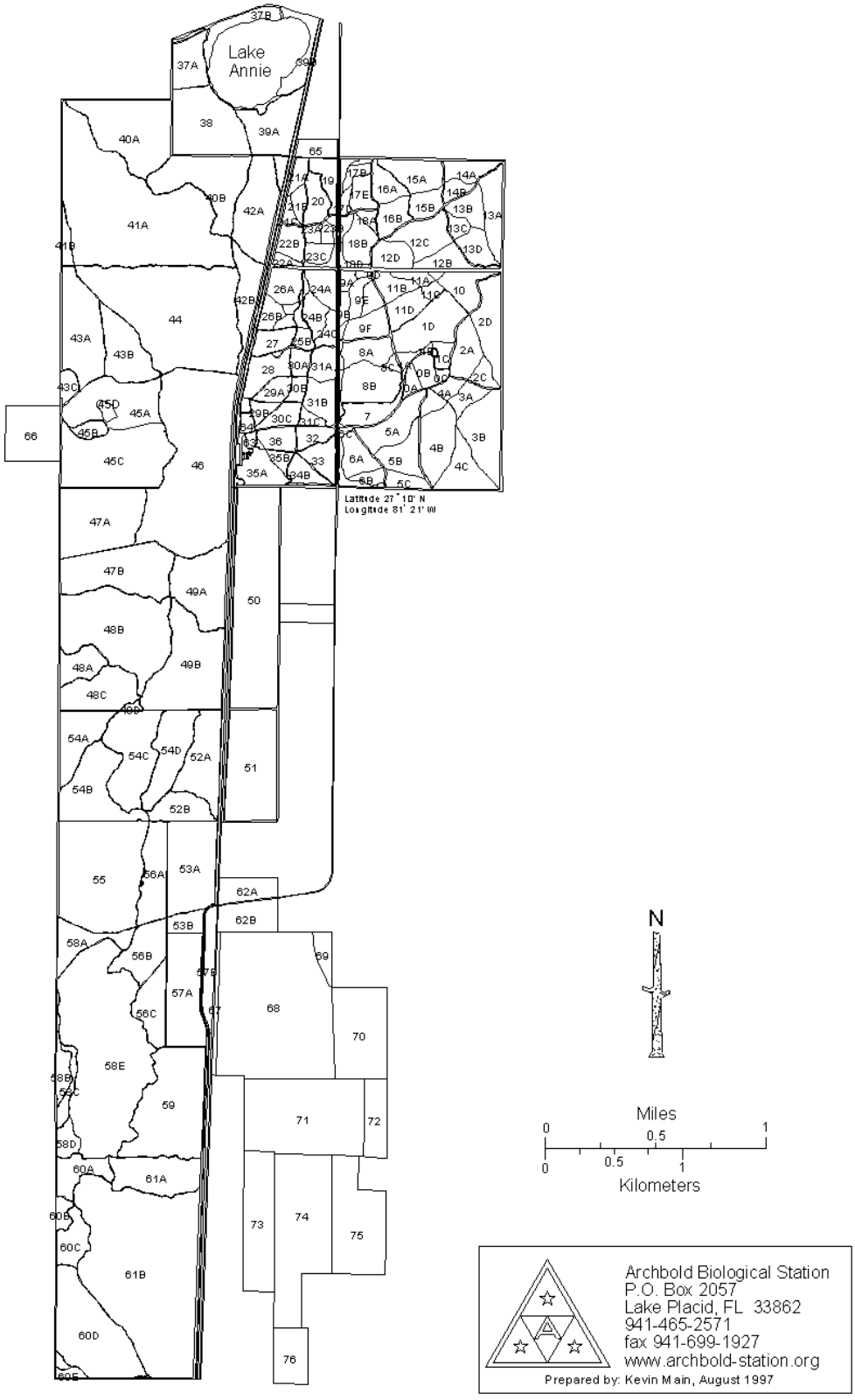
The diversity in fire-return interval may have a larger positive impact on goals (e.g., biodiversity) than would burning exactly on the mode for every fire. Therefore, we will burn individual units at both modal and non-modal intervals.

Additional factors affected the assignment of fire-return intervals to individual vegetation types. These include respecting the preferences of individual researchers performing long-term work (e.g., maintaining the long-unburned status of James N. Layne's mammal grids), preserving visual screens (e.g., at the north end of Lake Annie), and reducing fuel loads near buildings (e.g., the units just east of the Main Grounds). Grouping areas of similar burn frequency also occurred in some cases. This has several benefits. First, sequential burns can utilize recently burned areas as fire breaks. Second, adjacent burn units can be combined into larger, more realistically-sized burns, especially as initial burns reduce fuel loads. Finally, larger burns or larger areas of closely-timed burns can provide more realistic patch sizes for wider-ranging animals.

The assignment of fire-return intervals to individual burn units is regarded as somewhat flexible, and can be changed as more information becomes available, or as the priority of different goals changes.

Because the Station is a finite area and because vegetation types are not distributed randomly, there is no one solution that optimizes all fire-return intervals. Our goals in the iterative process of assigning fire-return intervals were to assign the majority or plurality of area for each vegetation type to the modal fire-return interval, and to provide cases of each fire-return interval for each vegetation type.

Fig. 14. Burn Units at Archbold Biological Station



Our most frequently-burned vegetation type is turkey-oak dominated sandhill vegetation (Fig. 15). The modal fire-return interval for this vegetation is 2-5 years, and the majority of the area is slated to burn every 2-5 or 6-9 years. Sandhill is juxtaposed with oak-dominated sand pine scrub on Red Hill, and therefore some sandhill falls within longer fire-return intervals. Trails and soft breaks have been used to burn sandhill portions of burn units without affecting sand pine scrub. Currently (1997), most of the sandhill area is overdue or due for prescribed fires (Fig. 15).

Also frequently burned are cutthroat-dominated communities (Fig. 16). Cutthroat grass (*Panicum abscissum*) is the dominant ground cover in these areas. The modal fire-return interval for cutthroat flatwoods is 2-5 years. Cutthroat-dominated ponds and zones of seasonal ponds cannot be easily separated from deeper zones, and are mainly in the 6-9 year fire-return interval. In practice, many fires will burn the cutthroat zones at pond margins but fail to burn interior pond zones that are flooded. Nonetheless, the actual assignment of cutthroat vegetation to fire-return intervals includes large areas in the 10-19 year fire-return interval (Fig. 16). This is inevitable due to the intermingling of flatwoods and ponds with scrubby flatwoods, which cannot be burned as frequently. More infrequent fires in cutthroat-dominated ponds and swales are generally not planned since these would be converted to other vegetation types under this regime. Currently, most cutthroat ponds and flatwoods are due or overdue for burning in the next five years.

Swales cover little of the Station and generally are burned every 2-5 years. Seasonal ponds have a modal fire-return interval of 6-9 years, but many will be burned less often for reasons discussed above. Most seasonal ponds and swales are due to be burned, or are overdue for burning, between 1997 and 2002 (Fig. 17).

Flatwoods, other than cutthroat-dominated flatwoods, have been assigned a modal fire-return interval of 6-9 years. However, many areas will be burned less often because of their juxtaposition with scrubby flatwoods (Fig. 18). Because flatwoods are widespread and interspersed with many other vegetation types, substantial areas are in most fire-return interval categories. Flatwoods appear resilient to a range of fire-return intervals, and probably vary considerably in flammability. Most of the flatwoods areas are due, but not overdue, for prescribed fire during the next five years (Fig. 18).

Scrubby flatwoods can be managed using fires in the interval of 6-19 years, and thus occupy two fire-return interval classes. This flexibility allows some units with mainly flatwoods and scrubby flatwoods to be burned more frequently, and some units with mainly scrubby flatwoods and rosemary scrub to be burned less often. Still, because all these vegetation types occur in a fine-grained mosaic, substantial areas of scrubby flatwoods fall outside the 6-19 year intervals (Fig. 19). The plurality of scrubby flatwoods is assigned to the 6-9 year fire-return interval. However, some scrubby flatwoods would probably not burn, or burn very patchily, at this return rate. Much of the scrubby flatwoods area of the Station is due for burning between 1997 and 2002 (Fig. 19).

Fig. 15. Distribution of Area of Turkey Oak Sandhill (RSt) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

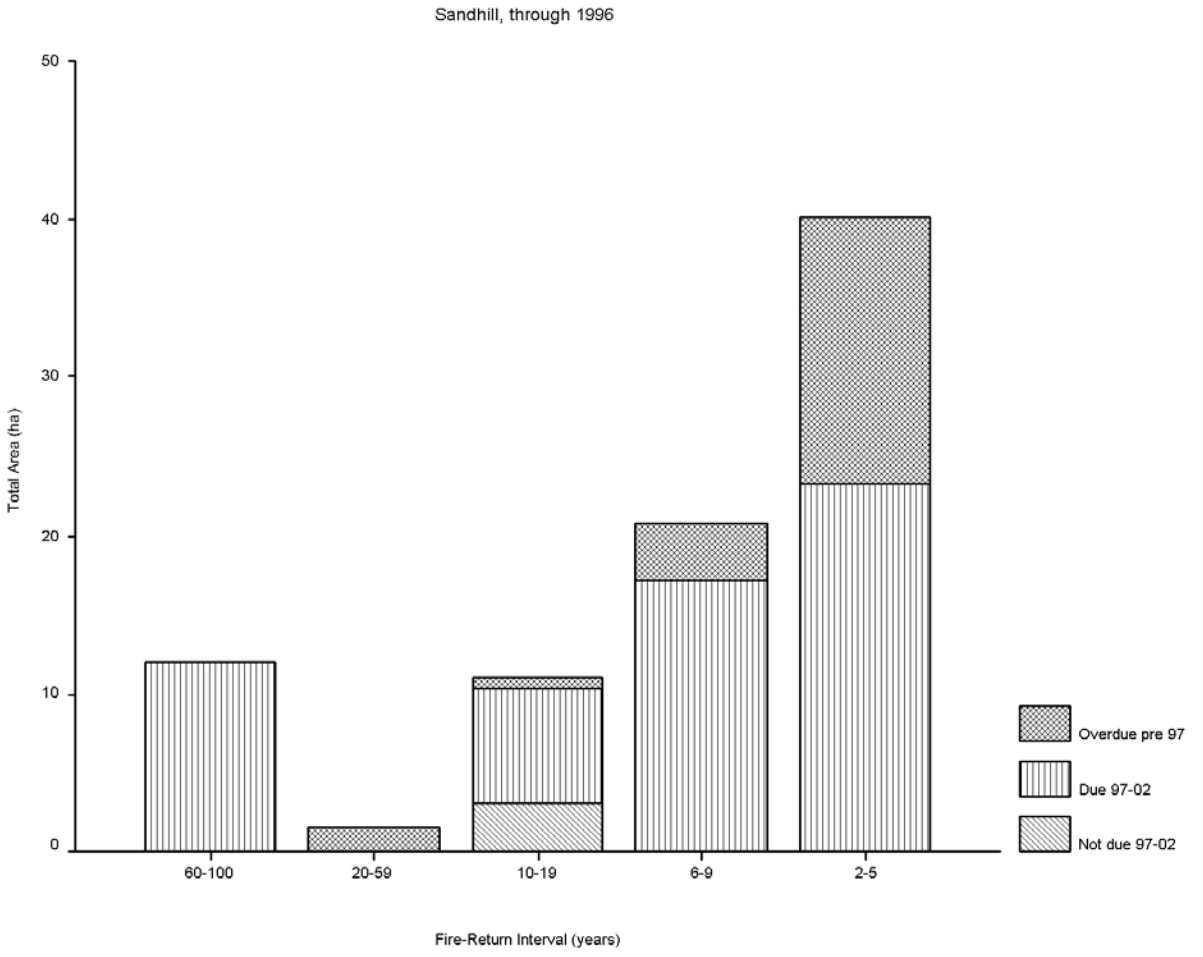


Fig. 16. Distribution of Area of Cutthroat-dominated Communities (Flatwoods; FLc, and ponds) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

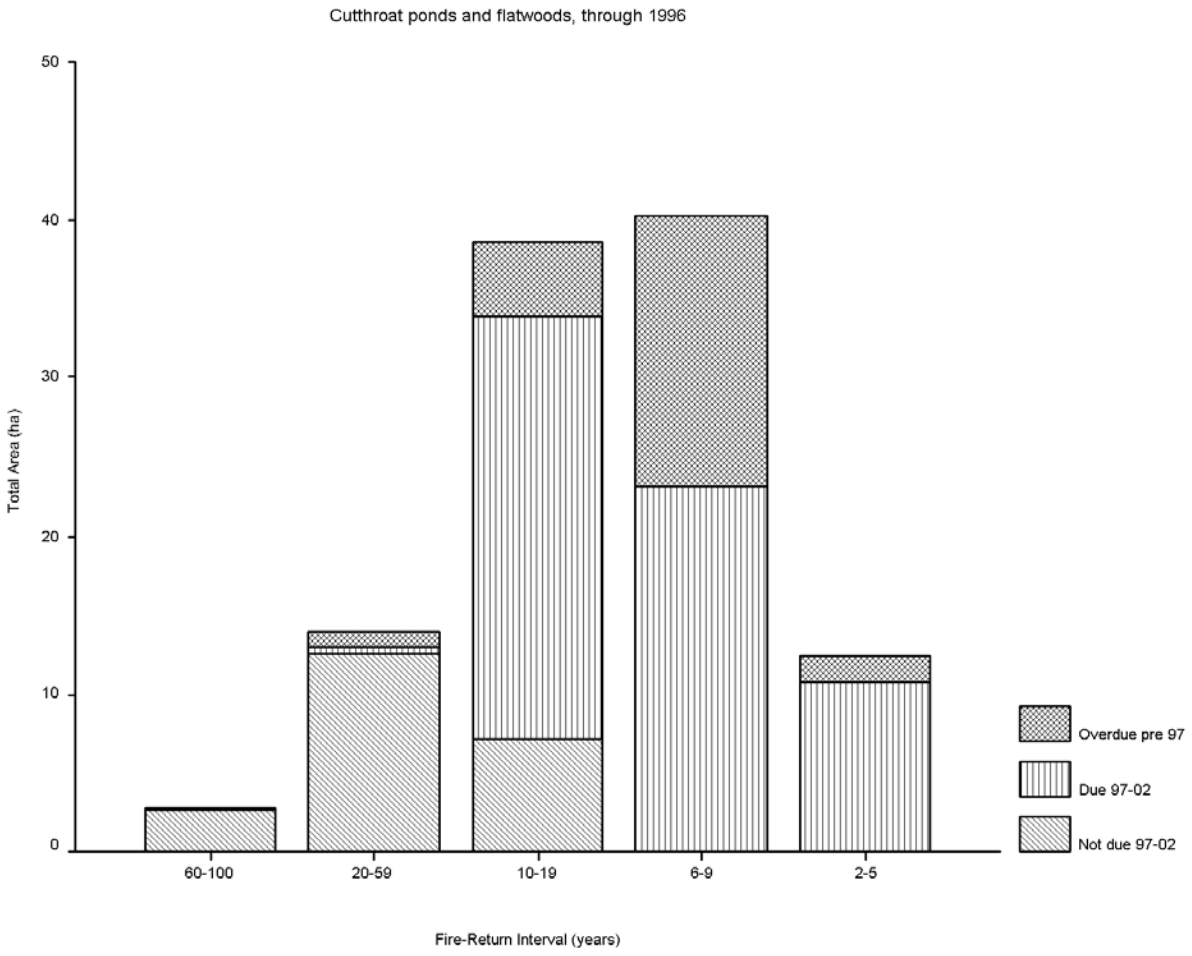


Fig. 17. Distribution of Area of Seasonal Ponds and Swales Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

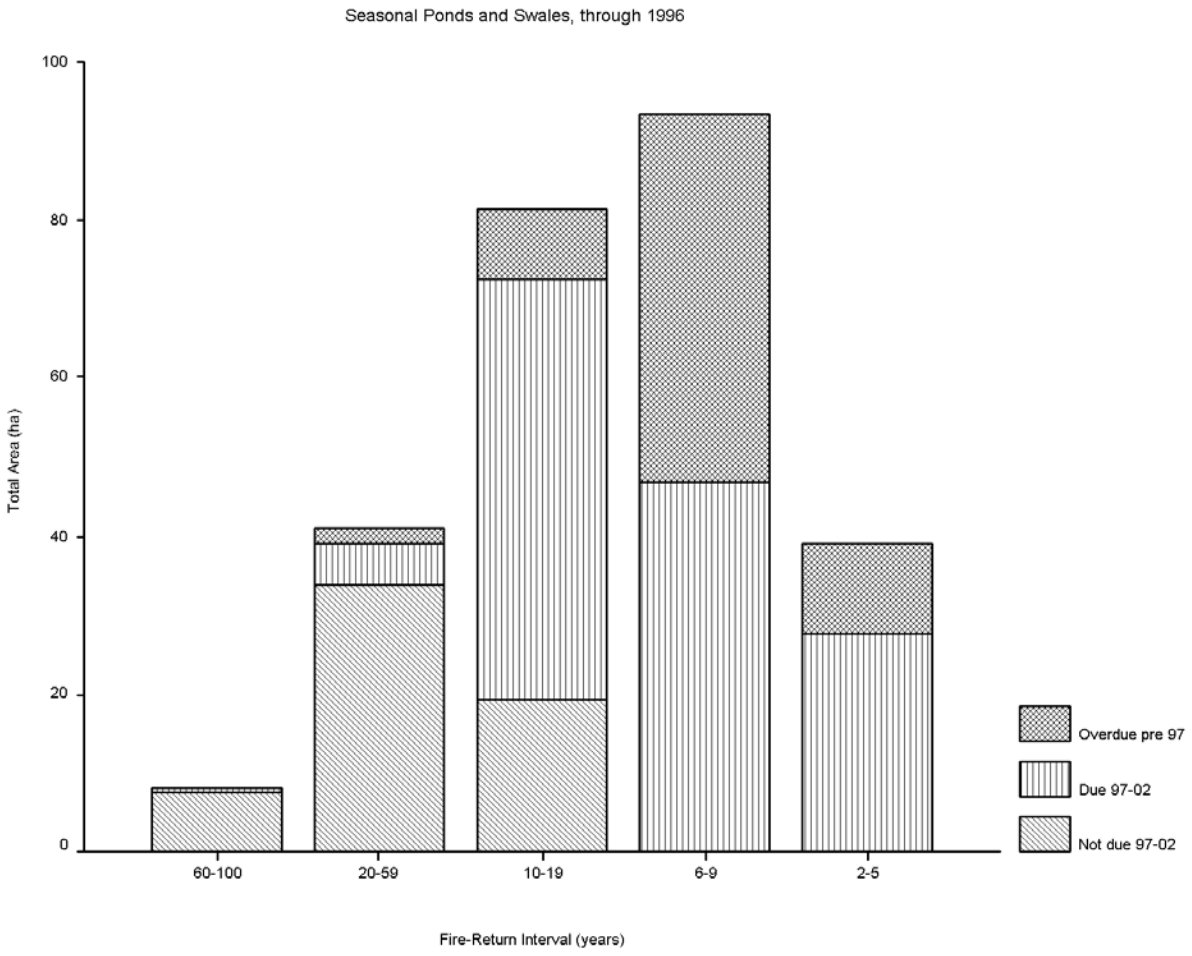


Fig. 18. Distribution of Area of Flatwoods (FL) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

