www.roavs.com EISSN: 2223-0343

RESEARCH OPINIONS IN ANIMAL & VETERINARY SCIENCES

Analysis of wildlife population dynamics using a connected scatter plot: Latvian wild animals as an example

Yukichika Kawata[1*], Jānis Ozoliņš[2] and Jānis Baumanis[2]

[1]Department of Animal and Food Hygiene, Obihiro University of Agriculture and Veterinary Medicine, Inada-cho, Obihiro, Hokkaido 080-8555, Japan; [2]Wildlife Management, Latvian State Forest Research Institute 'Silava', Rigas iela 111, Salaspils, LV-2169, Latvia

Abstract

An easy way to calculate index that summarizes population dynamics in a comparative manner may make it easy for wildlife departments to detect species that should be given the highest priority in management. The purpose of this study was to propose one possible index and an associated scatter plot to make the conditions of wild animal populations easy to compare. We developed a unit-free index to make it possible to compare populations at different stages of population expansion and/or populations of similar but different species. We applied our index and scatter plot empirically for Latvian game animals using data collected between 1922 and 2009 to verify the usefulness of our method. Our index appropriately reflects changes before and after the second independence and the accession to the EU. As expected, our results suggest that the conditions of wild animals in Latvia have been improving, particularly after accession to the EU.

Keywords: wildlife management; unit-free index; connected scatter plot; carnivores

To cite this article: Kawata Y, J Ozoliņš and J Baumanis, 2013. Analysis of wildlife population dynamics using a connected scatter plot: Latvian wild animals as an example. Res. Opin. Anim. Vet. Sci., 3(2), 50-59.

Introduction

The size of wild animal populations fluctuates because of various factors such as predator-prey relationships, severity of cold winters, availability of food, competition with other species, and hunting pressure from humans (Odum, 1983). As many empirical examples show, the size of wild animal populations can change substantially over the long term. The same annual absolute change in population would have different implications in populations of different size. Moreover, if we compare populations of the same species or if we compare the same population at different times, it is not necessarily easy to detect which population is doing better on the basis of population size or annual change.

It is often the case that the same department in charge of wildlife supervises various numbers and types of wild animals, including game species and protected species. Therefore, if there is a simple index that summarizes population dynamics in a comparative manner, a wildlife department may find it easy to detect which species should be given the highest priority in terms of management. For instance, the population size of the same species will vary through time. In such cases, it might be beneficial to refer to information from other similar species (e.g. herbivores, omnivores, or carnivores). When comparing secular change in populations of the same species, it might be easier to identify trends that are difficult to detect on the basis of raw data (such as population sizes), by using an index that does not depend on population size.

Existing studies mainly focus on the risk of extinction. One of the most well-known indexes is the Minimum Viable Population (MVP). However, the MVP calculates extinction risk on the basis of a single species or population, where relationships with other species are not explicitly shown. Among various species, the species targeted for hunting may change through time. Targets will change on the basis of trends

Corresponding author: Yukichika Kawata, Department of Animal and Food Hygiene, Obihiro University of Agriculture and Veterinary Medicine, Inada-cho, Obihiro, Hokkaido 080-8555, Japan

in hunter preferences and political changes (e.g. protection of other substitutable animals or the setting of a permit price). Therefore, it is preferable that there be some index that allows us to measure trends both of targeted species and of other related species in a simple and explicit manner.

There are some related published studies. For example, Smith and Zollner (2005) developed a conceptual framework to examine the sustainable management of wildlife habitat and the risk of extinction when considering the relationship with other multiple species. Although there have been some advances in related areas, as mentioned above, a simpler and visually more understandable index is desirable for use in the field.

Thus, in this study, we develop a simple index. We also propose the methodology to examine the stability of a population on the basis of a scatter diagram related to the simple index we developed. Further, we apply our index and methodology to 16 Latvian species to verify its usefulness and examine the conditions of these 16 species.

Materials and Methods

Data

We used data of estimated the population sizes of 16 Latvian species: wolf (*Canis lupus*), European lynx (*Lynx lynx*), moose (*Alces alces*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), raccoon dog (*Nyctereutes procyonoides*), red fox (*Vulpes vulpes*), marten (*Martes martes*, *Martes foina*), badger (*Meles meles*), otter (*Lutra lutra*), American mink (*Mustela vison*), muskrat (*Ondatra zibethicus*), brown hare (*Lepus europaeus*), mountain hare (*Lepus timidus*), and beaver (*Castor fiber*) (Table 1). These data are official Latvian governmental data and are also available from Vanags (2010).

New Index and Connected Scatter Plot

We created a new index $I(t)$ for a given year t, which was defined as follows:

$$I(t) = \frac{N(t) - N(t-1)}{N(t)} \qquad (1)$$

Here, $N(t)$ and $N(t-1)$ are estimated population sizes for the years t and $t-1$, respectively. A virtually identical index is used by, for example, Nielsen and Treue (2012).

One of the essential features of this index is that the change in population size is divided by the population size of the year t. Because of this procedure, the index $I(t)$ is unitless. This is quite important because it enables us to compare the population size of any two or more species at any time. For example, if we wish to compare the current conditions of elephants and house mice, the unit of mass for elephants and house mice would be substantially different (possibly tons and grams). However, our index makes it possible to compare the condition of these two species. The basic idea of this index comes from the concept of elasticity used in economics (see some introductory text, for example Nicholson and Snyder, 2005).

After calculating the index $I(\cdot)$ for the available time span of each species, we constructed a diagram (Figure 1). We put $I(t-1)$ and $I(t)$ on the horizontal and vertical axes, respectively, to draw a Connected Scatter Plot (CSP) of each species. Points in four quadrants can be interpreted as follows. If a point lies in the first quadrant, it implies that both $\Delta N(t) > 0$ and $\Delta N(t-1) > 0$. If a point lies in the third quadrant, it implies that both $\Delta N(t) < 0$ and $\Delta N(t-1) < 0$. If a point is in the second quadrant, it implies that $\Delta N(t) > 0$ and $\Delta N(t-1) < 0$, which suggests that the population size started to increase at year t. Likewise, if a point is in the fourth quadrant, it implies that $\Delta N(t) < 0$ and $\Delta N(t-1) > 0$, which suggests that the population size started to decrease at year t.

