

AN ANALYSIS OF FIRES AND THEIR IMPACT ON LEOPARDS IN SOUTHWEST PRIMORYE

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EXECUTIVE SUMMARY

We monitored the impact of fire in Southwest Primorski Krai from 1996 through 2003 by estimating the extent of area burned in 6 of those eight years, based on interpretation of satellite imagery. Due to the restricted time period when imagery is needed (late April-May), and the generally poor weather conditions (fog) during that period, it was not possible to obtain adequate imagery for all years. Nonetheless, for the six years that adequate imagery was available, we were able to determine the following key points by comparing the distribution of fires to various natural and anthropogenic parameters in Southwest Primorye:

A total of 46% of Southwest Primorski Krai, 3426.2 km², burned at least once during the six years in which fires were monitored. This must represent one of the highest rates of burning anywhere in Russia.

12-22% of Southwest Primorski Krai burns every year.

60% of those lands that burned, were burnt repeatedly.

Over 60% of all agricultural fields, wetlands, hayfields, and shrublands/meadows were burnt at least once over the 6 years studied.

34% of oak forests, the dominant forest type in Southwest Primorye, burned at least once in six years.

Spruce-fir forests (located on the Borisovskoe Plateau) were the only habitat type to escape fire over the six years studied.

56% of Barsovy Zakaznik burned over the six years, and 28% of Kedrovaya Pad Zapovednik burned at least once in six years.

Hunting leases incurred greater amounts of burning than protected areas, with those including large amounts of wetlands/meadows incurring the greatest impact.

Approximately 50% of the military “polygon” within Barsovy Zakaznik burned at least once in 6 years.

280 km² (12%) of lands managed by the Forest Service in Southwest Primorye burned in the six years that fire was monitored.

The frequency with which an area was burned was inversely related to its distance from villages, and distance from roads, indicating that humans are primarily responsible for most fires in Southwest Primorski Krai.

The border patrol fence acts as an important fire break, preventing many fires from crossing over into China.

Both tigers and leopards avoided areas burned by fires. This probably has as much to do with the habitat types that most frequently burn, than with the fire per se, but these recurrent

fires are a dominant force determining the distribution and amounts of leopard habitat that exist in Southwest Primorski Krai.

We believe that historically fires have been responsible for conversion of a large percentage of Southwest Primorski Krai from forests into open shrublands and meadows. Continued burning of these meadows and shrublands will prevent forests from ever regenerating in those areas, and the “creepage” of fires into forest lands leads to the slow but steady destruction of even more forest lands. Continuation of the status quo will continue to destroy forests and at a rate that is presently unknown.

Loss of habitat through continued burning represents a major threat to the last population of Far Eastern leopards. Although the rate at which forests are being lost is difficult to estimate, it is clear that available habitat is diminishing, pushing the leopard ever closer to extinction.

Fires can be suppressed in Southwest Primorye, and forest can be restored. We recommend 6 steps that need to be taken to initiate this process:

1. Conduct a survey in Southwest Primorye to determine more precisely who sets fires and why.
2. Initiate a mass media campaign directed to increase public awareness and reduce the amount of land burned on a yearly basis.
3. Improve fire-fighting capacity in Southwest Primorski Krai and improve cooperation between all agencies.
4. Provide necessary equipment to a re-organized team of fire fighters.
5. Enlist the assistance of local police and judicial branches to arrest and prosecute arsonists.
6. Create “model restoration sites” to demonstrate how to restore healthy forests to this region.

INTRODUCTION

The last known population of the Far Eastern leopard (*Panthera pardus orientalis*) resides in Southwest Primorski Krai. Although there are reports of leopards in nearby Jilin Province China, and a new reserve has been created there, available evidence still suggests that probably at least 90% of all surviving leopards rely on habitat and prey that reside in Khasan, Nadezhdinsky, and Ussuriisky Raions in Southwest Primorski Krai. The most recent survey, conducted in the 2003 winter (Pikunov et al. 2003) and partly corroborated by the findings of a camera-trap survey (Kostyria et al. 2003) indicates that there are approximately 28-30 individuals remaining in this region. These animals are largely confined to forest habitat, and therefore survival of this population will largely depend on retaining the remaining forest habitat in this region.

In Southwest Primorski Krai there has been a long history of man-caused fire. For the past century, since Russian settlers first arrived in this region, fire has been used commonly as a tool for clearing the land and maintaining and improving hayfields and agricultural lands. As in many places around the world, farmers understand that burning off standing dead material provides a mineral flush into the soil, and for many species of grasses, burning acts as a stimulant to growth, which in turn provides high quality forage for domestic grazing animals. Some of the first sika deer farms, created for the production of antlers, were created in Southwest Primorye, and fire was one of the tools used for improving fodder. Because Southwest Primorski Krai has one of the highest annual rainfalls in all of Russia, left alone, a luxuriant forest of mixed coniferous and deciduous trees develops, with lush understory and many lianas, an example of which partially remains in Kedrovaya Pad Zapovednik. However, due to human clearing, and a long and frequent fire history, much of this land has been converted to permanent grasslands (Map 1). Today, approximately 57% of Southwest Primorski Krai remains in forest land (Map 1). Burning appears to have become a “habit” in the region, and today, despite the fact that many of the deer farms have closed, and many of the agricultural fields are not in use, burning continues.

Burning usually occurs in two seasons: first in late fall, when standing dead material has sufficiently dried, and then again in the later part of spring, when usually even a greater amount of material has dried after snow has disappeared. Because snowfall is lower generally in this region than further north in Primorye, and melts more quickly because of the moderating effect of the nearby sea, snowpack disappears quickly here, providing an opportunity for dead and “down” material to dry sufficiently and be more susceptible to burning than other areas in Primorye.

The impact of fire on leopard habitat has been debated. Many are of the opinion that ground fires of the kind most common in Southwest Primorye have minor impact on forests and forest dynamics. Others, however, believe that these fires are responsible for the systematic loss of forest habitat in Southwest Primorski Krai. In recent informal surveys, many local people say they believe that the total amount of forested area is decreasing, and they suggest that fire has a primary cause for the loss of forest habitat in Southwest Primorski Krai. If this is indeed the case, ground fires pose a serious threat not only to leopards and tigers in Southwest Primorye, but to a host of other endangered species and plant communities that rely on forest habitats. Just as importantly, these fires may represent significant economic losses to the Russian Federation through their impact on forest stands, potential harvest volumes, and the environmental degradation associated with forest loss, e.g., loss of fish

habitat (via increased water temperatures associated with land clearing) and reduced functions of forested watersheds (e.g. protection against flooding).

In the 1970s, during a period of border disputes with China, Russia created a border patrol fence (referred to here as the “KSP” fence) that extends for over 200 km from the Russia-DPR Korea border up to the farmlands in Oktyabrsky Raion of Russia. This fence was an apparent attempt to reduce tensions between the two countries, but was built not on the border, but at varying distance (at places over 10 km) from the border within Russian territory (Map 1). To assist in revealing potential illegal boundary crossings, a 10-20 m clearing of all vegetation is maintained adjacent to the fence. Although designed for border patrol purposes, the clearing also acts as an effective fire barrier.

Beginning in 2000 Tigris Foundation began a fire suppression campaign by outfitting a special independent team with equipment to control ground fires in Southwest Primorye. The aim was to reduce the amount of area burned on a yearly basis in the region as a means to reduce habitat loss to leopards. If sufficient fire control could be implemented, it may actually be possible to begin restoration of habitat, as woody vegetation regains a foothold in present-day grasslands, leading hopefully to regeneration of forests. An important question concerning the program is of course, its effectiveness.

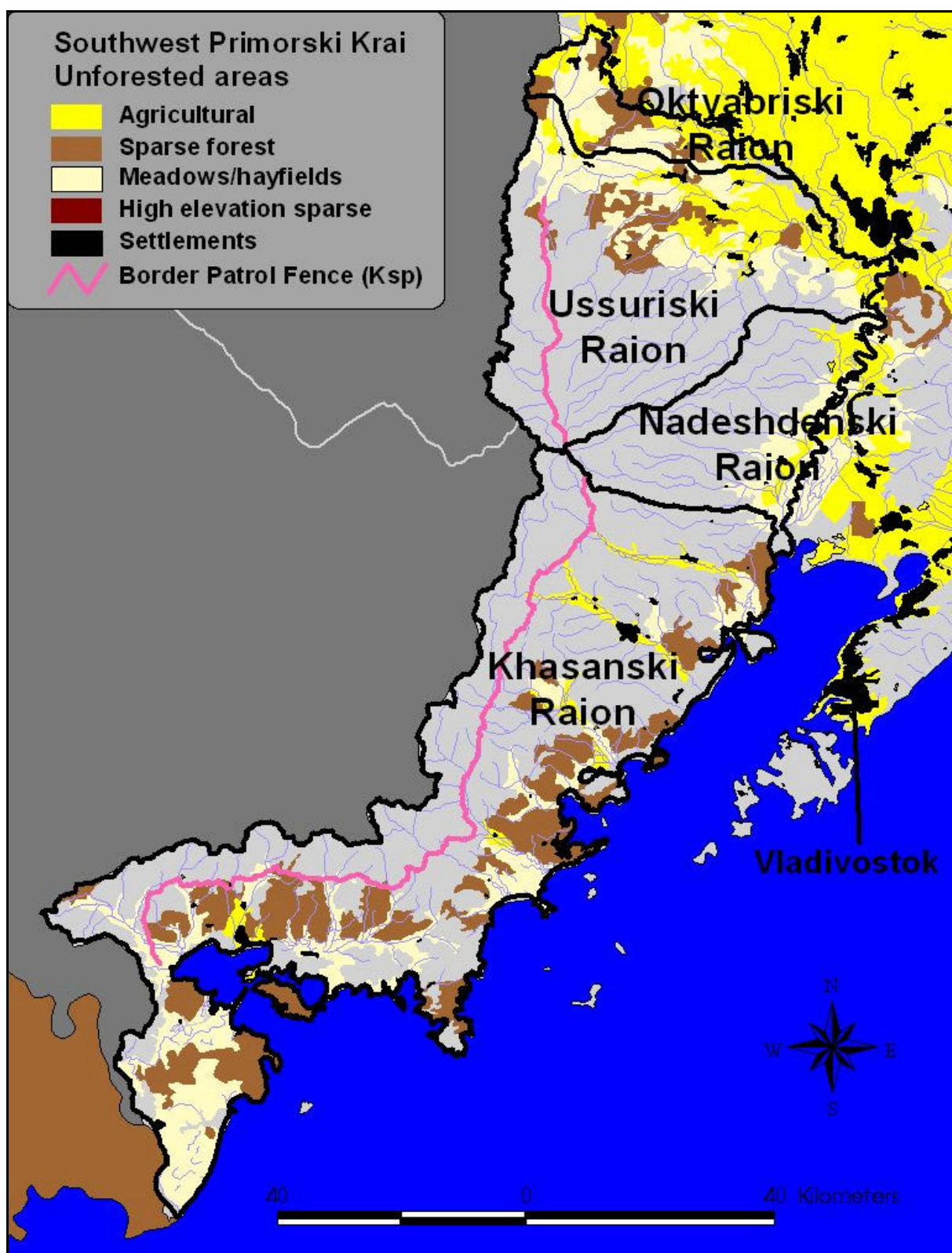
This project was developed to address the question of fire impact on forest habitats in Southwest Primorski Krai, and specifically to determine the potential impacts of fire on the remaining endangered population of Far Eastern leopards. Secondly, it was our hope to determine the feasibility of developing a regular fire monitoring program in Southwest Primorski Krai with the use of satellite imagery.

Specifically, the goals of our study were:

1. Determine the extent of burning on a yearly basis over the past 10 years
2. Determine where fires most frequently occur, and what types of areas are most likely to burn, in relationship to habitat types, landownership, land users, protected status, and relationship to humans and human activities.
3. Determine priority areas for fire suppression in the region.
4. Determine the feasibility of using satellite imagery as a means of monitoring fires, and the success of fire suppression.
5. Assess the impact of fire on leopard habitat.

STUDY AREA

We defined Southwest Primorye as that portion of Primorski Krai south and west of the Razdolnaya River. Khasansky Raion makes up the largest proportion and the southernmost portion of this region (4200 km²), followed by a “triangle” section of Nadezhdinsky Raion (900 km²). To the north is the westernmost section of Ussuriysky Raion (1,999 km²), followed by a small sliver of Oktyabrsky Raion in the northernmost section (338 km²). In total this region encompasses 7429 km².



Map 1. Area included in study of fire impact in Southwest Primorski Krai. Unforested regions are highlighted in this map.

