CBM:s Skriftserie 3: 149–165. Uppsala 2001.

Habitat-based population viability analysis for the Asiatic black bear in Mt. Chiri National Park, Korea

Soyoung Park

Park, S. 2001. Habitat-based population viability analysis for the Asiatic black bear in Mt. Chiri National Park, Korea. – CBM:s Skriftserie 3: 149–165.

The Asiatic black bear population in Korea has been reported to be close to extinction and is in urgent need of effective management. Suitable bear habitat in Mt. Chiri National Park and adjacent areas was assessed based on data from field surveys. When incorporated with demographic data, this data was fed into a habitat-based, stage-structured, stochastic model in Ramas/GIS. A population viability analysis was performed in this model to investigate the effects of poaching on the viability of the population and the potential of a restoration programme of the bear population by supplementation. Generally, the simulation results show that the risk of extinction is small when the carrying capacity and the population growth rate are large and the environmental stochasticity is small within the parameter ranges used in this model.
In conclusion, population viability analysis of a hypothetical Asiatic black bear population in the Mt. Chiri National Park area raises two points. Firstly, Mt. Chiri National Park can support a viable bear population in a demographic sense, though is probably inadequate for long-term survival in a genetic sense. Secondly, a viable bear population, in a demographic sense, may be restored through supplementation. Simulation results confirm that there can be a significant difference between a no supplementation policy and one of supplementing only a few individuals.

Soyoung Park, Swedish Biodiversity Centre, Box 7007, SE-750 07 Uppsala, SWEDEN.
E-mail: p_soyoung@hotmail.com

Introduction

Seven subspecies of Asiatic black bear are distributed over much of southern Asia including Pakistan, Afghanistan, northern India, China and Southeast Asia (Ellerman and Morrison-Scott 1968). Separate populations are also known to be present in eastern Russia, Korea, Taiwan and Japan (Servheen 1989). Throughout most of its range, conservation efforts aimed at the Asiatic black bear are almost nonexistent and legal protection is seldom enforced.

At present, there is no exact estimate of the wild Asiatic black bear population. Servheen (1989) considered that data on the Asiatic black bear was minimal and the validity of distribution information was questionable. Bunnell and Tait (1981) also commented on the lack of data on this species. Some studies have focused on foraging habits and consequent forest damage (Watanabe and Komiyama 1976, Watanabe 1980, Torii et al. 1989, Reid et al. 1991, Mizoguchi et al. 1996, Hashimoto and Takatsuki 1997). Other researchers have reported on the distribution, demographics and home range of the Asiatic black bear (Mizuno et al. 1972, Torii 1975, Nozaki et al. 1979, Hazumi et al. 1981, Nozaki and Mizuno 1983, Ma 1986, Liu and Xiano 1986, Ishida 1995).

The status of the Asiatic black bear population in Korea (*Selenarctos thibetanus ussuricus* Heude) is similar to that in other Asian countries. Servheen (1989) concluded that 'the Asiatic black bear is very close to extinction with a population estimate of 57 individuals in 1982 separated into five separate populations'. This species is listed as 'Natural Monument No. 329' by the Korean government and has been under legal protection since 1982 (Lee et al. 1994). Despite these efforts, the bear population decreased dramatically and it was considered to be extinct in the wild. However, traces of bears, such as footprints on the snow, scats and scratches on trees, were then found at Mt. Chiri and Mt. Odae where bears were once found. The exact number of remaining bears is unknown, but some experts estimate the number to be between 5 and 20 individuals. There has been almost no research on bears and bear populations in Korea.

The Korean government has attempted to control poaching by abandoning all unused or informal mounting trails, strictly controlling the use of firearms and the construction of ecological infrastructure, such as underpasses and eco-bridges. Some experts have insisted that all the wild Asiatic black bears in Korea should be caught and kept in captivity for protection and breeding, being reintroduced later, since the number of individuals is too small to sustain a viable population. Others have recommended the supplementation of individuals from China or Southeast Asia to avoid inbreeding depression.

These suggested management options can be summarised as:

1) anti-poaching;
2) establishing ecological infrastructure between fragmented habitat areas;
3) supplementation.

In addition to these actions, public education about the bear and the focusing of the efforts of a diverse group who have different interests, towards a management objective that will be beneficial to the bear, are also important. However, since the resources for conservation efforts are limited, the effect of diverse management options should be evaluated. Population viability analysis (PVA) is a quantitative method that makes it possible to evaluate the effects of management options through simulation (Shaffer 1990, Norton 1995, Possingham and Davies 1995). Effective management of a population largely depends on an understanding of habitat requirements as well as population dynamics. There are an increasing number of studies on these subjects, but few have tried to connect these two fields.

The objectives of thisstudy were to 1) compile all currently available knowledge, including habitat requirements and demographic data, on the black bear, 2) assess the suitable bear habitat in Mt. Chiri National Park and adjacent areas, 3) incorporate the habitat data and demographic data into a metapopulation model and perform a population viability analysis, and 4) evaluate the effects of poaching on population viability

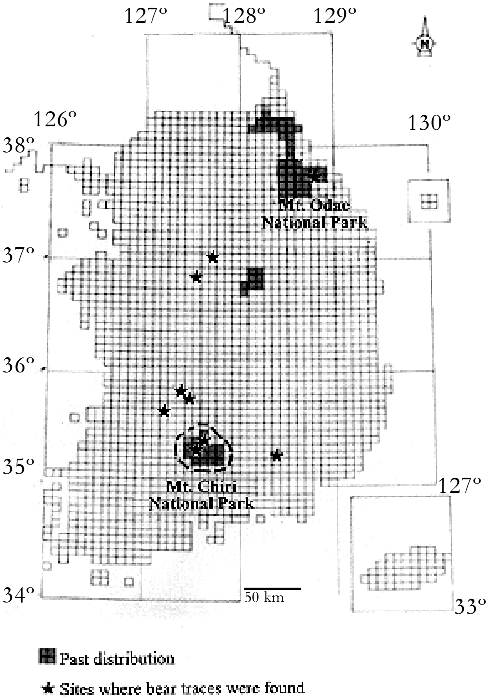

Figure 1. Distribution of *Selenarctos thibetanus ussuricus* Heude in South Korea.

and investigate the possibilities of restoration of the bear population, by supplementation, in Mt. Chiri National Park.

Methods

Study area

Mt. Chiri was designated as National Park No. 1 in 1967, and is located in the southern part of the Sobaek mountain range. It includes the second highest peak in S. Korea (1 915 m) and is the largest of the country's National Parks (about 440 km^2).

