A MONITORING PROGRAM FOR THE AMUR TIGER

SEVENTH-YEAR REPORT: 2003-2004

In accordance with the Russian National Strategy for Tiger Conservation

A cooperative project conducted by representatives of:

Wildlife Conservation Society
All Russia Research Institute of Wildlife Management, Hunting, and Farming
Institute of Geography, Far Eastern Branch of the Russian Academy of Sciences
Institute of Biology and Soils, Far Eastern Branch of the Russian Academy of Sciences
Sikhote-Alin State Biosphere Zapovednik
Lazovski State Zapovednik
Ussuriski Zapovednik
Botchinski Zapovednik
Bolshe-Khekhtsirski Zapovednik
Institute for Sustainable Use of Renewable Resources
World Wide Fund for Nature

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A MONITORING PROGRAM FOR THE AMUR TIGER

SEVENTH-YEAR REPORT: 2003-2004 WINTER

Executive Summary

Standardized survey techniques, agreed upon all collaborating biologists and scientific institutions, have been used since the 1997-1998 winter season to monitor the status of Amur tigers in the Russian Far East. These methods, and their accuracy in detecting change in numbers of tigers, are detailed in Sections 3.

The Amur Tiger Monitoring Program includes 16 monitoring units, totaling 23,555 km^2 (approximately 15-18% of suitable tiger habitat) which are surveyed to assess changes in tiger numbers using relative and absolute indicators of tiger abundance, cub production, and relative ungulate densities. A total of 246 survey routes are sampled twice each winter, representing 6114 km traversed in total.

Presently, indicators of tiger abundance suggest that tiger numbers may be declining. While one in of the three indicators (track density), showed a slight increase in 2004, overall the percentage of routes with tiger tracks has declined, as has the total number of tigers counted, which reached a 7-year low in the 2003-2004 winter Figure 1.

Cub production continues to be an area of concern. Although the total number of cubs produced in 2003-2004 on all sites combined (23) is very close to the 7-year average (23.7) (Figure 3), the number of litters being produced has decreased from earlier years (Figure 4). Results over the first six years suggested that fewer and fewer monitoring sites are producing cubs; 61% of the cubs reported over the 6 years of monitoring have been produced on 5 sites (31% of sites), and there was a trend towards fewer and fewer sites producing cubs. However, this trend was fortunately reversed in 2004, when 11 of 16 sites (69%) produced cubs. Further increases in litter size are unlikely, and therefore continued decline in cub production on many sites would suggest that recruitment in the future may not be able to compensate for total mortality, in which case we would anticipate a further decline in tiger numbers.

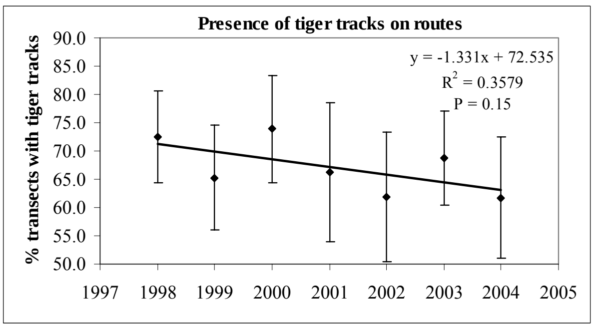


Figure 1. Percentage of routes where no tiger tracks were reported for all 16 sites of the Amur Tiger Monitoring Program, from the 1997-1998 winter through 2003-2004 winter season.

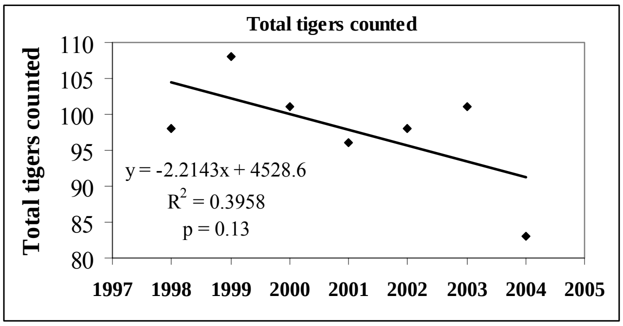


Figure 2 Total number of tigers counted for all 16 sites of the Amur Tiger Monitoring Program, from the 1997-1998 winter through 2003-2004 winter season.

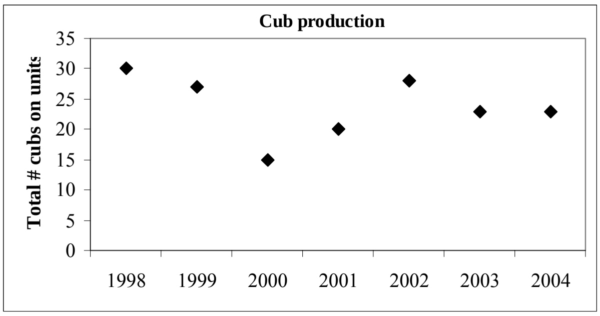


Figure 3. Total cub production for the 7 winter seasons, 1997-1998 through 2003-2004, on all 16 units combined for the Amur Tiger Monitoring Program.

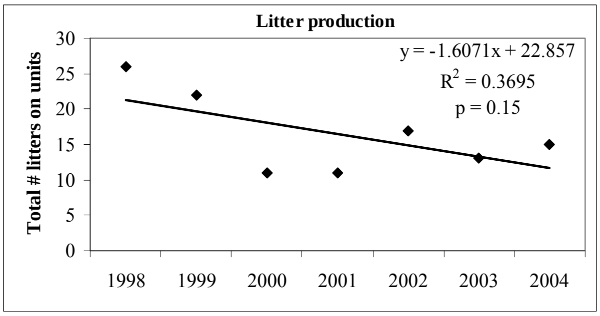


Figure 4. Litter production (total number of litters produced) for the 7 winter seasons, 1997-1998 through 2003-2004, on all 16 units combined for the Amur Tiger Monitoring Program.

When averaged across all 16 monitoring sites, track density indices of ungulate abundance suggest no major changes in overall densities, but this type of generalization obscures the dynamic situations that are occurring at the local level. Red deer densities are declining significantly in 4 of 16 monitoring units, wild boar numbers are decreasing in four units, and increasing in another four, and sika numbers appear to be declining generally across southern Primorye.

Sikhote-Alin Zapovednik and neighboring Terney Hunting Lease both have strong indications that tiger numbers are decreasing as well as wild boar and red deer. The cause for this decline is unclear, but special attention needs to be focused on this region to reverse these trends. Investigations should begin to determine the causes for these decreases, and appropriate actions should be taken.

Ussuriski Zapovednik and neighboring Ussuriski Raion also are areas of concern. Two of three indicators suggest that tiger numbers may be decreasing in the Zapovednik, and wild boar, sika deer and roe deer appear to be decreasing in one or both sites. Ussuriski Zapovednik traditionally has one of the highest tiger densities reported anywhere in the Russian Far East, but it is also one of the closest sites to major centers of human development (with the cities of Ussurisk and Vladivostok within easy driving distance). Therefore changes in the status of tigers and their prey here are of great concern.

Six of the 16 monitoring sites showed signs that tiger numbers are decreasing, 7 appeared to have stable numbers of tigers, and only 3 had indications that tigers may be increasing. Collectively weighing these indications, the results suggest that the Amur tiger population has been slowly decreasing over the 7 years of the Amur Tiger Monitoring Program (Figure 11).

To address this situation, and attempt to recover tiger numbers, conservation actions need to be taken to achieve two goals: 1) ensure that the death rate of tigers does not exceed the birth rate; and, 2) ensure that sufficient habitat exists to contain a viable population of tigers. Although these goals are simple to state, achievement of these conditions is extremely difficult. Tigers require vast landscapes, and must coexist with humans in the majority of suitable habitat. Conflict between tigers and humans is inevitable, both at its most fundamental level (encounters between humans and tigers in the forest) and at larger, socioeconomic scales (competition for

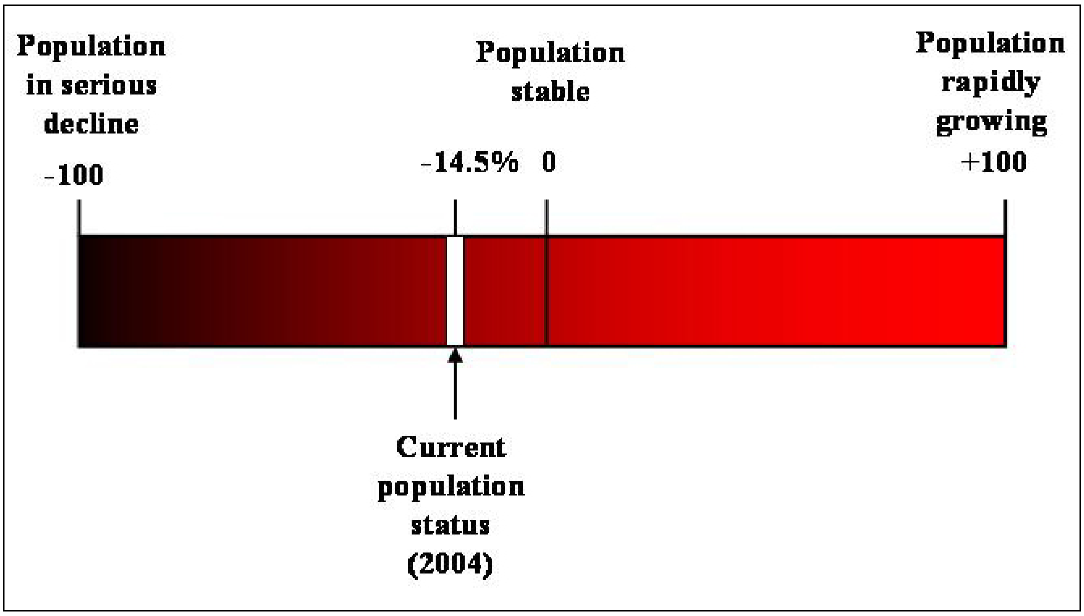


Figure 11. Assessment of the Amur tiger population in the Russian Far East.

ungulates, and conflicts in land use needs). Therefore, finding a means for tigers to survive in modern Russia is an extremely challenging task. Based on the results of 7 years of the Amur Tiger Monitoring Program, we provide 5 specific recommendations to improve efforts to conserve the Amur tiger population in the Russian Far East. These recommendations are intended to reverse current trends by achieving the above stated goals of decreasing mortality rates, increasing birth rates, and ensuring sufficient habitat for a viable population.

1. Reduce human-caused mortality, especially poaching. Recent analysis of existing data on tiger mortalities suggests that humans are responsible for 70-80% of all tiger deaths. The vast majority of human-caused deaths are the result of poaching. Existing information suggests that the current anti-poaching effort is not sufficient. *Therefore, we recommend that MPR review existing anti-poaching efforts and attempt to devise improved efforts to reduce the level of poaching of tigers in the Russian Far East.*

2. Recover prey densities outside protected areas. Increasing birth rates of tigers will be dependent on maintaining, or recovering high ungulate densities. As demonstrated in Sections 3.5 and 3.6, prey densities outside protected areas are low. Based on track densities as indicators of abundance, prey densities of red deer, wild boar, and sika deer (the three primary prey species for tigers) outside zapovedniks are less than 35% of the densities inside zapovedniks. While legal quotas established by both Primorye and Khabarovsk Hunting Departments are very conservative, the actual offtake by illegal hunting appears to be unsustainable. Recovery of prey populations is therefore a key component of tiger conservation to reduce tiger mortality and increase reproductive rates. *Specifically, we recommend that Primorski and Khabarovski Krai Administrations adopt the Ungulate Recovery Programs that are presently proposed, and that both MPR and the Hunting Department develop urgent measures to reduce the level of poaching on ungulates that is presently ongoing*.

3. Strengthen Zapovedniks. Our analysis (Section 3.6) demonstrates the importance of zapovedniks as breeding centers and core habitat for the existing population of Amur tigers.

Ideally, 10% of Amur tiger habitat would consist of zapovednik territory. Presently, zapovednik guards are poorly paid and poorly equipped to perform their duty, and zapovedniks receive minimal budgets to achieve their tasks. *Specifically, MPR should allocate sufficient funds and provide the necessary oversight to guarantee that zapovedniks are secure from poaching and other human disturbances.*

4. Complete the protected areas network in Primorye and Khabarovsk. A minimum viable population of 500 tigers requires all existing habitat that exists today in the Russian Far East. Conservation of that habitat, and tigers in it, will require a detailed and thoughtful land-use conservation plan. A habitat protection plan for tigers must include a core network of protected areas (with connectivity amongst protected areas insured), surrounded by a complex of multiple use forest lands where economic development is conducted in a manner compatible with conservation objectives. Protected areas represent core habitat where tigers can live free of human disturbance, where prey densities will be higher, and where reproductive rates of females can be increased. Existing zapovedniks (the best core habitat for tigers) represents only 3% of tiger habitat in the Russian Far East. Incorporation of zakazniks, national parks, and nature parks as part of the protected areas network, and making them effective tiger habitat, is essential, and requires no legislative change – only better enforcement. Essential to a comprehensive network is creation of protected areas that have already received approval at the regional level, but have not yet been created. In both Khabarovsk and Primorye, there are proposed national and nature parks that have been approved by the Administrations or regional Dumas, but have not yet been created, even though approval has been obtained more than 10 years ago. Creation of all proposed protected areas would result in a total of 8% of Primorski Krai allocated to protected areas, and 11% of southern Khabarovsk (south of the Amur River). We are not proposing that new protected areas be created – only that those which have already received some level of legislative approval to be finally gazetted. *Therefore, we recommend that the network of protected areas that has been proposed and partially approved for Khabarovsk (by the Administration) and Primorski Krai (via the Duma) be fully implemented.*

5. Implement a zoning system to define and prioritize tiger habitat, and apply this system in environmental assessments ("ecological expertiza") associated with any land use activities that include tiger habitat.
There is no doubt that the fate of the Amur tiger will be dependent largely on decisions involving economic development of forest lands in Primorski and Khabarovski Krai of the Russian Far East. Thus mechanisms must be developed that provide economic opportunities for humans, but retain habitat in a form that is suitable for tigers. *We recommend that local specialists develop tiger habitat maps that define all tiger habitat, as well as areas of highest priority for tiger conservation, and that regional administrations work with regional GUPR to officially acknowledge tiger habitat, and incorporate the needs of tigers in any ecological expertiza that includes land considered to be tiger habitat.*

We believe these recommendations are achievable within the existing constraints and conditions in Russia, and will go far towards achieving a secure future for tigers in the Russian Far East.

I. INTRODUCTION

At the international level, the Amur tiger (*Panthera tigris altaica*) is considered in danger of extinction. With only a few individuals remaining in China and an unknown number in North Korea, preservation of this animal has become primarily the responsibility of the Russian government and the Russian people. Accordingly, Russia has taken many steps to conserve this animal, starting with a ban of hunting in 1947. The Russian Federal government has since listed the animal as endangered (Russian Red Data Book), and has recently developed a National Strategy for Conservation of the Amur Tiger in Russia, as well as a Federal Program to implement the national strategy.

The recovery of the tiger after near extinction in the first half of this century (following the 1947 ban) has been fairly well documented through a series of surveys (Kaplanov 1947, Abramov 1962, Kudzin 1966, Yudakov and Nikolaev 1970, Kucherenko, 1977, Pikunov et al. 1983, Kazarinov 1979, and Pikunov 1990). Most recently, a range-wide survey provided a great deal of information on the distribution and status of tigers in the past decade (Matyushkin et al. 1996). Nonetheless, there remains a long standing need for a reliable and efficient means for monitoring changes in the tiger population.

The tiger is a rare, sparsely distributed, and secretive animal that is distributed across at least 180,000 km^2 of Primorski and Khabarovski Krais in southern Russian Far East. This combination of attributes make it a particularly difficult animal to count reliably, and the financial burden and logistical problems associated with range-wide surveys make it practically impossible to conduct full-range surveys with sufficient frequency to track changes in tiger abundance.

Nonetheless, there exists a need to monitor the tiger population on a regular (preferably yearly) basis. Such a monitoring program should serve a number of functions, including:

1. A monitoring program should act as an "early warning system" that can indicate dramatic changes in tiger abundance. Range-wide surveys, usually conducted between long intervals with no information, may come too late to allow a rapid response to a decline in numbers. Yearly surveys should serve to provide notice so that immediate conservation actions can be initiated.

2. Ultimately, tiger numbers, or at least trends in the tiger population, should be used as a basis to determine the effectiveness of conservation/management programs. In Russia, there have been tremendous efforts and significant support from regional, Krai-wide, federal, and international levels for implementation of tiger conservation efforts that range from anti-poaching programs to conservation education. All these efforts are aimed at protecting the existing Amur tiger population in Russia, yet without an accurate monitoring program that can determine trends in tiger numbers with statistical accuracy, the ultimate effectiveness of these conservation programs will remain unknown.

3. Among other indicators, a monitoring program should provide information on reproductive rate of the population, which may act most effectively as a predictor, or early indication of imminent changes even before there are dramatic changes in actual tiger numbers.

4. Changes in ungulate populations, as primary prey for tigers, may also provide important clues to potential impacts on tiger numbers.

5. Finally, changes in habitat conditions can also provide an indicator as to the present and future status of Amur tigers in the wild. Understanding the relationship of human impacts on habitat and tiger numbers is a difficult undertaking, but one way to gain better insight is to monitor specific sites over time to compare changes in human impacts with changes in tiger numbers.

In an attempt to address these needs, nearly all coordinators of the 1996 tiger survey have worked together to develop a reliable and effective monitoring program for Amur tigers. The task is a huge one, given the area involved and the logistics of working in a northern environment. The derived methodology has been tested over 5 years (1997-1998 winter through 2001-2002 winter season) and the results, as provided in the yearly reports, provides an indicator of the value of this program. Below we detail the methodology in use, provide justifications for its use, and indicate how the data can be employed to monitor trends in tiger numbers, and indicators of the status of the Amur tiger population in Russia.

II. GOALS AND OBJECTIVES

The ultimate goal of this program is the yearly implementation of a standardized system for collecting data that can be used to monitor changes in tiger abundance, and factors potentially affecting tiger abundance, across their present range in the Russian Far East. The intent is to provide a mechanism that will assess changes in the density of tigers, as well as other potential indicators of population status, within their current range over long periods of time. This methodology should provide a means of assessing the effectiveness of current management programs, provide a means of assessing new programs, and provide an "early warning system" in the event of rapid decreases in tiger numbers.

Objectives

Specifically, the objectives of this monitoring program are to:

1. Determine presence/absence of tigers on survey routes within count units as one indicator of trends in tiger numbers over time, and differences in tiger abundance among survey units in the Russian Far East.
2. Develop a standardized, statistically rigorous estimate of track density within count units as a second indicator of trends in tiger numbers over time, and differences in tiger abundance among survey units in the Russian Far East.
3. Develop an expert assessment of actual tiger numbers within count units as a third indicator of population trends over time.
4. Record presence of female tigers with young on count units across the range of tigers to monitor reproduction rates over time and identify areas of high/low productivity, and changes in reproduction over time.
5. Monitor trends over time in the prey base (large ungulates) of tigers within count units.
6. Record and monitor instances of tiger mortality within and in close proximity to count units.
7. Monitor changes in habitat quality.

III. METHODOLOGY

We emphasize that any survey design has limitations, and it is therefore the responsibility of program authors to clearly define their goals and objectives, and the methodology used to obtain those goals and achieve those objectives.

We believe that the following questions should be addressed in designing a monitoring program for Amur tigers:

1. What should be measured as an index of tiger abundance, and is the index a valid indication of true tiger abundance?
2. Where should the monitoring program be conducted, and how many count units are needed?
3. How should data be collected within monitoring sites?
4. When, and how often, should monitoring be conducted?
5. What should be measured as an index of tiger productivity?
6. What should be measured as an index of prey abundance?
7. How should mortality be monitored?
8. How should habitat changes be monitored?
9. How should data be stored?
10 How should data be analyzed?
11. Does the design of the monitoring program permit a reasonable statistical probability of detecting trends that may occur in the population index?

Below, we address each of these questions in the design of our monitoring program.

1. What should be measured as an index of tiger abundance, and is the index a valid indication of true tiger abundance?

All tiger surveys conducted in Russia since the 1940's have either relied on interview data of hunters and forest guards (Kudzin 1966, Kucherenko, 1977, Kazarinov 1979) or have relied on track information collected in winter (specifically track numbers, distribution, size, and age) to develop an "expert assessment" of tiger numbers (Kaplanov 1947, Abramov 1962, Yudakov and Nikolaev 1970, Pikunov et al. 1983, and Pikunov 1990. Of these two approaches, it is clear that expert assessments provide a more precise estimate of tiger numbers, but even this approach has its drawbacks: different experts interpret data in different ways, providing the possibility for the same data set to be interpreted in different ways (e.g., compare Pikunov 1985 and Bragin and Gaponov 199X, Kucherenko 2001).

Because reliance on a single methodology may lead to mistakes or misinterpretation of data, we developed a methodology that relies on three indicators of tiger abundance: 1) presence/absence of tiger tracks on routes; 2) track density on routes; 3) expert assessments of number of tigers in each count unit. These three indicators use different types of data to derive indicators of tiger abundance. Because they are at least partially independent, they provide distinct and separate indicators of trends in tiger numbers.

1. Presence/absence of tiger tracks on survey routes

Presence/absence of tiger tracks on survey routes (expressed as the percentage of routes on each monitoring unit with no tiger tracks recorded) should provide an indication of relative abundance of tigers. We record zero counts on routes when tracks were not reported on routes in either the early or later winter survey (as noted below, each survey route is sampled twice per winter season). Monitoring units can then be ranked on the basis of percentage routes with (without) tiger tracks as an indicator of relative abundance, which can also be compared among years within each unit.

2. Tiger track densities

An index of tiger abundance, based on track counts measured on sampling units well dispersed across the total range of tigers, should provide an index of relative abundance of tiger numbers that can be used to monitor trends. Changes in count estimates over time within each count unit should provide an indication of changes across the entire range. Furthermore, by distributing count units across the entire range of conditions that tigers exist in the Russian Far East, it may be possible to detect changes that may be regional or localized.

Tiger track densities are expressed as a function of number of tracks recorded along each survey route adjusted by the length of the survey route, and the time since last snow (the greater the interval since the last snow, the more time for tiger tracks to accumulate). The number of tracks is first divided by the length of each route for each survey (2 conducted per winter), providing an estimate of tracks/km for each survey separately. Tracks/km is then divided by the number of days since the last snowfall, providing an estimate of tracks/day/km, which is arbitrarily multiplied by 100 to provide an estimate of tracks/day/100 km. The mean derived from this value for both surveys in each winter is taken as the track density estimator for each separate route.

There are two problems using days since last snow to adjust the track density estimator. First, in some cases, the date of last snow is unknown, or not reported. Secondly, degradation/elimination of tracks can occur between snowfalls when the interval is large, resulting in an underestimation of track densities. Based on a preliminary assessment in Sikhote-Alin Zapovednik, nearly all tracks become immeasurable after 7-8 days. However, many of these can still be identified as tiger tracks. By approximately 14 days, however, most tiger tracks are fairly well obliterated.

Based on these considerations, we used the following standards for adjusting the track density estimator for days since last snowfall:

1. number of days since last snow, when the last snowfall was less than or equal to 14 days;

2. 14 days, if the last snow was greater than 14 days ago (assuming that tiger tracks will deteriorate beyond recognition by that time);

3. 14 days, if either date of last snow or date route was traveled is unreported.

