A MONITORING PROGRAM FOR THE AMUR TIGER

THIRD-YEAR REPORT: 1999-2000

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
Lasovki State Zapovednik
Ussurisk Zapovednik
Botchinski Zapovednik
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TABLE OF CONTENTS

Executive Summary

In the 1999-2000 winter, 16 monitoring units, totaling 23,555 km^2 (approximately 15-18% of suitable tiger habitat) were survey to assess changes in tiger numbers (using relative and absolute indicators), cub production, 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 three years (1997-1998 winter through 1999-2000 winter) of monitoring Amur tigers in the Russian Far East suggest that the tiger population may have experienced a slight increase between the first and second years, followed by a slight decrease between the second and third years. These changes were not statistically significant, but were persistent across a number of indicators. A decrease in cub production, and localized depressions in ungulate numbers, are also causes for concern. Future monitoring will be important to determine whether these trends continue.

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 with 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 second 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 review, 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:

protected/unprotected areas;

north/south gradient; and,

inland/coastal (in most cases this 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 (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	Geographic location	Coastal/ inland
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). Included as monitoring units are all 5 zapovedniks that include 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).

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

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.

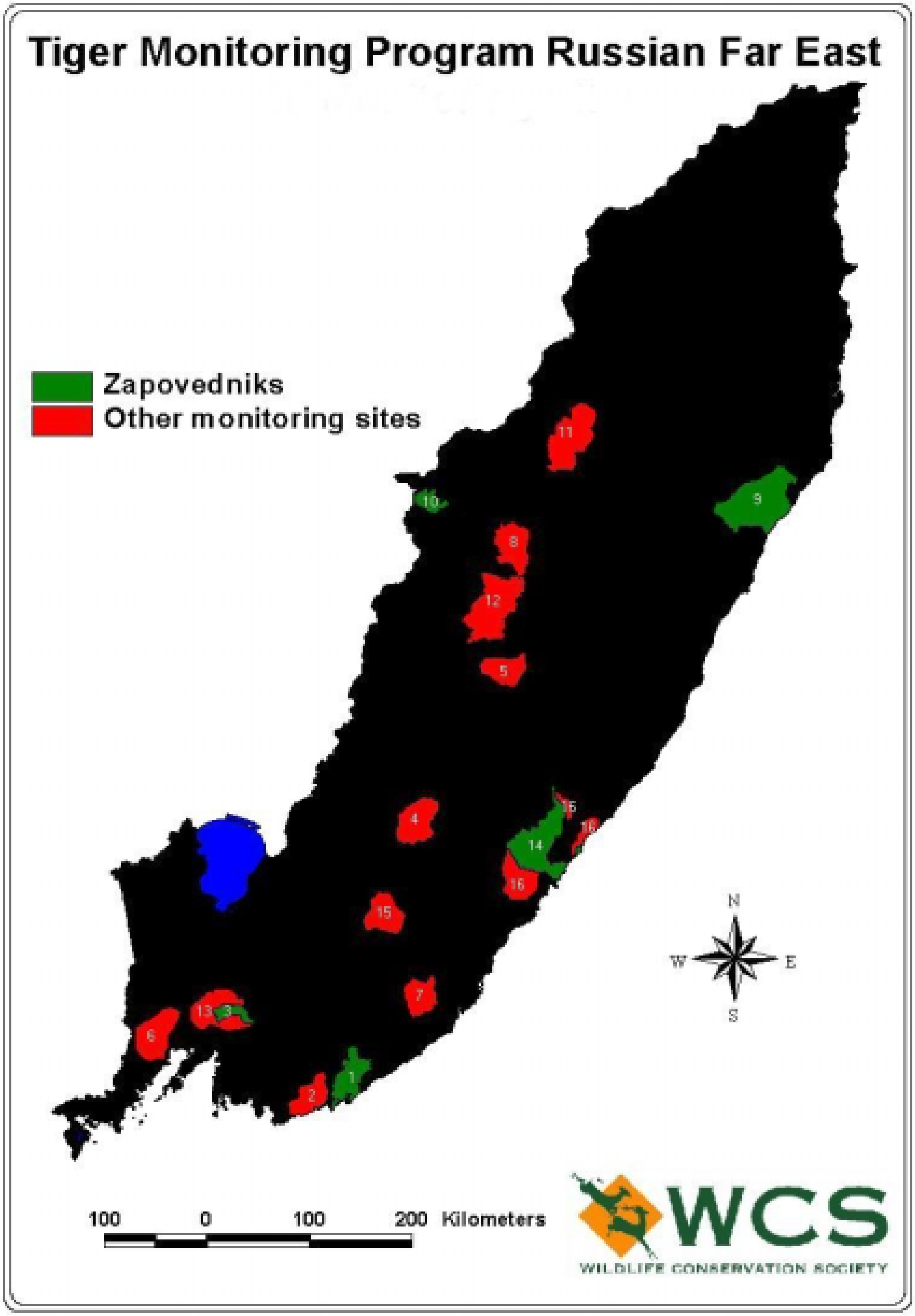

Figure 1. Location of the 16 sites used for monitoring Amur tigers in the Russian Far East. Numbers referenced in Table 1 and most other tables throughout text.

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 natural boundaries reflecting either boundaries of protected areas, or natural geographic boundaries (ridgetops, or large rivers);

In good tiger habitat, assuming that female home ranges average 400-500 km^2 (Miquelle et al. 1999) 100,000 - 150,000 ha should 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 regions where tigers occur, the snow cover afforded in the winter season in the Russian Far East provides a "clean pallet" which reveals presence of tigers, and usually retains that evidence for an extended period, often 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 along those routes that 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 of 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 detecting tracks than shorter routes, and that 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 (see below); 2) there should be sufficient number of routes to provide a statistical basis for comparisons among count units; 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), and a 94% chance of detecting a 10% increase in population size. Chances of detecting a 5% change are decidedly less (61-64%). With 20 routes, a 10% change in population size will almost certainly be detected (greater than 99%) and 5% changes also have a high probability of being statistically detectable (82%). Based on this analysis, it would be ideal to create 20 routes/count unit, but our ability to do so would likely be prohibitively expensive and create logistical problems. 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 due to variation 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 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)

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 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/year). Monitoring units can then be ranked on the basis of percentage routes with (without) tiger tracks.

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.

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 prior to previous snowfall, so that, when snowfalls are widely separated, track densities will be underestimated if time between snows is used. 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 for days since snow:

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) is then averaged for each route (for the two surveys per route per year), and becomes the test statistic to be 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 track density 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.

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, subadult, 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, subadults, 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 Spearmans rho (Conover 1980) on those ranks.

Trends in population status were assessed graphically, and by comparing means and confidence intervals for each of the abundance estimators derived as the mean for all 16 monitoring sites (mean percent of routes without tracks, mean track density estimator, and mean independent tiger density).

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 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. Exploratory analyses indicated that distributions of these ungulate track density estimators were in most cases non-normal. Therefore, while we report means and standard deviations, tests for changes over time use general linear models (SAS 1990) conducted on the ranks of track density estimators across all years and sites.

IV. RESULTS OF THE 1999-2000 WINTER MONITORING PROGRAM

Summary Data on Count Units and Routes

In the 1999-2000 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 twice (492 samplings), representing 3057 km of routes (with double sampling, a total of 6114 km traversed) (Table 1). On average, route length was 12.8 km. Route length was fairly consistent across monitoring units (Table 1), with the exception of the Khor and Ussuriski Zapovednik units, where routes are unusually short.