The past distribution of the Asiatic black bear and sites where traces have been found recently are shown in Figure 1. Mt. Chiri National Park and Mt. Odae National Park are both located within the former range of the bears, and some of the recent observations of bear signs were found within these areas. This study focused on Mt. Chiri National Park and the adjacent area, since it is the largest National Park in Korea and the main vegetation comunity of Mt. Chiri is dominated by *Quercus* that is known to be more suitable for the bear, whereas the main vegetation community at Mt. Odae National Park is dominated by *Abies* species. It was thought that some areas outside of the National Park might be suitable habitat for the bear, though these are not protected at present. Thus the areas adjacent to the Mt. Chiri National Park were also included in this study.

GIS database

The GIS Database consists of topographical and vegetation data. I used the digitised topographic maps (1:25000 or 1:5000) prepared by the Korean National Geographic Institute (NGI). These maps were integrated and converted into a raster (grid) format with a resolution of 50m, based on the home range size of bears and landscape heterogeneity (Layman and Barrett 1986). I analysed elevation (m), slope (°), aspect (°, 0 for north, 90 for east, 180 for south, and 270 for west) and distance from roads (m) and water (m) from this raster map.

A Digitised Actual Vegetation map (i.e., *Quercus mongolica* community, *Pinus densiflora* community), which was produced by the Ministry of Environment, and a Forest Type map (including age of forest, average diameter of trees and the density of trees), produced by the Forestry Service, were also converted to raster format with a resolution of 50m in Arcview (version 2.0).

These raster maps were converted into an ASCII format in Arcview and then converted into TXT format for use in the Ramas/GIS program.

Habitat requirements and habitat suitability index map

I chose environmental factors for analysing habitat suitability by reviewing literature on the Asiatic black bear and the American black bear (Torii et al. 1989, Reid et al. 1991, Clark et al. 1993, Rudis et al. 1995, Mizoguchi et al. 1996, Hashimoto and Takatsuki 1997). The factors chosen for use in the analysis were elevation, slope, aspect, distance from road and water, actual vegetation, forest type, age of forest, average diameter of trees and density of trees.

I collected absence and presence data for traces of the Asiatic black in the Mt Chiri National Park. In total, I found 12 traces of bears (i.e. denning site, bark scratches, broken branches) with the help of local people who have been moni toring the traces of bears since 1995. I recorded the geographical position of these traces using a portable GPS receiver (Model: Trimble Ensign GPS) and subsequently used as locations for presence data. During the field survey, vegetation type was recorded at each trace for comparison with a published map, which was converted. into a raster format. After locating each position on the raster map, environmental factors were then recorded for each point.

The National Park Authority (Anon. 1998) has identified and delineated 14 separate areas within Mt. Chiri National Park where bear traces have been found. Additional data was then gathered based on this literature. I digitised the boundary lines for these areas and set a 1 km buffer area around these boundaries to prevent collection of absence data within 1 km of these areas. Next, a point was located in the center of each trace area and these points (14 in total) were added to the presence data set. For absence data, 21 points were evenly placed outside the trace and buffer areas. No points were located far from the National Park, since most of those areas are developed or used for agriculture.

Next, I analysed correlations between existence data (absence and presence data) and environmental factors. A Mann-Whitney U test was used for elevation, slope, aspect, distance from road and water and existence data, and a Chi square test for other factors. Then, a multiple logistic regression analysis was used to calculate a habitat suitability function. A significance level of $p=0.05$ was used in both cases (correlation and logistic regression). SPSS (version 8.0) was used for statistical analysis. This habitat suitability function was used in Ramas/GIS (version 3.0) to predict the distribution of suitable habitat.

Population Viability Analysis (PVA) Simulation

Ramas/GIS

Ramas/GIS consists of 5 subprograms (Landscape data, Habitat dynamics, Metapopulation model, Sensitivity analysis, and Comparison of result) and combines spatial landscape data with demographic data of a population into a metapopulation model (Akçakaya 1998).

The landscape data program imports spatial data on the landscape (i.e. elevation, slope, aspect, vegetation etc.) and converts it into a habitat suitability map using the habitat suitability function. The landscape data program then identifies habitat patches in the habitat suitability map, within a given threshold habitat suitability (HS) and a neighbourhood distance that may relate to the foraging distance of the species.

The metapopulation model program then combines the habitat patch map with the demographic data (i.e. survival rates, fecundity, density dependence etc.). Simulations of management alternatives then estimate the risk of extinction within a projected time (e.g. 100, 500 or 1000 years) or time to extinction etc. Simulation scenarios can include several levels of poaching, population supplementation and natural catastrophes. Available literature on the black bear was reviewed and parameters, which were used in the simulation, were estimated. Each parameter had medium, lower and upper estimates (medium $\pm 1/2$SD). The medium estimate, in this case, refers to the average value from those that have been reported in different studies and the SD (standard deviation) refers to the variation among different studies.

Identifying habitat patches

After estimating a habitat suitability (HS) function, a threshold HS and a neighbourhood distance were used for identifying habitat patches. I used a threshold HS of 0.5 (0.45 for lower and 0.55 for upper estimates) and a neighbourhood distance of 1697m (SD=1544), based on the available literature (Young and Ruff 1982, Nozaki and Mizuno 1983, Ishida 1995). This means that bears can survive in areas where the habitat suitability value is 0.5 or above and individuals move up to 1697m when foraging.

Carrying capacity and initial abundance

I estimated the carrying capacity of the study area based on the average bear density (0.664/km^2, SD=0.838) that was reported in studies of the Asiatic and American black bear (Lecount 1982, Reid et al. 1991, Wang et al. 1994, Uh pers. comm. 1999). I assumed that these estimated densities reflected 80% of the carrying capacities. I used values of 100, 500 and 1000 for the carrying capacity in different simulations, as well as estimated values (78, 216 and 355 for lower, medium and upper estimates). I interviewed local people to estimate initial abundances. Values between 3 and 13 were obtained, with 3, 5 and 13 being chosen for lower, medium and upper estimates.

Stage structure

I modelled the dynamics using a stage-structured (juvenile and adult), stochastic matrix model. The parameter values (Table 1) in this model were based on the literature (Watanabe et al. 1976, Lecount 1982, Hellgren and Vaughan 1989, Wang et al. 1994, Powell et al. 1996). The standard deviation (variation among different studies) for each parameter was between 20 and 25 percentage of the average value. This standard deviation was used for simulating environmental stochasticity. I assumed that one third of juveniles would become breeding adults and that adult bears would breed every other year. Thus, the period between litters would be two years, which is shorter than the 2.4 years that was chosen for a PVA of the Asiatic black bear in Taiwan (Wang et al. 1994).

