Fire Management in the Inter Galatic Interface or 30 Years of Fire Management at Merritt Island National Wildlife Refuge/ Kennedy Space Center, Florida

Frederic W. Adrian[1]

Abstract—*Prescribed burning is essential on Merritt Island National Wildlife Refuge. Not only is it needed to manage the volatile fuels, but also to manage the complex system of fire maintained habitats found here. Fire management on the Refuge presents unique challenges. In addition to the restraints to prescribed burning that are common to many prescribed burning programs, Refuge fire managers must also consider the special needs of an operational space port. By using an active program of education, demonstration and negotiation with the Space Center, the Refuge has been able to maintain a prescribed burning program that has reduced the detrimental effects of unwanted wildland fires when they occur.*

Introduction

Merritt Island National Wildlife Refuge (Refuge) is located on the east central coast of Florida in Brevard and Volusia Counties (figure 1). The majority of the Refuge is an overlay of the National Aeronautics and Space Administration's (NASA) John F. Kennedy Space Center (KSC). The U.S. Fish and Wildlife Service (Service) administers these lands and waters under an interagency agreement. This agreement gives the responsibility for land management activities for KSC's non-operational lands to the Service. Included in these management responsibilities are wildland fire suppression and prescribed burning. The Refuge also has agreements with Canaveral National Seashore (CNS) to assist with both prescribed burning and wildland fire suppression and with the Cape Canaveral Air Force Station (CCAFS) to assist in prescribed burning. Together, these four federal agencies manage over 180,000 acres of relatively undeveloped coastal barrier islands and lagoons.

This coastal ecosystem is quite diverse. Schmalzer and others (2002) list 803 native plants on the Refuge and adjoining federal lands, with, 38 taxa listed as endangered, threatened or of special concern by the State of Florida. This wide array of plant species has been grouped into 20 native wetland and upland vegetative communities (U. S. Fish and Wildlife Service 2006). The Refuge's habitats provides protection and management opportunities for 10 regularly occurring federally listed threatened and endangered wildlife species, as well as for 36 species of federal management concern and 47 wildlife and plant species listed by the State of Florida (Epstein and Blihovde 2006). In addition, over 300 species of migratory and resident birds, 30 species of mammals, and 71 species of reptile and amphibians have been recorded on the Refuge (Adrian and others 2006).

In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management—How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

[1] Administrative Forester, Merritt Island National Wildlife Refuge, Titusville, FL. Fred_Adrian@fws.gov