3. Expert assessment of tiger numbers

Coordinators for each site develop an estimate of the number of tigers present on each monitoring site during the winter period (December-February). Their source of data for these expert assessments are threefold: 1) track data from the survey routes; 2) additional records of tracks on monitoring sites that are not recorded on survey routes during the 2-stage survey (see below); 3) interview information that is collected from local informants. Based on these sources, by comparing track sizes, distances of tracks from each other, dates tracks were created, and the coordinator's understanding of tiger social structure and behavior in relationship to the local physical environment, each coordinator derives an estimate of the likely number of tigers on the study site, and provides an estimate of age (adult, sub-adult, cub, unknown) and sex (male, female, unknown). If evidence of a particular tiger is recorded in only one of the survey periods (i.e., it may have been a transient, may have died, or was simply missed in one of the counts), that animal is nonetheless included in the total count for the study period as a measure of the "total number of tigers that were present at some time on the monitoring site during the monitoring period." While the way in which different experts interpret track data undoubtedly varies, these expert assessments, conducted by the same coordinators on the same sites over extended periods of time, provide a valuable indicator of changes in tiger numbers on that site.

For analyses, we combined all age classes except cubs (adults, sub-adults, and unknown) to form an estimate of number of "independent tigers" (i.e., independent of their mother) existing on a monitoring site during the survey periods. The number of independent tigers was used to estimate tiger density, which provides a basis for comparisons among sites. As with presence/absence and track density estimates, we conducted a trend analysis for all sites combined, and each site separately using track density data.

Variations in all three indicators of tiger abundance can be measured across at least 3 types of parameters:

i. overall trends in tiger numbers (by measuring changes across all count units);

ii. regional variation (assuming the population may be changing differently among regions, by looking for differences in:

-northern, middle, and southern monitoring sites;

-coastal versus inland monitoring sites;

-protected versus unprotected monitoring sites;

iii. variation among sites is likely due to a number of factors, and an assessment of the impacts and conditions within each site may reveal reasons for this variation.

2. Where should the monitoring program be conducted, how many count units are needed, and what size should they be?

Sampling only a portion of the entire distribution of tigers provides a more efficient and cost-effective means of monitoring tigers than an entire count. However, location of sampling units should be well dispersed across the total range of tigers. Changes in count estimates over time within each count unit should provide an indication of changes across the entire range. Furthermore, by creating several count units represented in each key geographic region across the entire range of conditions that tigers exist in the Russian Far East, it may be possible to detect changes that may be regional or localized.

We have attempted to define a set of count units based on criteria outlined below, and then develop a sampling scheme within each count unit that will provide an estimate of relative tiger abundance based on track abundance, as well as derive estimates of relative tiger abundance based on the three indicators described above. The sampling scheme was primarily designed to reduce variance in tiger track counts within each monitoring unit (which act as a sampling units), but the efficiency of sampling prey species was also considered. Below we define what criteria were used to select count units.

Location of count units

The set of count units selected should be dispersed across tiger range to represent the full range of conditions in which tigers occur. Both high quality and marginal areas should be monitored. It is also important that protected areas be monitoring using the same methodology as in unprotected areas to provide a comparison of the impacts of human activities on tiger populations. We also sought to create "parallel" monitoring units within and adjacent to the larger zapovedniks (Sikhote-Alin, Lazovski, and Ussuriski) to act as paired comparisons of protected and unprotected area that share nearly all features except protected status. Unprotected count units adjacent to protected areas should theoretically demonstrate higher densities of tigers and prey than most unprotected areas because they lay immediately adjacent to source populations, but not so high as the zapovedniks themselves. These paired comparisons may be sensitive indicators of the effect of human impacts.

We determined that the following parameters may be important determinants of tiger abundance:

Protected status: protected (as zapovednik)/unprotected areas;
Latitude: northern, central, or southern; and,
Geographic location: inland or coastal.

We defined protected areas only as those areas with zapovednik status. Although some sites have partially or wholly protected as zakazniks (Borisovkoe Plateau, Matai), these designations are either relatively new, or do not provide the same level of protection afforded to zapovedniks. It is commonly assumed that latitude is an important factor affecting tiger density, and that density decreases at the northern limits of its range. Therefore sites in Khabarovski Krai should theoretically retain lower tiger densities than sites to the south. We assigned all count units to one of three latitudinal sections: *northern*, which includes all of Khabarovski Krai; *central*, which includes the northern half of Primorski Krai; and, *southern*, which includes the southern half of Primorski Krai. Finally, there are important and habitat differences between *coastal* areas (i.e., those drainages that flow into the Sea of Japan) and *inland* sites (all drainages that flow into the Ussuri and/or the Amur River). Because forest types and weather varies between coastal and inland sites, it is possible that ungulate densities, and ultimately tiger densities, also vary. In all cases except for Borisovkoe Plateau, this designation represents the west and east sides of the Sikhote-Alin Mountains, respectively.

Number of count units

The number and location of count units should be determined by a number of factors: 1) there should be adequate representation of the environmental variables as defined above; and 2) the sample size should be sufficient to allow statistical analyses for overall trends in population and differences due to environmental variables (e.g., protected/unprotected); 3) there should be personnel and an infrastructure that will insure long-term monitoring will be consistently carried out on all designated sites; 4) financial constraints will largely limit the number of sites that can be consistently funded.

Size of count units

Our criteria for determining size of count units were as follows:

i) potential for variability in tiger numbers. To detect changes in tiger density, a count unit must be sufficiently large to potentially contain tiger numbers that could fluctuate over time, hopefully reflecting the conditions for tigers in the representative region. In other words, count units should be large enough to have a low probability of tigers being completely absent from the area during the survey period (if tigers are perennially absent from a count area, it is impossible to detect changes in population density), and large enough so that several or more tigers might be present. Hence, ideally a monitoring unit would contain an area large enough for 2-3 female territories.

ii) minimum size to provide variability but keep expenses low. Given that units must be large enough to contain several potential female home ranges; count units should be as small as possible to minimize the expenses of monitoring.

iv) natural or predefined boundaries. Count units should have natural boundaries reflecting geographic constraints on tiger movements (e.g., high ridgetops, large rivers) or predefined boundaries (e.g., protected areas boundaries, county or krai boundaries).

In good tiger habitat, assuming that female home ranges average 400-500 km^2 (Miquelle et al. 1999) 100,000 - 150,000 ha may contain 2-3 adult resident females, at least 1 adult male, transients, dispersers, and cubs. Therefore, we sought to create count units of approximately this size. Some exceptions were inevitable. For instance, the size of existing protected areas is obviously fixed (although with larger protected areas we sought to sample only a portion of the region). In general, we sought to keep count units with the range of 1000 - 1500 km^2.

Given these constraints, 16 permanent monitoring units have been created to be representative of the range of conditions across the present distribution of tigers (Figure 1, Table 1).

Table 1. Monitoring sites selected for the Amur tiger monitoring program in the Russian Far East.

#	Name	Size of unit (km^2)	Krai	Status	Latitude	Geographic location
1	Lazovski Zapovednik	1192.1	Primorye	Zapovednik	southern	coastal
2	Lazovski Raion	987.5	Primorye	unprotected	southern	coastal
3	Ussuriski Zapovednik	408.7	Primorye	Zapovednik	southern	inland
13	Ussuriski Raion	1414.3	Primorye	unprotected	southern	inland
6	Borisovkoe Plateau	1472.9	Primorye	Zakaznik (partially)	southern	coastal
7	Sandagoy (Olginski Raion)	975.8	Primorye	unprotected	southern	coastal
4	Vaksee (Iman)	1394.3	Primorye	unprotected	central	inland
5	Bikin River	1027.1	Primorye	unprotected	central	inland
14	Sikhote-Alin Zapovednik	2372.9	Primorye	Zapovednik	central	coastal
15	Sineya (Chuguevski Raion)	1165.4	Primorye	unprotected	central	inland
16	Terney Hunting lease	1716.5	Primorye	unprotected	central	coastal
8	Khor	1343.8	Khabarovsk	unprotected	northern	inland
9	Botchinski Zapovednik	3051	Khabarovsk	Zapovednik	northern	coastal
10	Bolshe Khekhtsirski Zapovednik	475.6	Khabarovsk	Zapovednik	northern	inland
11	Tigrini Dom	2069.6	Khabarovsk	unprotected	northern	inland
12	Matai River Basin (Zakaznik)	2487.6	Khabarovsk	new zakaznik	northern	inland

Summarizing the count units on the basis of the environmental variables outlined above shows that the resulting distribution of sites is well dispersed in a north-south gradient (6 southern, 5 central, and 5 northern) and the inland versus coastal gradient (9 inland, 7 coastal).

Table 2. Characteristics of monitoring units for tiger monintoring program.

	Protected (zapovednik)		Unprotected		
	Inland	Coastal	Inland	Coastal	Total
Southern	1	1	1	3	6
Central	0	1	3	1	5
Northern	1	1	3	0	5
Total	2	3	7	4	16

Included as monitoring units are all 5 zapovedniks that have potential tiger habitat. Obviously, location, size, and number of protected areas were not variables we could determine or randomize, limiting the extent to which we could develop a balanced design (Table 2). An imbalance of this design exists in the distribution of unprotected sites in inland versus coastal areas (7 versus 4), but we were constrained here by personnel and infrastructure capacities in selecting sites. In Khabarovsk (northern section), there is little coastal habitat for tigers, and access is very difficult. Hence, except for Botchinski Zapovednik, no effort has been made to monitor the northern coastal region.

3. How should data be collected within Monitoring sites?

Use of survey routes

Forty years of experience surveying tigers in the Russian Far East has demonstrated that counting tracks encountered while snow is on the ground along well-placed routes can be an effective means of describing the distribution and numbers of tigers in a region. Unlike other tiger range, in the Russian Far East the snow cover afforded in the winter season provides a “clean pallet” which reveals presence of tigers, and usually retains that evidence for an extended period, usually until the next significant snowfall.

Location of survey routes

Two potential approaches exist for positioning routes: either distribute them randomly throughout a given count unit as a non-biased indicator of the presence of tigers within the region, or place them along routes that have the highest probability of encountering tiger tracks. Because our interests lay in the ability to detect changes over time, it is more important that there be a high probability of tiger tracks being encountered along routes. If a large percentage of routes are devoid of tracks, there is no means of detecting changes in tiger numbers. Therefore, we sought to locate routes to have the greatest chance of intersecting tiger tracks, and to minimize the number of zero counts. Maximum efficiency of encountering tracks can be achieved by positioning routes along trails, ridgetops, roads, or natural travel corridors where tigers are most likely to travel (Matyushkin 1990).

Route length

Routes should be sufficiently long so as to have a high probability of encountering tracks, and should be of a length sufficient to reduce the variability of tracks encountered per route. However, determination of appropriate length is always a trade-off between the appropriate length for statistical rigor, the financial cost of conducting surveys with different route lengths, and the amount of time (money) that can be invested in covering routes. Ideally, we should select the shortest route length that will result in only a small percentage of routes without tiger tracks, and that is sufficiently long enough to reduce the variability in number of tiger tracks per route. When variability in track density among routes is high, our ability to statistically detect changes in tiger abundance decreases.

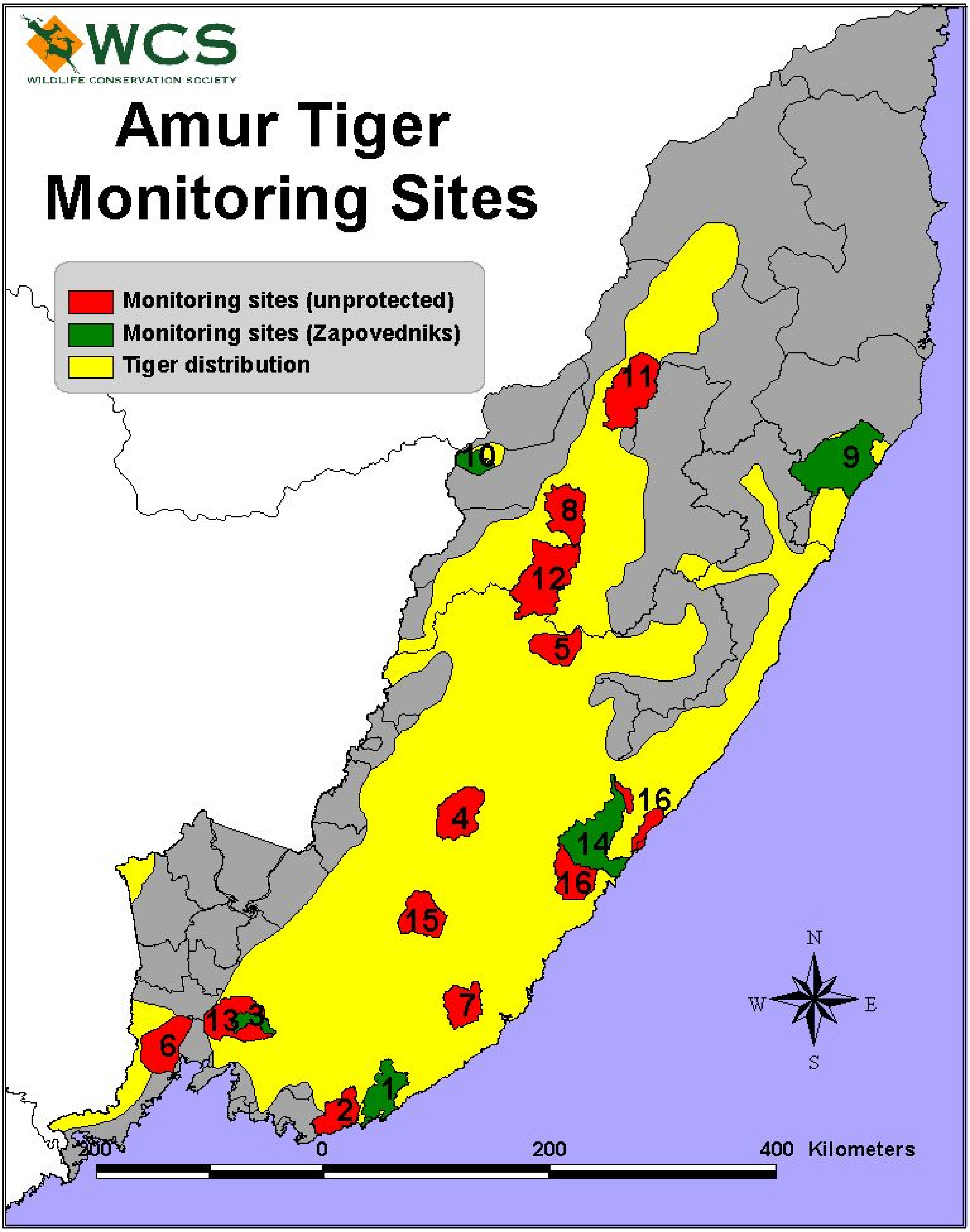


Figure 1. Location of the 16 sites used for monitoring Amur tigers in the Russian Far East. Numbers referenced in Table 1 and most other tables throughout text.

To attempt to determine the optimal route length, we used data developed in an initial experimental stage of this program at Sikhote-Alin Zapovednik (Hayward et al. in press), and conducted a set of tests to determine effect of route length first on presence/absence data (i.e., how does changing route length change the proportion of routes with zero counts?), and secondly on track density data (i.e., how does changing route length affect the variance associated with track density data).

Effect of route length on zero counts. Trend analysis procedures using linear regression do not perform well when the proportion of zero counts is high. Therefore, we employed both field and simulated data to examine the relationship between zero counts and route length.

Null model. To determine the functional form (e.g. linear or exponential decrease) of the relationship between zero counts and route length we simulated surveys in a model 60 x 60 km 'landscape'. For each computer simulation, two 'tiger trails' were randomly placed in each 10 x 10 km grid and 4 survey routes of a designated length (from 1 to 35 km long) were placed in the landscape with a random starting point and random direction. To avoid surveying 'outside' the landscape, route starting points were constrained to begin within the inner 20 x 20 km grid squares. Intersection of simulated tiger trails and survey routes were counted to determine the number of tiger detections for 2000 iterations for each of 25 route lengths to generate the function relating proportion of zeroes to route length.

Simulated track counts demonstrated that the proportion of zero counts should decline as a negative exponential as route length increases. The parameters for the function would be situation-dependent but clearly the probability of obtaining a count of zero will tend to be smaller when route length is longer and the shape of the function is similar to a negative exponential.

Analysis of field data. We also examined field data from survey routes to determine the relationship between zero counts and both route length and days since snow. We also compared the empirical data to the relationship developed in the simulation model. Patterns were compared qualitatively (visual inspection of plots of proportion zero counts vs. route length) rather than formally testing the similarity of the distributions because we were interested in whether the patterns were similar in shape rather than whether they reflect the same theoretical distribution.

Based on data from surveys, the relationship between zero counts and route length was not similar to the pattern observed with simulated data. As expected, increases in route length resulted in fewer routes with no tiger tracks (Table 3). However, the proportion of zero counts from field data for route length demonstrated a convex declining function rather than the concave function of the negative exponential. For both variables, a linear model fit the data better than a model when the independent variable was log-transformed (a negative exponential model) (proportion zero counts to route length for linear model, $R^2 = 0.945$, $F = 34.312$, $P = 0.028$; and for exponential model $R^2 = 0.753$, $F = 6.095$, $P = 0.132$).

Table 3. Relationship between proportion of zero counts and route length for surveys conducted on foot from 1995-1999 in Sikhote-Alin Zapovednik

Route length, km	n	Proportion zeros
0-5	207	0.652
5-10	220	0.573
10-15	87	0.494
>15	19	0.211

Relationship between route length and variance of track density data. We explored the relationship between variance in the track density index and route length in two ways. Based on a direct analysis of 427 routes surveyed in Sikhote-Alin Zapovednik, we evaluated variation in the track index in relationship to route length. Using this approach, sample size differed greatly among distance categories (for instance there were 172 foot surveys 0-5 km long but 66 foot routes 10-15 km) and long survey routes were rare, making it difficult to estimate variation of longer routes.

To examine variability in the track index without the constraints of sample size imposed by the field data, we created a simulation data set with equal samples sizes (n = 5000) by randomly combining up to 5 routes from field data to create new routes that fell within one of 6 length categories (0-2.9, 3-5.9, 6-11.9, 12-23.9, 24-47.9, 48-96 km). Variability in counts of tiger crossings was examined for both the original and artificial data set by calculating the standard deviation and coefficient of variation in the track index for each length category.

As expected, variability in the track index, as measured by its coefficient of variation, declined with longer routes (Table 4). However, the standard deviation did not decline with increasing route length. The simulated data combining individual survey routes further demonstrated the pattern of decline in variance as route length increased (Table 5). These simulations suggest a dramatic decrease in variability between the first two distance categories with a negative exponential decline in variability thereafter. The pattern suggests only marginal reductions in variance could be realized from the extreme effort necessary to produce long survey routes.

Table 4. Relationship between variability in the tiger track index with route length based on field surveys of Amur tigers in Sikhote-Alin Zapovednik. Variability in the track index is represented by the standard deviation and coefficient of variation from a sample of 427 foot routes conducted from 1995-1999.

Route length, km	Standard deviation	Coefficient of variation
0-5	0.0435	2.376
5-10	0.0589	2.293
10-15	0.0450	1.983
>15	0.0511	1.357

Summary of analysis of route length. Longer route lengths result in decreased variance and smaller percentages of routes with zero counts. However, feasible route length is limited by the realities of travel time and human endurance. It is clear from the above analyses that short routes should be avoided. If each route represents a sample unit, it will be imperative to successfully conduct counts on each route each year, independent of weather conditions. In deep snow years, there are situations where it is unlikely that a field worker can cover more than 15 km. Therefore, we recommend route lengths average 10 to 15 km in length.

Table 5. Relationship between route length and variability in the track index from 30,000 simulated track count surveys developed from actual field data

Route length, km	Track index		
	mean	SD	CV
0-3	0.198	0.7141	3.59
3-6	0.162	0.3181	1.95
6-12	0.150	0.2828	1.88
12-24	0.151	0.2121	1.40
24-48	0.153	0.1484	0.97
48-96	0.154	0.1061	0.69

Number of routes per site

The number of routes per site should be based on the following considerations: 1) there should be sufficient number of routes to have a high probability of encountering tracks of all tigers within the count unit (to allow for expert assessments of number of tigers); and, 2) there should be sufficient number of routes to provide a statistical basis for comparisons among count units and within a count unit over years.

We examined the statistical power of a monitoring program with different numbers of routes (see section 11 below), and determined that with 10 routes per count unit there is a 90% chance of statistically detecting a 10% decrease in population size (using density of tiger tracks as an indicator of tiger abundance) (see Table 9, in section 11). Chances of detecting a 5% change are decidedly less with 10 routes (45%). Increasing the number of routes to 20 increases the chance detecting a 10% decrease to 98%, but would represent a doubling of effort for a relatively modest gain. Therefore, we decided that our goal would be to establish 10-20 routes/count unit.

Method of transportation

Initial analysis of data from Sikhote-Alin (Miquelle and Smirnov 1995) indicated that there may be differences in detection rate of tiger and ungulate tracks dependent on the mode of transportation. Because we are primarily interested in monitoring changes in track density along each route for each year, variation in detection rate is acceptable between routes, but not in one route over years. Therefore, it is preferable that for each route the same mode of transportation (on foot, snowmobile, or vehicle) be used every year, for each survey, under all conditions.

Continuity of Personnel

People selected for the monitoring program should be selected on the basis of their experience in the region, their knowledge of tigers, and the probability of their continuing to participate in the monitoring program in the future. Stability in track counts will depend on retaining the same personnel over many years. Therefore, every effort has been made to retain the same coordinators and fieldworkers in each monitoring unit.

4. When should monitoring be conducted?

Timing of a monitoring program is vitally important. We consider three temporal issues in determining timing of the monitoring program.

4.1. How often, on a yearly basis, should the monitoring program be conducted?

Because statistically rigorous detection of trends in wildlife populations is difficult, the more often sampling is conducted, the greater the probability of detecting trends. Monitoring should be conducted every year, with the exact same protocol, to collect sufficient information to recognize trends in tiger numbers, prey numbers, and/or reproduction rates of tigers.

4.2 Should sampling be repeated within a year, or should increased number of samples (routes) be included at count units?

It is well known that counts of rare, secretive animals that occur in low numbers across a large area result in great variability because there are many parameters that affect the probability of encountering any one animal. Given these constraints, it is nearly impossible to count the entire population with a single simultaneous survey of all routes. An analysis of repeated surveys in Sikhote-Alin Zapovednik, where it is possible to check if radio-collared animals were included in a count, indicated that in a single, simultaneous count, as few as 20%, and up to 100%, of the tracks of known animals were encountered along routes. This variability in simultaneous counts makes it particularly difficult to monitor changes in tiger numbers between years, because it is impossible to determine whether differences in survey results reflect real changes in tiger numbers or simply fluctuations in ability to detect presence of animals.

Two ways to reduce the amount of variation between years are: 1) to saturate a count unit with greater numbers of routes for a single simultaneous survey in the hope that there will be more consistent detection of tigers. This approach may be helpful, but there are at least two reasons why a saturation approach may prove ineffective in reducing variability. First, because tigers are so mobile, part of the variation is due to the fact that some percentage of tigers is simply not present on the count unit during any single survey. Secondly, because tigers can stay on kill sites for up to a week, moving less than 100 meters, even with a very large number of routes some tigers could be missed in a single survey.

The second possible approach is to repeatedly survey a count unit within a given year. This process greatly increases the cost of the survey, but should also greatly increase the probability of encountering all tigers that use a count unit in the course of a winter, and should therefore greatly decrease inter-year variation in count accuracy.

