A MONITORING PROGRAM FOR THE AMUR TIGER

FOURTH-YEAR REPORT: 2000-2001

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
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Executive Summary. In the 2000-2001 winter 16 monitoring units, totaling 23,555 km^2 (approximately 15-18% of suitable tiger habitat) were surveyed to assess changes in tiger numbers (using relative and absolute indicators), cub production, mortality, and relative ungulate densities. A total of 246 survey routes were sampled twice (492 samplings), representing 3057 km of routes (with double sampling, a total of 6114 km traversed). Results of the first four years (1997-1998 winter through 2000-2001 winter) of monitoring Amur tigers in the Russian Far East suggest that the tiger population appears to be stable. Although some sites, such as Lazovski Raion, appear to be experiencing a decline in tiger numbers, others, like Botchinski Zapovednik, appear to have increasing tiger numbers. Red deer and roe deer appear to be experiencing small increases in population size overall, but local conditions vary greatly. Prey numbers and cub production outside protected areas (zapovedniks) is extremely low, and it is unlikely that cub production in zapovedniks will be sufficient to maintain the present population level. Recovery of ungulate populations on privately managed hunting leases should be a priority for tiger conservation efforts 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 a "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 an indication of trends in the populations.

4. Changes in ungulate populations, as primary prey for tigers, may also provide important clues to potential impacts on 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 results, and the effectiveness of this program are continually being evaluated, but we are hopeful that the results will demonstrate the value and the need for investing in such a program.

II GOALS AND OBJECTIVES

The ultimate goal of this program is the yearly implementation of a standardized system 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. Develop a standardized, statistically rigorous system based on track counts that will provide estimates of relative density as a mechanism for monitoring trends in relative numbers of tigers in representative "count units" throughout tiger range in the Russian Far East.

2. Determine presence/absence of tigers on survey routes as a second indicator of trends in tiger numbers, and differences in tiger abundance among survey units in the Russian Far East.

3. Combine the track counts with "expert assessments" of tiger numbers as a means to provide a third indicator of population trends.

4. Monitor reproduction across the range of tigers to identify areas of high/low productivity, and changes in reproduction over time.

5. Monitor changes 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 the design of any monitoring program has limitations. We decided to focus on developing a method that would, with statistical rigor, monitor changes in the tiger population that occur due to changes in density within the existing range of tigers (i.e., monitor changes in indicators of tiger density) instead of monitoring changes in tiger numbers due to increases/decreases in tiger distribution (i.e., fluctuations in range of tiger).

Extensive work has been conducted in developing a survey methodology that can provide a statistically rigorous mechanism for detecting trends in tiger numbers. The rationale for this methodology has been provided elsewhere (Hayward et al, in press, 1st Year Report). An abbreviated summary and rationale of methodologies is provided here.

Project Design

Given the logistical and financial constraints of implementing a full range census, a more efficient estimate of changes in relative abundance of tigers is required. To insure acceptance of methodologies at the local level, and to provide linkages with existing databases, it is to our advantage to attempt to develop a rigorous methodology that relies on the extensive experience of regional biologists and their understanding of tiger ecology.

An index of tiger abundance, based on track counts measured on sampling units well dispersed across the total range of tigers, may provide an efficient approach 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.

While an approach based on sampling provides the benefits of lower cost, more frequent implementation, and measures of precision, 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.

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 counts of actual tiger numbers based on expert assessments derived from track data. The sampling scheme was primarily designed to reduce variance in tiger track counts within each monitoring unit (which acts as a sampling unit), but the efficiency of sampling prey species was also considered. Below we delineate how the system was developed and what criteria were used for selecting this sampling scheme.

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 monitoring units within and adjacent to the larger protected areas (Sikhote-Alin, Lazo, and Ussuri) 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. They may be sensitive indicators of the effect of human impacts.

We determined that the range of environmental factors that should be represented include 3 primary variables:

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 area with zapovednik status. Although some sites have partially or wholly protected as zakazniks (Borisovkoe Plateau, Matai), these designations are relatively new, and 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. Finally, there are important differences forest types and presumably ungulate densities, between coastal areas (i.e., those sites on the coastal side of the Sikhote-Alin Divide) and inland sites. 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 an 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; 4) financial constraints will largely limit the upper allowable number of sites.

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

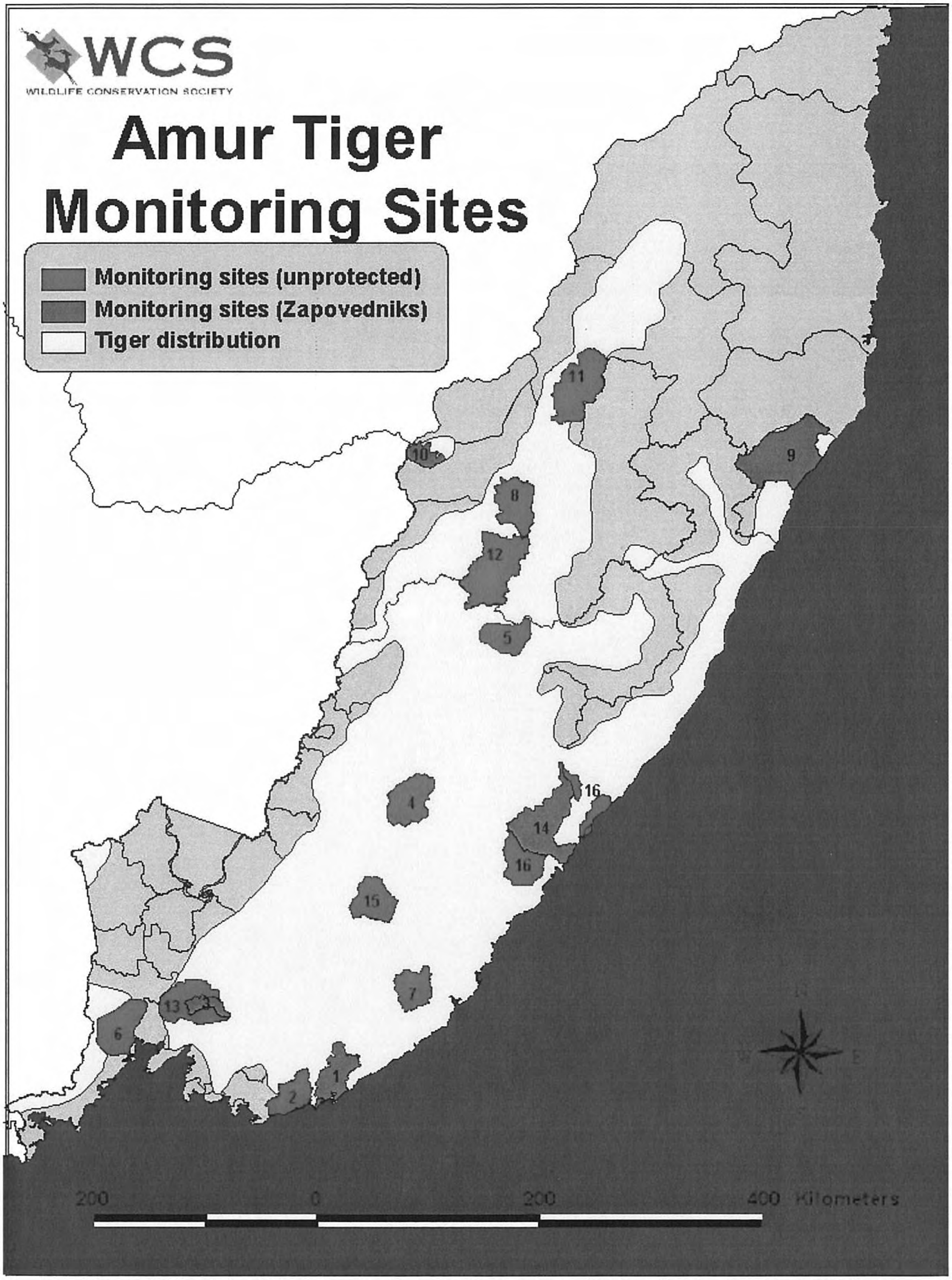


Figure 1. Location of the 16 sites used for monitoring Amur tigers in the Russian Far East. Numbers referenced in Table 1 and most other tables throughout text.

Included as monitoring units are all 5 zapovedniks that have potential tiger habitat. Obviously, location, size, and number of protected areas was not a variable 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.

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

i) 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) 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; and

iv) count units should have boundaries defined as boundaries of protected areas, or natural boundaries reflecting geographic constraints on tiger movements (e.g., high ridgetops, large rivers);

iii) 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 - the size of existing protected areas are 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.

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. When variability in track density among routes is high, our ability to statistically detect changes in tiger abundance decreases.

Using data we developed in the initial experimental stage of this program (Hayward et al. in review) we determined that routes longer than 10 km have a much greater chance of bisecting tiger tracks than shorter routes, and that while longer routes were always better, the savings (as measured in change in standard deviation) diminished greatly with routes over 20 km. Based on these preliminary data, therefore, we strove to create routes that ranged in length from 10 to 20 kilometers.

Number of routes/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); 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; and, 3) there should be a fairly standard density of route kilometers/km^2 across count units.

We examined the statistical power of a monitoring program with different numbers of routes, and determined that with 10 routes per count unit there is a 90% chance of statistically detecting a 10% decrease in population size (density of tiger tracks). Chances of detecting a 5% change are decidedly less with 10 routes(55-56%). 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.

Secondarily, we attempted to maintain route density to be greater than 1 kilometer of route/10 km^2 count unit.

Reducing variability in simultaneous counts by using repeated counts. 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 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 are 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 saturation approach some tigers could be missed.

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).

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.

Data Collection

Details of data collection are outlined in the Instructions to Coordinators and the Field Diary that is provided to all field workers (Appendix II). Very briefly, the data that is collected includes:

Basic information recorded on each field "diary":

Name of field worker
Name of count unit
Name/number of route
Length of route
Date route was covered
Mode of travel: on foot, snowmobile, or vehicle
Date of last snowfall
Snow depth measured at three places along each route (beginning, middle, end)

Tiger tracks:

a unique number is assigned to each track
location of a track is pinpointed onto a map (usually 1:100,000 scale)
track size of front pad (or measurement of overlap track of rear and front)
track size of rear pad (not mandatory, but included as a reference for field counters to be aware of which foot they are measuring)
estimated date track was created

Tracks found off routes are also reported to coordinators. These "non-survey" tracks are used by coordinators in developing "expert assessments" of the number of tigers in a count unit. These data are not used in developing an estimate of track density (which relies only on tracks recorded along permanent survey routes) and therefore insures that there is some independence in how track counts and expert assessments are derived. This independence is desirable when we assess the relationship of track counts and estimates of tiger numbers based on expert assessments

Ungulate tracks. For each route, the following information is recorded:

number of fresh tracks (less than 24 hours old) that bisect the route, by species, include the following species:

- red deer
- wild boar
- roe deer
- sika deer
- musk deer
- moose (so far not recorded on survey routes)

We generally report only on the 4 key prey species: red deer, wild boar, roe deer, and sika deer. Musk deer and moose are very rarely preyed upon by tigers, and form an insignificant portion of their diet.

Tiger Reproduction. Information should be recorded by each fieldworker on evidence of cubs in or near the count unit, including:

- Tracks of female with cubs
- Location of tracks
- Date tracks observed
- Estimated age of tracks
- Number of tracks (# cubs)
- Measurement of tracks (each set)

Tiger Mortality.

- Was there any evidence of tiger deaths in the past year in or near the count unit?
- Description of event (poaching, legal human killing, natural death, etc.)
- Location (on map of 1:100,000 scale).

Creation of a Spatially Explicit Data Base

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 a considerable amount of energy in developing a spatially explicit database in a standardized format that will provide relatively easy access for analysis. We have developed a database in Microsoft ACCESS that linked to an ARCINFO GIS (Geographic Information System) 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 the spatial data that coincides with 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 database now exists in a specially designed format so that data entry is possible without technical expertise in ARCINFO, or the need for digitizing data.

Analyses

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

1. Zero counts. Presence/absence of tiger tracks on survey routes (expressed as the percentage of routes on each monitoring unit with no tiger tracks recorded) may be an indicator 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 above, 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..

We compared relative abundance of tigers, based on presence/absence data, used ranks of the percentage of routes where tigers were reported for each site as a basis for comparison (presence/absence data is highly non-parametric). We assessed environmental parameters of sites that may explain presence/absence data by conducting a 3-way factorial ANOVA (SAS GLM), with protected status, latitude, and proximity to coast as independent variables (Tables 1 and 2)

For all three indicators of tiger abundance, to look for trends in the population we conducted linear regression analyses. For presence absence data, we used the average percentage of routes with tigers present for all sites combine, and then conducted separate analyses for each individual site. The same types of analyses were conducted for tiger track data, tiger density estimated from expert assessments, and track data for ungulates (see below). The intent of the regression analyses is to identify trends in the population across the whole region, and in each of the monitoring sites. We have defined sites as "areas for concern" if the trend analyses demonstrate 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). 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 of positive growth indicators" when in fact such may not be the case. This rationale is 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.