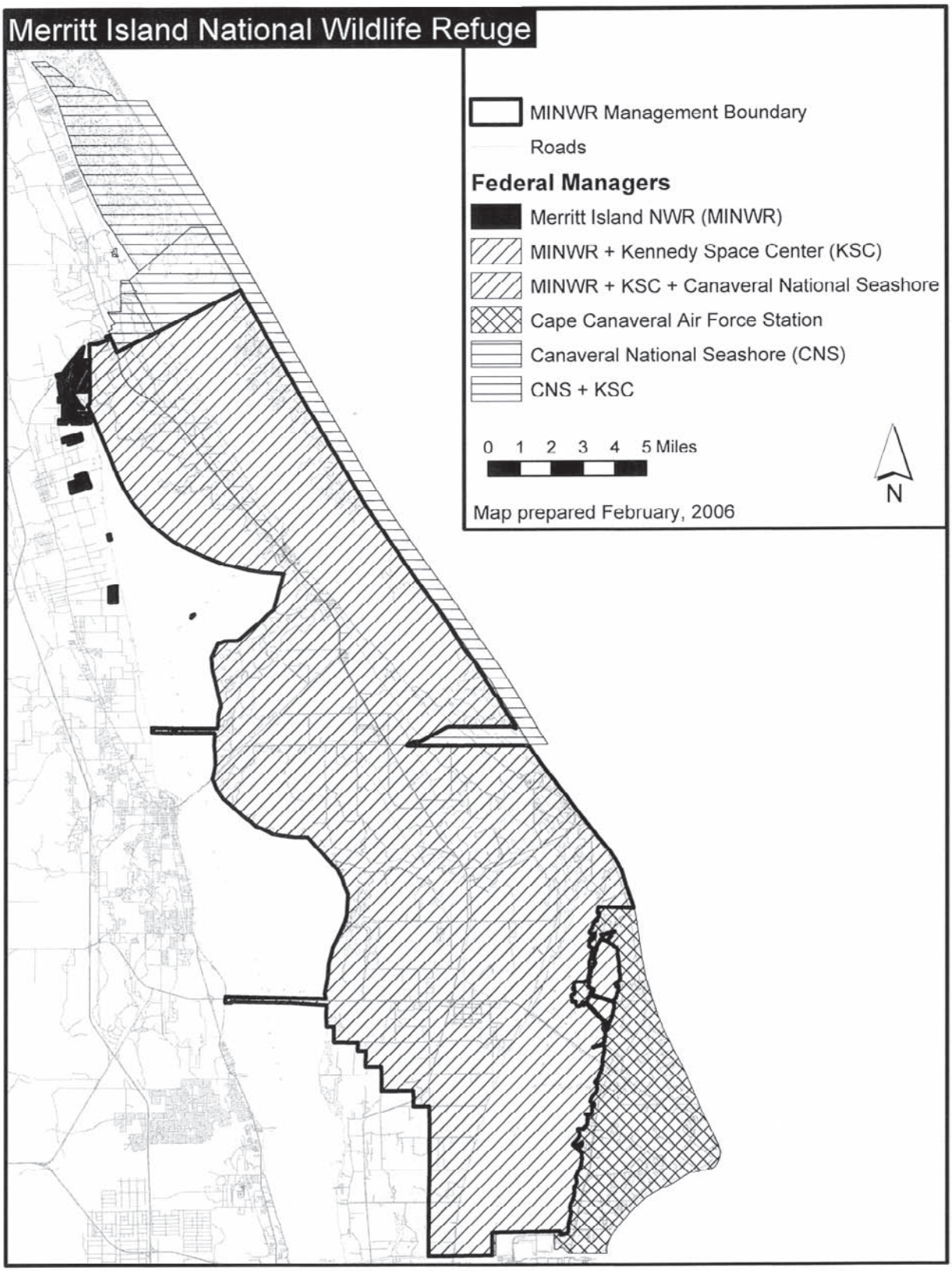

Figure 1—Location of Merritt Island National Wildlife Refuge and other federal agencies.

Fire History And Fire Ecology

Fire has been a component of the Florida ecosystem since before humans occupied the landscape. The National Weather Service Office in Melbourne, Florida states that Florida is the "lightning capital of the United States", with over 22,000 lightning strikes occurring in Brevard County alone each year (National Weather Service 2005). In historic times, lightning frequently ignited fires, which spread readily throughout the landscape. Examination of charcoal deposits in lake sediments show that fires have occurred in south central Florida for 50,000 years (Watts and Hansen 1988). It is logical to assume that fire has been instrumental in favoring the selection of fire-adapted traits in the Florida's vegetation.

Fire Maintained Vegetative Communities

Of the almost 77,000 acres of non-open water habitat on the Refuge, approximately 55,000 acres support plant communities that can be considered fire maintained. Without periodic fires, the characteristics of the four important fire-maintained vegetative communities on the Refuge described below would change drastically.

Oak Scrub: Oak scrub occurs on xeric sites. The shrub layer plants found here include sand live oak (*Quercus geminata*) myrtle oak *(Q. myrtifolia*) and Chapman's oak (*Q. chapmanii*) along with some palmetto (*Serenoa repens*). Occasionally, a sand pine (*Pinus clausa*) overstory is present. Historically oak scrub stands were low and open with many sandy patches.

The fire regime in the oak scrub can be described as intense and stand replacing. Oak scrub is difficult to ignite. In many cases, lightning fires started in more flammable areas, such as the flatwoods, and ran into the scrub areas. When ignited however, the oak scrub burns vigorously. Rates of spread are rapid and flame lengths of 40 to 50 feet were not uncommon. The natural fire return interval was between five and seven years. Stands of oak scrub regenerated quickly from root sprouting (Schmalzer 2003).

Scrubby Flatwoods: The scrubby flatwoods community is found on slightly wetter sites than the oak scrub. The shrub species found in the oak scrub are also found here, but palmetto is much more abundant. More mesic species such as gallberry (*Ilex glabra*) and *Lyonia* spp. are also present. In historic times a scattered overstory of south Florida slash pine (*P. elliottii* var. *densa*) was present. Both the oak scrub and the scrubby flatwoods are habitat for the federally threatened Florida scrub-jay (*Aphelocoma coerulescens*) and are the focus of a much of the Refuge's upland management activities.