Environmental stochasticity

Environmental stochasticity can affect the vital rates, carrying capacity and dispersal among populations in the Ramas/GIS. I introduced environmental stochasticity by using the standard deviation of estimates in the stage matrix, so environmental stochasticity will affect only the vital rates such as survival rates and fecundity.. The three levels of environmental stochasticity were modelled by manipulating the standard deviation matrix (abbreviated to S, 1/2S, and 1/3S). At each time step during the simulation, the Ramas/GIS program chose a value for vital rates randomly from a distribution, which was limited only by the average value and its standard deviation (S).

Density dependence and Allee effect

I assumed a ceiling-allee model for all simulation scenarios. This means that each population will grow exponentially in a stochastic way until it reaches the ceiling or carrying capacity. If the population increases above the carrying capacity, it will be decreased back to, or below, the carrying capacity. But, if the population is much below the carrying capacity, it will then be affected by an allee effect and drawn towards extinction. The allee effect was incorporated by setting a local extinction threshold of 10% of the carrying capacity. A subpopulation in the metapopulation that has fewer individuals than this threshold will be considered extinct, but these individuals will be included in the total and will participate in breeding.

Poaching

I assumed that poaching would take place throughout the simulation period, of a constant

Table 1. Parameter value estimation for the stage matrix.

Parameters		Lower estimate		Medium estimate	
Juvenile fecundity	Adult fecundity	0.096	0.405	0.119	0.503
Juvenile survival	Adult survival	0.590	0.830	0.665	0.935
Population growth rate		1.026		1.074	

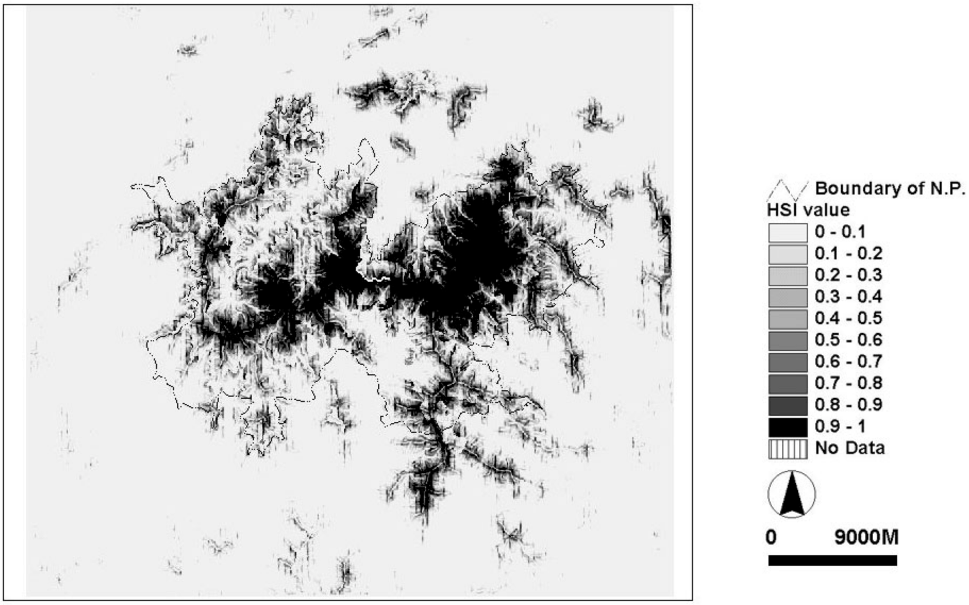

Figure 2. Habitat suitability index map for the Asiatic black bear in Mt. Chiri National Park.

proportion of the population, rather than a fixed number of individuals. I examined the effects of poaching levels of 1% and 2% of the population when the population growth rate was 1.026, and 1%, 5% and 7% when the population growth rate was 1.074. Poaching was modelled as a harvest in the Ramas/GIS program.

Supplementation

The objective of supplementation is to achieve a population with the same viability as a population at its carrying capacity, even though the initial population size is small. Three scenarios of supplementation were considered, with releases of 1/2K, 1/4K and 1/10K bears respectively. Supplementation was simulated every year during the first ten years. Thus, the actual numbers of supplemented individuals were 11 (1/2K), 5 (1/4K) and 2 (1/10K) per year when the carrying capacity was 216, and 25 (1/2K), 12 (1/4K) and 5 (1/10K) per year when the carrying capacity was 500. Both juvenile and adult bears were supplemented, corresponding to a stable demographic distribution.

Estimates of all parameters are shown in Table 2. Every simulation for each scenario (scenario and results are shown in Appendix 1, Appendix 2 and Appendix 3) was replicated 500 times and each replication projected the abundance of each population over 100 years. The upper estimate of population growth rate (λ) was not employed in simulations, as in these cases, populations could grow more than 23% per year. These populations would seldom go to extinction without severe poaching or catastrophes, which seems unrealistic.

Results

Habitat suitability index map

Among the habitat variables, only elevation (ELV), slope (SLP), distance from road (DRD) and actual vegetation (VEG) were significantly correlated with the absence and presence data of bear traces. A logistic regression function with four variables (ELV, SLP, DRD and VEG) was highly significant (p=0.0001) and the predictability was also very high. However, two of the regression coefficients (SLP and DRD) were not

Table 2. Estimates of parameters used in the model (For the choice of parameters, shaded areas were taken together as one estimate and un-shaded cells was taken separately for each parameter. Supplementation was simulated during the first ten years).

Parameter	Estimates Lower	 Medium	 Upper
Threshold HS	0.45	0.50	0.55
Neighborhood distance (m)	925.32	1696.89	2468.46
Dispersal distance (km)	9.253	16.969	24.684
Density (individuals/km^2)	0.245	0.664	1.083
Carrying capacity	78	216	355
Initial abundance	3	5	13
Population growth rate	1.026	1.074	1.234
Environmental stochasticity (Standard deviation matrix)	1/3S	1/2S	1S
Poaching level	0.01	0.02/0.05	0.07
Supplementation level (No. of individuals/year) (K=216/355/500)	2/3/5	5/9/12	11/18/25

statistically significant, so the DRD variable was excluded. The results of this logistic regression analysis with three variables are summarised in Table 3.