We have selected to conduct two surveys of each count unit each winter – once early in winter (December-January) and once closer to the end of winter (mid-February).

4.3 When should routes be covered in relation to snowfall?

We used the same approach for analyzing zero counts for presence/absence data and variance in track density data as for assessing the effect of route length. Based on data from surveys, the relationship between zero counts and days since snow was not similar to the pattern observed with simulated data (comparing Tables 6). As expected, increases in days since snow resulted in fewer routes with no tiger tracks. However, the proportion of zero counts from field data resulted in a convex declining function rather than the concave function of the negative exponential. A linear model fit the data better than a model when the independent variable was log-transformed (a negative exponential model) ($R^2 = 0.969$, $F = 63.315$, $P = 0.015$ for a linear model and $R^2 = 0.815$, $F = 8.787$, $P = 0.0975$ for the negative exponential model).

Table 6. Relationship between proportion of zero counts and days since snow for surveys conducted on foot from 1995-1999 in Sikhote-Alin Zapovednik

Days since last snow	n	Proportion zero
1-4	147	0.680
5-8	90	0.633
9-12	110	0.527
$\geq$13	90	0.411

Variability in the track index, as measured by its coefficient of variation, declined with greater intervals since snowfall (Table 7). Standard deviation also declined in relation to days since snow (Table 7).

Table 7. Relationship between variability in the tiger track index with route length and days since snow based on field surveys for Amur tiger in Sikhote-Alin Zapovednik. Variability in the track index is represented by the standard deviation and coefficient of variation from a sample of 427 foot routes conducted from 1995-1999

Days since last snow	Standard deviation	Coefficient of variation
1-4	0.0755	2.227
5-8	0.0374	2.143
9-12	0.0285	1.802
$\geq$13	0.0275	1.478

Results of these analyses demonstrate that conducting surveys immediately following snowfall results in a higher proportion of sample routes with no tiger tracks, and a higher variance of track density estimates, making it more difficult to detect real trends in the tiger population. Standard deviation of track density estimators decline dramatically if counts are conducted at least 5 days after snow. While the coefficient of variation shows its greatest drop when 9 days have passed since snowfall, at least in some years, when snows are common, waiting 9 days after a snowfall to initiate survey work may be difficult. Surveys conducted 9-12 days after snowfall may be ideal in terms of encounter rate, but this plus must be weighed against track disintegration (see above). Therefore, we recommend that surveys be conducted 5-10 days after snowfall, whenever possible. This time frame strikes a balance between reducing the proportion of zero counts, and reducing variance estimates, and the loss of information due to track disintegration.

5. What should be measured as an index of tiger productivity?

Data on number of litters, number of cubs, and litter size are reported for each site as part of the estimate of tiger numbers by coordinators. We summarize this data across all sites to develop an estimate of productivity for the year. There are four types of information that can be derived as indicators of tiger productivity:

1. Number of litters. We can compare the total number of litters produced across all sites combined over time, and can compare number of litters produced within each site over time.

2. Number of cubs. We can compare the total number of cubs produced across all sites combined over time, and can compare number of cubs produced within each site over time. However, because count units vary in size, it is better to use a standardized variable, such as cub density, that accounts for this variation in comparisons among sites (see #3).

3. Cub density. We prefer to report cub density (number of cubs reported for a site divided by area of the monitoring site), rather than simply the numbers of cubs, as a parameter for comparison across years and sites. This variable provides a basis for determining trends and allows for statistical testing.

4. Litter size. Litter size is often an indicator of the nutritional status of the mother, and is an important variable affecting overall productivity. Changes in litter size over time are indicator of shifts in productivity. However, because litter size varies dramatically with the age of the litter (with much mortality occurring in the first 3 months) interpretation of this data must be done carefully.

6. What should be measured as an index of prey abundance?

Good estimates of actual prey abundance require extensive work to acquire, and would become a major expense of a tiger monitoring program. Instead of trying to estimate actual density, we decided to use track density as an indicator of relative abundance of ungulates. At the same time, we are attempting to develop relationships between track density and actual animal abundance. In the meantime, changes in track density should, over time, act as an adequate indicator of changes in population numbers over time. Actual track densities show great variability over a season, and among routes covered within any single count unit. Therefore, we believe that double sampling (early winter and late winter) is a key component of the methodology to reduce variability, not only of tiger tracks, but of ungulate tracks as well.

7. How should mortality be monitored?

We recommend that reports of mortality should be included in a monitoring program in two formats: official reports, and unofficial reports.

Official mortality reports. Each year, the Ministry of Natural Resources is responsible for reporting all officially acknowledged deaths of tigers. This report provides information on only a small portion of the actual number of deaths, but its value lies in the fact that these mortalities have been thoroughly investigated and confirmed. For the most part, these deaths are usually related to a conflict or encounter with humans, and therefore provide an indicator of the number of mortalities related to human-tigers conflicts that can be monitoring over time.

Unofficial mortality reports. Each coordinator is responsible for collecting information on deaths of tigers in or in proximity to count units. In many cases, these reports cannot be confirmed, as coordinators often have to assure confidentiality to obtain the data. Thus, there are no doubt errors associated with this reports, but they nonetheless act as a "barometer" of tiger mortalities, again usually human-caused, that are occurring in and around count units within a given year. As such, they provide valuable information on the impacts of humans on tigers, and on the mortality rates for a given region. These data provide a different and very valuable perspective on tiger mortalities in comparison to official reports, and likely provide an estimate closer to actual mortality rates than official reports.

8. How should habitat changes be monitored?

A first step in defining count units is development of a passport, which should include the following information: boundaries, total area, vegetation cover, number of roads, area logged, forest cover types, locations of commercial objects, and villages in the area. The purpose of this table to record changes that have occurred in the past year.

We have derived a set of questions to determine changes in habitat quality for tigers and their prey on count units. Yearly monitoring is focused not so much in specifying exact conditions on count units, which would be a time consuming and difficult process, but identifying changes occurring on the unit. Therefore, nearly all questions seek to determine if changes have occurred, whether than to specify exactly what conditions exist. The questions relate to logging, fire, hunting, livestock use, and overall human use of the count units. Most questions that seek to quantify the level of activity require only categorical responses (e.g. we have 5 categories as potential responses to the question "How much logging has occurred on the count unit this past year?" ranging from none to greater than 1000 ha.). The questions are formulated as follows:

1. Have any new roads been built in the count unit this year? If so, how many kilometers?
2. Has there been repairs/reopening of any roads in the past year (e.g. asphalt)?
3. Have any roads been closed in the count unit this year?
4. Has logging occurred on the count unit this year? If so, what types and how many hectares
5. How many villages are there within 30 km of the count unit?
6: How many people are living within 30 km of the count unit?
7: Has there been a change in the number of people within 30 km of the count unit in the past year?
8. Specify type of fires (grass fire, crown fire) and area burned within your count unit this past year.
9: Report the number of livestock that have pastured on the count unit in the past year (total number of animals – not total number of days grazed).
10. Has the number of livestock using the count unit changed from last year?
11: Number of reports of depredation by tigers on livestock within the monitoring site, by species

12. Provide an estimate of the human disturbance factor on the count unit (number of person days on the count unit per month, for the months during which the monitoring program was conducted.

13. How many hunting licenses were provided for the count unit this year?

14. In your opinion, has the number of illegal shootings of ungulates increased or decreased from last year?

15. Estimate the number of illegal shootings of ungulates on your count unit this year.

16. In your opinion, has the number of illegal killings of tigers increased or decreased from last year?

17. In your opinion, has the status of tiger habitat on your count unit increased or decreased from last year.

18. Have there been any other changes on your count unit that may have an impact on the tiger population or tiger habitat?

9. How should data be stored?

A key component of creating a reliable, long-term monitoring program is the development of a means of storing and analyzing data. We have invested substantial finances and energy into developing a spatially explicit database in a standardized format that will insure long-term protection of the database, and at the same time provides relatively easy access for analysis. We have developed the database in Microsoft ACCESS that linked to a specially edited version of ArcView (ESRI Corp.) that contains all data collected by fieldworkers on every tiger track and individual, tiger deaths, route information (ungulate densities are reported by route), and count unit. The first two years of the program were spent in developing the database, and creating ArcView interface that spatially links the attribute data. Each count unit is defined by a series of "coverages" that includes: boundaries of count unit (and boundaries of protected areas), the river system, for most count units a forest cover map, location of survey routes, tiger tracks (coded by sex and age when possible) location of females with cubs, and sites of mortality. The MS ACCESS database exists as a series of linked tables, making analysis relatively easy, and the ArcView interface provides the opportunity to quickly visually assess the data and obtain necessary information. The ArcView project exists in two scales: 1) 1:500,000 for general reference to the entire range of tigers; and 2) 1:100,000, which is the scale used for recording and entering data on specific count units. The database now exists in a specially designed format (using AVENUE) so that data entry is possible without technical expertise in ARCINFO, or the need for digitizing data.

10. How should data be analyzed?

While an approach based on sampling provides the benefits of lower cost, more frequent implementation, and better measures of accuracy, there are problems. Counts of rare objects generally result in estimates with large variances. This leads to the potential for estimates that lack the level of precision necessary to make critical management decisions. Therefore, careful attention needs to be paid to how data can and should be analyzed.

We sought to determine trends in tiger populations and their key prey resources by assessing spatial and temporal variation in the following parameters:

Relative tiger abundance

We used three indices of relative tiger abundance: presence/absence of tiger tracks on survey routes (expressed as the percentage of routes within each count unit with no tiger tracks recorded); track density, adjusted for number of days since last snow; and "independent tiger" density. The mean and standard deviation of the first two indices for each site can be derived using each route as a subsample fore the site. The expert assessment of number of tigers exists as a single value (expressed as density of "independent tigers" with no error term (i.e., we have not derived a means of assessing error for expert assessments). These three sets of data can then be used to make the following comparisons:

Changes over time in tiger abundance across the entire range, and changes in tiger abundance indices over time for each count unit separately. *W*e conduct linear regression analyses for all sites combined (to give an indication of trends for the entire Amur tiger population) and each site separately (to look for trends within each site). The same types of analyses are conducted for presence/absence data, tiger track density, expert assessments of tiger density, and track data for ungulates (see below). The intent of the regression analyses is to identify trends over time in the population across the whole region, and within each of the monitoring sites. We have defined sites as "areas of concern" if the trend analyses demonstrates a negative slope for which the statistical probability was greater than 80% (i.e. $P < 0.2$) that the population was decreasing (i.e. that the slope of the line did not equal zero, i.e., $\beta \neq 0$). We have used the same criteria for defining sites as "areas with positive growth indicators" if the slope is positive.

This is a very conservative approach, as most statisticians use a P value of 0.05. By increasing the P-value to 0.2, we dramatically increase the probability of defining a site as an "area of concern" or an "area with positive growth" when in fact such may not be the case. We use this more conservative approach because we argue that we must have a mechanism for identifying areas early, so that remedial action can take place: a more liberal approach (with a smaller P value) would result in fewer "false alarms" but may not identify all areas in time to respond on an appropriate time scale. We balance this conservative approach by using a suite of indicators (3 for tigers, and one for each species of prey). We consider trends to be occurring in the tiger population (for the entire population or for any individual site) if two of the three indicators demonstrate a similar pattern (i.e., decline, growth, or stability in population status).

By assessing a host of variables, we believe the approach provides a balance between being overly alarmist and overly complacent.

Differences in tiger abundance among sites in any given year (or over all years). To assess whether variation in tiger abundance (for any of the three indicators) exists among sites in any given year (or all years combined), we employ a non-parametric analysis of variance using the ranks of each indicator. In most cases we use a non-parametric approach because the indicator values are not normally distributed. The results of the ANOVA F-test will determine if there are significant overall differences among sites, but will not provide a means of determining which sites are different from each other. To do that requires a "multiple comparison" test. We employ either protected LSD test – conducting the Fishers Least Significant Difference test (LSD test) only if the overall ANOVA is significant, or conducting a Tukey's "honestly significant difference" pair wise comparison test (as defined in SAS 1985)

The effect of environmental/geographic parameters on tiger abundance indicators. We assess the importance of environmental parameters in explaining variation in tiger abundance indicators by conducting a 3-way unbalanced factorial ANOVA, with protected status, latitude, and proximity to coast as independent variables. If the distribution of the tiger abundance indicator data is not normal, we first rank the values of the indicator for each count unit, and then conduct the same factorial analysis of variance on those ranked values. If the overall ANOVA is significant, we use one of the multiple comparison tests described above to test for differences within any one of the three parameters.

Paired comparisons of zapovedniks and adjacent unprotected territories. Paired comparisons of the 3 zapovedniks with adjacent monitoring sites (i.e., Ussuriski Zapovednik versus Ussuriski Raion, Lazovski Zapovednik versus Lazovski Raion, and Sikhote-Alin Zapovednik versus Terney Hunting Society) provide a means of comparing adjacent sites that retain similar characteristics, with the only major difference being protected status. Using these three pairs provides a clear demonstration of the importance of protected status and its impact on tiger and ungulate abundance indices.

The relationship of these three tiger abundance indices to each other. We compare how well the three tiger abundance estimators (presence/absence, track densities, tiger densities) correlate with each by ranking each site by its relative value for each of the estimators, and estimating Spearman's rho (Conover 1980) on those ranks.

Changes in the tiger productivity

Data on number of litters, number of cubs, and litter size are reported for each site as part of the estimate of tiger numbers by coordinators. We summarize this data across all sites to develop an estimate of productivity for the year. However, because sites varied greatly in size, we could not use simply the total number of cubs or litters as a parameter for comparison across years and sites. We instead used cub density (number of cubs divided by area of the monitoring site) as a measure of productivity to compare among sites and as a constant that could be used for analyses of trends across years.

Changes in prey populations

Relative abundance of the 4 primary prey species of tigers (red deer, wild boar, roe deer, and sika deer) is estimated on the basis of number of fresh (< 24 hours old) tracks intersecting survey routes. Estimates from both surveys in each winter (early and later winter surveys) are averaged to derive an estimate of mean number of tracks, for each species, that intersect each route for the winter. Each route acts as a sampling unit to develop a mean for the monitoring site. That mean value is used to conduct a trend analysis similar to that conducted for the tiger abundance indices (see above) for each site separately and for all combined. For each species, we conducted a separate a 3-way factorial model to assess environmental parameters (latitude, protected status, and proximity to coast).

11. Does the design of the monitoring program permit a reasonable statistical probability of detecting trends that may occur in the population index?

Introduction to power analysis

Our analysis assumes that trend will be examined using regression methods by testing for a significant slope coefficient based on a t-test of the null hypothesis that $B_1 < 0$ (Gibbs 1995, Gerrodette 1987, Thompson et al. 1998). Although other statistical approaches could be employed, we based our analysis on this method because its applicability for monitoring vertebrate populations has been thoroughly assessed in recent literature (see review in Thompson et al. 1998). Other approaches, such as dividing the time series into 2 or 3 intervals and testing for differences using a Wilcoxon signed rank test or employing graphical methods may also be useful. However, examining statistical power and other features of the pilot data employing regression provides a focus for analysis to assist in field protocol design.

We used Monte Carlo simulations to determine how route length, number of routes, and alpha (probability of a Type I error) influence power. Using the program MONITOR 6.2 (Gibbs 1995) we generated 10,000 simulations of track indices over a 5-year monitoring horizon to estimate power to detect an annual change in track index of +10%, +5%, no change, -5%, or -10%. The analyses assume that tiger tracks will be counted on routes for 5 years and trends assessed with a linear regression model of log-transformed track indices. We followed Thompson et al. (1998:160) and chose to model exponential, rather than linear population growth (or decline) because this model is expected to most closely approximate demographic processes of tiger populations.

Input values for the simulations were based on statistical summaries of surveys from Sikhote-Alin Zapovednik from 1995-1999. The simulations require a mean track index and standard deviation for each simulated route. A specified trend (say 5% decrease) is simulated by extrapolating an annual 5% decline, beginning with the specified mean index and then generating random index values, each year, for five years. The generated indices are drawn from a normal distribution whose mean is equal to the deterministic projection for a particular year and standard deviation based on the estimated value from our field studies. Most simulations assumed sampling from multiple routes to determine trend. Because trend would be expected to vary among sites within a region, we assumed that the standard deviation describing trend variation among sites would equal 0.015. This value is based on the standard deviation of the mean track index from 15 survey areas sampled in our field surveys. Because power to detect regional declines will be higher if one-tailed tests are employed and because ability to detect declines is of paramount importance, we examined the influence of monitoring design criteria on power for one-tailed tests assuming α = 0.20.. Input parameters for route length, number of routes, and alpha are described below.

Route length. The mean and standard deviation for the track index from survey routes were used for each of five length categories (0-5, 5-10, 10-15, 15-20 and 20-25 km). Each simulation examined index values over five years from a single route sampled twice each year. We focus on a sampling design that surveys each route twice a year because this provides a link to information collected in the past from the traditional census.

Number of routes. We examined the power of a monitoring system to detect a trend based on 3, 5, 10, and 20 routes. We used track index values corresponding to a mean route length of 8 km from the field surveys, α = 0.20, and a one-tailed test.

Alpha, probability of type I error. We examined the extent to which power increased as α is increased by comparing α = 0.05, 0.10, 0.15 and 0.20. For these analyses we simulated a monitoring design employing 10 routes monitored twice each year for five years.

Results of power analysis to detect trends in tiger tracks

Route length. Power increased with route length (Table 8). Based on the variance structure of data from survey routes, the most substantial improvements in power are realized by extending route length from 17.5 to 22.5 km.

Number of routes. Results demonstrate that it is difficult to detect a significant change in tiger tracks based on a single route (Table 8). Results also illustrate that it will be difficult to achieve sufficient power to detect a 5% annual change in tiger track counts even with a sample of 20 routes monitored within any region (Table 9). However, given a 10% annual trend, adequate power is achieved with a sample of 10 routes. The most substantial gains in power are achieved by increasing sample size from 3 to 10 routes. Monitoring more routes results in relatively modest increases in power if seeking to detect a trend of $\pm$ 10%.

Alpha, probability of type I error. Results demonstrate that a significance level (α) below 0.15 will achieve unacceptable power for all effect sizes (Table 10). Decisions regarding choice of (α) will depend on judgment regarding the effect size to monitor and the perceived consequences of Type I error vs. Type II error.

Table 8. Relationship between route length and probability of detecting a trend (power) using regression analysis of tiger track index from a single monitoring route. Trend refers to the annual proportional change in the track index (effect size) that the monitoring program wishes to detect.

Analysis is based on mean track index and standard deviation calculated from 427 foot surveys conducted from 1995-1999 in Sikhote-Alin Zapovednik. Mean and STD refer to the mean index for each route length and the standard deviation of that value calculated from the field surveys

Trend	Route length				
	2.5 km	7.5 km	12.5 km	17.5 km	22.5 km
-0.1	0.409	0.407	0.404	0.421	0.503
-0.05	0.292	0.301	0.293	0.295	0.337
0	0.200	0.188	0.201	0.197	0.197
0.05	0.305	0.302	0.299	0.304	0.348
0.1	0.415	0.415	0.400	0.434	0.528
Mean	0.0187	0.0213	0.0177	0.0196	0.0150
STD	0.03790	0.04148	0.03800	0.02988	0.01126

Table 9. Relationship between number of routes monitored and probability of detecting a trend in tiger track index based on foot surveys. See table 6 and text for further details.

Trend	Number of Routes			
	3	5	10	20
-0.1	0.593	0.724	0.892	0.984
-0.05	0.391	0.456	0.583	0.753
0	0.194	0.197	0.200	0.196
0.05	0.382	0.458	0.592	0.756
0.1	0.608	0.737	0.908	0.988

Table 10. Influence of alpha (level of significance) on power in a test of trend in a tiger track index based on 10 routes surveyed twice each year for 5 years. See table 6 and text for details.

Trend	Alpha (α)			
	0.05	0.10	0.15	0.20
-0.1	0.624	0.771	0.847	0.887
-0.05	0.258	0.399	0.504	0.586
0	0.048	0.096	0.156	0.199
0.05	0.266	0.406	0.503	0.586
0.1	0.653	0.793	0.855	0.901

Summary

Our results suggest that track counts can be employed as part of a system to monitor Amur tiger abundance given the critical assumption that changes in track counts reflect changes in tiger population size. A monitoring system employing 10 to 20 routes, 12 to 15 km long, sampled twice each year could provide over 80% power to detect a 10% annual decline in tiger tracks with a 20% chance of "false alarms" ($\alpha = 0.20$).

Each of the three indicators of tiger abundance has their problems. The exact relationship between numbers of presence/absence counts, track density, and expert assessment of tiger numbers, to the REAL number of tigers is unknown. This critical relationship between an index and population abundance has not been tested and application of an unvalidated index requires careful consideration of potential errors (Thompson et al. 1998). However, Caughley (1977) argued strongly that an index frequently provides the information needed for management. Thorough validation of our index would be extremely difficult because of significant problems encountered in executing the preferred alternative -- estimating abundance of Amur tigers.

Probability sampling (Van Sickle and Lindzey 1991, Becker 1991) and mark/recapture using genetic analysis of hair samples or camera traps represent alternative methods for directly monitoring tiger abundance (Karanth 1995, Hornocker Wildlife Institute 1998). These methods would avoid the problems encountered with an index. Logistical constraints related to aircraft availability, and an inability to detect tiger tracks in forest habitats from aircraft (especially mixed coniferous forests), have inhibited development of probability sampling with aerial surveys. In a similar way, low probability of "recapture" with low density populations may limit usefulness of mark-recapture procedures. The logistical constraints of sampling a rare animal across a vast landscape (nearly 200,000 km^2) will remain for any system employed, but large home ranges and long daily movements (Yudakov and Nikolaev 1979) of Amur tigers make probability of encountering tracks of any given animal during periods of snow cover relatively high. Use of a track index can provide statistical rigor, and act as a suitable link to the institutionalized and politically acceptable tiger counts that have been conducted in the past. Therefore, given the theoretical support for a track index to monitor other carnivores (Kendall et al. 1992, Beier and Cunningham 1996) we suggest that this index offers an acceptable monitoring tool.

If the track index represents the most feasible monitoring tool for Amur tigers, can implementation of a monitoring program using the index be defended given the realistic constraints of power, type I error rates, and the field effort? We feel the design criteria that emerge from our analysis support pursuing a program based on the above criteria. This approach provides the opportunity to monitor tiger abundance with a track index as well as to conduct other components of the traditional monitoring program (e.g. indices of reproduction, prey abundance, human impact, and tiger mortality).

Constraints associated with track degradation, in concert with variance associated with route length and time since snow help define many of the parameters for designing the monitoring program. Increasing the time since snow will decrease variance, but this factor must be weighed against the probability of track degradation due to recurrent snow, wind, or melt-out. We recommend that surveys conducted 5-10 days after snow during January and February will incur relatively little loss of tracks due to degradation, and benefit from reduced variance due to extended time since last snow.

Longer route lengths result in decreased variance and smaller percentages of routes with zero counts. However, feasible route length is limited by the realities of travel time and human endurance. If each route represents a sample unit, it will be imperative to successfully conduct counts on each route each year, independent of weather conditions. In deep snow years, there are situations where it is unlikely that a field worker can cover more than 15 km. Therefore, we recommend route lengths average 10 to 15 km in length.

Larger numbers of routes per count unit provide a greater probability of detecting trends. Based on the power analysis, we recommend that no fewer than 10 routes be located within each count unit.