Under natural fuel loadings, fires in the scrubby flatwoods were generally confined to the shrub layer, with overstory consuming fires only occurring during periods of extreme weather. Rates of spread were normally moderate as were the flame lengths. The fire return interval was between three and seven years. Most of the shrub layer vegetation regenerates from sprouting.

Pine and Palmetto Flatwoods: The pine and palmetto flatwoods community is found on the more mesic soils of the Refuge. The shrub layer is predominately palmetto with some gallberry, *Lyonia* spp. and wax myrtle (*Myrica cerifera*). Wire grass (*Aristida stricta* var. *beyrichiana*) is common. An overstory of south Florida slash pine is common, with some stands of pond pine (*P. serotina*) present in the wetter areas. Historically, fires kept the

understory low and open, and the overstory scattered to moderately dense. The pines in the flatwoods provide nesting habitat for the bald eagle (*Haliaeetus leucocephalus*).

The historic fire regime in the flatwoods consisted of moderately intense fires that occurred every three to five years. The understory of the flatwoods burns vigorously and completely. Much of the vegetation is highly flammable. Species such as palmetto contain resins and oils which ease ignition and increase rates of spread. As was the case in the scrubby flatwoods, fires in the canopy were infrequent and occurred during periods of drought or when fuel loads became excessive.

Marshes: Both saltwater and freshwater marshes occur on the Refuge. The saltmarshes, the majority of which are now impounded, occur along the edges of the lagoon system on the Refuge. The native vegetation is primarily sand cordgrass (*Spartina bakerii*) a tall grass with some short grasses such as saltgrass (*Distichlis spicata*) mixed in. The freshwater marshes, or swales, also contain sand cordgrass along with some *Andropogon* spp. The swales are intermingled with the upland vegetation described above and are important in the flammability of those landscapes.

The historic fire regime was similar in both types of marshes. It can best be characterized as rapidly moving, intense fires with a fire return interval between two and four years. Fires usually consumed all of the vegetation and the stand was regenerated by sprouting (Schmalzer and others 1991). These frequent fires kept the stands of grass in an open condition. They also reduced the encroachment of woody species such as wax myrtle and salt bush (*Baccharius* spp.)

Human Fire Use

Evidence exists that Native Americans used fire extensively prior to the arrival of the first European explorers (Robbins and Myers 1992). The journals of many of the early explorers indicate that in the southeast, Native Americans used fire to clear fields and drive game as well as for communications and warfare. Many of these fires were set outside of the natural fire season.

The early European settlers used fire extensively for many reasons. Turpentine operations burned in winter, cattlemen burned in the spring and hunters burned in the fall. These activities, combined with the naturally ignited summer fires resulted in fire on the landscape throughout the year.

The past 50 years have seen controversy over the use of fire. Ranchers, timber companies, wildlife managers and others have continued to use fire, much of the time outside of the natural fire season. During the 1950s and 1960s there was a concerted effort to stop burning the landscape. In addition, efforts to suppress wildfires were increased. This was especially true at KSC.

Changes in the Ecosystem

The removal of fire from the ecosystem caused major changes in the landscape. Pine stands in the flatwoods and scrubby flatwoods communities became dense and overgrown. Mesic forests began to invade marshes where frequent fires once kept this encroachment in check (Duncan and others 1999). The oak scrub increased in height and density becoming difficult to ignite except under extreme fire weather conditions (Schmalzer and Adrian 2001).

These changes to the habitats affected the wildlife utilizing them. The thickness of the scrub vegetation made the oak scrub and scrubby flatwoods less suitable for the Florida scrub-jay and other scrub fauna. Unburned marsh grasses made movement difficult for secretive birds such as black rails (*Laterallus jamaicensis*). In some cases, brush in the marshes was thick enough to shade out grasses changing the habitat entirely.

Fuel loads increased in all of these vegetative communities. When fires did start, they burned with greater intensity than in the past. This was especially critical in the pine flatwoods. While historic fires tended to stay in the shrub layer, the increase in pine density resulting from the lack of fire increased the potential for crown fires. This removed nesting substrate for the bald eagle.