Table 3. Characteristics of units surveyed for Amur tiger monitoring program, 1999-2000.

	Monitoring Unit	Coordinator	Size of unit (km2)	# 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 BolsheKhekhtsirski 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 exceeding 1 km/10 km^2 in all but two units (Botchinski and Tigrini Dom) (goal 1 km/10 km^2).

Measures Of Tiger Abundance

Zero Counts on Survey Routes

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 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 1999-2000 winter, 28.5% of routes did not intersect tiger tracks. If routes were sampled a single time, there would be zero counts on nearly half (49.1%) of the routes. This result indicates that the double sampling regime (early and late winter) dramatically increases the amount of information each route provides (nearly doubling it).

The percentage of routes without tracks varied greatly among monitoring units (Figure 2).

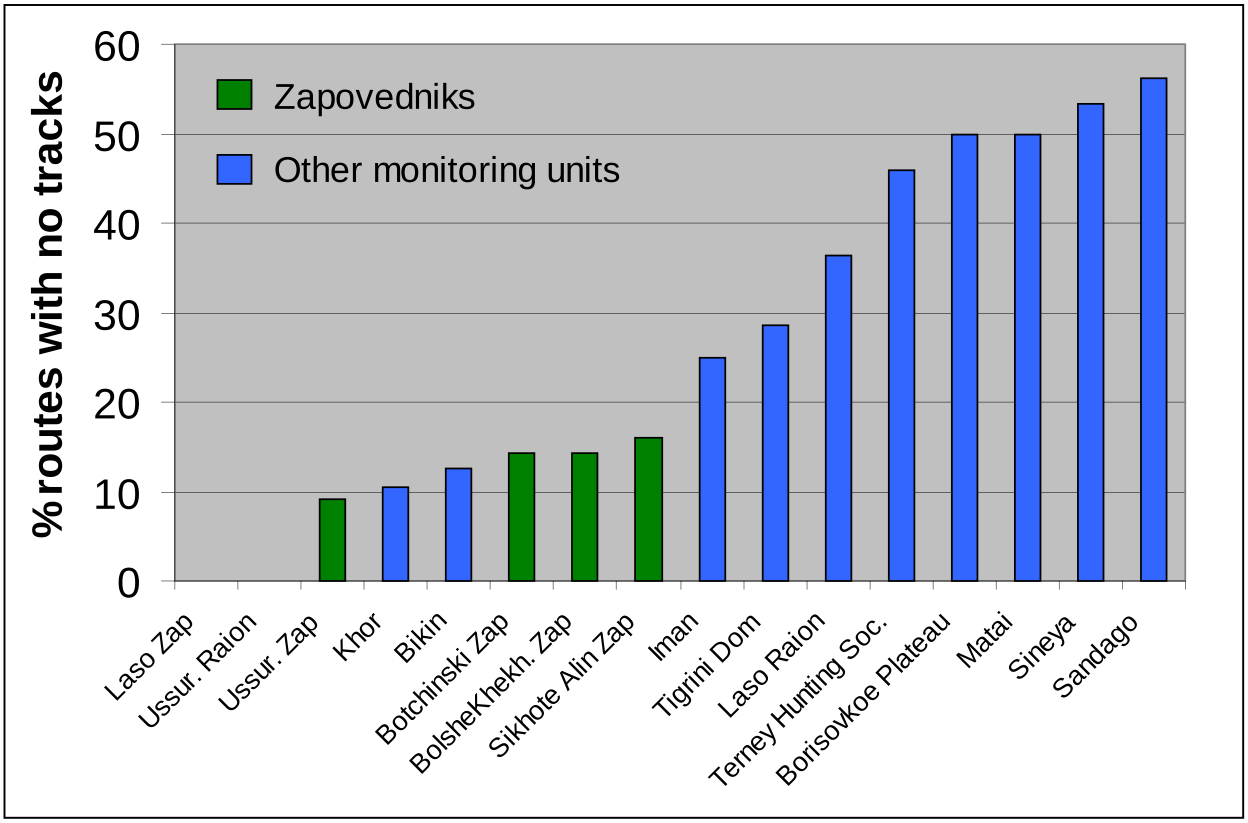

Figure 2. Percentage of survey routes with no tiger tracks within each of the 16 monitoring units of the Amur Tiger Monitoring Program, winter 1999-2000.

Five of the top 8 units with fewest zero counts were protected areas. Of the three zapovedniks with a paired unprotected site adjacent to it, differences between Ussuriski Zapovednik and Ussuriski Raion were small (0 vs. 9.1% of routes with no tracks, with the Raion, not the zapovednik having 0%), but differences between Sikhote-Alin Zapovednik and Terney Hunting Society (16 vs. 45.8%) and Lasovski Zapovednik and Raion (0 and 36.4%) were much greater, indicating greater relative abundance of tigers in the protected areas.

There was no clear relationship between zero counts and latitude, as those four units with the highest percentage of zero counts (Borisovkoe Plateau, Sandagoy, Sineya, and Matai) include the full spectrum of southern, central, and northern sites. Similarly, there was no clear relationship between zero counts and inland versus coastal sites (Figure 2).

Track Counts on Survey Routes

The track density estimator varied significantly among monitoring sites (GLM based on ranks of track density estimator, F = 6.04, df =15,230, P = 0.0001). Mean track density provides an indication of relative abundance of tigers on monitoring sites (Table 4), but the population of track density estimators was non-normal, making the mean value somewhat biased. Using ranked

Table 4. Summary of sample size (number of routes), track density (tracks/days since snow/100 km survey routes), standard deviation of track density, relative track density of monitoring sites using ranking of survey routes (see text), and results of Fishers Least Significant Difference range test for differences in track density among monitoring sites, based on the results of the 1999-2000 winter Amur tiger monitoring program.

Site #	Site	# routes	Mean track density	SD	Nonpara-metric ranking	LSD range test*
3	Ussuriski Zapovednik	11	6.45	4.30	1	A
1	Lasovski Zapovednik	12	3.18	1.62	2	A
13	Ussuriski Raion	12	1.90	1.29	3	A B
8	Khor	19	1.58	1.24	4	B C
9	Botchinski Zapovednik	14	1.22	1.05	5	B C D
14	Sikhote-Alin Zapovednik	25	1.29	1.58	6	B C D E
5	Bikin	16	0.95	0.83	7	B C D E
11	Tigrini Dom	14	1.13	1.26	8	C D E
6	Borisovkoe Plateau	14	2.03	3.11	9	C D E
4	Iman	12	0.86	0.78	10	C D E F
10	BolsheKhekhtsir Zapovednik	7	0.84	0.98	11	B C D E F
2	Laso Raion	11	0.99	1.23	12	C D E F
16	Terney Hunting Society	24	0.71	1.09	13	D E F
15	Sineya	15	0.47	0.59	14	E F
12	Matai	24	0.73	2.03	15	F
7	Sandagoy	16	0.34	0.58	16	F

*Sites with different letters are significantly different from each other.

track density estimators indicates a somewhat different relationship among monitoring sites (comparing columns of mean track density and non-parametric ranking, Table 4). For instance, although Borisovkoe Plateau had the third highest mean track density estimator (Table 4), tracks were located on a small number of routes (i.e., many zero counts - Figure 2), resulting in a high standard deviation (Table 4) and a lower estimate of relative abundance using ranked estimators.

Four of the top six ranked monitoring sites were zapovedniks.