A reduced sampling effort would not permit detection of declines of 10% which we feel is an effect size sufficient to require a conservation response. However, if 350 adult tigers exist in the Russian Far East, a 10% annual decline in abundance would lead to a population of about 200 tigers after 5 years; a change warranting immediate action. Therefore, given the precarious status of the Amur tiger, we feel uncomfortable recommending a smaller sample effort be employed with the goal of detecting a larger effect size. The system we recommend ($\alpha = 0.20$) would lead to a relatively high rate of false inferences that tigers are declining when, in fact, they are not. Allowing a Type-I error rate of 20% has been defended as a reasonable compromise in endangered species monitoring (Kendall et al. 1992, Beier and Cunningham 1996). Reducing the frequency of false alarms would lead directly to reduced ability to detect declines, delaying the initiation of further conservation management.

We have employed this above described methodology in implementing the Amur Tiger Monitoring Program as an experimental attempt to determine the feasibility of permanently establishing such a program. Our results demonstrate that not only can the program be successfully implemented, but that it provides a host of valuable information on tiger numbers, reproduction, mortality, that is critical to responsible management. Additionally, our methodology provides a database of assessment of the prey base upon which tigers depend, and the habitat upon which both tigers and their prey depend. Thus, we feel we have developed an effective measuring rod that will aid government officials in assessing the status of tigers, and the effectiveness of conservation measures.

Literature cited

Abramov, K. G. 1961. On the procedure for tiger census. Voprosy organizatsii i metody ucheta resursov fauny nazemnykn pozvonochnykh. Pages 53-54 *in* Mosk. Obschestvo Ispytaltely Prirody. Moscow, Russia. (in Russian).

Becker, E. F. 1991. A terrestrial furbearer estimator based on probability sampling. Journal Wildlife Management 55:730-737.

Beier, P. and S. C. Cunningham. 1996. Power of track surveys to detect changes in cougar populations. Wildlife Society Bulletin 24:540-546.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York, New York, USA.

Gibbs, J. P. 1995. Monitor user manual. Exter Software, Setauket, New York, USA.

Gerrodette, T. 1987. Power analysis for detecting trends. Ecology 68:1364-1372.

Hayward, G. D., D. G. Miquelle, E. N. Smirnov, and C. Nations. 2002. Monitoring Amur tiger populations: characteristics of track surveys in snow. Wildlife Society Bulletin 30(4):1150-1159.

Hornocker Wildlife Institute. 1998. Monitoring the status of the Amur tiger population in the Russian Far East: a final report to the World Wildlife Fund-US and interim report to World Wildlife Fund-Germany.

Kaplanov, L. G. 1948. The tiger in Sikhote-Alin. Pages 18-49 *in* Tiger. Iziubr. Los." Materialy k poznaniyu fauny i flory SSSR. Izd. Mosk. Obschestva Ispytateley Prirody. Novaya seria. Otdel. zool. No. 14 (29). Moscow, Russia. (in Russian).

Karanth, K. U. 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture-recapture models. Biological Conservation 71:333-338.

Karanth, K. U. and J. D. Nichols. 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852-2862.

Kendall, K., L. H. Metzgar, D. A. Patterson, and B. M. Steele. 1992. Power of sign surveys to monitor population trends. Ecological Applications 2:422-430.

Matyushkin, E. N., D. G. Pikunov, Y. M. Dunishenko, D. G. Miquelle, I. G. Nikolaev, E. N. Smirnov, G. P. Salkina, V. K. Abramov, V. I. Bazylnikov, V. G. Yudin, and V. G. Korkishdo. 1996.

Numbers, distribution and habitat status of the Amur tiger in the Russian Far East. Final report to the USAID Russian Far East Environmental Policy and Technology Project.
Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Chapman and Hall, London, United Kingdom.
Mescheryakov, V. S. and S. P. Kucherenko. 1990. Number of tigers and ungulates in Primorsky Krai: recommendations for protection and rational use. Final report. All Soviet Scientific Research Institute of Hunting Management, Far East Division of Primorye Commercial Hunting, and Primorsky Cooperative for Commercial Hunting. Vladivostok, Russia. (In Russian)
Matyushkin, E. N., and V. I. Zhivotchenko. 1979. Procedures of tiger counting in the zapovedniks of the Primorie. Pp. 250-251 in Ecologicheskie osnovy okhrany i ratsionalnogo ispolzovani khischnykh mlekopitaiuschikh. Materialy Vsesoiuzn. soveschania. Nauka, Moscow, Russia. (in Russian).
Morin, P. A. and D. S. Woodruff. 1996. Noninvasive genotyping for vertebrate conservation. Pages 298-313 *in* T. B. Smith and R. K. Wayne, editors. Molecular genetic approaches in conservation. Oxford Press, New York, New York, USA.
Pikunov, D. G. and A. P. Bragin. 1987. Organization and procedures for counting the Amur tiger. Pp. 39-42 in Organizatisia i metodika ucheta promyslovykh i redhikh mlekopitaiuschikh i ptits Dalnego Vostok. Tikhookeanskii institut geografii RAN. Preprint. Vladivostok, Russia. (in Russian).
Pikunov, D. G. 1990. Numbers of the Amur tiger in the Soviet Far East. Fifth Meeting of the All-Soviet Theriological Society 2:102-103. (in Russian)
Smirnov, E. N. and D. G. Miquelle. 1999. Population dynamics of the Amur tiger in Sikhote-Alin State Biosphere Reserve. Pages 61-70 *in* J. Seidensticker, S. Christie, and P. Jackson, editors. Riding the tiger; meeting the needs of people and wildlife in Asia. Cambridge University Press, Cambridge, United Kingdom.
Strayer, D. L. 1999. Statistical power of presence-absence data to detect population declines. Conservation Biology 13:1034-1038.
Thompson, W. L., G. C. White, and C. Gowan. 1998. Monitoring vertebrate populations. Academic Press, San Diego, California, USA.
Van Sickle, W. D., and F. G. Lindzey. 1991. Evaluation of a cougar population estimator based on probability sampling. Journal Wildlife Management 55:738-743.
Yudakov, A. G., and I. G. Nikolaev. 1973. Status of the population of the Amur tiger in Primorskiy Krai. Zoologicheskii Zhurnal 52:909-919. (In Russian).
Yudakov, A. G., and I. G. Nikolaev. 1979. The distance covered by the Amur tiger in a 24-hour period. Byulleten' Moskovskogo Obshchestva Ispytateley Prirody. Otdel Biologicheskiy. 84:13-19. (In Russian).

IV. RESULTS OF THE 2003-2004 WINTER MONITORING PROGRAM

Summary Data on Count Units and Routes

As in previous years, in the 2003-2004 winter the total area included in monitoring units was 23,555 km^2, or approximately 15-18% of the total area considered suitable tiger habitat, assuming either 156,571 (Matyushkin et al. Table 4) or 127,693 km^2 (Miquelle et al. 1999, Table 19.3) of suitable habitat.

A total of 246 survey routes were sampled (in nearly all units they were sampled twice), representing 3057 km of routes (with double sampling, a total of 6114 km traversed) (Table 1).

Table 1. Characteristics of units surveyed for Amur tiger monitoring program

	Monitoring Unit	Coordinator	Size of unit (km^2)	# survey routes	Total length of survey routes (km)	Average length of survey routes (km)	Survey route density (km/10 km2)
1	Lasovski Zapovednik	Salkina, G. P.	1192,1	12	121,4	10.1	1,02
2	Laso Raion	Salkina, G. P.	987,5	11	138,9	12,6	1,41
3	Ussuriski. Zapovednik	Abramov, V. K.	408,7	11	104,4	9,5	2,55
4	Iman	Nikolaev. I. G.	1394,3	12	176,9	14,7	1,27
5	Bikin	Pikunov, D. G.	1027,1	15	188,4	12,6	1,83
6	Borisovkoe Plateau	Pikunov, D. G.	1472,9	14	216,8	15,5	1,47
7	Sandago	Aramilev, V. V.	975,8	16	218,5	13,7	2,24
8	Khor	Dunishenko, Yu. M.	1343,8	19	190,3	10	1,42
9	Botchinski Zapovednik	Dunishenko, Yu. M.	3051	14	164,7	11,8	0,54
10	BolsheKhekhtsir Zapovednik	Dunishenko, Yu. M.	475,6	7	82,9	11,8	1,74
11	Tigrini Dom	Dunishenko, Yu. M.	2069,6	14	181,8	12	0,88
12	Matai	Dunishenko, Yu. M.	2487,6	24	372	15,5	1,50
13	Ussuriski Raion	Abramov, V. K.	1414,3	12	178,2	14,9	1,26
14	Sikhote Alin Zapovednik	Smirnov, E. N.	2372,9	26	277,7	10,7	1,17
15	Sineya	Fomenko, P. V.	1165,4	15	207,2	13,8	1,78
16	Terney Hunting Society	Smirnov, E. N.	1716,5	24	247,2	10,3	1,44
	Totals		23555,1	246	3057,3	12,428049	1,30

Snow Depth

Snow depth was generally close to the average snow depth of the previous 5 years (Figure 1). A few sites had significantly greater than average snow depth, including Sandagoy, Terney Hunting Lease, Sikhote-Alin Zapovednik, Botchinski Zapovednik, and Sineya. Nearly all these sites are on the coastal side of the Sikhote-Alin Mountains, which experienced heavier than normal snowfalls in winter 2004.

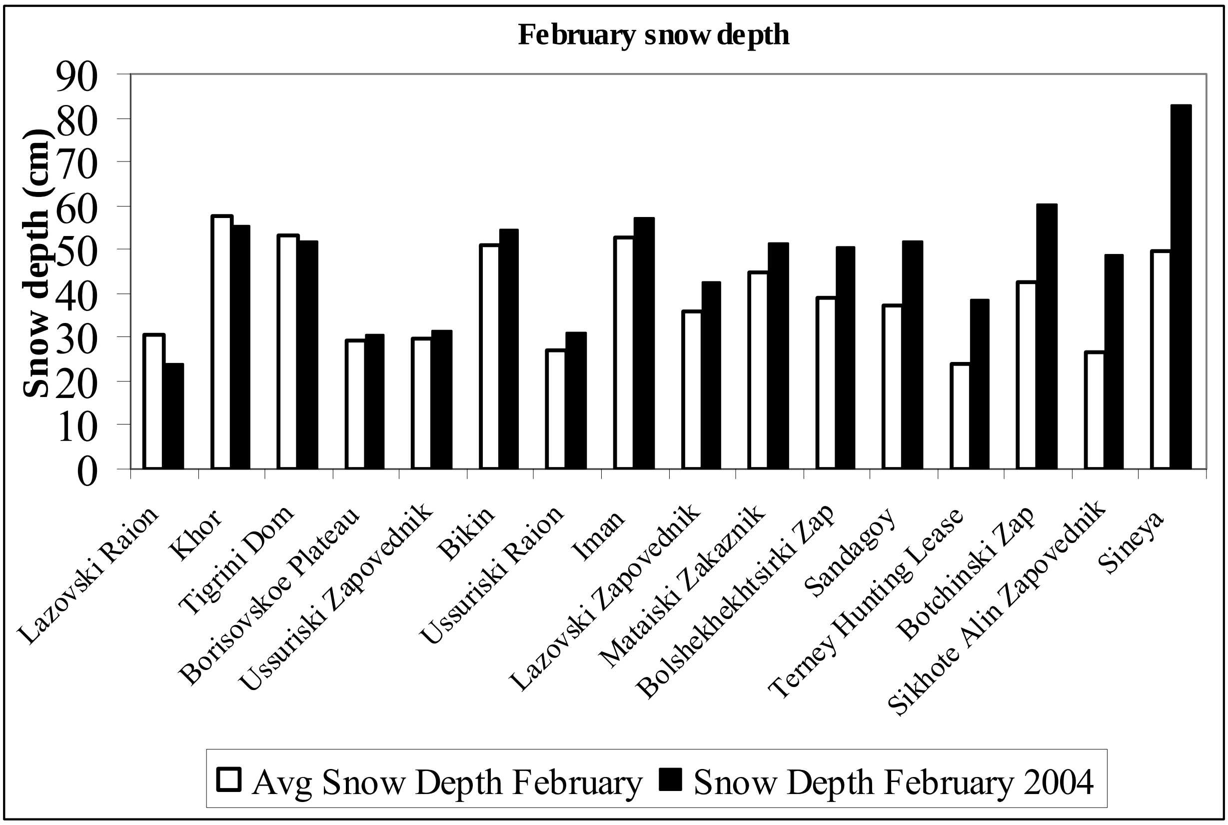


Figure 1. Snow depth within monitoring sites (averaged for all routes) of the Amur Tiger Monitoring Program, for February, 2004 compared to average of previous 5 years (1998-1999 through 2002-2003. Sites with lower than average snow depth on left side of chart, sites with higher than average snow depth on right side.

Measures Of Tiger Abundance

Zero Counts on Survey Routes (Presence/Absence)

Reporting on zero counts on survey routes serves two purposes.

1) as noted in the Introduction, from a methodological perspective large numbers of zero counts are not desirable because they reduce our capacity to detect changes in tiger numbers, i.e., if a survey route never has an occurrence of tiger tracks reported, it does not provide information on changes in tiger numbers. Therefore, understanding the distribution of zero counts is an important component of understanding the effectiveness of the sampling design.

2) Presence/absence is used as one of three indicators used to assess abundance (in this case, relative abundance) of tigers in each monitoring unit by ranking monitoring sites based on the percentage of routes without tiger tracks.

We report zero counts on survey routes when no tracks were recorded on both the early and late winter surveys. In the 2003-2004 winter 31% of 246 routes on monitoring sites did not intersect tiger tracks (Table 2). This estimate of track presence/absence is slightly lower than the 7 year average (33%), and overall, suggests a non-significant trend downwards (Figure 2). Although variance around these estimates is relatively large (Figure 2), the negative trend, although not statistically significant, is notable.

Table 2. Percentage of routes with tiger tracks present on routes in 16 units of the Amur Tiger Monitoring Program, 1997-1998 though 2003-2004.

		YEAR							
Monitoring Unit	routes	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	Grand Total
1 Lazovski Zapovednik	12	91.7	83.3	100.0	100.0	100.0	91.7	91.7	94.0
2 Lazovski Raion	11	100.0	72.7	63.6	45.5	90.9	90.9	81.8	77.9
3 Ussuriski Zapovednik	11	90.9	100.0	90.9	90.9	81.8	81.8	72.7	87.0
4 Iman	12	91.7	66.7	75.0	91.7	75.0	58.3	83.3	77.4
5 Bikin	15	63.6	87.5	87.5	93.8	81.3	81.3	75.0	81.4
6 Borisovskoe Plateau	14	57.1	57.1	50.0	57.1	50.0	64.3	50.0	55.1
7 Sandagoy	16	53.3	68.8	43.8	56.3	18.8	81.3	37.5	51.4
8 Khor	19	62.5	31.6	89.5	57.9	68.4	57.9	47.4	59.3
9 Botchinski Zap	14	64.3	57.1	85.7	100.0	64.3	78.6	42.9	70.4
10 Bolshekhekhtsirki Zap	7	85.7	42.9	85.7	14.3	28.6	28.6	42.9	46.9
11 Tigrini Dom	14	50.0	64.3	71.4	78.6	64.3	71.4	85.7	69.4
12 Mataiski Zakaznik	24	68.4	79.2	50.0	58.3	75.0	70.8	79.2	68.7
13 Ussuriski Raion	12	66.7	33.3	100.0	33.3	58.3	58.3	75.0	60.7
14 Sikhote Alin Zapovednik	26	88.0	80.0	84.0	76.0	66.7	80.0	48.0	74.7
15 Sineya	15	50.0	53.3	46.7	46.7	26.7	60.0	60.0	49.0
16 Terney Hunting Lease	24	76.2	66.7	59.1	60.9	40.0	45.8	15.0	52.0
Yearly Average		72.5	65.3	73.9	66.3	61.9	68.8	61.8	67.2

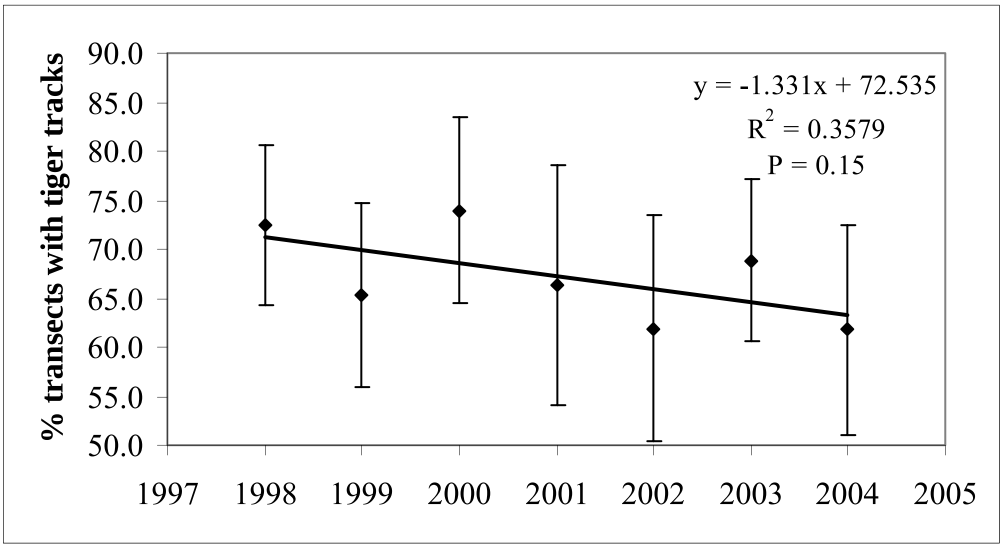


Figure 2. Overall trends in presence of tiger tracks on routes, averaged for all 16 sites of the Amur Tiger Monitoring Program, from the 1997-1998 winter through 2003-2004 winter season.

Percentage of routes with tiger tracks varied among the monitoring units from only 15% (Terney Hunting Lease) to 92% (Lazovski Zapovednik) among monitoring units in the 2002-2003 winter (Table 2). Four sites showed evidence of a significant downward trend last (Sikhote-Alin Zapovednik, Terney Hunting Lease, Bikin, Ussuriski Zapovednik) (Figure 3a-d), and only one showed evidence of a significant increase (Tigrini Dom) (Figure 3e). Sikhote-Alin Zapovednik and Terney Hunting Lease (neighboring units) continue a downward trend that was reported last year, as has Ussuriski Zapovednik. Tigrini Dom continues and upward trend that was also noted last year. The

Bikin monitoring unit is marginally significant only if the first year (1997-1998) is deleted from the analysis. We include this unit because, although the downward trend is marginal, it may be an important first warning. BolsheKhektsirski Zapovednik, which last year showed a significant downward trend in percent routes with tracks, was not statistically significant this year (Figure 3f), but the low numbers remained. This small unit appears to have suffered a reduction in tiger presence, and now remains at low levels.

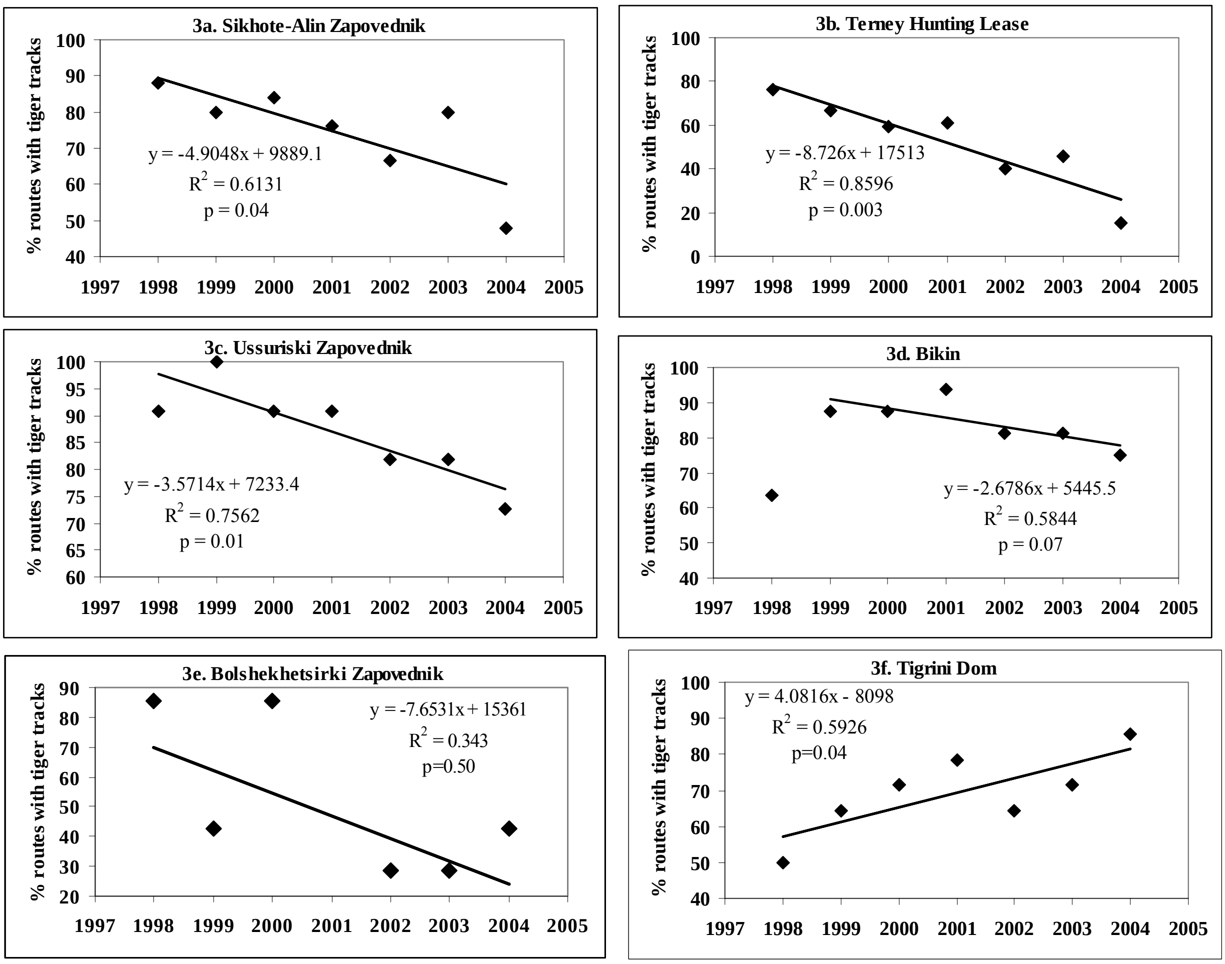


Figure 3a-f. Monitoring units which have shown a drop or increase ($P < 0.2$ for the regression) in percentage of survey routes with tiger tracks found across all 6 years of the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004 winter seasons. Bolshekhetsirski is included for comparison to status in previous year.

Track Counts on Survey Routes

Mean track density, adjusted for the number of days since the last snowfall (see Methods), provides an indication of relative abundance of tigers on monitoring sites (Table 3). Estimates of track density varied greatly among monitoring sites, more so than in any other year (range: 7.14 to 0.15 tracks/100 km/days since snow). In the 2003-2004 we recorded some of highest ever track densities on monitoring sites (7.14 in Bolshekhekhtsirski Zapovednik and 6.34 in Bikin) and also the lowest track density ever recorded (0.15 in Terney Hunting Lease). The large differences in mean track densities among sites resulted in large confidence intervals, making comparisons to other years difficult.