The logistic regression function is highly significant (p=0.0001). The predictability is also very high (91.49%, cut value for presence is 0.5) and all regression coefficients are statistically significant.

The probability for the presence of bear traces (habitat suitability) was calculated as:

P = 1-[1/{exp(ELV*0.0129+SLP*0.1919-VEG*3.6730-14.3114)+1}] = HS

A habitat suitability index (HSI) map based on the HS is shown in Figure 2 and the HS histogram is shown in Figure 3. Only 13.58% of the total number of cells have a value greater than 0.50 and the average HS for the whole area is 0.15. Most of the suitable areas are concentrated inside the National Park but some areas with high HS values are situated outside the National Park boundary. Some of these areas are

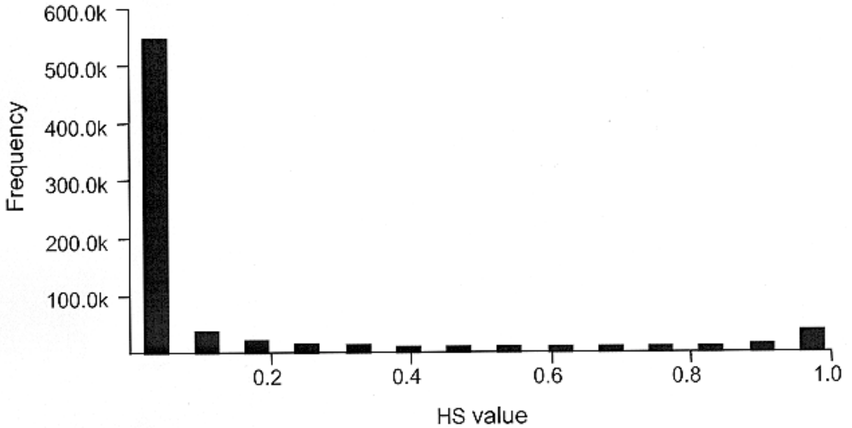

Figure 3. Frequency distribution of habitat suitability for the Asiatic black bear in the Mt. Chiri National Park area.

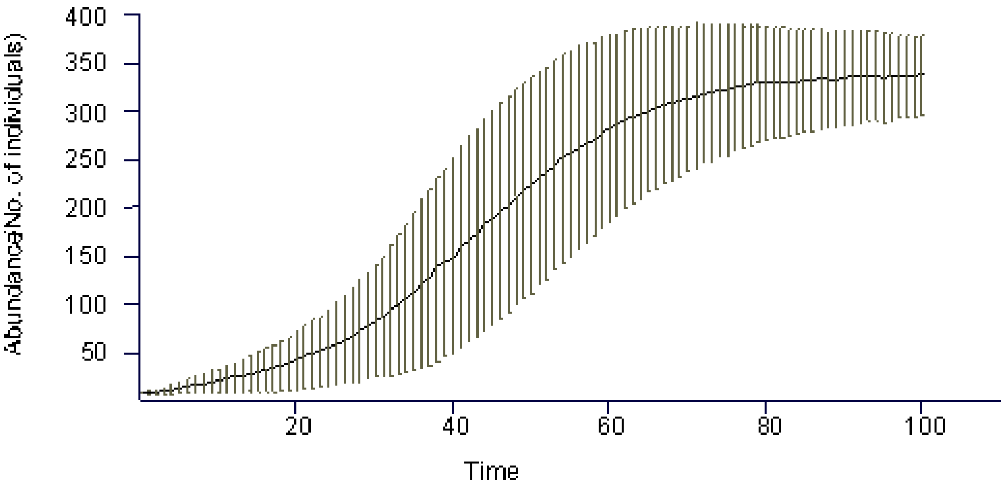

Figure 4. Trajectory summary for a hypothetical Asiatic black bear population (K=355, Init. abundance=13, population growth rate=1.0741, environmental stochasticity=1/3S; Appendix 1).

connected to the National Park, while others are isolated.

Using 0.5 as a threshold HS, three distinct habitat patches were found. Total HS, carrying capacity (K) and area (km^2) are shown in Table 4. Patch 2 covers the National Park and occupies 95.46% of the total suitable area. Some areas, which are not part of the National Park but connected to it, are included in this patch.

Population Viability Analysis

In general, the model predicted that the risk of extinction for a hypothetical Asiatic black bear population would be small when the carrying capacity (K) and the population growth rate (λ) are large and the environmental stochasticity is small, within the range between the lower and upper estimates used in this model (Figures 4 and 5).

Table 3. Results of logistic regression for a habitat suitability function with three variables.

Variables	Reg. coefficient	S.E.	Wald	p
ELV	0.0129	0.0050	6.6817	0.0097
SLP	0.1919	0.0947	4.1074	0.0427
VEG	-3.6730	1.3822	7.0617	0.0079
Constant	-14.3114	6.0016	5.6863	0.0171

Without poaching and natural catastrophes (such as fire, flood or typhoon), the model predicted that a hypothetical Asian black bear population, initially at its carrying capacity, would have a low risk of extinction ($p<0.05$), except if the carrying capacity and the population growth rate (λ) are both very low and the environmental stochasticity is high (K=78 and 100, population growth rate=1.0261, environmental stochasticity=S). Other hypothetical populations with a low initial abundance have a high risk of extinction, except if the carrying capacity and the population growth rate are very high and the environmental stochasticity is very low ($K \geq 216$, population growth rate=1.0741, environmental stochasticity=1/3S; Figure 6 and Appendix 1).

The effect of poaching was severe when the poaching level approached the value of the population growth rate. When population growth was assumed to be 7.41% per year, poaching of 5% of the population caused a large effect on population viability. Even in a hypothetical population initially at its carrying capacity, the model predicted that this population would have a high risk of extinction when the poaching level was 7% (Figure 7). Even with a lower poaching level, the risk of extinction can be high for a population with a small carrying capacity and a low population growth rate (Appendix 2).

Table 4. Summary of habitat patches (0.5 was used for threshold HS).

Patch	Total HS	Average HS value	K	Area (km^2)	Percentage of the total suitable area	Percentage of the landscape
1	3104	0.75	9	10.3	3.98	0.54
2	82324	0.83	206	247.9	95.46	12.96
3	393	0.68	1	1.5	0.56	0.08
Sum	85821		216	259.7	100	13.58

The model also predicted that the risk of extinction for a hypothetical population with a low initial abundance could be decreased by supplementation (Figure 8 and Appendix 3). It is possible to decrease the risk of extinction from 0.46 to 0.001 by supplementing the population with a number of individuals equivalent to a quarter of the total carrying capacity (initial abundance=5, K=216, population growth rate=1.0741, poaching=0.01, environmental stochasticity=S; Appendix 3).