Refuge Fire Management

Early Fire Management

Fire management on the Refuge has changed considerably over the past three decades. Between the time the Refuge was created in 1963 and 1981 little active fire management was done. A review of the somewhat sketchy early Refuge records shows a few small prescribed burns, and occasional suppression activities. During this time, the responsibility for suppression of wildfires was confused with the Refuge taking action on some fires, and with KSC Fire (primarily a structural fire organization) suppressing others. Training of Refuge personnel was minimal and equipment was typically converted military vehicles and other used equipment.

Fuels Management Prescribed Burning

With little fire activity in the ecosystem, fuel accumulated to a point where it was only a matter of time before severe fires would occur. This happened in the summer of 1981 when 46 wildfires burned over 17,000 acres and two firefighters were killed. This calamity initiated the second phase of fire management on the Refuge. Training of wildland firefighters was increased, new equipment was purchased, and a contract helicopter was acquired for both fire suppression and prescribed burning.

An aggressive prescribed fire program was begun with fuels management as the primary objective. During this time period, burn units were large, with some up to 4,000 acres. Between 1982 and 1992 the Refuge had 108 prescribed burns totaling 121,743 acres with an average size of 1,127 acres.

Most units were designated using existing natural and man made-barriers. It was normal to find several different vegetation communities within a single burn unit. This meant that fire prescriptions could not be tailored to meet specific requirements for individual communities. This phase of the Refuge's prescribed burning did meet the overall objective of reducing the fire danger. In 1992, a year with similar weather conditions to 1981, the Refuge experienced 45 wildfires, but only 378 acres were burned and no injuries or fatalities were experienced.

Habitat Management Prescribed Burning

In the early 1990s fire management objectives began changing from simply reducing fuel loads to meeting wildlife and habitat management objectives. Beginning in 1993 the Refuge began to subdivide the larger units

in an attempt to focus more on the burning requirements of the individual vegetative communities and the wildlife species they supported. Of primary importance was the maintenance and restoration of oak scrub habitat for the threatened Florida scrub-jay. Also of great interest was maintaining nesting substrate for the bald eagle in the flatwoods and managing habitat for black rails and other marsh birds in the grassy wetlands.

The size of the subdivided burn units was greatly reduced. Between 1993 and 2002 the Refuge had 202 prescribed burns totaling 93,402 acres in fire maintained habitats. The average burn size was 460 acres. Although some large burns are still conducted, especially in the marshes, it is expected that the trend for more burns covering smaller areas will continue. This is especially true as the Refuge continues to restore scrub habitat.

Space Exploration and Its Effect on Prescribed Burning

Many of the constraints and restrictions on prescribed burning on the Refuge are common to other fire programs. Concerns such as safety of firefighters and the public, increasing urbanization, fickle weather, staffing and funding shortages that are encountered on other stations are likewise present here. In addition to these considerations, this Refuge must deal with an active space port. While the Refuge fire program was evolving, the mission of the KSC was also changing. The Apollo and Saturn V programs were phased out in the late 1970s and the new Space Transportation System (STS) or Space Shuttle program was beginning.

At first, with limited launches and non-sensitive payloads, Shuttle operations had little impact on fire management operations. Burning was prohibited forty-eight hours prior to a scheduled launch and twenty-four hours prior to landing. Pre-launch concerns included danger while fueling the spacecraft, exposure of the orbiter to the elements and increased ground and air traffic just prior to launch. Pre-landing concerns revolved around smoke causing visibility problems in the Orbiter's glide path and anomalies (mishaps) during the landing itself. This soon changed. When KSC was determined to be the primary emergency landing site, rather than Edwards Air Force Base in California, burning was severely curtailed the entire time the Shuttle was in orbit. Although this was ten to fourteen days per space mission, with only two to three launches per year, sufficient burning could still be accomplished. However, as the number of launches increased, lost burning opportunities became substantial.

Additional constraints were established as plans progressed for the launch of the $2.2 billion Hubble Space Telescope (HST) in 1990. Original prescribed burning restrictions for the HST called for no burning within 25 miles of clean rooms where components of the telescope were being processed. This would shut down burning on the entire Refuge for the six to nine months of the Hubble's residency on the KSC. This situation did not bode well for the Refuge's fire management program. Especially since the HST was the first in a series of space-based observatories and other smoke sensitive spacecraft that were expected to be launched over the next fifteen years.

