Appendix L.
Riparian Ecology and Fire Management

A. Introduction: General Concepts of Disturbance

Disturbance has been defined as "any relatively discrete event that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment" (Pickett and White 1985). The size, intensity, frequency, and timing of a disturbance all influence ecosystem structure and function. Generally, natural disturbances maintain high diversity of habitat patches in the landscape and thus maintain species diversity. Many plant and animal species depend upon periodic disturbance.

Different types of disturbances - be they fire, flood, or landslide - produce different effects on ecosystems. Plant species have evolved suites of traits that adapt them to the particular types and patterns of disturbance that they routinely experience. "Novel" disturbances, new combinations of disturbances, or changes in the intensity, timing, duration, and/or scale of a disturbance all can alter ecosystem structure and function outside the range of conditions to which the species are adapted (Paine et al. 1998). For many of our Southwestern riparian ecosystems, due largely to land and water management practices, fires have replaced floods as the primary disturbance factor. This change has had adverse consequences for many native species.

B. Historical Fire Regimes in Southwestern Willow Flycatcher Habitats

Fires require an ignition source and adequate amounts of fine, dry fuel (McPherson 1995). Historically, fire was probably uncommon in southwestern willow flycatcher habitat. However, there is little quantitative information on the frequency, seasonality, intensity, and spatial extent of fire, all of which are components of the fire regime (Agee 1993). Turner (1974), for example, in a review of vegetation change over the past century along the Gila River (Arizona), stated that "the dense seasonally dry vegetation along the Gila River and other sites of the region periodically caught fire, but with what frequency cannot be determined."

The frequency of riparian fire probably varied temporally with drought cycles and the prevalence of lightning strikes, the primary natural ignition source for riparian fires. Spatially, riparian fire regimes probably varied with those in the surrounding uplands. Although riparian zones tend to burn less frequently than the uplands (Skinner and Chang 1996), fire probably was more frequent along rivers located in grassland and savanna biomes than along those in deserts, chaparral shrublands, and conifer forests. Other factors being equal, fires probably were more frequent in narrower, smaller riparian zones than in wide ones (Agee 1993).

In the following sections, we discuss in more detail the fire regimes in two broad vegetation types used by the willow flycatcher: 1) low to mid-elevation riparian forests, and 2) high elevation willow shrub lands.

1. Low to Mid-Elevation Riparian Forests

In this category, there are several types of biotic communities: Sonoran riparian cottonwood-willow gallery forests, dominated by Fremont cottonwood (*Populus fremontii)* and Goodding willow *(Salix gooddingii)* trees; Great Basin gallery forests vegetated by Rio Grande cottonwood (*P. deltoides* subsp. *wislizeni)* and peach leaf willow (*S. amygdaloides*); Interior riparian mixed broadleaf deciduous forests vegetated by Fremont cottonwood, Goodding willow, and other trees such as box elder (*Acer negundo*) and Arizona ash (*Fraxinus pennsylvanica* var *velutina*); and California Riparian Deciduous forests vegetated by Fremont cottonwood, Goodding willow, California sycamore (*Platanus racemosa*) and white alder (*Alnus rhombifolia*). Many shrubs including seep-willow (*Baccharis salicifolia*), coyote willow (*S. exigua*) and buttonbush *(Cepthalanthus occidentalis*) grow under or adjacent to the riparian trees.

Three lines of evidence suggest that fires historically were not a primary disturbance factor in these forest types. First, some of the dominant trees, notably Fremont cottonwood and Rio Grande cottonwood are not considered to be fire-adapted (Abrams 1986, Adams et al. 1982, Busch 1995). In general, plants are considered to be fire-adapted if they have traits that allow them to maintain their structure and not be altered by the fire, or that allow them to rapidly regenerate afterwards. Thick bark, for example, allows some trees to resist fire damage. Other traits allow for resilience, or the ability to rapidly return to the pre-disturbance condition. For example, some seeds germinate only in response to very high temperatures, allowing for post-fire regeneration. Cottonwoods show neither resistance nor resilience to fires. The cambium of Fremont cottonwood can be damaged by even light ground fire (Turner 1974), indicating low resistance. Burned cottonwood trees have a low probability of resprouting. Stuever (1997) reported that light burns completely killed about 50% of Rio Grande cottonwood trees, moderate burns about 75%, and highly severe burns killed all the cottonwoods in a stand (Figure 1). Higgins (1981) observed that Fremont cottonwood had high post-fire mortality and no recovery. Davis et al. (1989), however, observed that two of three burned Fremont cottonwoods vigorously sprouted three years after a fire. Summer burns tend to cause more mortality than winter burns, because less heat energy is required to raise plant tissue to lethal levels.

Several tree and shrub species in these biotic communities show some resilience to fires. White alder, buttonbush, Arizona ash, California sycamore, Goodding willow and coyote willow, for example, are readily top killed by fire, but can recover by resprouting (Barstad 1981, Barro et al. 1989, Davis et al. 1989). Resprouting provides some resilience to fire disturbance as well as to flood disturbance. Fires, however, generally do not create the opportunities for seed-based regeneration of these riparian tree and shrub species. The seeds of many species of willow and cottonwood are adapted to germinate at particular times of the year when flood disturbance is most likely -- a time that rarely coincides with high fire risk. This life-history strategy provides resilience to floods but not necessarily to fire.

Figure 1. This fire, called the Rio Grande Complex, occurred on April 18, 2000, and burned over 1,900 acres from La Joya to Los Lunas in the Rio Grande bosque. The intense fire burned the bark from the Rio Grande cottonwoods. Photo taken by Charlie Wicklund, April 20, 2000.

Another factor contributing to infrequent fires is the high water content of most riparian forests. Willows, cottonwoods, and many other obligate riparian trees and shrubs grow at sites with perennially available shallow ground water, enabling them to maintain high water content even during dry seasons. Additionally, the riparian forests are often associated with other vegetation types that had high moisture content. Large expanses of river flood plains in the Southwest were wet and marshy, and thus not very fire-prone (Hendrickson and Minckley 1984). Some parts of the flood plains are drier than others, however. Desert rivers carry high sediment loads, and flood plains can aggrade appreciably over time. The old cottonwood or willow forests that grow on the aggraded flood plains can develop a seasonally dry understory of non-phreatophytic grasses and forbs. These older stands were probably more likely to catch fire than were the younger forest stands along channel edges.

Fire was historically uncommon in many of the upland biomes that surround the low to mid-elevation riparian habitats. The rivers that support Sonoran riparian cottonwood-willow forests, which include segments of the Gila, Salt, Verde, Bill Williams, Santa Maria, Kern, Mojave, Virgin, San Pedro, and Colorado Rivers, were surrounded by Sonoran or Mojave Desert. The sparse vegetation in these deserts generally had insufficient fuel loads to carry fire (Brown and Minnich 1986). Portions of other rivers with riparian zones inhabited by flycatchers, such as the Rio Grande, San Pedro, and Gila, were surrounded by Chihuahuan Desert. Others, such as the San Juan, flowed through Great Basin Desert scrub vegetation. The drier portions of these deserts also had insufficient fuel loads to carry fire. Thus, there were few opportunities for fire to spread from uplands into riparian zones located along the desert rivers.