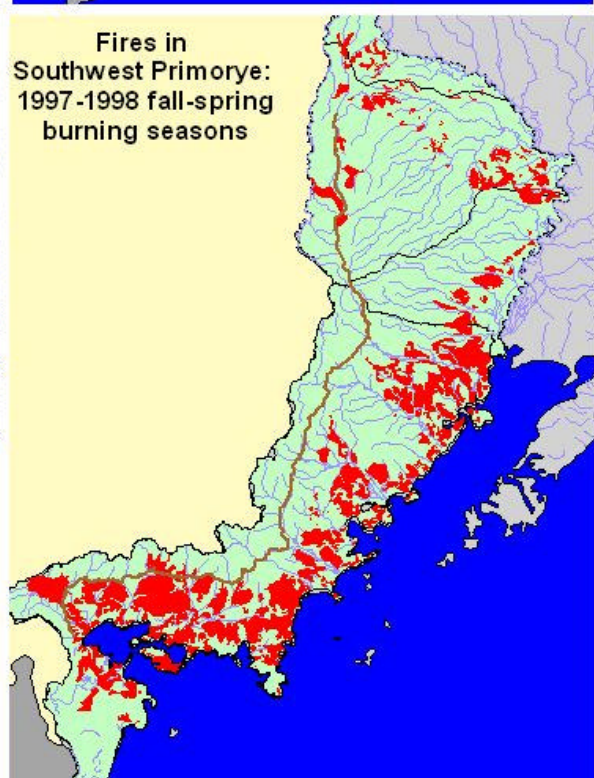
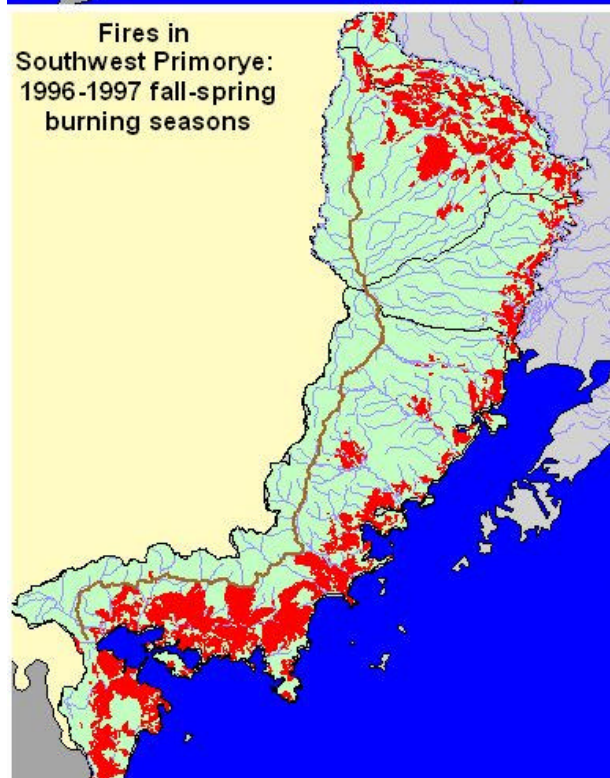
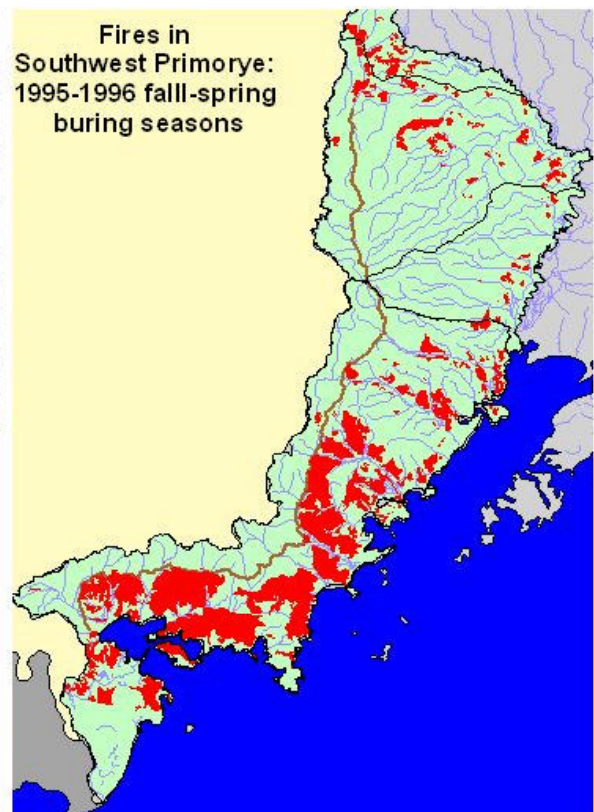
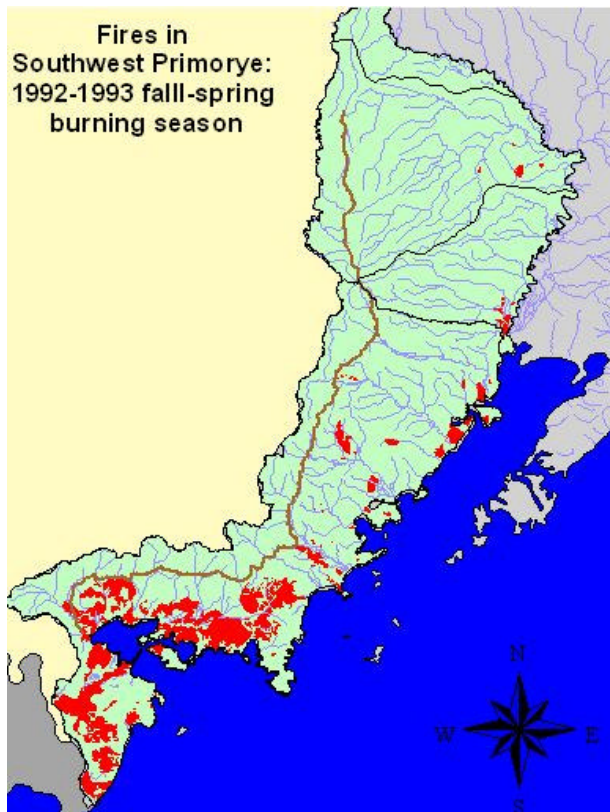
Settlements are primarily along the coast and in the northern sections, associated with agricultural fields and coastal ports (Map 1). Protected areas comprise a large percentage of this region. Two zapovedniks, Kedrovaya Pad and Far Eastern Marine Reserve, comprise a small fraction of the total area: Kedrovaya Pad is only 176 km², and the Marine Reserve is restricted to coastal tidal land and the sea itself. Barsovy Zakaznik (wildlife refuge) was created with federal-level status to protect habitat for leopards, and is the largest protected area at 1,218 km². Logging is permitted in Barsovy as much of the land is actually Forest Service land (GosLesFund). Additionally, a military polygon exists in the central portion of the zakaznik, and much of the region is highly impacted by humans. Borisovskoe Plateau Zakaznik, created only 1995, is completely contained within Forest Service lands, is more completely forested than Barsovy, and has less human impact. Poltavski Zakaznik, in the northwest corner of Southwest Primorye, is dominated by agricultural lands, but does have some oak and birch forests. However, neither leopards nor tigers have been reported in Poltavski Zakaznik in the recent surveys. Khasan Nature Park at the southern tip of Southwest Primorye was created to protect wetlands, and is not considered leopard habitat. For this reason, and due to the fact that most satellite images did not cover this parcel (see below), we have not included this southernmost region in our analyses.

RESULTS

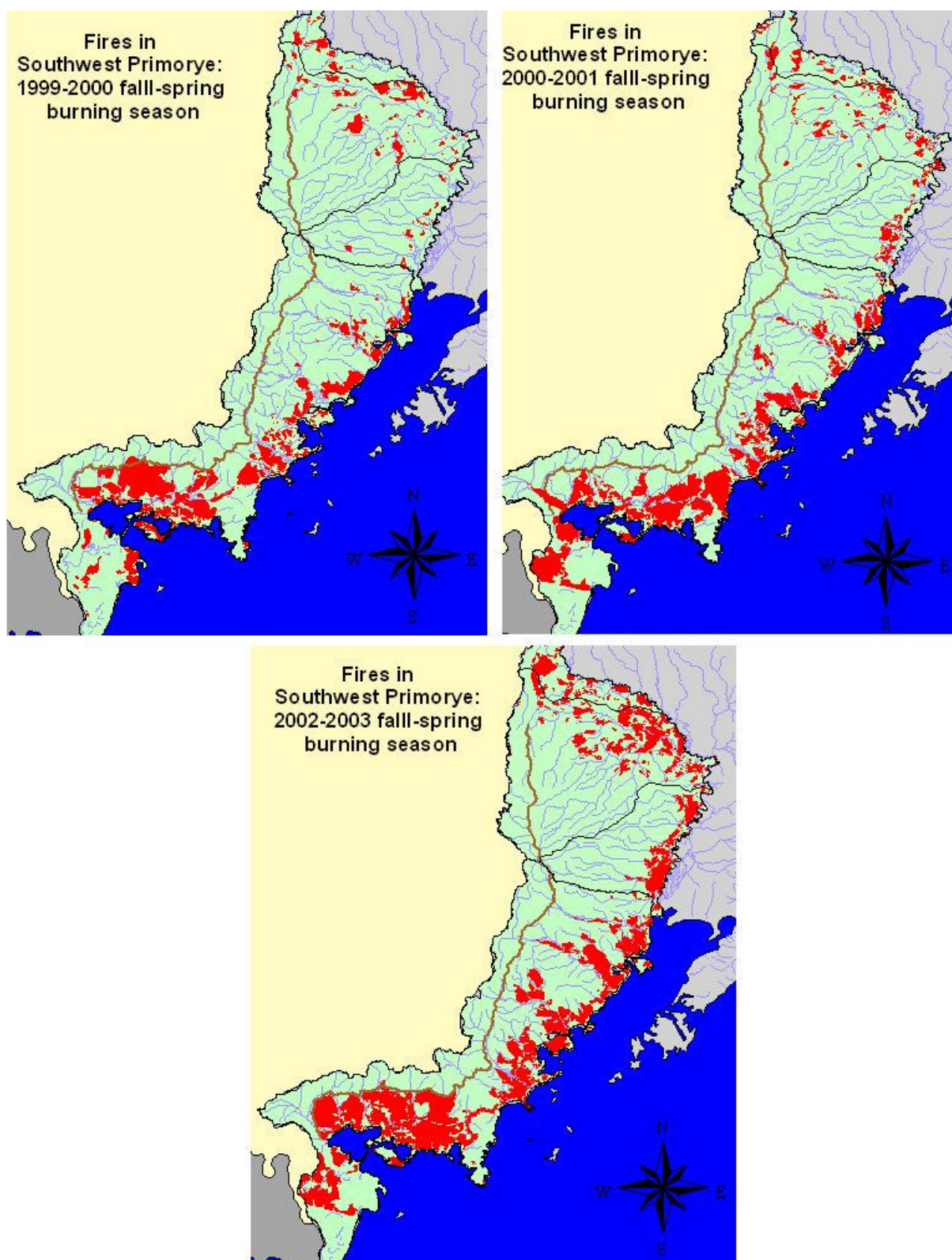
Obtaining satellite images for monitoring fires in Southwest Primorye

We determined that to accurately define the extent of burning in any given year, it is necessary to obtain satellite images in late April or May. Because burning occurs in both the fall and spring, scenes in late spring provide the most accurate picture of the full extent of burning between growing seasons. The extent of burning in the fall and spring varied greatly between years, dependent at least partly on the wetness of the season. Therefore acquiring images, for instance, in late fall, prior to snow fall, would not provide an accurate indication of total area burned, because there appeared to be no relationship between area burned in fall and spring. In late May, green-up begins, and it becomes impossible to detect where burns have occurred the previous year. Therefore, acquisition of good images in the appropriate time frame (late April-early May) is critical to accurately assess the extent of fires.

Unfortunately, in late spring cold air masses over the cold Sea of Japan collide with warming air masses coming off the mainland. Consequently, fog is common, and opportunities for acquiring good images, free of cloud cover, are relatively rare. An additional complication is the fact that Landsat 7, the cheapest and most accessible form of satellite imagery, began taking pictures only in 1999. This fact precludes purchase of the same type of images in earlier years. Therefore, we were forced to search for other types of satellite images that might be available for the short time of each year we were interested in. Ultimately, we were able to secure scenes only for seven of the 10 years, and decided to reject one of the scenes (1993) because of poor quality, and a likely poor estimate of the extent of burning for that year (especially in the north). In summary, we used the following satellite imagery to estimate the extent of fires in Southwest Primorye:



Map 2a-d. Extent of fires in Southwest Primorski Krai during the fall-spring burning seasons, based on interpretation of satellite imagery from late spring for:
a) 1992-1993; b) 1995-1996; c) 1996-1997; d) 1997-1998.