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

2. Variation in tiger track densities across:

i. all monitoring sites (assuming a uniform response across the entire range of tigers in the Russian Far East);

ii. within regions (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. over time.

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

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, nearly all tracks become unmeasureable 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 values as 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 covered is unreported.

This value (tracks/days since snow/km *100) averaged for each route (for the two surveys per route per year), is the track density estimator used for trend analyses and comparisons among sites. Because this test statistic was not normally distributed (due primarily to the large number of zero counts), we used the rank value of the track density estimator to test for differences among sites using an unbalanced GLM (SAS 1998), the mean of those ranks as an indictor of relative abundance on each monitoring sites, and used Fisher's LSD test to determine which sites were different from each other.

To look for trends across time, we combined visual graphic assessments with regression analyses. For each route, we tested whether there existed a significant slope (i.e., β not equal to 0), and then compared years (as above) for all sites combined, and separately for each.

3. Changes in the numbers of tigers on each site, based on expert assessments. 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 part of our 2-stage survey; 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, or may have died), that animal is nonetheless included in the count for the study period. 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.

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, and as a basis for comparison among sites.

We compared how well these three abundance estimators (presence/absence, track densities, tiger densities) correlated 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.

Trends in population status, converted to density, were conducted as with the other two indicators of tiger abundance.

4. Changes in the 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 an 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.

5. 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 (< 2 hours old) tracks intersecting survey routes. Freshness is a subjective estimate whose accuracy is yet to be defined, but which hopefully retains a consistent error across sites and years. 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. For each species, we conducted a separate a 3-way factorial model to assess environmental parameters (latitude, protected status, and proximity to coast) and conducted trend analyses using linear regression for each site separately and for all combined.

IV. RESULTS OF THE 2000-2001 WINTER MONITORING PROGRAM

Summary Data on Count Units and Routes

In the 2000-2001 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 3).

In the southern part of Primorski Krai, and in some central areas, snow depth was unusually high this winter (Figure 2). In Borisovkoe Plateau (usually one of the warmest, and most snow-free areas), a heavy snowfall occurred on November 27th, and by the February count snow depth had reached 50-60 cm in some areas. In Lazovski Raion, snow depth reached 80 cm in some areas. In both the Iman and Sikhote-Alin units, some routes were not passable in February due to deep snow, and therefore were not surveyed a second time.

This winter was also exceptional cold in the Russian Far East, and for that matter, across much of Russia. In Khabarovsk, it was estimated that mean daily temperatures were 7-8^{o} C colder than normal. Cold temperatures may be a significant factor affecting tiger hunting success (see Dunishenko report in section on individual sites), and deep snow is often a contributing factor to winter mortality of ungulates. Overall, winter conditions were harsh this year, and likely affected wildlife populations in a number of ways.

Table 3. Characteristics of units surveyed for Amur tiger monitoring program, 2000-2001.

	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	12.42805	1.30

Overall, goals for size and coverage of monitoring units were met: the average size of monitoring units was 1472 km^2 (goal: 1000-1500 km^2); all units except Bolshe-Khekhtsirski Zapovednik (which is exceptionally small) had 11 or more survey routes (goal: minimum of 10), average survey route distance was at least 10 km in all but Ussuriski Zapovednik (goal: 10-20 km), and average density of survey routes exceeded 1 km/10 km^2 in all but two units (Botchinski and Tigrini Dom) (goal 1 km/10 km^2). The only problems encountered, as mentioned above, was the inability to cover some routes a second time in the Iman and Sikhote-Alin sites due to excessive snow.

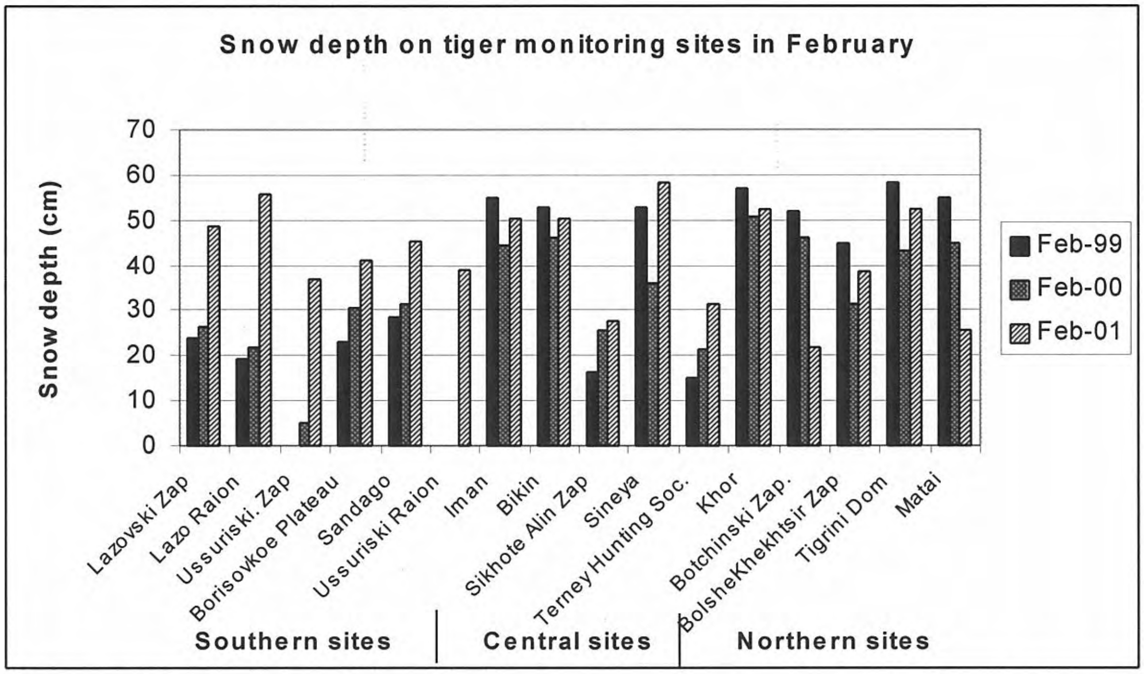


Figure 2. Average snow depth on routes within monitoring sites of the Amur Tiger Monitoring Program, for February, 1999-2001 (snow data was not collected in the 1997-1998 season).

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 2000-2001 winter, 32.9% of routes did not intersect tiger tracks, a slight increase from 1999-2000. when 28.5% of routes were without tracks.

The percentage of routes without tiger tracks varied from 0 to 67% among monitoring units (Table 4) in the 2000-2001 winter. In general, presence/absence indices for 2000-2001 followed patterns of previous years (Table 4, Figure 3), but there were some important changes. In Ussuriski Raion, Lazovski Raion, and Bolshe-Khekhtsirski Zapovednik the percentage of routes without tiger tracks increased dramatically from the 4-year average (Figure 3). As in the past, the 3 zapovedniks in the southern and central portions of tiger range in the Russian Far East (Lazovski, Ussuriski, and Sikhote-Alinski) had some of the lowest incidences of absence on routes, and over the past 4 years these sites stand out as those with the overall lowest percentage of routes without tiger tracks (Table 4). The northern zapovedniks, Botchinski and Bolshe-Khekhtsirski, do not seem to consistently demonstrate this same pattern. Bolshe-Khekhtsirski is very small, and therefore subject to dramatic fluctuations in tiger activity, and Botchinski, on the northern range of tigers along the coast, is likely also subject to fluctuations, as well as inherently low tiger numbers.

Table 4. Percentage of routes with tiger tracks absent on 16 sites during the first four years of the Amur Tiger Monitoring Program, and results of least signficance difference range test after a nonparametric. analysis of variance.

#	Monitoring site	Year				Overall	LSD Range test*
		1997-1998	1998-1999	1999-2000	2000-2001		
3	Ussuriski. Zapovednik	9.1%	0.0%	9.1%	0.0%	4.5%	A
1	Lazovski Zapovednik	8.3%	16.7%	0.0%	0.0%	6.3%	A B
4	Iman	8.3%	33.3%	25.0%	8.3%	18.8%	A B C
14	Sikhote Alin Zapovednik	12.0%	20.0%	16.0%	24.0%	18.0%	A B C D
5	Bikin	56.3%	12.5%	12.5%	6.3%	21.9%	A B C D E
9	Botchinski Zapovednik	35.7%	42.9%	14.3%	0.0%	23.2%	A B C D E
2	Lazo Raion	0.0%	27.3%	36.4%	54.5%	29.5%	F B C D E
11	Tigrini Dom	50.0%	35.7%	28.6%	21.4%	33.9%	F G C D E
16	Terney Hunting Society	33.3%	33.3%	45.8%	41.7%	38.5%	F G C D E
13	Ussuriski Raion	33.3%	66.7%	0.0%	66.7%	41.7%	F G C D E
12	Matai	50.0%	20.8%	50.0%	45.8%	41.7%	F G D E
8	Khor	52.6%	68.4%	10.5%	42.1%	43.4%	F G D E
10	BolsheKhekhtsir Zapovednik	28.6%	57.1%	14.3%	85.7%	46.4%	F G E
6	Borisovkoe Plateau	42.9%	42.9%	50.0%	42.9%	44.6%	F G E
7	Sandago	56.3%	31.3%	56.3%	43.8%	46.9%	F G
15	Sineya	53.3%	53.3%	53.3%	53.3%	53.3%	G

*Sites with no letters in common are significantly different from each other.

To assess whether variation among sites existed in presence/absence indices, we used all four years of data and ranked all percentage presence indices from 1 to 64, and then conducted a nonparametric ANOVA (Kruskal-Wallis) test using SAS GLM. This analysis demonstrated significant differences among sites ($F = 3.07$, $df = 15, 48$, $P = 0.0016$), even with a sample size of only 4 (i.e., 4 years) for each site (Table 4). The least significant difference range test tends to confirm that zapovedniks stand out as somewhat separate, but other sites, such as the Iman, also appear to have consistently higher presence indices than other sites.

Differences in presence/absence indices may be due to variation in detection rates among monitoring sites (i.e., on some sites routes may be better positioned to increase the probability of encountering tiger tracks). For instance, zapovedniks and the Iman have been the sites of extensive research, and coordinators there may have more information on tiger movement corridors, resulting in placement of survey routes that are more likely to "capture" tiger tracks. Alternatively, there may be some inherent characteristics of some sites that result in higher presence indices (e.g., latitude, protected status, or geographic location).

To determine whether some inherent characteristics help explain the variation in presence indices among sites, we conducted a second nonparametric analysis of variance using a full factorial model for the following parameters: status (protected/unprotected), latitude (northern/central/southern), and geographic location (inland/coastal). A significant difference was found ($F = 3.0$, $df = 3, 54$, $P = 0.0057$), but the only significant parameters were protected status ($F = 13.75$ $P = 0.0005$), and the interaction of protected status and latitude ($F = 3.36$, $P = 0.0422$). The interaction factor is not surprising, as both northern zapovedniks (Bolshe-Khekhtsirski and Botchinski) have characteristics that might lead to lower densities and greater variance of tiger density estimates (see above). The other parameters, latitude and geographic location, did not appear to be important in explaining variation in presence/absence indices. This statistical result confirms a visual assessment of Figure 3, where there is a mixture of central, southern and northern sites in the lower echelons of the ranking of presence/absence indices. Similarly, there is no clear relationship between coastal and inland sites.