Some rivers were bordered by fire-prone upland vegetation. For example, the San Luis Rey River flowed through California Valley grasslands, the upper San Pedro River and upper Gila River flowed through semidesert grassland, and the upper Rio Grande flowed through Plains grasslands. All of these grasslands are fire-adapted and burned fairly frequently. Semidesert grasslands historically burned about once every ten years, started by lightning strikes in June or July that signaled the end of the summer dry season (McPherson 1995). In dry years, fires probably did occasionally spread from the grasslands into the riparian zones. Reports from explorers in the 1800s, for example, describe periodic riparian fires along the San Pedro River in the reach bordered by desert grasslands (Davis 1982). Generally, the riparian forests along such rivers were vegetated by mixed riparian broadleaf forests or other vegetation types rather than by 'pure' cottonwood-willow forests. Frequent fires probably allowed the fire-adapted riparian grass, giant sacaton (*Sporobolus wrightii*) to maintain its high abundance along the upper San Pedro River (Bock and Bock 1978). Cottonwoods and willows were historically present, but were less abundant than they were in the lower reaches of the San Pedro River that were bordered by desert vegetation. Other rivers, such as New Mexico's Rio Chama, flowed through Great Basin conifer woodland (pinyon-juniper savannahs). These pinyon-juniper savannahs historically had an abundance of grasses that carried frequent fire that probably occasionally spread into the riparian corridor.

Many of the coastal California rivers that support willow flycatchers flowed through California chaparral or California coastal sage scrub ('soft chaparral'). Both of these seasonally dry vegetation types are fire-adapted. Chaparral tends to burn with low frequency but high intensity. Chaparral fires have a recurrence interval of 30-65 years, for example, in the Santa Barbara area of California (Davis et al. 1989). Severe chaparral fires can spread into riparian zones in hot, dry years, such as occurred at the upper Santa Ynez River in July, 1985 (Barro et al. 1989).

2. High Elevation Willow Shrublands

At these high elevation riparian sites (which range to about 2600 m), shrub willows are a major component of the vegetation. The canopy generally is less than 7 m tall. Several species of willow may be present, including coyote willow (*Salix exigua*), Geyer willow (*S. geyeriana*), red willow (*S. laevigata*), arroyo willow *(S. lasiolepis*) and yellow willow (*S. lutea*). Peach-leaf willow (*S. amygdaloides*), a tree-like willow that grows to 9 m tall, also may be present. Sometimes, flycatcher nests are placed in or near other associated shrubs species such as Wood's rose (*Rosa woodsii*), twin-berry (*Lonicera involucrata*), or river hawthorn (*Crataegus rivularis*). The willow groves often are interspersed with wet meadow vegetation and open water.

The surrounding upland vegetation includes various types of montane conifer forests. Several of the flycatcher-inhabited riparian zones are bordered by ponderosa pine (*Pinus ponderosa*) forests. Historically, ponderosa pine stands were more park-like and open than they are today. Low intensity ground fires would sweep through the grassy undergrowth one or more times per decade (Covington et al. 1997). Stein et al. (1992) suggest that fires in the ponderosa pine stands of northern Arizona may have spread frequently into small, intermittently flowing creeks dominated by arroyo willow *(S. lasiolepis*). However, these small intermittent streams with narrow riparian zones typically do not provide suitable flycatcher habitat. Those with flycatcher habitat tend to have wet meadows, beaver ponds, and willow groves. Being along larger, perennial streams, these sites probably burned infrequently. During very dry years, if the vegetation was sufficiently stressed, the riparian meadows and willow stands may have burned. More often, fires would stop at the edge of the wet riparian zone as was observed by DeBenedetti and Parsons (1979) in the Sierra Nevada. Fire frequency data are lacking for shrub willow sites known to support southwestern willow flycatchers, but charcoal layering suggests a fire frequency of once every 250 to 300 years for some wet meadows in the Sierra Nevada (Chang 1996).

Most shrub willow species, including Geyer willow and arroyo willow, are able to resprout after low to moderate-intensity fires that kill only the aboveground plant parts. Low to moderate-intensity fires thus can maintain the willow patches in an early successional state, and also create habitat for particular animal species. The post-burn resprouts of many willows have a high growth rate and are preferentially foraged upon by elk (Stein et al. 1992; Leege 1979). Patchy fires may create mosaics of shrub stands with different canopy heights and stem densities. High-intensity fires, however, can burn deeply into the soils and kill the willow roots, thereby eliminating the possibility of basal sprouting. Stein et al. (1992) suggest that the vigorous post-fire resprouting ability of arroyo willow may be an adaptation to frequent fire; although it is equally plausible that resprout ability evolved as a response to flood damage.

Many willow species regenerate by seed after floods. Fires also can create seed beds for some willows, if they expose mineral soils at the appropriate time of the year (Zasada and Viereck 1975, Zedler and Scheid 1988, Uchytil 1989). Opportunities for seedling establishing after a fire decrease quickly as the mineral soils become vegetated by herbaceous species (Densmore and Zasada 1983). In some cases, fires or beavers may create the disturbance needed to allow the willows to encroach into areas dominated by perennial grasses, sedges, rushes, and other herbs (Cottrell 1995).

C. Recent Changes to Fire Regimes in Riparian Zones

1. Low and Mid-Elevation Habitats: Fire Increases.

There have been two distinct trends with respect to changes in riparian zone disturbance regimes. Foremost, there has been a shift from a flood-dominated to a fire-dominated disturbance regime on many of the cottonwood-willow rivers that historically supported large populations of southwestern willow flycatchers. Increases in fire size or frequency have been observed for the lower Colorado and Bill Williams rivers (Busch 1995), Rio Grande (Stuever 1997), Gila River (Turner 1974), and Owens River (Brothers 1984). Along the lower Colorado and Bill Williams, over a third of the riparian forests studied burned over a recent 12-year period (Busch 1995). The increased prevalence of fire on these rivers is due primarily to an increase in the abundance of dry, fine-fuels and secondarily to an increase in ignition sources.