Expert Assessment of Tiger Numbers on Monitoring Sites

Tiger densities, based on expert assessments, varied nearly tenfold, from nearly 1 animal/100 km^2 in Ussuriski Zapovednik, to 0.13 /100 km^2 in Botchinski Zapovednik (Table 5). Explanations for this variation probably include a number of environmental factors as well as biases in the estimate. Zapovedniks (Ussuriski, Sikhote-Alin, and Lasovski) had the highest concentrations of tigers (all greater than 0.8/100 km^2), indicating that protected status is an important indicator of density (a conclusion supported by both the presence/absence and track density data). However, latitude appeared to also be an important factor: the two northernmost zapovedniks (BolsheKhekhtsirski and Botchinski) despite their status, reported low tiger density,

Table 5. Number of independent tigers (those classified as adults, subadults, and unknown) based on expert assessments of tiger tracks on 16 sites in the Russian Far East, during the first 3 years of monitoring.

		Area	Number of independent tigers			Tiger density (independents/100 km^2)		
#	Site	(km^2)	97-98	98-99	99-00	97-98	98-99	99-00
1	Lasovski Zapovednik	1192.1	6	8	10	0.503	0.671	0.839
2	Laso Raion	987.5	8	4	5	0.810	0.405	0.506
3	Ussuriski. Zapovednik	408.7	7	10	4	1.713	2.447	0.979
4	Iman	1394.3	8	6	5	0.574	0.430	0.359
5	Bikin	1027.1	3	10	7	0.292	0.974	0.682
6	Borisovkoe Plateau	1472.9	4	5	4	0.272	0.339	0.272
7	Sandago	975.8	6	6	5	0.615	0.615	0.512
8	Khor	1343.8	3	4	4	0.223	0.298	0.298
9	Botchinski Zapovednik	3051	3	3	4	0.098	0.098	0.131
10	BolsheKhekhtsir Zap.	475.6	2	1	2	0.421	0.210	0.421
11	Tigrini Dom	2069.6	4	6	4	0.193	0.290	0.193
12	Matai	2487.6	3	5	4	0.121	0.201	0.161
13	Ussuriski Raion	1414.3	5	5	2	0.354	0.354	0.141
14	Sikhote Alin Zapovednik	2372.9	24	21	23	1.011	0.885	0.969
15	Sineya	1165.4	5	6	5	0.429	0.515	0.429
16	Terney Hunting Society	1716.5	11	11	13	0.641	0.641	0.757
	Sum/Average*	23555.1	102	111	101	0.517	0.586	0.478

*Sum for numbers of independent tigers, average for densities of tigers.

as did generally the monitoring sites to the north in Khabarovski Krai (Matai, Khor, Tigrini Dom).

There are also, however, a number of biases that may be influencing these results. The size of the monitoring site, in relation to coverage by survey routes, can inflate or depress density estimates. For instance, Botchinski Zapovednik has the lowest coverage (km survey routes/km^2) by far of any monitoring site (Table 3), so that the low density estimator may simply reflect a low search effort.

In assessing other potential biases of expert assessments, two questions are of interest: 1) how much do expert assessments vary among coordinators?, and, 2) how well do the expert assessments correlate with the other two measures of relative tiger abundance? The second issue is covered in the next section.

In an attempt to determine how much expert assessments varied among coordinators, we compared the ratio of all tracks reported for a monitoring site (only those reported on survey routes, as well as those both on and off survey routes) and the number of tigers based on expert assessments, to determine if there are large variations among coordinators (Figure 3). The results suggest that the track data are interpreted quite differently by different coordinators. The pattern demonstrated in Figure 3 suggests, for instance, that for a given number of tracks, it is likely that Dunishenko would report far fewer tigers that Smirnov. The results seem fairly stable whether only tracks on routes are used as a basis for comparison, or whether all tracks reported on a site are used (although the data also suggest this supplemental data off survey routes are an important source of information for some coordinators). The ratio appears to remain fairly constant across different monitoring sites by an individual coordinator (e.g., Dunishenko is always low, Smirnov is always high). These results suggest that these expert assessments may not be extremely valuable in comparing density estimates across monitoring sites, and that their main value will be

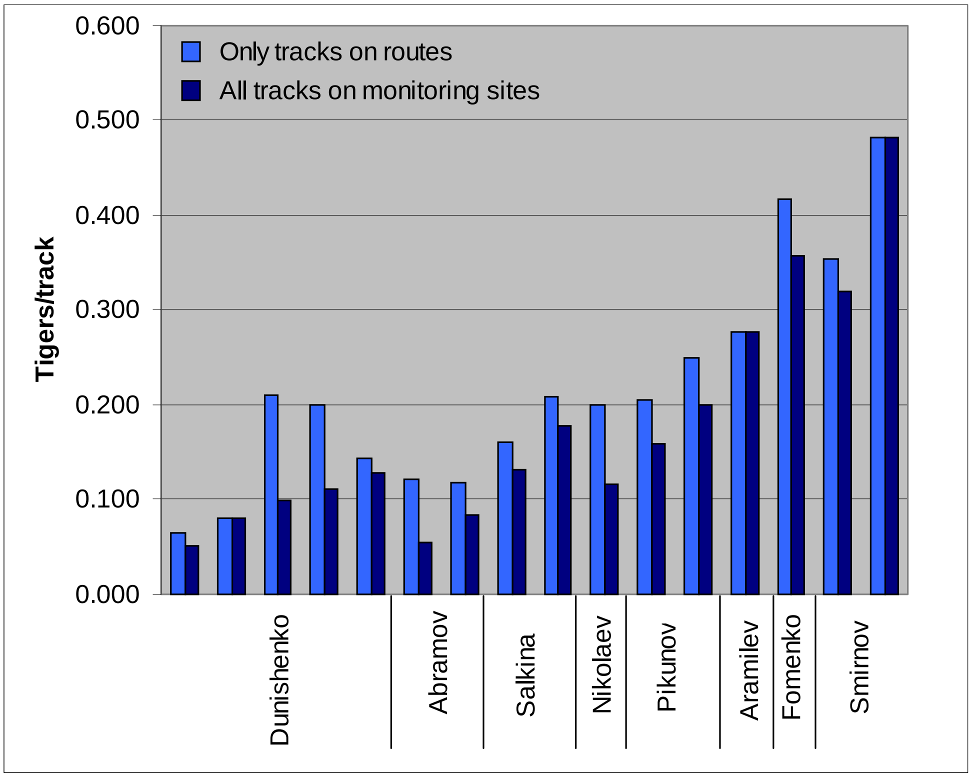

Figure 3. Variation in interpretation of track data for expert assessments by coordinators of the Amur tiger monitoring program, estimated from only tracks found along survey routes, and from total number of tracks throughout monitoring site (i.e., including tracks reported off survey routes). For any given number of tracks, a smaller tigers/track ratio indicates that fewer tigers would be reported.

in evaluating trends within each give site, assuming that the same coordinator does the evaluation of data for an extended time period.

Correlations Among 3 Tiger Abundance Indices

To assess the relationship of presence/absence, track densities, and expert assessments of tiger numbers, we ranked each site for each separate index in terms of relative abundance of tigers, and then estimated Spearman's rho for the three, 2-way comparisons to determine correlations among the three indicators (Table 6).