We looked for trends in the tiger population using track data by applying a regression analysis to all 16 monitoring sites averaged for each year (Figure 4), but because differences in sites may be masked by averaging, we also pay attention to trends in individual sites (Figures 5 and 6). When looking at the overall regression for 6 years combined, there is clearly no significant trend in track density ($r^2 = 0.027$) (Figure 4). The overall track density mean was slightly higher in the 2003-2004 winter than the previous year (2002-2003), reversing a declining trend over the past five years (Figure 4). However, this reversal was largely attributable to the two unusually high track densities reported in Bolshekhekhtsirski Zapovednik and Bikin. If these two sites are excluded, the overall track density average is very similar to last years' estimate (2003 = 1.12, and 2004 = 1.18 tracks/days since snow/100 km). Nonetheless, eleven of the 16 units (69%) reported higher track densities in the 2003-2004 winter than the previous

Table 3. Track density (tracks/days.since snow/100 km survey routes) of tigers on 16 sites during the first seven years of the Amur Tiger Monitoring Program.

Monitoring unit	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	Mean
1 Lazovski Zapovednik	3.62	2.19	3.40	3.57	2.52	3.50	4.15	3.28
2 Lazovski Raion	1.44	0.67	0.99	1.02	1.62	0.93	1.34	1.14
3 Ussurisk Zapovednik	3.28	9.66	6.21	6.15	3.49	2.62	2.12	4.79
4 Iman	0.96	2.81	0.86	0.76	0.81	0.65	0.52	1.05
5 Bikin	3.61	7.71	0.95	3.70	2.31	2.63	6.34	3.89
6 Borisovskoe Plateau	0.50	0.85	1.45	0.60	0.51	1.17	0.71	0.83
7 Sandagoy	0.47	0.66	0.34	0.41	0.23	0.73	0.40	0.46
8 Khor	0.44	0.80	1.67	1.50	1.35	0.45	1.05	1.04
9 Botchinski Zapovednik	0.88	0.74	1.20	1.29	1.04	0.46	0.58	0.88
10 Bolshekhekhtsirki Zapovedn	1.99	0.87	0.84	0.71	0.71	0.42	7.14	1.81
11 Tigrini Dom	0.67	1.47	1.13	1.51	1.66	1.27	2.21	1.42
12 Mataiski Zakaznik	0.63	1.18	0.73	2.42	0.38	0.39	0.59	0.90
13 Ussuriski Raion	1.01	0.61	1.93	1.44	1.70	0.45	0.72	1.12
14 Sikhote Alin Zapovednik	1.99	1.28	1.52	1.18	0.91	1.04	1.06	1.28
15 Sineya	0.24	0.33	0.47	0.58	0.38	0.58	0.86	0.49
16 Terney Hunting Lease	0.83	0.64	0.73	0.90	0.39	0.61	0.15	0.61
Yearly average	1.41	2.03	1.53	1.73	1.25	1.12	1.87	1.56

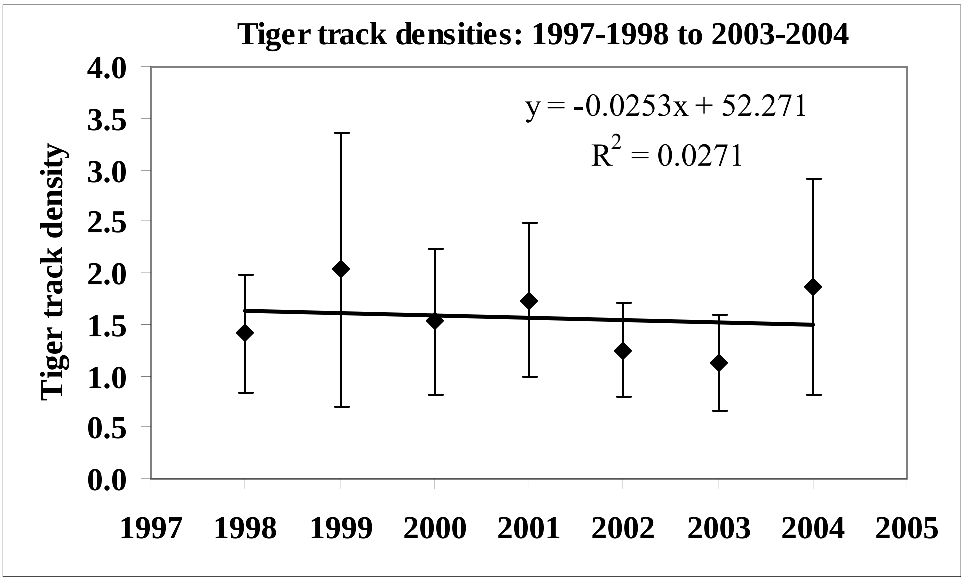


Figure 4. Density of tiger tracks (tracks/100 km/days since last snow) as an indicator of relative tiger abundance averaged across 16 sites included in the Amur Tiger Monitoring Program, winter 1997-1998 through 2003-2004.

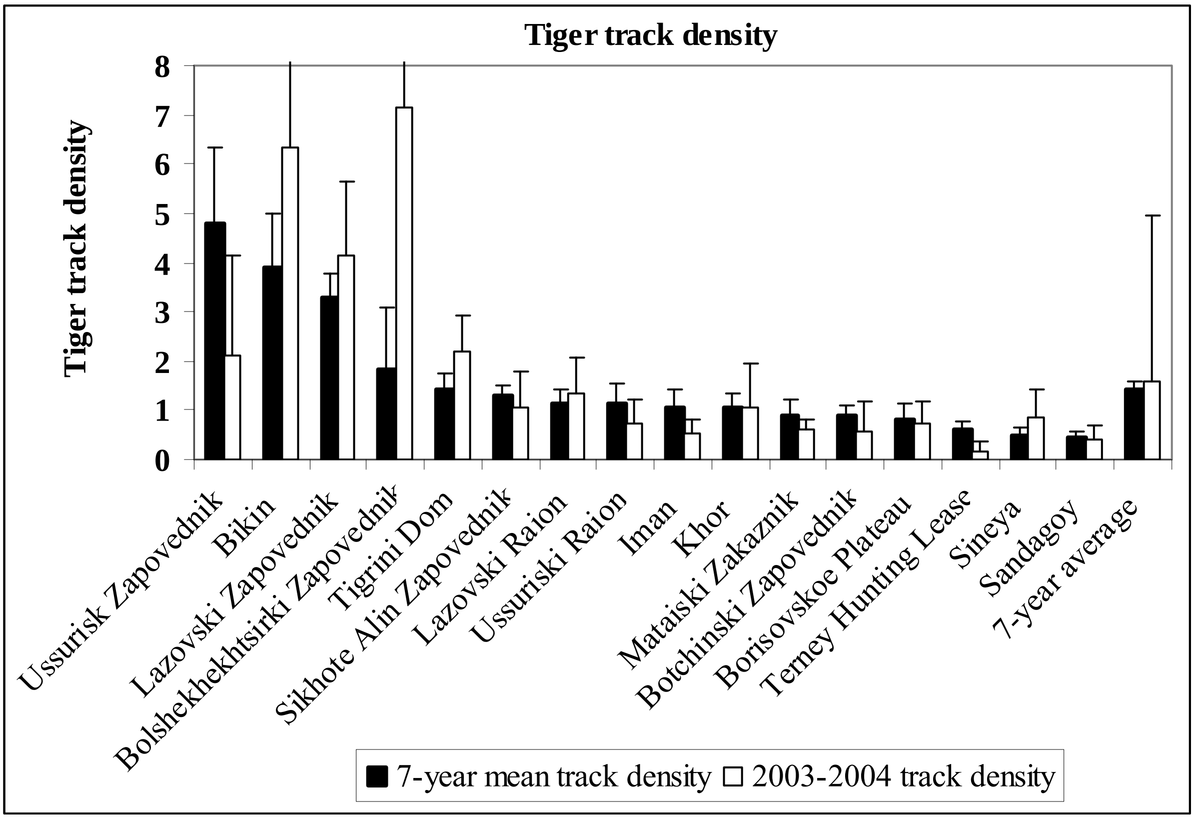


Figure 5. Comparison of the average tiger track density (tracks/100 km/days since last snow) over the past 7 years to the 2003-2004 tiger track density for each monitoring unit, and overall. Based on data collected across 16 sites included in the Amur Tiger Monitoring Program, winters 1997-1998 through 2003-2004.

winter, although differences were minor in many cases (Table 3). In general, it appears that with the exception of a few sites, track densities appear similar to the 7-year average for each monitoring site (Figure 5).

Unlike previous years, when Ussuriski and Lazovski Zapovedniks ranked highest in track densities estimates, the Bikin and Bolshekhekhtsirski Zapovednik were highest this year. Trends from previous years, however, continued in a relatively similar fashion for a number of the sites. Sikhote-Alin Zapovednik and neighboring unit Terney Hunting Lease continued to demonstrate falling track densities (Figure 6a-b), with track densities in Terney Hunting Lease reaching the lowest value of any unit over all 7 years. As with last year, Ussuriski Zapovednik also continued to show a decline in track densities, and now its neighboring monitoring unit, Ussuriski Raion, is also showing a downward trend (Figure 6c-d). The Khor monitoring unit also continues its

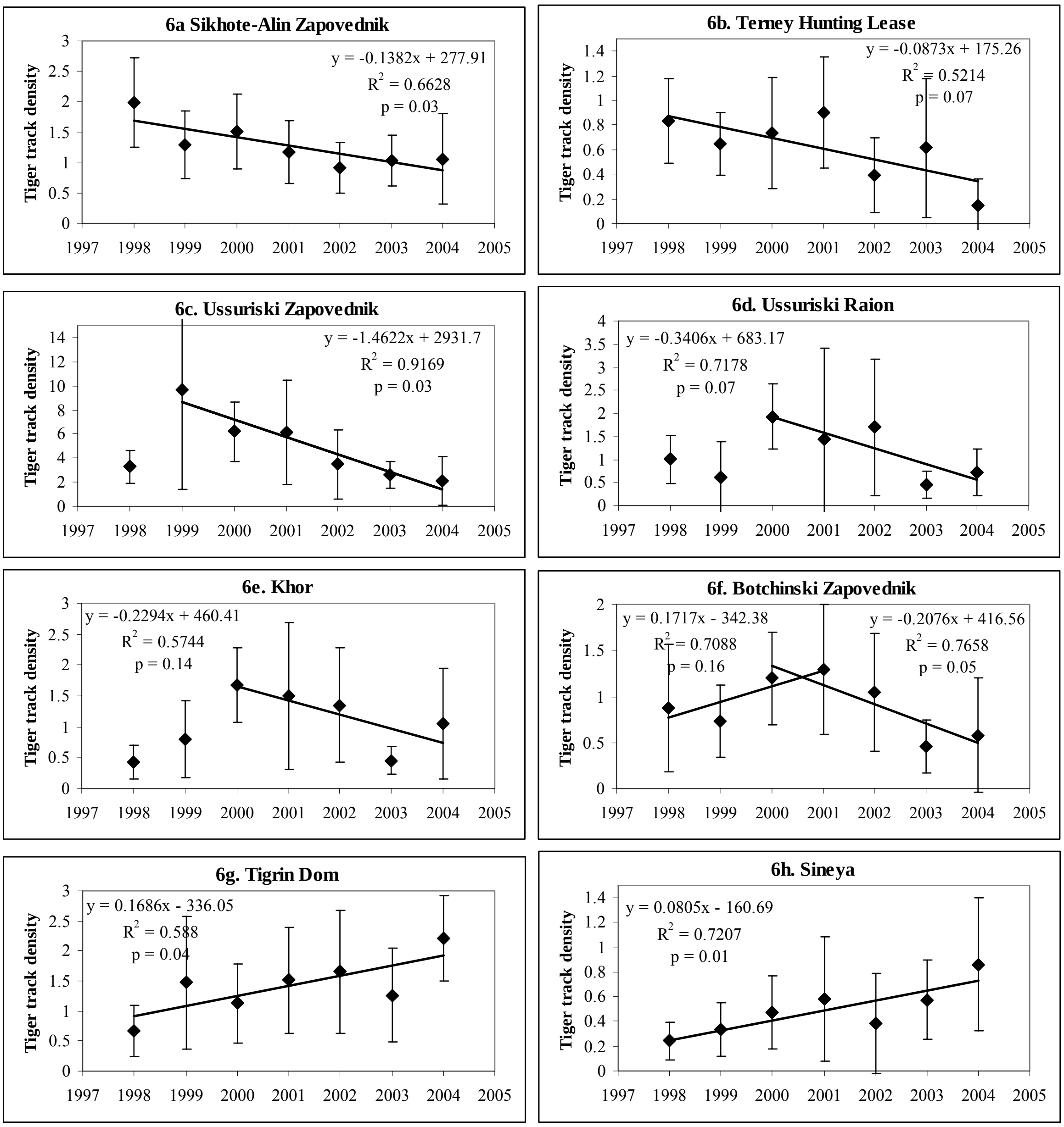


Figure 6a-h. Track density (tracks/100 km/days since last snow) and trends for 8 of the 16 sites of the Amur Tiger Monitoring Program which show trends from 1997-1998 through 2003-2004, or over shorter periods of time.

pattern of last year, with a relatively strong indication of decreasing track densities (Figure 6e). Botchinski Zapovednik, which showed an increasing trend over the first four years of the monitoring program, has reversed that pattern and is now showing a negative trend over the past 5 years (Figure 6f). While the above 6 units demonstrated relatively strong negative trends ($p \leq 0.07$ in 5 of 6 cases) only two units showed positive trends: both Tigrini Dom and Sineya continued growth trends which were noted in 2002-2003 winter (Figure 6g-h).

A comparison of trend lines for the two Krais suggests that tiger track densities tend to mirror each other, with track densities in Khabarovsk being slightly lower (Figure 7). However, this past winter was an exception in which track densities in Khabarovsk were higher than those reported in Primorye for the first time in 7 years (Figure 7). The large value reported for Khabarovsk is due to the very high track density reported in Bolshekhekhtsirski Zapovednik, and does not reflect the general pattern observed elsewhere. Both krais had demonstrated decreasing estimates of tiger track densities over the past 3 years, but in the most recent winter those trends were reversed, again in both krais.

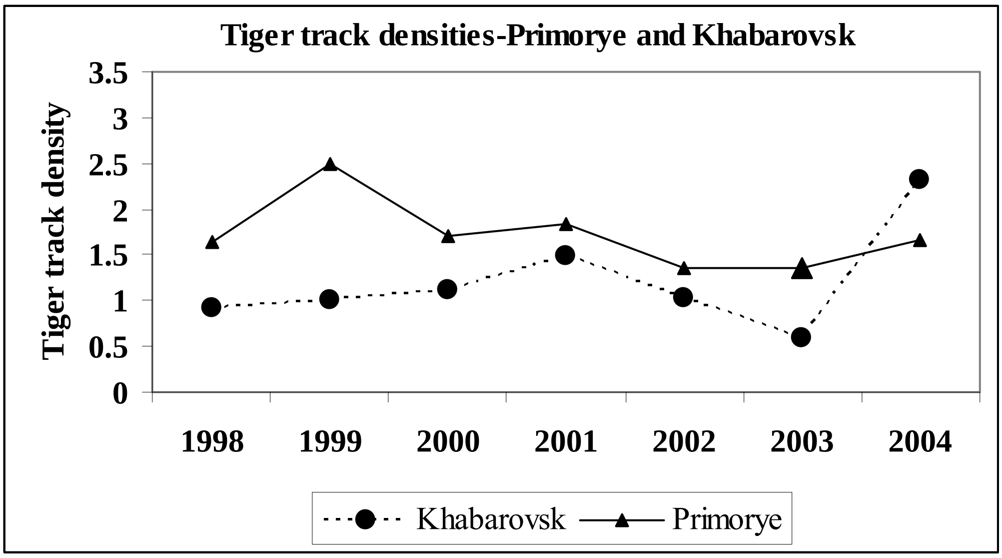


Figure 7. Comparison of trends for monitoring sites in Khabarovsk and Primorye, from 1998-2003.

Expert Assessment of Tiger Numbers on Monitoring Sites

For seven years the same coordinators have been making expert assessments on each of the 16 monitoring units across the range of Amur tigers in the Russian Far East. Although there is likely variation among coordinators in how they interpret track data to estimate tiger numbers, the year to year estimates within any given unit are likely to reflect real changes in tiger numbers, assuming coordinators interpret track data consistently. While the variation among coordinators (and therefore among sites) is more difficult to account for, we believe providing estimates of tiger abundance across all sites provides a mechanism for comparing density across the range of tigers.

Total number of tigers reported by coordinators on all 16 sites combined represented an all-time low in the 7 years the monitoring program has been ongoing (Table 4, Figure 8). The total count of tigers (83) was 17 animals below the average number of animals counted over the previous six years (100). The correlation coefficient associated with this trend is reasonably strong ($R^2 = 0.396$), and the decline is below the p-value of 0.2 ($p = 0.13$) which we consider of conservation significance, and we therefore consider this indicator a potentially important early warning signal. When converted to densities, the magnitude of this drop is partially masked by a few monitoring units with high densities, and much variation between sites. Although a small drop in the overall density estimate is noticeable (Table 5, Figure 9), the correlation coefficient is low ($R^2 = 0.247$) and the p-value is above the 0.20 cut-off ($p = 0.25$).

Table 4. Number of independent tigers (adults, subadults, and unknown), based on expert assessments of tiger tracks on 16 sites in the Russian Far East Amur Tiger Monitoring Program, during the first seven years of monitoring, 1997-1998 through 2003-2004.

	Independent tigers on monitoring unit						
Monitoring unit	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
1 Lazovski Zapovednik	6	9	10	11	12	9	10
2 Lazovski Raion	8	4	5	4	6	5	4
3 Ussurisk Zapovednik	6	10	4	5	4	6	7
4 Iman	8	6	5	6	6	4	5
5 Bikin	3	10	7	6	7	8	5
6 Borisovskoe Plateau	4	5	4	3	3	5	3
7 Sandagoy	6	6	5	7	3	7	5
8 Khor	3	4	4	4	4	5	5
9 Botchinski Zapovednik	3	3	4	4	6	4	2
10 Bolshekhekhtsirki Zapovednik	2	1	2	1	1	1	2
11 Tigrini Dom	4	6	4	4	5	6	5
12 Mataiski Zakaznik	3	5	4	4	5	5	5
13 Ussuriski Raion	6	1	2	2	9	6	5
14 Sikhote Alin Zapovednik	21	21	23	17	17	16	12
15 Sineya	5	6	5	7	5	7	5
16 Terney Hunting Lease	10	11	13	11	5	7	3
Grand Total	98	108	101	96	98	101	83

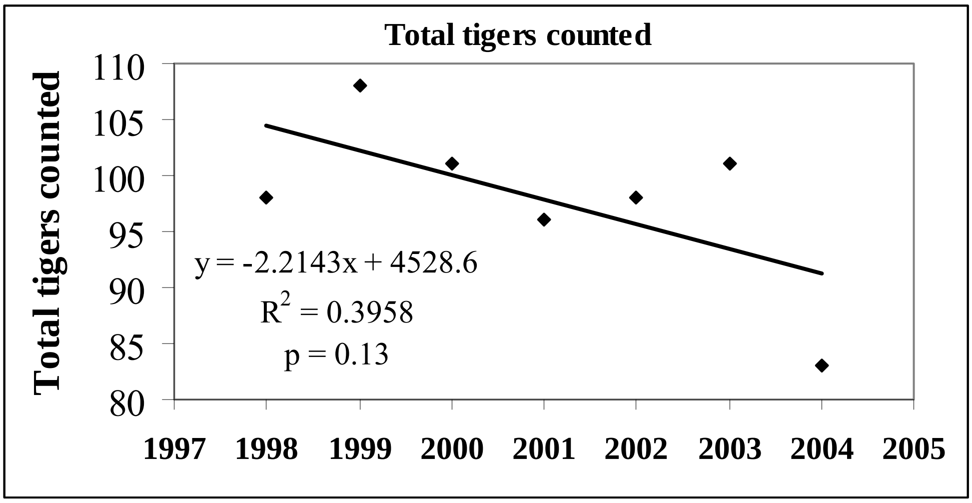


Figure 8. Trend in number of independent tigers counted on monitoring units, based on expert assessments for 16 sites in the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004 winter seasons.

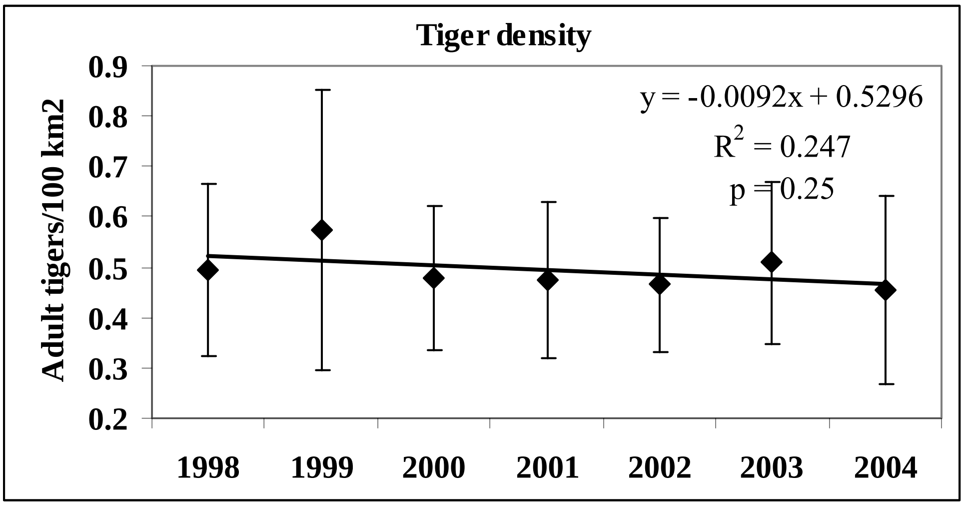


Figure 9. Trend in density of independent tigers counted on monitoring units, based on expert assessments for 16 sites in the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004 winter seasons.

Tiger density varied greatly across monitoring units, from 1.7animal/100 km^2 in Ussuriski Zapovednik, to 0.07/100 km^2 in Botchinski Zapovednik (Table 5). The three southern and central zapovedniks (Ussuriski, Lazovski, and Sikhote-Alin), which have the highest 7-year average densities (Table 4), once again reported the three highest densities of independent tigers (all greater than 0.50/100 km^2), although density in Sikhote-Alin continues to drop (see below) (Table 4).

Although expert assessments of tiger densities appeared to be stable when averaged across all sites, individual sites are showing a range of trends. Over the seven years of monitoring, only six sites have demonstrated no significant trends in tiger densities (Lazovski Raion, Bolshekhekhtsirski Zapovednik, Mataiski Zakaznik, Borisovskoe Plateau, Sandagoy, and Sineya). Four sites show evidence of declining tiger densities (Sikhote-Alin, Terney Hunting Lease, Iman, and the Bikin (Figure 10a-d). Last year, three of those sites (all except the Bikin), had the same negative trend, providing supporting evidence that declines are real.

Five sites have demonstrated signs that tiger densities are increasing – Ussuriski Zapovednik and Raion, Lazovski Zapovednik, Khor and Tigrini Dom in Khabarovsk. Only two of these sites (Lazovski and Khor) showed significant upward trends (i.e., $p < 0.2$) last year.

