Feb 11, 13  Home Range Size and Body Size
Introduction

Home range is the area normally traversed by an individual animal or group of animals during activities associated with feeding, resting, reproduction, and shelter-seeking.
Introduction

Home range is closely related to, but not identical with, the concept of "territory", which is a defended area.

Territorial boundaries of rurous-collared sparrows.

Home ranges of two unpaired kit foxes overlap with those of two paired males in western Arizona.
Introduction

The home range of an individual animal is typically constructed from a set of location points that have been collected over a period of time identifying the position in space of an individual at many points in time.

Minimum convex polygon - smallest possible convex polygon around the data

Variation among species in home range size (ha)
- *Sorex vagrans* 0.11
- *Canis lupus* 20,276
- *Ursus arctos* 204, 120
Introduction

How is it important for conservation and management?

Species Most Vulnerable to Extinction (Primack 2010).
- Species with a narrow geographical range
- Species with one or a few populations
- Species with small population sizes or declining population sizes
- Species that are overharvested
- Species that need a large home range (also Hunter and Gibbs (2007))
  - A species in which individual animals or social groups need to forage over wide areas is prone to die off when part of the range is damaged or fragmented by human activity.
- Animal species with large bodies.
Body size and extinction rates

**FIGURE 8.4** Body mass of herbivorous mammals from North America (A) and Australia (B) that survived (green area of bars) until historical times (the time of European arrival) and that died between the time of the first human arrival and historical times (red area of bars). Note that Australia has fewer mammals than North America, with a more even distribution of size classes. Most of the extinctions were of the largest animals such as (top image) a woolly mammoth and (bottom image) a Thylacine or Tasmanian tiger. (After Johnson 2009; A © INTERFOTO/Alamy; B, a print from William Home Lizars/Alamy Images)
Introduction

How is it important for conservation and management?

- In the case of protected areas, animals with large home ranges are more likely to roam onto surrounding lands where they are subject to increased human-induced mortality and increased risk of extinction.

- In the case of game harvest units, knowledge of home range size is needed to estimate population abundance and set harvest rates.

- With respect to conservation planning and species recovery programs, it is important to know how much space individuals need when estimating potential carrying capacities for recovery areas.
Introduction

Topics

Energetics of home range size

Environmental correlates of home range size

Conservation implication of the influence of ecosystem productivity on home range size

Alternative hypotheses of controls on body size

Test of hypotheses

Conclusions
Energetics of Home Range Size

Home range size is thought to have a basis in an animal’s energetics.

Seton (1909) stated that "the size of home region corresponds somewhat with the size of the animal. Flesh eaters as a class have a larger home region than herb eaters."
Energetics of Home Range Size

Herbivores: $r^2 = 0.75$;

Omnivores: $r^2 = 0.90$;

Carnivores: $r^2 = 0.81$.

*Figure 19.13* 13. Relationship between the size of home range and body weight of North American mammals. (Adapted from Harestad and Bunnell 1979:390.)
Energetics of Home Range Size

The size of an animal’s home range is thought to be dictated by its energetic requirements.

Energy requirements are largely determined by body weight and basal metabolic rate.

Hence,
• home range size is known to increase with body weight,
• is larger for homeotherms than endotherms because of their relatively higher energy requirements, and
• is larger for carnivores than herbivores because of lower average density of utilizable production at higher trophic levels.
Energetics of Home Range Size

Among vertebrates there is a well-documented relationship between size of home range, $H$, and body weight $W$, of the form

$$H = aW^k$$

home range size = proportionality factor x body weight x exponent that relates to trophic level.
Energetics of Home Range Size

Why might this be?
1. Basal metabolic rate (BMR) is the amount of energy expended daily by humans and other animals at rest.
2. BMR is a function of body size (Kleiber’s law). BMR increases proportional to body weight. Thus, larger animals require more energy, procuring more energy requires a larger home range.

Kleiber 1947
Energetics of Home Range Size

The effect of ecosystem productivity
Consider that an animal of weight $W$ has energetic requirements $R$ (kcal/day). The environment provides utilizable energy at a rate $P$ (kcals/day/unit area). The simplest expression of home range ($H$) is thus

$$H = \frac{R}{P}$$

The effects of body weight, trophic status, productivity of the habitat, and season can be synthesized by considering how these factors affect either $R$ or $P$. 
Energetics of Home Range Size

R should increase with weight.
If R is proportional to basal metabolic rate
then (from Kleiber 1961)

\[ R = a \ W^{0.75} \]

But modified in a predictable fashion by the trophic status of the animal and the density and productivity of its resource base.
Energetics of Home Range Size

P-The production of utilizable energy is affected by animal weight, trophic status, productivity of the habitat, and season.

1) Body weight.-We expect $P$, the density of utilizable production of energy, to decrease with increasing energetic requirements $R$ which increase with body weight. The relationship results from "patchiness" of resources in the environment.