Table 6. Correlations (using Spearman's rho) of three indicators of tiger abundance, based on the ranks of each monitoring site for each indicator, for data from the 1999-2000 Amur tiger monitoring program

	Presence/ absence	Track indicator	Expert assessment
Presence/absence	1		
Track indicator	0.901	1	
Expert assessment	0.101	0.094	1

The results suggest that while the correlation between presence/absence and track density estimators is very high and significant (Spearmans $\rho = 0.9007$, n=16, P = 0.0001), there were non-significant and very poor correlates with the expert assessments (Table 6).

The correlation between presence/absence counts and track density is perhaps not

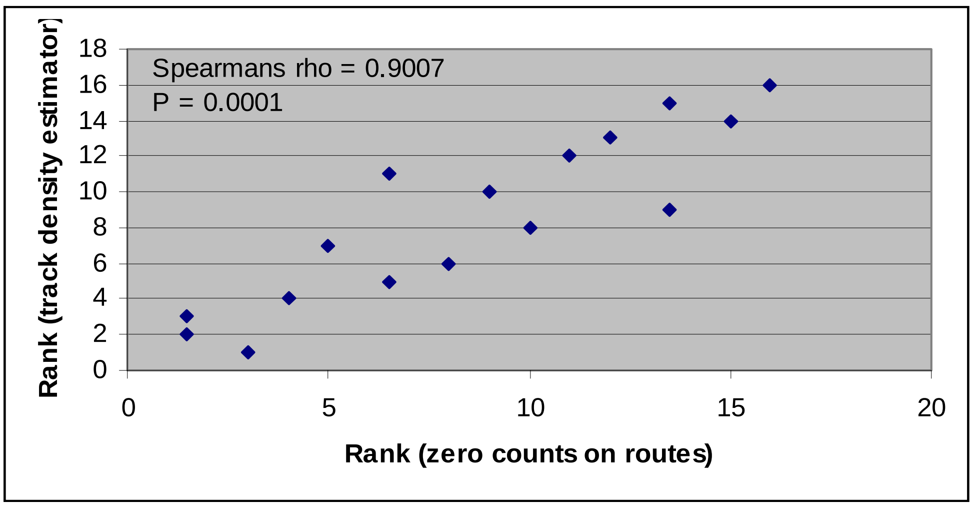

Figure 4. Relationship of two indicators of relative abundance on monitoring sites, based on: 1) ranking of sites based on percentage of survey routes with tigers (presence/absence); and, 2) ranking of sites based on mean of ranked track density estimators.

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 (Figure 3) 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. Reproduction appeared to drop off slightly for the 1999-2000 season (Table 10, Figure 5). On all 16 sites combined, only 12 litters produced 15 cubs, with both number of litters and number of cubs decreasing from previous years. However, and analysis of cub density (see below) demonstrated no significant change.

Litter size has remained fairly stable, with litters of one making up over 83% of the total number of litters (88, 78, and 83% for the 3 years) (Table 11). The first litter of 3 reported in the

Table 7. Number of litters, and number of cubs produced on each monitoring unit for 3 winters, based on expert assessments of tiger tracks.

		Year							
		97-98		98-99		99-00		Total	
	Monitoring site	# litters	# cubs	# litters	# cubs	# litters	# cubs	# litters	# cubs
1	Lasovski Zapovednik	1	1	1	2	0	0	2	3
2	Laso Raion	2	2	1	2	0	0	3	4
3	Ussuriski. Zapovednik	2	2	3	3	1	3	6	8
4	Iman	0	0	0	0	1	1	1	1
5	Bikin	1	1	0	0	2	2	3	3
6	Borisovkoe Plateau	0	0	1	1	1	1	2	2
7	Sandago	2	3	1	1	0	0	3	4
8	Khor	0	0	0	0	0	0	0	0
9	Botchinski Zapovednik	1	1	1	1	2	2	4	4
10	BolsheKhekhtsir Zapovednik	0	0	1	1	0	0	1	1
11	Tigrini Dom	0	0	1	1	1	1	2	2
12	Matai	2	3	2	2	1	2	5	7
13	Ussuriski Raion	-	-	1	2	0	0	1	2
14	Sikhote Alin Zapovednik	5	5	3	4	1	1	9	10
15	Sineya	1	1	0	0	1	1	2	2
16	Terney Hunting Society	-	-	2	2	1	1	3	3
	Total	17	19	18	22	12	15	47	56

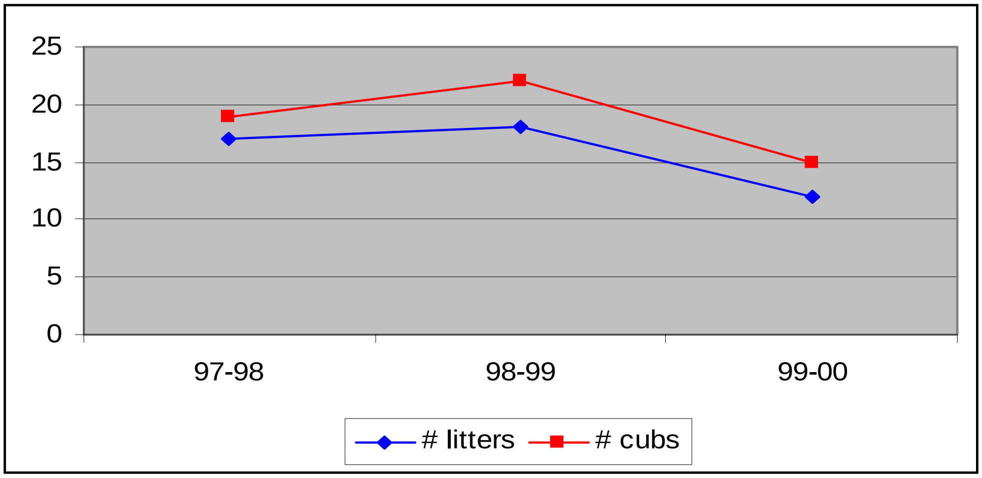

Figure 5. Total number of litters and total cub production summed across all 16 monitoring sites in the Russian Far East, for the first 3 years of monitoring.

monitoring program was recorded in Ussuriski Zapovednik this winter. Because litter size is recorded for cubs of all ages that are still in association with their mothers, this value in no way reflects litter size at birth, which is no doubt significantly higher. Because litter size has not varied across years, number of cubs and number of litters has retained a tight association (Figure 5).

Table 8. Size of all litters recorded in 4 winter surveys in 16 monitoring sites for Amur tigers in the Russian Far East.

Litter size	97-98	98-99	99-00	Total
1	15	14	10	39
2	2	4	1	7
3	0	0	1	1
Total	17	18	12	47

We used cub density to compare productivity across areas and years, ranking all estimates for all sites across all years, and employing an unbalanced GLM analysis (estimates for two sites were not available for the first year). We included two variables, year, and protected status into this model. The analysis indicated that there has been no significant change in cub density among the three years ($F = 0.41$, $df = 2, 45$, $P = 0.6633$), but that zapovedniks had much higher cub densities than unprotected areas ($F = 6.27$, $df = 1, 45$, $P = 0.0165$) (Figure 6). The 1998-1999 winter was particularly productive in zapovedniks (Table 10, Figure 5). Although we are not able to compare recruitment in various monitoring sites, these results suggest that protected areas are acting as source populations for the Sikhote-Alin tiger population, and may be critical to maintaining stability in the overall population.