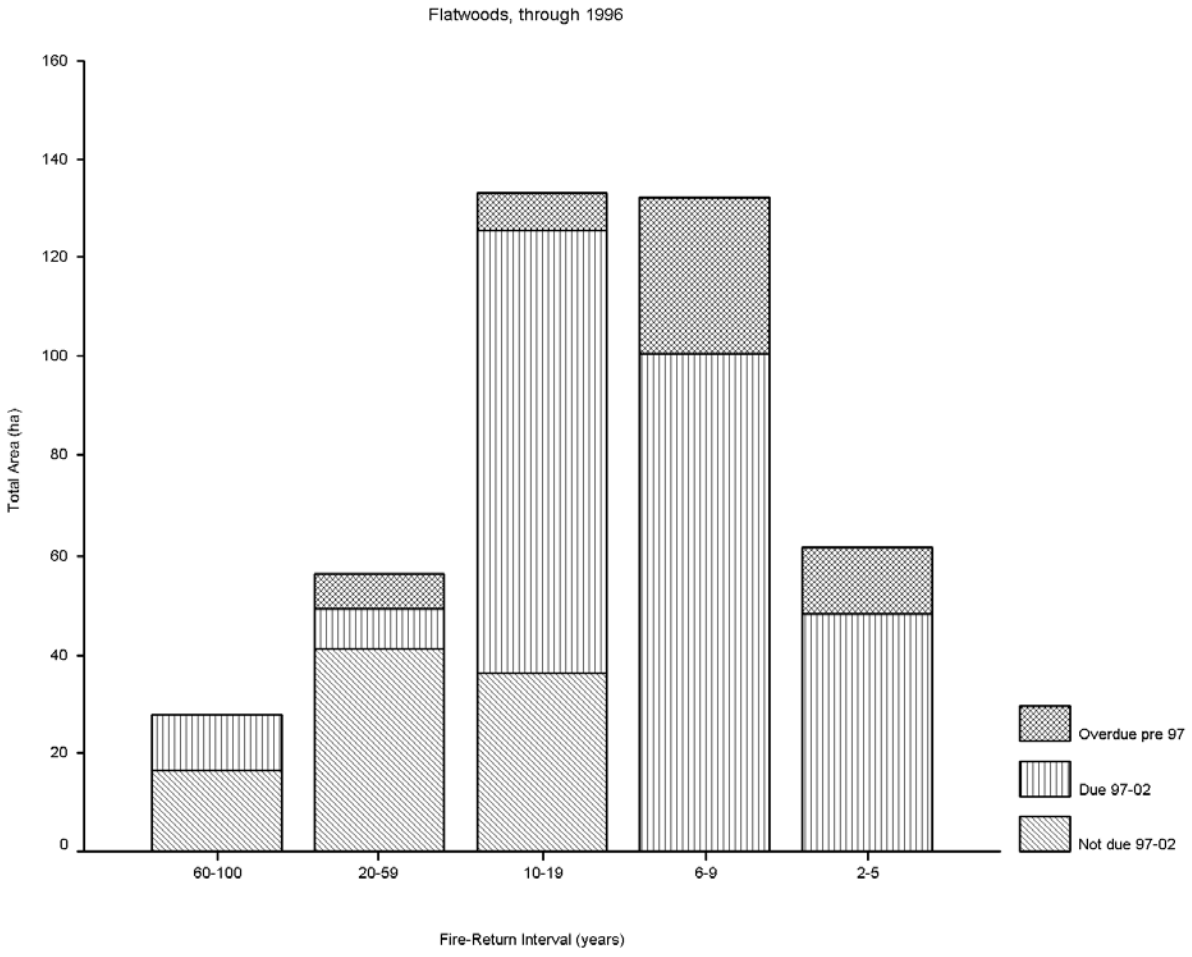
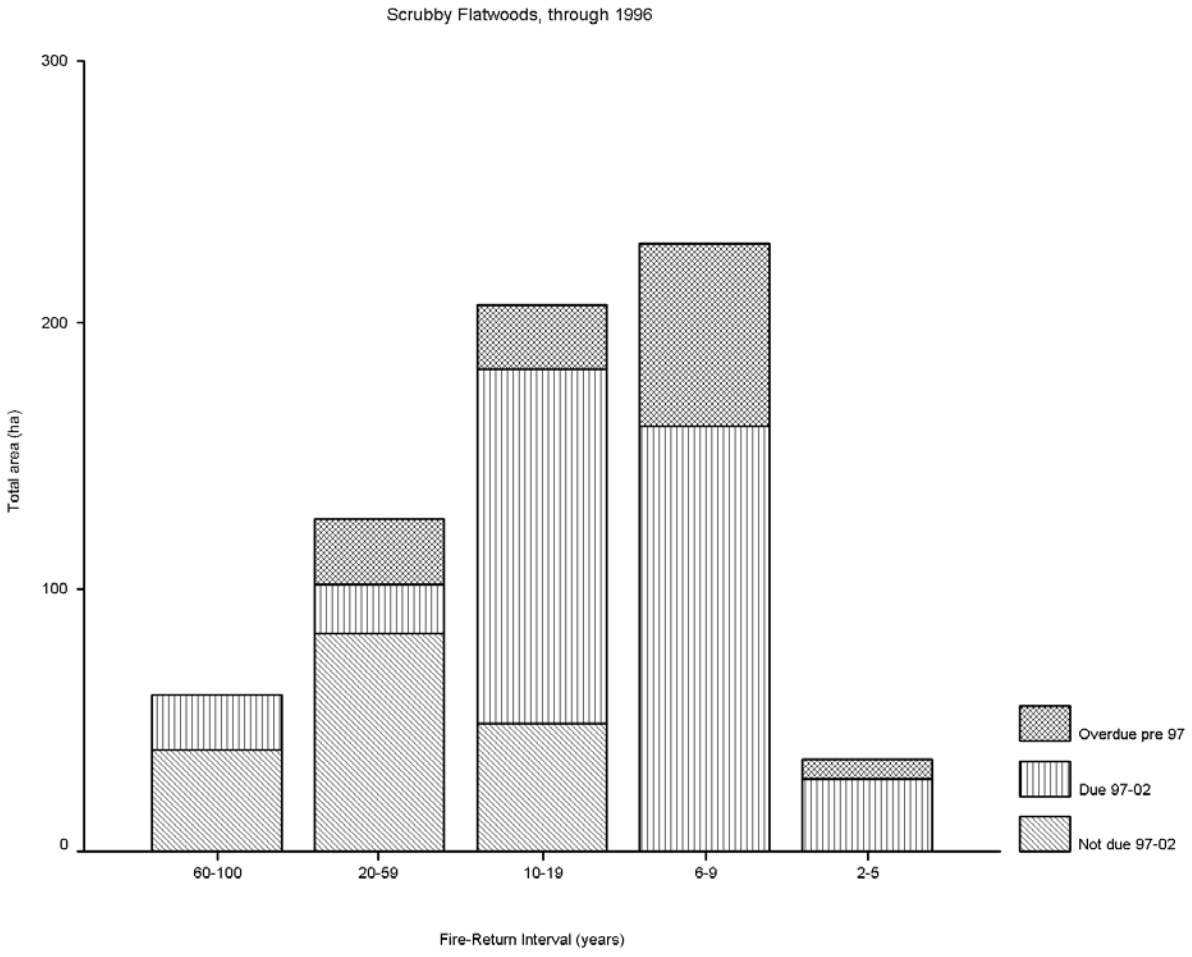


Fig. 19. Distribution of Area of Scrubby Flatwoods (SF) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.



Hickory scrub (southern ridge sandhill, hickory phase, Abrahamson et al. 1984) is a poorly known vegetation type. With floristic similarities to both sandhill and scrub, vegetation structure similar to scrub, and very rapid recovery postfire, the true fire-return interval is not known. Partly to manage for the Lake Placid scrub mint (*Dicerandra frutescens*), which occurs mainly in hickory scrub, long fire-return intervals cannot be modal (Menges 1992). We have chosen a 10-19 year modal fire-return interval, and included a great deal of variation in the interval for this vegetation (Fig. 20). Small areas within the 2-5 year interval are in flatwoods-dominated burn units and will not re-burn with every fire at this interval. We are on schedule with hickory scrub, having little area overdue; however, about half of the area is due for burning during the next five year planning cycle (Fig. 20).

Rosemary scrub is thought to burn every 20-59 years, although shorter fire-return intervals may be favorable for many of its endemic herbaceous plants (Johnson and Abrahamson 1990, Menges and Kimmich 1996, Abrahamson and C.R. Abrahamson 1996, Quintana-Ascencio and Morales-Hernandez 1998). The 10-19 year fire-return interval is also inevitable for some rosemary scrub because it is embedded within a scrubby flatwoods matrix. Our assignment of fire-return intervals to burn units results in the majority of rosemary scrub in 10-19 or 20-59 year intervals (Fig. 21). About half of the rosemary scrub is due or overdue for burning during the coming five years.

Sand pine scrub (oak phase) may burn every 20-59 years or even more infrequently (Myers 1990, Abrahamson and J.R. Abrahamson 1996). Our burn unit assignments place the plurality in the 60-100 year class with substantial amounts in the 20-59 and 10-19 year class (Fig. 22). The latter results from sharing of burn units between sand pine scrub and more frequently burned vegetation such as sandhill and scrubby flatwoods. Because of the history of fire suppression in the Station's Red Hill, large areas of sand pine scrub are overdue for burning (Fig. 22). Large areas last burned in 1927, but, as they are in the 60-100 year class, they are due for burning now but will not be overdue until 2028. Prescribed burning in sand pine scrub will be phased in gradually (see later).

Bayheads with large trees owe their existence to the lack of fire. Although bay trees usually resprout following surface fires, the forest structure of the bayhead is lost. Burns during droughts or after drainage may consume the organic soil that characterizes bayheads and may lead to their destruction. However, natural fires often burn the edges of bayheads, creating a natural dynamic of tree invasion, top-killing, and resprouting at bayhead ecotones to seasonal ponds and wet flatwoods. Because bayheads are spatially limited at Archbold and because burns near bayheads are logistically difficult, most bayheads will rarely, if ever, be deliberately burned (Fig. 23).

Fig. 20. Distribution of Area of Hickory Scrub (RSh) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

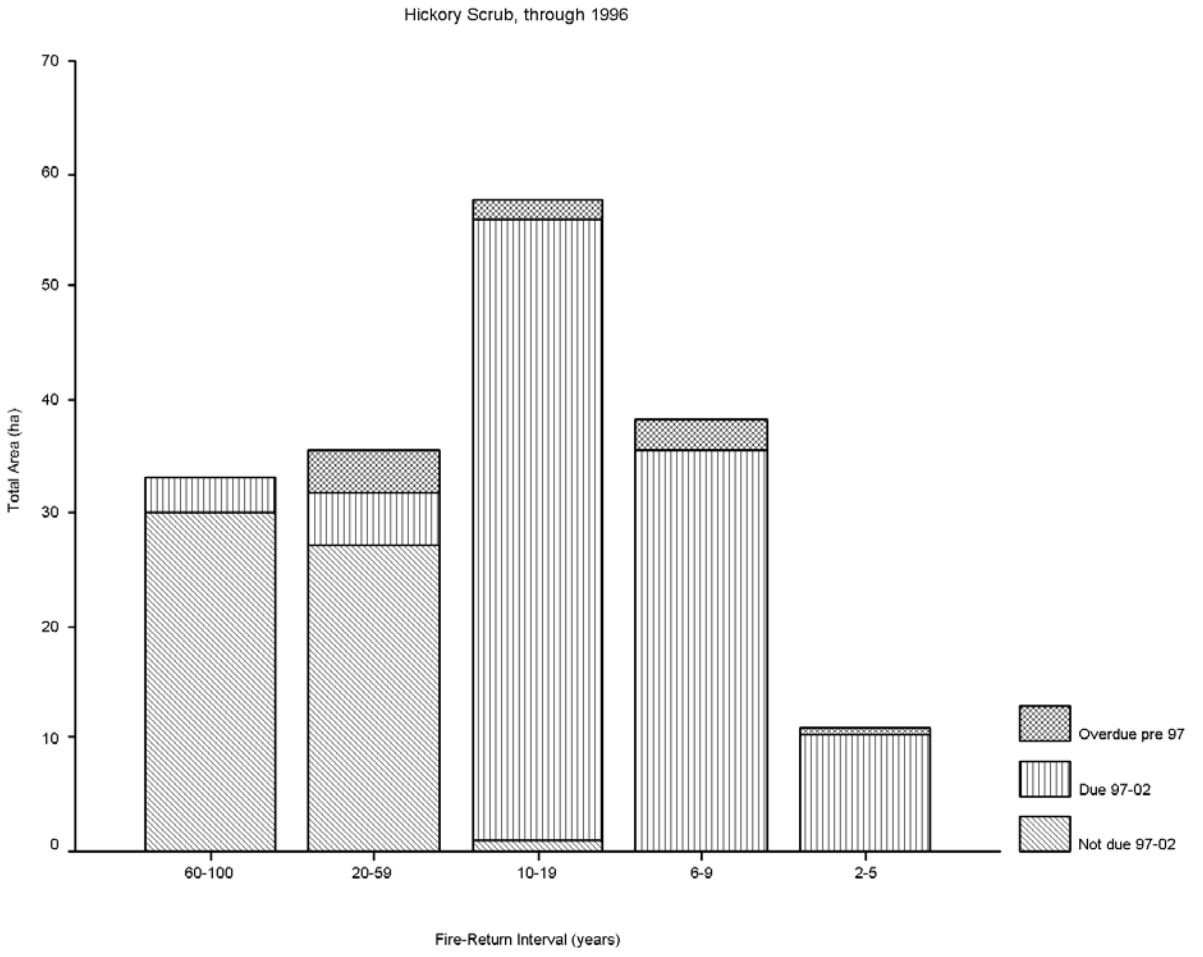


Fig. 21. Distribution of Area of Rosemary Scrub (SSr) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

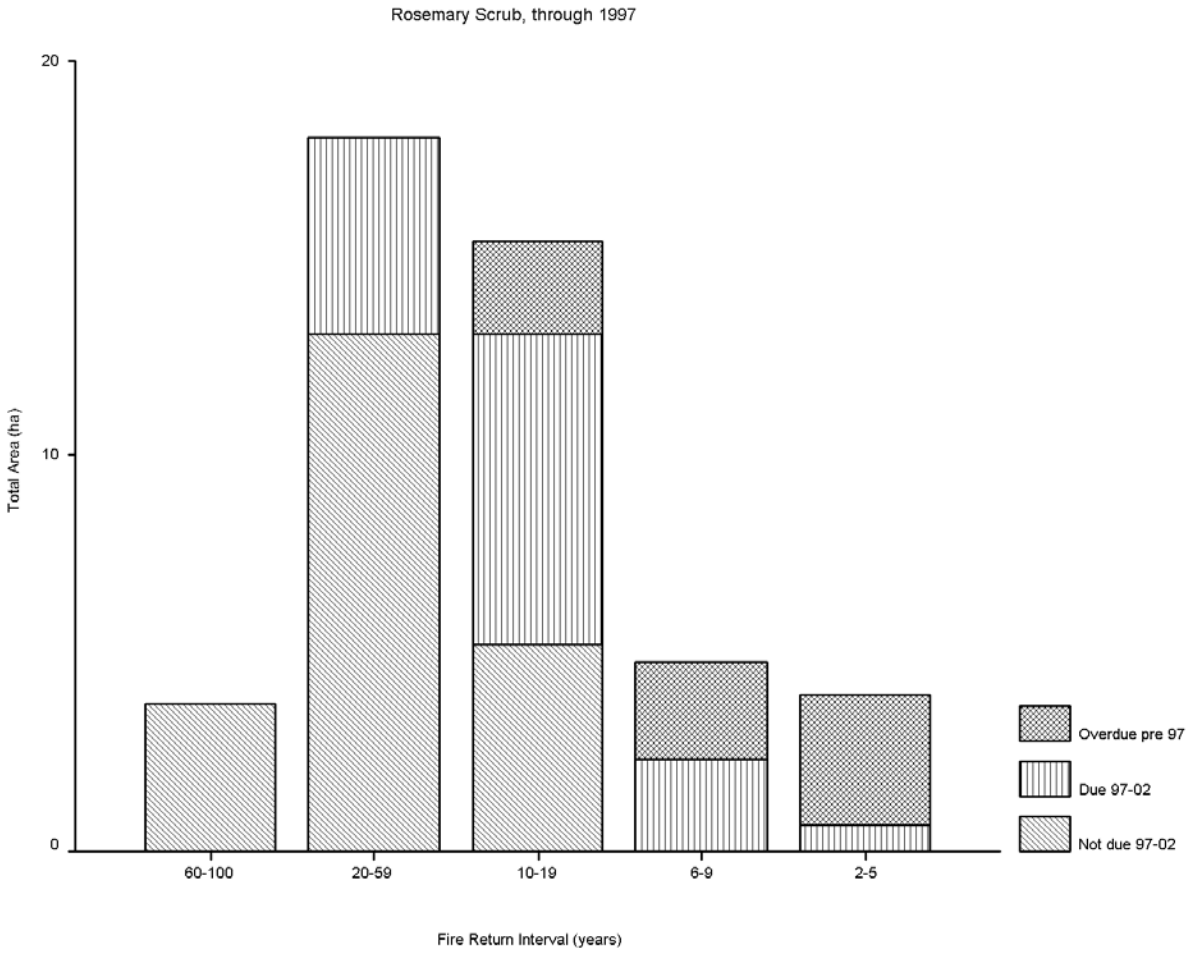


Fig. 22. Distribution of Area of Sand Pine Scrub, oak phase (SSo) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.