Map 2e-g. Extent of fires in Southwest Primorski Krai during the fall-spring burning seasons, based on interpretation of satellite imagery from late spring for:
e) 1999-2000; f) 2000-2001; g) 2002-2003

1993	? ? -4 satellite RESURS-F2 for 1993 (mapping conducted – see Map 2a – but not included in analysis because of poor quality and poor resolution in determining extent of fires).
1996	TM satellite Landsat5
1997	OPS satellite JERS1 & sensor AVNIR satellite ADEOS for 1997
1998	TM satellite Landsat5
2000	ETM satellite Landsat7
2001	ETM satellite Landsat7
2003	ETM satellite Landsat7

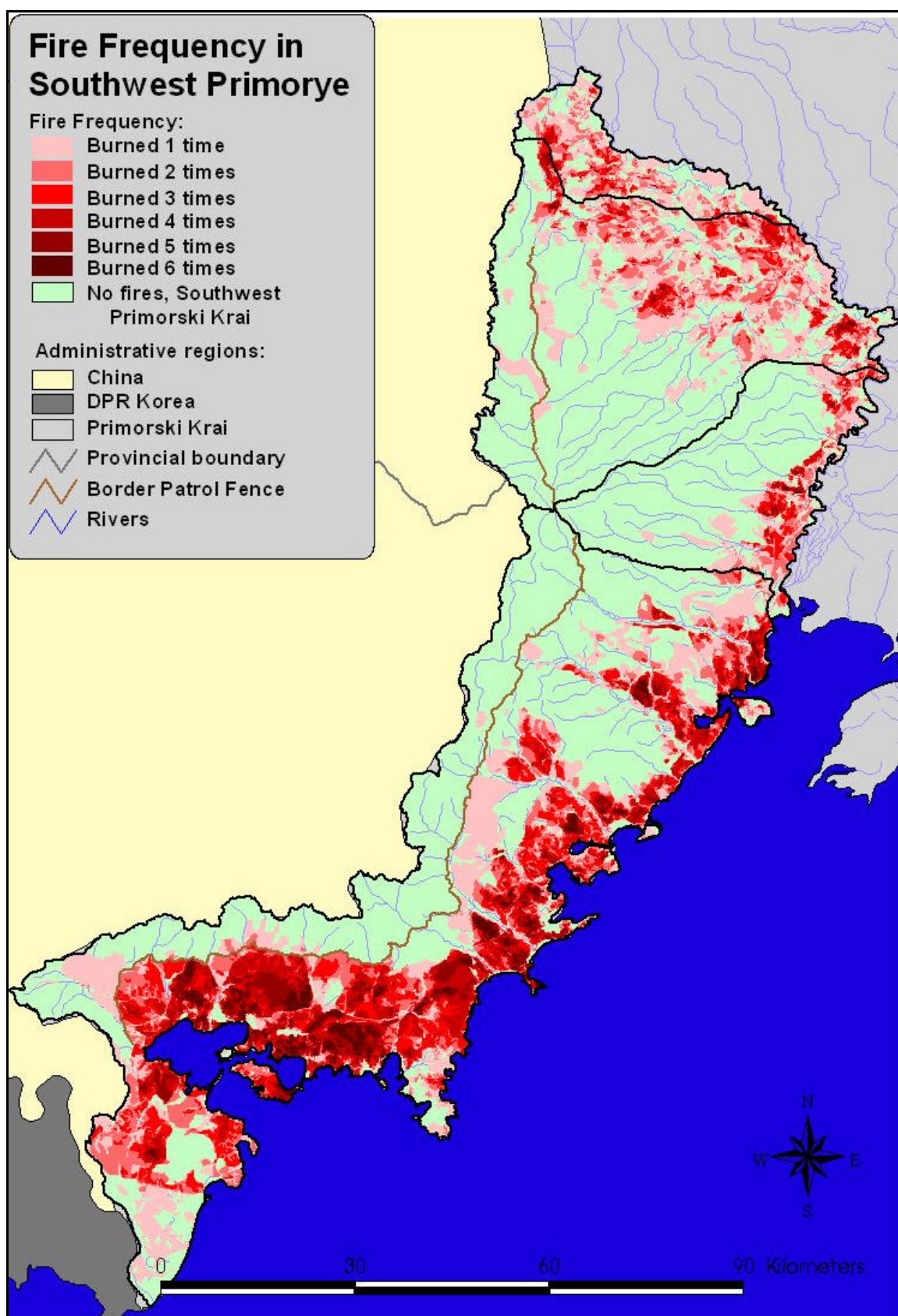
The imagery for 1993 was poor quality, particularly in the north. We have provided an interpretation of fire frequency for this year (Figure 2a), but have not included this year in our calculations because it is likely an underestimate of the extent of fires for that year. Therefore all further discussions are based on the 6 years when good coverages were available, from 1996-2003.

A second problem in surveying Southwest Primorye with satellite imageries was the fact that the flight path of Landsat satellites excludes the southernmost portion of Khasansky Raion. Most of this area is comprised of wetlands that were part of the Khasansky Nature Park and the “Golubiniy Utes” hunting area (managed by the Naval Hunters Society). Because it is not considered significant habitat for tigers or leopards (the focus of our study), this limitation was considered not significant, and we did not feel the extra expense of purchasing a second Landsat image was justifiable. Therefore, we have excluded this southernmost section of Khasan Raion in most analyses.

Characteristics of burned areas

Total area burned and patterns of burning. Total area burned in Southwest Primorski Krai averaged 113,000 ha per year, but varied from 90,000 to over 160,000 ha, representing 12-22% of the total area of the region (Map 2, Figure 1). In total, 3426 km² were burned at least once over the 6 years sampled. Thus 46% of Southwest Primorski Krai burned at least once over the six years studied.

Of the 6 years between 1993 and 2003 where good imagery was available, the largest area burned was in 2003, and the smallest in 2000. Despite the great variation in the amount of land burned, the pattern in terms of which areas were burned was remarkably consistent among years (Map 2a-g). Areas closest to the coast (especially in the southern third of Khasansky Raion), as well as areas in the north comprised of agricultural and hay fields in Oktyabrsky Raion, burned every year. The border patrol fence, and its cleared strip of land, acted as a very effective fire barrier, stopping major fires in nearly every year from burning inside the KSP (between the fence and the Chinese border) and likely prevented many fires from crossing the border into China. Only in 1998 did fires cross the KSP border patrol fence, and the pattern suggests that some of these fires may have started within this patrol zone (Map 2d).



Map 3. Frequency of fires in Southwest Primorski Krai, summed over 6 years for which satellite imagery was available between 1996 and 2003 (southern tip of Khasansky Raion is not available in most images, and fire frequency is underestimated)

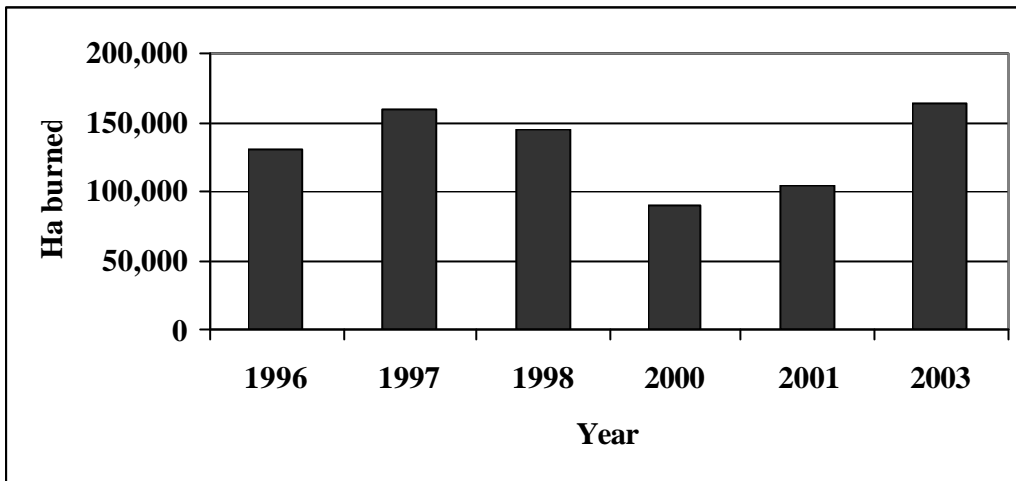


Figure 1. Total number of hectares burned per year in Southwest Primorski Krai, Russian Far East, based on interpretation of satellite imagery from the spring of each year.

Fire frequency. The extent to which particular sites are repeatedly burned can be determined by looking at the total area burned multiple times in Southwest Primorye (Map 3, Figure 1). Only a small percentage of Southwest Primorye burned in all six years (2%) suggesting that while there is a clear general pattern as to which areas are likely to burn (Map 3), predicting the exact locations would be difficult. Nonetheless, areas that burned once had a high probability of burning a second time: of the areas burned, 60% burned more than once, while only 40% burned a single time (Figure 2).

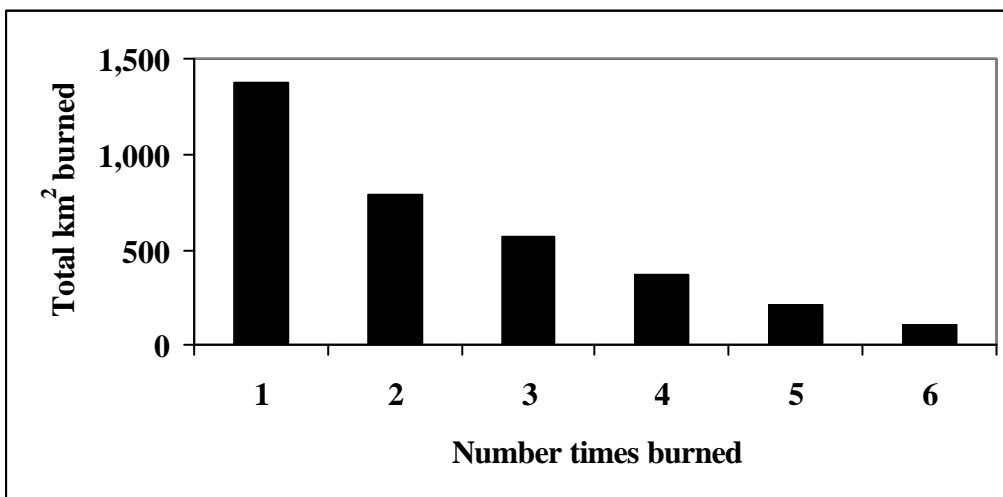


Figure 2. Total area burned, and the frequency (number of times burned) in Southwest Primorski Krai, for the 6 years between 1996 and 2003 for which satellite imagery was available.

Habitat types burned.

For the purposes of this analysis we used the following habitat classification system to assess the frequency of fires in different habitat types:

Deciduous broad-leaved forest – are forest types dominated by Mongolian oak (*Quercus mongolica*), one of the most common forest types in human-disturbed areas.

Deciduous small-leaved forest – are forest types dominated by one of several species of birch, or other narrow-leaved deciduous tree species. As with oak forests, birch forests are most commonly relatively young forests that have had human disturbance in the recent past (e.g. last 40 years).

Deciduous Valley forests – are mixed forests in valley floors that include a variety of species, but dominated by deciduous tree species. Deciduous valley forests are one of the most diverse habitats in the region.

Korean pine forests – are forest types dominated by Korean pine (*Pinus koraiensis*), but can include a wide variety of both deciduous and coniferous species.

Spruce-fir forests – are dominated by some combination of spruce (*Picea* spp.) and fir (*Abies* spp.), including the relatively rare black fir (*Abies holophylla*) found only in southern Primorski Krai. Spruce fir forests are normally associated with higher elevation zones, such as the Borisovskoe Plateau region (Map 4).

Shrub-meadows – are habitats largely without trees, and dominated by some mixture of shrubs and grasses.

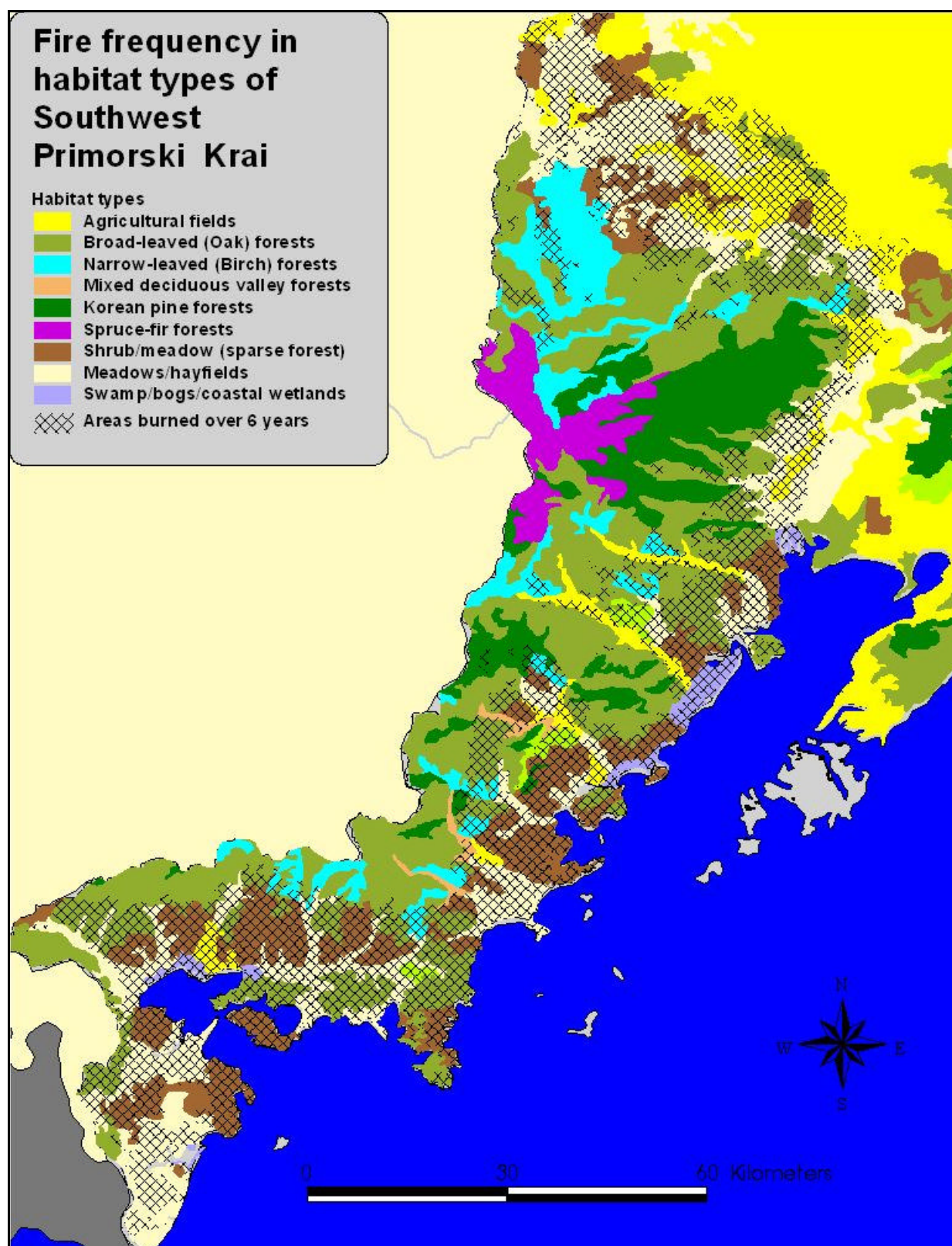
Meadow/hayfields – are treeless regions dominated solely by grasses. Some of these meadows may be regularly mowed to produce hay.