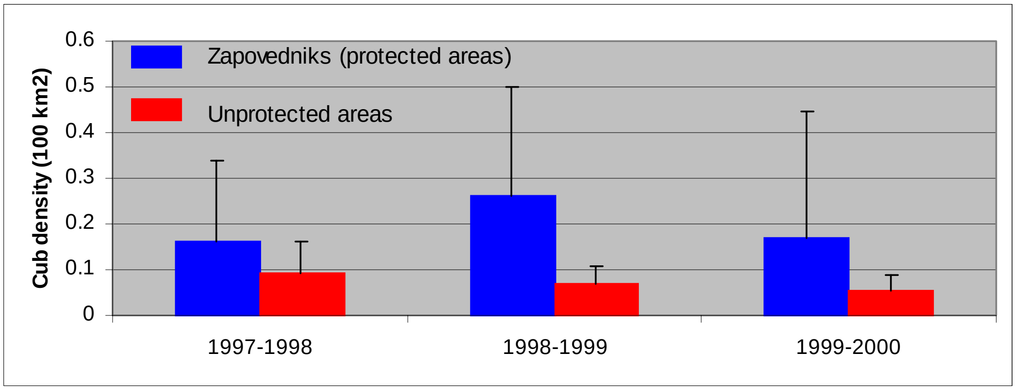

Figure 6. Cub density in zapovedniks and unprotected areas for the first 3 years of monitoring Amur tigers in the Russian Far East.

Sex-age Structure on Monitoring Sites

Although there are numerous sources of potential error in using expert assessments of track data to derive sex-age structure of tiger populations, two factors suggest this information can be useful: 1) a high percentage of unknowns (Table 9) 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 trends if there are any changes in population structure.

Table 9. Number of tigers, by age class, and sex (for adults only) on 16 monitoring sites in winter 1999-2000, 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	3	4				3	7	10	10
2	Laso Raion	3	1				1	4	5	5
3	Ussuriski Zapovednik	1	2			3	1	3	4	7
4	Iman	2	1		1	2	1	3	5	7
5	Bikin	2	2	1	1	1	1	5	7	8
6	Borisovkoe Plateau	1	2	1		1		4	4	5
7	Sandago	1	1				3	2	5	5
8	Khor	2	2					4	4	4
9	Botchinski Zap.	2	2			2		4	4	6
10	BolsheKhekhtsir Zap.	1	1					2	2	2
11	Tigrini Dom	3	1			1		4	4	5
12	Matai	1	1		2	2		2	4	6
13	Ussuriski Raion	1	1					2	2	2
14	Sikhote-Alin Zap.	7	7		4	1	5	14	23	24
15	Sineya	2	2		1	1		4	5	6
16	Terney Hunting Soc.	5	5			1	3	10	13	14
	Total	37	35	2	9	15	18	74	101	116

*Independent = adults, subadults, and unknown.

The tiger population in all monitoring sites combined is dominated by adults (63%), with subadults representing 8%, and animals of unknown age (which probably all represent adults and subadults) representing 15% of the population (Table 9). Cubs represent 13% of the total animals recorded. The male:female ratio of adults was nearly equal this year (Table 9). We combined adults, subadults, and animals of unknown age to develop a sex ratio statistic for independent animals across all years (Table 10). This sex ratio estimator demonstrates a consistent trend of females being a slightly larger percentage of the population than males (1.2:1). However, about one-third of the animals are reported of unknown age. Radiotelemetry studies suggest that the majority of these are likely females, in which case the actual sex ratio of the population is likely to be much more skewed than these data suggest.

Table 10. Sex ratio of independent tigers on 16 monitoring site 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

Only 2 reports of tiger mortalities were recorded by project coordinators for the 1999-2000 winter, bringing a total 21 mortalities reported across the first three years of the monitoring program. These results contrast sharply with 1998-1999, when 14 deaths were reported in Primorski Krai (Table 11). This database is presently maintained only for Primorski Krai, and therefore represents only a portion of the total 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 three 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 7).

Adults make up a smaller percentage of the mortalities than of the reported population in the monitoring sites (38 versus 63%), and subadults slightly more (19 versus 8%), but the number of animals of either unknown age or sex makes all comparisons questionable (Tables 9 and 11). Reports of cubs, both in the living population and in mortality data, may be slightly more reliable because they are such a distinctive class. Their representation in the monitoring sites and in the mortality database are approximately equal (13 versus 19%, respectively).

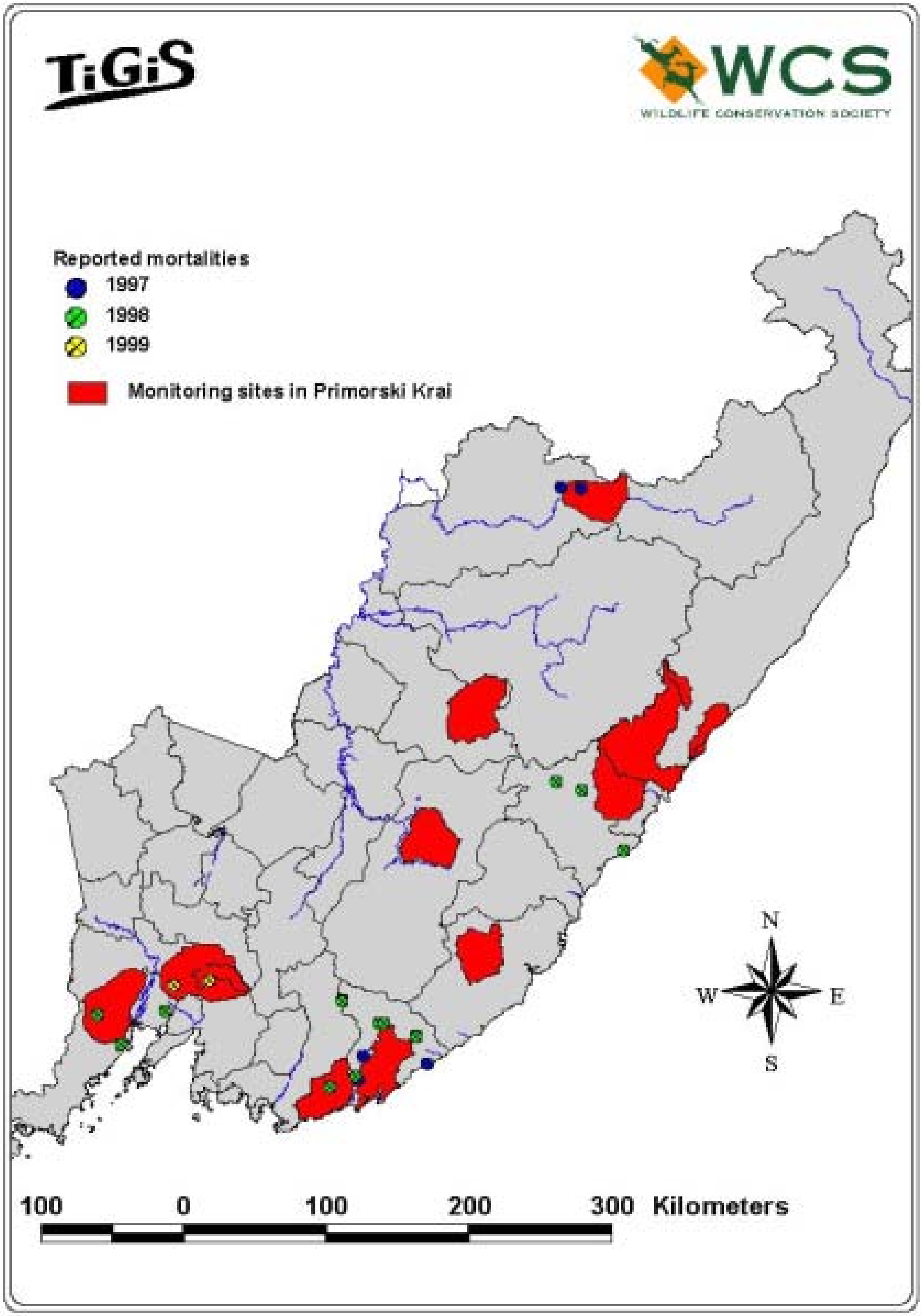

Figure 7. Locations of reported tiger mortalities from coordinators of the Amur tiger monitoring program (Primorski Krai only), for 1997-1998 through 1999-2000.