Discussion and management implications

In this model, habitat suitability was a function of elevation, actual vegetation and slope. Distance from the road was correlated with the existence of bear traces but it was excluded, since the habitat suitability function was not significant statistically. As a result, habitat suitability does not reflect anthropogenic impacts on habitat. Forest type, such as old growth forest, and water resources that usually seem to be critical for the survival of wildlife, were not included in this model. Only 12 of the 47 presence and absence data points are based on personal observation, with others taken from the literature. But, I still obtained a statistically significant and highly predictable (91.49 %) habitat suitability function. However, it would be useful to have more data, especially from field surveys, to develop a habitat function that incorporates natural environmental factors and anthropogenic factors.

All the data used in the population viability analysis originated from literature on the American black bear and the Asiatic black bear in Japan, China and Taiwan. Thus, the data included

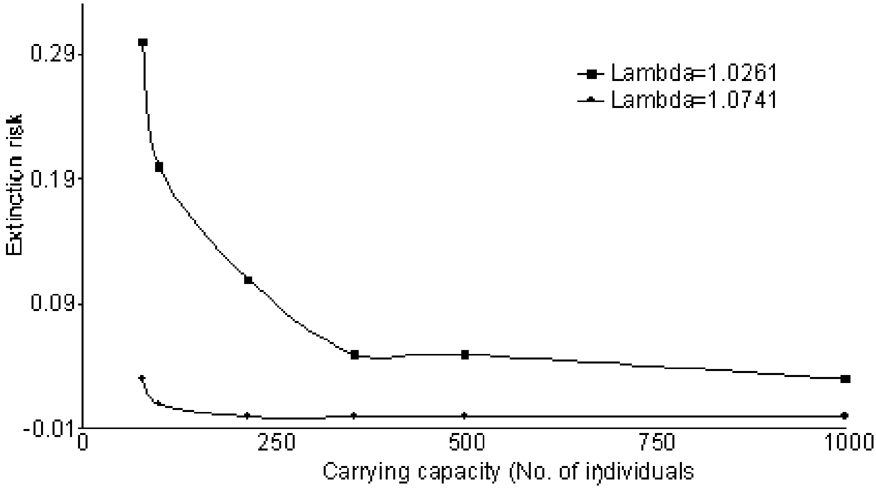

Figure 5. Comparison of extinction risks for a hypothetical Asiatic black bear population (init. abundance=K, population growth rate=1.0261 and 1.0741, environmental stochasticity = S; Appendix 1).

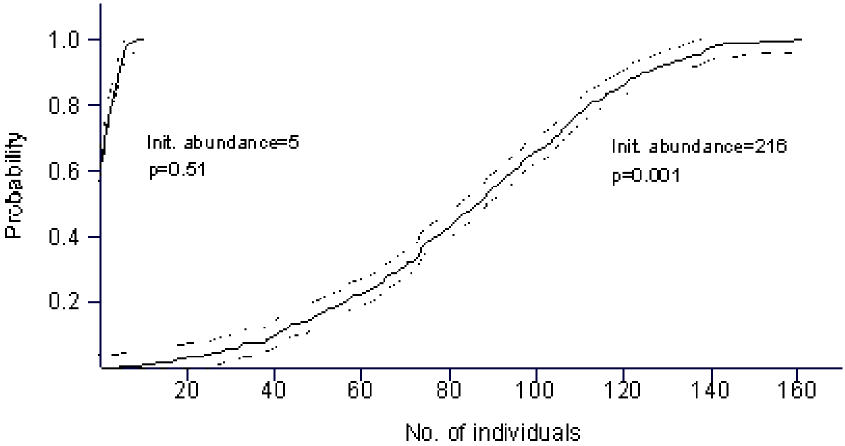

Figure 6. Comparison of interval extinction risk between two hypothetical populations (K=216, init. abundance=5 and 216, population growth rate=1.0261, environmental stochasticity = 1/3S; Appendix 1).

a wide range of different habitats, subspecies and even species. Future field surveys on this specific bear population would be helpful in improving this model.

The carrying capacity of the Mt. Chiri area can be calculated directly as a function of habitat suitability, or from the density of bears per unit area. I used the latter method, but limited the area to the suitable habitat as predicted by the habitat suitability function. But the density, which was used for calculating the carrying capacity, pertained to total area rather than just suitable area. Thus, actual carrying capacity may be underestimated.

Shaffer (1981) suggested that systematic pressures and stochastic perturbations, such as demographic stochasticity, genetic stochasticity, environmental stochasticity and natural catastrophes, contribute to the extinction process of a species.

In this population viability analysis, I only considered demographic stochasticity, environmental stochasticity and poaching as a systematic pressure. So, the risk of extinction as shown in this analysis, might be an underestimate. In spite of these limitations, it was

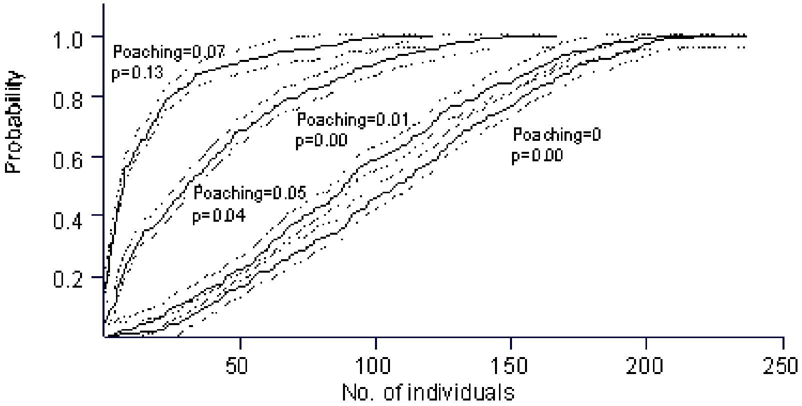

Figure 7. Comparison of interval extinction risk between four hypothetical populations with different poaching levels (K=355, init. abundance=355, population growth rate=1.0741, environmental stochasticity = S; Appendix 2).