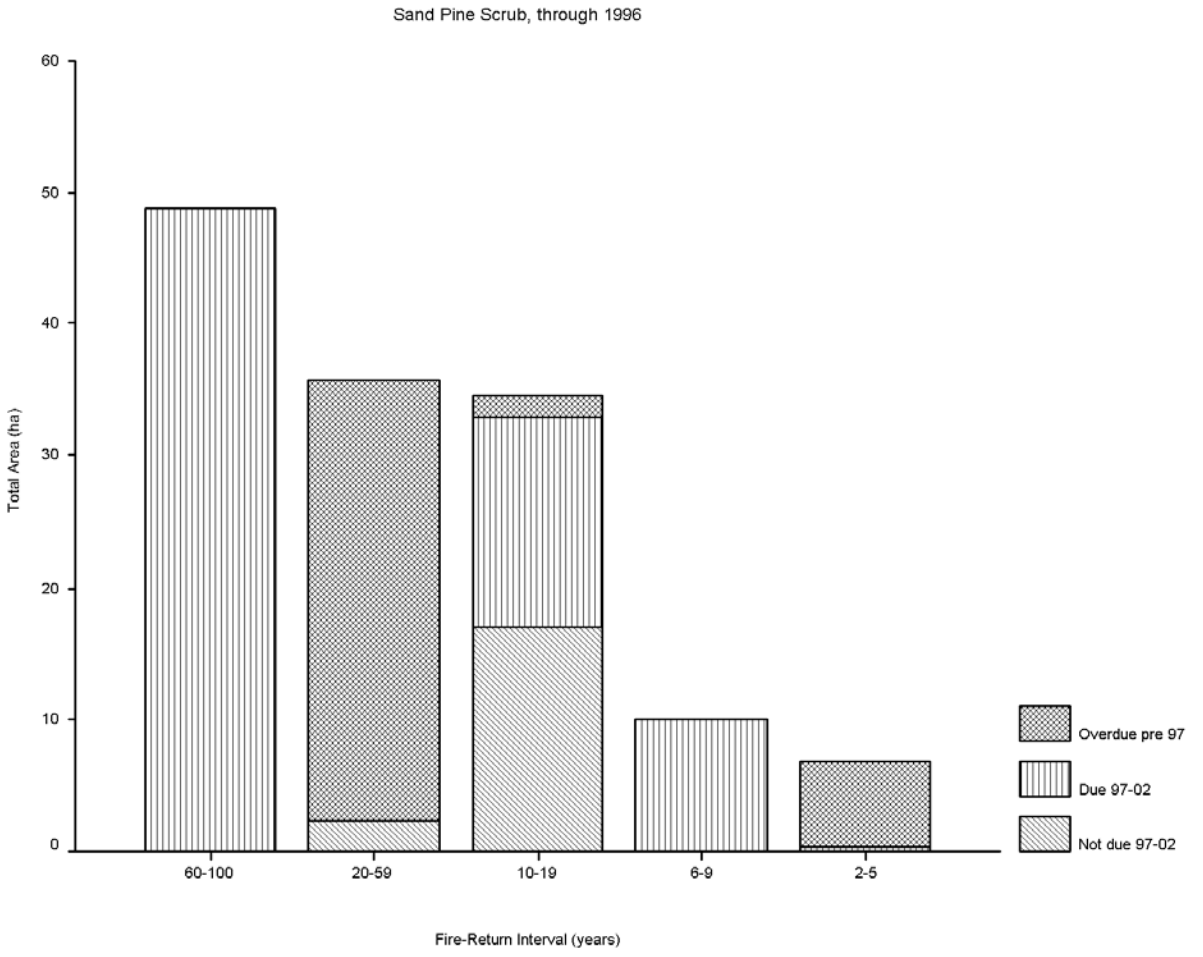
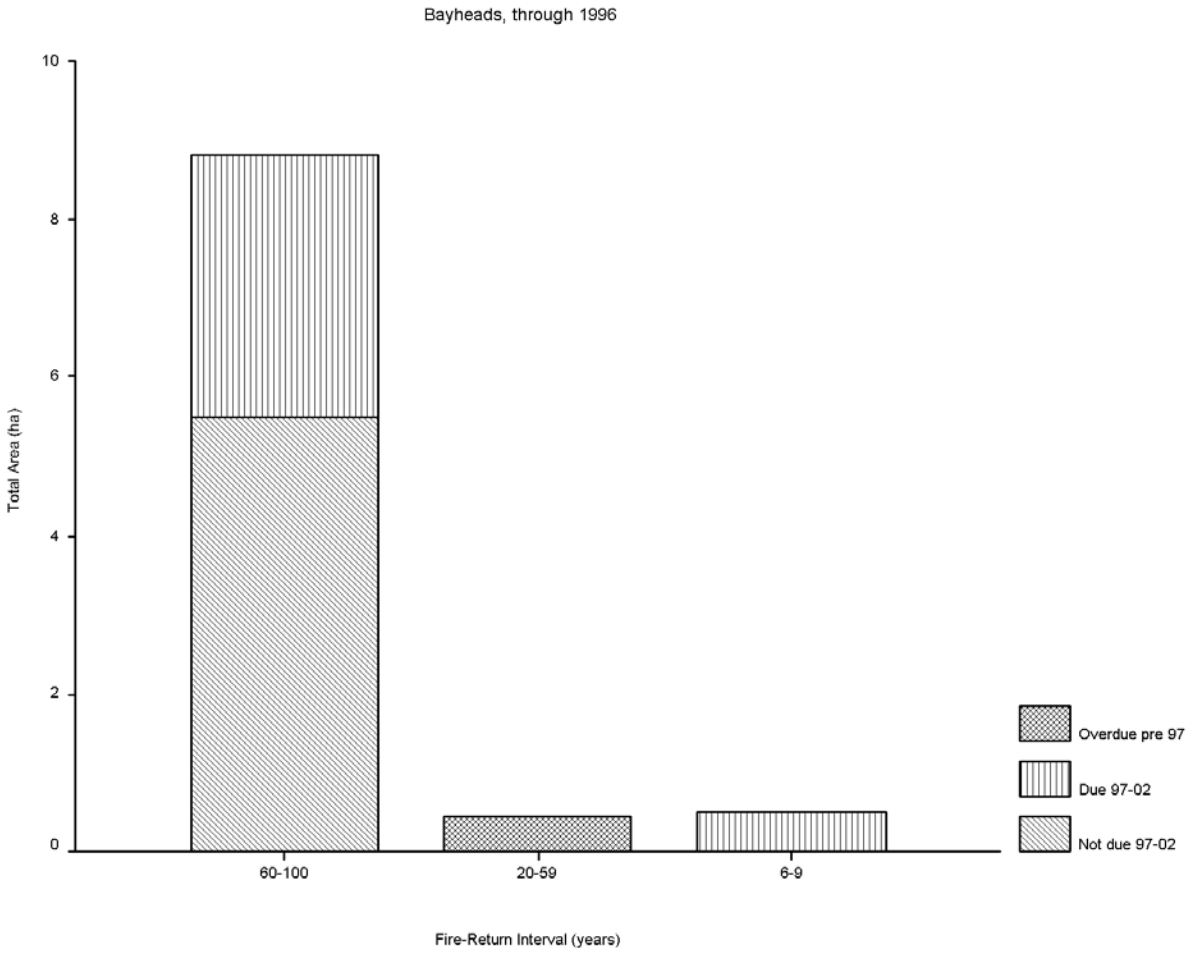


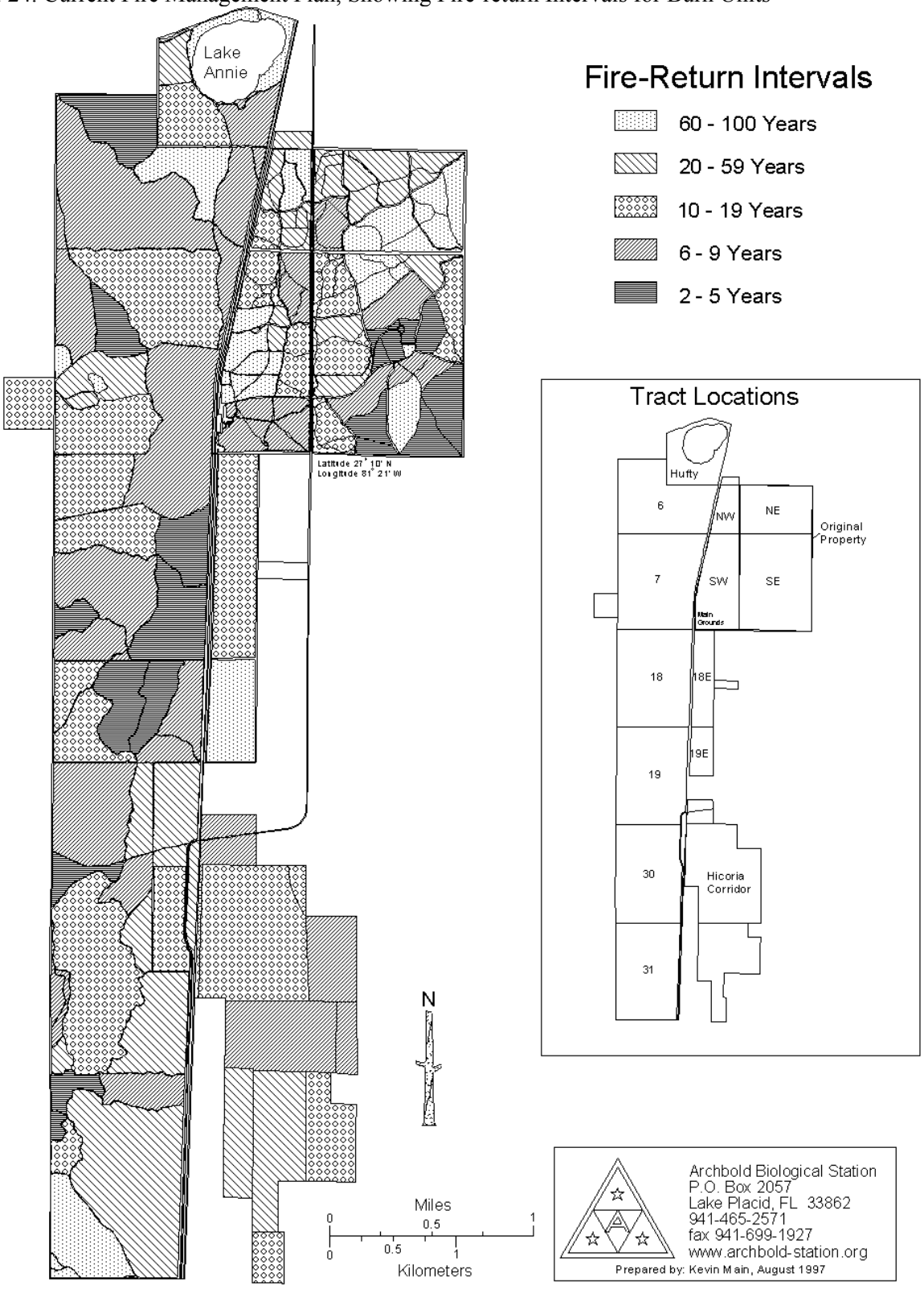
Fig. 23. Distribution of Area of Bayhead (BH) Across Fire-return Intervals and by Burn Status (1996) at Archbold Biological Station, Highlands County, Florida.



The resulting fire management plan, as of this date, shows the fire-return intervals for each burn unit (Fig. 24). Infrequently burned areas (60-100 years) occur in the original property and in scattered areas elsewhere. They encompass important areas of sand pine scrub and sandhill (NE and SE tracts), rosemary scrub and scrubby flatwoods (Tracts 6 and 31), long-unburned scrubby flatwoods (SW tract), bayhead (NW tract), and hickory-dominated sandhill (Tract 19E). Areas burned every 20-60 years include large parts of the NE tract (sand pine scrub), the Hicoria corridor (hickory-dominated sandhill), Tract 31 (including many patches of rosemary scrub) and the southern portion of the Hicoria Corridor (mainly scrubby flatwoods and rosemary scrub).

Much of the West Section of the Station is dominated by scrubby flatwoods slated to burn at 10-19 year intervals (Fig. 24). Other large areas assigned to this fire-return interval are found in the original property (scrubby flatwoods and sand pine scrub largely), Tract 18E (hickory-dominated sandhill), and the northern portion of the Hicoria Corridor (various communities). Most burn units dominated by scrubby flatwoods also contain considerable flatwoods. More frequently burned units (6-9 years) include many West Section units with flatwoods, ponds, and scrubby flatwoods, the extensive flatwoods areas of the central Hicoria corridor, and the burn units just east of the Station buildings, where fuel reduction is a key concern. Finally, the most frequent burning (2-5 years) will be concentrated in sandhills on Red Hill and in Tract 6, and various swale, pond, and flatwoods areas of the central West Section (Fig. 24).

Fig. 24. Current Fire Management Plan, Showing Fire-return Intervals for Burn Units



E. Consideration of Threatened and Endangered Species

A large number of federally threatened and endangered species occur on the Station property (Table 6). With a prescribed fire program it is inevitable that there is some incidental take, in some populations of some of these listed species, on an annual basis as a result of fire management. However, there is a large body of research, much of it conducted at Archbold Biological Station, to show that many listed species, especially those that are scrub associated, are well-adapted and often dependent on fire and will recover and be enhanced as a result of burning (e.g., Diemer 1992, Godley 1992, Layne 1992, Menges 1992, Moler 1992, Robbins and Myers 1992, Deyrup 1994, Menges and Kohfeldt 1995, Menges and Kimmich 1996, Woolfenden and Fitzpatrick 1996, Quintana-Ascencio and Morales-Hernandez 1998). In the vast majority of cases, we assume the best protection will lie in the application of a range of fire-return intervals for habitat of each species of concern. Although burning much of a vegetation type at the modal fire-return interval, and other areas at various intervals, should conserve habitat for most species, some endangered and threatened species may require special consideration. In particular, species with limited distributions within the Station may be found in only a few units, and therefore could be vulnerable to specific fire regimes. Research projects at the Station and elsewhere can sometimes suggest what are the best intervals for burning. However, this information is often not known or well documented. Variation in fire-return intervals and other features of the fire regime, when coordinated with research or monitoring, can help answer questions about fire management for threatened and endangered species.

To illustrate these general principles, we use data here from five species with limited Station distributions, shown in Table 7, together with their known responses to fire and general comments on fire management. The Florida scrub-jay's demography (Woolfenden and Fitzpatrick 1984) helps define a fire-return interval of 6-19 years in scrubby flatwoods, its primary habitat. Fire-return intervals that are ideal for scrub mint (*Dicerandra frutescens*) and Wedge-leaved button snakeroot (*Eryngium cuneifolium*) may cause us to increase burning in selected burn units with oak-hickory scrub and rosemary scrub, respectively. On the other hand, populations of the Perforate reindeer lichen (*Cladonia perforata*) could be threatened by frequent burning. Units assigned to burn very infrequently have been selected to safeguard this species until more is discovered of its biology. The burn units known to support *Dicerandra frutescens* are slated to be burned at various intervals (Fig. 25). However, it is unlikely that the specific habitats containing *Dicerandra frutescens* would burn every time in units scheduled at the most frequent fire-return interval.

A full inventory of all populations of threatened and endangered species by burn unit would be an enormous and unnecessary effort. It would be extremely onerous, if not impossible, to predict or estimate annual incidental take, and monitor recovery of threatened and endangered species in each burn unit on an area the size and complexity of Archbold Biological Station. Instead, our assumption is that by mimicking natural burn processes the net effect will be enhancement for all listed species. Listed species monitoring is discussed in section VII.

Table 6. Federally Listed Species at Archbold Biological Station, Highlands County, Florida.

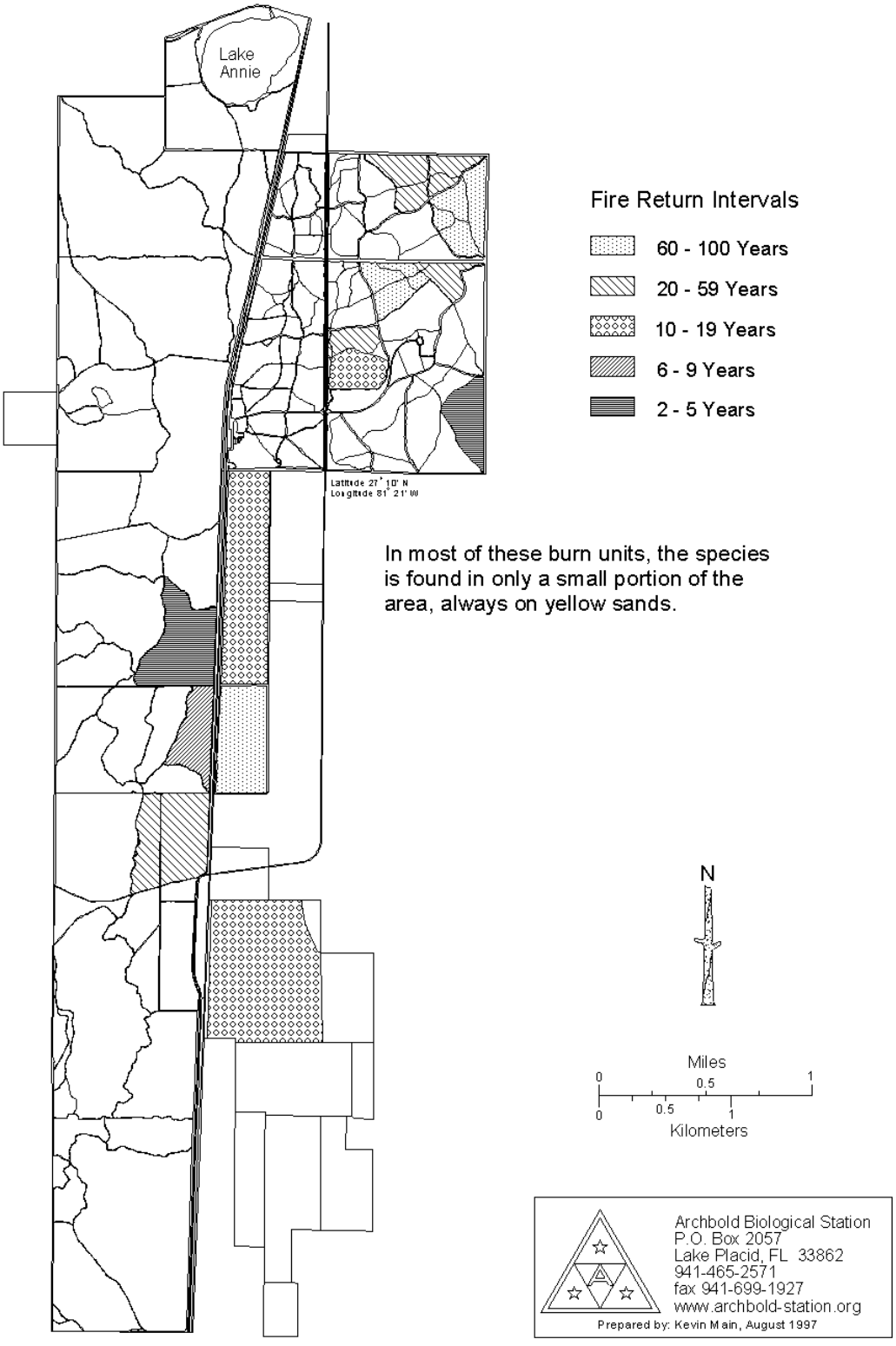
Scientific Name	Common Name	Population Abundance	USFWS Status
BIRDS			
Aphelocoma coerulescens	Florida Scrub-Jay	common in scrubby flatwoods	Threatened
REPTILES			
Alligator mississippiensis	American Alligator	rare in lakes and wetlands	Threatened
Drymarchon corais couperi	Eastern Indigo Snake	uncommon in scrubby flatwoods, flatwoods and sandhills	Threatened
Eumeces egregius lividus	Bluetail Mole Skink	fairly common in scrubby flatwoods and rosemary scrub	Threatened
Neoseps reynoldsi	Sand Skink	common in scrubby flatwoods and rosemary scrub	Threatened
PLANTS			
Cladonia perforata	Perforate Reindeer Lichen	rare in rosemary scrub	Endangered
Clitoria fragrans	Pigeon-wing Butterfly-pea	rare in sand pine scrub and hickory scrub	Threatened
Dicerandra frutescens	Lake Placid Scrub Mint	occasional in sand pine scrub and hickory scrub	Endangered
Eriogonum longifolium var. *gnaphalifolium*	Scrub Buckwheat	occasional in sand pine scrub and hickory scrub	Threatened
Eryngium cuneifolium	Wedge-leaved Button Snake-root	occasional in rosemary scrub	Endangered
Hypericum cumulicola	Highland's Scrub St. John's Wort	occasional in rosemary scrub and sand pine scrub	Endangered
Liatris ohlingerae	Scrub Blazing Star	rare in scrubby flatwoods and rosemary scrub	Endangered
Nolina brittoniana	Scrub Beargrass	rare in scrubby flatwoods and turkey oak sandhills	Endangered
Paronychia chartacea	Papery Whitlow-wort	common in scrubby flatwoods and rosemary scrub	Threatened
Polygonella basiramia	Hairy Jointweed	common in rosemary scrub, scrubby flatwoods and sand pine scrub	Endangered
Polygonella myriophylla	Small's Jointweed	rare in sand pine scrub	Endangered
Prunus geniculata	Scrub Plum	rare in scrubby flatwoods	Endangered
Warea carteri	Carter's Mustard	rare and local in scrubby flatwoods	Endangered