Several interrelated factors have contributed to the increase in flammable fuel load. First, and perhaps foremost, is flood suppression. Flood flows are very large relative to base flows in unregulated rivers of the semi-arid Southwest. Large floods can scour extensive areas, clearing away live and dead vegetation and redistributing it in a patchy nature on the flood plain. Willows and other pioneer species quickly revegetate the scoured areas, replacing older, senescent stands with stands of young, 'green' wood. Small to moderate floods frequently remove litter and woody debris from the flood plain surfaces and disperse them into aquatic environments. Floods also increase the patchiness of the vegetation, thereby creating natural fire breaks between stands of riparian habitat. The net effect of this natural flood regime is to 'fire-proof' riparian habitats (Ellis et al. 1998). When floods are suppressed, litter cover and dead biomass accumulate; vegetation can increase in extent, density, senescence, and homogeneity; and fuels become more continuous. On the flood-suppressed Bill Williams River and portions of the Colorado River, riparian vegetation (most of which is fire-prone tamarisk; *Tamarix ramosissima*) has increased in density since dam construction (Turner and Karpiscak 1980, Shafroth 1999), setting the stage for frequent, intense, and large fires. Indeed, most of the rivers with documented fire increases are flow-regulated.

Dewatering of rivers also increases the frequency and intensity of fires by increasing the flammability of the vegetation. Reduced base flows, lowered water tables, and less frequent inundation all can cause plants to lose water content, and cause mortality of stems or whole plants. Stress-related accumulation of dead and senescent woody material is a primary factor contributing to the fire increase on the Lower Colorado (Busch 1995, Busch and Smith 1995). Dewatering also facilitates the replacement of broad-leaved riparian vegetation by more drought-tolerant, and often more flammable, vegetation such as tamarisk (Smith et al. 1998).

Loss of beavers has altered local hydrology, vegetation composition and possibly fire patterns. Beaver activities help to expand areas of shallow ground water and hydrophytic vegetation, and generally create a more heterogeneous flood plain (Apple 1985). This can create natural fire breaks and provide refugia from fire effects, especially where beaver activity results in extensive areas of marsh, wetland, and open water habitats. Beaver were extirpated from many Southwest rivers in the 1800s (Tellman et al. 1997), perhaps contributing to increased flammability of riparian vegetation.

Replacement of native vegetation by exotic plant species, many of which are highly flammable, also has contributed to riparian fire increase. Tamarisk, giant reed (*Arundo donax),* and annual grasses such as red brome *(Bromus rubens)* all are highly flammable. The spread of many of these exotics is due partly to the same changes in stream flow regimes that render the riparian areas more flammable, making it difficult to disentangle the effects of the exotic species from the effects of management factors that have enhanced their spread (see Appendix H). Nevertheless, we will focus discussion on tamarisk because it is such a key factor in the flood-to-fire regime shift.

Tamarisk plants have many stems and high rates of stem mortality, resulting in an accumulation of dense, dry dead branches. Large amounts of litter - including dead branches and the small, needle-like leaves - are caught in the branches elevated above the ground surface, enhancing its flammability. Fallen leaves of the native broadleaf trees decay quickly relative to tamarisk, thus reducing the relative fuel loading. Based on studies conducted along the Rio Grande (Ellis et al. 1998), there is some evidence that tamarisks produce less litter than cottonwood stands, though this does not mean that tamarisk stands are therefore less fire prone.

When the fire-prone characteristics of tamarisk are coupled with conditions brought about by flood suppression, fires become inevitable in the tamarisk forests. Rosenberg et al. (1991) stated that "Saltcedar is deciduous and, without floods, large amounts of leaf litter accumulate. Therefore, after 10 or more years fires almost become a certainty, especially during the hot and dry summer months." Faber and Watson (1989) suggested that fires become a real hazard when the stands reach 15 to 20 years of age. Anderson et al. (1977) noted that 21 of the 25 tamarisk stands they studied along the lower Colorado River had burned in the prior 15 years. Weisenborn (1996) calculated a fire return interval of about once every 34 years for tamarisk stands along the Colorado River.

When dense tamarisk stands burn, the fires are often intense and fast moving, characteristics that have led to substantial acreages of burned riparian habitat along the Lower Colorado River (Table 1; note that Table 1 data are reported in acres, not hectares). During just three years, recent fires burned a total of 1,000 ha of the 6,200 ha of occupied or potentially suitable willow flycatcher habitat that existed along the Lower Colorado River in 1998 (U.S. Bureau of Reclamation 1999a). Altered fire regimes also have played a role in reducing the amount of cottonwood-willow vegetation on the Lower Colorado River from approximately 36,000 ha (based on 1938 aerial photography with appropriate adjustments: U.S. Bureau of Reclamation 1999a) to the current extent of less than 6,500 ha.

Although fire hazard is greatest with the combination of flood suppression, water stress, and tamarisk presence, tamarisk stands on free-flowing perennial rivers also can burn. Some of the tamarisk stands on the San Pedro River, for example, have large numbers of dead stems (Stromberg 1998) and occasionally ignite. In June 1996, a fire burned along the lower San Pedro River in a stand of cottonwood-willow with an understory of tamarisk (Paxton et al. 1996). The fire was primarily carried by the understory tamarisk, but almost all cottonwoods in the burned area were killed. The patchiness of the forest stands along the free-flowing San Pedro presumably results in smaller fire sizes than on flood-suppressed rivers.

Other human actions have increased the frequency of accidental and intentional fires. Turner (1974) describes the intentional setting of fires by ranchers to clear tamarisk thickets to allow access by cattle. More common, though, are accidental fires caused by campfires, cigarettes, automobile sparks, agricultural burning, and “kids-with-matches.” Riparian areas on military bases or ranges may also be at risk to frequent fires due to use of explosive ordinance, military vehicle traffic, or other ignition sources. Brothers (1984) attributed increased fire along the Owens River to increased use of the riparian zones by campers and fishermen in the past 30 years. Some managers recognize a '4th of July fire syndrome', due to the prevalence of riparian fires started by fireworks. According to Wiesenborn (1996), "Wildfires are an increasingly common occurrence in saltcedar along the lower Colorado River, partly the result of increasing population densities along the river's shorelines." In fact, John Swett (pers. comm.; U.S. Bureau of Reclamation, Boulder City, Nevada) reports that 95% of fires along the Lower Colorado River are human caused. Fires also can be started by homeless people or transients, especially along rivers near urban areas where dense riparian vegetation provides relatively attractive sheltering sites (see Appendix M).

Another factor that may be contributing to riparian fire increase is an increase in fires in the desert uplands. As is true for Sonoran riparian cottonwood-willow forests, fire has become a 'new' disturbance in the Sonoran and Mojave Desert during the past century (Brown and Minnich 1986). Dry, fine fuel-loads, as well as ignition rates, have increased in these deserts. Livestock grazing has contributed to the establishment of grazing-adapted, exotic annual plants which carry fire more readily than native annuals (Brooks 1995). The dense stands of exotic annuals that develop in wet, El-Nino years create opportunities for spread of fire in these non fire-adapted communities far in excess than would have been produced by native riparian plant species during similar El-Nino events. Fires also have become more frequent in other upland vegetation types, such as California chaparral. Extensive urban development in southern California has increased the ignition sources from cars, cigarettes, and other sources, thus providing more opportunities for upland fires to spread into riparian corridors.