2) Trophic status.-Utilizable energy per unit area, $P$, is greater for herbivores than for carnivores.

3) Productivity of habitat. -Within a specific trophic group and weight-class, habitats of greater productivity ($P$) will generate smaller home ranges, for the energetic requirements ($R$) will not change.

4) Season.-Among herbivores, both $R$ and $P$ are affected, $R$ by the quality of forage. As their food dies, becomes dormant, or is covered with snow, $P$ should decrease below summer values. The direction of change in size of home range will depend on the relative rates of change of $P$ and $R$. 

Energetics of Home Range Size

Thus

Home range size is hypothesized to be inversely related to habitat productivity, controlling for body size and trophic level (Harestead and Bunnell 1979)

in more productive environments, energy requirements can be met in a smaller area, allowing home ranges to be smaller.
Ecosystem Productivity as a Predictor of Home Range Size

Ecosystem Productivity as a Predictor of Home Range Size

Case Study: Herfindal et al. 2005

Study Aim: explain variation in home range size in terms of readily available indices of prey density and environmental productivity.

Methods: Individual Level.
• Relate the sizes of 52 home ranges, derived from 23 (9:14 male:female) individual resident lynx obtained from south-eastern Norway, with an index of density of roe deer Capreolus capreolus.
• The index was obtained from the density of harvested roe deer within the municipalities covered by the lynx home ranges.
Ecosystem Productivity as a Predictor of Home Range Size

Case Study: Herfindal et al. 2005

Results: Individual Level.

• Mean annual home-ranges size (95% MCP) was 917 km² and 560 km² for males and females respectively (SD=580 km² and 205 km²).
• The best model home-range size of lynx included roe deer density lynx sex (model r² =0.523, F =9.31, df=2,17, P=0.002).

Table 3. List of parameter estimates for the two final models

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>SE</th>
<th>t-value</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (female–male)</td>
<td>-0.474</td>
<td>0.155</td>
<td>-3.049</td>
<td>21</td>
<td>0.006</td>
</tr>
<tr>
<td>Roe deer index</td>
<td>-0.781</td>
<td>0.227</td>
<td>-3.434</td>
<td>28</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Fig. 2. Observed home-range size and roe deer Capreolus capreolus density for males (filled triangles) and females (open circles), and predicted relationship from the multivariate linear mixed model (filled line, males; dashed line, females). The models are calculated from all 52 annual home ranges, whereas the symbols are illustrative and reflect an average value for each of the 23 individual lynx Lynx lynx.
Ecosystem Productivity as a Predictor of Home Range Size

Case Study: Herfindal et al. 2005

Methods: European Level.

- Lynx home range size for 111 lynx (48:63 male: female) from 10 study sites to estimates derived from remote sensing of environmental productivity and seasonality.

- Monthly global 4×4 km MODIS FPAR data sets were downloaded from NASA MODIS home page, covering October 2000 through October 2002.

- FPAR is an expression for the fraction of photosynthetical absorbed radiation, and is a measure of the percentage of radiation, available for photosynthesis, that is absorbed
Ecosystem Productivity as a Predictor of Home Range Size

Case Study: Herfindal et al. 2005

Results: European Level.
- Mean home range size (100% MCP) was 625 km$^2$ (SD=509 km$^2$) for males and 319 km$^2$ (SD=231 km$^2$) for females.
- The model with lowest AICc included sex and the interaction between seasonality and productivity.

<table>
<thead>
<tr>
<th>Model</th>
<th>K</th>
<th>AICc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study area level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Sex] + [Productivity] * [Seasonality]</td>
<td>6</td>
<td>36.471</td>
</tr>
<tr>
<td>[Sex] + [Productivity]</td>
<td>4</td>
<td>37.443</td>
</tr>
<tr>
<td>[Sex] + [Productivity] + [Seasonality]</td>
<td>5</td>
<td>39.453</td>
</tr>
</tbody>
</table>

Table 2. AICc-values for models on individual and study area level. For study area level, only those with AICc less than 40 is listed.

Fig. 3. The relationship between home-range size, productivity and seasonality for (a) male and (b) female lynx for 10 study sites throughout Europe.
Ecosystem Productivity as a Predictor of Home Range Size

Case Study: Herfindal et al. 2005

Conclusions
• These analyses support widely held predictions that variation in home-range size is due to variation in prey density.
Small-group exercise

Draw a box and arrow diagram on the linkages among home range size, body size, trophic level, basic metabolic rate, and habitat productivity, homeotherms, and endotherms.
Ecosystem Productivity as a Predictor of Home Range Size


Study Aim: Evaluate the utility of FPAR to explain interpopulation variation in home range size for 12 carnivore species globally.

Methods:
- Collect data on home range size from the literature (199 studies) for 12 species of carnivores.
- Use same FPAR data as previous case study.
- Use model selection to relate home range size to annual productivity and seasonality.