Information for Federal status from FGFWFC 1996.
Population abundance for birds and reptiles from Station scientists (pers. comm.).
Population abundance for plants from the Archbold Biological Station Plant List (Menges and Salzman 1992).

Table 7. Fire Regimes for Selected Endangered and Threatened Species at Archbold Biological Station, Highlands County, Florida.

Species	**Vegetation**	**Response to Fire**	**Fire Management**
Aphelocoma coerulescens	Scrubby Flatwoods	Temporary decrease, then abundant for several decades, then decrease.	Helps define scrubby flatwoods fire-return interval of 5-20 yrs.
Dicerandra frutescens	Hickory Scrub (Rsh) Sand Pine Scrub	Individuals killed, but rapid population recovery from seed bank, then decrease.	Helps define upper limit of 20 years for modal fire-return interval in hickory. May affect sand pine scrub burning.
Eryngium cuneifolium	Rosemary Scrub	Most individuals killed, then very rapid increase. Absent from areas unburned for more than 25 yrs.	Burn some rosemary scrub within 25 years.
Cladonia perforata	Rosemary Scrub	Killed by fire. Slow increase over decades. Possibly declines in long-unburned patches.	Burn very infrequently.
Hypericum cumulicola	Rosemary Scrub	Killed by fire. Most abundant in decade after fire, but persists in small patches for many decades.	Less sensitive than prior two species to fire regime, also more widespread at the Station. Will have little effect on fire management.
Warea carteri	Flatwoods/Scrubby Flatwoods	Killed by fire. Most abundant the year after a fire, but probably persists in seedbank for many decades.	Population expansion after fire is followed by quick decline to previous levels. May help define lower limit of modal fire-return interval in scrubby flatwoods.

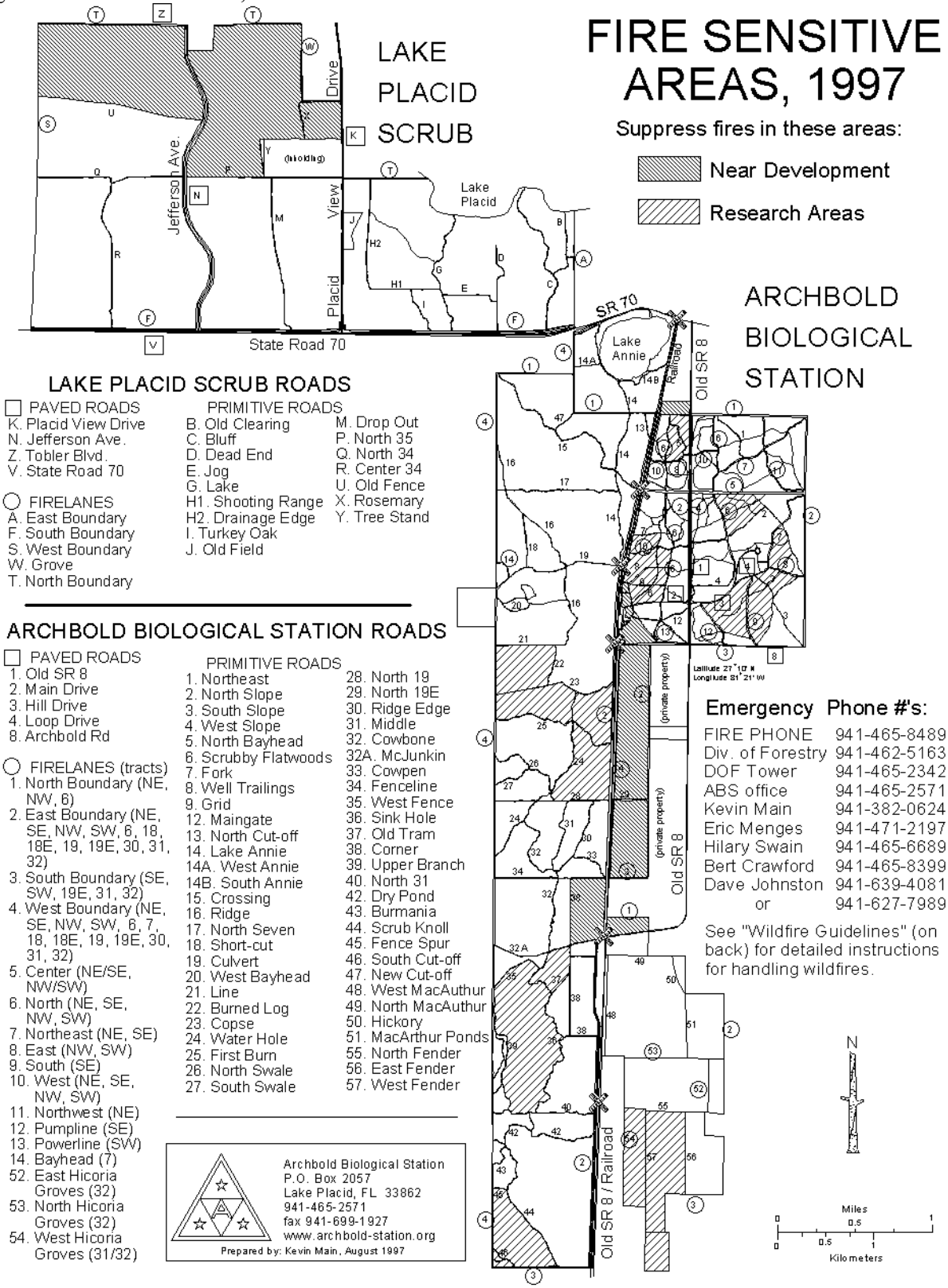
Fig. 25. Distribution of Lake Placid scrub mint *Dicerandra frutescens* by Burn Unit, with Fire-return Intervals Indicated



F. Delineating Fire-Sensitive Areas

Fire-sensitive areas are areas near housing or other developments, research that requires restricted burning, and areas containing listed species with limited distributions at the Station (e.g., *Cladonia perforata*). A map showing fire-sensitive areas (Fig. 26) is useful for prescribed fire contingency planning and for guiding decisions in case of a lightning or accidental fire (see section VI for details). Areas containing fire-sensitive research vary from year to year, so this map must be updated yearly.

Fig. 26. Fire-sensitive Areas, 1997



V. DETERMINING BURN DATES FOR INDIVIDUAL BURN UNITS

A. Determining Year of Burn for Previously Fire-Maintained Units

1. Generating a List of Possible Burn Units

The Fire Management Plan does not set specific dates for burning any units, but only initiates the possibility of a unit being selected in any given year if it meets certain criteria. All units are treated equally in the selection process, except for long-unburned areas that will be selected for burning based on restoring fire to all units within one cycle (in further detail in section C). Appendix A and Fig. 14 provide information about Station burn units. A three-step process is used to create a list of possible burn units that will be considered during any given year:

a. Determine the fire-return interval to which the unit has been assigned by referencing the fire management map (Fig. 24).
b. Determine when the last fire occurred in that area using the fire history maps (Figures 5-8).
c. If the time since the last fire falls within the assigned fire-return interval, include unit as a possible unit to be burned that year.

This process can be extended to look at a range of years to help the planning process (Fig. 27). This is useful to researchers who wish to design projects that will not conflict with burning schedules. Since there is an ever-increasing pressure for more research at the Station, it is especially important to provide researchers with as much fire-planning information as possible in order to avoid conflicts and unnecessary constraints on burning (see Goal D).

2. Constraints and Special Circumstances that Help to Narrow the List of Possible Burns

Of the total possible units for a given year, only a few will be selected, based on constraints such as the amount of area to burn each year (see section C, below), delays for research, and management concerns (for example, delaying the burning of certain units until other units not yet within prescription are burned to improve safety conditions). Special circumstances may change the schedule of burning (Table 8). Units that are not burned will again be selected as possible units for the following year.

Fig. 27. Burns Units Overdue, Within Prescription Window, and Not Yet in Prescription Window, 1997-2001

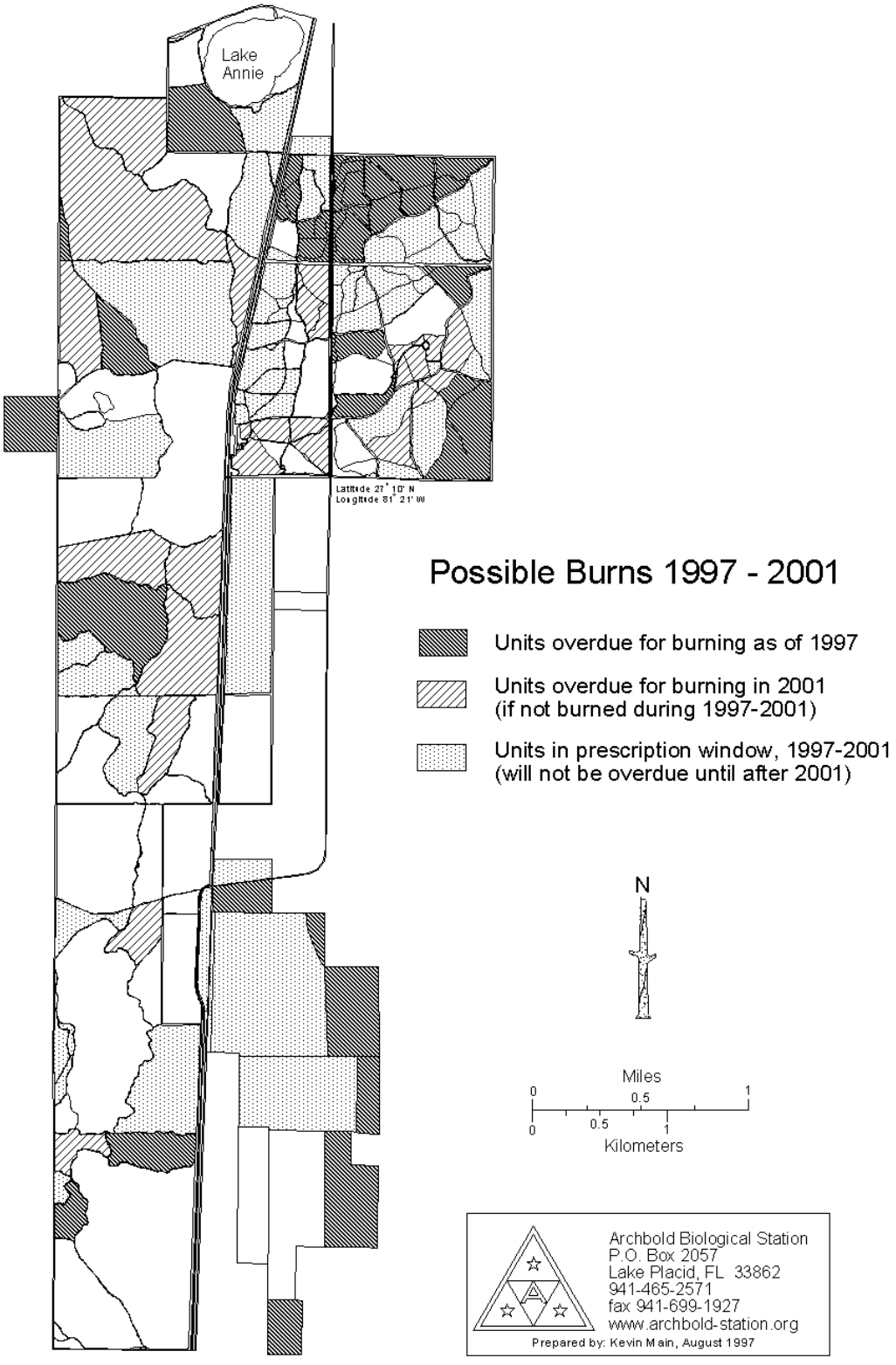


Table 8. Examples of Special Circumstances that have Affected Fire Planning at Archbold Biological Station, Highlands County, Florida.

Category	Circumstance	Effect on Fire Planning
Research	Blue Jay study requires no changes in long-unburned study areas	Postpone some burns
	Scrub-jay study waiting to document territory abandonment	Postpone one burn
	Study on fire and nutrients	Prescribe certain burns
Conservation	Rare lichen has limited Station distribution	Assign less frequent burning to certain burn units
	Fire demonstrated to favor rare plant	Adjust fire-return intervals
Education	Shade needed along nature trail	Conduct burns with sub-units excluded from fire
Aesthetics	Vegetation screen desired near Lake Annie	Assign to less frequent burn category
	Already have many fire-killed pines	Avoid fall burns, adjust lighting patterns near roads
Safety	Station Buildings lie downwind of Old State Road 8	Reduce intervening fuels using frequent prescribed fire
	Increased probability of wildfires along public roads	Burn units adjacent to roads more frequently to reduce fuels
	Increased liability from smoke adjacent to roads and developments	Burn units adjacent to roads and developments under restricted conditions

3. Selection/Deselection

Each year a map highlighting possible burn units (e.g., Fig. 27) is reviewed by management and scientific staff, visiting researchers, and interns well before burning begins. On the map, units with higher priority are specified by the land manager. Units will be added or dropped based primarily on research needs. Usually, if some units are dropped, other units may be added to maintain the level of burning necessary to meet the fire management goals.

B. Determining Year of Burn for Overdue Units

Overdue units are simply units that have gone without fire for longer than their assigned fire-return interval (for the purpose of the plan, the term "overdue" is used more in a planning sense than as a biological indicator). For example, a unit with a 2-5 year fire-return interval would be overdue for burning after the fifth year, whereas a unit with a 60-100 year fire-return interval would not be overdue for burning until 100 years post-fire. Fig. 28 shows units that are currently overdue for a fire. Selecting units that are "overdue" for burning is done in a different manner from selecting previously fire-maintained units to assure that we don't "catch-up" too quickly, though the constraints and special considerations described above are the same for overdue units. Overdue units are selected so that these units are burned across one full cycle for each vegetation type. This slow approach ensures that there is no radical change to the Station's landscape, creates a range of time since fire within each fire-return interval, and hedges the bets in case fire-return intervals for certain vegetation types have disadvantages. Table 9 provides details for burning overdue units.