Agricultural fields: open fields that had evidence of plowing and planting in the recent past.

Swamp/coastal wetlands – are wetlands, swamps, bogs, and coastal wetlands characterized by standing water or continuously soggy ground, and wetland vegetation dominated by grasses and sedges.

These habitat types were inferred from interpreting satellite images from recent years. Mapping of these habitat types was conducted in association with habitat mapping of the entire Primorski Krai, and was done at a lower level of resolution (1:500,000) than other coverages presented here. Therefore, accuracy of boundaries, and accuracy in definition of habitat types could be lower. Nonetheless, the general pattern and distribution of habitats appears fairly accurate (Map 4).

Those habitat types most frequently burned were clearly those already impacted by anthropogenic activities (Map 4, Figure 3). Nearly 30% of all shrublands, meadow/hayfields, and wetland meadows burned on a yearly basis. Of the forest types, oak forests were the most severely impacted, with total amount burned ranging from 7-19% for each of the six years, and averaging 11%. Birch forests burned only slightly less often than oak (averaging 8% of total area), and while burning in deciduous valley forests was slightly less common (6%), there was wide variation in the percentage area burned (ranging from less than 1 to 19%). Spruce-fir forests were unaffected by fires in the six years studied, and Korean pine forests generally sustained little impact, with maximum percentage burned (3%) occurring in 1996.



Map 4. Occurrence of fire on different habitat types in Southwest Primorski Krai. Habitat types and fire frequency derived from with satellite imagery from six years, 1996-2003.

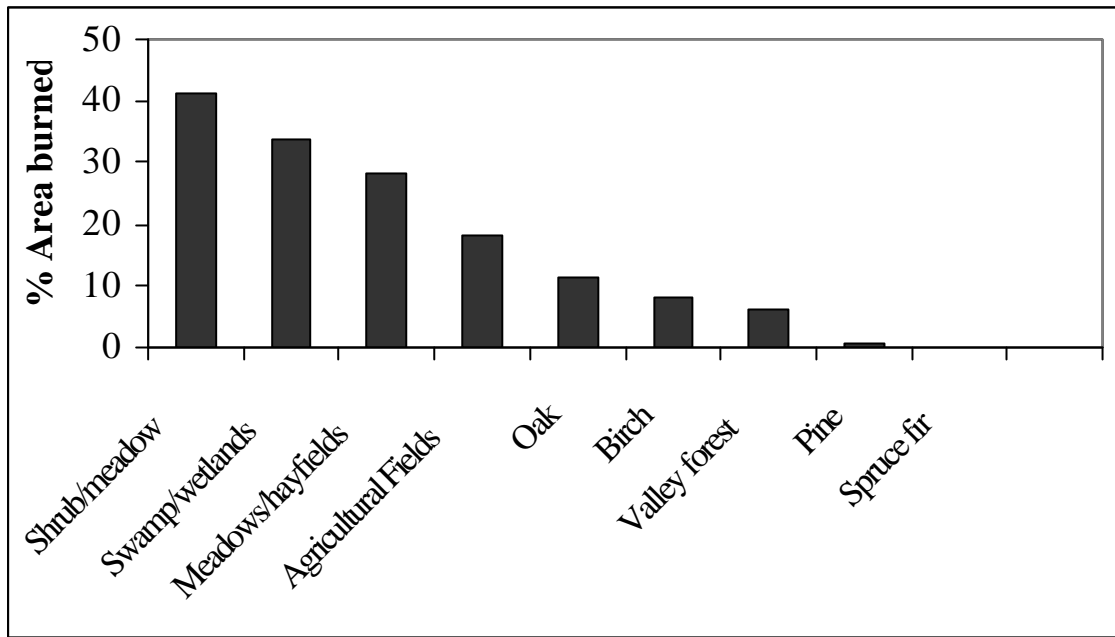


Figure 3. Average percent of different habitat types burned on a yearly basis in Southwest Primorski Krai for six years between 1996 and 2003.

Determining the total area burned at least once during the six years studied probably gives a better indication of the extent of impact incurred by each habitat type during the total study period (Figure 4). The vast majority of shrublands, meadows, and agricultural fields -over 60% - burned at least once in the 6 years observed. Forest habitat types incurred less impact, but 28% of all birch and 34% of all oak forests were burned at least once in Primorski Krai

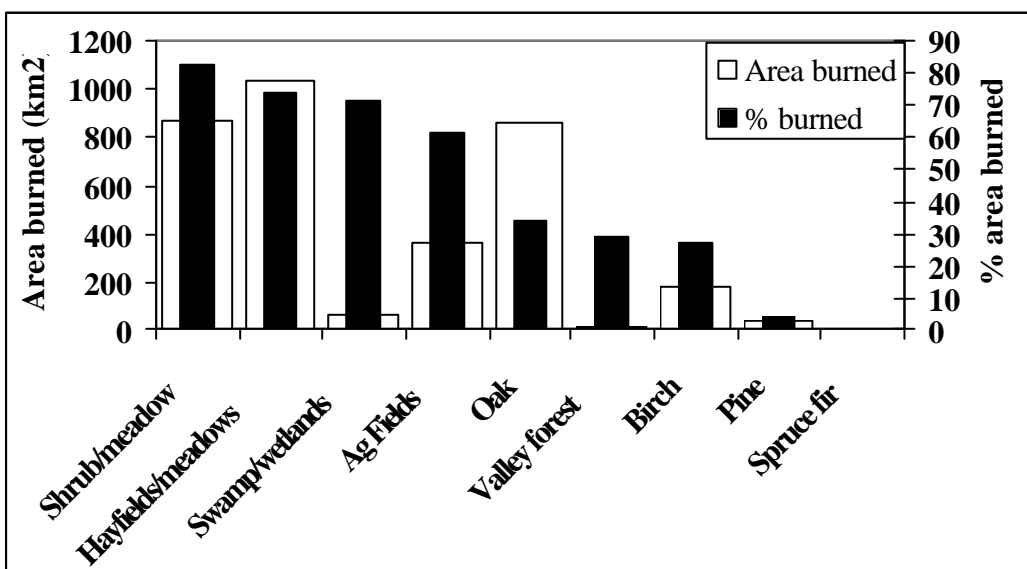
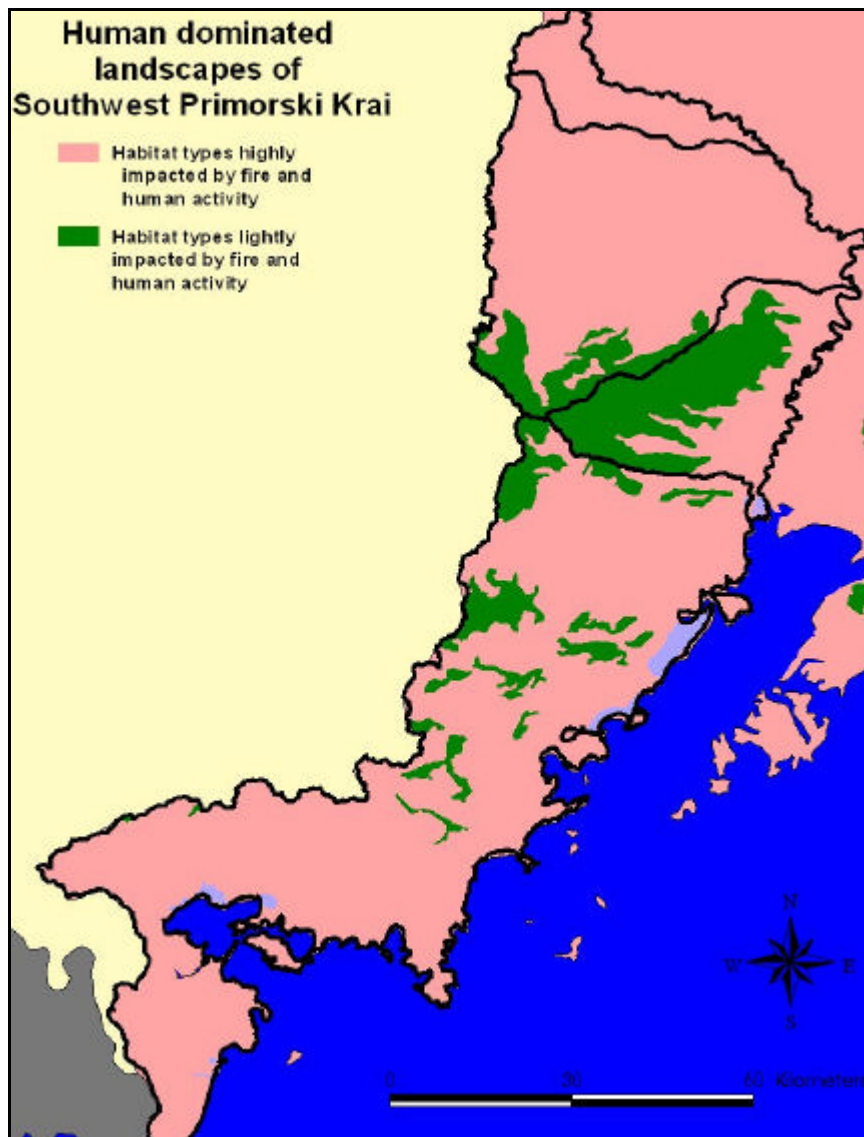


Figure 4. The total area burned (km²), and the percent of each habitat type burned at least once in Southwest Primorski Krai, during 6 years between 1996 and 2003. Total area burned based on interpretation of satellite imagery in spring of each year.

over the six years. Riverine deciduous forests and Korean pine forest were rarely burned (13 and 2%, respectively) and only spruce-fir forests completely escaped fires in all years (Figure

4). Because oak is the dominant forest type in Southwest Primorye (Map 4, Figure 4), the extent of fires in there is particularly significant. These data suggest that the majority of non-forested habitat types are regularly being impacted by fire, and that the dominant forest types (oak and birch forests) are also regularly being impacted by fire.

It should be emphasized that most ground fires seldom killed overstory trees, and therefore fires that burn through forest stands do not destroy the forest in most cases. However, these fires do kill undergrowth, preventing replacement of overstory trees, and preventing natural successional patterns from occurring. Most oak and birch forests in the region are a product



Map 5. Habitat types dominated by some combination of fire and human activity in Southwest Primorski Krai, based on habitat types classified from Landsat-7 imagery.

of early burning or clearing by humans, and therefore are indicative of the extent of burning and human impact over the past 50-100 years. It is clear that shrubfields, meadows, and hayfields are all a product of clearing and burning by humans. Southwest Primorye is one of the wettest areas in all of Russia, and therefore open expanses of grasses are not a natural phenomenon in this region. Looking at the extent of the surviving native forest types (Korean pine and spruce-fir) in Southwest Primorye probably provides an indication of the full extent of human impact over recent historical times in converting forests to non-forest or into stands dominated by either oak or birch. Clearly, with the exception of Korean pine and spruce-fir forests, nearly all other habitat types in the region (except coastal wetlands) have been created due to the influence of humans (Map 5), with fire playing a major role.

Relationship of Fire to Land users and Landowners

Ownership and landuse patterns in relation to fires provide some indications of the extent to which different entities have been impacted by, and are capable of controlling fire on their lands. There are multiple layers of land users in Southwest Primorski Krai, and it is therefore necessary to look at fire impacts on several levels. Because some of the protected areas represent core habitat for leopards and tigers, we begin with a comparison of burns on protected lands and hunting lease lands (the right to manage tracts of land for hunting in Russia has been largely privatized, and leasees are responsible for managing habitat, game species, and hunters on tracts of land allocated to them). Fire can play a key role in structuring vegetation on hunting leases, consequently affecting game animal distribution and abundance. For that reason, lease managers, as well as managers of protected areas should have a high interest in the impact of fire on lands they manage.