Modified Average Value of the Index (MAVI)

We also calculated the modified average value of the index $I(\cdot)$ using the following definition:

$$MAVI = \frac{\sum_{t=1}^{t=T} |I(t)|}{T}$$

Here, $|I(\cdot)|$ indicates an absolute value of the index $I(\cdot)$. Therefore, if the value of $MAVI$ is large, it suggests that the population size fluctuated widely. Because we divided the difference of the population sizes of consecutive years $t-1$ and t ($N(t) - N(t-1)$) by $N(t)$, a value for $MAVI$ is standardized and can be compared among different local populations or different species as explained above.

Next, we calculated the variance of the index $I(\cdot)$ in the normal manner, denoted as Var. We also calculated the average population size in the normal manner, denoted as P. We categorized the 16 species into two types: carnivores or non-carnivores (herbivores or omnivores). We defined a dummy variable $C = 1$ if the species is a carnivore and $C = 0$ if it is not.

Table 1: Available data spans

Species	Available time spans
moose, red deer, roe deer, wild boar	1922–1937, 1940, 1954–2009
wolf, lynx	1923–1938, 1940, 1958–2009
beaver	1954–2009
raccoon dog, fox, marten, badger, American mink, muskrat, grey hare, mountain hare	1958–1998, 2001–2009
otter	1958–1998, 2001–2008

Table 2: Statistical results (all available periods)

	$MAVI$	Var	P	C
wolf	0.296	0.125	295	1
lynx	0.218	0.066	337	1
American mink	0.164	0.023	10,124	1
marten	0.119	0.066	11,482	1
raccoon dog	0.096	0.009	10,527	1
otter	0.086	0.008	3,370	1
fox	0.062	0.004	16,113	1
badger	0.054	0.003	8,182	1
musk rat	0.178	0.028	3,504	0
roe deer	0.153	0.040	58,185	0
beaver	0.141	0.011	15,612	0
wild boar	0.129	0.011	14,812	0
moose	0.125	0.012	9,044	0
red deer	0.103	0.009	10,847	0
grey hare	0.077	0.008	35,148	0
mountain hare	0.056	0.003	18,215	0

Note: C = 1 if the species is carnivores and C = 0; otherwise.

Regression Analysis

We applied the Ordinary Lease Squares (OLS) method to find the determinants of $MAVI$. We used the following equation:

$$MAVI_j = \alpha + \beta_1 VAR_j + \beta_2 \ln P_j + \beta_3 C_j + \varepsilon_j$$

Where,

j : Index denoting species

α : The intercept

β_k : The parameters associated with Var_j, P_j and C_j

ε_j : The error for observation j

Results and Discussion

Comparison of MAVI and CSP between carnivores and non-carnivores

The values of $MAVI$, Var, and P are tabulated in Table 2. The CSPs of each species are shown in Figures 2 to 17. Because in the cases of the wolf, lynx, roe deer, and marten, $I(\cdot)$ takes values >1, we include complementary figures that show the whole image in the Appendix.

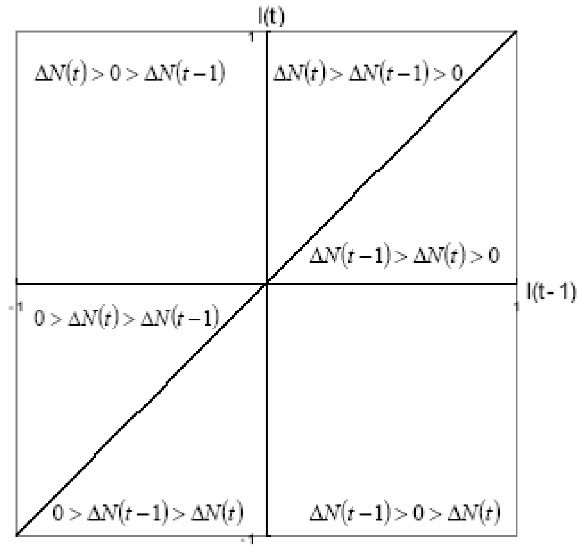


Fig. 1: Theoretical implication of plot location

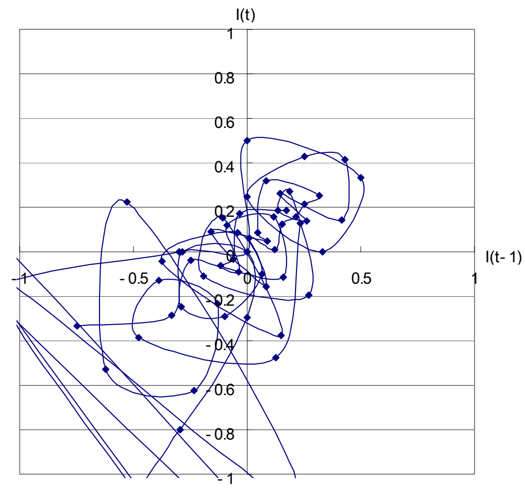
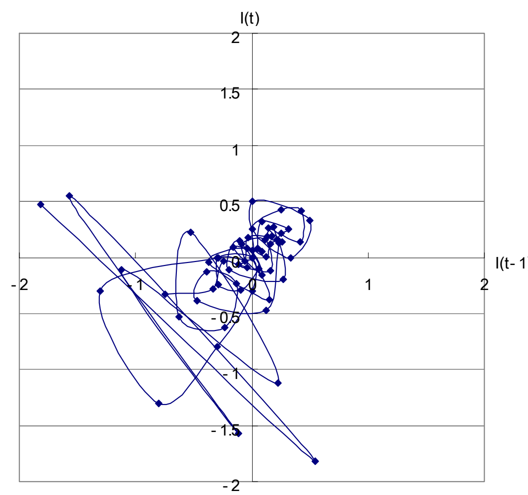