2. Low and Mid-Elevation Habitats: Fire Decreases.

We speculate that fire has become less frequent along rivers that historically flowed through grassland or savannah habitats, given the documented declines in fire frequency in these upland habitats (MacPherson 1997). In addition to direct fire suppression, many of the grassland and savannah habitats have been replaced by less flammable vegetation types such as shrublands. There is some evidence that these changes have influenced the adjoining riparian cottonwood-willow-mixed broadleaf forests. For example, the upper reaches of the San Pedro River historically were vegetated primarily by marshland and sacaton grass, with fewer stands of riparian trees than today. Recurrent fire probably favored the herbaceous vegetation types. In the mid 1800s, for example, Leach (1858, in Davis 1982) describes a fire along the San Pedro River that destroyed "large quantities of Cottonwood, Ash, and willow timber with which the banks of the river were densely overgrown", but says that three weeks later "the Sacaton grass had grown up and covered the entire valley with a beautiful carpet of verdure". Only recently and only locally has fire returned as an ecological force to the San Pedro uplands, due to cessation of grazing and subsequent recovery of the grassy-fuel load (Krueper 1992). As a result, several fires have spread into the older riparian forests in the past decade. The fires are carried into the riparian corridor by the seasonally dry understory of perennial grasses and forbs, and have killed several patches of cottonwood and willow trees. In other areas throughout the range of the southwestern willow flycatcher, desert grasslands have been so degraded that they have reached a new stable state composed of shrublands and small trees; thus precluding the return of the historical upland fire regime.

There is other anecdotal evidence that fires have become less frequent at some mid-elevation sites. In some areas, fires may have decreased in frequency because Native Americans no longer set fires to improve hunting success. In others, ranchers no longer are setting fires to increase access and improve forage for cattle (Boukidis 1993). Part of the reason for the decline in prescribed burning is the difficulty in obtaining permission from the permitting agencies, as well as risks to the increasing number and distribution of rural homes.

3. High-Elevation Habitats.

There is little hard evidence that fire regimes of the high elevation wet meadows and willow shrublands have changed. In some of the adjacent upland conifer forests, including the *P. ponderosa* forests, fires have become less frequent but more intense. Heavy livestock grazing has eliminated the fine fuel load that historically contributed to frequent low-intensity fires in some of the forest types (Belsky and Blumenthal 1997). Active fire suppression has allowed for the accumulation of high fuel loads (i.e., very dense stands of young conifer trees) that results in very high fire intensities when the forest do burn (Covington et al. 1997). These changes may have altered fire patterns in the associated riparian zones. With higher intensity, the fires may be more likely to penetrate into the riparian corridor. Additionally, catastrophic fires can trigger catastrophic flooding events, which in turn can destroy wetlands or eliminate populations of some wetland plants (Hendrickson and Minckley 1984, Bowers and McLaughlin 1996); but at the same time create opportunities for establishment of disturbance-dependent species such as willows.

D. Impacts on Southwestern Willow Flycatcher

1. Low and Mid-Elevation Habitats: Fire Increases

The willow flycatcher is a bird that lives in a dynamic habitat. Suitable nesting patches historically underwent frequent loss and replacement due to flood disturbance. When assessing the impacts of fire regime change on the flycatcher, we must compare the population dynamics of the birds between flood-disturbance and fire-disturbance scenarios. Although there are some similarities, there also are substantial differences in the ways in which fires and floods influence the bird and its habitat. We stress the management implications of one similarity: because fires and floods both periodically cause localized habitat loss, the total numbers of individual flycatchers and of flycatcher populations need to be sufficiently large to buffer the species from these habitat losses. This requires that riparian habitat patches be sufficiently abundant and distributed appropriately throughout the birds' range to allow for post-disturbance recolonization.

Historically, most floods that were large enough to scour and remove nesting trees and shrubs from the Sonoran Desert rivers occurred in winter, spring, late summer or fall, but rarely in the early summer period coincident with the flycatcher breeding season. Thus, despite the floods, nest sites had a high probability of remaining intact throughout the breeding season. Riparian fires, however, tend to burn during the summer breeding season and thus can cause direct loss of nests and young. Some nesting flycatchers may move to other, unburned habitat to re-nest, but the resultant delayed breeding and use of alternative habitat may lower their overall seasonal breeding success. For example, the 13 willow flycatcher pairs breeding in the area burned by the San Pedro PZ Ranch fire in June 1996 abandoned the site (Paxton et al. 1996). Their subsequent reproductive success, if they had renested in the same year, probably would have been reduced because willow flycatcher clutch size is significantly reduced each time a flycatcher renests within a season (Holcomb 1974). Although some willow flycatchers returned to unburned portions of the PZ Ranch site during subsequent years, the population there continued to decline over time through 1999, when only a single unpaired male remained (Arizona Game and Fish Dept., unpubl.

data).

We do not know how many flycatchers are affected directly by burns in any given year. The number may be large given the dominance of tamarisk along rivers in the desert southwest and the prevalence of fires in this vegetation type. In 1998, for example, a major fire along the lower Colorado River destroyed large portions of dense tamarisk habitat at Topock Marsh. Approximately 100 ha of suitable flycatcher habitat was consumed in the blaze (of a total 1,200 ha burn), though effective fire suppression kept the fire out of known occupied habitat that supported over a dozen territories, and thus no known flycatcher nests were destroyed (U.S. Fish and Wildlife Service 1998). However, the potential for loss in such situations is high.

Fires at any time of the year can affect breeding success by causing changes in vegetation structure and composition. The structural characteristics of post-disturbance riparian vegetation and suitability as flycatcher habitat differ substantially between floods and fires. Floods, unlike fires, trigger primary succession along alluvial desert rivers. By scouring sediment from aggraded floodplains, creating new channels, redistributing sediment, recharging aquifers, and moistening sediments, floods create opportunities for seed-based regeneration of cottonwoods and willows, and create a mosaic of age classes in the flood plain. Natural flood regimes provide a mechanism for the continued development of habitat patches with suitable nesting structure. Fires, in contrast, do not cause these same geomorphic, hydrologic, and vegetational changes.