Protected areas. Borisovskoe Plateau was the only upland terrestrial protected area that was lightly impacted by fire. On average 14% of both Poltavski and Barsovy Zakazniks (wildlife refuge) burned each year (Table 1, Figure 5). As a zapovednik Kedrovaya Pad is supposed to

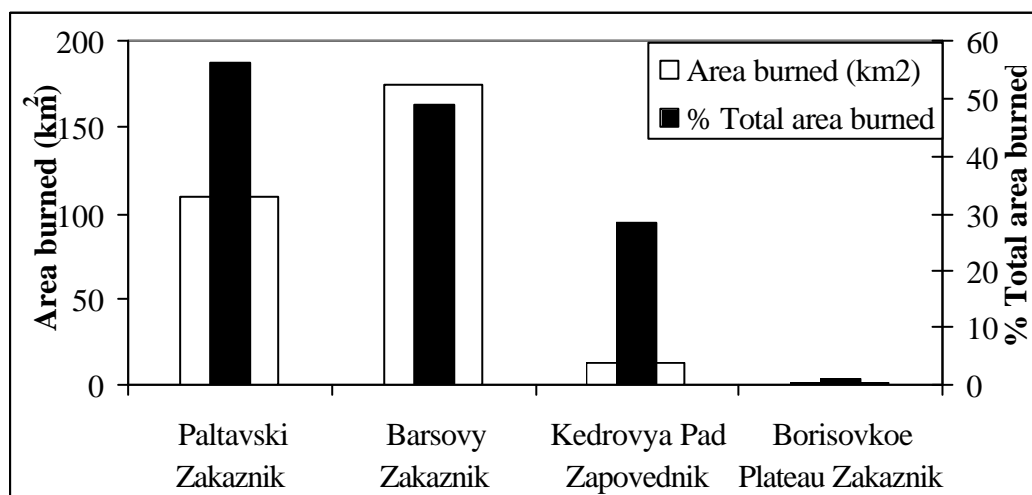
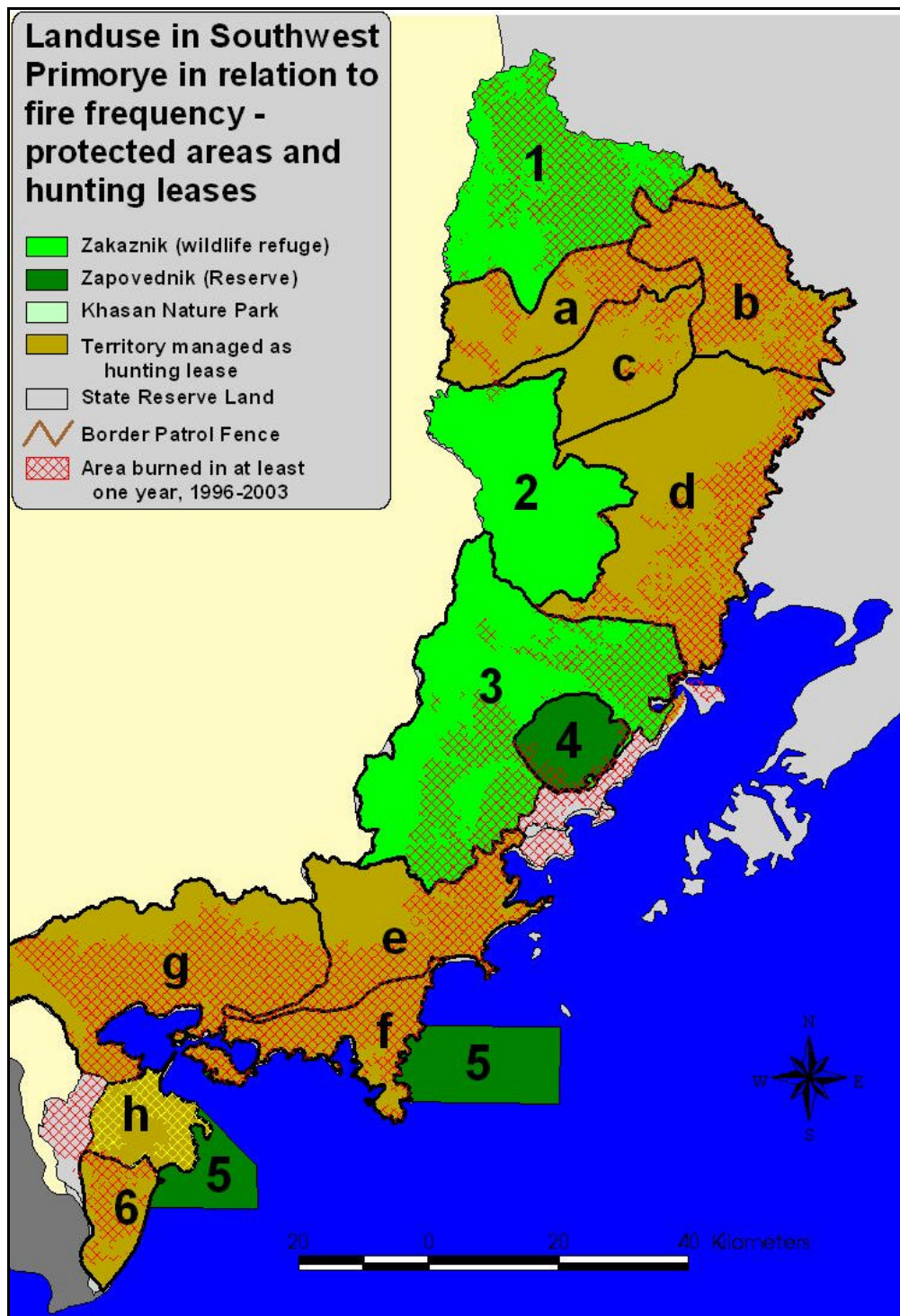


Figure 5. The total area burned (km²), and the percent of territory burned at least once for the 4 protected areas in Southwest Primorski Krai that retain some forest habitat, during 6 years between 1996 and 2003. Total area burned based on interpretation of satellite imagery in spring of each year.

represent a natural community unaffected by human activity, but every year an average 7% of the zapovednik burns. More impressive is the total area impacted over the six years studied: we found that 49 and 56% of Barsovy and Poltavski zakazniks, respectively, burned at least once, and 28% of Kedrovaya Pad burned at least once over the six years. Kedrovaya Pad is impacted along its entire southern border, as well as large portions of the northeast border. Because the total area of Kedrovaya Pad is so small, these border infringements, in total, represent a large percentage (28%) of the total area of the zapovednik. These results suggest that even in what are considered strictly protected areas, fires in Southwest Primorye are likely having severe effects.

Hunting leases. Most hunting leases suffered greater impacts from fire than protected territories (Table 1, Map 6, Figure 6). Not surprisingly, those hunting leases that included large tracts of wetlands (for waterfowl hunting) and open meadows incurred the greatest amount of fires (e.g. Khasansky and Lebedinoe), with 20-47% of their territory burning each year, and 58-88% of their territory burning at least once. Those leases that included large tracts of open meadows and shrublands (e.g. Fauna, Pavlinovski, and Ussuriisky) burned slightly less frequently (except for Ussuriisky, which had one of the highest burning frequencies), but still at least 45% of these hunting leases burned at least once (Figure 6). Even Nezhinskoe, which is dominated by forest cover, had an average 12% of its area burned on an annual basis, and in total had 35% of its area burned at least once. Admittedly, most of the area burned in Nezhinskoe was in their wetlands, but nonetheless these fires creep into forest lands (Map 4). Of all the hunting leases, it could be argued that burning on Fauna lease has perhaps the overall greatest impacts, because not only is the percentage of land burned high, but the total area burned is significantly larger than any other lease (Figure 6).

Table 1. Total area of "upland" terrestrial protected areas and hunting leases in Southwest Primorski Krai, percent area burned during six years between 1996-2003 where satellite imagery was available, and the percent of the total area of each land unit burned at least once in the six years studied..										
			% Area burned							
		Total area (km ²)	1996	1997	1998	2000	2001	2003	Average % area burned/yr	% total area burned at least once
Protected areas										
	Paltavski Zakaznik	110.0	12.4	27.1	9.9	10.0	9.7	18.6	14.6	52.7
	Barsovy Zakaznik	175.1	25.3	7.3	19.1	6.6	9.5	18.4	14.4	41.4
	Kedrovyya Pad Zapovednik	12.2	11.8	0.7	11.3	6.8	4.0	7.0	6.9	21.1
	Borisovkoe Plateau Zakaznik	1.5	0.1	0.0	1.0	0.3	0.0	0.0	0.2	1.4
Hunting leases										
	Khasanski Hunting Organization	302.2	48.2	59.1	54.5	30.5	48.4	40.9	46.9	84.8
	Ussuriski Society of Hunters and Fisherman	505.8	8.1	34.5	18.2	11.2	13.5	32.3	19.6	68.1
	Lebedenoe (Swan) Society for Hunters, Khasan	194.1	22.7	56.5	26.3	23.6	15.9	19.3	27.4	67.2
	Khasanski Raion Society of Hunters and Fisherman (Slavyanski)	529.6	37.4	37.5	29.7	27.6	33.8	31.3	32.9	58.4
	Fauna Society of Hunters and Fisherman	900.9	33.0	27.0	40.1	28.4	19.3	39.5	31.2	62.2
	Pavlinovka Hunting Society	409.3	8.0	19.1	10.5	5.5	4.8	9.9	9.6	38.1
	Neshinskoe Military Hunting Society	1,024.1	7.4	13.0	18.4	4.4	9.2	18.5	11.8	35.3
	Borisovkoe Military Hunting Society	361.7	1.4	12.4	0.4	1.6	1.1	3.4	3.4	17.1



Map 6. Extent of areas burned in relationship to hunting leases and protected areas. Numbers on map refer to following protected areas: 1 = Poltavski Zakaznik; 2 = Borisovskoe Plateau Zakaznik; 3 = Barsovy Federal Zakaznik; 4 = Kedrovaya Pad Zapovednik; 5 = Far Eastern Marine Zapovednik; 6 = Khasan Nature Park. Letters refer to the following hunting leases: a = Pavlinovka Hunting Society; b = Ussuriisky Society of Hunters and Fisherman; c = Borisovskoe Military Hunting Society; d = Nezhinskoe Military Hunting Society; e = Khasansky Raion Society of Hunters and Fisherman (Slavyanka); f = Khasansky Hunting Organization; g = Fauna Society of Hunters and Fisherman; h = Lebedinoe (Swan) Society for Hunters, Khasan.

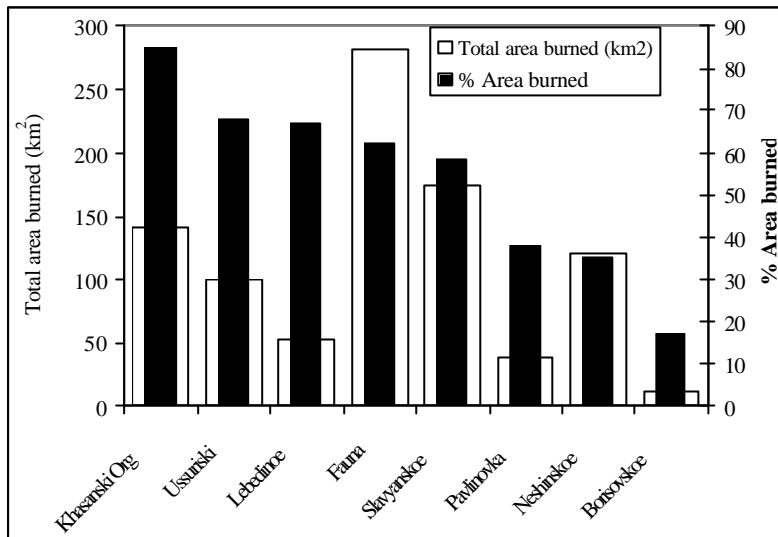


Figure 6. The total area burned (km²), and the percent of territory burned for 9 hunting leases in Southwest Primorski Krai, during 6 years between 1996 and 2003. Total area burned based on interpretation of satellite imagery in spring of each year.

Land ownership. Patterns of fire associated with legal ownership show similar patterns to the analysis of landuse (Map 7, Figure 7). Lands surrounding settlements and agricultural lands burned at very high rates (70-80% of total area burned at least once) (Figure 7). State Reserve lands (land that has not been allocated to any specific owner) also showed very high burning rates (Map 7). Most State Reserve lands lay in close association to human settlements, and are used as agricultural fields, and/or meadows/hayfields. Therefore, it is not surprising that fire is common on these lands. However, State Reserve land between the border patrol fence and the Chinese border incurred very little impact from fire (Map 7).

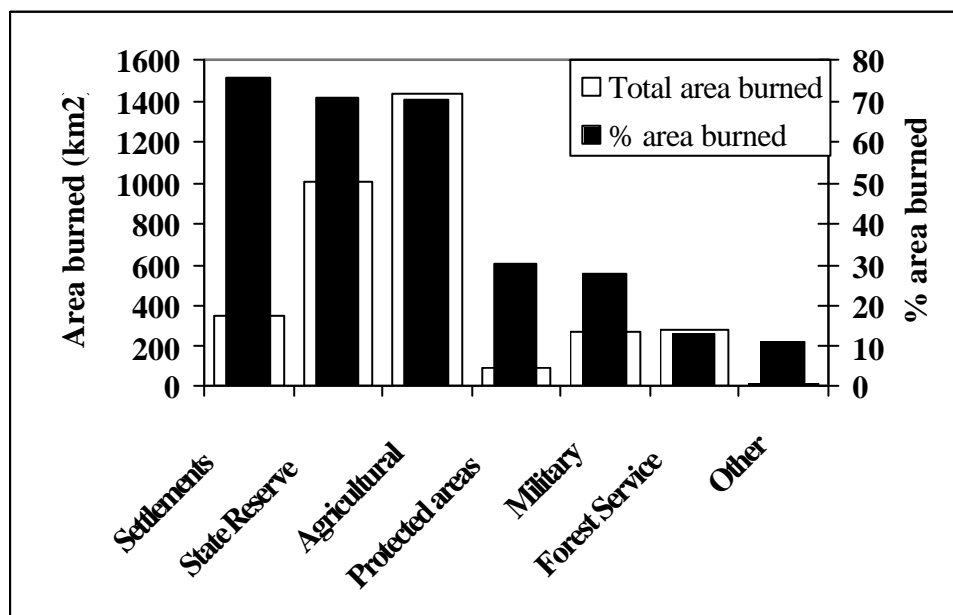


Figure 7. Percentage of land ownership categories burned at least once during six years of analysis (1996-2003) where satellite imagery was available for Southwest Primorski Krai.

Two tracts of land are maintained by the military for training and other activities (Map 7). The southern “polygon” within Barsovy Zakaznik gets burned fairly intensively: approximately 50% of the territory burned at least once in 6 years versus only 4% in the northern polygon.