Along with restrictions on burning from space operations on KSC, the Refuge had to deal with CCAFS. At CCAFS, each different type of launch vehicle had its own set of managers, payload processors, and bureaucracy. Additionally, some of the payloads were military missions and much of the information about timing was secret. When it came to getting authorization to burn, almost anyone in either the KSC or CCAFS chain of command

could trigger a no-go for the fire. Refuge fire managers spent countless hours fielding phone calls, explaining the reasons for burning and begging to get permission to execute a burn.

The situation was quickly becoming untenable. There was a time when it appeared that all of the issues in force would reduce burning on the Refuge to a point where fire would no longer be a viable tool. It was obvious to all fire knowledgeable people that not burning would lead to a continued increase in the amount of very flammable vegetation. This would not only lead to a serious public safety problem from possible wildfires, but would also prevent effectively managing habitat for the numerous wildlife species found on the Refuge. Some way had to be found to provide for the integrity of both the space program's mission, and the purposes and objectives of the Refuge.

Conflict Resolution

The first step in the resolution process was to educate all of the concerned parties about the reasons for burning. The best selling point was the possible impact of severe wildfires that would occur if the vegetation on the Refuge/KSC was not burned on a regular basis. Here we had some help from Mother Nature. While the memory of the fires of 1981 were still vivid, burn approvals were relatively easy to obtain. As institutional memory faded, approval became more difficult. Florida's bad fire season in 1998 refreshed NASA's collective memory when fires shut down operations for almost a week. This situation precipitated much discussion as to how find more windows of opportunity for burning.

The second factor that helped sell the importance of burning was the Endangered Species Act. The Florida Scrub-jay Recovery Plan identifies the Refuge as having one of the four Primary Core Recovery Units (PCRU) for the threatened Florida scrub-jay (U. S. Fish and Wildlife Service, 2003). In the early 1990s jays were discovered on the site where the Space Station Processing Facility was to be constructed. As part of mitigation for continued use of this and other areas in scrub-jay habitat, NASA agreed to assist the Refuge in restoring overgrown scrub (Schmalzer and others 1994). Since burning is a critical component of scrub restoration, this compelled the KSC to work more aggressively to find windows for burning.

Along with establishing the need for burning, it was also necessary to demonstrate a level of competence in fire management activities. Although the vast majority of prescribed burns nationwide are executed with minimal impact to the surrounding areas, the small percentage of burns that do cause problems are well documented by the media. This situation can cause concern to neighbors when the Refuge announced that a burn is forthcoming. We in the fire community are well aware of the amount of planning, training and skill required to carry out a successful prescribed burn. In many cases however, those we deal with outside our community are not. In most situations, knowledge helps combat the fear of the unknown. This proved to be the case when dealing with NASA managers.

The importance of good communication in solving the problems between space operations and Refuge fire activities cannot be over emphasized. To ensure proper information flow, meetings were set up with all interested parties. In addition to stressing the needs for an active prescribed burning program, a presentation on the behind the scenes work that goes on was given. The extensive training given to burn bosses, firing specialists, air operations staff and other key fire personnel was detailed. The prescription development

process, including smoke screening, environmental parameters, equipment and staffing needs were explained. It was also pointed out that the Service requires that a qualified burn boss of appropriate skill level from outside the Refuge review the prescription. At the same time, NASA managers had a chance to express their concerns, ask specific questions concerning fire operations and, most importantly, meet Refuge fire managers face to face.

To further establish our credentials, key NASA managers were invited to observe burns. They were given the whole burn day experience, from the crew briefing to the critique at the end of the day. The overall result of these discussions and observations was an improved level of confidence in the Refuge's ability to conduct a successful burn. It was also important not to hide anything. All of us that have done any burns know that things can go wrong that are beyond our control. The most notable problem is fickle weather. NASA recognized the need for them to be able to initiate emergency protection measures for sensitive areas, such as clean rooms, should this occur.