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) demonstrate that there are clear differences in presence/absence indices within and adjacent to protected areas (Figure 3)

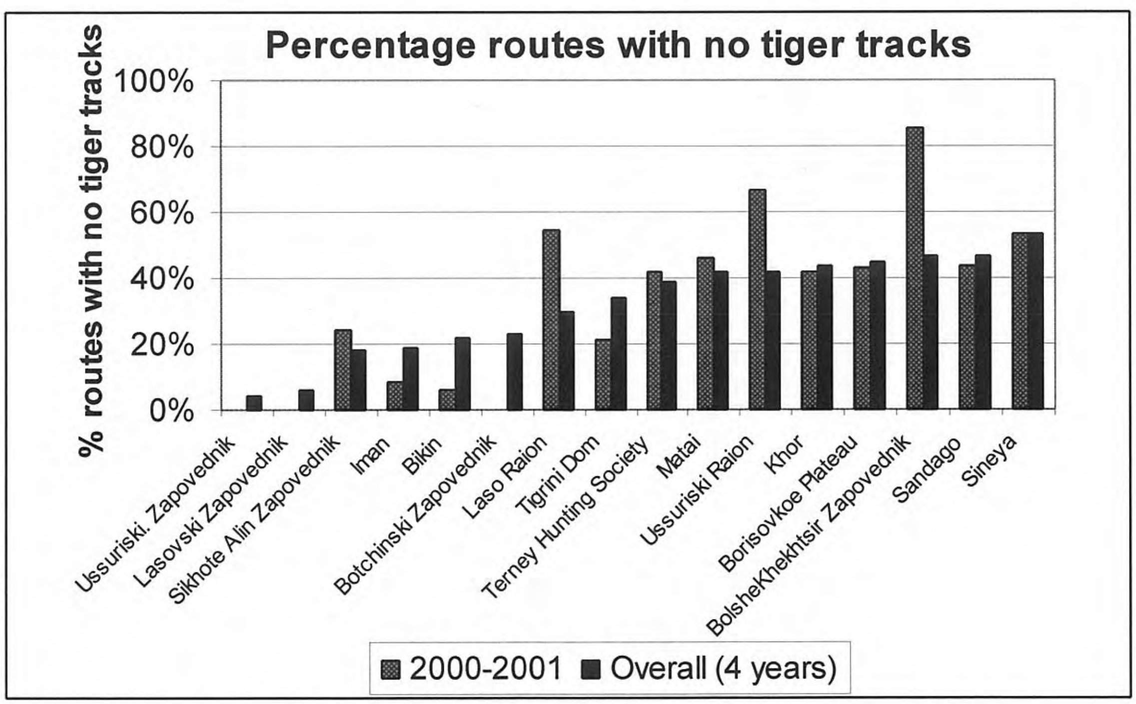
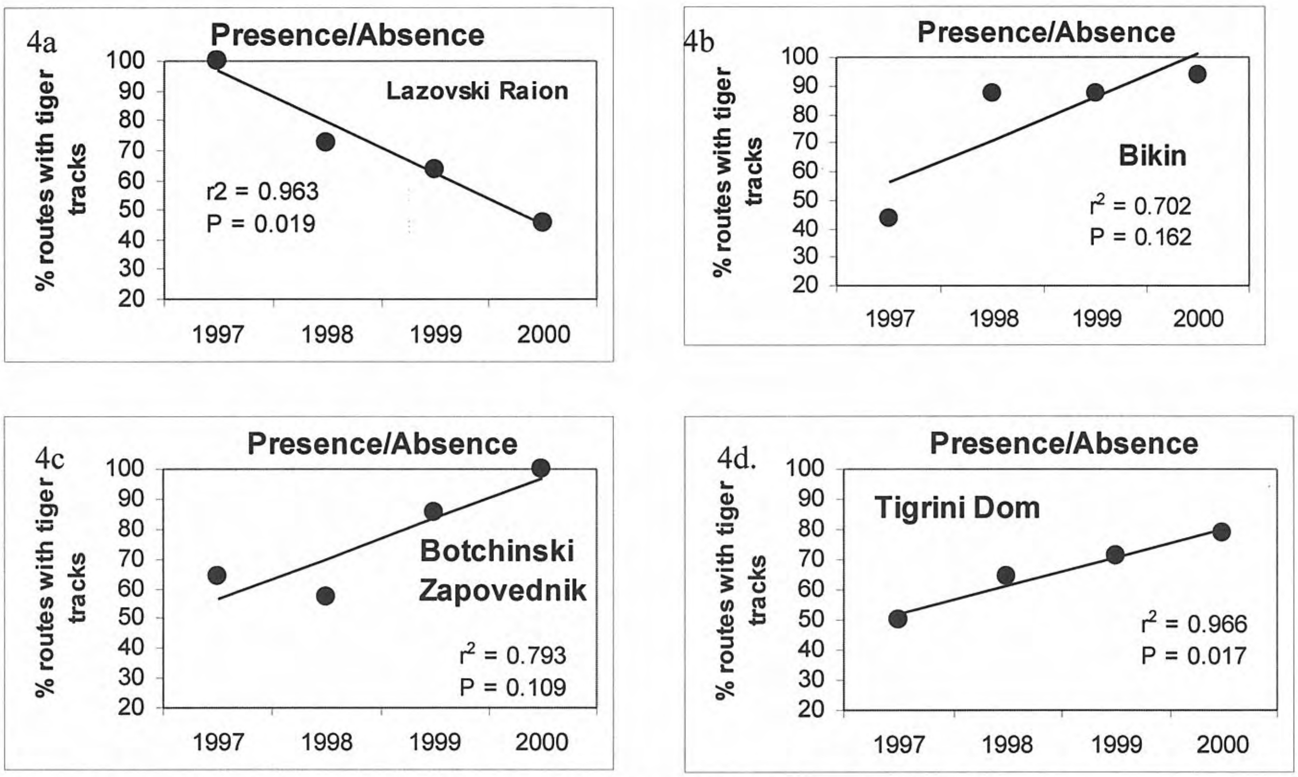


Figure 3. Percentage of survey routes with no tiger tracks within each of the 16 monitoring units, winter 2000-2001, and averaged across all 4 years of the Amur Tiger Monitoring Program.

We looked for trends in the tiger population using presence/absence data by applying a regression analysis to individual sites, and all 16 monitoring sites combined. Overall, there was no change in relative abundance of track presence on routes within all monitoring sites combined ($F = 0.759$, $P = 0.475$, $r^2 = 0.275$). However, when regression analyses were conducted for individual sites, there were significant trends ($P < 0.05$) found at Lazovski and Tigrini Dom



Figures 4a-d. Trends in presence of tiger tracks on routes on 4 monitoring sites where $P < 0.2$ for the regression over 4 years.

(Figures 4a, 4d), and non-significant, but potentially meaningful trends ($P < 0.2$) for the Bikin and Botchinski Zapovednik sites. Since presence/absence data is perhaps the least sensitive indicator of tiger abundance, the important of these findings should be weighed in combination with the other two indicators.

Track Counts on Survey Routes

Mean track density, adjusted for the number of days since the last snowfall (see Methods), should provide an indication of relative abundance of tigers on monitoring sites (Table 4). As in previous years, estimates of track density varied significantly among monitoring sites (GLM $F = 5.21$, $df = 15, 48$, $P = 0.0001$), with Ussuriski Zapovednik reporting the highest track density. Three of the four sites with the highest track density estimators were zapovedniks (Ussuriski, Lazovski, and Sikhote-Alinski Zapovedniks), but track density in the Bikin monitoring site was also high (Table 5). Three northern sites (Matai, Khor, and Tigrini Dom) also reported unusually high track densities.

As with presence/absence data, we conducted an analysis of variance to determine if protected status, latitude, or proximity to coast were important factors explaining variation in the

Table 5. Track density (tracks/days since snow/100 km survey routes) of tigers reported on 16 sites during the first four years of the Amur Tiger Monitoring Program, and results of at least significance range test after an analysis of variance.

#	Monitoring site	Year				Overall	LSD Range			
		1997-1998	1998-1999	1999-2000	2000-2001		Range test*			
3	Ussuriski. Zapovednik	1.027	10.808	6.448	5.916	6.050	A			
5	Bikin	3.941	7.710	0.950	3.704	4.076		B		
1	Lazovski Zapovednik	3.355	2.191	3.181	3.443	3.043		B	C	
14	Sikhote Alin Zapovednik	1.961	1.316	1.294	1.675	1.561			C	D
4	Iman	0.930	2.810	0.865	0.761	1.342			C	D
12	Matai	1.262	1.396	0.733	1.884	1.319			C	D
8	Khor	0.424	0.798	1.581	1.996	1.200			C	D
11	Tigrini Dom	0.671	1.471	1.127	1.454	1.181				D
10	BolsheKhekhtsir Zapovednik	1.508	1.474	0.842	0.714	1.135				D
13	Ussuriski Raion	0.388	0.611	1.896	1.438	1.083				D
9	Botchinski Zapovednik	0.876	0.736	1.216	1.295	1.031				D
6	Borisovkoe Plateau	0.620	0.711	2.025	0.601	0.989				D
16	Terney Hunting Society	0.822	0.633	0.711	1.316	0.870				D
2	Lazo Raion	0.791	0.384	0.990	1.018	0.796				D
7	Sandago	0.466	0.661	0.344	0.385	0.464				D
15	Sineya	0.242	0.329	0.472	0.580	0.406				D

*Sites with no letters in common are significantly different from each other.

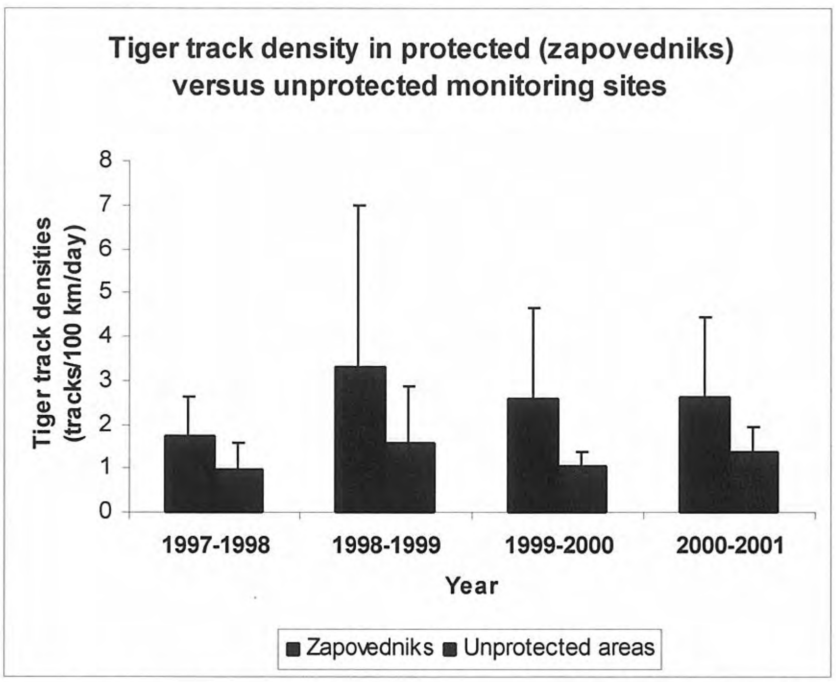


Figure 5. Track density estimators for protected (zapovedniks) and unprotected sites included in the Amur Tiger Monitoring Program, 1997-1998 through 2000-2001.

average track density (averaged for 4 years) among sites. Because proximity to coast was not a significant factor (F = 0.86, P > 0.358), we conducted a full factorial model for the remaining two parameters. This analysis demonstrated that both protected status and latitude, as well as their interactions, explained some of the variability in track density among monitoring sites (for overall model, F= 5.24, $P < 0.001$). Protected areas had significantly higher track densities than unprotected areas ($F = 10.42$, $P < 0.004$) (Figure 5), and southern sites had higher track densities than central sites ($F = 4.44$, $P < 0.016$), but not northern sites (Figure 6). Oddly, central sites had non-significant, but nonetheless lower overall track densities than northern sites. High variability in track density, as reflected in the large confidence intervals, reduce the power of this comparison. However, the low track densities in central sites may be related to greater human impact than in the northern sites.

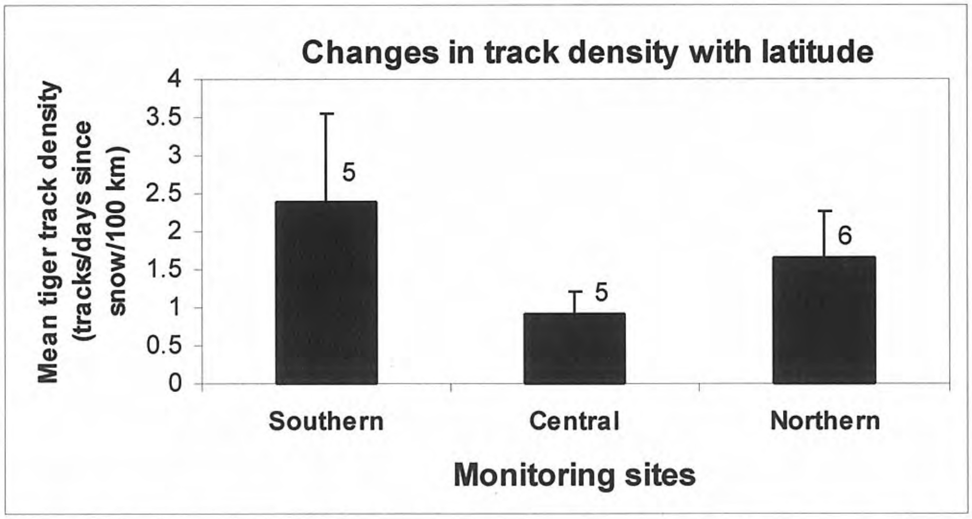
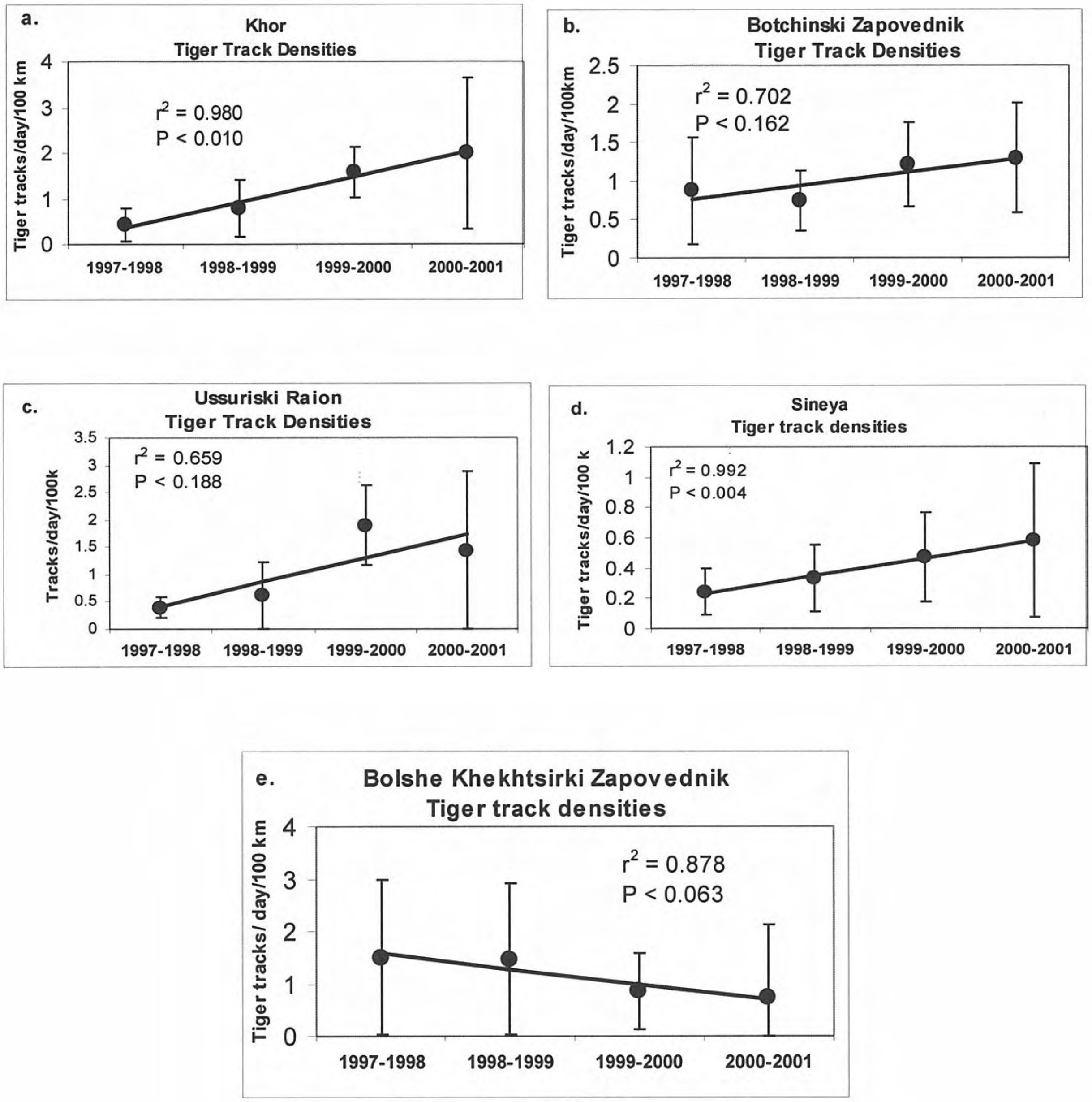