Forest Service lands (GosLesFund) were burned less frequently (Figure 7) – only 12% of Forest Service lands burned at least once, but nonetheless this represents 280 km² of lands managed by the Forest Service in Southwest Primorye that burned in the study period.

Relationship between Settlements and Fire

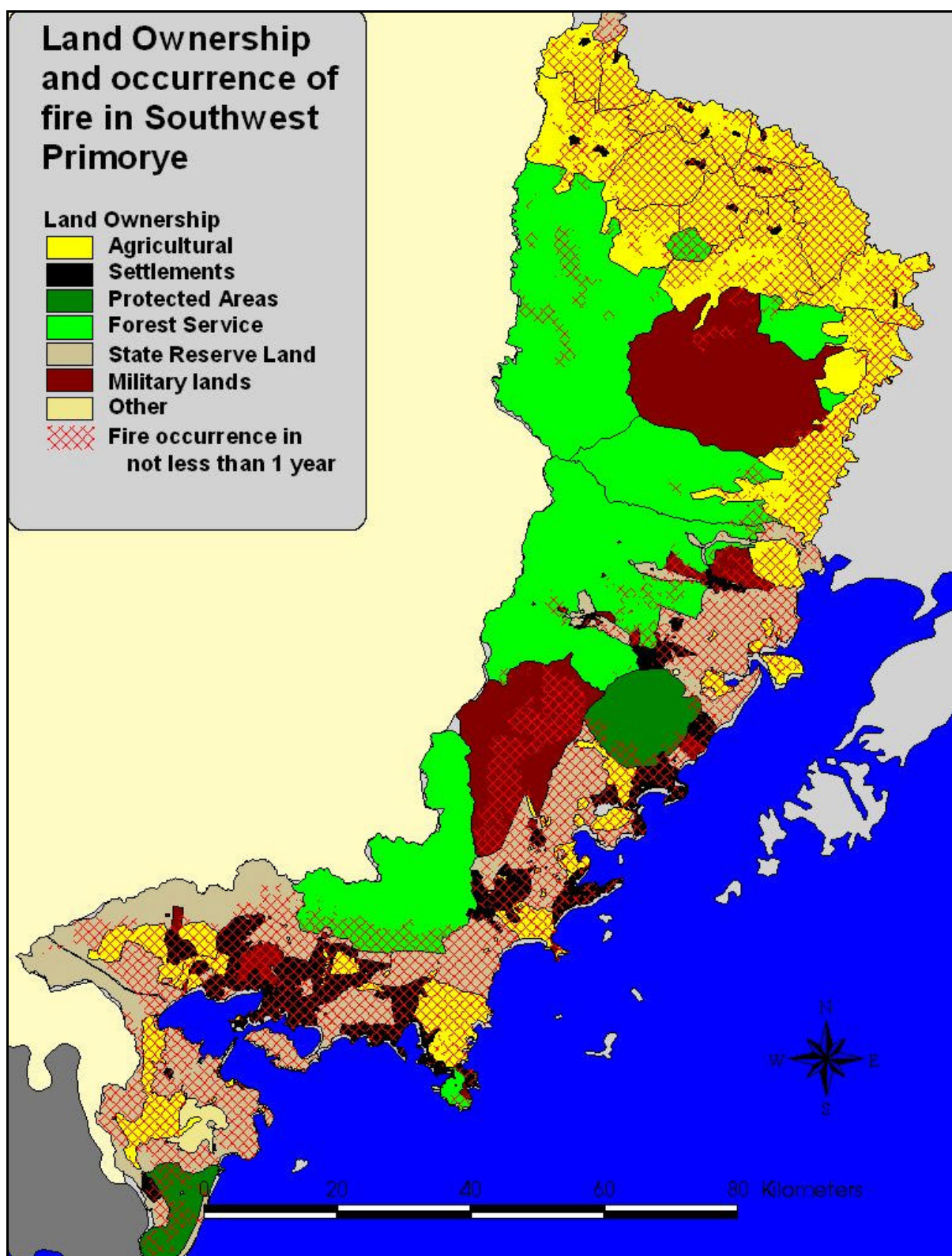
To assess whether there is a relationship between human activity and fires, we looked at the proximity of fires to both settlements and roads. We assume that the majority of fires in Southwest Primorye are set by humans. If this is the case, we would expect most fires to be either in close proximity to settlements, or in close proximity to roads. An additional factor in Southwest Primorye is the railway line. Many observers believe that sparks from passing trains are responsible for many fires. Therefore, we also look at the relationship of fires and the railway system.

To assess the relationship between fires and their proximity to settlements, we categorized lands in Southwest Primorye into the following classes:

1. Inside boundaries of settlements;
2. From settlement boundary to 2 km from settlements;
3. 2 – 5 km from settlements;
4. 5 – 10 km from settlements; and ,
5. greater than 10 km from settlements.

We then determined the percentage of each zone that was burned in each of the six years for which we have data on fires. The results suggest an interesting pattern that is consistent across all 6 years (Map 8, Figure 8).

The overall pattern is summarized in Figure 9. As might be expected, only a very small percentage of land within the borders of villages themselves are burned (i.e., people are careful not to burn down their houses!). However, the land immediately adjacent to settlements (0-2 km from the edge of settlements) received the greatest pressure (Figure 9). At distances greater than 10 km from settlements, the percent area burned becomes very small, essentially the same as that within settlement boundaries (Figure 9). When viewed for the entirety of Southwest Primorye, the pattern of fires closely mirrors the distribution of villages (Map 8), suggesting that the vast majority of fires are indeed human-caused.



Map 7. Occurrence of fire on different landownership types in Southwest Primorski Krai. Fire frequency derived from with satellite imagery from six years, 1996-2003.

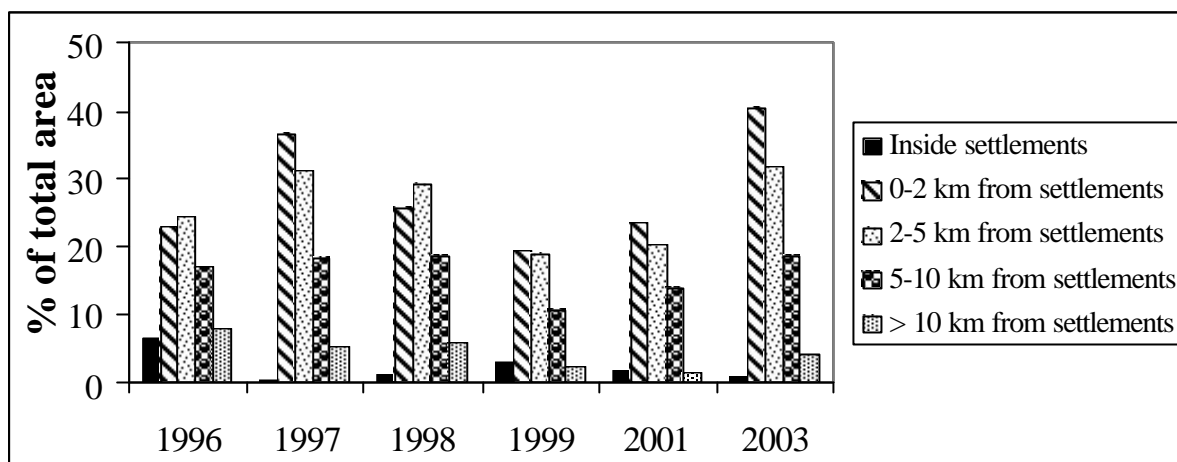


Figure 8. Percent of total land burned within 5 zones, each representing increasing distances from settlements, in Southwest Primorski Krai, for 6 years between 1996 and 2003 when satellite imagery was used to estimate extent of fires.

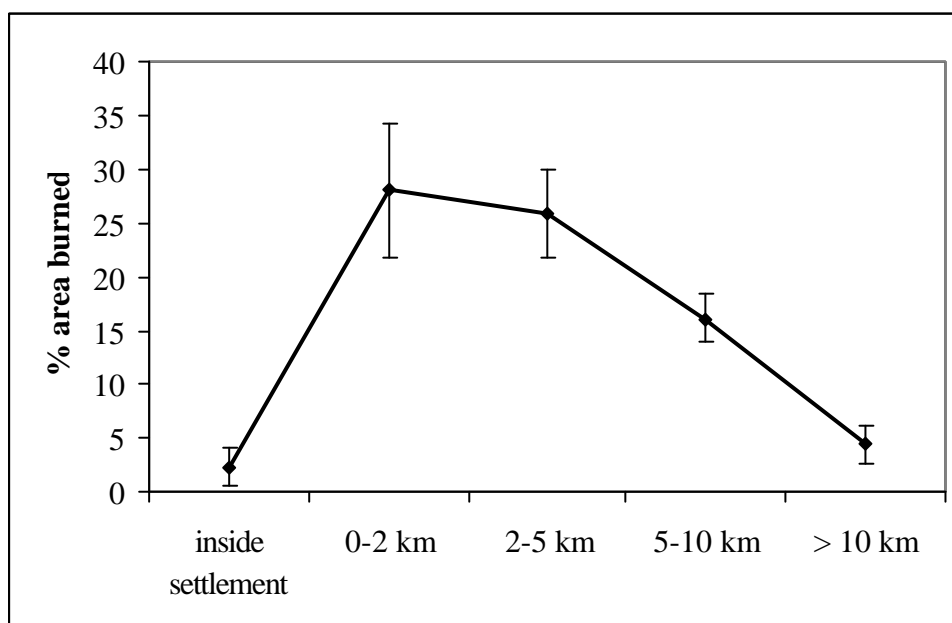
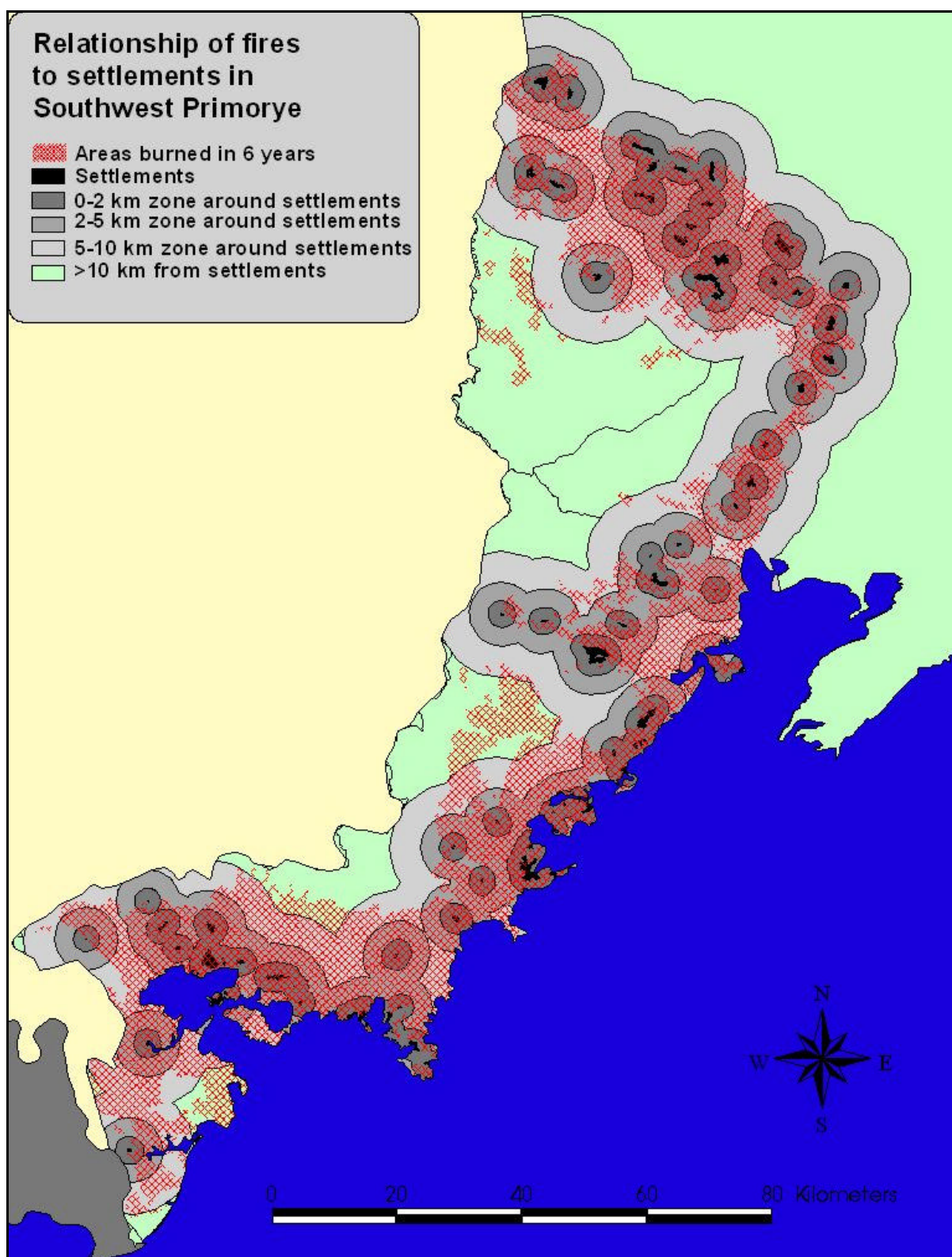


Figure 9. Mean (and 95% confidence interval) percent of area burned at increasing intervals from settlements in Southwest Primorski Krai, based in interpretation of satellite imagery from 6 years, 1996-2003.

Relationship between Roads and Fire

We used a similar approach as with settlements for addressing the relationship of fires and proximity to roads. We categorized all of Southwest Primorski Krai into 5 categories in relation to road proximity:



Map 8. Occurrence of fire in relationship to proximity to settlements in Southwest Primorski Krai. Distribution of fires derived from with satellite imagery from six years, 1996-2003.