Fires cause directional change in the composition of the riparian stand, and trigger secondary successional processes. Along the lower Colorado and Bill Williams rivers, fires have contributed to the replacement of many native species including Fremont cottonwood, quail bush (*Atriplex lentiformis*), and salt bush (*Atriplex* spp.), by tamarisk (Anderson et al. 1977, Higgins 1981, Busch 1995, Shafroth 1999). Tamarisks can be killed by very hot or frequent fires, but generally resprout from the root crown in as little as a few days after the fire (Faber and Watson 1989, Hoddenbach 1990). Horton (1977) found that "fire burning through a saltcedar stand will not kill the shrubs, as they tend to sprout vigorously unless they are growing under stress. Then as many as half of the shrubs may not survive." Although some native species, including honey mesquite and Goodding willow, also resprout after fire, the development of a fire-cycle triggered by the dominance of tamarisk ultimately can result in the loss of these species. Anderson et al. (1977) noted that "with the initiation of a burn cycle, the dominance of an area by saltcedar becomes successively more complete." The native shrub arrow-weed *(Pluchea sericea*) also is favored by frequent fire, and thus tall forests of Fremont cottonwood, Goodding willow, and mesquite along the Colorado River have been replaced by short shrublands of arrowweed and tamarisk. Along the Owens River, fires may be favoring the shrubs narrowleaf-willow (also known as coyote willow; *Salix exigua*) and rabbitbrush (*Chrysothamnus nauseosus*) over Fremont cottonwood and Goodding willow trees (Brothers 1984).

Flycatcher breeding success can be impaired for several years after a fire. The extent and duration of the impairment varies with many factors including the size and severity of the fire, rate of vegetation regrowth, and post-fire changes in vegetation structure and insect community structure and productivity. Post-fire regrowth of tamarisk can be quite rapid if site conditions are favorable, with resprouts growing to 4 m high in a year after burning (Horton 1977). In other cases, over a decade may be required for the resprouted tamarisks and/or willows to attain the requisite structure for flycatcher breeding (Paxton et al. 1996).

The following case study illustrates the complexity of the post-fire response. In March 1997, an agricultural brush-pile fire on land adjacent to Escalante State Wildlife Area, Colorado escaped control and burned through the small patch of flycatcher habitat on the area (Owen and Sogge 1997). The habitat burned during the non-breeding season when flycatchers were not present, and approximately 95% of the known breeding area burned. Subsequently, the number of flycatchers present in 1997 (six territories) was lower than during 1996 (10 territories). Three territories within the burned area retained approximately 50-60% willow coverage and were occupied by breeding pairs. The other three territories were in completely burned habitat (much of which was previously tamarisk), and two of these three territories were only occupied by unpaired males. By 1998, resprouting willow and tamarisk vegetation provided dense habitat in the burned area, but only five territories were found (Sogge unpubl. data). Thus, although flycatchers occupied the site after the burn, it presumably reduced the local population size and lowered the overall breeding success.

Southwestern willow flycatchers breed in dense, tall, and typically older tamarisk patches at many sites in the Southwest (see Appendix D). We do not yet know if tamarisk patches can reach a state of maturity or decadence in which they would lose their suitability as flycatcher breeding habitat. This could theoretically occur if the tamarisk plants undergo senescence, become decadent, and lose vigor (and thus live-foliage density). This question has significant ramifications in terms of the sustainability of currently occupied sites, and for the future suitability, availability, and distribution of substantial amounts of flycatcher habitat. This important issue deserves future research attention.

If tamarisk stands can "age" beyond suitability for flycatchers, such conditions would require the absence of disturbance factors such as fire or floods. In these situations, small fires may be beneficial by allowing for development of younger stands. Fires may perpetuate a mosaic of size classes, in the absence of other disturbances. Thus, it is theoretically possible to use fire as a tool to manage for key structural types in saltcedar (Anderson et al. 1977) if research determines that older structural types are not suitable for flycatchers or that a mix of saltcedar successional stages is superior for flycatchers. However, older stands of dense tamarisk may be so fire-prone that it is impossible to keep a fire "small enough" to serve as an effective tool that does not destroy an entire riparian area.

Overall, many questions need to be answered regarding tamarisk and fire management. If fires are going to persist as the dominant disturbance factor on some rivers, we need to define more explicitly the tamarisk structural types and age ranges that are preferred by the flycatchers. More research is needed in general on relationships between riparian stand age and flycatcher habitat suitability (Farley et al. 1994). We also need to know the response of tamarisk to repeated burning. How long can tamarisk survive under a frequent-burn scenario? Will the resprouted plants die at the end of some fixed natural life span, or does burning reconfigure them to a juvenile state? More research also is needed to determine how post-fire forest stands differ from post-flood stands in terms of insect food base, or other habitat suitability factors.

2. Low and Mid-Elevation Habitats: Fire Decreases

As we noted earlier, fires have returned as an ecological force along some rivers, including the upper San Pedro, that are bordered in the uplands by fire-adapted vegetation types. We anticipate that the restoration of the fire regime in this reach will reduce the abundance of cottonwood-willow forests, particularly on the highest (and thus most surface-dry) flood plains. Fire-related losses of these habitat patches need to be countered by restoring riparian habitat to other sites throughout the flycatchers' range. Because there are other rare species that depend on the fire-adapted riparian vegetation types, we advocate a multi-species approach to riparian ecosystem management.

3. High-Elevation Habitats

We are not aware of published evidence that fire regime changes have had either positive or negative effects on the flycatcher in high elevation habitats. Mature stands of willows grow in some meadows in the Sierra Nevada. While fire may be a tool to rejuvenate willows in these situations, the ecological processes that lead to the stands natural presence and persistence are unknown (Valentine, pers. obs.). In some high-elevation willow habitats (e.g., the Alpine site in the White Mountains of Arizona), intentional removal of beavers dried the site substantially, contributing to reduced water ponding, conversion of perennial stream flow to intermittent, restriction of the flow to the narrow creek channel, and declines in the extent and density of willows (Langridge and Sogge 1997). Drier herbaceous and shrub vegetation, essentially pasture-like in nature, can surround the remaining willow patches where willow flycatchers still breed. These changes in vegetation and hydrology have the potential of increasing fire frequency, and are another topic that warrants research attention.

E. What Can Be Done

There are many actions that could be taken, and that are being undertaken at various riparian sites, to restore appropriate disturbance regimes. Some of these actions, such as restoring flood flows, fall in the category of "ecological restoration" approaches because the intent is to restore habitat by restoring desired physical processes. Others, such as clearing woody debris, fall in the "active intervention" category. Some actions focus on prevention of fires (e.g., reducing ignition sources, reducing the abundance of flammable fuel loads) while others focus on extinguishing fires once they have started. Some actions are long-term with regard to implementation and benefits. Others can be carried out more quickly, often at smaller scales, and result in relatively rapid reduction in fire risk and impacts. Some of the actions could be undertaken in adjacent uplands, where fires have become a new disturbance, to reduce probabilities of spread of upland fires to riparian corridors.

In this section, we discuss some of the caveats, constraints, and benefits of several action-items with respect to willow flycatcher habitat quality. Our primary focus is cottonwood-willow habitats (now cottonwood-willow-tamarisk), the type that has undergone the greatest change in disturbance regime.