Table 11. 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	Total
Adults	Males	1	2		3
	Females		2	2	4
	Unknown	1			1
Subadults	Males	1	1		2
	Females		1		1
	Unknown	1			1
Unknown	Unknown		5		5
Cubs		1	3		4
Totals		5	14	2	21

Ungulate populations on Monitoring Sites

As expected, prey numbers varied greatly among sites (Table 11). Sika deer populations, which only occur in southern and central monitoring sites, can occur at very high densities (e.g., Lasovski Zapovednik and Boriskovkoe Plateau), which greatly increases the total prey biomass potentially available in those regions. Red deer populations tend to be inversely related to sika deer populations, but red deer never attain the densities reported for sika deer. Highest densities of red deer, based on track density estimators, are in Sikhote-Alin Zapovednik, and secondly, in BolsheKhekhtsirski Zapovednik.

Wild boar and sika deer tend to occur in larger aggregations than roe and red deer, and this clumped distribution results in larger errors associated with means. This clumped distribution may also account for what appears to be more dramatic variation in yearly averages across all sites (Figure 10) – averages vary dramatically dependent on whether our sampling design “hits” upon a few large groups. Based on track densities, wild boar tend to be the least common of the prey species on 14 of 16 sites (excluding sika deer where they do not occur or rarely occur).

Using mean values of these indicators to test for variation among sites or across years is inappropriate because exploratory analyses demonstrated that many were non-normally distributed. To test for differences among years for each species, we ranked estimators for each route for each site, plotted median track densities across all sites, (Figure 8), and compared ranks of track density estimators across years using a GLM model (SAS 1998). These analyses suggested that there were significant changes in red deer (F= 7.03, df = 3, 980, P = 0.0001) and roe deer (F= 5.40, df = 980, 3, P = 0.0011) numbers, but not wild boar (F= 0.72, df = 980, 3, P = 0.5378) or sika deer (F= 1.1, df = 980, 3, P = 0.3485) (sika deer tested only for those 7 sites where they normally occur). For both red deer and roe deer, the only year that was significantly different from others was the 1997-1998 winter. Given that this year represented the first year of the monitoring program, it is not clear whether these differences reflect real changes in population densities, or simply methodological problems associated with initiation of the program. Estimates of ungulate densities were initially given a lower priority in establishing the monitoring program, and because there was less discussion of the methodologies to be used, it is highly likely that these statistically significant variations may simply be methodological anomalies. Despite the apparent upward trend in sika deer numbers, because of their clumped distribution, variation was too great across the range to detect a significant trend.

Table 12. Track count estimates for 4 prey species of tigers on 16 monitoring sites for the 1999-2000 winter period.

		# routes	Red deer		Wild boar		Roe deer		Sika deer	
#	Monitoring site	n	mean	std	mean	std	mean	std	mean	std
1	Lasovski Zapovednik	12	6.94	15.66	5.24	10.45	3.90	4.89	108.28	158.11
2	Laso Raion	11	1.18	3.76	0.30	0.49	0.67	1.41	41.79	65.13
3	Ussuriski. Zapovednik	11	6.98	6.98	4.13	3.31	10.33	10.65	30.72	45.74
4	Iman	12	5.34	7.23	0.19	0.40	2.98	3.94	-	-
5	Bikin	16	8.01	6.62	0.30	0.65	1.74	2.85	0.00	0.00
6	Borisovkoe Plateau	14	0.00	0.00	5.53	5.95	4.58	6.46	65.74	87.40
7	Sandago	16	9.90	10.78	2.68	4.04	6.70	5.69	4.06	3.98
8	Khor	19	3.98	4.46	0.37	0.74	2.73	3.38	0.00	0.00
9	Botchinski Zapovednik	14	4.33	2.50	0.00	0.00	2.69	2.85	-	-
10	BolsheKhekhtsir Zapovednik	7	13.65	12.75	0.61	1.09	0.16	0.42	-	-
11	Tigrini Dom	14	1.38	1.39	1.00	0.90	0.36	0.74	-	-
12	Matai	24	3.76	3.97	2.05	2.03	2.10	1.22	-	-
13	Ussuriski Raion	12	4.28	3.67	2.07	2.68	12.05	7.70	2.69	3.56
14	Sikhote Alin Zapovednik	25	27.02	22.64	3.25	5.09	20.05	21.05	4.68	12.59
15	Sineya	15	2.77	3.74	0.61	1.07	2.37	1.83	0.00	0.00
16	Terney Hunting Society	24	10.75	11.62	1.33	2.02	5.52	8.19	1.73	5.29
	Totals	16*	6.89	6.52	1.85	1.83	4.93	5.25	32.46	38.46

*sample size for sika deer =8 sites where sika deer normally occur.

Aside from the first year differences, there do not appear to be any clear trends in any of the prey populations, when viewed as an average, across all 16 sites(Figure 8). These data, suggesting stable, or potentially slightly increasing populations, do not reflect the opinions of may regional biologists and local hunters, who often express concern of decreasing numbers of ungulate species. This issue is of critical concern to tiger conservation, and deserves a more thorough treatment than is possible using our tiger monitoring methodologies, which are designed with a priority to detect changes in the tiger population, and not ungulate numbers.

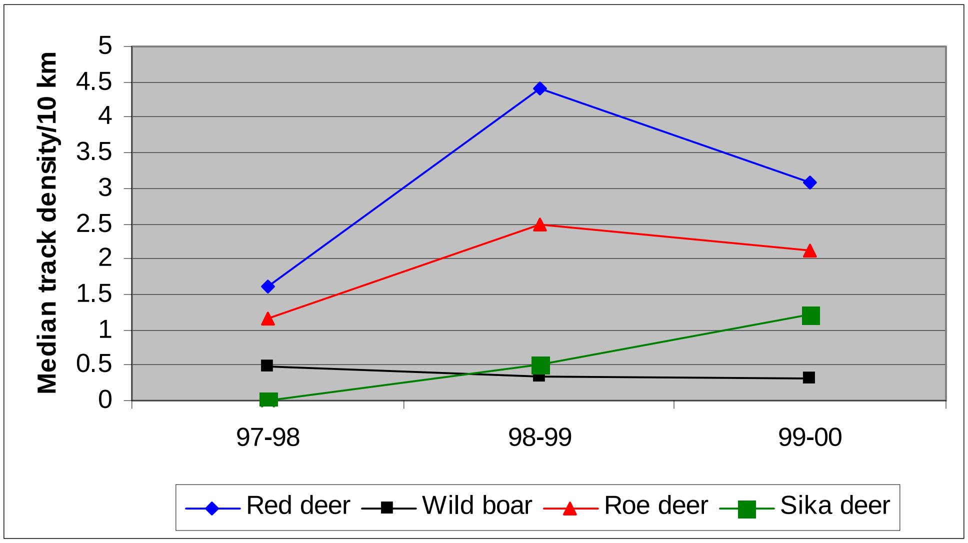

Figure 8. Changes in relative abundance of prey numbers, 1997-98 through 1998-99, based on track density estimators derived from survey routes on 16 monitoring sites across Amur tiger habitat in the Russian Far East (estimates for sika deer are derived only from those sites where they regularly occur, n=7).