< 200 m from a road
 201-500 m from a road
 501 – 1000 m from a road
 1001-2000 m from a road
 > 2000 m from a road.

We then compared the frequency of fires within these 5 categories. The results show a similar pattern as that seen with settlements (Figure 10). The general pattern demonstrated that the closer to a road, the greater the percentage area burned. Areas within 500 m of roads had approximately equal probabilities (about 20%) of burning. Areas slightly further (500-1000) had slightly less area burned (17%), but it was not until distance from road exceeded 1 km that the proportion of area burned began to drop significantly (Figure 10). On average very few areas greater than 2 km from roads burned (less than 4%), and the small confidence interval indicates that this relationship varied little amongst years (Figure 10).

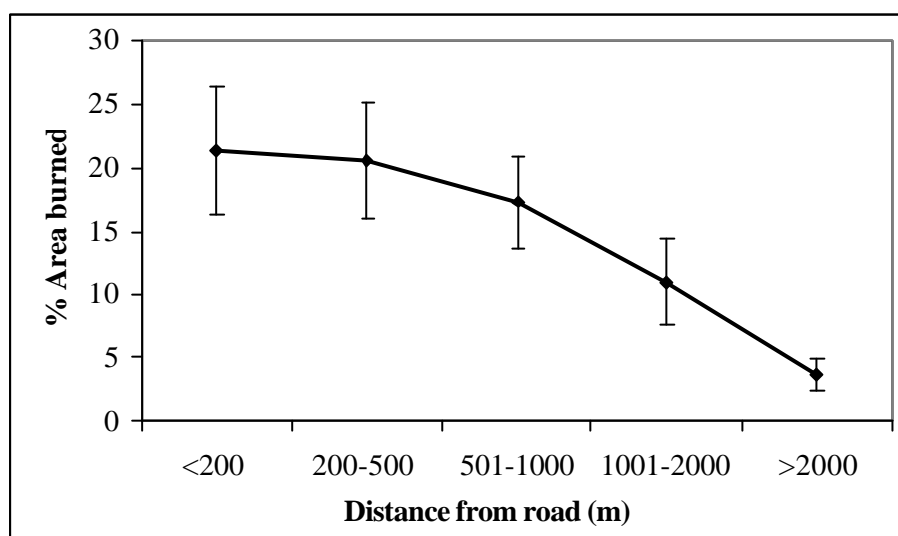
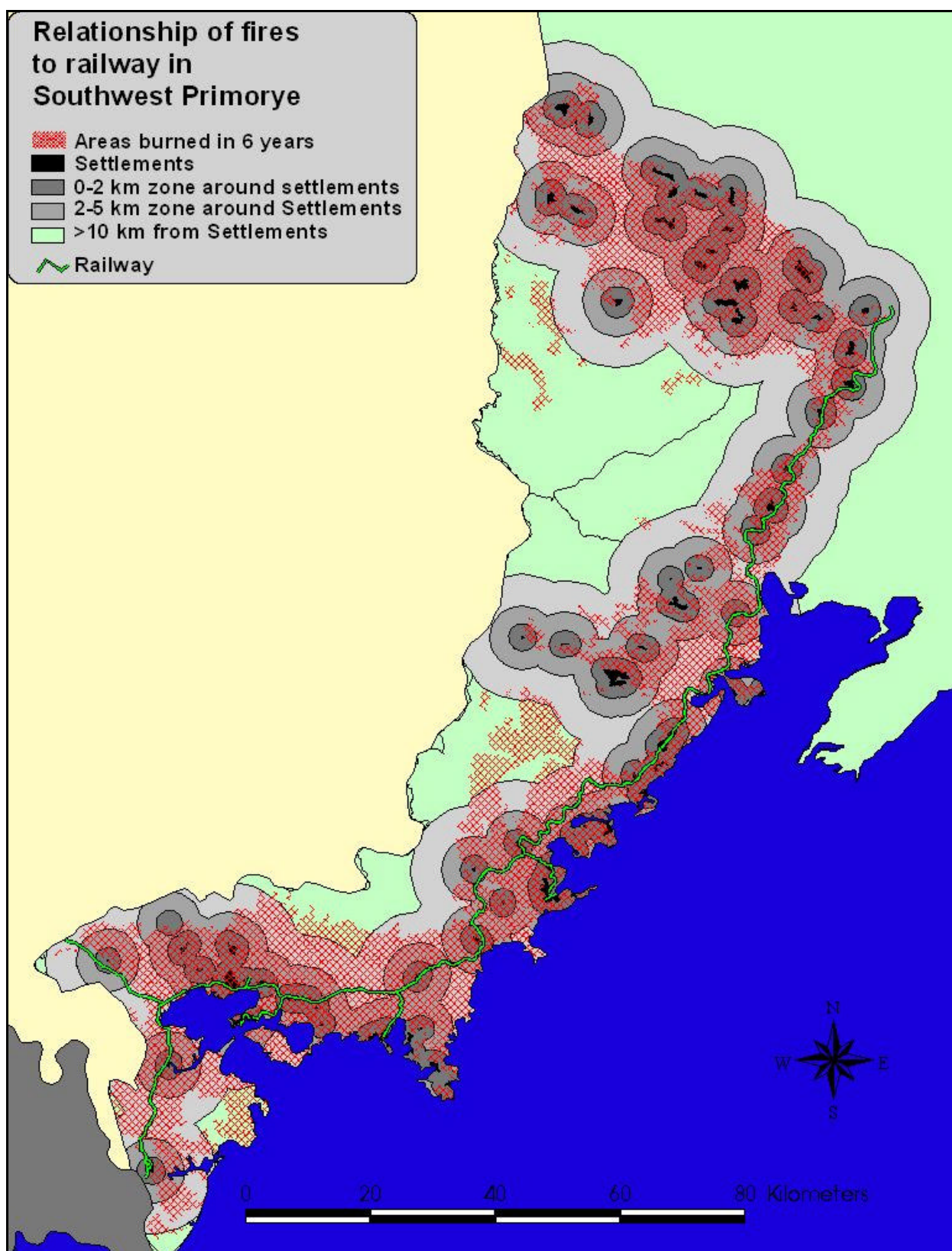


Figure 10. Mean (and 95% confidence interval) percent of area burned at increasing intervals from roads in Southwest Primorski Krai, based on interpretation of satellite imagery from 6 years, 1996-2003.

Relationship between Railroads and Fire

Because there is a concern that sparks from railroad trains may be responsible for starting many fires in Southwest Primorski Krai, we plotted the distribution of fires in relation to railways to visually assess this relationship (Map 9). Unfortunately, the railway lies in the same “beltway” as the collection of settlements along the coast, making it very difficult to determine which of the two may be the more important factor. However, railways obviously play no role in the northern section of Southwest Primorye, which does not have a railway but where nonetheless fires are extremely common. Therefore, although the railway may be responsible in some specific locations for starting fires, we believe the evidence suggests that it is not a major reason for the prevalence of fires in Southwest Primorye. The prevalence of fires close to settlements and roads strongly suggest that humans are intentionally setting the majority of fires, and that sparks from the railway may play a secondary role.



Map 9. The distribution of fires in Southwest Primorski Krai in relationship to railways in the region. Distribution of fires derived from with satellite imagery from six years, 1996-2003.

Burning within the Border Patrol Zone (KSP).

Burning was significantly less common in the border patrol zone than in the rest of Southwest Primorski Krai (Map 3, Figure 11). Although fires did occur there in each of the 6 years studied, the only time a significant portion of the KSP zone burned was in 1998, when 92 km², or approximately 7% of the area burned. In all other years, less than 13 km² burned, representing no more than 1% of the total area (Figure 11). These results suggest that the KSP border patrol zone, with the wide strip of cleared land, acts as a very effective barrier to fire. It also demonstrates that the majority of fires originate to the east of the border patrol fence, and burn westward towards the fence. Very few fires appear to originate within the KSP zone. Because the majority of fires are no doubt human-caused, it is not surprising that this border patrol zone, where few people are allowed to enter, is largely free of fires. Because some people do gain access to the patrol zone, it is inappropriate to consider all fires there to be naturally caused, but nonetheless the differences between inside and outside the patrol zone do provide an indication of the sweeping impact of human-caused fires east of the patrol fence.

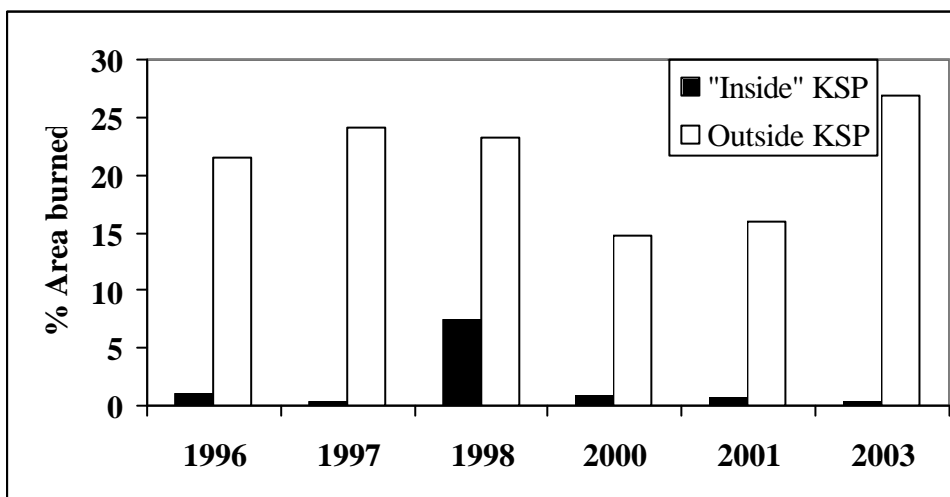
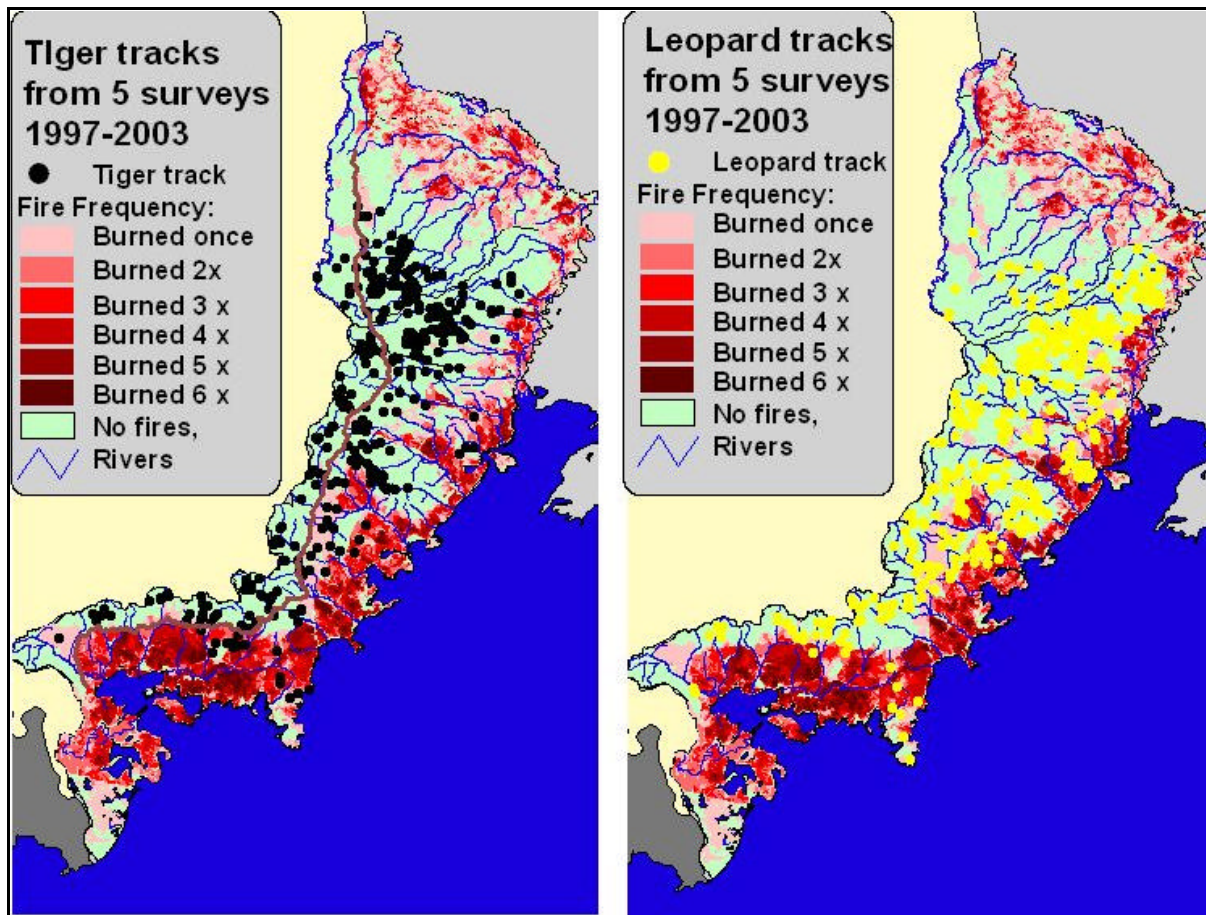


Figure 11. Percent of the border patrol territory (KSP) territory burned “inside” the patrol fence (i.e., between the fence and the Chinese border) and outside (from the patrol fence eastward).