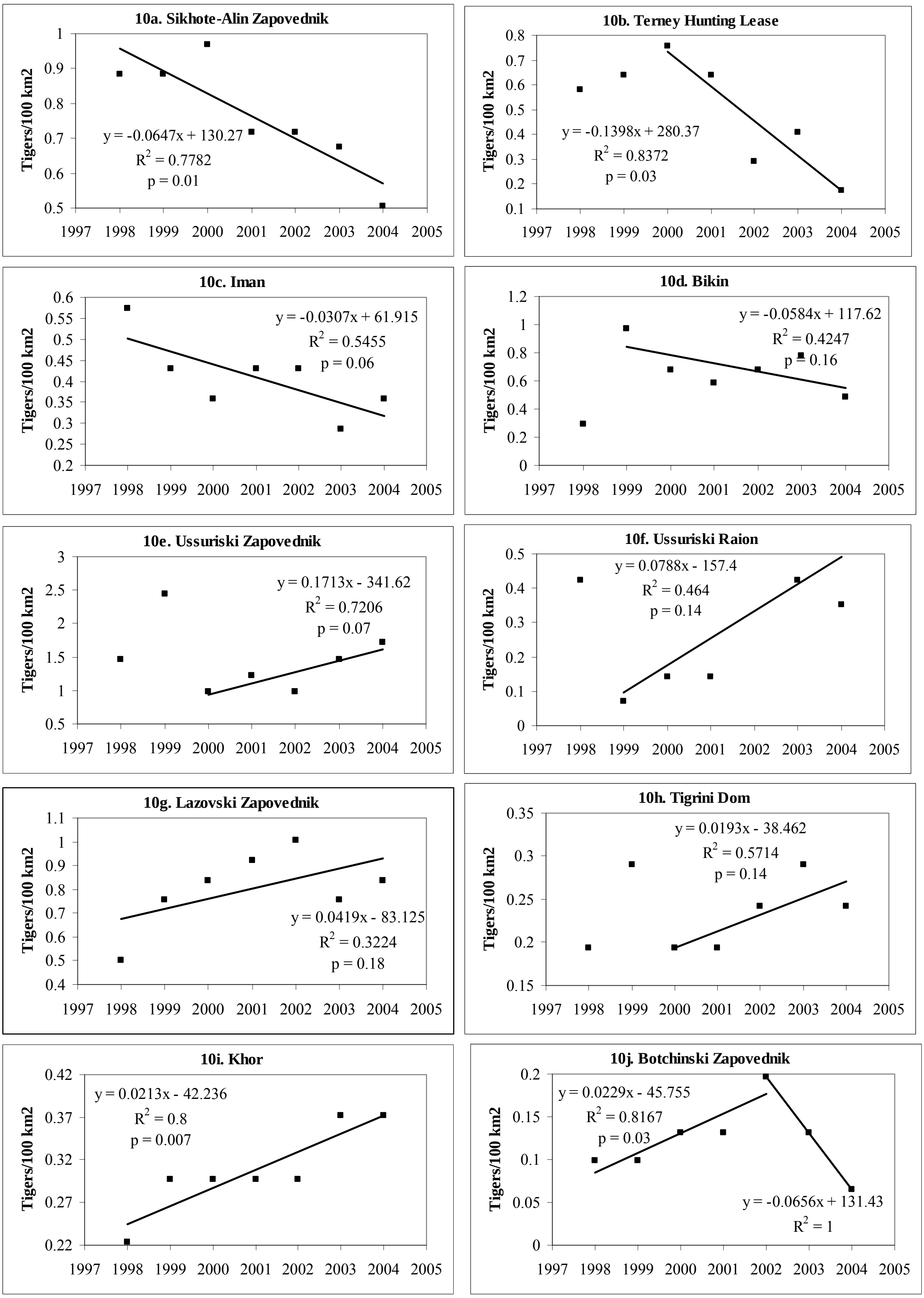


Figure 10a-h. Trend regression analyses for individual monitoring sites with P-values of a linear regression < 0.20 for changes in density of independent tigers across the 7 years of the monitoring program, winters 1997-1998 through 2003-2004.

Table 5. Density of independent tigers (adults, subadults, and unknown), based on expert assessments of tiger tracks on 16 sites in the Russian Far East Amur Tiger Monitoring Program, during the first seven years of monitoring, 1997-1998 through 2003-2004.

	Independent tigers/100 km^2							
Monitoring unit	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	7-year average
3 Ussurisk Zapovednik	1.47	2.45	0.98	1.22	0.98	1.47	1.71	1.47
1 Lazovski Zapovednik	0.50	0.75	0.84	0.92	1.01	0.75	0.84	0.80
14 Sikhote Alin Zapovednik	0.88	0.88	0.97	0.72	0.72	0.67	0.51	0.76
5 Bikin	0.29	0.97	0.68	0.58	0.68	0.78	0.49	0.64
7 Sandagoy	0.61	0.61	0.51	0.72	0.31	0.72	0.51	0.57
2 Lazovski Raion	0.81	0.41	0.51	0.41	0.61	0.51	0.41	0.52
16 Terney Hunting Lease	0.58	0.64	0.76	0.64	0.29	0.41	0.17	0.50
15 Sineya	0.43	0.51	0.43	0.60	0.43	0.60	0.43	0.49
4 Iman	0.57	0.43	0.36	0.43	0.43	0.29	0.36	0.41
13 Ussuriski Raion	0.42	0.07	0.14	0.14	0.64	0.42	0.35	0.31
8 Khor	0.22	0.30	0.30	0.30	0.30	0.37	0.37	0.31
10 Bolshekhekhtsirki Zapovednik	0.42	0.21	0.42	0.21	0.21	0.21	0.42	0.30
6 Borisovskoe Plateau	0.27	0.34	0.27	0.20	0.20	0.34	0.20	0.26
11 Tigrini Dom	0.19	0.29	0.19	0.19	0.24	0.29	0.24	0.23
12 Mataiski Zakaznik	0.12	0.20	0.16	0.16	0.20	0.20	0.20	0.18
9 Botchinski Zapovednik	0.10	0.10	0.13	0.13	0.20	0.13	0.07	0.12
Yearly average	0.49	0.57	0.48	0.47	0.46	0.51	0.46	0.49

Assessment of Trends in Numbers of Amur Tigers over the past Seven Years

We use three indicators to assess changes in the status of the Amur tiger population in the Russian Far East over the past seven years. Because any single measurement has its inherent biases and errors associated with it, we believe that by using a weighting system that compares three different estimators will give a more balanced assessment of the status of tigers at any given point of time. Our monitoring program is designed not to provide an assessment of the absolute numbers of tigers in either Primorski or Khabarovski Krai, but to provide an assessment of changes in numbers. We believe that such a monitoring system, is sufficiently accurate, should act as an "early warning signal" which will allow the appropriate governmental agencies to react with this information.

We provide a summary of the results of the three analyses of tiger abundance (percentage of transects with tigers present, tiger track density, and expert assessment of tiger density) in Table 6. We record each instance where a potential trend was identified (i.e. the p-value, which provides an estimate of the probability of a trend being real, is less than 0.2) for each of the monitoring sites for each of the three estimators of tiger abundance. If significant positive trend was present, we grade each such episode as "+", and similarly, each significant negative trend as a "-". Summing for each monitoring site, we can derive values ranging from complete agreement that a population is increasing (+100) to complete agreement that a population is decreasing ("-100"). Because there are three indicators, gradations come in thirds (e.g., 33, 66).

For half of the monitoring sites, all three indicators were in agreement concerning the trend of tigers in that site, while in 5 sites there was some combination of neutral estimators (no indication of change) and either a decrease or decrease. In only three sites were there conflicting results where one estimator suggested an increase in tiger numbers, while another suggested a decrease (Ussuriski Zapovednik, Ussuriski Raion, and Khor). Combination of these three indicators appears to provide a reasonable and conservative assessment of status of tigers in each of the sites.

Table 6. Comparison of three estimators of tiger abundance on 16 monitoring sites of the Amur Tiger Monitoring Program. Sites are ranked from areas of greatest concern (where all three indicators suggest tigers are decreasing) to areas of least concern (where all three indicators suggest tiger numbers are increasing. Based on data from 7 winters (1997-1998 through 2003-2004). Ratings represent the extent of agreement in estimators, and the direction in trend (decreasing/increasing) of the population.

		Tiger abundance					
#	Monitoring unit	% tiger presence on rtes	Tiger track density	Tiger density	Rating	Conflicting results	Scale of Concern
14	Sikhote-Alin Zapovednik	-	-	-	-100		Great concern:
16	Terney Hunting lease	-	-	-	-100		areas where tigers
5	Bikin River	-	0	-	-66		are decreasing
9	Botchinski Zapovednik	0	-	-	-66		
4	Vaksee (Iman)	0	0	-	-33		
3	Ussuriski Zapovednik	-	-	+	-33	+	
8	Khor	0	-	+	0	+	
13	Ussuriski Raion	0	-	+	0	+	
2	Lazovski Raion	0	0	0	0		
6	Borisovkoe Plateau	0	0	0	0		
7	Sandagoy (Olginski Raion)	0	0	0	0		
10	Bolshe Khekhtsirski Zapovedni	0	0	0	0		
12	Matai Zakaznik	0	0	0	0		
1	Lazovski Zapovednik	0	0	+	33		Areas where tigers
15	Sineya (Chuguevski Raion)	0	+	0	33		are increasing:
11	Tigrini Dom	+	+	+	100		No concern

The results suggest that Terney Raion, including Sikhote-Alin Zapovednik and Terney Hunting Lease, is an area of great concern. On both monitoring sites, which lie adjacent to each other, all three estimators of tiger abundance suggest that the tiger population there is decreasing. This is the third year in a row that the monitoring program has detected a change in tiger numbers in this region, but this year provides the clearest indication that numbers there are decreasing.

The Bikin monitoring site, and to lesser extents the Iman and Ussuriski Zapovednik, also show signs that tiger numbers may be decreasing in those areas. The indicators are not as strong, and for Ussuriski Zapovednik there was discordance among the indicators (two suggesting a decrease, one suggesting an increase). Nonetheless, we identify these sites as potential areas of concern.

Five sites (Borisovkoe Plateau, Lazovski Raion, Sandagoy-Olginski Raion, Bolshekhekhetsirski Zapovednik, and Matai Zakaznik) show some fluctuations over time, but cumulatively all appear to have retained relatively stable populations of tigers over the seven years of the monitoring period.

Lazovski Zapovednik and Sineya (Chuguevski Raion) both had one estimator which suggested that tiger numbers may be increasing at those sites. Further monitoring will help to determine whether these trends are maintained.

Only one site – Tigrini Dom in Khabarovsk – showed positive growth trends for all three estimators of tiger abundance. This site appears to be the only place, of all 16 monitoring sites, where growth in the tiger population may be taking place.

The pattern that emerges from this assessment is that there is great variation in trends of tiger numbers across their range, making it difficult to extrapolate these results to the total population. However, we can average the values of trend estimators for all 16 sites to derive a crude assessment of the status of the Amur tiger in the Russian Far East (Figure 11). Interpreting the results of all three estimators, it appears that 4 to 6 sites may be suffering a decline in tiger numbers, and only 1 to 3 may be witnessing an increase (Table 6). All other sites appear relatively stable. Collectively, these results suggest that overall there are more sites undergoing a decline in tiger numbers than are undergoing an increase in numbers, and therefore, overall, it appears more likely that the Amur tiger population may be decreasing in the Russian Far East.

These results are based on the best possible available information, but there is still room for error in these results. Nonetheless, in light of the present situation, we feel it is timely that the Full Range Amur Tiger Survey will be conducted in the 2004-2005 winter. This count will provide more details on the status of the tiger population, and provide an opportunity to verify the findings reported here.

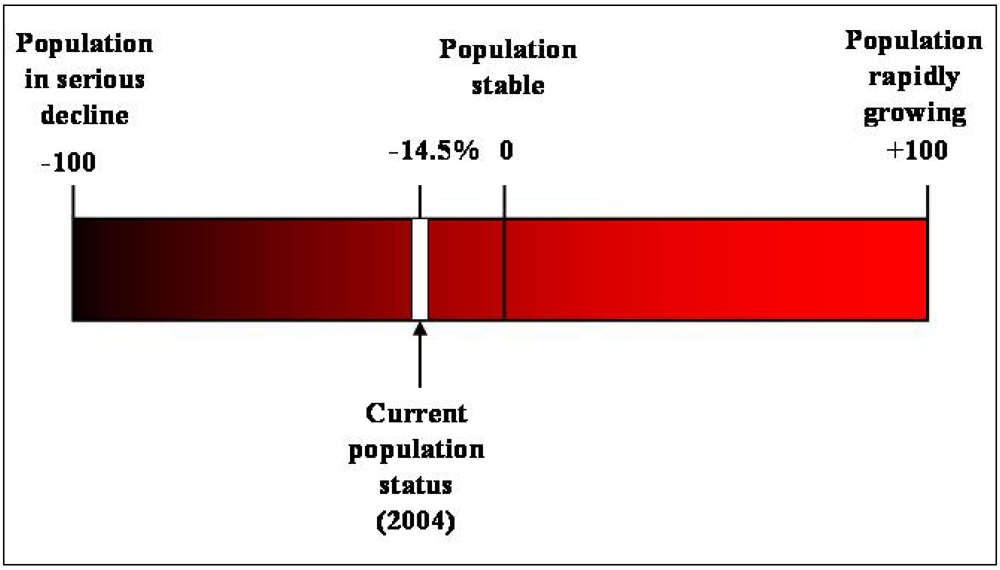


Figure 11. Estimate of status of the Amur tiger population, based on cumulative average of trends for tigers within 16 sites of the Amur Tiger Monitoring Program. Based on data collected from 1997-1998 winter through 2003-2004 winter.

Reproduction on Monitoring Sites

Expert assessments of tiger numbers and sex-age structure provide an opportunity to track changes in reproduction over time. We adjusted the number of litters in each monitoring unit to include tracks of cubs that were reported without adult females. These individuals may represent either young cubs temporarily without mothers, or cubs which have lost their mothers, but nonetheless they represent reproduction that has occurred on or partially on the monitoring units. Therefore, we have attempted to include such individuals in our estimates for this year.

Since the 1997-1998 winter, the number of litters reported on all sites combined has ranged from 11 to 26, with 15 litters reported for the 2003-2004 winter, slightly under the 7-year average number of 16.4 litters per year (Table 7). The number of cubs reported for this year (23) was identical to cub production in 2002-2003, and virtually the same as the 7-year average (23.7) (Table 8). The percentage of monitoring units without cubs has ranged from 18.7 to 56.7%, with this past winter (2003-2004), at 31%, close again to the 7-year average of 35%. In general, these values suggest that overall reproduction across the range was close to average for the 2003-2004 winter monitoring period.

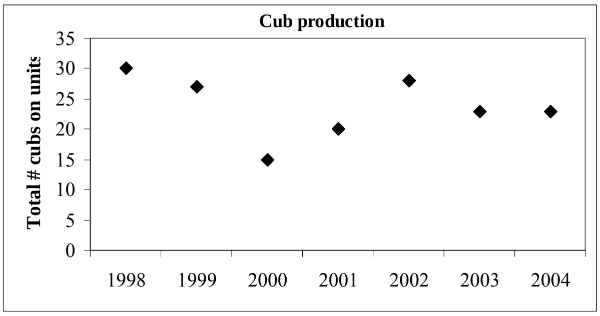


Figure 12. Total cub production for the 7 winter seasons, 1997-1998 through 2003-2004, on all 16 units combined for the Amur Tiger Monitoring Program.

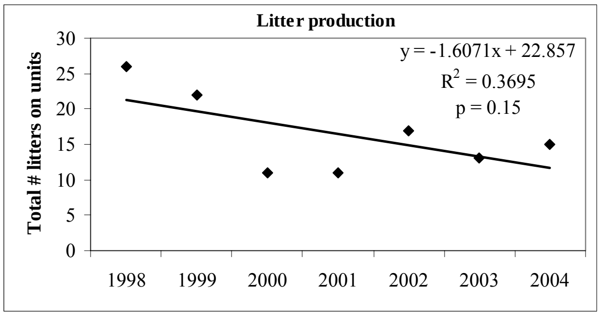


Figure 13. Litter production (total number of litters produced) for the 7 winter seasons, 1997-1998 through 2003-2004, on all 16 units combined for the Amur Tiger Monitoring Program.

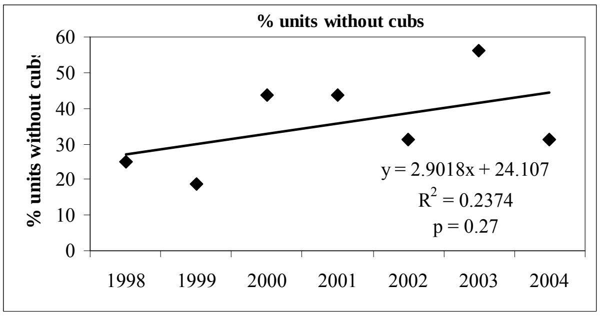


Figure 14. Percent of 16 monitoring sites without cubs in the Amur Tiger Monitoring Program, based on 7 years of monitoring, winter 1997-1998 through 2003-2004.

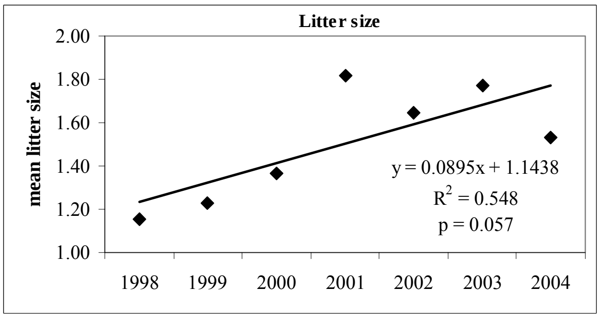


Figure 15. Mean litter size on 16 sites over 7 years of the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004.

Table 7. Number of litters produced on each monitoring unit for 7 winters, 1997-1998 through 2003-2004, based on expert assessments of tiger tracks for the Amur Tiger Monitoring Program.

		Litter production							
	Monitoring unit	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	Total litter
1	Lazovski Zapovednik	1	1		2	2	3	1	10
2	Lazovski Raion	3	2		1	4	1	2	13
3	Ussurisk Zapovednik	3	4	1	1	2	1	2	14
4	Iman		2	1	1	1			5
5	Bikin	3		1		1	2		7
6	Borisovskoe Plateau	2	1	1	1		1		6
7	Sandagoy	3	1			1		1	6
8	Khor	1	1			1		1	4
9	Botchinski Zapovednik	1		2	1			1	5
10	Bolshekhekhtsirki Zapovednik		1						1
11	Tigrini Dom		1	1	1	2		1	6
12	Mataiski Zakaznik	3	2	1		1	2	2	11
13	Ussuriski Raion		1					1	2
14	Sikhote Alin Zapovednik	4	3	2	2		3	2	16
15	Sineya	1				1		1	3
16	Terney Hunting Lease	1	2	1	1	1			6
	Totals	26	22	11	11	17	13	15	115

Table 8. Number of cubs produced on each monitoring unit for 7 winters, 1997-1998 through 2(2004, based on expert assessments of tiger tracks for the Amur Tiger Monitoring Program.

		Cub production							
	Monitoring unit	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	Total cub productio
1	Lazovski Zapovednik	2	2		5	4	7	3	23
2	Lazovski Raion	3	3		3	7	1	3	20
3	Ussurisk Zapovednik	4	4	3	2	4	3	4	24
4	Iman		3	2	2	1			8
5	Bikin	3		1		2	2		8
6	Borisovskoe Plateau	2	1	1	1		2		7
7	Sandagoy	4	1			2		1	8
8	Khor	1	1			1		1	4
9	Botchinski Zapovednik	1		2	2			2	7
10	Bolshekhekhtsirki Zapovednik		1						1
11	Tigrini Dom		1	1	1	2		1	6
12	Mataiski Zakaznik	4	2	2		1	4	3	16
13	Ussuriski Raion		2					2	4
14	Sikhote Alin Zapovednik	4	4	2	3		4	2	19
15	Sineya	1				3		1	5
16	Terney Hunting Lease	1	2	1	1	1			6
	Totals	30	27	15	20	28	23	23	166

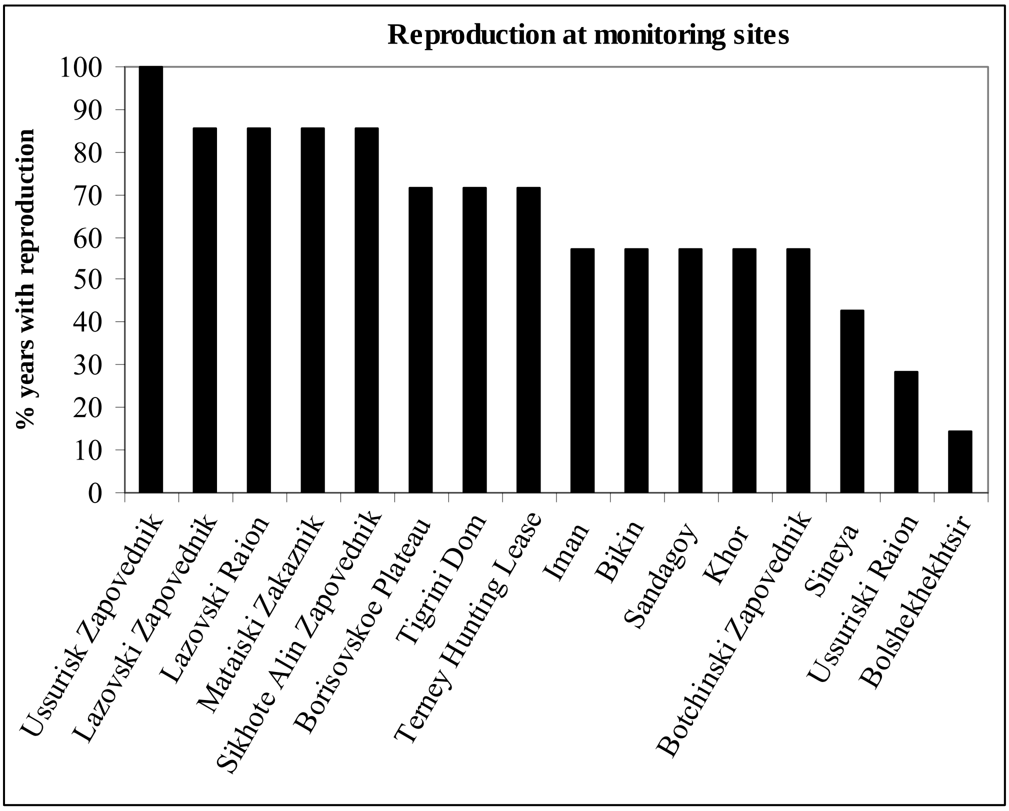


Figure 16. Percentage of years when reproduction was reported, for each of the 16 sites included in the Amur Tiger Monitoring Program, for the seven years 1997-1998 through 2003-2004.

What had been an unusual situation in regards to tiger reproduction on monitoring sites appears to be slightly changing. Over the past few years, total cub production on all 16 units has varied some (for instance, in 2000 there was a drop), but in general has been relatively stable (Figure 12). However, overall litter production appears to have dropped since the beginning of the monitoring program (Figure 13), as reflected in the fact that the number of units reporting reproduction (presence of cubs) is decreasing over time (Figure 14). Despite these trends, overall cub production has remained fairly stable (Figure 12), apparently due to increasing litter size (Figure 15). This situation represents a potentially large threat to the tiger population, because maintenance of cub production was dependent on continual increasing litter size. Since there are clear limits to how many cubs females can raise, the fact that reproduction was declining on many sites was a great concern. However, analysis of the data over the past four years suggests that all four parameters of interest (cub production, litter production, % units with cubs, and litter size) has largely stabilized (Figures 12-15). Additionally, the trends that have been detected may have been partially an artifact of changes in data collection protocols. Much of the reason for the existence of trends were the low values reported during the first two years of the monitoring program. Details of how to report females with cubs were more fully developed at the end of the second year of the monitoring program, so we may simply be witnessing the effect of variation in how data was collected. Nonetheless, monitoring of cub and litter production is a vital component of the monitoring program, and needs to be continued.