1. Fire Risk Evaluation and Planning

* *Fire risk and management plans.* As a first step in reducing the risk and effects of fire, land owners or managers should develop a fire plan for all current flycatcher breeding sites, and for sites where flycatcher-related riparian restoration is planned. This can be accomplished quickly and with relatively little cost, and yet can yield great rewards in minimizing or avoiding loss of occupied habitat. This was the case for the 1998 fire that occurred at the Topock Marsh site along the Colorado River – advance risk-evaluation and response planning played a key role in preventing the destruction of active flycatcher nests and important breeding habitat. Fire control efforts involved on-the-ground "flycatcher advisors", working with the fire team to identify and protect occupied willow flycatcher habitat. The suppression tactics would have been different if fire crews were not aware that the flycatchers were present, and the fire would likely have burned occupied willow flycatcher habitat. This involvement of the willow flycatcher resource advisors was critical, and they will provide assistance on any future fires at the site.

Other fire-suppression planning for flycatchers has occurred. The Bureau of Reclamation distributed 10,000 brochures on the dangers of wildfire along the Lower Colorado River to local federal and state land management offices. Management agencies along the Lower Colorado River have developed cooperative strategies for fire response. In the BLM Lower Colorado Fire Management Plan, protection of riparian habitat is given suppression priority second only to human life and property. The BLM and USFWS prohibit campfires on their lands along the Colorado River from May 1 through September 30 from Davis Dam to Mexico.

A comprehensive fire evaluation and response plan (hereafter referred to as the fire plan) should have several components including:

(a) evaluation of the degree of fire threat for that particular site. This section of the fire plan involves consideration of vegetation composition and structure, hydrologic conditions, patch morphology/structure, historical and recent fire regime, assessment of the fire risks posed by land-use management (e.g., livestock grazing, fire suppression) on-site and adjacent to flycatcher habitat, and potential sources of ignition (especially with regard to intensive human use) as well as identifying entities that contribute to control of fireworks risks.

(b) identification of short-term preventative actions that will be taken to reduce the risk of fire. This section of the fire plan could include many of the recommendations made later in this appendix, such as reduction of ignition sources (e.g., recreational use management, signage), efforts to produce less flammable conditions (e.g., development of 'wet' fire breaks, periodic inundation to moisten the soils and litter, modifying grazing to achieve reduced flammability), encouraging fireworks regulating entities to eliminate or restrict sales and use areas, etc.

(c) direction for quick response for fire suppression. This section of the fire plan should be very detailed and identify flycatcher breeding locations, prioritize areas for protection, locate access points, provide important site contacts (including the management agency and the USFWS), etc. The plan should be developed in conjunction with local fire management agencies, and periodically updated (at least biennially). Updates should be reviewed with the associated fire management agencies so that firefighters know about the management plan *before* a fire actually threatens a site.

(d) post-fire remediation/restoration. This section of the fire plan should have a goal of enhancing the recovery of desired vegetation that is suitable for breeding flycatchers, and should take advantage of the vegetation-clearing role of the fire. Remediation plans will, of course, vary from site to site depending on site potentials and logistic considerations. For example, at some sites the flood plain surface could be cut and lowered closer to the water table, flood irrigated and seeded with desired species. At other sites, it may be possible to excavate channels and then revegetate their margins. Some areas may simply need planting of the desired species without undertaking any earth moving activities.

(e) identification of long-range efforts to reduce risk of fire. This section of the fire plan can include reducing ignition sources (e.g., educational efforts), producing less flammable conditions by restoring more natural hydrologic and ecologic conditions (e.g., release of flood pulses, increase of ground water levels, restoration of willow, cottonwoods and other native species; release of beavers), etc.

(f) development of long-term monitoring of conditions in the riparian zone and watershed that maintain flood regimes and reduce fire susceptibility. This section of the fire plan should consider efforts such as monitoring regional water use patterns; water level trends in the regional and flood plain aquifers; fire-related recreational activities; and fuels loading.

2. Ecological Approaches to Reducing Risk

**Restore flood flows.* Flood pulses can be restored by breaching dams or releasing prescribed flows from dams. Both approaches can serve to reduce fire frequency and size in the short-term by scouring flammable fuel loads and moistening the vegetation and in the long-term by selecting for less flammable vegetation types. This ecological approach has tremendous value in that it addresses the root causes behind the shift in the nature of the disturbance regime. To be most effective, flood pulse restoration should be part of an overall restoration plan that will allow for ongoing establishment and survivorship of the native tree and shrub species that constitute flycatcher habitat (see Appendices I, J, and K).

Ideally, floods should be released in a fashion that mimics the natural flow regime. Water or power demands, or physical characteristics of the dam structure itself, may constrain the size or frequency of flood releases. To reduce fire size and frequency, floods should be sufficiently large to scour and remove accumulated forest floor debris and moisten the surface soils and tree bases. Based on flood recurrence intervals calculated for free-flowing rivers (Stromberg et al. 1991), an approximate frequency for such floods is once every two to five years. Larger floods that remove dead branches and scour patches of forest should be released, at longer intervals, to further reduce fuel loads and allow for successional regeneration processes. Where river channels below dams have become entrenched, there may be a need to mechanically grade and lower the adjacent flood plains and/or to raise the channel, to allow the flood plain surfaces to be inundated by smaller flood flows. Site-specific hydrologic and ecologic studies should be conducted to determine specific flood frequencies and magnitudes. Hydrography information for the reach in question can be calculated from upstream gauging or other hydrological information to guide prescriptions on flood size, frequency, and timing (see Appendices I and J).

* *Restore ground water and base flows.* Restoration of water availability also is an ecologically-based approach that will aid willow flycatchers not only by reducing fire risks but by improving habitat quality in other ways. Depth to ground water should be sufficiently shallow to restore or maintain native cottonwood-willow forests in non-water stressed condition (i.e., no lower than 3 m below the flood plain surface for mature forests and within 0.5 to 1 m of the flood plain for younger forests measured during the peak water-demand periods). Hypothetically, shallow depth to ground water also might allow tamarisk stands to be more fire resistant than if water is deeper because they maintain higher internal water content. Such high water tables may also allow native cottonwoods and willows to outcompete tamarisk. If a stream has become intermittent, perennial surface flows should be restored. In lieu of restoring the natural hydrology (the preferable option), other actions to improve plant water content and raise water tables could be undertaken such as flood irrigation, sprinklers, or agricultural tail water.

* *Reintroduce beavers*. By locally raising water tables, creating ponds, and increasing the extent of marshy, wetland vegetation (Parker et al. 1985, Johnston and Naiman 1987, Naiman et al. 1988), beavers may reduce fire size or frequency at a site. By promoting these habitat conditions, beavers appear to generally enhance site quality for flycatchers (Albert 1999). Apple (1985) showed that introduction of beaver into deteriorated or deteriorating riparian habitats lead to substantial improvements in 3 years. Subirrigated meadows formed where the channel formerly was downcutting into a gully-cut channel and "full riparian recovery was underway." Beavers have recolonized many riparian sites on their own, and they will likely spread (through natural dispersal or human intervention) into additional sites in the future.