Trends in the Amur Tiger Population

Normally, trend analyses combine a graphical assessment with regression analyses (Thompson et al. 1998). With only three years of data, it is still early to conduct intensive regression analyses, but it is still possible to plot out yearly averages and begin to look for patterns in all three tiger abundance indices. Additionally, we can conduct non-parametric analysis of yearly abundance indices to determine if significant differences exist between any years. Assessments of tiger reproduction, population structure, and information on trends in ungulate numbers can help to assess present status, and provide a basis for making prognoses for the future. Finally, reviews provided by individual coordinators (see Section II) help provide clues to trends in individual monitoring sites. Cumulatively, the assessments of these coordinators provide a valuable resource for tracking changes at each site, and ultimately, over the entire range of tigers.

All three indicators of tiger abundance showed similar trends – a slight increase in the second year of monitoring, followed by a slight decrease in the 1999-2000 season (Figures 9-11). Overall, none of these changes were large, but the fact that all three indicators show the same pattern gives some validity to the idea that there were small shifts in tiger numbers. Nonetheless, the overall results suggest that the tiger population was fairly stable as a whole over the entire range.

To test for yearly variation in track densities, we used the non-parametric "Quades" test (Conover 1980, which uses the ranks of the observations (mean track densities within each site) within each block (site) across treatments (years). This 2-way analysis of variance on ranks essentially tests whether certain years were higher/lower than others, on average. The results (Quades test $T = 1.02$, $df = 2, 30$, $P > 0.25$) appear to conclusively rule out changes in population numbers between years, based on track density estimators.

It may be more valuable to look at the pattern of changes for each of the units to determine if any regional and local shifts may have been occurring. Comparing changes in both track densities and tiger densities between the first and second years, and second and third years of monitoring, there do not appear any obvious trends that carry across all sites (Figures 12, 13, Table 13). Changes in track density estimates between the first two years suggest that there were more negative changes (10) than positive (5), but just the opposite trend is suggested in looking at tiger densities (Table 13). Changes between the second and third year appear to be more balanced, with approximately equal numbers of sites showing decreases and increases (Table 13).

Table 13. Number of monitoring sites that showed increases (+), decreases (-) or no change (0) in track and tiger density estimators, based on comparisons of each pair of consecutive years (see Figures x and x) of the Amur tiger monitoring program.

		Direction of change		
Winters under comparison	Density estimator	+	-	0
(1997-1998) - (1998-1999)				
	Track densities	5	10	1
	Tiger densities	8	4	4
(1998-1999) - (1999-2000)				
	Track densities	8	7	1
	Tiger densities	6	9	1

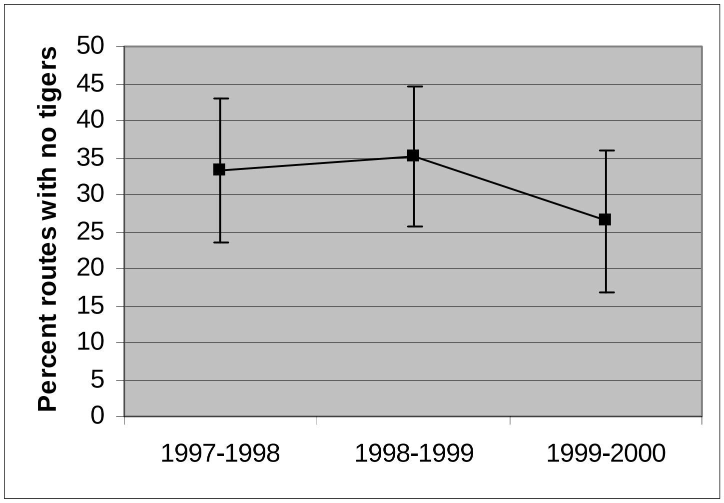

Figure 9. Mean percentage of routes without tigers for 16 monitoring sites for Amur tigers, Russian Far East over three years.

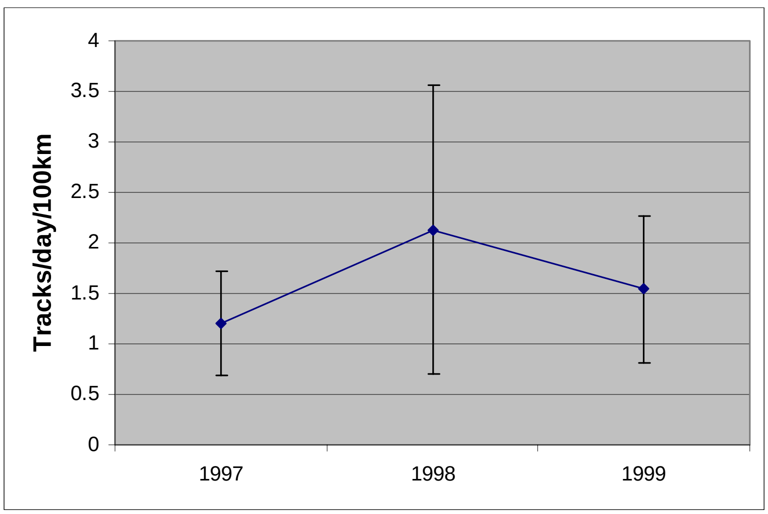

Figure 10. Mean track density estimator for 16 monitoring sites for Amur tigers, Russian Far East over three years.

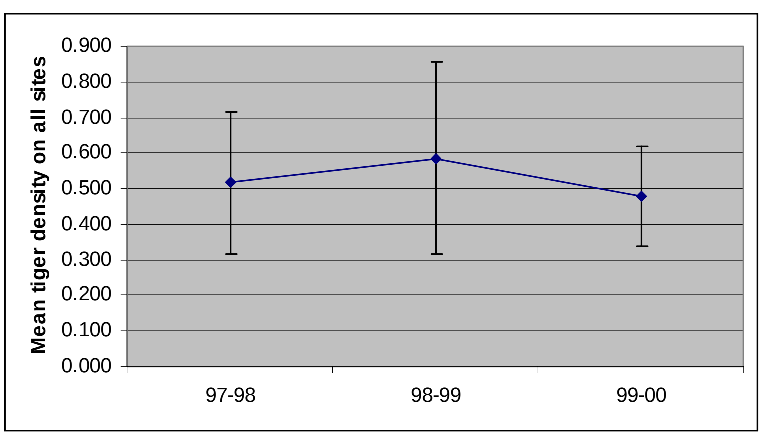

Figure11. Mean tiger density (independent animals/100 km^2), based on expert assessments, 16 monitoring sites for Amur tigers, Russian Far East over three years.