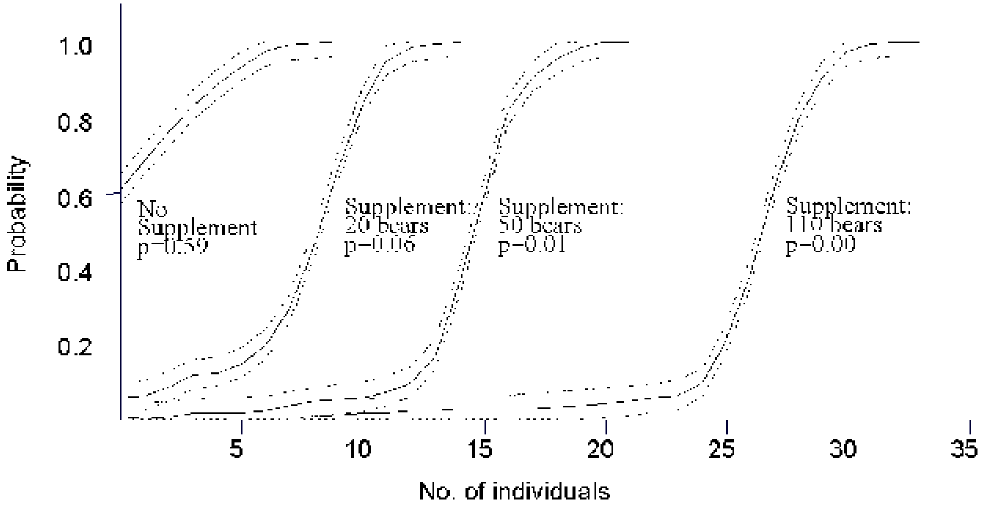

Figure 8. Comparison of interval extinction risk of supplemented hypothetical populations (K=216, init. abundance=5, population growth rate=1.0261, poaching=0.01, environmental stochasticity=1/2S; Appendix 3).

generally predicted, within a range of parameters values, that the risk of extinction for a hypothetical Asiatic black bear population would decrease with a relatively high population growth rate (λ), low environmental stochasticity and a large carrying capacity and initial abundance.

Franklin (1980) proposed that a genetically effective population size of 500 could be enough to maintain sufficient genetic variability to adapt to changing environmental conditions, and a genetically effective population size of 50 could be enough to maintain short-term fitness. This means that population size should be more than 150-500 individuals to sustain short-term fitness. But results from the present study show that a population size of 500 or 1000 is not enough if this is combined with high environmental stochasticity, low population growth rate and a high level of poaching. This theoretical population would then go extinct. This indicates that to attain sufficiency and long-term survival, population size should be larger and there may be a need to connect isolated populations to other areas with suitable bear habitat to promote geneflow. These genetic aspects are very important for small populations, but other factors, such as systematic pressures, demographic stochasticity and environmental stochasticity, should also be highlighted for species conservation.

Akçakaya and Atwood (1997) suggest two practical uses of this model. One is that sensitivity analysis can give information about which parameters need to be more carefully estimated, and through this careful estimation the model can be continuously improved by incorporating new data. Shaffer (1981) also suggested that if the information for the simulation is gathered over a long period time, it is possible to ensure that it is representative of the full range of conditions that the population is subject to and the simulation will provide a more realistic alternative to population viability analysis. Other studies suggest, based on a sensitivity analysis, that adult survival, especially female, is critical and insist that increased adult survival should be a principal management objective (Powell et al. 1996, Wiegand et al. 1998). The other use of the model is to rank management options in terms of the predicted effect on the viability of the target species. Since it is not always possible to experiment with a species, especially when considering large or rare animals, a population viability model can be an effective alternative for predicting the effect of management options and aid decision making.

In conclusion, the population viability analysis of a hypothetical Asiatic black bear population in the Mt. Chiri National Park area raises two points. Firstly, Mt. Chiri National Park can support a viable bear population in a demographic sense, though it is probably insufficient for long-term survival in a genetic sense. This condition might be improved by enlarging the National Park to support more individuals, or connecting it with other populations to promote gene flow. Secondly, a viable bear population, in a demographic sense, may be restored through supplementation. Results from a population viability analysis show that a few supplemented individuals can possibly make a significant difference.

According to this model, the management of a bear population should be aimed at maintaining a high population growth rate and controlling poaching to a level much less than the population growth rate. Other studies suggest that female adult survival is critical to maintain a high population growth rate and insist it should be a primary management objective (Powell et al. 1996, Wiegand et al. 1998).

I suggest that the poaching of adult bears should be strictly prohibited. A public awareness or environmental education program could be an effective way of preventing poaching. The enhancement of suitable habitat within the National Park may be another option, primarily by decreasing human access to suitable bear habitat and eliminating roads. Some areas of high suitability are found outside the National Park, but still connected to it, and I suggest that these areas should be included in the National Park.

Acknowledgements – I am deeply grateful to Torbjörn Ebenhard and Tong-Mahn Ahn for leading me to this subject and for their supervision, Staffan Ulfstrand, Lennart Hansson, Henrik Andrén and Linus Svensson for their constructive comments on an earlier manuscript, Thomas Elmqvist and Börge Pettersson for encouraging me in this project, and the Swedish Biodiversity Centre for funding this research.

I would like to thank Dr. Uhshin Lee for providing me with precious articles on the Japanese black bear, the local community in Kurye for helping me during the field survey and providing me with information on bears, and Sanghee Shin for helping me with GIS database processing.

References

Akçakaya, H. R. 1998. RAMAS GIS: Linking landscape data with population viability analysis (version 3.0) – Applied Biomathematics Setauket, New York.

Akçakaya, H. R. and Atwood, J. 1997. A Habitat-Based Metapopulation Model of the California Gnatcatcher. – Conservation Biology 11: 422–434.

Anonymous. 1998. Surveying the wildlife ecosystem in Mt. Chiri National Park. – National Park Authority. pp. 13–22. In Korean.

Bunnell, F. L. and Tait, D. E. N. 1981. Population Dynamics of Bears – Implications. – In: Smith, T. D. and Fowler, C. (eds), Dynamics of large mammal populations. John Wiley and Sons. New York.

Clark, J. D., Dunn, J. E. and Smith, K. G. 1993. A multivariate model of female black bear habitat use for a geographic information system. – J. Wildl. Manage. 57: 519–526.

Ellerman, J. R. and Morrison–Scott, T. C. S. 1968. Checklist of Palaeartic and Indian Mammals 1758 to 1946. – Trustees of the British Museum (Natural History). London.