Figure 6. Changes in track density of Amur tigers with latitude, based on averages over 4 years for 16 sites (number of sites in each category listed beside error bar) in the Amur Tiger Monitoring Program, 1997-1998 through 2000-2001.

As with presence/absence data, we looked for trends in the tiger population using track data by applying a regression analysis to individual sites, and all 16 monitoring sites combined. This regression analysis suggested that there was no trend in relative abundance of track density across all monitoring sites combined ($F = 0.300$, $P = 0.639$, $r^2 = 0.130$). However, when regression analyses were conducted for individual sites, five sites had trends for which their P value (for the test that the slope of the line did not equal zero) was less than 0.20 (Figure 7). Four of these sites indicated positive trends in track densities, including two, Khor and Ussuriski Raion, that demonstrated strongly significant, positive trends ($r^2 = 0.98$ and 0.99, respectively, with $P \leq 0.01$). The trends for Botchinski Zapovednik and Ussuriski Raion were weaker and non-significant (Figure 7), but should be considered in light of other indicators. Only track density data from Bolshe-Khekhtsirski Zapovednik suggested a negative trend that was nearly significant ($r^2 = 0.878$, $P = 0.063$).

Of these five sites, only Botchinski Zapovednik demonstrated a similar response in both presence/absence and track density data.



Figures 7a-e. Trends in track density estimators (calculated as the number of tiger tracks/days since last snow x100 km of transects covered) for 4 years on 5 sites {a) Khor, b) Botchinski Zapovednik, c) Ussuriski Raion, d) Sineya, and e) Bolshe- Khekhtsirski Zapovednik} of the Amur Tiger Monitoring Program, for which P-values of the regression analysis (test that B, or slope of the line, does not equal 0) were less than 0.20.

Expert Assessment of Tiger Numbers on Monitoring Sites

Tiger densities, based on expert assessments, varied nearly tenfold, from over 1.2 animal/100 km^2 in Ussuriski Zapovednik, to 0.13 /100 km^2 in Botchinski Zapovednik (Table 6). As with the other indicators (presence/absence and track density data), the three southern and central zapovedniks (Ussuriski, Lazovski, and Sikhote-Alin) contained some of the highest densities of tigers (all greater than 0.7/100 km^2), indicating once again that protected status is an

Table 6. Number and density of independent tigers (those classified as adults, subadults, and unknown), based on expert assesments of tiger tracks on 16 sites in the Russian Far East Amur Tiger Monitoring Program, during the first four years of monitoring, 1997-1998 through 2000-2001.

#	Site	Area (km2)	Number of independent tigers 97-98	98-99	99-00	00-01	Density of independent tigers (animals/100 km^2) 97-98	98-99	99-00	00-01
3	Ussuriski. Zapovednik	408.7	7	10	4	5	1.71	2.45	0.98	1.22
1	Lasovski Zapovednik	1192.1	6	8	10	11	0.50	0.67	0.84	0.92
7	Sandago	975.8	6	6	5	7	0.61	0.61	0.51	0.72
14	Sikhote Alin Zapovednik	2372.9	24	21	23	17	1.01	0.88	0.97	0.72
16	Terney Hunting Society	1716.5	11	11	13	11	0.64	0.64	0.76	0.64
15	Sineya	1165.4	5	6	5	7	0.43	0.51	0.43	0.60
5	Bikin	1027.1	3	10	7	6	0.29	0.97	0.68	0.58
4	Iman	1394.3	8	6	5	6	0.57	0.43	0.36	0.43
2	Laso Raion	987.5	8	4	5	4	0.81	0.41	0.51	0.41
8	Khor	1343.8	3	4	4	4	0.22	0.30	0.30	0.30
10	BolsheKhekhtsir Zapovednik	475.6	2	1	2	1	0.42	0.21	0.42	0.21
6	Borisovkoe Plateau	1472.9	4	5	4	3	0.27	0.34	0.27	0.20
11	Tigrini Dom	2069.6	4	6	4	4	0.19	0.29	0.19	0.19
12	Matai	2487.6	3	5	4	4	0.12	0.20	0.16	0.16
13	Ussuriski Raion	1414.3	5	5	2	2	0.35	0.35	0.14	0.14
9	Botchinski Zapovednik	3051	3	3	4	4	0.10	0.10	0.13	0.13
	Totals		102	111	101	96	0.52	0.59	0.48	0.47

important parameter determining tiger density.

The importance of protected status and latitude was supported with the factorial model (conducted for the other indicators as well) (F = 16.26, df = 9,54, P = 0.0001) for all 4 years combined. Although proximity to coast explained a significant amount of the variability in the overall 3-way model (F = 4.41, P =0.040), the least significant difference test failed to demonstrate a significant differences between inland and coastal sites in terms of tiger densities. This variable was therefore dropped from the model. Subsequently, protected area status (F =

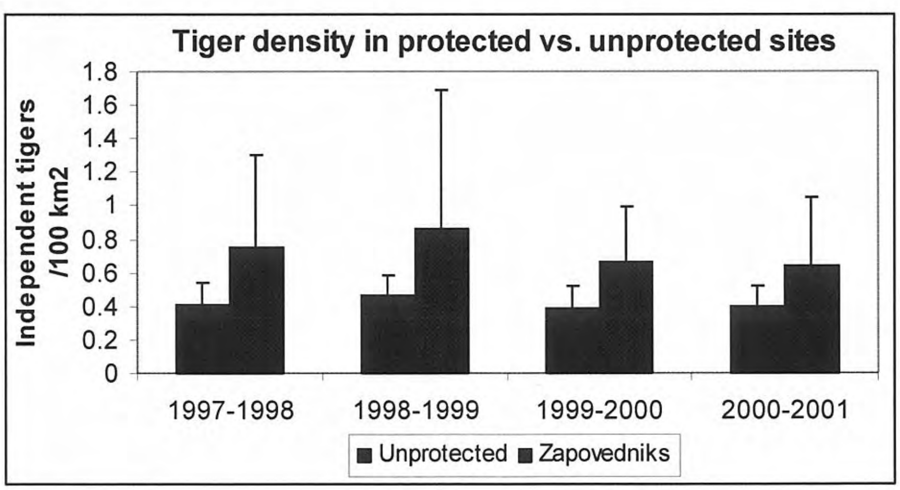


Figure 8. Density of independent tigers (/100 km^2) in protected (zapovedniks) versus unprotected areas included in the Amur tiger monitoring program 1997-1998 through 2000-2001.

20.42, df = 1, 58, P = 0.0001), latitude (F = 19.26, df = 2, 58, P = 0.001) and their interaction (F = 14.19, df = 2, 58, P = 0.001) were significant factors. The difference between protected areas and unprotected areas is very consistent across all years (Figure 8). Southern areas had significantly higher tiger densities than northern areas (but not central), and central areas also had significantly higher estimates of tiger densities than northern areas (Figure 9). This pattern of decreasing density with increasing latitude is expected since more northern latitudes are less productive, and is likely a more realistic pattern than that depicted with the track density data (Figure 6).

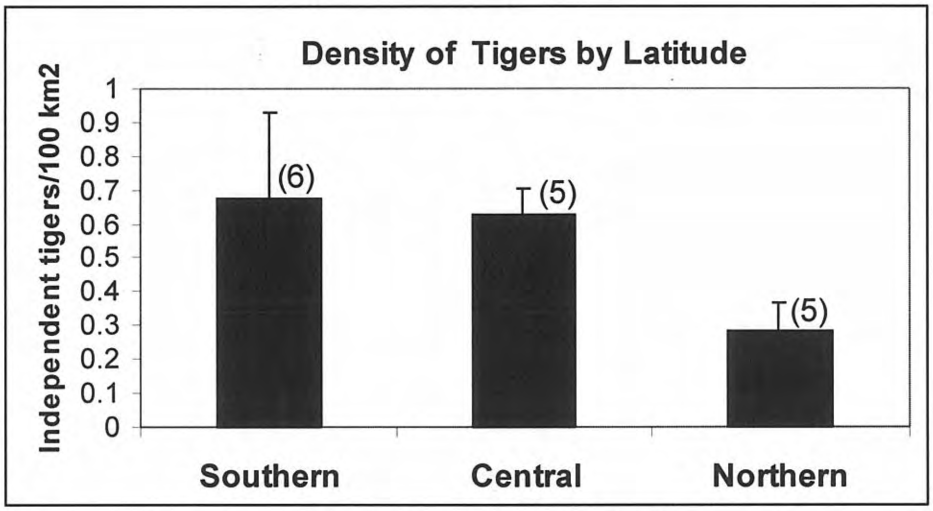


Figure 9. Density of independent tigers (/100 km^2) in southern, central and northern areas included in the Amur tiger monitoring program 1997-1998 through 2000-2001. Numbers in parentheses refer to number of sites in each region.

Biases associated with density estimates have been reported previously (1999-2000 report) and will not be repeated here.

We conducted the same trend analysis with tiger density data as with presence/absence and track density data. As with the others, we found no significant trend in overall changes with all 16 sites combined (F = 1.068, df = 1,3, P = 0.410), but there were three sites where the regression analysis demonstrated significant or near significant trends (Figure 10). The trend in Lazovski Zapovednik is likely a result in changes in how sex-age data were recorded over the years, and may not reflect a real change in numbers. As with other indicators, Botchinski demonstrated a strong positive trend, suggesting that the population of tigers there is increasing. For Ussuriski Raion, contrary to the track density indicator, which showed a positive trend, independent tiger densities show a negative trend. Neither is statistically significant (i.e. P > 0.05), but this is one of the few cases where there are relatively strong relationships for individual sites that contradict each other.