There are several issues that must be considered before releasing beavers as a habitat restoration tool. The site should be assessed to ensure that there is an adequate food base of preferred foods, and to ensure that the natural successional dynamics are in place that will allow these plant species to regenerate over time. Otherwise, beaver foraging can reduce habitat quality by reducing densities of wetland herbs and riparian trees and shrubs below replacement levels. For example, in very small riparian patches, beaver might render the site unsuitable for breeding flycatchers by girdling or cutting down too many trees and shrubs. Arizona Game & Fish (unpubl. data) observed this event at the Tavasci Marsh flycatcher breeding site in the Verde Valley. There, beaver activity lead to a 50 percent loss of dominant large willows that dramatically reduced the live foliage. Subsequently, willow flycatchers did not nest at the site. However, these short-term losses in habitat quality may be offset by long-term improvements. Beaver habitat suitability analysis models (e.g., Allen 1982) should be consulted to determine if a site is likely to support beavers.

Another potential complication in using beavers for flycatcher habitat improvement is that beavers were not historically present in some parts of the Southwest (e.g., Southern California). There, introduction of beaver could violate proscriptions against introduction of new species. Furthermore, the hydrological conditions created by beaver activity (especially perennial ponds) could provide favorable conditions for unwanted species, such as the introduced bullfrog (*Rana catesbeiana*), at the expense of locally rare or endangered fish or amphibians. However, beavers are already so widespread in Southern California that it may be acceptable to consider them as vital agents in the functioning of riparian areas. In general, additional site- and context-specific research is needed about the role of beavers in creating and maintaining suitable willow flycatcher breeding habitat, and any ecological ramification or trade-offs of such actions.

* *Exclude livestock or follow proper utilization rates.* Livestock grazing is one of the factors that can cause drying of riparian sites and that can favor flammable exotic species such as tamarisk and red brome (see Appendices G and H). Many of these exotics are more flammable than the native species they replace. There is no guarantee that simple removal of livestock or reduction to more appropriate utilization rates will allow the native species to recover. Exotics can remain dominant for decades after a stressor, or factor that enabled their establishment, is removed. For example, Harris (1967 in Krebs 1972; 313) noted that the invasive cheatgrass (*Bromus tectorum*) is very resistant to displacement by native perennial grasses. In Washington, native wheatgrass (*Agropyron* sp) was not able to invade the *Bromus* stands even after 30-40 years of protection from fire and grazing. Further, some exotics may not even require the stressor to gain dominance in a community. Mensing and Byrne (1999) assert that red-stem filaree (*Erodium cicutarium*) was introduced to the West Coast of North America in the feed imported to support livestock of the first Spanish mission. However, its dispersal exceeded the spread of livestock from the mission, suggesting that the species was pre-adapted to the Mediterranean climates of the West coast. Therefore, simple removal of a stressor may not be adequate to recover native flora. However, removal of

the stressor, when coupled with other restoration measures such as seeding or soil manipulations (see Appendix H) may be necessary to hasten the recovery to a less flammable community type. Where the consequences of fire are high due to fine fuel loads, livestock grazing might be used as a tool to reduce the risks (Boukidis 1993, Chang 1996).

* *Use sustainable agricultural practices.* We need to address all of the factors that are causing riparian habitats to be more flammable. Some agricultural practices, for example, amplify the amount of salt and its delivery into rivers, in some cases favoring tamarisk and other exotics over willows and other native species. Increase in salinity is one subtle factor that can give tamarisks a competitive edge over willows (see Appendix H). Shifts towards more efficient use of water and less reliance on applications of fertilizers would help to reduce salt loads. Flood plains and watersheds should be managed in such a way as to keep salinity levels within the tolerance ranges of the native plant species.

3. Physical Manipulation of Fuel Loads

* *Manually/mechanically reduce fuel loads.* On heavily regulated rivers where natural flood regimes will not be restored, we must regularly intervene to actively manage the fire disturbance regime. One type of intervention involves clearing the 'fine woody debris' such as litter and dead branches, from dense stands of flammable vegetation, such as tamarisk. This also could entail clearing the duff of annual grasses from forest understories. These actions may reduce the intensity of fires and ease suppression, but are likely very time-intensive and could reduce site suitability. Such actions should be carefully planned, and adopted as part of a larger plan only after the benefits and costs are assessed to avoid causing more harm than good with respect to habitat quality. For example, it may be necessary to develop access roads to remove the fuel loads. The resulting fragmentation and opening of the vegetation may reduce quality of the flycatcher habitat or provide an avenue of ingress for threats to habitat or the species.

There has been little, if any, experimentation with fuel reduction in riparian habitats (especially tamarisk), and there are no standard guidelines on how best to accomplish this. Therefore, riparian fuel reduction actions should be considered as experimental, and initially conducted only in unoccupied habitats until the success and ramifications are better understood. Efficacy of these actions as a fire management tool, and effects on bird habitat quality, should be tested in a scientifically explicit, controlled fashion.

* *Dry fire breaks*. This approach, in some respects, is related to the one above. Here, the goal is to reduce the spread of fires by clearing all of the vegetation from swaths of land. Because of concerns over fragmentation of flycatcher breeding habitat, including the potential for providing increased human access to and into breeding sites,

fire breaks are not a preferred choice at most flycatcher sites. In addition, the effectiveness of firebreaks in dense willow and saltcedar willow flycatcher habitat is questionable. For example, the Topock Marsh fire of July 1998 jumped an existing firebreak. West (1996) indicated that fire breaks should be at least 100 feet (ca. 30 meters) wide, which would remove a substantial amount of habitat and greatly fragment a site. Furthermore, there is anecdotal evidence that flames from fires in dense tamarisk can travel across even 100 m wide bare strips, thus restricting the utility of fire breaks at tamarisk sites. In occupied or suitable flycatcher habitat, creation of wide fire breaks might render the habitat unsuitable. Situations where dry fire breaks may be effective include:

- along grass-edged roadways. Mowing or clearing dry vegetation along roadways may reduce fire ignition and spread from discarded matches and cigarettes.
- where large areas of fire-prone vegetation, unsuitable for flycatcher breeding, separate a breeding site from potential ignition sources or high-frequency fire areas. A wide fire break, far from the flycatcher breeding patch, could prevent or slow fire from spreading into the occupied patch.
- between agricultural "burn areas" and flycatcher sites, to prevent brush-pile fires from spreading into breeding sites.

Additional research is needed on the potential values, effectiveness, and ramifications of creating fire breaks in riparian habitats. Such research should first be conducted only in unoccupied sites.