Fig. 28. Units Overdue for Burning, 1997

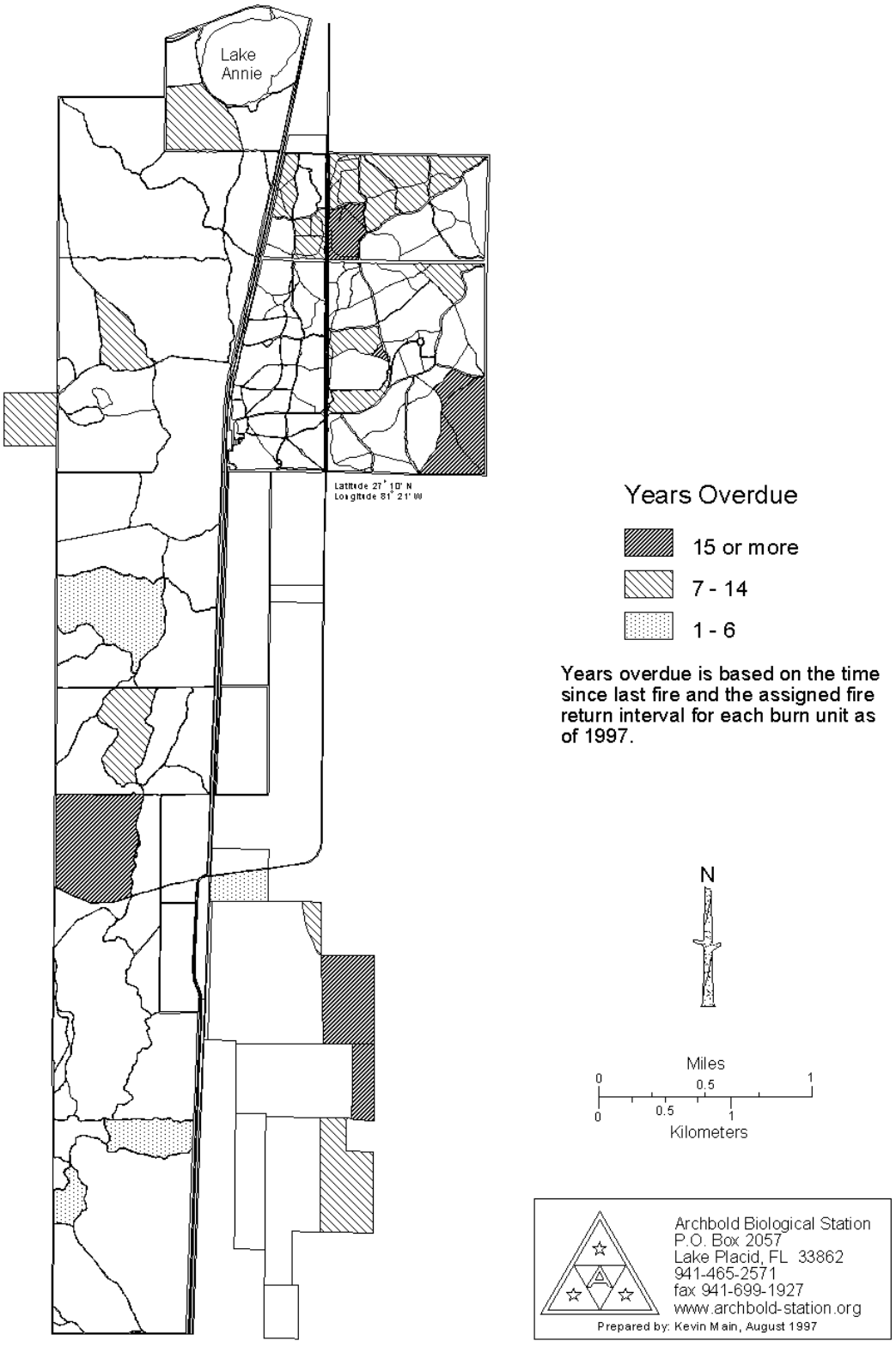


Table 9. Catch-up Details for Various Vegetation Types at Archbold Biological Station, Highlands County, Florida.

Vegetation Type	Total Area (ha)	Area Overdue for Burning (ha)	Percent Overdue	Modal Fire-return Interval	Average Amount to Burn (ha) Each Year to Spread Burns Across Entire Interval (total overdue divided by top end of modal fire-return interval)
Hickory Scrub	179	8	4.5	10-19	8/19 = 0.4
Sandhill	86	23	26.7	2-5	23/5 = 4.6
Sand Pine Scrub	136	42	30.9	20-59 & 60-100	42/59 = .7 & 42/100 = .4 Average = 0.55
Rosemary Scrub	46	8	17.4	20-59	8/59 = 0.1
Scrubby Flatwoods	658	126	19.1	6-9 & 10-19	126/9 = 14 & 126/19 = 6.6 Average = 10.3
Flatwoods	425	63	14.8	6-9	63/9 = 7.0
Seasonal Ponds	262	69	26.3	6-9	69/9 = 7.7
Bayheads	10	0	0	60-100	0/100 = 0
					Total = 30.6 ha

C. Amount (hectares) to Burn Each Year

This section looks both at the amount of area that has to be burned each year in general, and the extra amounts that have to be burned for overdue units. Though no units are scheduled to burn on specific dates, broad goals can still be determined for amount of area to burn each year based on the assigned fire-return intervals. To determine the amount of area to burn for previously fire-maintained units, the total area in each fire-return interval is divided by the modal return interval. This gives a rough idea of how much to burn each year (Table 10). For overdue units the total area in each fire-return interval is divided by the maximum length of the interval to give a rough idea of how much to burn each year. Wide variation in the amount of area burned from year to year may occur because of research restrictions, weather conditions, and other management constraints, so broad goals for areas burned are probably more realistic for a period of five years rather than a single year.

It is important to note that the Fire Management Plan does not set specific goals for area burned. Though rough goals can be calculated (Table 10), they serve only as a guide in the selection process. Other goals of the plan, including maintaining biological diversity and providing research opportunities are more important in deciding the amount of area to burn each year.

D. Spatial Configuration of Units Selected for Burning

The spatial configuration of units selected for burning for any given year is defined by both research and management goals and constraints. Mimicking natural processes, such as large scale fires, can be accomplished by burning several adjacent units. This also eases safety and management constraints by reducing the number of burn days per year. Burning areas adjacent to other recently burned units is also useful for simulating natural fire boundaries (by letting the fire burn into the adjacent, recently burned unit and going out on its own). Fig. 29 shows the spatial configuration of units selected for burning in 1997.

While managing a few large burns is easier than dealing with several small burns, other goals, such as providing research opportunities, reducing fire hazards around buildings and providing suitable habitat for listed species may limit the scale of burning in certain areas.

Constraints mentioned above on burning overdue units and constraints based on the assigned fire-return interval for each unit also help define the spatial configuration of burns in a given year. For example, many of the overdue units on the original property are in the 20-59 and 60-100 fire-return intervals. These units will need to be burned by performing several small burns over many years.

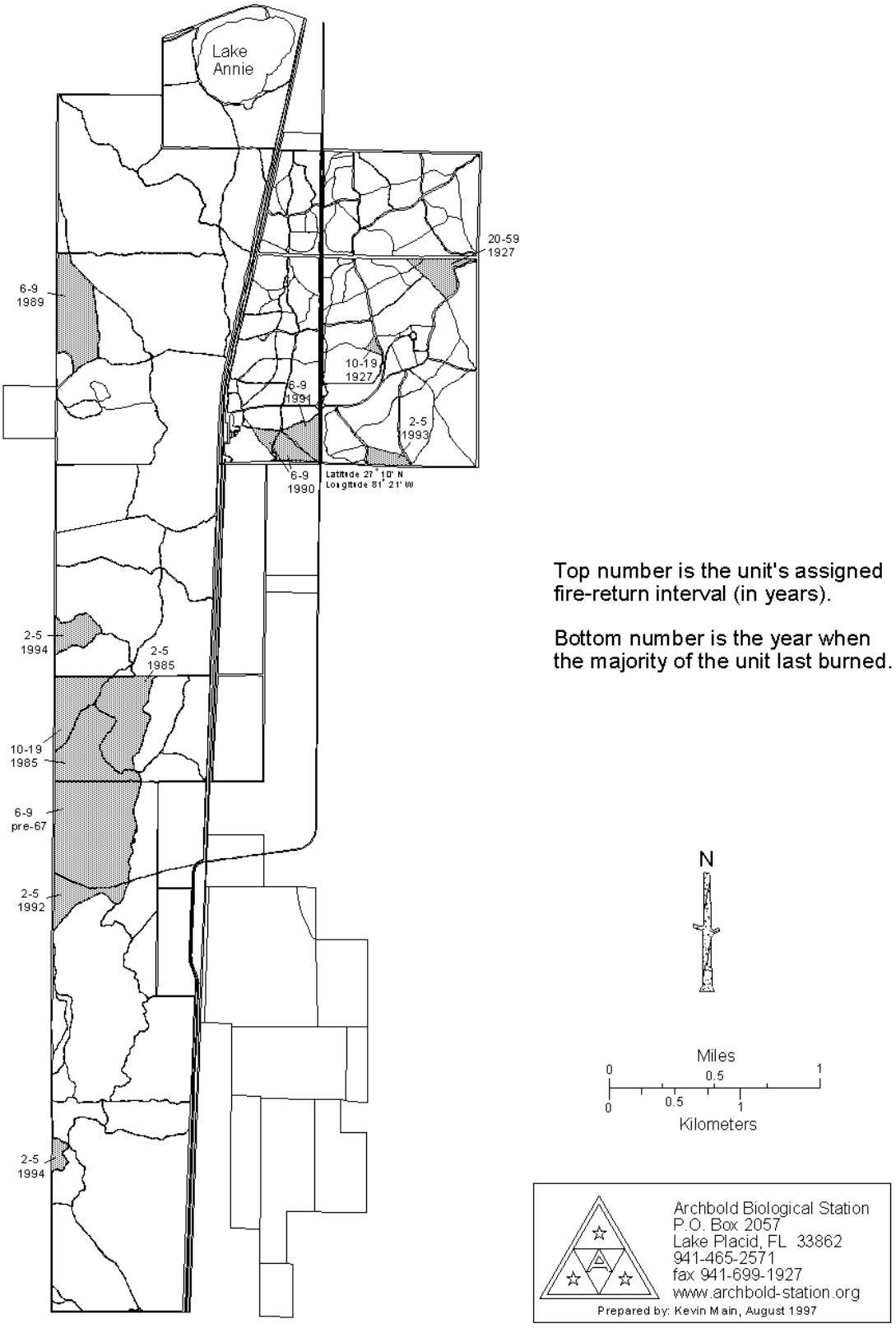
The range of years within each fire-return interval also provides flexibility for selecting units based on management considerations. For instance, a unit may not be selected until an adjacent unit is also ready to burn.

Table 10. Average Amount (ha) to be Burned for the next 5 Years Determined by The Fire-return Interval for a) Fire-Maintained and b) Overdue Units and c) Total Overall at Archbold Biological Station, Highlands County, Florida.

a) Amount to Burn for Fire-Maintained Units (Not Overdue)				
Return Interval (Years)	Modal Return Interval	Total Fire-Maintained (Not Overdue) Hectares	Hectares to Burn Each Year (Total Hectares Divided by the Modal Return Interval)	Total Hectares to Burn in a Five-Year Period
60-100	80	203.2	2.5	12.5
20-59	39.5	258.2	6.5	32.5
10-19	14.5	498.4	34.4	172.0
6-9	7.5	389.6	51.9	259.5
2-5	3.5	145.8	41.6	208
TOTAL		1495.1	136.9	684.5
b) Amount to Burn for Overdue Units				
Return Interval (Years)	Top End of Return Interval	Total Overdue Hectares	Hectares to Burn Each Year (Total Hectares Divided by Top End of the Return Interval)	Total Hectares to Burn in a Five-Year Period
60-100	100	- 0 -	- 0 -	- 0 -
20-59	59	72.8	1.2	6
10-19	19	47.9	2.5	12.5
6-9	9	160.4	17.8	89
2-5	5	59.1	11.8	59
TOTAL		340.1	33.3	166.5

c) Totals for Fire-Maintained and Overdue Units		
Return Interval (Years)	Total Fire-Maintained and Overdue Hectares to Burn Each Year	Five-Year Total
60-100	2.5	12.5
20-59	7.7	38.5
10-19	36.9	184.5
6-9	69.7	329.2
2-5	53.4	261.4
TOTAL	170.2	826.1

Fig. 29. Spatial Configuration of Units Selected for Burning in 1997



E. SEASON OF BURN

1. Winter Burning (December - February)

In general, winter burning is used in areas that have been fire-suppressed, causing unusually high fuel loads and duff build-up. Burning is used to restore these areas to more typical fuel loads. Units around buildings or other developments may also be burned in winter, since sudden wind shifts are less likely during this time of year. Units requiring burning when the water table is low may also be burned in the winter. Though several units may be burned during a winter season, total area burned during the winter will usually be much less than area burned during the summer. During 1990-1995, 102 hectares (253 ac) were burned during winter.

2. Summer Burning (May - August)

Most area is designated to be burned in the summer because summer burns match the natural fire season (Abrahamson et al. 1984, Abrahamson and Hartnett 1990, Myers 1990). Habitat maintenance is the primary goal. In fire-suppressed areas, winter burns (one or more) may be used to reduce the fuel load before the unit is returned to a summer burn schedule. Units requiring a high water table are more likely to be burned in late summer. During 1990-1995, 446 hectares (1,102 ac) were burned during summer.

3. Spring and Fall Burning (March - April and September - November)

Some burning is also done during spring and fall seasons. Florida scrub-jay nestling mortality is a concern for early spring burns. Scrub-jay researchers provide input into spring burns and most burns are delayed until nestlings have fledged. Fall burns may create high levels of pine mortality (Menges and Deyrup, in preparation), and are often avoided in flatwoods and sandhill areas where pine canopies are important. Research projects needing fires at particular times, training exercises, and burns to reduce fuel loads may also be done in the spring or fall. During 1990-1995, 155 hectares (384 ac) were burned in spring and fall.

VI. PLANNING AND EXECUTING INDIVIDUAL FIRES

A. Burn Unit Surveys

Each burn unit is thoroughly surveyed before burning to assess vegetation, soils, firebreaks, hazards, rare species occurrences, and other factors affecting burn planning and execution. Anything unusual about the unit is recorded. If unexpected vegetation or soil conditions are discovered, the unit may be reconsidered for burning at another time. For instance, if a small bayhead with deep organic soils was found in a unit scheduled to be burned during the dry season, burning of the unit may be postponed until the soil is damp, so that the soil will not smolder and possibly cause smoke problems. Notes are taken on pre-burn preparations needed before burning can begin.

All units are surveyed for presence of rare and listed species. Many of these surveys are done by Station biologists as part of their research projects, so information on rare species is often already available when a unit is considered for burning. Appropriate research biologists and others concerned with species present in a unit are consulted for special management or temporary fire exclusion. This Fire Plan has been submitted for approval as part of a Section 10a 1a permit to the U.S. Fish and Wildlife Service (USFWS) to allow take of listed species associated with research activities.

B. Burn Unit Prescriptions

A specific prescription is written for each burn unit (Appendix B). The prescription includes descriptions of the unit, logistical considerations, lighting protocol, contingency plans, and the specific weather conditions under which the unit can be burned. A burn that is in prescription has met the predetermined conditions and can proceed. Out-of-prescription burns are not started. If a burn is started when conditions are within prescription and, during the course of the burn, conditions go out-of-prescription, the burn may have to be stopped (for example relative humidity dropping too low or a change in wind direction). Fire-behavior modeling is used in the process of constructing prescriptions; it allows predictions of fire behavior from the conditions used to formulate the prescription. What behavior is acceptable varies with the burn unit, the burn boss, the burn crews, and is a matter of judgement. The prescription provides explicit directions and helps guide decision making before and during the burn. Burn unit prescriptions are usually developed weeks or months prior to the fire, although some details such as crew assignments often change the day of the fire. The prescription, together with data and notes gathered during the fire and post-fire monitoring and mapping, are filed in a folder for each fire.

1. Major Considerations for the Prescription

a. *Wind Direction and Speed* - Units that will burn intensely, due to vegetation type and/or high fuel loads, are usually burned with lower wind speeds and usually with fewer choices of wind direction. Higher wind speeds are used for units with dense vegetation that inhibit light winds from penetrating the interior of the unit. Units near roads or developments generally have fewer choices for wind direction, and therefore receive priority for burning over other units with broader wind direction prescriptions. Research requirements may influence preferred wind speeds and directions.

b. *Relative Humidity* - Some vegetation types, such as sand pine scrub and scrubby flatwoods will only burn with lower relative humidity (RH), reducing the window of opportunity for burning these units. These vegetation types usually will not burn with RH higher than 50-55%. Turkey-oak Sandhills, flatwoods, seasonal ponds, and swales will burn at higher RH. Prescribed RH for these areas can be as high as 70-75%. When RH is low (< 35%), fire conditions are generally extreme for all vegetation types.

c. *Drought/Drought Index* - The Keetch-Byram Drought Index (KBDI) is used as a guide to how dry the conditions are based on rainfall and maximum daily temperature (Keetch and Byram 1968). When the Drought Index is high (over 500 on a scale from 0 to 800), drought conditions may limit burning. Drought Index levels can be used to predict fire behavior (Melton 1996). Some vegetation types will not burn when the Drought Index is low (less than 200). Burns conducted when the Drought Index is low are usually patchier, and do not consume organic soils, while increased fire intensity, duff smolder, and smolder of 100 hr and larger fuels (e.g., snags and stumps) usually accompany burns conducted when the Drought Index is high. The Drought Index measures long-term drought in 100 and 1000 hour fuels (fuels that require several days to dry out after getting wet). While these fuels may not burn when the Drought Index is low, 1 and 10 hour fuels will still burn readily, so many units at the Station can burn intensely even if the Drought Index is low. Additional prescription components may specify short-term drought indicators, such as specifying that burns should take place no more than 3 days after a rain or at least 2 days after a heavy rain. All large lightning fires and all but one prescribed/escaped fires have occurred when the Drought Index was high (Table 11).

Table 11. The Cause of all Large (50 Ha+) Fires and the Drought Index for that Date at Archbold Biological Station, Highlands County, Florida.

DATE	CAUSE	DROUGHT INDEX
3 January 1967	Accidental	601
20 March 1968	Accidental	556
23 March 1972	Accidental	649
7 November 1973	Lightning	447
27 April 1976	Accidental	653
26 May 1977	Lightning	626
7 July 1980	Lightning	571
26 September 1984	Prescribed/Escaped	521
16 January 1985	Prescribed/Escaped	626
7 June 1986	Lightning	691
22 May 1989	Lightning	532
25 May 1993	Prescribed/Escaped	546
10 June 1994	Prescribed/Escaped	83
4 August 1994	Prescribed/Escaped	475
21 February 1996	Prescribed/Escaped	464

d. *High Fuel Loads* - If the fuel load in a unit is high, the prescription is usually written to exclude very windy, dry days. Units with high fuel loads are usually smaller, and may be burned with low intensity firing techniques. Many times these units are first burned in the winter, when weather conditions are more stable. To reduce pine mortality, back fires or spot fires may be used under individual trees to lower the fire intensity around them. A primary goal of burning units near buildings is to reduce high fuel loads.

e. *Smoke Management* -Units near roads are burned on days when wind will blow the smoke away from the road (rarely other safety considerations may have higher priority and force burning toward a road). Other smoke-sensitive areas, such as housing developments, are always burned when the smoke will not affect residents. Local residents with severe reactions to smoke are notified of the burning schedule. The Florida Division of Forestry (DOF) must shut down a burn if smoke becomes a problem for these people. Burning organic soils (muck) can cause extreme smoke problems. Burning units with areas of organic soils is generally restricted to times when these soils are wet and will not burn. Duff smoldering following a fire is typical, especially in fire suppressed units. Smoldering can be reduced by burning at a lower drought index and by using head fires which burn faster and therefore do not allow the duff fuels to heat up as much. Limiting smoke exposure to roads and developments can be accomplished by mopping-up unit boundaries and burning when the wind will blow away from smoke sensitive areas for 2-3 days post-fire. Cold air drainage and dispersion indices predicted the night following the fire will affect the degree to which complete mop-up is essential to control smoke. A low dispersion index coupled with high relative humidity creates optimum conditions for dense smoke and fog to develop. Indicators such as the Low Visibility Occurrence Risk Index (Lavdas 1996) can be used to predict when dense smoke can be a problem. If conditions are favorable for dense smoke, additional mop-up may be required or a burn may be postponed.

f. *Adjacent Units* - Burn units may be grouped when prior burns and other conditions allow larger fires. Some prescriptions may vary depending on which units are grouped and which units are burned first, either in separate fires or linked fires occurring on the same day. Potentially downwind units are always a consideration and are usually treated in some detail in the prescription.

g. *Water Table* - Bayheads and other areas with organic soils will generally not be burned, and fires in adjacent areas will only occur if the bayhead soils are flooded or saturated. As mentioned above, burning of organic soils is limited due to potential smoke management problems. Once a organic soil is burning, it is very hard to put out and it may burn for several days, causing smoke problems on roads and in housing developments. Water level may be a factor in other situations, for example when a wetland needs to be burned (low water table) or is intended to act as a firebreak (high water table).