Fig. 2: Connected Scatter Plot (wolf)



Appendix Fig. 1: Connected Scatter Plot (wolf)

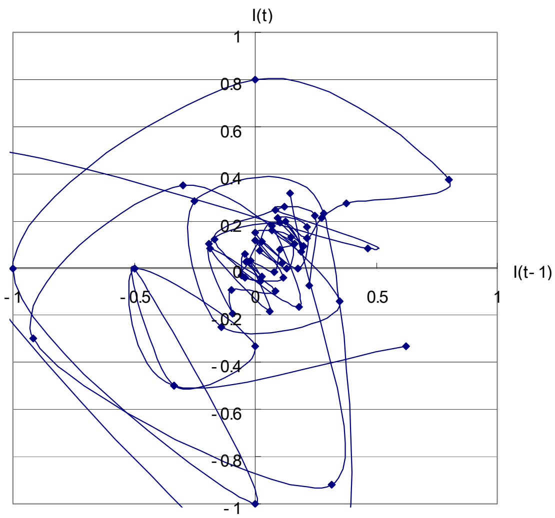
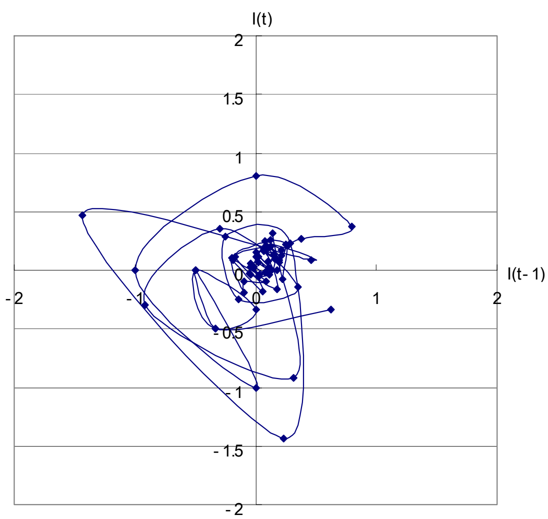


Fig. 3: Connected Scatter Plot (lynx)



Appendix Fig. 2: Connected Scatter Plot (lynx)

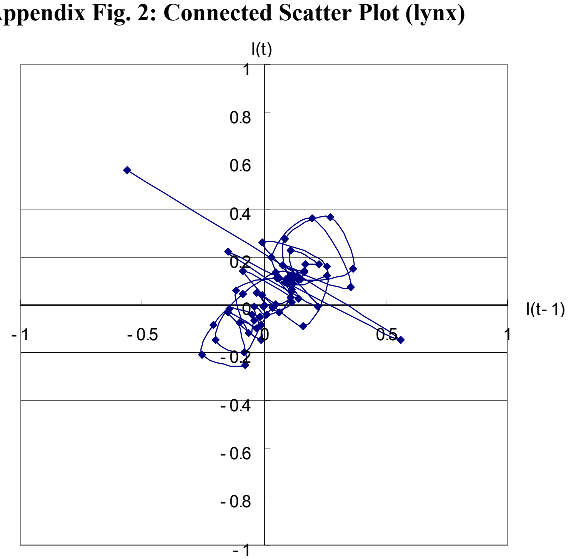


Fig. 4: Connected Scatter Plot (moose)

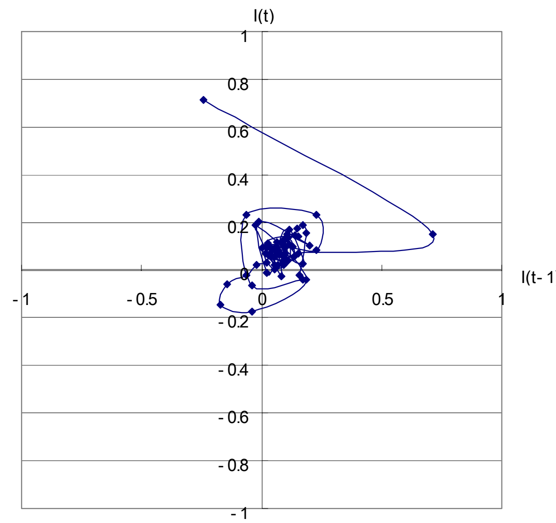


Fig. 5: Connected Scatter Plot (red deer)

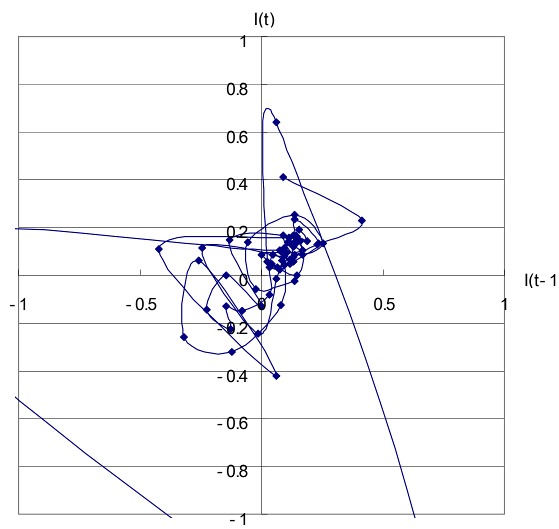
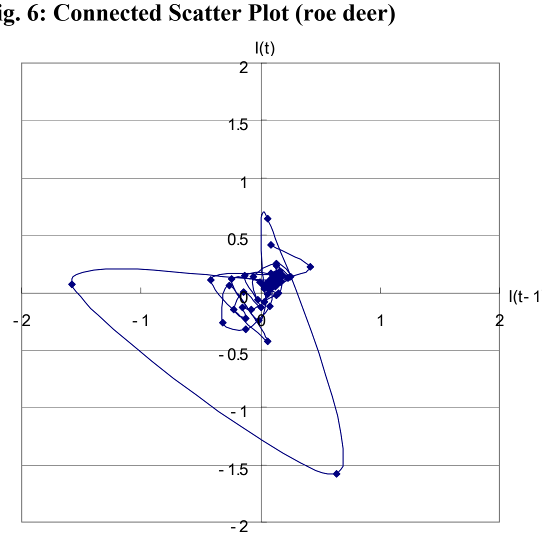