Table 9. Litter size of all litters recorded in 7 winters of the Amur Tiger Monitoring Program, based on expert assessment of tracks.

	Litter size			
Year	1	2	3	Total
1997-1998	23	4	0	27
1998-1999	17	5		22
1999-2000	8	2	1	11
2000-2001	4	5	2	11
2001-2002	8	7	2	17
2002-2003	7	2	4	13
2003-2004	8	6	1	15
Total	75	31	10	116

Over the seven years of monitoring, cub production has been recorded in each of the 16 monitoring sites at least once (Table 7), but only one site, Ussuriski Zapovednik has reported reproduction in each of those 7 years. Four more sites - Sikhote-Alin Zapovednik, Lazovski Zapovednik, Lazovski Raion, Mataiski Zakaznik – have reported cubs in 6 of 7 years. Four of those five sites are either zapovedniks or a zakaznik. Reproduction was lowest in Sineya, Ussuriski Raion, and Bolshekhekhtsirki Zapovednik, where there were reports of reproduction in only 3, 2, and 1 year, respectively.

Litter size decreased from the previous year (Figure 15), when there was an unprecedented 4 litters of 3 cubs reported (Table 9). In 2003-2004 there was only a single litter of 3 reported, and the majority was litters composed of a single cub, as has been the case for the entire period of monitoring.

Ungulate Populations on Monitoring Sites

Red deer, wild boar, and sika deer are the primary prey of Amur tigers. Roe deer are taken relatively infrequently, and may be considered secondary prey. The ability of the Amur tiger population to survive will be largely determined by the prey base available. Therefore, monitoring the prey base, and understanding trends or changes in abundance of prey species, is an integral part of monitoring the Amur tiger population.

We used track density as an indicator of ungulate abundance on Amur tiger monitoring units. As in previous years, prey numbers varied greatly among sites (Table 10). To attempt to understand how density estimates varied across monitoring sites and time, we conducted a regression analysis to look for trends across time (7 years of monitoring), looking first at trends for all sites combined, and then separately for each site and each species. We report all sites where the probability is less than 0.2 that the slope is not zero, with the understanding that we are looking for general trends and potential early warning signs across the region and within each monitoring site.

Red deer.

Red deer track densities varied greatly among monitoring sites, from 34.3 tracks/10 km in Bolshekhekhetsirski Zapovednik to 0.18 in Lazovski Zapovednik, not including Boriskovskoe Plateau, where they are no longer reported. As in past years, track count densities of red deer were highest in Bolshe-Khekhtsirski Zapovednik, and secondly, in Sikhote-Alin Zapovednik (Table 7). While one might expect red deer density to decrease with increasing latitude, in fact this was not the case (Figure 15). Red deer reach their highest densities in the central portion of their range in the Russian Far East, and their lowest densities in the south where competition (or perhaps disease) with sika deer appears to be decreasing their densities (Figure 17): in Borisovkoe Plateau red deer no longer occur (Table 10), although 30 years ago they were considered the most abundant ungulate in the area (Pikunov, pers. comm.).

Looking at all monitoring sites combined, estimates of red deer track density fluctuated more in the past 4 years, but there was no significant trend in red deer numbers over the seven years (Figure 18).

Table 10. Mean track density (tracks/10 km of transect, sample size (number of routes) and standard deviation from the mean on 16 units of the Amur Tiger Monitoring Program, for the 2003-2004 winter.

	Track density/10 km											
	Red deer			Wild boar			Sika deer			Roe deer		
Monitoring Unit	mean	n	Std Dev	mean	n	Std Dev	mean	n	Stdev	mean	n	Stdev
1 Lazovski Zapovednik	5.53	12	11.86	11.18	12	21.95	83.71	12	83.29	0.97	12	1.65
2 Lazovski Raion	0.18	11	0.61	3.48	11	7.97	30.34	11	58.93	0.97	11	2.97
3 Ussurisk Zapovednik	3.56	11	4.77	4.15	11	7.80	22.95	11	26.72	1.53	11	1.88
4 Iman	5.36	12	3.93	6.15	12	7.62	0.00	12	0.00	3.76	12	6.12
5 Bikin	4.54	16	3.22	4.67	16	7.20	0.00	16	0.00	4.70	16	3.25
6 Borisovskoe Plateau	0.00	14	0.00	5.42	14	4.38	28.29	14	38.71	4.36	14	4.36
7 Sandagoy	5.07	16	5.29	5.40	16	7.78	1.26	16	1.50	3.26	16	2.62
8 Khor	6.35	19	4.67	2.07	19	3.30	0.00	19	0.00	6.45	19	7.41
9 Botchinski Zapovednik	11.58	14	6.12	0.00	14	0.00	0.00	14	0.00	7.78	14	5.37
10 Bolshekhekhtsirki Zapovednik	34.34	7	26.16	4.89	7	5.76	0.00	7	0.00	4.63	7	6.94
11 Tigrini Dom	1.69	14	1.95	0.35	14	0.74	0.00	14	0.00	0.47	14	0.60
12 Mataiski Zakaznik	3.61	24	3.58	1.01	24	1.84	0.00	24	0.00	1.55	24	1.89
13 Ussuriski Raion	1.48	12	2.68	1.59	12	1.99	0.62	12	1.17	2.46	12	3.02
14 Sikhote Alin Zapovednik	20.23	25	20.83	2.48	25	3.90	18.04	25	45.00	21.43	25	20.83
15 Sineya	1.82	15	1.59	0.52	15	0.78	0.00	15	0.00	2.15	15	1.26
16 Terney Hunting Lease	3.75	24	6.01	0.86	24	1.58	1.17	24	3.18	6.33	24	8.74

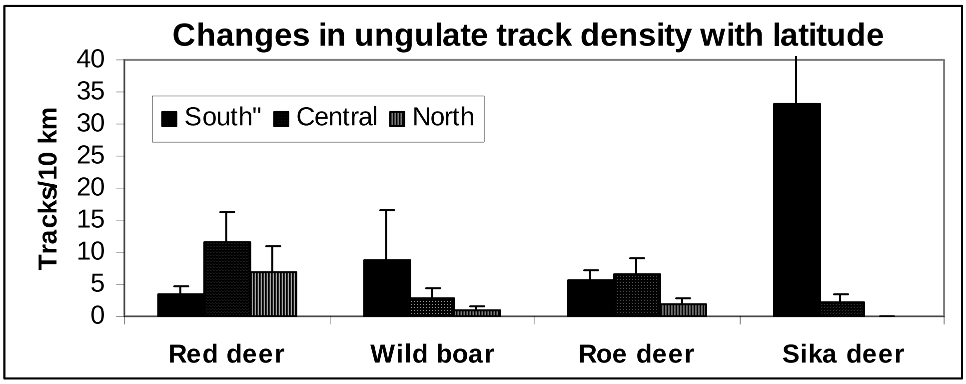


Figure 17. Changes in ungulate track density (fresh tracks/10 km of routes) with changes in latitude, with each monitoring site categorized as southern, central, or northern (see Table 1). The average track density for each site for each year considered a sampling unit (n = 64).

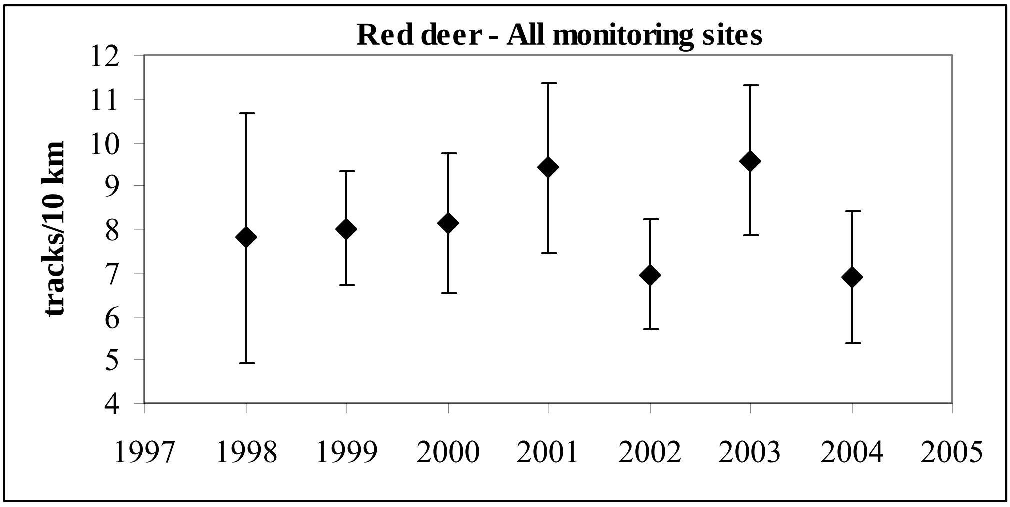


Figure 18. Average red deer track density and 95% confidence intervals for all sites except Borisovkoe Plateau (where red deer are absent) for the first six years of the Amur Tiger Monitoring Program, 1997-1998 though 2003-2004.

However, the pattern of trends within monitoring sites is complicated, with 4 sites showing negative trends, and 2 sites showing positive trends (Figure 19). Sikhote-Alin Zapovednik and neighboring Terney Hunting Lease both appear to have decreasing numbers of red deer over the 7-year study period, coincident with the decrease in tiger numbers. Ussuriski Zapovednik and Lazovski Raion also appear to have decreasing numbers, which may be related to the overall downward trend of red deer in southern Primorye. The only places where there is evidence that red deer may be increasing is in the two northern zapovedniks Bolshekhekhtsirski and Botchinski (Figure 19). Overall, it appears that red deer are decreasing in at least some of the southernmost sites (having already disappeared from Borisovkoe Plateau monitoring site), are decreasing in the Terney-Sikhote-Alin area, and may be increasing in the north only in the protected areas.

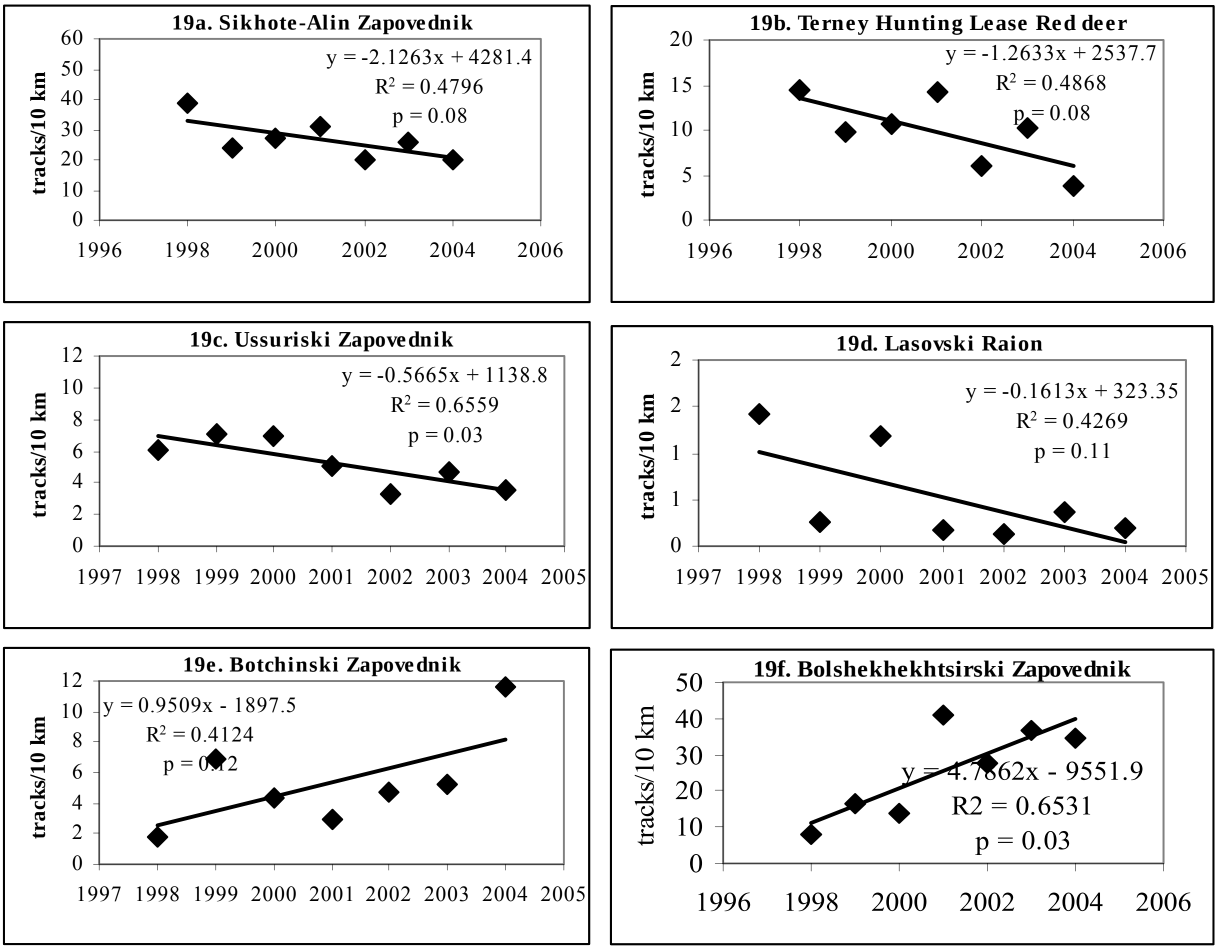


Figure 19a-h. Changes in red deer densities, as measured by fresh tracks/10 km along routes in 8 of the 16 monitoring sites of the Amur Tiger Monitoring Program.

Wild boar.

Wild boar populations are known to fluctuate more dramatically than deer populations, and because they are commonly found in groups, are more problematic to accurately estimate density.

Wild boar populations varied greatly amongst sites, both in their densities, and their dynamics. Track density varied from 11 tracks/10 km in Bolshe-Khekhtsirski Zapovednik to 0 encounters in Botchinski Zapovednik, where wild boar tracks have not been reported since the first year of the monitoring program. As with red deer, trends in the wild boar populations varied dramatically among sites (Figure 20). In Sikhote-Alin and Terney Hunting Leases, track density estimates suggest that wild boar decreased through the 2000-2001 winter, and then have remained at low levels (Figure 20a-b). In the Ussuriski area, data from both Ussuriski Zapovednik and Raion indicated that boar numbers there have also decrease (Figure 20c-d). However, there are strong indicators that boar numbers have increased in Lazovski Zapovednik and neighboring Lazovski raion (Figure 20e-f). Two other sites, Sandagoy in Olginski Raion (Figure 20g), and Khor in Khabarovsk (Figure 20h), also show increasing trends in wild boar numbers, while two other sites in Khabarovsk, Tigrini Dom (Figure 20i) and Matai Zakaznik (Figure 20j) show identical patterns of an increase in boar numbers through 2000 or 2001, followed by a decline, with a possible rebound in effect now.

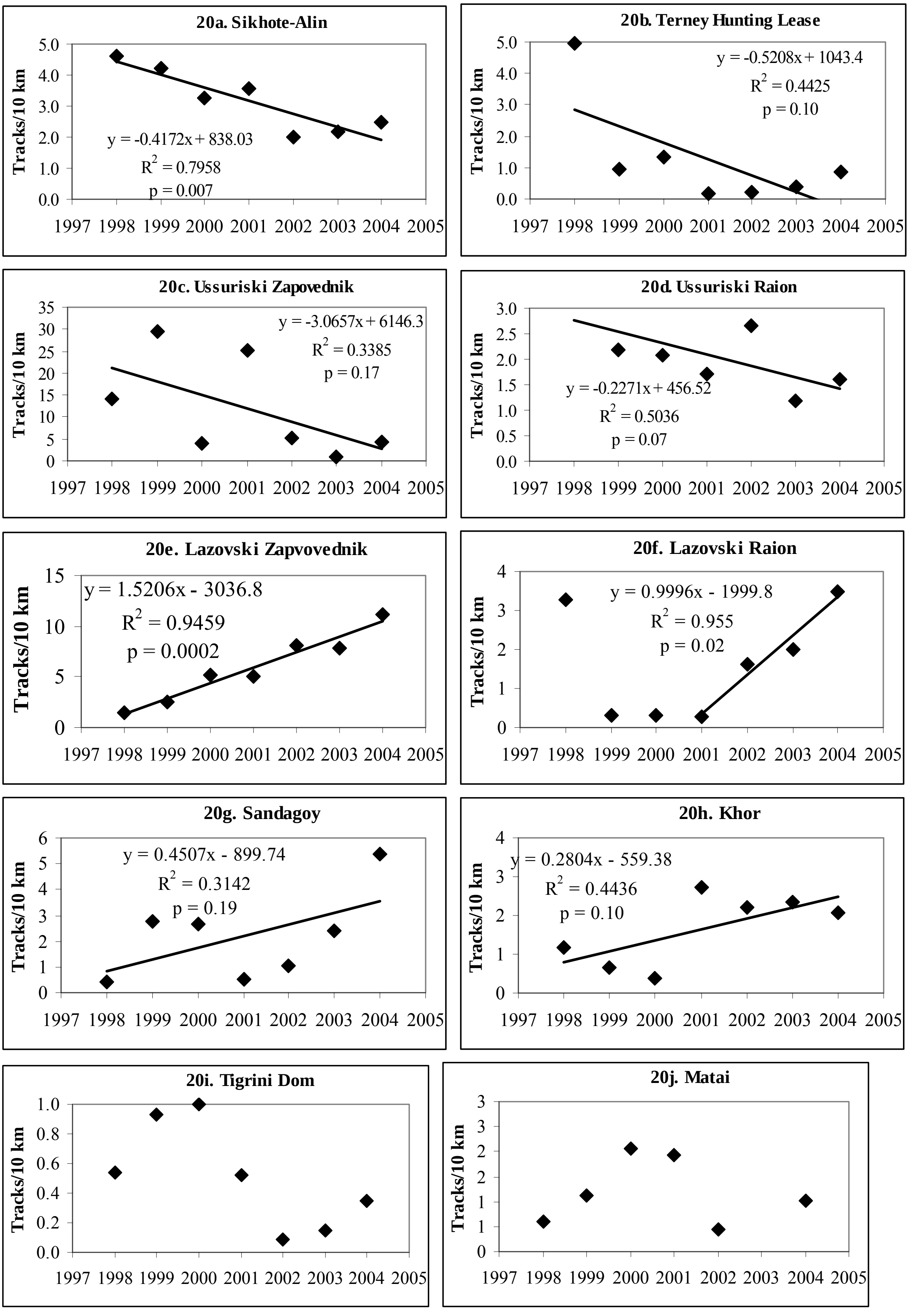


Figure 20a-j. Changes in wild boar densities, as measured by fresh tracks/10 km along routes in 8 of the 16 monitoring sites of the Amur Tiger Monitoring Program where the probability is less than 0.2 that the slope of the line does not equal zero.

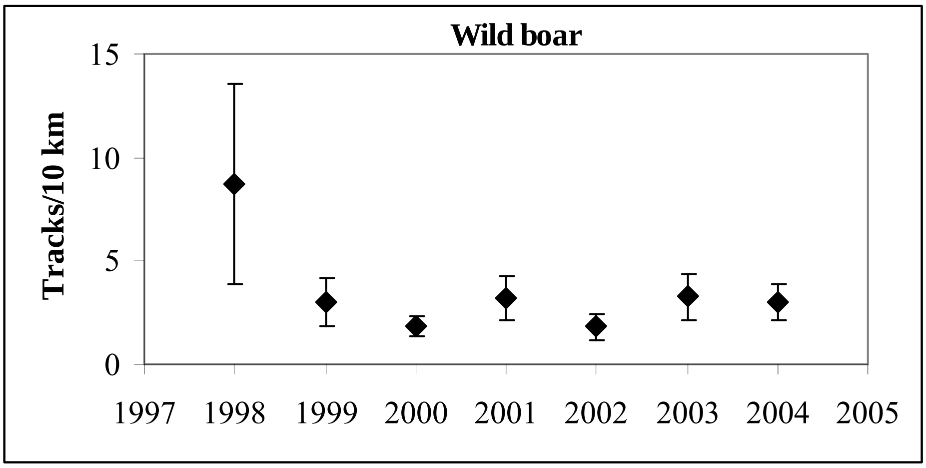


Figure 21. Average wild boar track density and 95% confidence intervals for all sites, for each of the first 7 years of the Amur Tiger Monitoring Program, 1997-1998 though 2003-2004.

Despite the dramatic variation among sites, the overall picture for wild boar, averaged across all sites, suggests that population numbers are relatively steady (Figure 21). This averaging masks the tremendous variation among sites, but suggests that overall the population appears to be steady across all sites

Sika deer.

Sika deer reach their highest densities in southern Primorski Krai, but also occur regularly in some of the central Amur tiger monitoring sites. Although there are reports of a few sika deer in Khabarovsk, they are mostly absent from this region (Figure 17). Sika deer are found regularly in only eight of the monitoring units, including all 6 in the south, and 2 of the

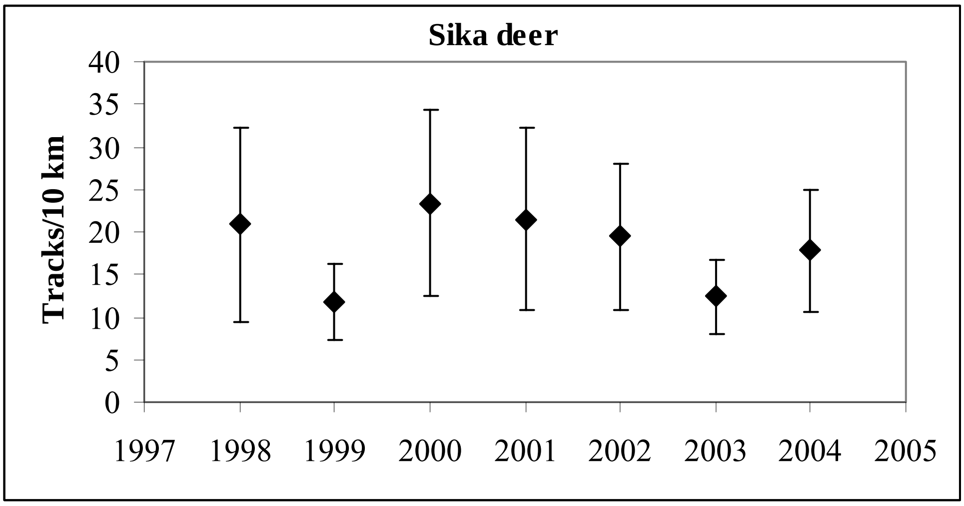


Figure 22. Average sika deer track density and 95% confidence intervals for all eight sites where they regularly occur, for each of the first seven years of the Amur Tiger Monitoring Program, 1997-1998 though 2003-2004.

Table 11. Sika deer track densities on 8 Amur tiger monitoring units, 1997-1998 through 2003-2004.