2. Modeling Fire Behavior

Predictions of fire behavior define the conditions under which the burn can proceed and help prepare the burn boss and the crew for the burn. However, predictions using the currently available tools are approximate at best, and are often considerably in error. Future models geared more to scrub and other Florida vegetation could improve the predictions.

a. *Use of BEHAVE* - Fire behavior parameters, such as flame length, rate of spread, and fire intensity can be modeled using the BEHAVE program (Andrews 1986). One key component for the burn unit is the determination of a fuel model (Anderson 1982). Only about a dozen fuel models are defined by BEHAVE, and only a few of these can be applied to Station vegetation. Fuel model 4 is used for scrubby flatwoods, sand pine scrub and fire-suppressed areas. Fuel model 7 is used for flatwoods. Fuel model 2 is used for grassy areas. Low scrubby flatwoods may be modeled by fuel model 5. If several vegetation types occur in the unit, the fuel model that predicts the most extreme fire behavior is used in the prescription, or individual runs are made to explore the variation in detail. The BEHAVE model can be used to define uncertainty in two variables by entering multiple possible values and exploring the range in predicted fire behavior. For example, after entering a range for the prescribed wind speed and 1-hour fuel moisture, the model produces a chart of expected fire behavior at different wind speed/fuel moisture levels. Fire behavior output produced includes flame heights, rate of fire spread, and fireline intensity. Additional model modules predict maximum spotting distance. The probability of ignition can be looked up in tables. These five variables are used by the fire manager in fashioning a reasonable prescription for each burn unit.

   Fuel Model 4 is used most often for Station vegetation. This fuel model was actually designed for western chaparral, but works reasonably well for vegetation types such as tall scrubby flatwoods, sand pine scrub, and overgrown sandhills. Measurements of fire spread and flame length taken at the Station seem to indicate that scrub fires may actually be somewhat more intense than predicted using Fuel Model 4, which has led to the use of generic prescriptions based, in part, on our own observations.

b. *Use of generic prescriptions for Archbold Biological Station vegetation* - Generic prescriptions (Table 12) based on BEHAVE outputs and local fire behavior observations have been formulated by Menges and Main based on conditions at the Station. They may be used in case of a wildfire on the property. They can also be used in the prescriptions of burn units with similar vegetation types (fuel models). These are useful as starting points in designing prescriptions for individual burn units. Essentially, the generic prescriptions provide general guidelines for controllable fires in generic fuel situations such as low scrub, scrub, long-unburned scrub, flatwoods, grassy fuels, etc. These are being constantly evaluated and updated with each burn.

   The generic prescriptions are only useful for modeling fire behavior based on fuel and weather parameters. Other concerns, such as location and size of fire, crew size, and safety issues must also be factored into each individual burn situation.

Table 12. Generic Prescriptions Based on BEHAVE Outputs for Vegetation Types at Archbold Biological Station, Highlands County, Florida.

FUEL MODEL PARAMETER	4 Mature Scrub*	4 Dense Scrub*	4 Mature Scrub*, Conservative	5 Low Scrub*	7 Flatwoods	1 Grass	2 Sandhill, Wiregrass
Vegetation Types LONG-UNBURNED	RSt,RSh, SSo, SF, FL	RSh, SSo, SF	RSt,RSh, SSo, SF, FL	(N/A)	(N/A)	ponds	RSt
Vegetation Types 10-20 YEARS POST FIRE	RSh, SSo, SF, FL	RSh, SSo, SF	RSt,RSh, SSo, SF, FL	SF	FL	ponds	RSt
Vegetation Types 0-10 YEARS POST FIRE	(N/A)	FL	FL	SF, FL	FL	ponds	RSt
20' Wind (mph)	6-16	8-16	4-10	5-20	5-20	10-25	6-22
Midflame wind (mph)	3-8	4-8	2-5	2-8	2-8	4-8	2-8
Relative Humidity (%)	25-69	25-54	30-74	30-84	30-90	40-84	30-70
1 Hour Fuel Moisture (%)	5-9	4-7	6-10	6-10	6-16	6-10	6-10
PREDICTED FIRE BEHAVIOR (Head fire)							
Rate of Spread (ft/min)	62-176	65-186	25-89	13-86	8-57	39-266	9-101
Flame Length (ft)	14-29	17-29	11-20	4-11	3-8	2-7	3-10
Max. Spotting Distance (miles)	.3-.7	.4-.8	.1-.4	.1-.4	.1-.4	.1-.4	.1-.3
Probability of Ignition (%)	40-70	50-80	40-60	30-60	10-60	30-60	30-50

* Fuel model 4 can be used for long-unburned flatwoods as well as scrub vegetation.

Notes: Calculated for fuels <50% shaded, wind adjustment factor for fuel model 4 = 50%.
Calculated for May - July wildfire, or April prescribed burn.

3. Preparing Units for a Fire

Recommendations for widths of firelanes often suggest a width of 1.5 or 2 times the predicted flame length (e.g., National Wildfire Coordinating Group 1981). Since scrub flame lengths can often approach or even exceed 40 feet (12 meters), such firelane width recommendations would result in significant loss of habitat. Nonetheless, many of the Station's firelanes are quite wide (30 feet). In some vegetation types, back fires can be lit along firelanes to control wildfires, usually with no additional preparation. Narrower primitive roads and trails may need additional preparation to hold a backing fire. Our firelanes are acceptable places to start a fire, but are not intended to stop a fire without additional assistance, i.e. a backfire creating a black line. None of our firebreaks can be depended upon to hold a head fire. Because of the intensity of fires in scrub and flatwoods vegetation, careful planning and additional preparations are required to conduct safe burns. Several techniques are commonly used.

a. *Mowing Around and/or Within Unit* - Mowing with a Brown treecutter is commonly used to widen a firebreak without extensive soil disturbance. Mowing is done along roadsides, firelanes, and trails if needed. Mowing is done at least a week in advance of a burn to allow mown vegetation to dry. Two or more passes are sometimes necessary to make the break wide enough to safely perform the burn. Mowing inside a unit can be used to provide access to large roadless areas. These mowed strips can also be used to break up the burning of large areas. After the burn, these mowed trails are allowed to grow back. Mowing inside units can also be use to eliminate ladder fuels under pines to help reduce pine mortality in fire-suppressed areas. Extensive use of mowing within units is not recommended because of possible impacts to research areas, including limited soil disturbance and abnormal vegetation structure along the mowed path. The effects of mowing as a substitute for fire and mowing as an adjunct to burning have only recently been studied (Smyth 1991, Schmalzer et al. 1994, Schmalzer and Hinkle 1996).

b. *Disking Around Unit* - Some firelanes and primitive roads may require disking before a fire if enough fuels are present to carry the fire across the break. Disking is only done in previously disturbed soils. All perimeter firelanes are disked annually.

c. *Felling Snags Close to Perimeter* - Snags near the edge of a burn unit are generally the most common source of sparks that can create spot fires (fire outside the prescribed area). This can happen during the course of a fire and, sometimes, days later. For this reason, all snags within "1½ times the snag height" of the unit boundary are usually felled before a fire. Units with a large number of snags may require additional work farther inside the unit. Sometimes it is necessary to fell snags in adjoining units as well.

d. *Other Preparation* - Other preparations include trimming branches from trees along the border, raking fuels from firebreaks, setting up drafting stations, and putting down wet lines with water and foam.

e. *Notifying Adjacent Land Owners* - Landowners directly adjacent to the Station may be notified of a prescribed fire, especially if smoke will be a possible problem. A list of phone numbers is kept to notify our neighbors in the case of a wildfire (see section VI). Prescriptions are written to avoid fires that will be a threat to non-Station property, and special care is taken to prevent fires from escaping onto adjacent property. People who are extremely sensitive to smoke are informed of burns scheduled in their area. The Florida Division of Forestry will not issue a burn permit if forecast winds would put smoke on the property of residents that have filed with the State for smoke protection.

f. *Use of Prescriptions Before Potential Burn Days* - After burn units are selected for a season and prescriptions are written for each unit, priority of burning is determined based on the parameters within each prescription. Units are prioritized by wind direction, Drought Index, and other factors unique to each unit (Table 13). Wind direction plays an important role in choosing which unit will be burned on any given day. A chart is made showing the available wind directions for each unit and which unit gets priority for that wind direction (Table 14).

Table 13. Factors for Prioritizing Units to be Burned Within a Season at Archbold Biological Station, Highlands County, Florida.

RESEARCH PROJECTS	Some units may require burning in order to meet a research need.
LISTED SPECIES	Units may need to be burned at a certain time within the season to reduce mortality or increase abundance of listed species.
OVERDUE FOR BURN	Units longer overdue might receive priority over other units.
DEVELOPMENT NEARBY	Units near development may have a narrow prescription window.
WEATHER FACTORS	Units may require specific wind directions, relative humidity, time since last rain, etc.
RESOURCES AVAILABLE	Some units require more crew members and equipment than others.

Table 14. Example of Prioritization of Candidate Burn Units by Wind Direction at Archbold Biological Station, Highlands County, Florida.

Wind Direction	Order of Burning (Unit Number)
N	5C, 48A, 58A, 55, 54, 60B
NE	5C, 34B, 33, 58A, 55, 54
E	43A, 48A, 54, 55, 58A, 60B, 5C
SE	54, 55, 58A, 43A, 48A, 34B, 33, 43A
S	33, 34B, 35B, 54, 55, 58A, 60B, 43A
SW	10, (34B, 35B only after burning 33)
W	10, 8C, (35B only after burning 34B)
NW	8C, 5C, 10

C. Burn-Day Preparations

1. Assemble Weather Information

On the morning of a potential burn, weather data and forecasts are obtained from the weather radio, Okeechobee DOF office, and Lakeland DOF office. Past weather data are also compiled, including drought conditions and days since last rain. During the course of a burn, if an emergency arises, the National Weather Service can be called for a spot weather forecast. In the future, Internet access or a private weather agency may be used for detailed weather forecasts.

2. Check Prescription

With weather information in hand, we determine which burns are in prescription. This may often entail site visits to check prescription parameters that may change from day to day. If no units are in prescription, no burns will occur that day.

3. Check staffing

Appropriate staffing needs to be available for the burn. Currently, minimum staff on the burn must number 7 people. Larger burns may call for larger minimum crew size in the fire plan. An additional person to handle the radio in the office is necessary. All fire crew members should be able to attend the burn from start to finish, if this is not possible, arrangements must be made before burning to make sure replacements are available.

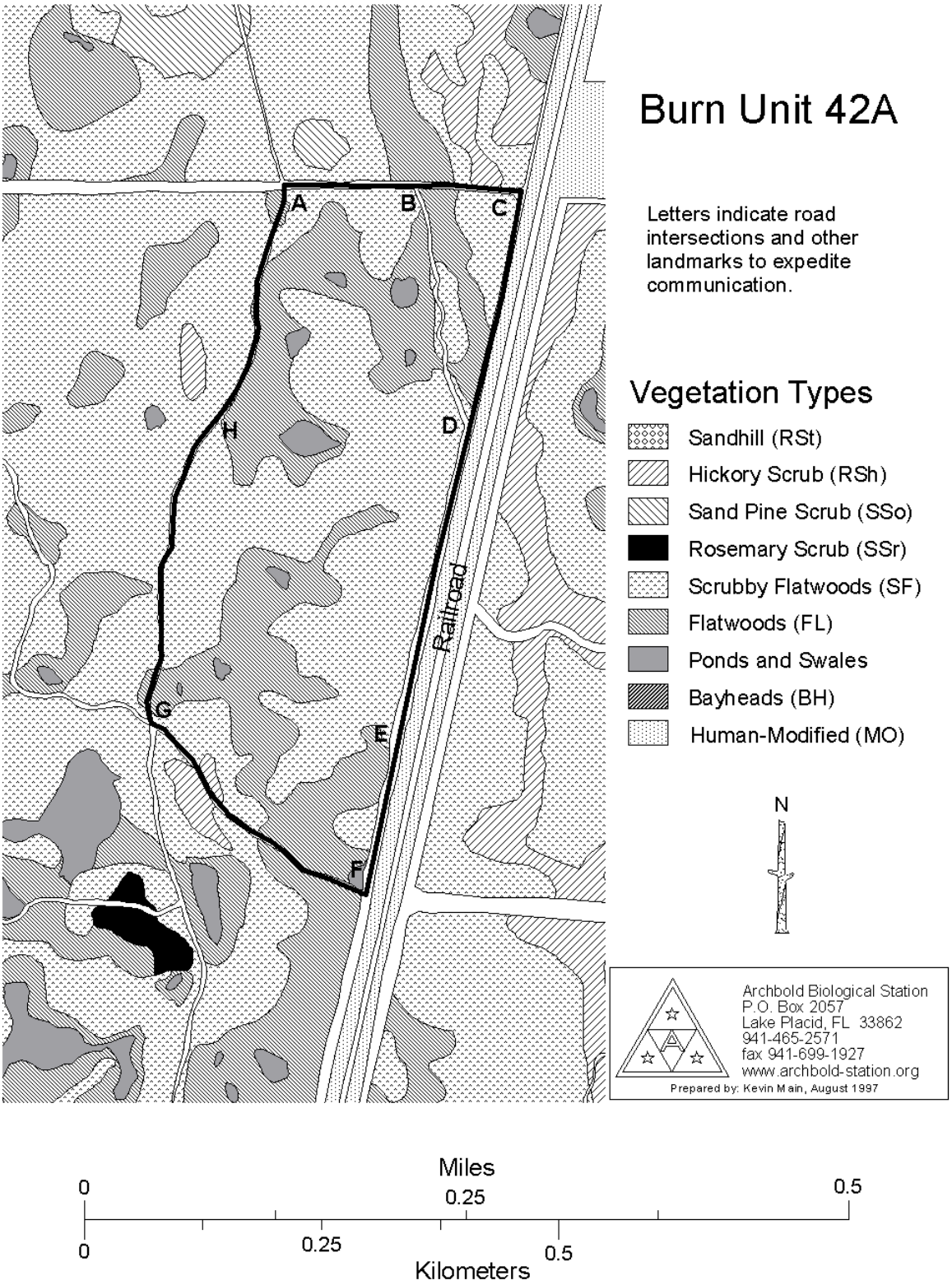
4. Get Florida Division of Forestry (DOF) Permit

The DOF district office in Okechobee issues permits for burning at the Station. The burn boss will call DOF (941-462-5160) the morning of the burn to request a permit. Permits may not be issued during a period of drought, when weather conditions are favorable for extreme fire behavior, or when smoke dispersion is poor.

5. Prepare Fire Maps

Fire maps may be prepared before the day of the burn and updated, or take about 20 minutes to prepare and copy the morning of the burn. Fire maps show a closeup of the unit, with road intersections and other landmarks labeled for easy reference during the burn (Fig. 30). Other information, such as the fire history of adjacent burn units, vegetation types, hazard areas, roads, buildings and predicted wind direction may also be included on the map. Every crew member will have a map. In addition, maps of the entire Station showing fire-sensitive areas (Fig. 26) are given to each vehicle driver in case of an escaped fire.

Fig. 30. Example Fire Map Used in a Prescribed Burn at Archbold Biological Station, Highlands County, Florida.



6. Prepare Crews and Equipment

Volunteer fire crews are selected from available trained staff, interns and volunteers the morning of the burn. A briefing is held before the burn to go over all details, including predicted weather, fire map locations, goals, hazards, safety reminders, crew assignments, and contingency plans. Briefings generally take place in the Auditorium in the late morning beginning about 1 hour before lighting is expected; they usually take 30 minutes or so. Additional briefing by crew leaders or the burn boss often takes place at the site. Vehicles must be filled with water and gas and have drinking water and fire tools on them. All crew members must have all personal protective equipment. Lunches and cold drinks are prepared by the kitchen staff for all burns. The burn boss must bring the prescription to the burn in case problems arise and DOF has to respond to an escaped fire.

7. Coordinate Inter-Agency Assistance

Other agencies that may assist the Station on a prescribed burn are notified as soon in advance as possible, usually the night before or the morning of the burn. Several land management agencies, including The Nature Conservancy (TNC), DOF, and FGFWFC are willing to participate in such burns.

VI. FIRE POLICIES AND REGULATIONS

This section is an update of the fire policy in the Station's policy notebook (ABS Policy Book 1996) which describes the policies and regulations regarding prescribed fires and wildfires at the Station. Some sections of the policy are somewhat redundant and have already been stated but, since overlap is minimal, all sections of the policy are included.

The fire policy covers many important topics, such as how to deal with fires on and adjacent to the Station, who is allowed to work a fire, what crew members must wear for protection, and what kind of training is necessary to work at different levels within the command structure. The fire policy also describes the Station's current fire equipment, procedures for using two-way radios, and road and firelane maintenance.

A. Administration

1. Trained staff members are expected to participate in fire activities if requested at any time during working or non-working hours. In the latter case, equivalent time off will be allowed as compensation for time spent on fires. Overtime pay will be given to maintenance crew and office staff manning the Station radio for all hours above their normal working period at two times the normal hourly wage.

2. The Station assumes no responsibility for individuals who walk or drive their own vehicles to a fire. Permission to visit a fire must be granted by the burn boss.