Relationship between Leopard, Tigers, and Fires

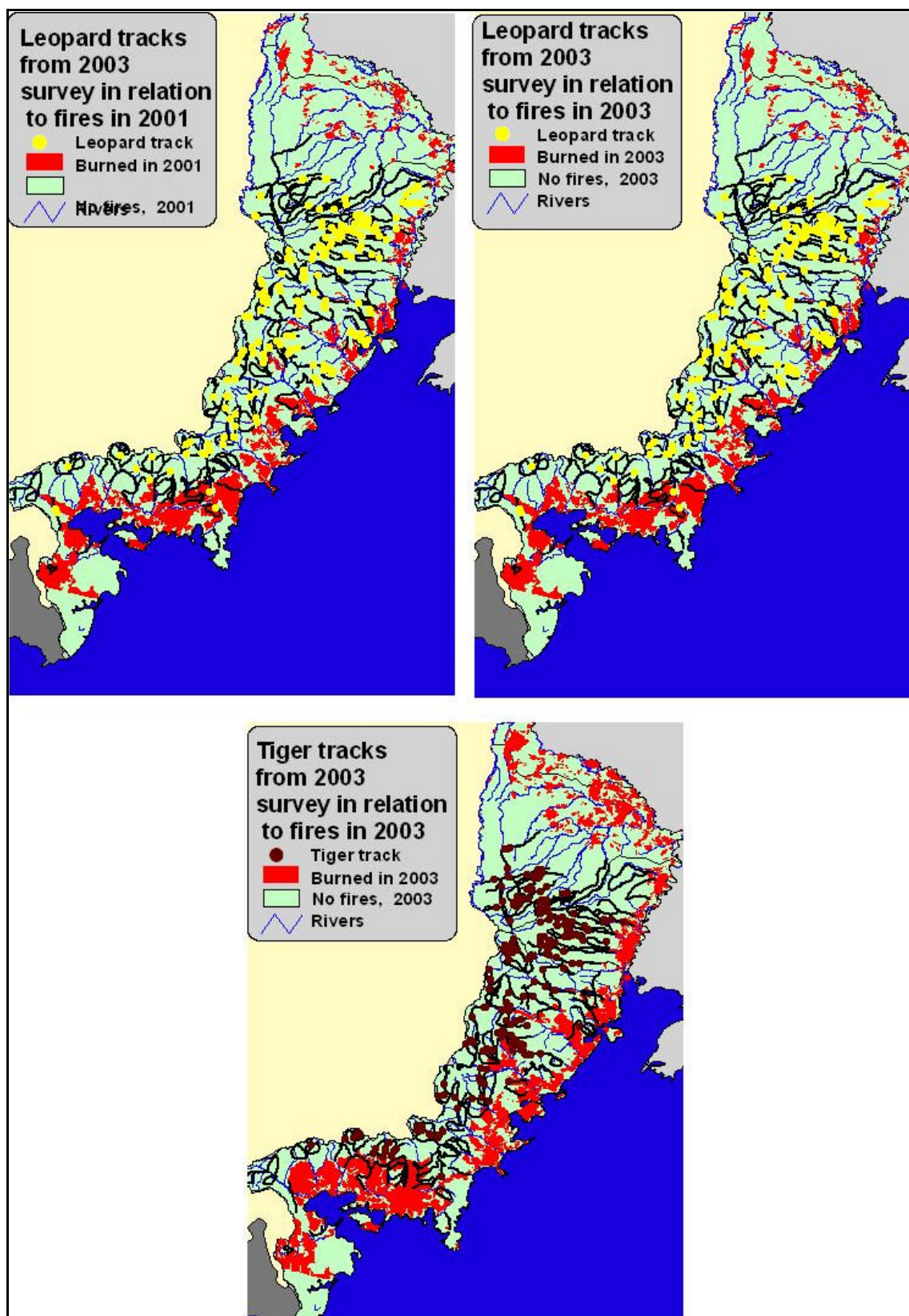
We can compare the distribution of fires in Southwest Primorye to distribution of leopards and tigers using data from 5 surveys that have been conducted in the same general time frame (1997-2003). From 5 surveys we have records of 467 tracks of leopards and 360 tracks of tigers in Southwest Primorski Krai. Only 101 leopard tracks (< 22%) were recorded within areas that had burned at least once, and only 12% of tiger tracks were reported in areas burned, despite the fact that burned areas covered 46% of Southwest Primorye (Map 10). Hence, the overall pattern of tiger and leopard distribution suggests that both species avoid areas that burn, and that tigers may avoid burnt areas even more than leopards (12 versus 22% occurrence on burnt areas).



Map 10. Distribution of tracks of tigers and leopards in Southwest Primorski Krai, based on 5 surveys conducted between 1997 and 2003, in comparison to the distribution of fires that occurred in 6 of those years.

To conduct a more rigorous analyses we concentrated only on data from the last full survey in 2003 (Pikunov 2003). Distribution of leopards and tigers in this year are at least partly impacted by fires reported in all previous 6 years, and thus provide a gauge of how fires may be affecting distribution of these animals. However, we focused attention on the most recent years when significant fires occurred (2003 and 2001). Because fire provides a flush of nutrients into the soil, we hypothesized that perhaps ungulates, primary prey for both species, may be attracted to areas that have recently burned to obtain more nutritious forage, and consequently, tigers and leopards may make greater use of such areas.

Because the distribution of tracks reported during surveys is largely dependent on where fieldworkers look for tracks, it is necessary to consider how many tracks would be expected in burns based on the ratio of survey routes inside versus outside burns. Therefore, to accurately determine whether leopards and tigers are avoiding or attracted to areas that burn, we compared the expected number of tracks in and outside burns based on the effort placed on searching inside and outside burned areas. Map 11 shows routes and tracks of tigers and leopards, and fires.



Map 11. Distribution of tracks of tigers and leopards in Southwest Primorski Krai based on a 2003 winter survey, location of survey routes covered during that survey, and their relationship to fires of 2001 and 2003.

We estimated expected number of tracks found in fires based on the proportion of survey routes that went through burns (assuming tracks are randomly distributed in relation to burns, the proportion of tracks in burns should be the same as the proportion of kilometres of survey routes in burns), and conducted a multinomial test to compare observed and expected number of tracks in burns. Results using fire data from both 2003 and 2001 were similar: in both cases leopards used burns less frequently than expected (for 2003: $\chi^2 = 13.1$, $df = 1$, $p = 0.0003$; for 2001 $\chi^2 = 5.4$, $df = 1$, $p = 0.02$) (Map 11a-b). Using the same data for tigers, we found an even stronger trend towards avoidance of burned areas, based on expected and observed proportions of tracks in burned areas (for 2003: $\chi^2 = 17.78$, $df = 1$, $p = 0.00001$) (Map 11c).

DISCUSSION

Across Southwest Primorski Krai there are extensive areas that were formerly forested that now exist as shrublands, grasslands, or agricultural fields (many of which are not in use) (Map 1). The available evidence suggests that fire is a major agent that has been converting forest lands into open shrublands and fields, probably for decades. The vast majority of fires in Southwest Primorye are ground fires that destroy dead and standing materials (standing dead grasses, leaf litter) in grasslands, and are relatively harmless in that context. However, as these fires creep into forest lands, the impact changes significantly.

First, the impact of ground fires in forest lands is dependent on the species of trees present. While oak is fairly resistant to fire, other species, such as Korean pine, are relatively intolerant. Therefore, damage to saplings and young trees, as well as overstory trees, is partially dependent on the species present. Oak persists across much of Southwest Primorye largely because it is fairly fire resistant.

However, even oak trees are susceptible to repeated fires. Although such grounds fires seldom damage large overstory trees directly, repeated fires dry soils, increasing stress on trees dependent on moist soils. Damage to bark of trees provides access for a variety of pests and diseases, increasing the probability of death of overstory trees. Those trees that do die in fire-related causes increase the amount of fuel material on the forest floor, increasing the intensity of fires that later pass through. Opening of the forest canopy accelerates the process of drying soils, and increases the fuel load through increased growth of grasses. Although these impacts may not be great, repeated burnings of the frequency which occurs in Southwest Primorye greatly increases the probability of death of overstory trees, and likely accelerates the process of habitat conversion.

The impact to the understory by ground fires is significantly more dramatic because ground fires do damage, and often kill shrubs and undergrowth saplings. As these fires repeatedly occur over many years, they prevent understory trees from growing, creating a “park-like” forest with a mature overstory, and only grasses and herbaceous plants in the understory. Some percentage of trees will be killed due to fires (drying of soils, and disease and pests associated with fire all having an impact), but in most instances the mature canopy trees begin to die out naturally. However, with no replacement by understory trees, the land is slowly converted from forest lands to grasslands. Once these meadows and shrublands are created, fires are frequent enough to insure that recovery into a forest stand is extremely unlikely to happen. Although the total area converted is immeasurable on a yearly basis, the

impact across Southwest Primorye is obvious and significant. This impact is particularly important for a number of reasons:

many consider this region to be the biologically richest area in all of Russia. It retains a unique complex of floral and faunal species that occur nowhere else in Russia, and because of intense human pressures in nearby China and DPRK Korea, there are no adequate representations of this ecosystem type anywhere in the world except in Southwest Primorye. The biological wealth of the Southwest Primorye is in its forests, which are slowly being destroyed.

Along with a host of many other species, both tigers, leopards, and their prey rely on forest habitat. For the Far Eastern leopard, the situation is particularly dire because Southwest Primorski represents the last habitat patch where this subspecies occurs. Loss of habitat due to burning therefore represents a significant threat that will, if left unchecked, eventually destroy enough habitat to push the leopard population towards extinction.

In neighboring Jilin Province, China, great attention is placed on fire suppression because timber production, along with a host of other uses of the forest ecosystem (non-timber forest product production, forage for domestic animals, and food for locals) is dependent on a healthy forest ecosystem. Suppression of fire in this region of China is religiously practiced, and they view Russia as a source of fires, and a real threat to their standing forests.

Loss of forest habitat also represents a lost source of revenue that could be derived from both timber and non-timber resources. Loss of forests will also impact fisheries (by increasing water temperature) and decrease the potential of the land to moderate the effects of floods.



Photo 1. Ground fires such as this prevent regeneration of trees, creating a “park-like” forest with little or no understory. As adult trees die out, the forest is converted to grasslands.

We believe that historically fires have been responsible for conversion of a large percentage of Southwest Primorski Krai from forests into open shrublands and meadows. Continued burning of these meadows and shrublands will prevent forests from ever regenerating in those areas, and the “creepage” of fires into forest lands leads to the slow but steady destruction of even more forest lands. As forests are destroyed, the amount of habitat available to Far Eastern leopards decreases. Loss of habitat through continued burning represents a major threat to the last population of Far Eastern leopards. Although the rate

at which forests are being lost is difficult to estimate, it is clear that available habitat is diminishing, pushing the leopard ever closer to extinction.

Unfortunately it is impossible to determine whether the rate of burning has increased or decreased in recent times. Satellite imagery is not available far enough back to determine whether there has been a change in rates. Over the six years that were monitoring, there is no clear trend suggesting a change in rates. Although fire suppression efforts have increased in the past few years, there was an increase in the amount of lands burned from 2000 to 2003, suggesting that fire suppression efforts were as yet not making a difference. However, interpretation is difficult: the extent of fires is probably largely dependent on rainfall levels in the fall, snowpack in winter, longevity of the winter (how long snow remains on the ground), and rainfall in the spring. These factors have not yet been modelled, but it would probably be useful to include weather data in analyses if monitoring of fires continues to determine if it is possible to predict the extent of burning based on weather variables.



Photo 2. Repeated fires have converted this area from forest to open parklands. Fires may kill the last trees, or they may die out from other natural causes, leading to completion of the process of conversion from forest to grassland.

RECOMMENDED ACTIONS

Because the majority of fires in Southwest Primorye are man-caused, it is very feasible to change the pattern of fires, reduce the impact of fires, and initiate recovery of forest lands in this region. We believe that six major steps need to be taken to reverse the present situation:

- 1. Conduct a survey in Southwest Primorye to determine more precisely who sets fires and why, and to determine public opinion towards fires.*
- 2. Based on the results of the public survey, initiate a mass media campaign to increase public awareness and reduce the amount of land burned on a yearly basis . We believe that public education could be a key tool in reshaping behaviour of people in Southwest Primorye.*

3. *Improve fire-fighting capacity in Southwest Primorski Krai by improving cooperation between Forest Service, Hunting Department, Hunting lease managers, and Raion officials. Development of a strategic approach to fire fighting that increases effectiveness of efforts will be vital.*
4. *Provide necessary equipment to a re-organized team of fire fighters to insure that supplies are available. However, provision of equipment should be based on development of a strategic cooperative plan that includes creation of fire breaks in key areas.*
5. *Enlist the assistance of local police and judicial branches to arrest and prosecute arsonists.*
6. *Identify 2-3 areas to initiate intensive fire suppression efforts, and simultaneously initiate forest restoration efforts. These areas should act as “model restoration sites” and demonstrate that it is possible to restore healthy forests to this region.*

We believe it is possible to reverse the present trends and actually increase forest cover in Southwest Primorski Krai. To do so will require significant effort, but that effort is essential to save the Far Eastern leopard and the forests that it depends upon. Additionally, we believe it is to the advantage of the Krai and Raion to support such initiatives, as the present situation also destroys economic potential of the region, including harvest of forest products as well as ecotourism potential. Southwest Primorye is acquiring international recognition as home of the last Far Eastern leopards, as well as a biodiversity hotspot. Eventually, this will be a source of both pride and revenue for Russia that should not be wasted.