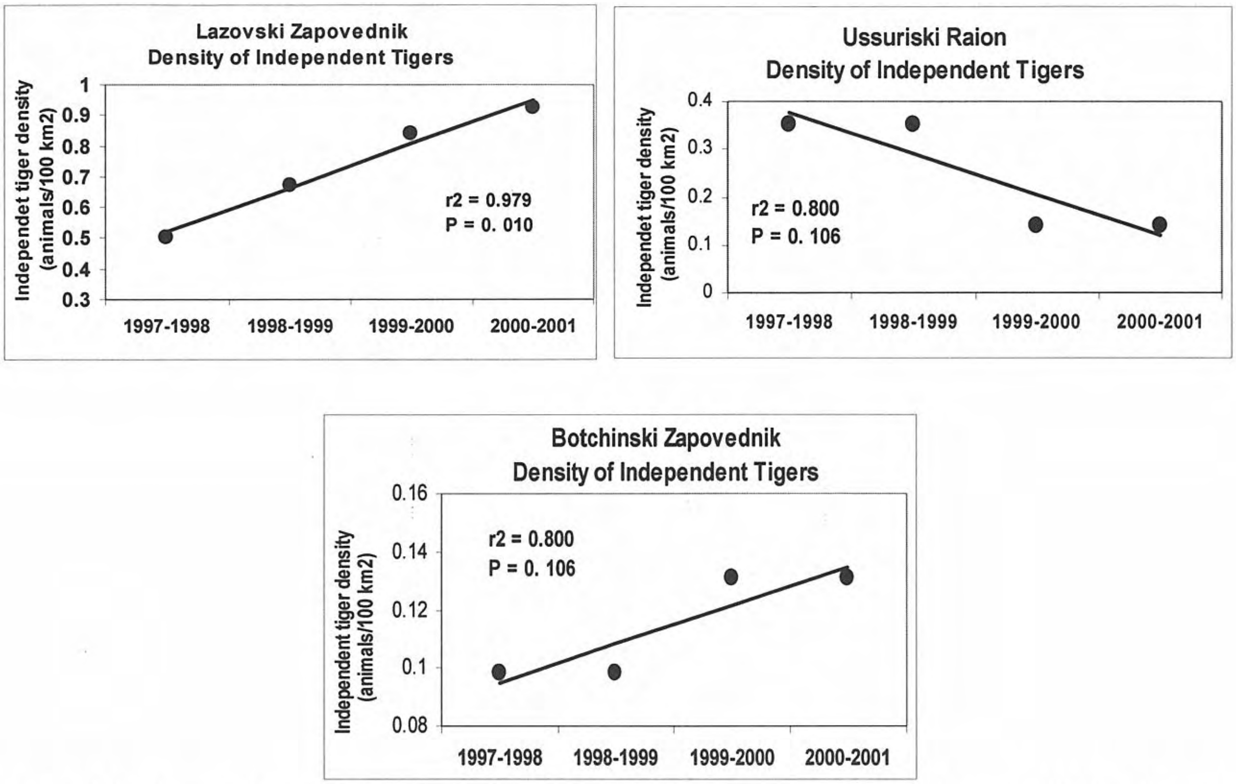


Figure 10. Regression analyses for individual monitoring sites with P-values < 0.20 for changes in density of independent tigers across the four years of the monitoring program, 1997-1998 through 1999-2000.

Correlations Among 3 Tiger Abundance Indices

To assess the relationship of presence/absence, track densities, and expert assessments of tiger numbers, we averaged indices across all four years for each site, then ranked each site for each separate index, and then estimated Spearman's rho for the three, 2-way comparisons to determine correlations among the three indicators (Table 7).

Table 7. Correlations (using Spearman's rho) of three indicators of tiger abundance, based on the ranks of each monitoring site for each indicator, for data averaged for the first four years of the Amur tiger monitoring program, 1997-1998 through 2000-2001.

	Presence/ absence	Track indicator	Expert assessment
Presence/absence	1		
Track indicator	0.744	1	
Expert assessment	0.432	0.306	1

The results suggest a similar pattern to that conducted previously for specific years. While the correlation between presence/absence and track density estimators is high and significant (Spearman's ρ = 0.744, n=16, 0.05 < P < 0.1) (Figure 11a), these two estimators showed relatively poor correlates with the expert assessments (Table 7, Figures 11b, 11c).

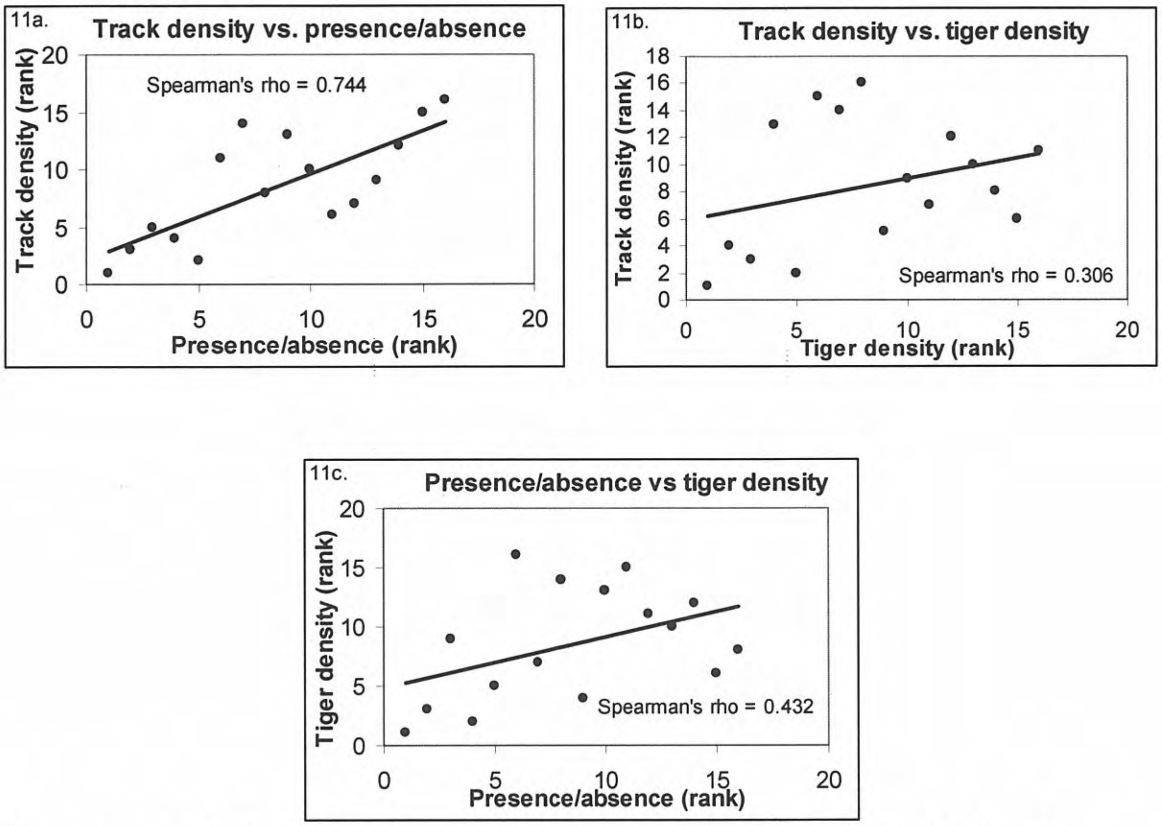


Figure 11a-c. Relationship of three indicators of tiger abundance on monitoring sites, based on: a) ranking of sites based on percentage of survey routes with tigers (presence/absence) versus ranking of sites based on track density estimators; b) track density estimator versus expert assessment of tiger density; c) presence/absence estimator versus expert assessment of tiger density.

The correlation between presence/absence counts and track density is perhaps not surprising, given that the information is coming from the same source (tracks on survey routes), but the strength of the relationship (Figure 4) is reassuring in that both indicators demonstrate the same pattern in terms of tiger abundance. There are a number of potential explanations for the lack of correlation between the expert assessments and other abundance estimators. While the presence/absence and track indicators both rely solely on data from survey routes, expert assessments include track data from other sources, and interview information. The fact that coordinators apparently interpret track data differently (see 1999-2000 report) also makes it unlikely that track densities and expert assessments will show a strong correlation.

Measures of Reproduction, Sex-age Structure, and Mortality

Reproduction on Monitoring Sites

Expert assessment of tiger numbers and sex-age structure provide an opportunity to track changes in reproduction and population structure over time. In the 200-2001, there were 20 cubs from 11 litters reported for all 16 monitoring sites; only 9 of the 16 sites reported tracks of cubs during the winter survey periods.

Over the course of the first four years of monitoring, cub production has been recorded in each of the 16 monitoring sites (Table 8). However, there is considerable yearly variation, both within and between sites. In only 4 sites (Ussuriski Zapovednik, Botchinski Zapovednik, Sikhote-Alin Zapovednik, and Matai) were tracks of cubs reported for all 4 years.

Cub production appears to have remained fairly stable across the 4 years of monitoring (Figure 12). However, the number of litters appears to be decreasing over time (Figure 13). Whereas in previous years cub production and litter production appeared to be fairly tightly

Table 8. Number of litters, and number of cubs produced on each monitoring unit for 4 winters, based on expert assessments of tiger tracks.

		Year									
		97-98		98-99		99-00		00-01		Total	
		# litters	# cubs	# litters	# cubs	# litters	# cubs	# litters	# cubs	# litters	# cubs
1	Lasovski Zapovednik	1	1	1	2	0	0	2	5	4	8
2	Lazovski Raion	2	2	1	2	0	0	1	3	4	7
3	Ussuriski. Zapovednik	2	2	3	3	1	3	1	2	7	10
4	Iman	0	0	0	0	1	1	1	1	2	2
5	Bikin	1	1	0	0	2	2	0	0	3	3
6	Borisovkoe Plateau	0	0	1	1	1	1	0	0	2	2
7	Sandago	2	3	1	1	0	0	0	0	3	4
8	Khor	0	0	0	0	0	0	1	1	1	1
9	Botchinski Zapovednik	1	1	1	1	2	2	1	2	5	6
10	BolsheKhekhtsir Zapovednik	0	0	1	1	0	0	0	0	1	1
11	Tigrini Dom	0	0	1	1	1	1	1	1	3	3
12	Matai	2	3	2	2	1	2	0	0	5	7
13	Ussuriski Raion	-	-	1	2	0	0	0	0	1	2
14	Sikhote Alin Zapovednik	5	5	3	4	1	1	2	2	11	12
15	Sineya	1	1	0	0	1	1	1	3	3	5
16	Terney Hunting Society	-	-	2	2	1	1	0	0	3	3
	Total	17	19	18	22	12	15	11	20	58	76

associated, this is the first year where a clear divergence appears to have emerged. Cub production has retained stability, in the face of decreasing litter production, due to an increase in litter size (Table 9). Whereas in the first two years of monitoring, no litters of three were recorded, there were three sets of triplets recorded this past winter. Although the decrease in litter production should be considered as a potential warning signal of decreasing productivity, as long as it is balanced by an increase in litter size, it should not pose a threat to overall productivity. However, this shift in how total cub production is being attained may indicate that cub production is becoming concentrated in only a few of the monitoring sites.

We examined whether cub production is becoming concentrated in fewer sites by looking at productivity, measured as cub density, in zapovedniks versus other monitoring sites. Because

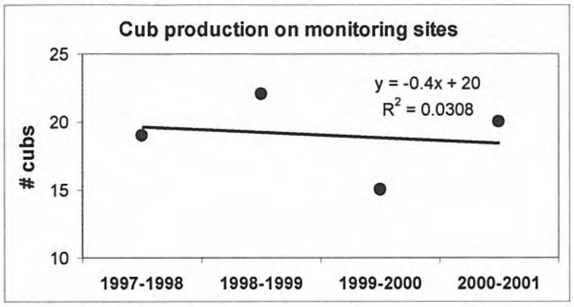


Figure 12. Total number of tiger cubs produced on 16 monitoring sites in the Russian Far East, during the first 4 years of the program.

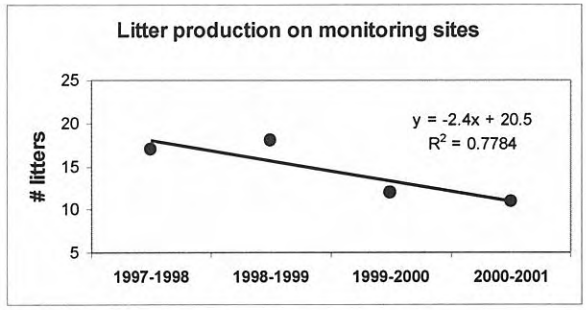


Figure 13. Total number of litters produced on 16 monitoring sites in the Russian Far East, during the first 4 years of the program.

all other indicators (presence/absence, track density, and tiger density) suggest that tiger densities are higher in zapovedniks, we predict that conditions are better there (e.g. prey densities higher, see below) and therefore productivity is higher. In fact, when we compared cub density across years and protected area status (zapovedniks versus others), ranking all estimates for all sites across all years, there was no significant change in cub density among the four years (F = 0.68, df = 3, 54, P = 0. 5669), but zapovedniks had much higher cub densities than unprotected areas (F = 4.13, df = 1, 54, P = 0.0471). From these analyses, it is clear that zapovedniks are responsible for the majority of cub production.

Table 9. Litter size of all litters recorded in 4 winters of the Amur Tiger Monitoring Program, based on expert assessments of tracks.