3. The following guidelines and maps will be available in the front office:
    a. Wildfire Guidelines (Fig. 31) stating procedures for dealing with any unplanned fire.
    b. Sensitive Areas Map (Fig. 26), found on the reverse side of the Wildfire Guidelines, highlights areas that are close to developments (housing and other fire-sensitive properties) and areas where fires should be suppressed due to research interests. Fires near these areas should be suppressed according to the Wildfire Guidelines. A map of the Lake Placid Scrub Wildlife and Environmental Area is included as part of the Sensitive Areas Map. Since the Station manages this property for the State, wildfires in this area should be treated in the same manner as wildfires on the Station. DOF will have a copy of the Sensitive Areas Map. This map is updated yearly, or as needed.
    c. Fire Extinguisher Location Map (Fig. 32) shows where each fire extinguisher can be found in the Station buildings.
    d. Fire Hydrant Map (Fig. 33) shows location of fire hydrants on the main grounds.

Fig. 31. Wildfire Guidelines for Archbold Biological Station, Highlands County, Florida.

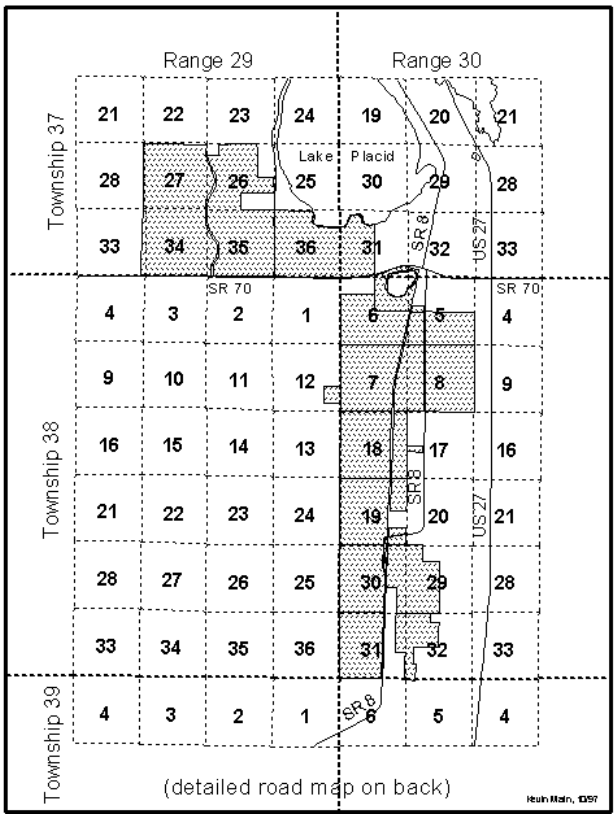
WILDFIRE GUIDELINES

1. Call the Florida Division of Forestry (DOF) dispatch (941-462-5160) and tell them we are investigating a possible wildfire.

2. Send someone to check fire. A second person will need to stay by the Station's Base radio in the front office.
WHO TO SEND: Must be 18 or older, experienced with fires, and familiar with roads. Must have a hand-held radio and a "Fire Sensitive Areas" map (on back*) from front office.
WHAT TO CHECK: fire size_____, wind direction_____, weather conditions _____, fuels presently burning_____, fuels in path of fire_____, roads/structures/private property in path of fire_____, best access to fire for vehicles_____.

3. Use the "Fire Sensitive Areas" map on back to identify developed areas and research areas.

4. NOTIFY A CERTIFIED BURN BOSS BY PAGING THE STATION OR CALLING THE LISTED NUMBERS. IF NO ONE CAN BE REACHED, OR IF THE FIRE IS NEAR A DEVELOPED AREA, CALL THE FLORIDA DIVISION OF FORESTRY (DOF) AT 941-462-5160 AND REQUEST THAT THEY DISPATCH A RANGER. GIVE DOF FIRE LOCATION IN SECTION/ TOWNSHIP/RANGE COORDINATES USING THE MAP AT RIGHT:



PHONE NUMBERS		
ARCHBOLD STAFF (CALL IN ORDER)		
Certified Burn Boss, Kevin Main	Mobile Home	941-465-8489 941-382-0624
Certified Burn Boss, Eric Menges	Home	941-471-2197
Op. Manager, David Johnston	Home Mobile	941-639-4081 941-627-7989
ABS Director, Hilary Swain	Home	941-465-6689
Maint. Supervisor, Bert Crawford	Home	941-465-8399
FLORIDA DIVISION OF FORESTRY (DOF)		
DIVISION OF FORESTRY DISPATCH		941-462-5160
Division of Forestry Tower on Red Hill		941-465-2342
Division of Forestry Ranger Station		941-465-3763
National Weather Service (spot weather)		813-645-2323

5. Certified burn boss will keep DOF informed of fire location and behavior, and if help is needed. DOF has the right to enter ABS to put out fires or to order ABS to suppress. DOF personnel are sensitive to our desire to avoid plowlines.

6. Based on DOF approval, certified burn boss will decide to SUPPRESS or CONTROL fire:

SUPPRESS FIRE IF:
a. **EXTREME DROUGHT** - Conditions posted in front office.
b. **NEAR SENSITIVE AREA** - Check map on back.
c. **EXTREME CONDITIONS -**
Relative humidity < 30%
Wind (ground) > 8 mph
Wind (20'; forecast) >20 mph (or Extreme fire behavior observed)
d. **LESS THAN 6 CREW MEMBERS ARE AVAILABLE.**

Suppression Tactics include active attack on fire with water, halting fire within portions of burn units, and (if necessary), entry onto burn units with vehicles. Backing fires may also be set. Halt the fire as soon as possible at the smallest size.

CONTROL FIRE IF NONE OF THE ABOVE APPLY. Control Tactics use backing fires to safely confine the fire to desired burn units. Avoid entering burn units with vehicles. Contain the fire with minimal impact on vegetation.

7. Certified burn boss will form lighting and holding crews:

CREW MEMBER QUALIFICATIONS	
Trained in lighting, holding and safety procedures	permanent release form on file if not full-time staff
Must have all Personnel Protective Equipment (PPE): boots, nomex, hardhat, gloves, goggles, canteen	in good physical condition (step test score of 40 or more)
Available to work until fire is out	must follow certified burn boss instructions

Certified burn boss will brief crews, make sure everyone has maps, and water and that there is drinking water on all vehicles. Someone will be assigned to stay near office radio. Fire tools are in garage and in fire truck. PPE is in plant lab attic. Weather kit and radios are in Kevin Main's office.

* The wildfire guidelines are desigined as a two-sided document. See Fig. 26 for the map "on back" referred to here.

Fig. 32. Fire Extinguisher Locations at Archbold Biological Station, Highlands County, Florida.

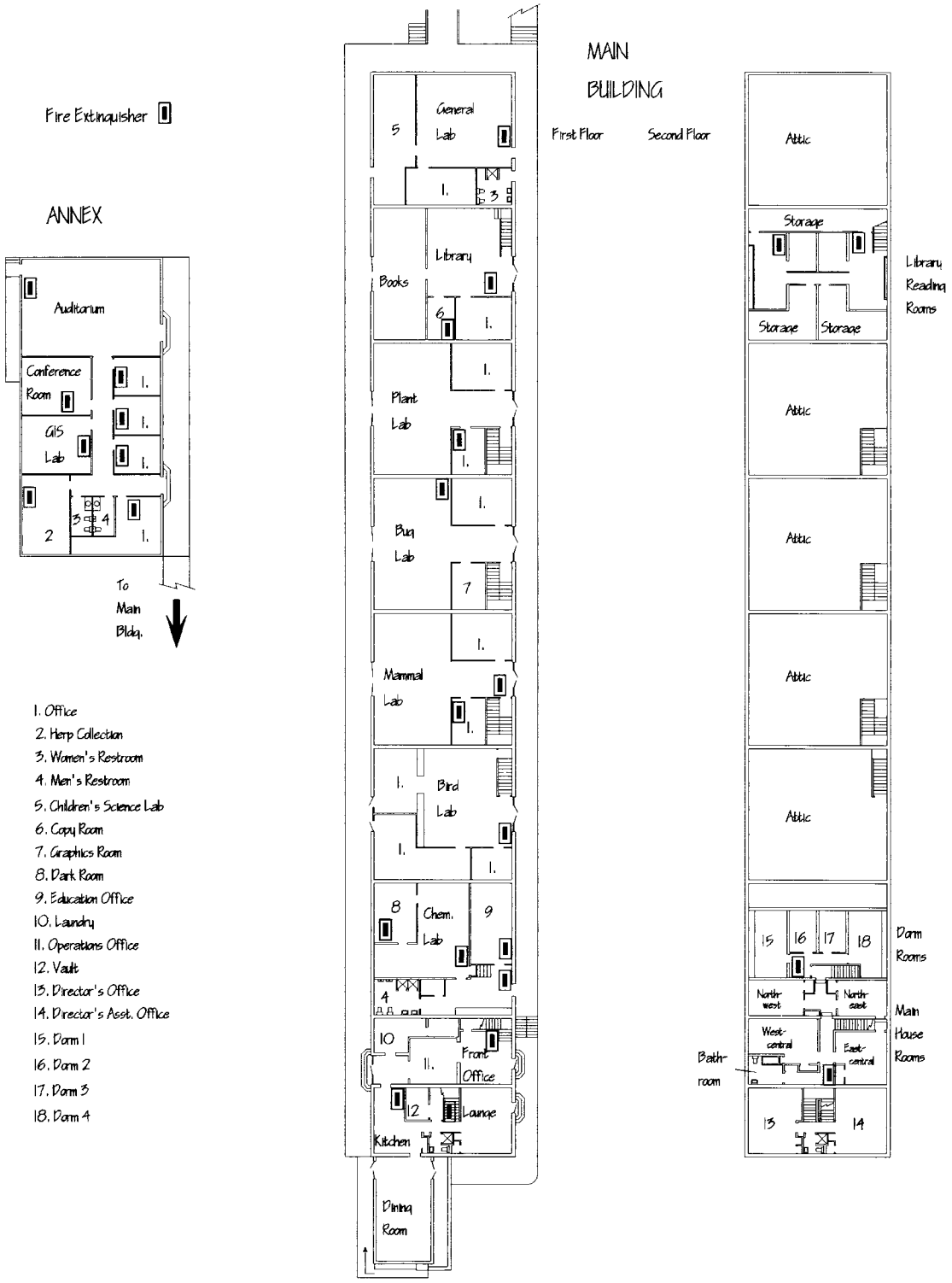
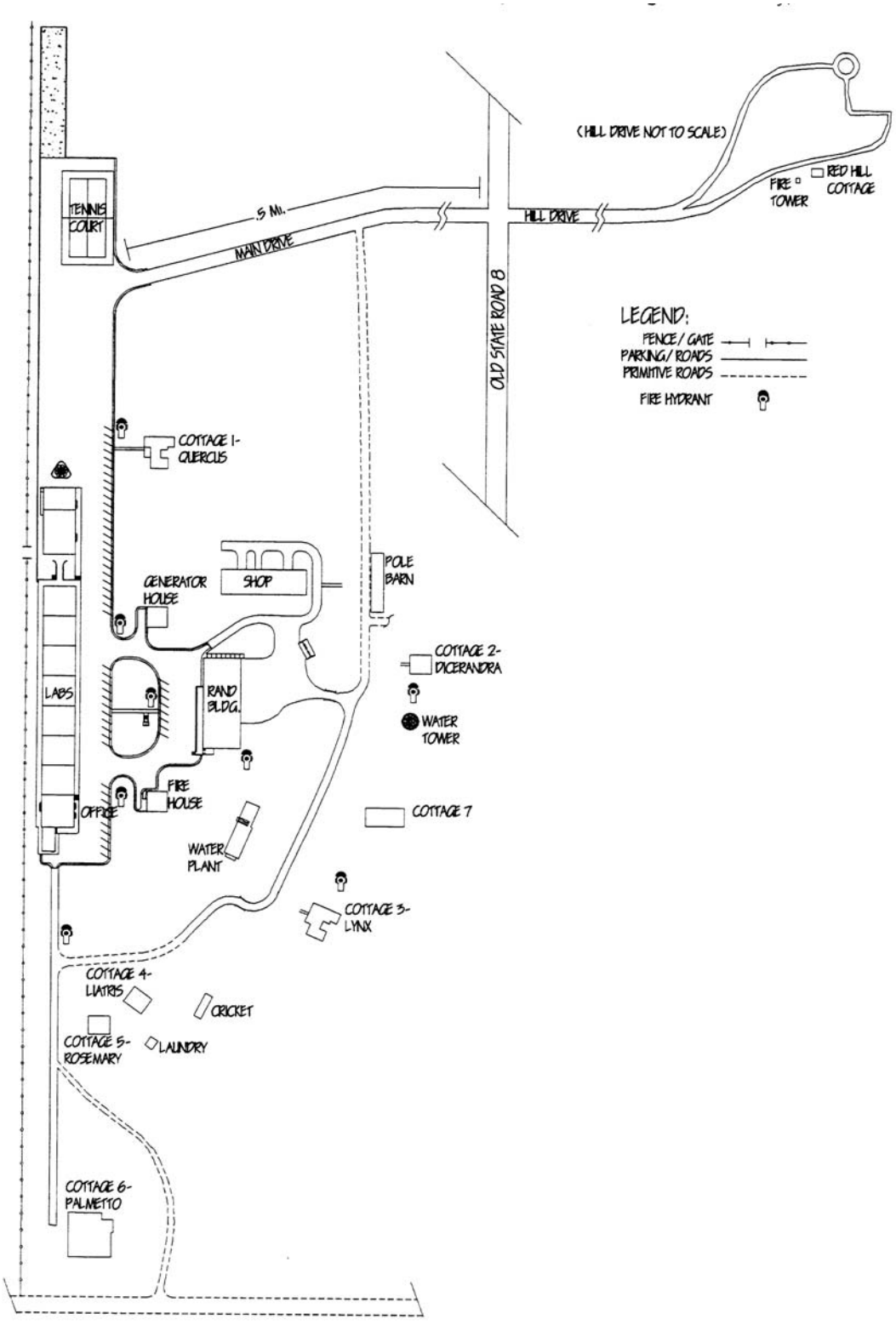


Fig. 33. Fire Hydrant Locations on the Main Grounds of Archbold Biological Station, Highlands County, Florida.



4. All Station personnel are expected to be aware of potential fire hazards in their particular office or work area and to take every precaution to minimize the danger of fire. Any condition or situation that may increase fire hazard should be immediately corrected by the individual employee or reported promptly to the Station Manager. The employee should know the location of fire extinguishers in his or her work area and be familiar with their operation.

5. Smoke detectors and fire extinguishers are located in all areas of the main buildings, cottages, and shops; and all vehicles are provided with a fire extinguisher and first aid kit.

6. Only staff members and other individuals with specific authorization are permitted to work on fires. Non-full-time staff must have a release form on file. All crew members must have fire training. Refresher courses are recommended on a yearly basis.

7. Fire equipment will be maintained by the land manager and maintenance crew. A list of all available fire equipment and its location will be maintained and reviewed; and all equipment will be regularly inspected and updated.

B. Safety

1. General Rules

    a. Fire crew members must ride inside cabs of fire vehicles en route to and from fires if driving on non-Station property.
    b. No fire crew member is ever to be out of radio contact with the rest of the crew during the course of a fire.
    c. During a fire, the burn boss is in control of all activities.
    d. All Personnel Protective Equipment (PPE) must be worn at all times during the burn (see next section).

2. CPR and First Aid Training

    Burn boss and Crew bosses must have CPR and First Aid training. All other fire crew members are encouraged to have this training as well. A CPR training course will be offered yearly for untrained employees and for recertification of trained employees. First Aid training will be given as needed.

3. Fire Training

    All training is available through various Federal, State and private agencies in the central Florida area. The Station will also host some of these courses. The Station land manager will schedule training sessions for all fire crew members. Training to use the fire vehicles will also be scheduled by the land manager.

    a. Burn boss must have successfully completed the DOF "Basic Prescribed Fire Training" course (certified burner's number is issued by the State after taking this course), along with S-130, S-190, Standards for Survival, S-290, S-390 (all U.S. Forest Service courses), and a yearly refresher course. Taking additional training courses each year is recommended.
    b. Crew boss must complete S-130, S-190, Standards for Survival, S-290, and a yearly refresher course. Other courses such as S-230 (Crew Boss Training) are recommended. Taking additional training courses each year is recommended.
    c. Fire crew (full-time staff) must complete S-130, S-190, Standards for Survival, and a yearly refresher course.
    d. Fire Crew (non-full-time staff and volunteers) must complete basic Archbold Fire Training (given by the Station land manager). S-130, S-190, and Standards for Survival are recommended.

4. Crew Size

    Crew size varies depending on several factors. Generally, burns on smaller units can be performed with a smaller crew. Conditions requiring larger crews include large units, extreme weather conditions, a higher probability of escape into adjoining units, units with high fuel loads, units near developments, and units with potential problem spots (for example, an area with lots of snags). Crew size will be established in the prescription for the unit based on these factors and other contingency plans.

5. Postfire Feedback

After each burn the land manager will request feedback from the crew. Questions and concerns from the crew about problems during the course of the burn or ideas for conducting the burn in a different manner are helpful for making adjustments in the burning process and increase the safety level of future burns.

C. Equipment

1. The following Personal Protective Equipment (PPE) is required for all crew members for Station fires and for off-Station fires that Station staff take part in:

   Equipment Provided by the Station:
   * **Nomex Fire Clothing** - this material is flame resistant, NOT fireproof
   * **Leather Gloves**
   * **Hard Hat with NOMEX Neck Protector**
   * **Radio and Backup Battery** (not all crew members will have a radio)
   * **Canteen**
   * **Goggles**

   Equipment not provided by the Station:
   * **Leather Boots with a Hard Rubber Sole** - interns and others planning to work on a fire must provide their own boots

   Personal Protective Equipment (PPE) can be found in the Plant Lab closet, radios are in the land manager's office in the Plant Lab.

2. Trained scientific and maintenance staff are expected to know the location of and be able to use all fire-fighting equipment, including fire extinguishers, hoses, hydrants, fire truck, dump truck and slip-on pumper, trailer mounted pumper, Personal Protective Equipment (PPE), drip torches, fire tools, radios, etc.

3. The Fire Truck

   The fire truck is a 1956, standard shift, 4-wheel drive International Harvester. Only trained personnel are allowed to operate the fire truck. The truck is always equipped with drip torches, fire tools, and foam. The water tank and gas tank are always kept full. All valves and hoses are correctly positioned for immediate use as soon as pump is engaged. The truck is equipped for use with water only. A mobile radio is installed in the truck, but another radio should be issued to a member of the fire truck crew not driving the vehicle for improved communication. The fire truck must be reloaded with water after a fire. <u>The fire truck is the only vehicle kept ready for a fire at all times</u>.