Franklin, I. R. 1980. Evolutionary change in small populations. – In: Soulé, M. E. and Wilcox, B. A. (eds), Conservation biology: an evolutionary–ecological perspective. Sinauer, Sunderland, MA, pp. 135–150.

Hashimoto, Y. and Takatsuki, S. 1997. Food habits of Japanese black bear: A review. – Honyurui Kagaku. 37: 1–19. In Japanese with English summary.

Hellgren, E. C. and Vaughan, M. R. 1989. Demographic analysis of a black bear population in the Great Dismal Swamp. – J. Wildl. Manage. 53: 969–977.

Horino, S. I. and Miura, S. 1997. Population model and its application in wildlife management. – Japanese Journal of Ecology. 47: 189–191. In Japanese.

Ishida, K. 1995. Life history and food habit of Japanese black bear. – Honyurui Kagaku 35: 71–78. In Japanese.

Layman, S. T. and Barrett, R. H. 1986. Developing and testing habitat–capability models: Pitfalls and recommendations. – In: Verner, J., Morrison, M.L. and Ralph, C. J. (eds), Wildlife 2000. Modelling habitat relationships of terrestrial vertebrates. The University of Wisconsin Press.

Lecount, A.L. 1982. Characteristics of a central Arizona black bear population. – J. Wildl. Manage. 46: 861–867.

Lee, I. K., Kim, K. J., Cho, J. M., Lee, D.W., Cho, D. S. and Yu, J. S. 1994. Biodiversity Korea to 2000. – Mineumsa. Seoul. In Korean.

Liu, X. and Xiano, Q. 1986. Age composition, sex ratio and reproduction of bears in Heilongjiang Province, China. – Acta theriologica sinica. 6: 161–170. abstract only seen. In Chinese with English summary.

Ma, Y. 1986. The distribution and the changing trends of bear resources in Heilongjiang province (China) in the last ten years. – Acta theriologica sinica. 6: 89–92. abstract only seen. In Chinese with English summary.

Mizoguchi, N., Katayama, A., Tsubota, T. and Komiyama, A. 1996. Effect of yearly fluctuations in beechnut production on food habits of Japanese black bear. – Honyurui Kagaku. 36: 33–44. In Japanese.

Mizuno, A., Hanai, M., Ogawa, I. and Watanabe, H. 1972. A trial of radio–tracking of Japanese black bear. – Bulletin of the Kyoto University Forests. 43: 1–8. In Japanese with English summary.

Norton, T.W. 1995. Introduction. – Biological conservation 73:91.

Nozaki, E., and A. Mizuno. 1983. Home range and daily activity of Japanese black bear – A bio–telemetrical study in the Ozo valley. – Bulletin of the Hakusan Nature Conservation Center. 9: 77–83. In Japanese.

Nozaki, E., Furubayashi, K., Maruyama, N., Tokia, K. and Toyke, Y. 1979. Distribution of Japanese black bear in Kanto district – by the questionnaire and interview methods. – The Journal of the Mammalogical Society of Japan 8: 14–32. in Japanese.

Oli, M. K., Jocobson, H. A. and Leopold, B. D. 1997. Denning ecology of black bear in the white river national wildlife refuge, Arkansas. – J. Wildl. Manage. 61: 700–706.

Possingham, H. P. and Davies, I. 1995. Alex: a model for the viability analysis of spatially structured populations. – Biological conservation 73: 143–150.

Powell, R. A., Zimmerman, J. D., Seaman, D. E. and Gillam, J. F. 1996. Demographic analyses of a hunted black bear population with access to a refuge. – Conservation Biology 10: 224–234.

Reid, D., Jiang, M., Teng, Q., Qin, Z. and Hu, J. 1991. Ecology of the Asiatic black bear in Sichuan, China. – Mammalia 55: 221–238.

Rudis, V. A., and J. B. Tansey. 1995. Regional assessment of remote forests and black bear habitat from forest resource surveys. – J. Wildl. Manage. 59: 170–180.

Schooley, R. L., Mclaughlin, C. R., Matula, Jr. G. J., and Krohn, W. B. 1994. Denning chronology of female black bears: Effects of food, weather, and reproduction. – Journal of Mammalogy 75: 466–477.

Servheen, C. 1989. The status and conservation of the bears of the world. – 8th International Conference on Bear Research and Management, Victoria, British Columbia, Canada.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. – Bioscience 3: 131–134.

Shaffer, M. L. 1990. Population viability analysis. – Conservation biology 4: 39–40.

Torii, H. 1975. Japanese black bear in the upper stream region of the Ooi river. – A natural history of the upper stream region of the Ooi river, Japan. pp. 56–60. In Japanese with English summary.

Torii, H. 1989. Food habits of the Japanese black bear in the headwaters of the Ohwi River. – Journal of the Japanese Forestry Society. 71: 417–420. in Japanese with English summary.

Torii, H. 1989. Home ranges of radio–tracked Japanese black bear (Selenarctos thibetanus) in the upper stream region of Ohwi river, central Japan. – Bulletin of Shizuoka prefecture forestry technology center 17: 79–83. In Japanese with English summary.

Torii, H., Maruyama, N., Nozaki, E., Watanabe, H. and Furubayashi, K. 1981. Radio–tracking of Japanese Black Bears in Omote–Nikko, Tochi prefecture. – The Journal of the Mammalogical Society of Japan 8: 191–193. in Japanese with English summary.

Wang, Y., Chu, S. and Seal, S. (eds), 1994. Asiatic black bear population and habitat viability assessment workshop report. – Taipei Zoo, Taipei, Taiwan. Conservation Breeding Specialist Group CBSG/SSC/IUCN.

Watanabe, H. 1980. Damage to conifers by the Japanese black bear. – In: Martinka, C.J. and McArthur, K. L. (eds), Bear, their biology and management. Bear biology association conference series 3: 67–70.

Watanabe, H. and Komiyama, A. 1976. Conservation of wild bears and control of its damage to forest trees (II). – Bulletin of the Kyoto University Forests No. 48 (Reprint). In Japanese.

Wiegand, T., J. Naves, Stephan, T. and Fernadez, A. 1998. Assessing the risk of extinction for the brown bear (Ursus arctos) in the Cordillera Cantabrica, Spain. – Ecological Monographs 68: 539–570.

Young, B.F., and Ruff, R. L. 1982. Population dynamics and movements of black bears in east central Alberta. – J. Wildl. Manage. 46: 845–860.

Yowata, M.A. 1994. Conservation and management of the Asiatic black bear in Japan forest. – Forest Science 11: 32–42. In Japanese.