Once the importance of burning was established, restrictions negotiated down to an agreeable level and comfort levels established, the final piece of the puzzle was to formulate a comprehensive burn notification process. The Space Center's dispatching office agreed to be the focal point for this endeavor through its Joint Base Operations Support Contract (JBOSC) Duty Office. In its early stages the Duty Office received the Refuge's request to execute a burn, and then notified telephonically a long list of interested parties. Not only was this time consuming, but there was still the problem of almost anyone being able to trigger a no-go situation. Over the years this system was improved. Through negotiations with NASA Test Director (NTD), Payload Processing, the Center Director and the Commander of the Air Force Station, this list of people that could actually cancel a burn was reduced to less than ten. All others on the notification list were only provided information. Any concerns had to be forwarded to one of the decision makers. The Duty Office also fielded most of the questions concerning the burn and only passed on to Refuge fire managers those calls they could not handle. The final step was to send all correspondence electronically.

Compromises Achieved

The process of education and confidence building resulted in a compromise that was acceptable to all parties. NASA managers recognized that burning is an essential part of managing the vegetation types that exist on the Refuge/Space Center. They also realized that no burning would eventually result in unacceptable impacts on both the space program and the environment. On the other side, Refuge fire managers became more aware of the sensitivity of spacecraft to smoke and the possible economic and scientific impacts should damage occur to these craft. Both parties recognized the need for compromise and communication.

Through negotiation, the original 25 mile radius burn prohibition when sensitive payloads were present was reduced to a more manageable six miles. Burns were allowed while the Orbiter was in space so long as all its systems were "nominal" and Edwards Air Force Base was available for emergency landings. Lines of communication helped find times in payload processing streams where burning could be done with minimum risk to space craft. Refuge and NASA managers meet several times a year to discuss upcoming operations on both sides that may come into conflict.

A Measurement of Success

The real question is: Did all this effort to find ways of maintaining a prescribed burning program in the middle of an operational space port have any measurable results? One way to quantify the results is to determine if the effects of wildfire events in years similar to 1981 were in any way less catastrophic. In 1981, there were 40 wildfires burned a total of 19,335 acres. Four fires were over 1,000 acres in size, with the largest being 6,300 acres. The average fire size was 483.8 acres. There were also two fatalities. When 1981 is compared to several subsequent severe wildfire seasons, one can see a considerable difference in acres burned and average fire size as shown in table 1.

The first of these seasons occurred in 1992. Several years of below normal rainfall preceded this fire season, as was the case in 1981. Forty-eight wildfires were ignited during the spring and summer. However, only 1,404 acres were burned, most of this was in one 1,200 acre fire which occurred when resources were spread thin on a day when several fires were started. The average fire size was 29.7 acres. There were no injuries to firefighters or other personnel, nor were any structures damaged.

Another bad fire season occurred six years later in 1998, when 25 wildfires burned 5,555 acres. As in 1992, multiple starts exceeded initial attack capabilities and several fires burned together to account for 4,090 acres of this total. The average fire size was 222.2 acres. While this is much larger than the average size in 1992, it is still less than half of what was experienced in 1981. Again no injuries occurred and no structures were damaged.

The drought that began in 1998 continued through 1999 and 2000. In 1999, 16 fires burned a total of 1,219 acres. Once again, one large fire that burned 1,084 acres. The average fire size this year was 76.2 acres. No injuries resulted and no structure damage occurred. By 2000, the drought had abated somewhat. More thunderstorms resulted in 25 starts a third again more than the previous year. This year only 319 acres were burned, with the biggest fire only amounting to 150 acres. No injuries or structure damage resulted.

The Refuge burns between 15,000 and 20,000 acres in a normal year. Even in these strenuous wildfire seasons a number of prescribed burns were completed. It is difficult to determine how much of this reduction in acreage burned should be attributed to the fuels reduction resulting from prescribed burning. Training of personnel and improved equipment certainly played a role. However, without the consistent application of prescribed fire to the Refuge's landscape, more acreage would have been burned by unwanted wildland fire in 1992 and the years of 1998 through 2000. More importantly, the risk to Refuge firefighters suppressing of these fires would have been greater.

Table 1—Comparison of severe fire years at Merritt Island National Wildlife Refuge.

Year	Number WF	Acres burned	Av. Fire size	Largest fire	Number Rx fires	Acres burned
1981	40	19,335	483.8	6,300[a]	2	3,690
1992	48	1,404	29.7	1,200	8	7,552
1998	25	5,555	222.2	4,090	20	5,605
1999	16	1,219	76.2	1,084	19	2,380
2000	24	319	13.3	150	25	7,414

[a] Four fires were over 1,000 acres.