Litter size	97-98	98-99	99-00	00-01	Total
1	15	14	10	5	44
2	2	4	1	3	10
3	0	0	1	3	4
Total	17	18	12	11	58

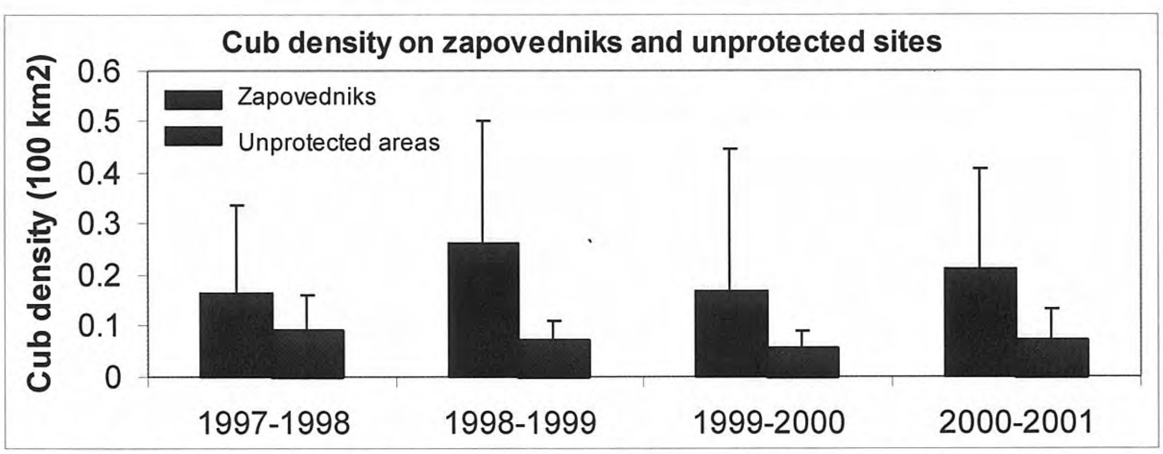


Figure 14. Cub density in zapovedniks and unprotected areas during the first 4 years of monitoring Amur tigers in the Russian Far East.

This process requires careful study incoming years. In the meantime, it is clear that protected areas are acting as source populations for the entire Russian Amur tiger population, and may be critical to maintaining stability in the overall population.

Sex-age Structure on Monitoring Sites

Although there are numerous sources of potential error in using expert assessments to derive sex-age structure of tiger populations, two factors suggest this information can be useful: 1) a high percentage of unknowns (Table 10) suggest that project coordinators are fairly conservative in attributing sex-age attributes to animals where information is insufficient; 2) assuming the same coordinators develop these data for extended periods, the data will show

Table 10. Number of tigers, by age class, and sex (for adults only) on 16 monitoring sites in winter 2000-2001, based on expert assessments.

		Age						Totals		
		Adults								
#	Site	Males	Females	Un-known	Sub-adults	Cubs	Age unknown	Total adults	Total independents*	Total (all tigers)
1	Lasovski Zapovednik	1	2			5	8	3	11	16
2	Laso Raion		2			3	2	2	4	7
3	Ussuriski Zapovednik	2	2	1		2		5	5	7
4	Iman	2	3		1	2		5	6	8
5	Bikin	2	4					6	6	6
6	Borisovkoe Plateau	1	2			1		3	3	4
7	Sandago	2	1		1		3	3	7	7
8	Khor	2	2			1		4	4	5
9	Botchinski Zap.	2	1		1	2		3	4	6
10	BolsheKhekhtsir Zap.		1			3		1	1	4
11	Tigrini Dom	2	1		1	1		3	4	5
12	Matai	1	2	1		2		4	4	6
13	Ussuriski Raion	1	1					2	2	2
14	Sikhote-Alin Zap.	3	7		2	4	5	10	17	21
15	Sineya	2	3		1	3	1	5	7	10
16	Terney Hunting Soc.	3	3			1	5	6	11	12
	Total	26	37	2	7	30**	24	65	96	126

*Independent = adults, subadults, and unknown.

**Sum number of cubs does not equal value in Table 8, which was adjusted for inconsistencies in cub identification.

trends if there are any changes in population structure.

The tiger population in all monitoring sites combined is dominated by adults (52%), with sub-adults representing 5%, and animals of unknown age (which probably all represent adults and sub-adults) representing 19% of the population (Table 10). Cubs represent 23% of the total animals recorded, according to Table 9, but this value likely represents an error (either in the database, or in track interpretation) that must be resolved. The female:male ratio of adults was 1.4:1 (Table 9). We combined adults, sub-adults, and animals of unknown age to develop a sex ratio statistic for independent animals across all years (Table 11). This sex ratio estimator demonstrates a consistent trend of greater numbers of females in the population, but that ratio varies from 1.6:1 to 1:1 (Table 11). Because radiotelemetry studies suggest that that the ratio of females and males is higher than 1:1, we suspect that the true ratio in the population is at the higher end of this spectrum of values.

Table 11. Sex ratio of independent tigers on 16 monitoring sites based on expert assessments of track data during 4 winter surveys.

	Males	Females	Unknown	Ratio (Females:Males)
1997-1998	35	39	28	1.1 : 1
1998-1999	26	41	44	1.6 : 1
1999-2000	38	39	24	1 : 1
2000-2001	34	47	15	1.4 : 1
Total	133	166	111	1.2 : 1

Reports of Tiger Mortalities

Sixteen instances of tiger mortalities were recorded by project coordinators for the 1999-2000 winter, bringing a total 37 mortalities reported across the first four years of the monitoring program (Table 12). This is the first year that data has been received from Khabarovski Krai, and therefore the database is not fully representative of the distribution of mortalities across tiger range in Russia. At present there are likely too many biases in how this data is collected to derive any estimates of mortality rates (human-caused or otherwise) or spatial distribution of mortalities. Results from these first four years demonstrate that most reports come from the vicinity of zapovedniks, where a cadre of forest guards, scientists, and interested field technicians are more likely to report tiger mortalities than elsewhere across tiger range (Figure 15).

Adults make up a smaller percentage of the mortalities than of the reported population in the monitoring sites (51 versus 63%), and the proportion of sub-adults is about the same as in the populations (10 versus 8%), but the number of animals of either unknown age or sex makes all comparisons questionable (Tables 10 and 12).

Table 12. Reports of tiger mortalities from coordinators of the Amur tiger monitoring program in Primorski Krai, 1997-1998 through 1999-2000.

Age	Sex	1997-1998	1998-1999	1999-2000	2000-2001	Total
Adults	Males	1	2		4	7
	Females		2	2	3	7
	Unknown	1				1
Subadults	Males	1	1			2
	Females		1			1
	Unknown	1				1
Unknown	Unknown		5		6	11
Cubs		1	3		3	7
Totals		5	14	2	16	37

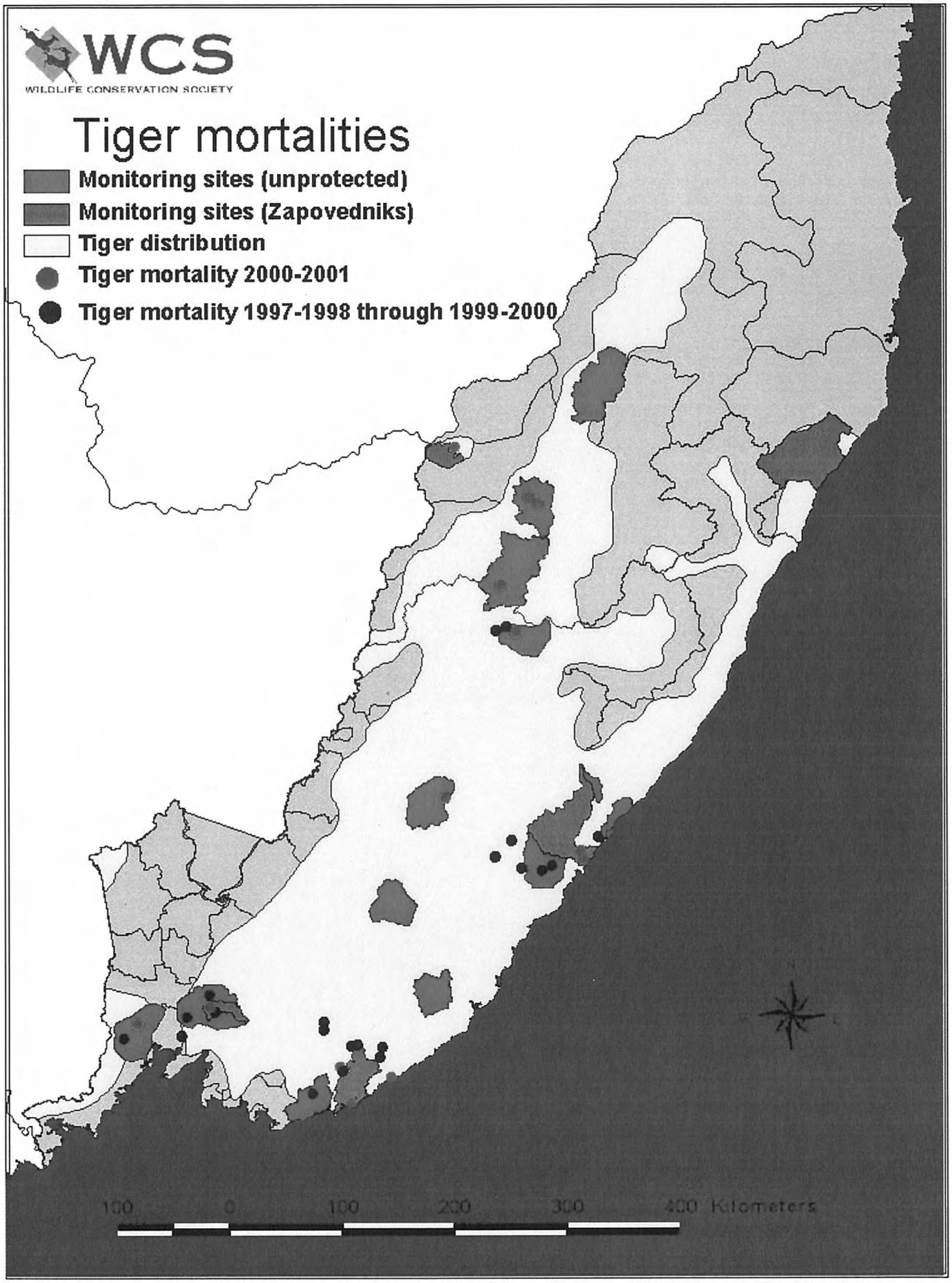


Figure 15. Locations of reported tiger mortalities from coordinators of the Amur tiger monitoring program (Primorski Krai only), for 1997-1998 through 1999-2000.

Ungulate Populations on Monitoring Sites

As in previous years, prey numbers varied greatly among sites (Table 12). To attempt to understand how density estimates varied across monitoring sites and time, we conducted two separate analysis. First, we used the average track density estimates for each of the monitoring sites for each of the past 4 years, and assessed how those density estimates were affected by protected status, latitude, and proximity to coast in a 3-way factorial analysis to assess potential variables affecting track density estimators for each species (using SAS GLM). Secondly, we conducted a regression analysis to look for trends across time (4 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, under the understanding that firstly, sample sizes are small (4 years) and that we are looking for general trends and potential early warning signs across the region and within each monitoring site. Many of the details of ungulate densities are provided in the individual accounts of each site (Part II). We report results separately for each species.

Table 12. Track count estimates for 4 prey species of tigers on 16 monitoring sites for the 2000-2001 winter period, for the Amur Tiger Monitoring Program.

		# routes	Red deer		Wild boar		Roe deer		Sika deer	
#	Monitoring site	n	mean	std	mean	std	mean	std	mean	std
1	Lasovski Zapovednik	12	9.16	12.57	5.08	6.45	2.73	3.05	123.38	155.86
2	Laso Raion	11	0.18	0.46	0.27	0.59	0.11	0.36	51.64	105.40
3	Ussuriski. Zapovednik	11	5.03	4.78	25.21	27.41	6.49	4.81	26.65	30.41
4	Iman	12	5.56	3.71	0.66	2.03	4.45	7.10	-	-
5	Bikin	16	9.53	9.05	3.97	5.83	2.88	3.15	-	-
6	Borisovkoe Plateau	14	0.00	0.00	7.47	12.02	6.22	5.57	20.81	16.99
7	Sandago	16	7.41	8.55	0.54	0.99	8.98	8.57	7.91	13.77
8	Khor	19	4.29	4.92	2.73	3.15	3.35	3.51	0.00	0.00
9	Botchinski Zapovednik	14	2.92	2.98	0.00	0.00	4.24	3.66	-	-
10	BolsheKhekhtsir Zapovednik	7	40.97	47.01	3.52	3.93	0.92	1.44	-	-
11	Tigrini Dom	14	1.60	1.70	0.53	0.89	0.32	0.50	-	-
12	Matai	24	2.21	1.73	1.94	3.03	1.53	0.98	-	-
13	Ussuriski Raion	12	1.79	2.02	1.71	3.63	7.86	5.19	1.98	3.33
14	Sikhote Alin Zapovednik	25	31.28	16.80	3.57	4.63	16.77	19.66	8.71	22.33
15	Sineya	15	3.35	2.27	0.60	1.23	3.96	2.49	0.00	0.00
16	Terney Hunting Society	24	14.13	11.43	0.15	0.47	8.24	11.56	0.47	1.43
	Total	246	8.8729	14.944	3.1656	8.6094	5.5976	9.242	17.22	57.90

Red deer. Track count estimates of red deer were highest in Bolshe-Khekhtsirski Zapovednik, and secondly, in Sikhote-Alin Zapovednik (Table 12). In general, red deer densities were higher in protected areas, but this relationship was not straightforward. The overall 3-way factorial model was highly significant ($F = 19.02$, $df = 9,54$, $P = 0.0001$) with protected status ($F = 58.56$, $P = 0.0001$) and latitude ($F = 45.1$, $P = 0.0001$) being highly significant, and proximity to coast being marginally non-significant ($F = 3.08$, $P = 0.0563$). Interactions between protected status and latitude ($F = 11.3$, $P = 0.0001$) and latitude and coast ($F = 7.03$, $P = 0.002$) were also significant, again indicating that these relationships were rather complicated. While one might expect red deer density to decrease with increasing latitude, in fact this was not the cast (Figure 16). 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 (Figure 16), and paired LSD comparisons of each category demonstrate that those differences are statistically significant ($P < 0.05$).