Appendix 1. Probability of extinction of a hypothetical Asiatic black bear population without poaching and supplementation.

K	Population growth rate	Initial abundance	Environmental stochasticity		
			1/3S	1/2S	S
78	1.0261	3	0.69	0.74	0.85
78	1.0741	3	0.51	0.51	0.63
78	1.0261	78	**0.01**	**0.03**	0.30
78	1.0741	78	**0.00**	**0.00**	**0.03**
100	1.0261	3	0.69	0.74	0.81
100	1.0741	3	0.50	0.33	0.47
100	1.0261	100	**0.01**	**0.01**	0.20
100	1.0741	100	**0.00**	**0.00**	**0.01**
216	1.0261	5	0.51	0.61	0.74
216	1.0741	5	**0.05**	0.15	0.29
216	1.0261	216	**0.00**	**0.00**	**0.11**
216	1.0741	216	**0.00**	**0.00**	**0.00**
355	1.0261	13	0.25	0.32	0.59
355	1.0741	13	**0.01**	0.07	0.17
355	1.0261	355	**0.00**	**0.00**	**0.05**
355	1.0741	355	**0.00**	**0.00**	**0.00**
500	1.0261	13	0.25	0.32	0.57
500	1.0741	13	**0.01**	0.07	0.16
500	1.0261	500	**0.00**	**0.00**	**0.05**
500	1.0741	500	**0.00**	**0.00**	**0.00**
1000	1.0261	13	0.32	0.40	0.59
1000	1.0741	13	**0.00**	0.09	0.18
1000	1.0261	1000	**0.00**	**0.00**	**0.03**
1000	1.0741	1000	**0.00**	**0.00**	**0.00**

Appendix 2. Probability of extinction of a hypothetical Asiatic black bear population an initial abundance of K and poaching levels of 0.01 and 0.02 (when population growth rate = 1.026) and 0.01, 0.05 and 0.07 (when population growth rate = 1.074)

K	Population growth rate	Poaching	Environmental stochasticity		
			1/3S	1/2S	S
78	1.0261	0.01	**0.00**	**0.02**	0.32
78	1.0261	0.02	**0.03**	0.07	0.33
78	1.0741	0.01	**0.00**	**0.00**	**0.03**
78	1.0741	0.05	**0.01**	**0.01**	0.13
78	1.0741	0.07	**0.02**	0.07	0.24
100	1.0261	0.01	**0.00**	**0.01**	0.23
100	1.0261	0.02	**0.02**	**0.04**	0.27
100	1.0741	0.01	**0.00**	**0.00**	**0.02**
100	1.0741	0.05	**0.00**	**0.00**	0.10
100	1.0741	0.07	**0.01**	**0.02**	0.23
216	1.0261	0.01	**0.00**	**0.00**	0.14
216	1.0261	0.02	**0.00**	**0.00**	0.19
216	1.0741	0.01	**0.00**	**0.00**	**0.00**
216	1.0741	0.05	**0.00**	**0.00**	**0.03**
216	1.0741	0.07	**0.00**	**0.01**	0.07
355	1.0261	0.01	**0.00**	**0.00**	0.09
355	1.0261	0.02	**0.00**	**0.00**	0.17
355	1.0741	0.01	**0.00**	**0.00**	**0.00**
355	1.0741	0.05	**0.00**	**0.00**	**0.04**
355	1.0741	0.07	**0.00**	**0.00**	0.13
500	1.0261	0.01	**0.00**	**0.00**	0.07
500	1.0261	0.02	**0.00**	**0.00**	0.11
500	1.0741	0.01	**0.00**	**0.00**	**0.00**
500	1.0741	0.05	**0.00**	**0.00**	**0.02**
500	1.0741	0.07	**0.00**	**0.00**	0.09

Appendix 3. Probability of extinction of a hypothetical Asiatic black bear population with different levels of poaching, environmental stochasticity, and supplementation.

Carrying capacity	Initial abundance	Population growth rate	Poaching	Supplementation											
				1/2K			1/4K			1/10K			No		
				Environmental stochasticity											
				1/3S	1/2S	S	1/3S	1/2S	S	1/3S	1/2S	S	1/3S	1/2S	S
216	5	1.0261	0.01	**0.00**	**0.00**	0.09	**0.00**	**0.01**	0.16	**0.02**	0.06	0.23	0.51	0.60	0.73
216	5	1.0261	0.02	**0.00**	**0.00**	0.16	**0.01**	**0.02**	0.20	**0.04**	0.08	0.32	0.57	0.60	0.78
216	5	1.0741	0.01	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	0.11	0.27	0.46
216	5	1.0741	0.05	**0.00**	**0.00**	**0.03**	**0.00**	**0.00**	0.05	**0.00**	**0.00**	0.09	0.17	0.30	0.49
216	5	1.0741	0.07	**0.00**	**0.00**	0.07	**0.01**	**0.01**	0.10	**0.01**	**0.02**	0.15	0.19	0.35	0.61
355	13	1.0261	0.01	**0.00**	**0.00**	0.09	**0.00**	**0.01**	0.10	**0.00**	**0.01**	0.17	0.27	0.35	0.59
355	13	1.0261	0.02	**0.00**	**0.00**	0.10	**0.00**	**0.00**	0.18	**0.01**	**0.02**	0.24	0.30	0.39	0.59
355	13	1.0741	0.01	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.02**	0.05	0.19
355	13	1.0741	0.05	**0.00**	**0.00**	**0.03**	**0.00**	**0.00**	**0.03**	**0.00**	**0.01**	0.08	0.07	0.14	0.34
355	13	1.0741	0.07	**0.00**	**0.00**	0.09	**0.00**	**0.00**	0.13	**0.01**	0.05	0.20	0.17	0.26	0.47
500	13	1.0261	0.01	**0.00**	**0.00**	0.06	**0.00**	**0.00**	0.08	**0.00**	**0.00**	0.14	0.24	0.31	0.54
500	13	1.0261	0.02	**0.00**	**0.00**	0.08	**0.00**	**0.00**	0.11	**0.01**	**0.02**	0.21	0.27	0.33	0.55
500	13	1.0741	0.01	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	0.06	0.21
500	13	1.0741	0.05	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.03**	**0.00**	**0.00**	0.06	0.07	0.11	0.34
500	13	1.0741	0.07	**0.00**	**0.00**	0.05	**0.00**	**0.00**	0.08	**0.01**	**0.02**	0.15	0.15	0.20	0.46