	Sika deer track densities/10 km							
Monitoring Unit	1998	1999	2000	2001	2002	2003	2004	Average
Borisovskoe Plateau	116.3	42.9	65.7	20.8	32.5	18.6	28.3	46.4
Lazovski Raion	9.3	11.4	41.8	51.6	47.3	29.0	30.3	31.5
Lazovski Zapovednik	45.2	43.8	108.3	123.4	92.5	42.7	83.7	77.1
Sandagoy	0.9	2.5	4.1	7.9	4.3	2.9	1.3	3.4
Sikhote Alin Zapovednik	10.2	5.2	4.7	8.7	11.5	15.9	18.0	10.6
Terney Hunting Lease	5.2	1.6	1.7	0.5	0.8	2.7	1.2	1.9
Ussurisk Zapovednik	22.6	16.1	30.7	26.7	23.1	11.2	22.9	21.9
Ussuriski Raion	0.6	0.3	2.7	2.0	1.2	1.0	0.6	1.2
Average	26.3	15.5	32.5	30.2	26.6	15.5	23.3	24.3

central monitoring sites (Table 10). However, in the two central units where they occur (Sikhote-Alin Zapovednik and Terney Hunting Lease) they exist in localized pockets, and are not uniformly distributed throughout the monitoring units. Sika deer appear to be increasing in the coastal areas of Terney Raion, and we expect them to become a more important prey item in the diet of tigers there in the future.

Track densities (and presumably animal densities) are generally much higher for sika deer than other ungulate species, reaching 83 tracks/10 km in Lazovski Zapovednik (Table 11). Track densities average above 20/10 km on half of the sites (Table 11). Highest track densities have been recorded in Boriskovkoe Plateau (in 1998) but highest sika deer densities are apparently in Lazovski Zapovednik. Sika deer are highly gregarious, and there is great variation in track counts dependent on the number of groups encountered along transects. Greater sampled is probably required to obtain more accurate estimates of track densities, with smaller confidence intervals. No significant trends appear across the 8 southern sites for the 7 years of monitoring, but there are trends for some of the individual sites (Figure 23).

Sika deer numbers appear to be increasing in Sikhote-Alin (Figure 23a), where red deer and wild boar appear to be declining. However, there is no clear trend in neighboring Terney Hunting Lease (Figure 23b). In Ussuriski Zapovednik (Figure 23c) and Raion (Figure 23d), there are signs that the sika deer population may be decreasing, but a significant trend was found only for the Ussuriski Raion monitoring site since the 1999-2000 winter. In Lazovski Zapovednik (Figure 23e), Lazovski Raion (Figure 23f), and nearby Sandagoy (Figure 23h), sika deer appeared to have reached a peak in the 2000 or 2001 winter, and then started to decline. This trend is most clearly seen in Sandagoy. There is evidence that sika deer numbers are declining Borisovskoe Plateau (Figure 23g), but it is not clear is the strong value (0.04) is due to the single high estimate in the first winter of monitoring. Over the past four winters, numbers appear relatively stable in Borisovskoe Plateau.

The overall results suggest that sika deer numbers may be decreasing falling across southern Primorye. The correlation coefficients are not strong in all sites, but there appears evidence that over the past four years sika deer numbers have began a slow decline.

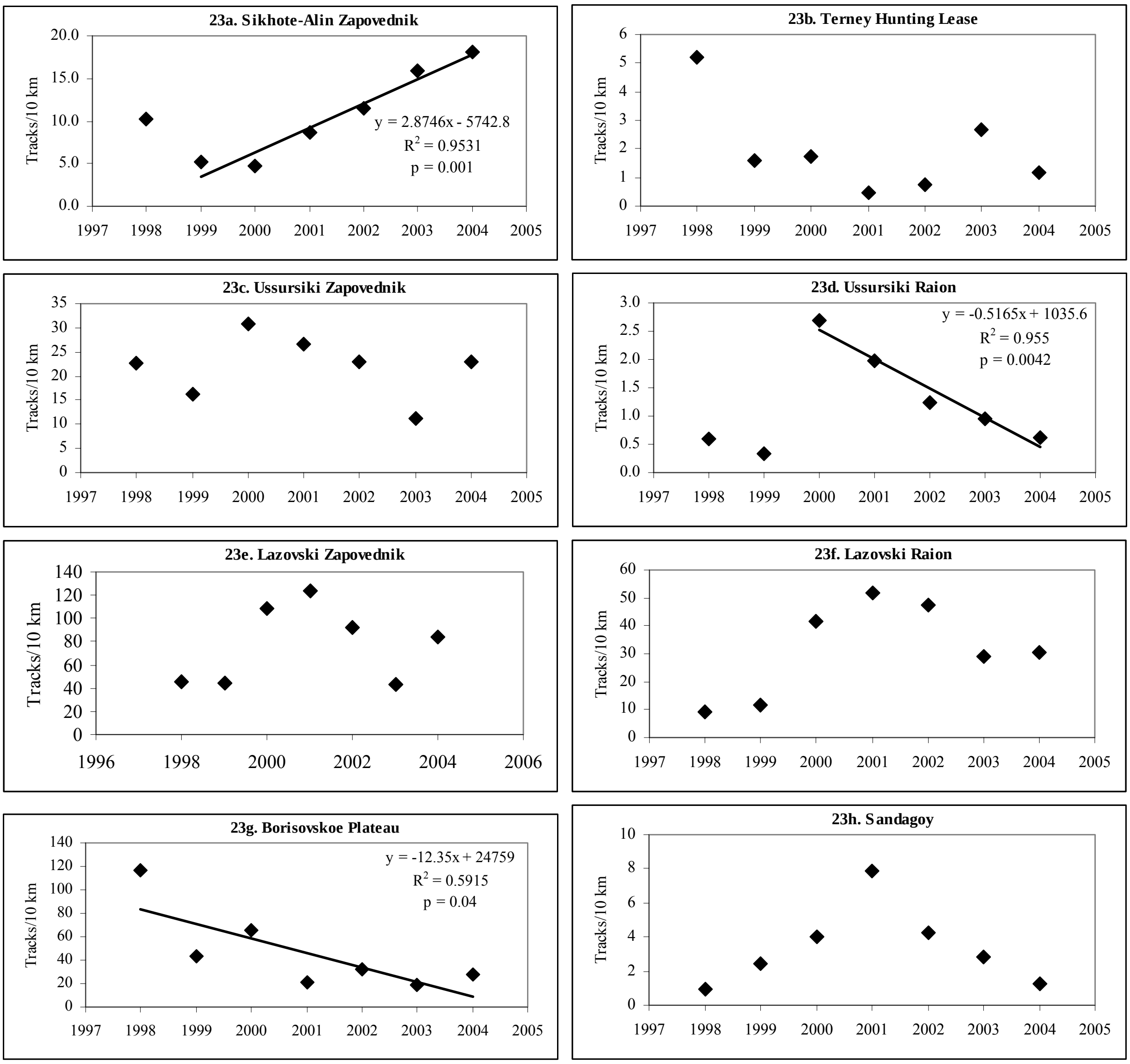


Figure 23a-h. Changes in sika deer densities, as measured by tracks/10 km along routes in all 8 monitoring sites where this species occurs in the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004.

Roe deer.

Because roe deer are not a primary prey species of tigers, we briefly review status of this species on monitoring sites. Roe deer are the only species, of the four primary prey, which are found on all 16 monitoring sites. In the 2003-2004 winter track abundance indices range from a low of 0.47 tracks/10 km in the northern site of Tigrini Dom, to a high of 21.43 in Sikhote-Alin Zapovednik (Table 10, Table 12). Roe deer abundance appears clearly higher in Sikhote Alin Zapovednik, where track abundance indices are 3 or more times greater than any other monitoring site (Tables 10, 12).

Estimates of roe deer density have been the most stable of all ungulate species (Figure 24). Although there has been no statistically significant change in roe deer track densities across all 7 years of monitoring, there have been fluctuations within sites. Most notable is the apparently dramatic decline of roe deer in Ussuriski Zapovednik and adjacent raion. (Figure 25a-b). Reasons for this decline are not apparent, but should be investigated.

Table 12. Roe deer track densities on Amur tiger monitoring units, 1997-1998 through 2003-2004.

	Tracks/10 km							
Unit	1998	1999	2000	2001	2002	2003	2004	Average
Bikin	1.49	4.96	1.74	2.88	4.49	3.41	4.70	3.38
Bolshekhekhtsirki Zapovednik	0.45	1.27	0.16	0.92	4.53	0.68	4.63	1.81
Borisovskoe Plateau	3.38	8.48	4.58	6.22	8.42	2.69	4.36	5.45
Botchinski Zapovednik	0.42	3.00	2.69	4.24	3.91	6.44	7.78	4.07
Iman	3.38	2.68	2.98	4.45	4.29	6.83	3.76	4.05
Khor	2.69	7.60	2.73	3.35	6.07	5.01	6.45	4.84
Lazovski Raion	3.42	1.01	0.67	0.11	1.30	0.10	0.97	1.08
Lazovski Zapovednik	4.30	2.40	3.90	2.73	4.07	0.62	0.97	2.71
Mataiski Zakaznik	1.37	2.62	2.10	1.53	1.43	4.11	1.55	2.10
Sandagoy	2.50	2.44	6.70	8.98	11.94	6.39	3.26	6.03
Sikhote Alin Zapovednik	17.60	11.50	20.05	16.77	14.32	21.75	21.43	17.63
Sineya	2.48	2.59	2.37	3.96	2.92	5.40	2.15	3.12
Terney Hunting Lease	7.32	5.71	5.52	8.24	4.15	11.08	6.33	6.91
Tigrini Dom	0.65	1.04	0.36	0.32	0.67	0.09	0.47	0.51
Ussurisk Zapovednik	13.81	8.61	10.33	6.49	6.14	2.18	1.53	7.01
Ussuriski Raion	7.93	7.92	12.05	7.86	4.65	1.90	2.46	6.40
Average	4.58	4.62	4.93	4.94	5.21	4.92	4.55	4.82

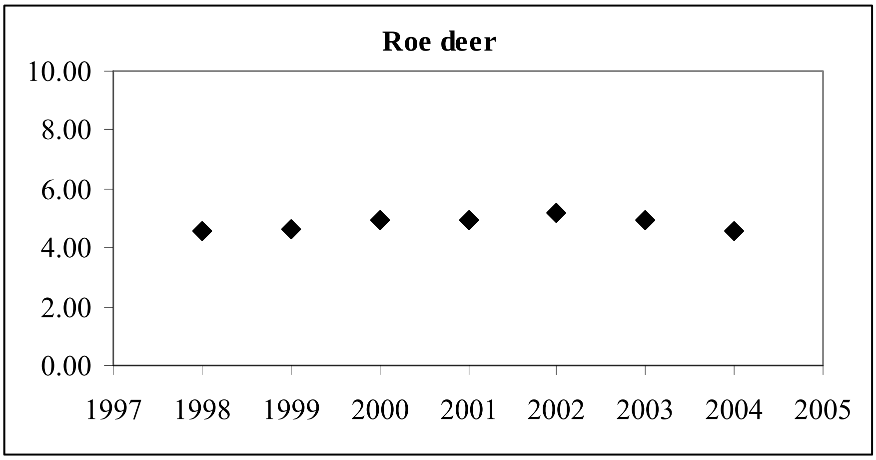
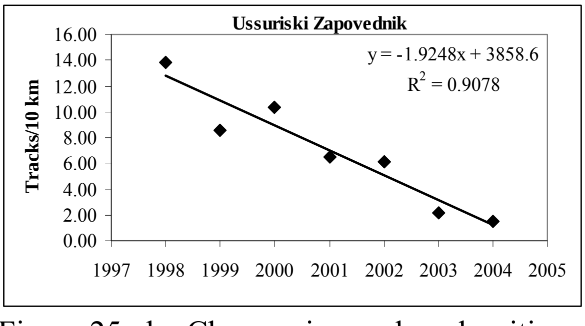


Figure 24. Average roe deer track density for all sites, for the first six years of the Amur Tiger Monitoring Program, 1997-1998 though 2003-2004.



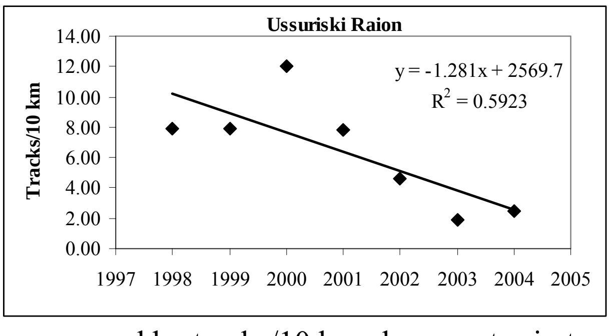


Figure 25a-b. Changes in roe deer densities, as measured by tracks/10 km along routes in two monitoring sites in the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004.

The Importance of Protected Areas in Amur tiger Conservation: a comparison of tiger and prey abundance in protected areas versus unprotected areas.

It is assumed that protected areas should act as core habitat to insure long-term survival of many species, but often it is unclear how important protected areas really are in conserving any particular animal or plant. Zapovedniks represent a small fraction of the total area of tiger habitat, and therefore it might be considered that they play a minor role in tiger conservation. However, an analysis of the relative abundance of tigers and their prey, as well as the level of reproduction by tigers inside and outside protected areas, can provide a clear demonstration of their importance.

When the Amur Tiger Monitoring Program was initially designed we included all zapovedniks with tiger habitat, and intentionally established monitoring units adjacent to the key zapovedniks. For Sikhote-Alin, Lazovski, and Ussuriski Zapovedniks, we created neighboring monitoring units to compare status of tigers under similar conditions inside and outside protected areas. In so doing, we created a set of paired plots to make comparisons. Such pairing ensures that general conditions experienced by animals inside and outside the protected areas – weather, snow depth, climatic factors - will be similar, and therefore the major differences will represent largely the impact of humans (logging, hunting, roads, human disturbance, etc.). We review the results of these comparisons here to demonstrate the impact of humans on tiger populations and their prey.

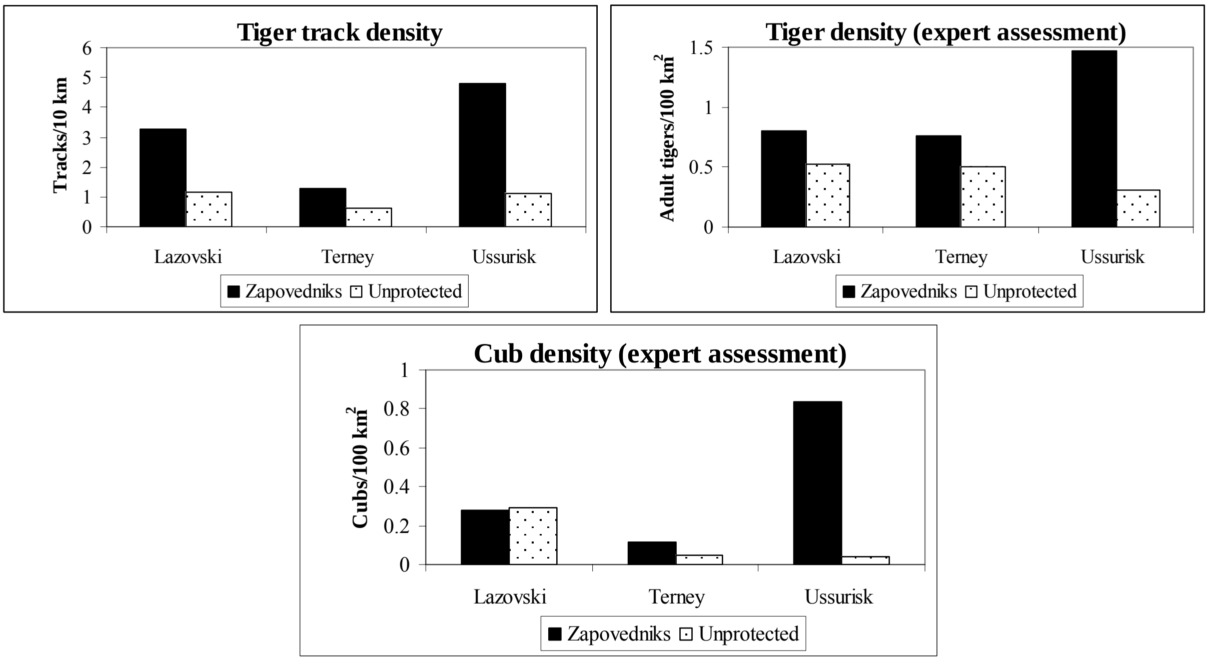


Figure 26. A comparison of tiger abundance and productivity inside zapovedniks and in adjacent territories: a) relative abundance of tigers, based on tiger track density (tracks/100 km/days since snow) (average of 7 years); b) adult tiger density, based on expert assessments derived from tiger tracks; c) cub density, based on expert assessment interpretation of tracks. All data collected on monitoring sites of the Amur Tiger Monitoring Program and averaged for 7 years, 1997-1998 through 2003-2004.

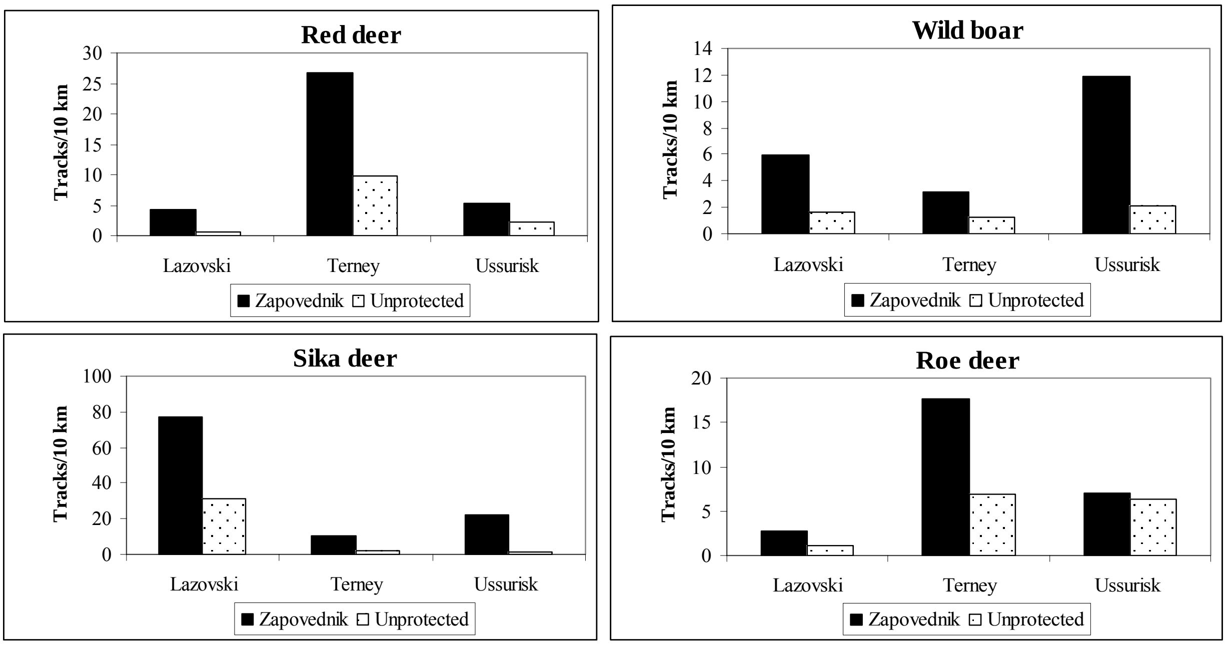


Figure 27. Relative abundance of prey species of tigers (measured as tracks/10 km), as determined from data collected by the Amur Tiger Monitoring Program, 1997-1998 through 2003-2004.

Tiger abundance, based on two estimators (track density, and expert assessment of tiger numbers) appears to be clearly lower outside versus inside zapovedniks (Figure 26a-b). Tiger track density outside zapovedniks, is on average, only 35% of track density inside the three zapovedniks, and tiger density based on expert assessments outside zapovedniks is on average 51% the density within. These differences exist despite the fact that adjacent territories likely share some of the same tigers (as most tigers have boundaries that range outside protected areas (Goodrich et al, unpubl.), and therefore these adjacent territories likely represent higher densities than would exist on territories only slightly further from zapovedniks.

Cub density, an indicator of productivity of monitoring sites, adjacent to zapovedniks is on average only 51% of cub density inside the zapovedniks, although there is more variation here between the three sites (Figure 27c).

Differences between zapovedniks and adjacent territories are even more striking in comparing ungulate densities (Figure 27). For all species in all sites (except for roe deer in Ussurisk), ungulate track densities, an estimator of relative abundance, are consistently higher inside versus outside protected areas. Red deer track densities outside protected areas are on average 31% those inside, wild boar track densities outside protected areas are 28% of zapovedniks, sika deer densities outside are 22% of zapovedniks, and roe deer densities outside are on average 57% of densities inside.

Clearly prey bases are considerably higher inside protected areas, and zapovedniks are therefore able to support higher densities of tigers, and those tigers appear to be more productive than tigers outside protected areas. This fact is reinforced if we look at cub productivity inside the zapovedniks compared to all other sites. We restrict this analysis to Primorski Krai, because zapovedniks in Khabarovsk are either extremely small, or not in prime tiger habitat, and therefore comparisons there are inappropriate. Across Primorye however, 8 monitoring units that are not zapovedniks produced the same number of cubs as three zapovedniks over the 7-year span of monitoring (66 cubs each), but they represent 78% of the total area monitored, compared to only 32% that is zapovednik (Figure 28). These data suggest that zapovedniks are more than twice as effective at producing cubs than other sites monitoring in Primorski Krai.

These data clearly illustrate that zapovedniks represent core habitat for tigers, not simply because they provide secure habitat from human disturbance, because they represent breeding centers for the entire population. Zapovedniks produce a large percentage of the cubs that disperse throughout the region. Therefore, protection of zapovedniks, and the maintenance of connectivity between zapovedniks and all other tiger habitat, is a critical component of a comprehensive habitat management plan for tigers.

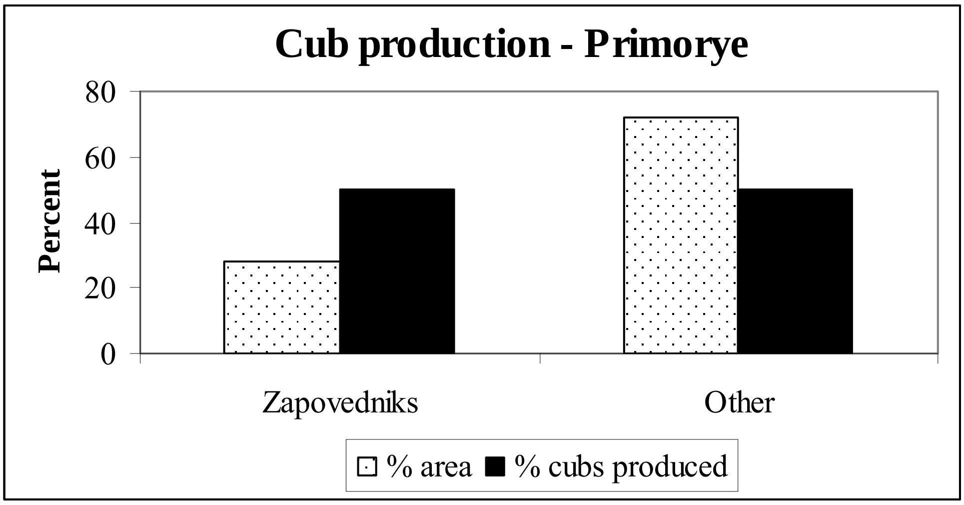


Figure 28. Contribution of zapovedniks and other monitoring sites to production of tiger cubs on 11 monitoring sites (3 zapovedniks, 8 non-zapovedniks) in Primorski Krai. "% area" represents the percentage of total land included in the Amur Tiger Monitoring Program in Primorski Krai that is zapovednik versus other territory, and "% cubs produced" represents the percent of total number of cubs produced on all monitoring units in Primorski Krai in zapovedniks versus other monitoring units.