Fig. 6: Connected Scatter Plot (roe deer)



Appendix Fig. 3: Connected Scatter Plot (roe deer)

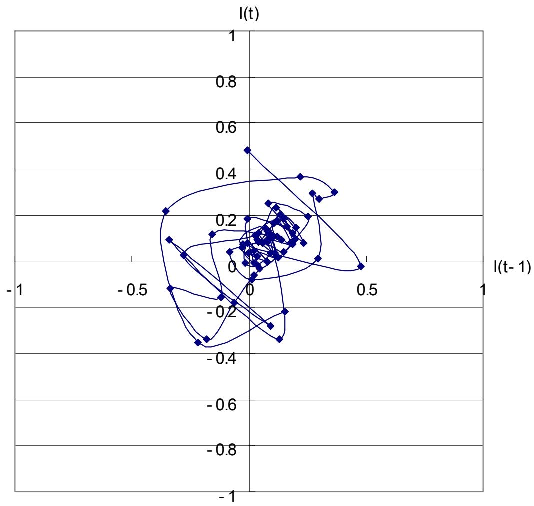


Fig. 7: Connected Scatter Plot (wild boar)

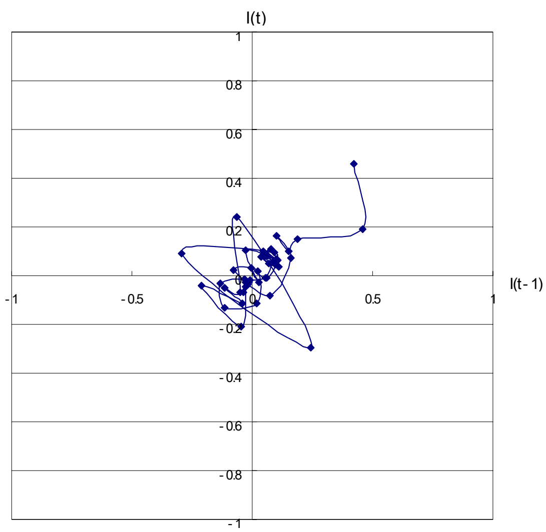


Fig. 8: Connected Scatter Plot (raccoon dog)

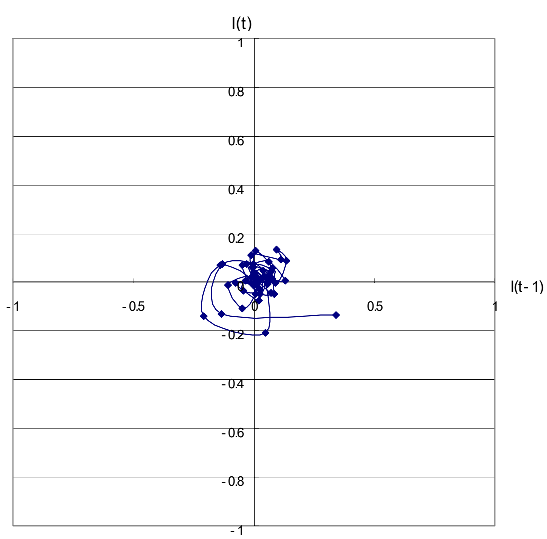


Fig. 9: Connected Scatter Plot (red fox)

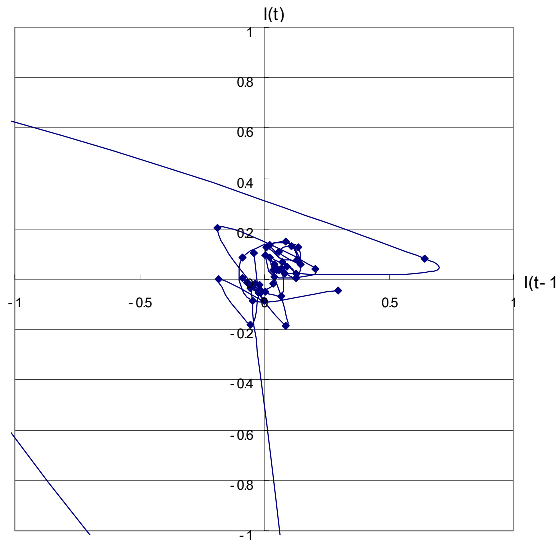
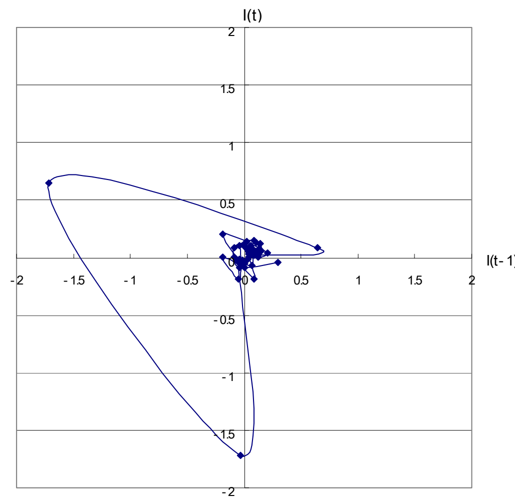


Fig. 10: Connected Scatter Plot (marten)



Appendix Fig. 4: Connected Scatter Plot (marten)