4. The Dump Truck

   The dump truck is a 1982, standard shift, 4-wheel drive Ford. Only trained personnel are allowed to operate the dump truck. The slip-on pumper for this vehicle is kept in the tractor barn. The pumper must be put on the truck and filled with water before being available for a fire. A foam unit (previously on the fire truck) is installed on the dump truck to allow foaming capabilities.

5. Trailer-Mounted Pumper

The trailer-mounted pumper is kept in the tractor barn. The tractor is used to pull the trailer. Only trained personnel are allowed to operate the tractor/trailer. The pumper must be filled with water before being available for a fire.

6. 150-Gallon Slip-on unit

This unit is stored in the shed on the hill. It can be put in the back of any standard pickup truck. Only trained personnel are allowed to operate this slip-on unit. The unit must be filled with water before being available for a fire.

7. Use of the Radios

The Station is equipped with three types of radios: hand-held radios (generally referred to simply as "radios"), mobile radios (in the fire truck, the dump truck and the current maintenance crew truck), and the base station radio (generally referred to as “base”) located in the front office.

Broadcast frequency is 157.560 megahertz. Due to the higher wattage, the base radio should not be operated when someone is on the water tower (where the antenna is located) due to the possibility of receiving a burn during the transmission. Water tower access is kept locked during fires. Hand-held radios will not cause a burn.

There are 9 hand-held radios; 8 are stored in the land manager’s office, one is kept by the base radio in the front office for use in scouting a wildfire. Effective range between these hand-held radios is approximately ½ mile. Effective range between a radio and the base station is approximately 10 miles.

All radios have 2 or more channels. Channel 1 (157.560 megahertz) is for communication with Station personnel, channel 2 (159.315 megahertz) is for communication with the mobile band of DOF.

When using a radio, keep transmissions brief to preserve the battery. A battery will last approximately 6-8 hours on stand-by before needing a recharge. Heavy transmission reduces battery life to 1 hour. An extra battery is supplied with each radio.

The radio call sign is “KNIE 751.” It must be announced before each transmission, such as “This is KNIE 751 Base to Burn Boss, Over.” When there is going to be heavy and regular use of the radios on a given day (like a prescribed burn day), the Burn Boss can announce “This is KNIE 751 on the air for the day, frequent transmissions will all be from this call sign.” The Burn Boss should repeat this message approximately every hour to avoid all participants from being required to use call letter identification on each transmission.

D. Responsibility

1. One individual will serve as burn boss in handling fires on or off Station property. The burn boss is responsible for all operations relating to a fire. These include communication with DOF or other fire management agencies as necessary; obtaining information on the location and status of an unplanned fire; determining when and how the fire is to be fought; signing permits accepting responsibility for a fire; authorizing individuals to work on a fire; deploying vehicles, personnel, and equipment; and preparing all reports and evaluation of the fire.

2. The burn boss may request aid from other staff members in making decisions and may delegate full or partial authority to a staff member or DOF. The burn boss should remain mobile, with a radio and a vehicle, to provide overall supervision and coordination of personnel involved in a fire. The burn boss will instruct crew bosses in charge of holding or lighting activities.

3. The Station land manager will normally serve as burn boss for all fires. If the land manager is not available, other certified personnel may serve as burn boss.

E. Unplanned fires (wildfires) on the property

1. Any structural fire is to be extinguished at once in the most expedient manner, but no one is allowed to enter a burning building. Vehicles should be used to fight fire from outside the building and keep fire from spreading to adjacent buildings. **Call 911 at once for any structure fire**.

2. Unplanned NON-STRUCTURAL fires may be suppressed or controlled according to conditions stated in the Wildfire Guidelines (Fig. 31). This section describes in detail how the Station will respond to a wildfire. These guidelines are posted in each lab, in the lounge, in the main office, and are provided to interns and visiting researchers.

3. Any fires that threaten to burn off the property should be suppressed immediately, and DOF should be called to respond.

F. Unplanned fires off property

1. The station will respond to a fire off Station property upon request by DOF. However, DOF has been advised that the Station would prefer not to engage in fire-fighting off the property unless there is an imminent threat to life or Station property.

2. If the Station receives a direct request from a resident in the area to respond to a fire, the caller should be asked first to call DOF. The Station can respond only if DOF asks for our assistance.

G. Prescribed burning

1. All planning, pre-burn surveys, pre-burn preparation, prescription writing, bossing of prescribed fires , post-burn surveys and reports, and Geographic Information System (GIS) digitizing shall be conducted or supervised by the land manager.

2. Scheduling of burns will be determined by the Archbold Biological Station (ABS) Fire Management Plan. All proposed burns are subject to review from the scientific staff.

3. A pre-burn briefing will be given before each burn, stating the goals of the burn, current and forecast weather conditions, safety reminders, crew assignments, lighting patterns, holding responsibilities, contingency plans and access routes. Each crew member will receive a map of the unit, showing the area to be burned, names of roads and trails, and letters for each intersection or landmark. Each crew boss or vehicle driver will receive a map of the entire station, for use in the event of an escaped fire.

4. An escape from a prescribed burn shall be treated as an unplanned fire. The burn boss will direct crew using the Wildfire Guidelines (Fig. 31) in the event of an escape.

5. A permit must be granted by DOF for all prescribed fires. The Burn Boss will call to receive the permit and notify DOF that the Burn Boss is a certified burner for the State of Florida (and give burner's number). **DOF will not ask for this information, but it is very important that they know this, so that we will be covered by the State statutes on prescribed burning.**

6. Prescribed fires will be numbered in sequence with all other burns on the property.

7. Requirements for Personal Protective Equipment (PPE), responsibilities, crew member qualifications, use of equipment, etc., will be the same as for an unplanned fire (Fig. 31).

H. Reports and Evaluation

1. For every fire on the property, a report shall be prepared by the burn boss stating the unit(s) burned, date of fire, lighting pattern (for prescribed fires), estimates of fire intensity, rates of spread, problems on the burn, and any other information necessary to evaluate the burn. A standard report form shall be used to record this information (Appendix C). For unplanned fires where DOF had to be called, the location of any plow lines shall be mapped.

2. A map of each fire shall be prepared by the burn boss showing areas of differing intensity of fire within the unit(s) burned. These maps will be digitized onto the Geographical Information System (GIS) for use in evaluation or scientific research.

3. Scientific staff meetings to evaluate the effectiveness of the fire program shall be held yearly to determine if any changes need to be made to the fire management plan, or the way burns are handled.

I. Firelane and Road Maintenance

1. In all cases of firelane and road maintenance, strong consideration is given to research and biota needs. A memo notifying staff of upcoming maintenance will be provided at least a month in advance so that areas to avoid can be clearly marked.

2. Firelanes will be maintained by yearly disking to remove grasses or other annual vegetation that might carry a fire across the firelane. Perimeter firelanes shall be maintained at 30 feet wide. Interior firelanes shall be maintained at 20 feet wide. Disking should be done between December and February. Exceptions for research will be allowed.

3. Primitive roads shall be maintained by mowing road shoulders yearly, usually in winter or early spring. Roads shall be maintained at 10 ft. wide. Exceptions for research are allowed.

4. Trails shall be maintained by mowing, usually in the winter or early spring. Not all trails are mowed every year. Trails shall be maintained at 5 feet wide to allow ATV passage. Exceptions for research will be allowed.

5. Vegetation growing under electrical transmission lines will be mowed when vegetation height exceeds 15 feet. Exceptions for research will be allowed.

6. All firelanes, roads, and trails are subject to additional disking or mowing on a unit by unit basis.

7. The treads of any non-Station vehicle must be cleaned of all vegetation before being used on the Station property to discourage the movement of exotic plants.

J. Cooperation with Other Fire Management Agencies

1. The Station will allow staff members and fire equipment to be used on inter-agency burns, both on and off the Station property. Other agencies shall be allowed to use their staff and equipment on Archbold Biological Station (ABS) supervised burns, as long as they are willing to sign the release form. Inter-agency coordination shall be handled by the land manager.

VII. MONITORING AND RESEARCH ON FIRES

A. Mapping Fire Extent and Fire Intensity

Fire intensity is mapped for all fires at the Station. Intensity is measured visually, using vegetation indicators divided into four classes (Table 15). Intensity classes are defined by the extent to which vegetation is burned and the patchiness of the burn . Other fire management agencies use a fire intensity classification system similar to the Station's, so in the future, burns from several different sites may be cross-analyzed. This method was first used at the Station by James Layne and Warren Abrahamson and has been updated by Menges and Main. All fires are mapped and digitized into the Station's GIS for research use and as a historical data base. Mapping should be done within two months of the burn for best interpretation of fire intensity classes (before significant plant regrowth).

1. Use of GIS

The Station's GIS and coverage library were vital to the production of the fire management plan. Digital coverages of vegetation, roads, and individual fires were used to create most of the figures (using ArcView 3.0). Spatial data from the vegetation and burn unit coverages was necessary to develop fire-return intervals based on vegetation type, determine overdue vs. not overdue units, and develop plans for future burns.

GIS is also used to relate fire intensity to vegetation, soil type, time since last fire and other coverages within the system. Individual GIS fire coverages are used in several ways: designing future research plots to study fire effects, spatial analysis with other coverages, planning future burns, and making color plots.

2. Routine Aerial Photography

After each burn period, an aerial flight (at 200'-400') of the Station property is made to photograph each burned area. Usually several burns are photographed during one flight. Photographs are taken from an open window on the plane as it circles each burned area. Photographs of each unit are taken from several different directions and elevations to provide detail for mapping and as a pictoral database which is stored in the land manager's office.

3. Mapping Process

a. Lines are marked showing fire intensity boundaries on rectified blueline aerial photographs (1:2400 scale) of the area using the aerial photos described above. Areas of different fire intensity can usually be mapped down to about 50 m^2 resolution, depending on whether landmarks are available to accurately place the boundary line. In large areas without landmarks small patches of different intensity must be incorporated into the fire intensity class surrounding it. This typically occurs where small areas of scorched vegetation are found within large areas of completely burned vegetation. Future use of Global Positioning Systems (GPS) will enable us to pinpoint these locations on the ground.

b. The marked-up blueline map is taken into the field to ground truth and make any corrections to the fire intensity boundaries. This usually requires very little time in intensely burned areas, but may take several days to complete on a large, patchy burn.

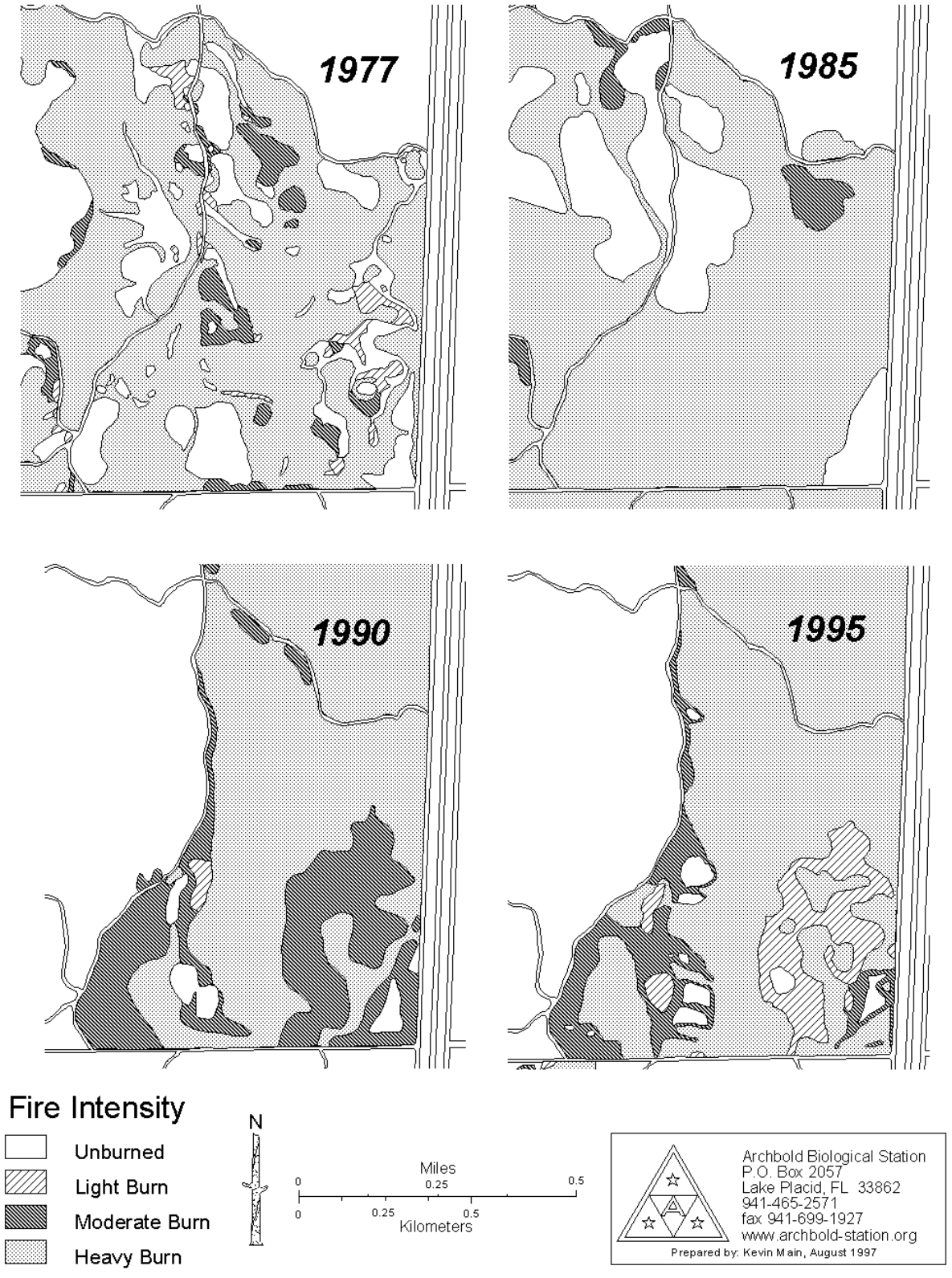
c. Corrected intensity boundaries are digitized into GIS. The Station uses a Gateway P5-120 pentium computer running PC Arc-Info (ver. 3.5.1), along with a Calcomp 9100 digitizer (48"x60") to digitize coverages. Field maps are digitized with a registration error of no more than .004 digitizer inches. After intensity boundaries are digitized, arcs from the Station's road coverage are added where they form the perimeter of the burn. Each new coverage then goes through a cleaning process to establish topology and database items are added. All coverages are stored in Universe Transverse Mercator (UTM), zone 17, NAD 27 coordinates. Each fire is stored as a separate coverage in the GIS fire coverage library. Fig. 34 is an example of some of the fire intensity coverages stored on the GIS.

Table 15. Fire Intensity Classes for Mapping Fires at Archbold Biological Station, Highlands County, Florida.

FIRE INTENSITY	DESCRIPTION	SURFACE LITTER *	DEAD LEAVES (0-2 M)	TWIGS	PALMETTO LEAF BLADES
0	Unburned	Unburned	All Unburned, (Green)	Not Consumed	Not Consumed (Green)
1	Light	Patches Unburned	Some Leaves Not Consumed (Green)	Mainly Not Consumed	Scorched- (Brown)
2	Moderate	Consumed	Leaves Scorched (Brown)	Mainly Not Consumed	Leaf Blades Partially Consumed
3	Heavy	Consumed	All Burned Off	Small Twigs Consumed	Leaf Blades Completely Consumed-Petioles May Remain

***Some areas have deep remaining litter**

Fig. 34. Series of Four GIS Fire Intensity Coverages for Unit 49B



B. Ground Photopoints

Photos taken at photopoints set up in 1992 are taken at 200 road and trail intersections on the Station. Pictures are taken every five years at all the points. In addition, pictures are taken annually for two years post-fire at photopoints around each burned area, and before major planned burns.

C. Observations During a Burn

1. Weather

During the course of a burn, a crew member will take weather readings every half hour. Wind speed and direction, relative humidity and air temperature are recorded. Changes in wind direction are announced over the radio. The amount of cloud cover, development of thunderstorms, rain, and any other unusual weather events are indicated on the weather log.

2. Fire Behavior

Notes are taken on: estimated rate of spread and flame height for back fires, flank fires and head fires, extreme fire behavior such as fire whirls and running crown fires, strong convection currents, number of spot fires and their distance from the fire boundary, and fire intensity within different vegetation types. This information is useful for updating generic Station prescriptions (Table 12). Additional information, usually acquired for specific research projects, is taken on some fires. For example, temperature sensitive paints have been used on several burns to sample fire intensity (Abrahamson and J.R. Abrahamson 1996, Menges and Deyrup, in preparation).

D. Archival of Fire Information

Fire notes, the fire plan and prescription, the fire intensity maps, weather data, and other paper records are stored in files in the land manager's office, with a separate file for each fire. Digitized coverages of each fire are stored in the GIS library.

E. Habitat Research and Monitoring

A myriad of research and monitoring involving fire has been accomplished at Archbold Biological Station by staff and visiting scientists. Specific information on research and monitoring conducted at the Station can be found in the Station's biennial reports (Lohrer 1993, 1995, 1997) and in the Station bibliography, which contains over 1000 articles over a 52-year period (Fred Lohrer, pers. comm.). Research has involved many different organisms, including many threatened and endangered species, many vegetative communities, different spatial scales of observation, and both comparative and before/after approaches. Examples of some of the projects related to fire are listed in Table 16. Proper fire management is dependent on continued fire-related research and monitoring at the Station.

Table 16. Selected Research Projects Utilizing Fire at Archbold Biological Station, Highlands County, Florida.

Subjects of Research	Publications
Plant community responses to fire	Abrahamson 1984 a,b; Myers 1985, Myers and White 1987, Johnson and Abrahamson 1990, Hawkes and Menges 1996, Abrahamson 1995, Abrahamson and C.R. Abrahamson 1996, Abrahamson and J.R. Abrahamson 1996
Fire-suppression effects on plant communities	Givens et al. 1984, Peroni and Abrahamson 1986, Menges et al. 1993
Life history strategies of plants with fire	Menges and Kohfeldt 1995
Demographic responses of various plants to fire	Abrahamson 1991, Menges 1992, Ostertag and Menges 1994, Gibson and Menges 1994, Hawkes and Menges 1995, Menges and Kimmich 1996, Menges and Gordon 1996, Quintana-Ascencio and Morales-Hernandez 1998
Metapopulation and landscape aspects of fire	Quintana-Ascencio and Menges 1996, Menges and Hawkes 1997
Scrub-jay responses to fire; fire management for scrub-jays	Woolfenden and Fitzpatrick 1984, Fitzpatrick et al. 1991, Fitzpatrick et al. 1994

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APPENDICES