* *Create wet fire breaks*. As an alternative to creating 'dry' fire breaks, 'wet' fire breaks could be created along heavily managed rivers by developing channels and restoring strips of less flammable vegetation along their margins. In dense, wide tamarisk stands, channels could be excavated to the level of the water table, or provide a water source directly into the channel. Site conditions adjacent to the channel would need to be assessed to determine what vegetation types could survive. If the soil is not too salty and if water tables are relatively stable, willows and cottonwoods could be restored (though this may require active establishment and maintenance). Another option is to plant marsh species such as cattails and bulrush. The channel and adjacent vegetation would have to be relatively wide (30 m to 100 m) to be an effective fire break. Potential ancillary benefits of this approach include increasing availability of flycatcher nest sites, enhancing the amount of water (an important habitat parameter) on-site, and increasing the productivity of the insect food base. Another benefit is that the presence of surface water can provide another source of water to be used for suppression purposes. However, even wet fire breaks have the potential to fragment habitat and provide increased access to flycatcher breeding sites, and should be approached with the same cautions noted for dry fire breaks (above).

* *Burning issues: Implement controlled burns.* There may be benefits to the use of prescribed fire in

riparian areas, from the perspective of flycatcher habitat. In older tamarisk stands, fire might create a mosaic of patches in different age classes and structural classes, which may provide for long-term maintenance of tamarisk at the site. It may also decrease the chance that an accidental fire will burn large areas and homogenize the landscape. However, these are theoretical benefits, and some fire experts consider dense tamarisk habitat a poor choice for controlled burns. Tamarisk is highly flammable (observers of some recent fires describe tamarisk plants as literally "exploding" in succession as the fire swept through stands) and there is a high risk of losing control of the burn (Kerpez and Smith 1987). In some cases, though, such as after rains or floods, managers were unable to ignite the tamarisk (Jorgensen 1996, West 1996). To better manage the controlled burns in tamarisk stands, one may wish to limit efforts to the rainy season, inundate the stand before burning, or reduce the fuel loads mechanically before burning. These possibilities warrant further research. Until then, however, controlled burns should be avoided in occupied habitat (or where the fire could spread to occupied sites), and considered only as experimental management techniques if dealing with suitable unoccupied habitat.

4. Public Education and People-Management

* *Reduce recreational fires*. In occupied habitat and in large buffer strips surrounding the occupied habitat, fires and fire-prone recreation uses should be prohibited during high fire-risk periods. In areas with suitable but unoccupied habitat, manage the numbers and/or distribution of recreationists to concentrate them into locations where fire suppression efforts can be more effectively deployed (and thus habitat loss minimized). Some areas may need to be closed to recreational use during high-risk periods, such as 4th of July weekends or drought periods. Additional patrolling by enforcement personnel would help to enforce restrictions.

* *Educate recreationists.* Brochures, signs, and other interpretive materials should be developed to educate river and riparian recreationists about the ecological roles of fires and floods, and the potential dangers of accidental fires. As noted above, such a program has been initiated by the U.S. Bureau of Reclamation along the Lower Colorado River. In the long-term, this should help to reduce accidental fires and garner public support for the implementation of ecological restoration approaches.

5. Reactive Measures: Fire Suppression

* *Suppress fires*. Fires in occupied habitat and adjacent buffer zones should be rapidly suppressed. As part of each breeding site's Fire Evaluation and Management Plan (described above), maps of occupied habitat and buffer zones should be updated at frequent intervals, and the maps made available to local fire commanders to aid in active suppression process. "Ok-to-burn" areas should be identified based on site-specific analysis of the size, structure and composition of the riparian habitat throughout the management area, the recent fire history in the area,

and the ease of extinguishing the fire once it has moved beyond the area targeted for burning.

F. When and Where to Apply Measures

Table 2 lists the suite of actions that should be taken to restore an appropriate disturbance regime for the southwestern willow flycatcher. We classify the actions based on the quality and occupancy of the habitat. The actions in Table 2 apply to low and middle-elevation riparian forests that have undergone shifts from flood to fire disturbance regimes.

For all riparian community types throughout the flycatcher's range, including those at low, middle and high elevations, we need more information on the fire regime and ecological effects of fire. As noted above, all occupied sites, even those at high elevations, should undergo a fire risk evaluation and development of a fire plan.

G. Literature Cited

Please see Recovery Plan Section VI.

Table 1. Recent fire history along the Lower Colorado River, Arizona and California (Source: U.S. Bureau of Reclamation 1997, 1998, and 1999).

Reporting period	Number of fires	Number of fires in known occupied willow flycatcher sites	Total acres burned (range/fire)	Total acres of potential or suitable willow flycatcher habitat burned
October 1996 - July 1997	8	2	431 (.1 - 158.0)	306*
October 1997 – August 1998	5	1	3238 (3.1 -2925.0)	2303
September 1998 – September 1999	27	0	1119 (.1 - 158.0)	7
October 1996 – September 1999	40	1	4776	2506

* best estimate, based on limited data

Table 2. Suggested actions for reducing and eliminating the risk and impacts of fire in southwestern willow flycatcher potential breeding habitat. These actions pertain primarily to low and middle elevation riparian forest types, which have undergone recent shifts from flood to fire disturbance regimes. Note, however, that fire risk and management plans should be developed for all occupied breeding sites.

Action	Occupancy and Condition Status of Habitat Patch		
	Occupied	Unoccupied but Suitable	Targeted for Restoration
Planning and Suppression			
Develop Fire Risk and Management Plan	Yes	Yes, if goal is occupancy	Yes
Develop Fire Remediation Plan	Yes	Yes, if goal is occupancy	Yes
Suppress Fire if it Occurs	Yes	Yes, if goal is occupancy	Possibly, if fire incompatible with restoration effort
Ecological Approaches			
Restore or maintain flood flows	Yes	Yes	Yes
Restore or maintain perennial surface flows and shallow ground water	Yes	Yes	Yes
Reintroduce Beaver	Yes, if site conditions are favorable	Yes, if site conditions are favorable	Yes, if site conditions are favorable
Manage livestock (exclude or proper utilization rates)	Yes	Yes	Yes
Use sustainable agricultural practices	Yes	Yes	Yes
Intervention: fuel load management			
Manually or mechanically reduce fuel loads	No	Experimentally	Experimentally
Create dry fire breaks	Not in habitat, possibly nearby	Not in habitat, possibly nearby	Not in habitat, possibly nearby
Create wet fire breaks	Not in habitat, possibly nearby	Experimentally	Possibly, as part of site design
Controlled burns	Not in habitat, possibly nearby	Experimentally	Experimentally
Education and People Management			
Public outreach and education	Yes	Yes	Yes
Manage activities or restrict access in high risk areas	Yes	Yes	Yes