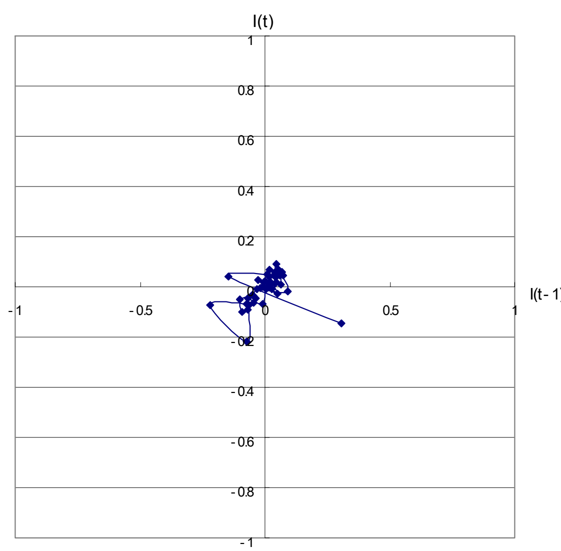


Fig. 11: Connected Scatter Plot (badger)

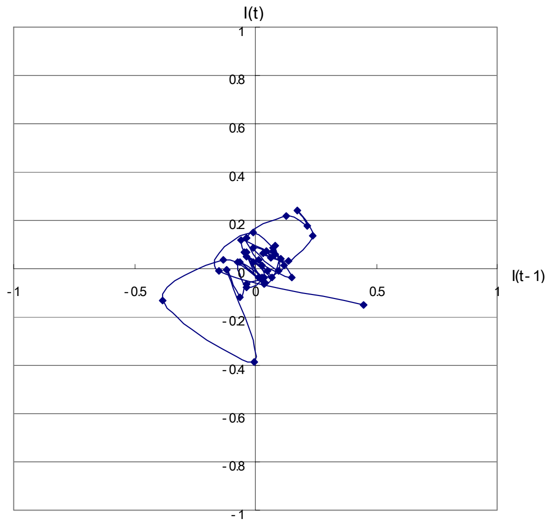


Fig. 12: Connected Scatter Plot (otter)

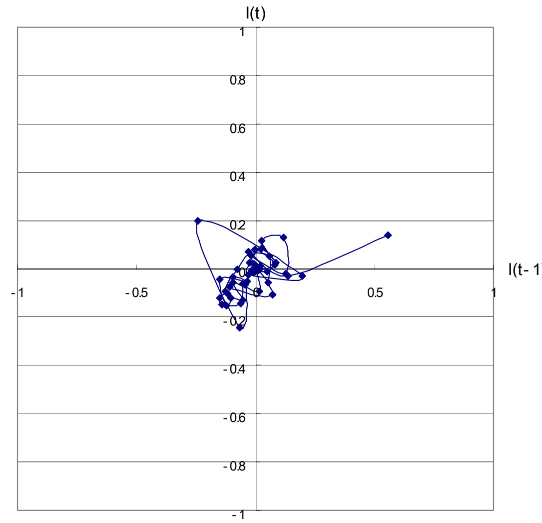


Fig. 15: Connected Scatter Plot (brown hare)

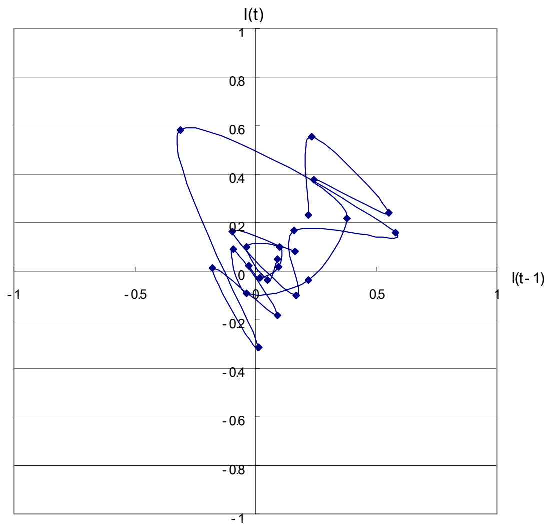


Fig. 13: Connected Scatter Plot (American mink)

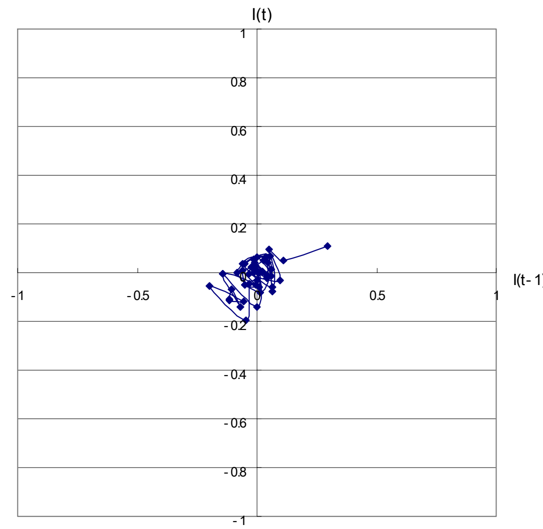


Fig. 16: Connected Scatter Plot (mountain hare)

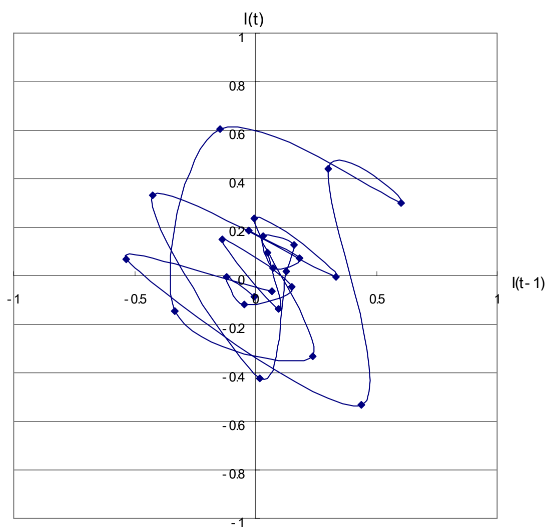


Fig. 14: Connected Scatter Plot (muskrat)