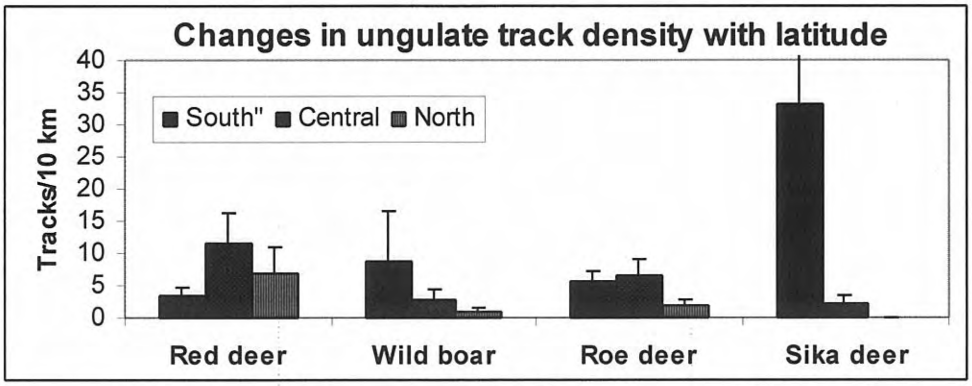


Figure 16. Changes in ungulate track density (fresh tracks/10 km of routes) with changes in latitude, with each monitoring site categorized as southern, central, or northern (see Table 1). The average track density for each site for each year considered a sampling unit (n = 64).

It has been commonly assumed that the decrease in red deer density in the south is attributed to competition with sika deer numbers. Our data, however, does not substantiate that assumption. We conducted a regression analysis of red deer and sika deer densities for the southern and central monitoring sites (Figure 17) and did not find a clear relationship between sika and red deer numbers ($r^2 = 0.0794$, $P = 0.401$). Thus, there may be other factors explaining the low numbers of red deer in the south.

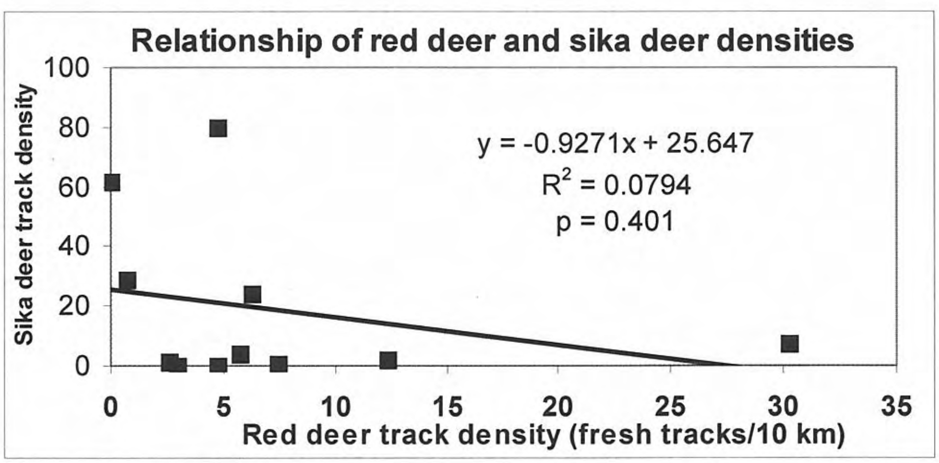


Figure 17. Track densities (fresh tracks/10 km route) of sika deer and red deer in southern and central monitoring sites of the Amur Tiger Monitoring Program, averaging across all four years for each site.

The relationship between protected area status and red deer density is more clear cut (Figure 18). Red deer track densities are, on average, three times higher in protected areas than in unprotected areas.

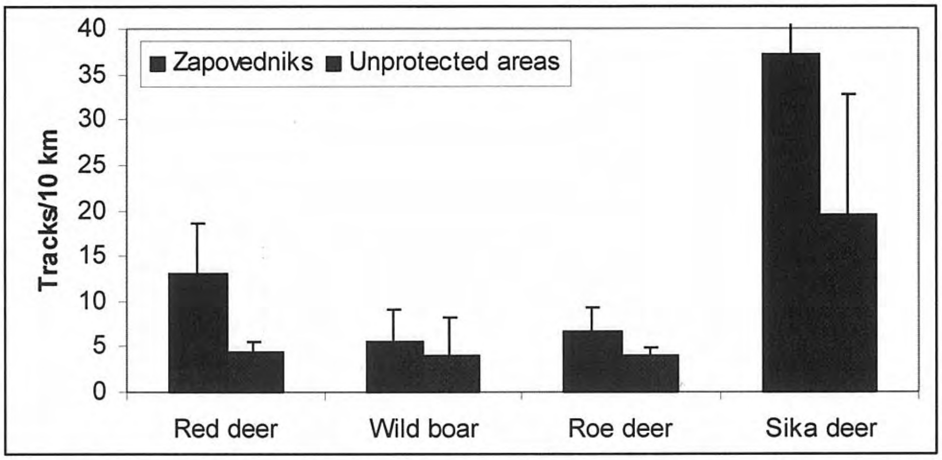


Figure 18. Track densities (fresh tracks/10 km route) for red deer, wild boar, roe deer, and sika deer in zapovedniks (protected areas) versus unprotected areas, with each yearly average for each monitoring site used as a sample (sample size = 64), for the Amur Tiger Monitoring Program, 1997-1998 through 2000-2001.

There was a significant positive trend in red deer numbers over the four years for all sites combined ($r^2 = 0.887$, $P = 0.05$) (Figure 19). Given the large amount of error associated with each estimate, it is as yet unclear whether this trend is significant, biologically, but this evidence suggests that red deer numbers appear to be slightly increasing.

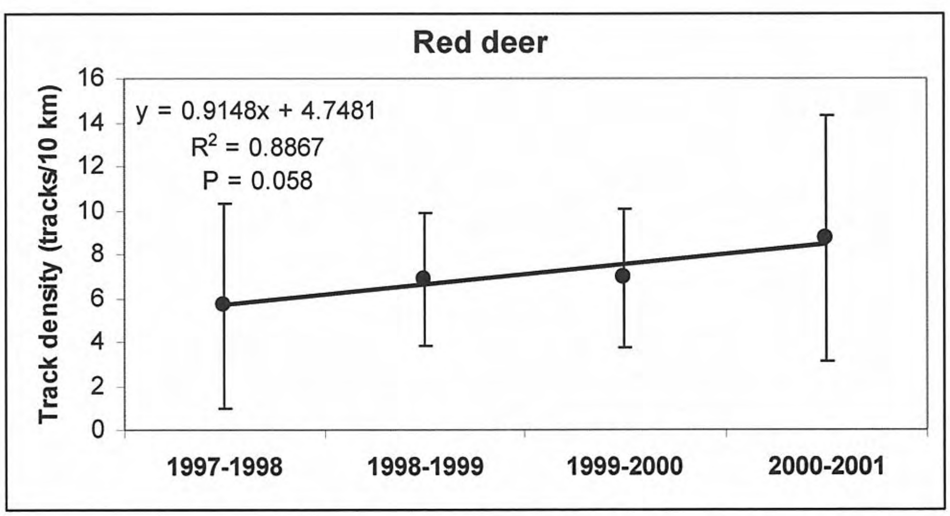


Figure 19. Average red deer track density for all sites for each of the first four years of the Amur Tiger Monitoring Program, 1997-1998 though 2000-2001.

There were three monitoring sites (Lazovski Zapovednik, Sandagoy, and Bolshe-Khekhtsirski Zapovednik) where red deer numbers may be increasing (Figure 20) , but that trend was statistically significant only for Lazovski Zapovednik (r^2 = 0.904, P = 0.049).

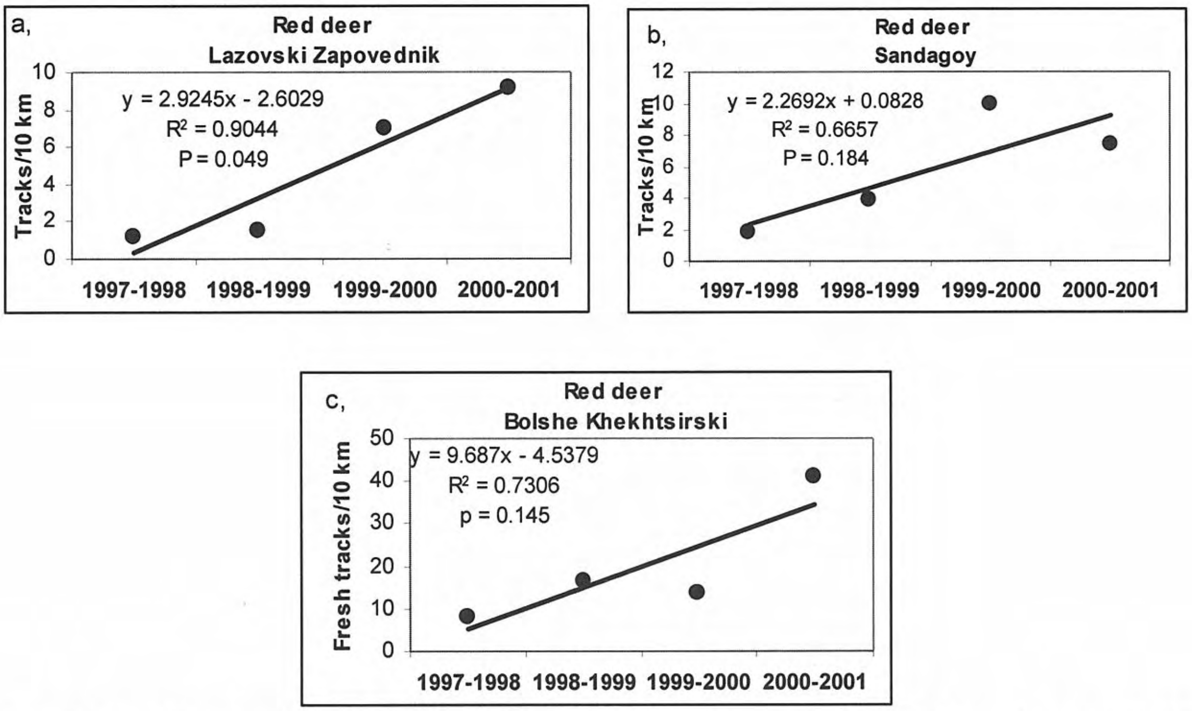


Figure 20a-c. Changes in red deer densities, as measured by fresh tracks/10 km along routes in 3 of the 16 monitoring sites of the Amur Tiger Monitoring Program: a) Lazovski Zapovednik; b) Sandagoy; c) Bolshe-Khekhtsirski Zapovednik.