Conclusions

Carrying out an prescribed fire program on Merritt Island National Wildlife Refuge presents some unique challenges. The dialogue between Refuge fire managers and the various components of the Nation's space program is an ongoing process. As the space program changes, new points of conflict will arise and new ways to meet the objectives of all the agencies involved must be developed.

Managing fire at Merritt Island National Wildlife Refuge has many unique aspects, but many of the conflict resolution processes described here are applicable in other places. Certainly talking with neighbors and other concerned parties is necessary to sell a burning program. It is likewise important for fire managers to learn the specific concerns of those who live and work in the vicinity of burns. Establishment of communication channels through homeowner associations, the media and personal contact is essential to obtaining the support of the community for a burning program. Allow the public to see the degree of professionalism that is a part of the burning activities.

It is also important to be honest. No amount of planning, no amount of training nor the best forecast in the world can guarantee that nothing will go wrong. However, up front discussions of this possibility and the presence of a good contingency plan can go far in mitigating a bad situation should it occur. Remember, use discretion and care. History has shown that one mishap can undo years of successful confidence building. In spite of all this, the experience of the Refuge's fire program shows that, with perseverance, and initiative, an effective prescribed burning program can be developed under difficult circumstances.

Literature Cited

Adrian, F. W.; Epstein, M.; Lloyd, R.; Lyons, J. 2006. Draft habitat management plan for Merritt Island National Wildlife Refuge. U. S. Fish and Wildlife Service. Titusville, FL. 175 p.

Duncan, B. W.; Boyle, S.; Breininger, D. R.; Schmalzer, P. A. 1999. Coupling past management practices and historic landscape change on John F. Kennedy Space Center. Landscape Ecology 14: 291-309.

Epstein, M.; Blihovde, B. 2006. Listed species of the Merritt Island National Wildlife Refuge. U. S. Fish and Wildlife Service. Titusville, Florida. 13 p.

National Weather Service, Melbourne, Fl. 2005. http://www.srh.noaa.gov/mlb/ltgcenter/ltgmain.html

Robbins, L. E.; Myers, R. L. 1989. Seasonal effects of prescribed burning in Florida: a review. The Nature Conservancy. Tallahassee, FL. 119 p.

Schmalzer, P.A. 2003. Growth and recovery of oak-saw palmetto scrub through ten years after fire. Natural Areas Journal 23: 5-13

Schmalzer, P.A.; Foster, T. E.; Duncan, B. W. 2002. Revised flora and list of threatened and endangered plants of the John F. Kennedy Space Center area, Florida. NASA/TM-2002-211175. John F. Kennedy Space Center, FL. 75 p.

Schmalzer, P.A.; Adrian, F. W. 2001. Scrub restoration on Kennedy Space Center/Merritt Island National Wildlife Refuge 1992-2000. In: Zattau, D. ed. Proceedings of the Florida scrub symposium 2001. U. S. Fish and Wildlife Service. Jacksonville, FL. 17-20.

Schmalzer, P. A.; Breininger, D. R.; Adrian, F. W.; Schaub, R.; Duncan. B. W. 1994. Development and implementation of a scrub habitat compensation plan for Kennedy Space Center. Technical memorandum 109202, Kennedy Space Center, Florida. 54 p.

Schmalzer, P.A.; Hinkle, C. R.; Mailander, J. L. 1991. Changes in community composition and biomass in Juncus roemerianus Scheele and Spartina bakeri Merr. marshes one year after a fire. Wetlands 11: 67-86.

U. S. Fish and Wildlife Service. 2006. Draft comprehensive conservation plan and environmental assessment for Merritt Island National Wildlife Refuge. Merritt Island National Wildlife Refuge. Titusville, FL, 297 p.

U. S. Fish and Wildlife Service. 2003. Draft revised recovery plan for the Florida scrub-jay. U. S. Fish and Wildlife Service. Atlanta, Georgia. 169 pp.

Watts, W. A. and Campbell, L. F. 1988. Environments in Florida in the late Wisconsin and Holocene. In: B. A. Purdy ed. Wet site archaeology. The Telford Press, Cadwell, NJ. pp 307-323.