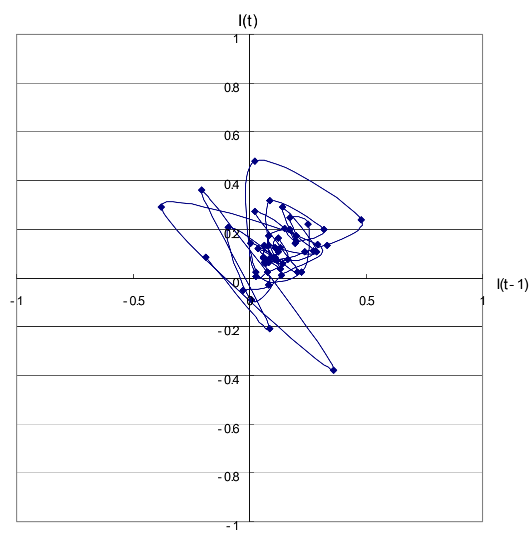


Fig. 17: Connected Scatter Plot (beaver)

First, we need to briefly discuss Latvian game management. The following contents rely heavily on Andersone-Lilley and Ozolins (2005). Hunting is regulated by the Hunting Law and Hunting Regulation with additional documents by the Latvian State Forest Service. Hunting species are specified in the Hunting Regulation and quotas are set for some of these hunting species. Game species are under scientific management, although some uncontrollable incidents may happen (e.g. the population sizes of many species declined in the 1990s, possibly because of poaching during the political instability of the state after independence). Therefore, differences in $MAVI$ may be attributed to factors such as hunters' attitude towards hunting animals (e.g. they do not fully realize cull limits under diminished needs) and differences in management policy (e.g. regarding large carnivores as pests).

There are some trends. First, at a glance it can be easily recognized that the set of $I(\cdot)$s is widely scattered in the case of large carnivores (wolf and lynx). In fact, the values of the $MAVI$ of the wolf and the lynx are the first and second largest (Table 2). This reflects the fact that these carnivores (particularly wolves) were seen as pest animals until recently, particularly in Soviet era. Andersone-Lilley and Ozolins (2005) also pointed out that 'fluctuations of population dynamics reflect the intensity of persecution by humans'.

If values of $I(\cdot)$ and $MAVI$ are small, it suggests that the fluctuation of the population is small. Most wildlife species are involved in predator-prey relationships. Therefore, population size fluctuates to some extent and the values of $I(\cdot)$ and $MAVI$ will be non-zero. If these values are close to zero, it suggests that human intervention towards those species is strong. When interpreting the results, we should be careful that the values obtained are within appropriate ranges. This paper proposes this index and the specification of the appropriate range is one of the remaining issues of this paper.

Second, values of $MAVI$ of non-carnivores are more stable than those of carnivores because the range of non-carnivores is between 0.056 and 0.178 while that of carnivores is between 0.054 and 0.296. There are several possible reasons for this. The first reason is that, because the population size of predators (carnivores) are usually smaller than their corresponding prey (herbivores or omnivores), the index $I(\cdot)$ for predators could be larger than that for prey.

On the basis of a winter diet study conducted in Latvia and Estonia, ungulates seem to be the staple food for both wolves and lynxes (Valdmann et al., 2005). In addition, on the basis of the results obtained by Kawata, Ozolins and Andersone-Lilley (2008), predator-prey relationships are detected among the main Latvian large carnivores (wolf and lynx) and ungulates (red deer, roe deer, moose, and wild boar), even under the influence of human hunting. Therefore, it is appropriate to compare the $MAVI$ of these large carnivores and ungulates. The results are shown in Figure 18. As this figure shows, the range of $MAVI$ is wider when the population size is lower. Because population sizes of

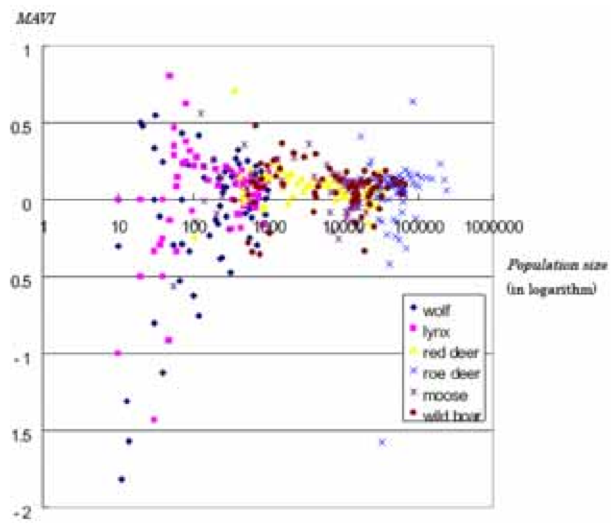


Fig. 18: Comparison of $MAVI$ s among large carnivores and ungulates

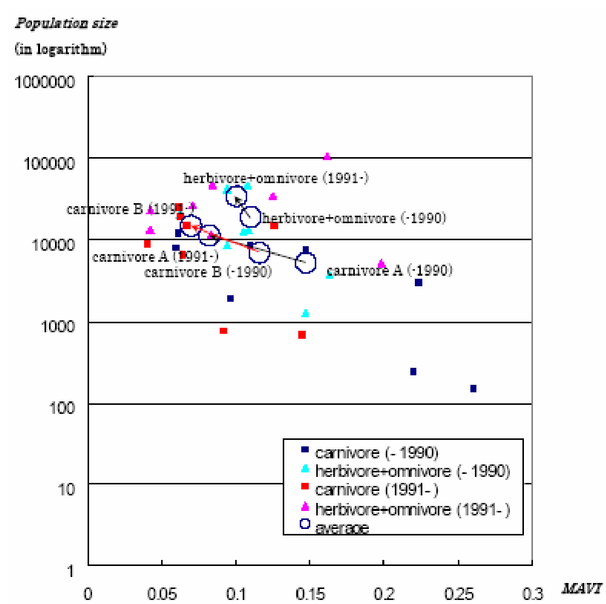


Fig. 19: Comparison of average $MAVI$ s before and after independence; Note: 'carnivore A' includes all carnivores whereas 'carnivore B' does not include large carnivores (wolf and lynx).

large carnivores are smaller than those of prey ungulates, the $MAVI$ of large carnivores are more widely scattered.