Wild boar. Wild boar populations tend to fluctuate more dramatically than deer populations, and because they are commonly found in groups, are more problematic to accurately estimate density. Track density in Ussuriski Zapovednik was dramatically higher than any other

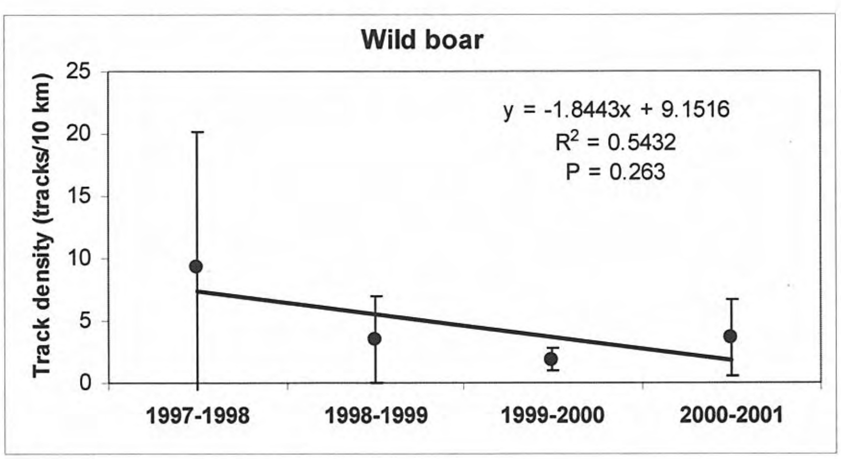


Figure 21. Average wild boar track density for all sites, for each of the first four years of the Amur Tiger Monitoring Program, 1997-1998 though 2000-2001.

site (Table 12), suggesting a large concentration of boar in this region, or replicate counting of a few groups. Boar track densities in Borisovkoe Plateau were also high (Table 12). In comparison to Ussuriski Zapovednik (where track density was 25 tracks/10 km), seven sites had

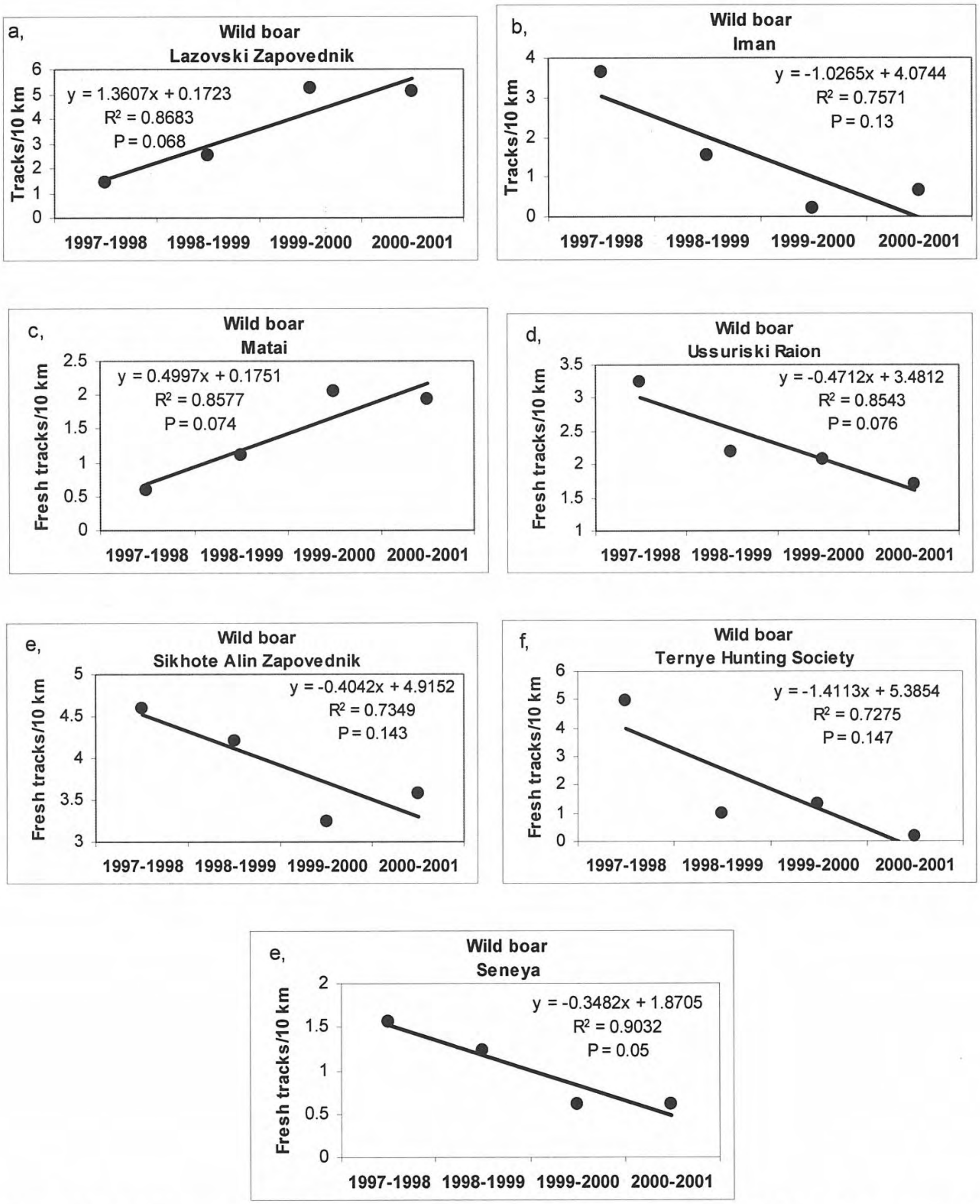


Figure 22a-c. Changes in wild boar densities, as measured by fresh tracks/10 km along routes in 7 of the 16 monitoring sites of the Amur Tiger Monitoring Program where the probability is less than 0.2 that the slope of the line does not equal zero.

boar track densities less than 1 track/10 km (Table 12). Unlike red deer, there was no relationship between track density of wild boar with protected status, latitude, or proximity to coast (for overall model, $F = 1.05$, $df = 9, 54$, $P = 0.416$).

Although there was a negative slope to the trend analysis (Figure 21), there was no statistically significant evidence ($r^2 = 0.543$, $P = 0.263$) that wild boar numbers are decreasing across the region. Boar populations show great variation both spatially and temporally (as evidenced by large confidence intervals in some years), and it is probably exceedingly difficult to get good indications of trends in the boar population. This overall pattern should be compared with analyses of individual sites (see below and Part II), and should be monitored closely in coming years to assess changes.

Analyses at individual sites reinforce the hypothesis that the wild boar population is decreasing across a large portion of tiger habitat (Figure 22a-g). Five sites demonstrated a negative trend (where the probability is less than 0.2 that the slope does not equal zero), with only one statistically significant site (Sineya), but only two sites, Lazovski Zapovednik and Matai, had indications of a positive trend (both nearly significant, $P = 0.068$ and 0.074, respectively). Negative trends were concentrated in the central portion of tiger range (Iman, Sineya, Sikhote-Alin Zapovednik, Terney Hunting Society), although boar appear to be decreasing around Ussuriski Raion as well. Perhaps the most clear evidence of a decline in boar numbers (even though non-significant) exists for Sikhote-Alin and Terney Hunting Society, which are adjacent to each other, and which demonstrate nearly identical trends (Figures 22 d and f).

Sika deer. Sika deer occur regularly in only nine of the monitoring units, including all 6 in the south, and 3 of the central monitoring sites (Table 12). The 3-way factorial analysis for just these sites demonstrated that, even while excluding the northern sites, latitude was an important factor affecting track density ($F = 14.72$, $P = 0.0005$), with the majority of sika deer concentrated in the southern part of tiger range (Figure 16). Protected areas also retained higher concentrations of sika deer ($F = 4.46$, $P = 0.042$) (Figure 18). Unlike red deer, proximity to coast was also an important factor affecting sika deer densities ($F = 10.04$, $P = 0.003$), with greater densities of sika deer in coastal areas (Figure 23)

There was no significant trend in sika deer numbers when averaged across all nine sites where sika deer are commonly found ($r^2 = 0.241$, $P = 0.509$) (Figure 24), but there were interesting trends in many of the sites (Figure 25 a – f). In three of these sites, sika deer populations appear to be increasing (Lazovski Zapovednik, Lazovski raion, and Sandagoy) (25a,

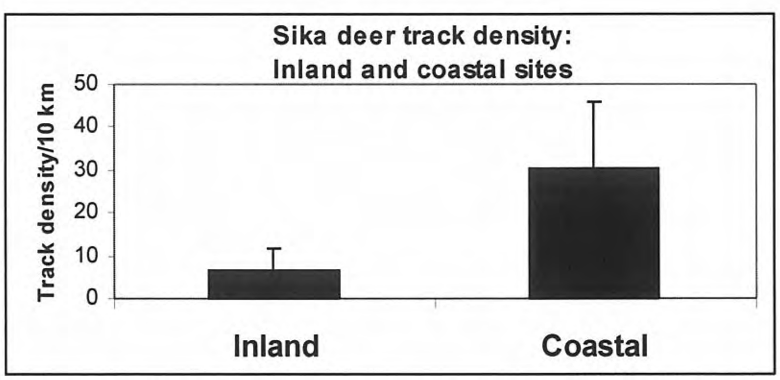


Figure 23. Variation in sika deer track densities between inland and coastal monitoring sites, based on 4 years

of the Amur Tiger Monitoring Program, 1997-1998
through 2000-2001.

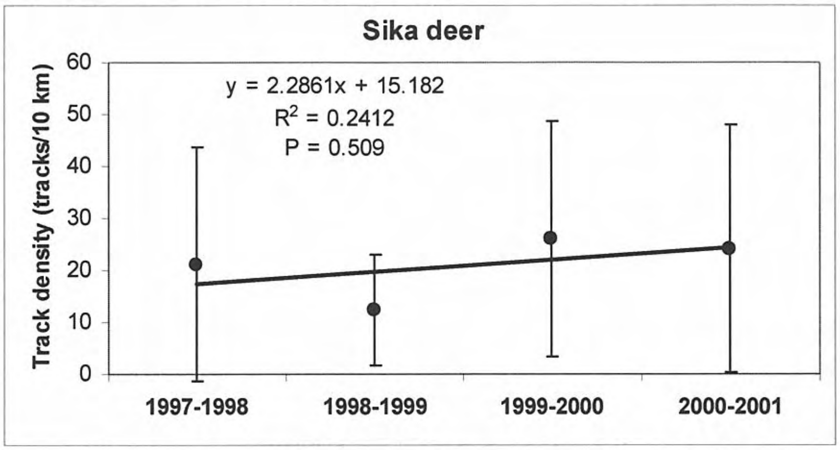


Figure 24. Average sika deer track density for all sites, for each of the first four years of the Amur Tiger Monitoring Program, 1997-1998 though 2000-2001.

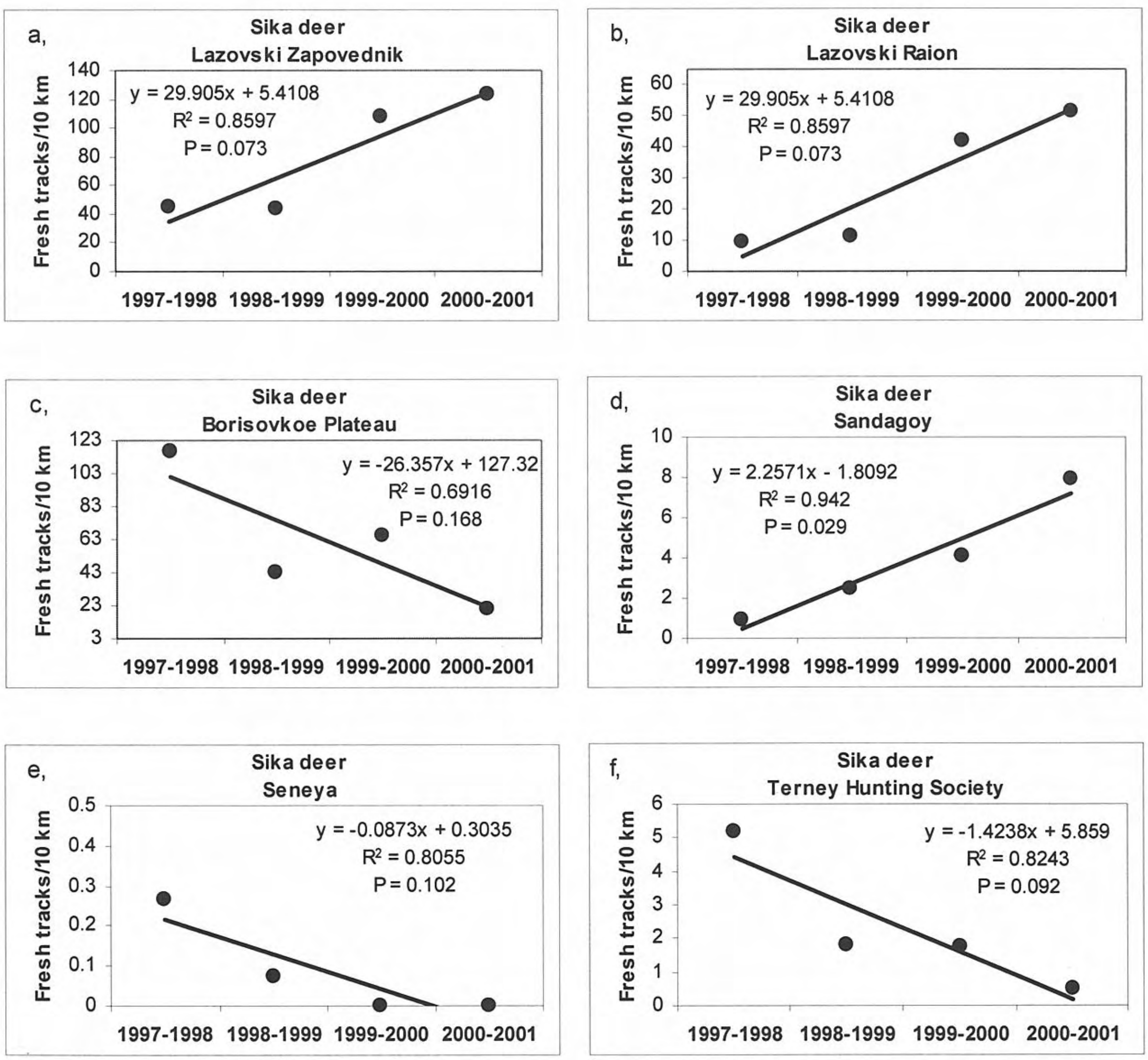


Figure 25a-f. Changes in sika deer densities, as measured by tracks/10 km along routes in 6 of the 9 monitoring sites where this species occurs in the Amur Tiger Monitoring Program.