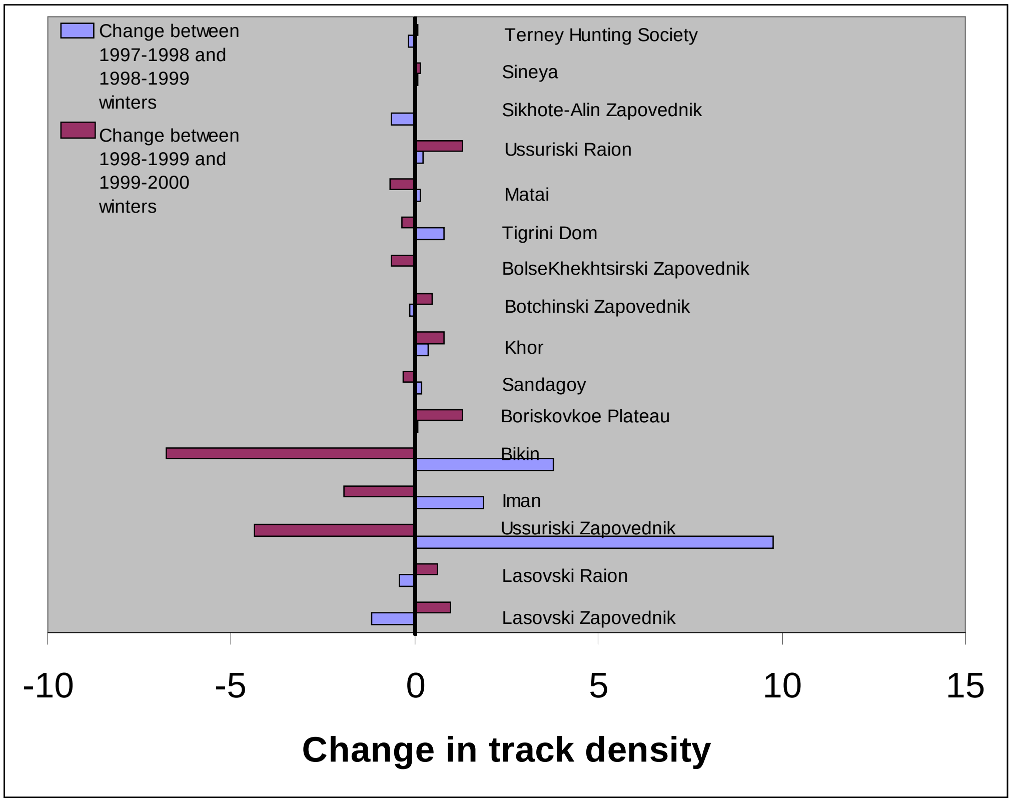

Figure 12. Changes in track density estimators for Amur tiger monitoring sites from the 1997-1998 winter to the 1998-1999 winter, and from the 1998-1999 to the 1999-2000 winter.

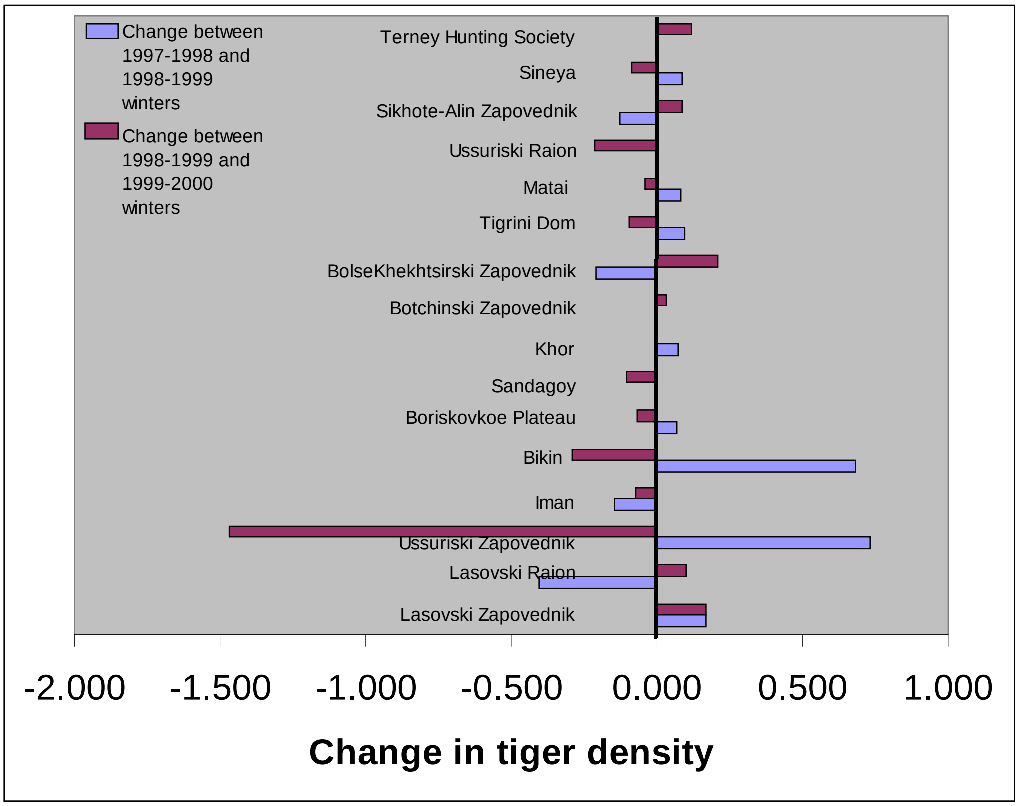

Figure 13. Changes in tiger density estimates based on expert assessments for Amur tiger monitoring sites from the 1997-1998 winter to the 1998-1999 winter, and from the 1998-1999 to the 1999-2000 winter.

Two sites, Ussuriski Zapovednik and the Bikin, showed dramatic increases between the first two years, and subsequently nearly as dramatic decreases between the next two years, whether track or tiger density estimators are compared (Figures 12, 13). These sites should be monitored closely in the future to determine if these fluctuations were temporary abnormalities, whether instability is a feature of these particular systems, or perhaps whether there are methodological issues that need to be addressed.

Aside from first year variations, the ungulate data, when viewed in summary, does not suggest that there are dramatic changes occurring in any of the prey species populations. However, lumping all sites together may result in a smoothing effect that is not truly indicative of local conditions. A review of individual sites (see Section II) suggests that there are localized regions of concern. Project coordinators for the Bikin, Ussuriski Zapovednik and Raion sites suggest that ungulate numbers are decreasing in those areas. In contrast, for the 5 sites in Khabarovsk, the ungulate population appears to be relatively stable (Section II). Coordinators for 7 of the 16 sites commented that habitat conditions or populations themselves of either ungulates or tigers were worsening, but others considered the situation relatively stable for the short term. No one indicated that conditions are improving, although localized increases in some prey populations were noted (e.g. wild boar in Boisovkoe Plateau).

A drop in number of litters and number of cubs in the 1999-2000 is a point of concern, and this indicator should be tracked closely in the coming years. This dip, in connection with the indications of slight declines in all three tiger density estimators, is sufficient cause for concern, but by themselves are insufficient to indicate conclusively that the population had declined over the past year. Next years results, particularly in relation to cub production and ungulate densities, will be particularly interesting.

In summary, results of the first three years of monitoring Amur tigers in the Russian Far East suggest that the population may have experienced a slight increase between the first and second years, followed by a slight decrease between the second and third years. These changes were not statistically significant, but were persistent across a number of indicators. A decrease in cub production, and localized depressions in ungulate numbers, are also causes for concern. Future monitoring will be important to determine whether these trends continue.

V. LITERATURE CITED

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VI. REPORTS ON INDIVIDUAL MONITORING SITES 1999-2000 (new document)