The second reason is that it is often the case that prey possesses two aspects: that of beneficial animals and pest animals. This is because prey are often objectives of sports hunting (and other types of hunting) and, at the same time, prey often cause agricultural or forestry damage. On the other hand, as we mentioned above, it is often the case that predators possess only a pest aspect because they compete with human hunters for hunting animals (Andersone and Ozolins, 2004). It follows that we have more incentive to appropriately conserve prey rather than predators. Therefore, values of $MAVI$ for non-carnivores are more stable than those of carnivores.

Comparison of MAVI and CSP before and after policy changes

In the above analysis, we examined all periods without considering political changes. In this subsection, we take political changes into account. Latvia regained her sovereignty from the Soviet Union in 1991 and became a member state of the European Union in 2004. Wildlife management policy and practices changed to reflect these different political systems. There were several prominent differences before and after these political changes.

First, large carnivores were seen as pests during the Soviet era and wolf exclusion was official policy (Andersone, 2003). Because of this long experience, even after the second independence, the attitudes of local people and hunters towards large carnivores were retained for some time. In fact, an anti-wolf campaign, which promoted wolf hunting, was carried out in the middle of the 1990s. Hunting was permitted year-round with no limit, and there was even a reward (Ls 75) paid for each wolf killed between 1997 and 1999 (Andersone-Lilley and Ozolins, 2005).

However, hunters' attitudes towards large carnivores gradually changed in the early 2000s during preparations for accession to the EU. The new hunting regulations were enacted in 2003 and a hunting season limit was set for wolves and lynx (Andersone-Lilley and Ozolins, 2005). In the earlier stage (before accession to the EU), the general public was more supportive than hunters to the coexistence with and conservation of large carnivores (Andersone and Ozolins, 2002; Andersone-Lilley and Ozolins, 2004). However, hunters' attitudes towards large carnivores have also changed, probably because of educational practices and various other activities. For example, the involvement of hunters in research activities, such as reporting to the State forest service, replying to questionnaires on hunted carnivores, and cooperating with the gathering of dead carcasses for research (Andersone, 2003; Ozolins at al. 2008).

Second, some hunting animals were conserved more appropriately during the Soviet era because the Soviet markets that were open to Latvian products of hunting animals were closed after independence. One of the most notable examples is the beaver. In Latvia, beavers were exterminated in the 1870s and artificially reintroduced in 1927 and thereafter (Balodis, 1990). Thanks to a successful increase in the population size, beaver hunting was reinitiated in 1981. From 1981 to 1991, the annual beaver quota was strictly fulfilled. However, after independence, real hunts were always lower than the annual quota because Soviet fur markets were closed for Latvian products and other parts of the beaver had little value. This increased the acceleration of the size of the beaver population and associated forest damage in many parts of Latvian territory.

However, the case of the beaver is exceptional for the following reasons. First, beavers were reintroduced and the recovery of the population size was necessary to some extent. Second, the market value of the beaver had decreased after independence, but those of other game species, particularly ungulates (red deer, roe deer, moose, and wild boar), remained relatively high. It follows that most of the herbivores and omnivores have been under preferable conditions after independence.

Now, let us compare the difference before and after these policy changes in wildlife management. The average values of $MAVI$, Var, and P for each species are calculated for the three time periods (1958–1990, 1991–2003, 2003–2009) in Table 3. When comparing the average values of $MAVI$ and P between the first time period (1958–1990) and the third time period (2004–2009), in most cases the average value of $MAVI$ decreases while that of P increases. These results are intuitive and imply management has improved, as we mentioned above.

However, there are three exceptions: the average values of both $MAVI$ and P increased for roe deer and both values decreased for grey and mountain hares. The population size of roe deer increased. The fact that $MAVI$ also increased implies that sudden changes in population have occurred. Although population size has increased over the long term, careful monitoring might be necessary. On the other hand, the population size of hares has decreased. The fact that $MAVI$ has also decreased implies that although the population size has decreased, cases are rare or non-existent where a large sudden change in population has happened. Therefore, if the population size is above a lower limit (e.g. the lower limit set by the department in charge of wild animals to retain a sustainable population size), no specific care might be required.

Table 3: Statistical results (specific periods)

	1958–1990			1991–2003			2004–2009		
	$MAVI$	Var	P	$MAVI$	Var	P	$MAVI$	Var	P
wolf	0.260	0.077	148	0.155	0.010	698	0.121	0.004	646
lynx	0.220	0.057	243	0.072	0.003	646	0.136	0.007	961
American mink	0.224	0.023	2,934	0.172	0.028	11,009	0.051	0.001	21,682
marten	0.148	0.096	7,546	0.071	0.002	15,523	0.050	0.001	25,719
raccoon dog	0.110	0.012	8,437	0.061	0.001	11,708	0.078	0.001	19,856
otter	0.096	0.011	1,902	0.067	0.001	5,377	0.059	0.002	8,640
fox	0.061	0.005	11,617	0.070	0.002	20,935	0.048	0.000	32,000
badger	0.060	0.004	7,944	0.041	0.000	7,556	0.041	0.001	10,642
musk rat	0.147	0.019	1,253	0.264	0.044	4,867	0.090	0.003	5,510
roe deer	0.108	0.004	47,369	0.171	0.011	72,759	0.142	0.003	175,391
wild boar	0.106	0.009	12,481	0.140	0.006	25,186	0.091	0.001	54,024
moose	0.109	0.006	13,053	0.113	0.004	10,156	0.021	0.000	14,448
beaver	0.163	0.013	3,674	0.096	0.002	34,059	0.063	0.000	75,041
red deer	0.094	0.003	8,348	0.072	0.004	23,706	0.068	0.000	31,784
grey hare	0.095	0.011	41,237	0.061	0.002	22,681	0.012	0.000	24,518
mountain hare	0.062	0.004	20,699	0.045	0.001	13,650	0.038	0.003	12,924

Note: Data are not available for some time spans for some species. Available time spans are shown in Table 1.