Table I. Mean sex-specific home-range (HR) size and number of studies for each species. In the table, mean home-range size (SD in parentheses) is given.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Latin name</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of studies</td>
<td>Mean HR size in km²</td>
<td>Number of studies</td>
</tr>
<tr>
<td>Brown bear</td>
<td>Ursus arctos</td>
<td>30 1,060 (1,506)</td>
<td>32 351 (472)</td>
</tr>
<tr>
<td>Black bear</td>
<td>Ursus americanus</td>
<td>18 232 (399)</td>
<td>21 34 (34)</td>
</tr>
<tr>
<td>Wolverine</td>
<td>Gulo gulo</td>
<td>7 621 (438)</td>
<td>7 259 (122)</td>
</tr>
<tr>
<td>American marten</td>
<td>Martes americana</td>
<td>8 12 (14)</td>
<td>8 8 (9)</td>
</tr>
<tr>
<td>Fisher</td>
<td>Martes pennanti</td>
<td>7 25 (14)</td>
<td>7 10 (5)</td>
</tr>
<tr>
<td>Leopard</td>
<td>Panthera pardus</td>
<td>11 179 (327)</td>
<td>9 71 (100)</td>
</tr>
<tr>
<td>Canadian lynx</td>
<td>Lynx canadensis</td>
<td>13 153 (112)</td>
<td>11 85 (58)</td>
</tr>
<tr>
<td>Bobcat</td>
<td>Lynx rufus</td>
<td>24 43 (29)</td>
<td>23 20 (13)</td>
</tr>
<tr>
<td>Puma</td>
<td>Puma concolor</td>
<td>17 352 (218)</td>
<td>20 193 (177)</td>
</tr>
<tr>
<td>GROUP OR PACK HR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wolf</td>
<td>Canis lupus</td>
<td>25 611 (511)</td>
<td></td>
</tr>
<tr>
<td>Coyote</td>
<td>Canis latrans</td>
<td>18 42 (34)</td>
<td></td>
</tr>
<tr>
<td>Red fox</td>
<td>Vulpes vulpes</td>
<td>11 10 (8)</td>
<td></td>
</tr>
</tbody>
</table>
Ecosystem Productivity as a Predictor of Home Range Size

Results:
- FPAR added predictive power to the models for eight of the species.
- The explanatory power varied between 16% and 71% for different species.
Body Size
Bergmann's rule is an ecogeographic principle that states that within a broadly distributed genus, species of larger size are found in colder environments, and species of smaller size are found in warmer regions.

The rule is named after a nineteenth-century German biologist, Christian Bergmann, who was among the first to describe the pattern in 1847.

Larger animals have a lower surface area to volume ratio than smaller animals, so they radiate less body heat per unit of mass, and therefore stay warmer in cold climates.

Warmer climates impose the opposite problem: body heat generated by metabolism needs to be dissipated quickly rather than stored within. Thus, the higher surface area-to-volume ratio of smaller animals in hot and dry climates facilitates heat loss through the skin and helps cool the body.
Body Size


H & W 2011 proposed an alternative hypothesis for geographic variation in body size based on food availability, as regulated by the net primary production (NPP) of plants, specifically NPP during the growing season, or eNPP (ecologically and evolutionarily relevant NPP).

![Diagram of food surplus and deficit]

**eNPP concept** – animal growth rates are set by productivity during the plant growing season.

During the non-growing, dormant, or “starvation” season, the survival of organisms depends on the amount of resources that they have acquired during the growing season.

Thus, body size should vary with eNPP.
Body Size

eNPP = total annual NPP/length of growing season
Body Size


Results.

Fig. 3. The distribution of body size in North American Cervidae, which peaks at 50–60° N latitude, conforming to the eNPP rule and Geist’s rule (from Geist [1998: Fig. 1.9]). The figure is reprinted with the permission of Stackpole Books.
Body Size


Results.
Body Size


Conclusions.
• The data do not fit Bergmann’s Rule.
• The data for most species are inadequate for testing the eNPP hypothesis, except for wolves?
In the case of protected areas, animals with large home ranges are more likely to roam onto surrounding lands where they are subject to increased human-induced mortality and increased risk of extinction.


- Theory predicts that small populations may be driven to extinction by random fluctuations in demography and loss of genetic diversity through drift.
- However, population size is a poor predictor of extinction in large carnivores inhabiting protected areas.
- Conflict with people on reserve borders is the major cause of mortality in such populations, so that border areas represent population sinks.
- The species most likely to disappear from small reserves are those that range widely—and are therefore most exposed to threats on reserve borders—irrespective of population size.
Summary

Animal home range size is influenced by the productivity of the environment. A fact that should be taken into account when designating the size of reserve areas, harvest rates, and area needed for population restoration.

Animal body size likely varies with productivity of the environment in ways that are currently not well understood.