Table 4: Result of OLS estimation

Variables	Coefficients	t value	
constant	0.260	3.275	***
Var	1.350	4.315	***
$\ln P$	-0.017	-2.119	*
C	-0.037	-2.144	*
$adj.R^2$	0.788		

Note1: The dependent variable is $MAVI$; Note 2: *** significant at the 1% level and * significant at the 10% level.

Next, if we consider the second period (1991–2003) in addition to the first and the third periods, the results are more difficult to interpret. This is because for some species $MAVI$ increased when comparing the first and the second periods (fox, musk rat, roe deer, wild boar, and moose) and for some species $MAVI$ increased when comparing the second and the third periods (lynx, raccoon dog, and badger). These results suggest that under drastic political changes, wildlife management faces difficulties such as a lack of obvious direction (particularly towards large carnivores), the possibility of increased poaching, changes in hunters' attitudes towards game species, and others. However, fortunately, Latvian game management seems to have been successful over the long term because when comparing the first and the third period, the average values of $MAVI$ and P have changed in a favourable manner for most game species.

As the above results suggest, the second period can be seen as a transitional phase. In what follows, we group together the second and the third period. We calculate the set of average values of $MAVI$ and the population size of carnivores and non-carnivores (herbivores and omnivores) for these time periods (Figure 19). Trends are not necessarily easy to understand for single species. However, when we check average trends for carnivores and non-carnivores in Figure 19, both the average population size and $MAVI$ of both groups have improved when comparing the periods before and after independence. While $MAVI$ substantially improved in the case of carnivores, population size has greatly improved for non-carnivores.

Finally, we examine the impact of large carnivores. As mentioned above, large carnivores, particularly wolves, have been persecuted until recently. This implies that $MAVI$ takes larger values when including large carnivores. In fact, when we remove large carnivores and recalculate the average values of $MAVI$ and the population size of carnivores, the results are modified as shown in Figure 19. Although the locations of plots are different, the result that $MAVI$ has substantially improved for carnivores is preserved.

Regression

We applied OLS, where the dependent variable is $MAVI$ and the independent variables are Var, $\ln P$, and C. The result is tabulated in Table 4. All variables are statistically significant at the 10% level and $adj.R^2$ = 0.788, which is relatively high for this type of cross-sectional regression. The results suggest that if the variance of the index $I(\cdot)$ is marginally increased, the value of $MAVI$ is increased by 1.350. On the other hand, if the population size in logarithmic scale is marginally increased, the value of $MAVI$ is decreased by 0.017. For non-carnivores (herbivores and omnivores) the value of $MAVI$ is lower than that of carnivores by 0.037.

These results are intuitively appropriate. The high variance could be associated with a higher value of $MAVI$. If the population size is large, some factors such as human hunting pressure can be relatively moderate, which results in a lower value of $MAVI$. As we have already discussed, carnivores possess mainly pest aspects while non-carnivores (herbivores and omnivores) possess both pest and beneficial aspects. Therefore, the value of $MAVI$ for non-carnivores could be relatively lower than that for carnivores.

Conclusions

Finally, it can be said that our index and associated methodology of the Connected Scatter Plot describe the trends of 16 species in an understandable manner. Our method makes it easier to check the current population status on the basis of past data even if past data were accumulated when population sizes were quite different. We also successfully showed using our index and associated methodology that Latvian wild animal management has improved after some political changes.

References

Andersone, Z. 2003. Wolves in Latvia: Past and present. *Wolf Print*, 16: 13-14.

Andersone, Z. and Ozolins, J. 2002. Investigation of the public opinion about three large carnivores in Latvia. WWF Latvia.

Andersone, Z. and Ozolins, J. 2004. Food habitats of wolves *Carnis lupus* in Latvia. *Acta Theriologica*, 49(3): 357-367.

Andersone-Lilley, Z. and Ozolins, J. 2004. Public perception of large carnivores in Latvia. *Ursus*, 15(2): 181-187.

Andersone-Lilley, Z. and Ozolins, J. 2005. Game Mammals in Latvia: Present Status and Future Prospects. *Scottish Forestry*, 59(3): 13-18.

Balodis, M. 1990. The Beaver. Biology and Management in Latvia. Zinātne Publishers (in Russian with English and Latvian summary).

Kawata, Y., Ozolins, J. and Andersone-Lilley, Z. 2008. An Analysis of the Game Animal Population Data from Latvia. *Baltic Forestry*, 14(1): 75-86.

Nicholson, W. and Snyder, C. 2005. Microeconomic Theory: Basic Principles and Extensions. 10th Edition. Thompson Higher Education. Ohio.

Nielsen, M.R. and Treue, T. 2012. Hunting for the Benefits of Joint Forest Management in the Eastern Afromontane Biodiversity Hotspot: Effects on Bushmeat Hunters and Wildlife in the Udzungwa Mountains. *World Development*, 40(6): 1224-1239.

Odum, E.P. 1983. Basic Ecology. CBS College Publishing. Philadelphia.

Ozolins, J., Pupila, A., Ornicans, A. and Bagrade, G. 2008. Lynx management in Latvia: population control or sport hunting? in: Opermanis, O. and Whitelaw, G. (editors), Economic, Social and Cultural Aspects in Biodiversity Conservation. The University of Latvia Press, Riga.

Smith, W.P. and Zollner, P.A. 2005. Sustainable management of wildlife habitat and risk of extinction. *Biological Conservation*, 125: 287-295.

Valdmann, H., Andersone-Lilley, Z., Koppa, O., Ozolins, J. and Bagrade, G. 2005. Winter diets of wolf *Canis lupus* and lynx *Lynx lynx* in Estonia and Latvia. *Acta Theriologica*, 50(4): 521-527.

Vanags, J. 2010. Medības: Atziņas un Patiesības [Hunting: Opinions and Truth]. Author's edition. (in Latvian).