Habitat Fragmentation and Edge Effects

Topics:
• Definition
• Root in Island Biogeography
• Ecological Consequences
  • Case studies:
    • East African Forest Fragments
    • EDF Birds
• Ecosystem Sensitivity to Fragmentation
Land clearing for agriculture has produced substantial change in the structure of the Cadiz Township landscape.

**Figure 18.20** Human-caused change in forest cover in Cadiz Township, Wisconsin (data from Curtis 1956, maps after Curtis 1956).
Habitat Fragmentation:

Breaking up of habitat into smaller pieces

More Specifically:

• Reduction in habitat area
• Decrease in patch size (increase in edge effects)
• Increase in distance among patches (change in connectivity)
Habitat Fragmentation:

Variations in base model:

- Rate of recovery of disturbance patches;
- Disturbance history/natural vegetation dynamic;
- Type of matrix

Cadiz township, WI
Curtis 1956
Figure 28.12 Number of bird species on various islands of the East Indies in relation to area. The abscissa gives areas of the islands. The ordinate is the number of bird species breeding on each island. (From Preston 1962:166.)
Species Area Relationship

Figure 28.12 Number of bird species on various islands of the East Indies in relation to area. The abscissa gives areas of the islands. The ordinate is the number of bird species breeding on each island. (From Preston 1962:105.)

$S = cA^z$

number of species = intercept * area $^{slope}$
Smaller islands have fewer species than large islands.

Why?

Figure 28.12 Number of bird species on various islands of the East Indies in relation to area. The abscissa gives areas of the islands. The ordinate is the number of bird species breeding on each island. (From Preston 1962:198.)
Figure 28.13 Equilibrium model of species on a single island. The point at which the curve for rate of immigration intersects the curve for rate of extinction determines the equilibrium number of species in a given taxon on the island. $S$ represents the equilibrium number of species.

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Figure 28.14 Graphical representation of the island biogeography theory, involving both distance and area. Immigration rates decrease with increasing distance from a source area. Thus distant islands attain species equilibrium with fewer species than near islands, all else being equal ($S_3 > S_2$ for large islands, $S_2 > S_1$ for small islands). Extinction rates increase as the size of the island becomes smaller.

Implications for Habitat Islands?
Habitat as islands?

If habitats in an inhospitable matrix act as islands, then we expect smaller, more isolated habitat patches hold fewer species.
Ecological Consequences of Fragmentation

• Reduction in habitat area
  - reduction in population sizes;
  - decreased habitat heterogeneity.
Ecological Consequences of Fragmentation

• Reduction in habitat area
  - reduction in population sizes;

Figure 2. Relation critical reserve size and female home range size calculated for 10 species of large carnivore. $r^2 = 0.84$, $F_{1,8} = 42.1$, $P < 0.005$. Critical reserve size estimated by using the logistic regression models to predict the area at which populations persisted with a probability of 50%. (Woodroffe and Ginsberg 1998)
Ecological Consequences of Fragmentation

• Reduction in habitat area
  - reduction in population sizes;
  - decreased habitat heterogeneity.
Pre-isolation  Post-isolation

\[ A_{\text{total}} \quad A_{\text{fragment}} \]

\[ S_{\text{total}} \quad S_{\text{original}} \quad S_{\text{fragment}} \]

Number of Species

Brooks et al. 1999
Bird Extinctions in Forest Fragments: Kenya (Brooks et al. 1999)

<table>
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<th>Fragment</th>
<th>$A_{\text{fragment}}$</th>
<th>$S_{\text{original}}$</th>
<th>$S_{\text{now}}$</th>
<th>$S_{\text{fragment}}$</th>
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</table>
Ecological Consequences of Fragmentation

• Reduction in habitat area - reduction in population sizes; decreased habitat heterogeneity.

• Reduction in Patch Size - Increasing edge effects
Figure 18.11 The effects of edges on small nature reserves of equal area but different shape. Note that long, thin reserves have a greater proportion of their area as an edge and that circular reserves will have more interior habitat.
Hypotheses about edge effects
Forest edges

Wind direction

Tree height (m)

Distance (m)

1.0 m/sec

1.5

2.0

3.0

4.0

T
Hypotheses about edge effects
Fig. 6.4. A typical distribution of animal species at a closed forest edge. The arrow indicates the boundary of the gap-forming disturbance.
Bird distributions across clearcut/forest edges
Fig. 5.1 Proportion of woodlots of each size class in which the species indicated were found (Robbins 1980).

Fig. 5.2 Worm-eating warbler.
Fig. 5.3 Percentage of nests preyed upon as a function of forest size. Closed squares are large forest tracts, open circles are rural fragments, and closed circles are suburban fragments. The number above each point is the number of artificial nests placed in that forest (Wilcove 1985b).
Fig. 5.5 An index to cowbird abundance from 1900 to 1980 taken from Audubon Christmas bird count records (Brittingham and Temple 1983).

Fig. 5.6 Brown-headed cowbird
Fig. 5.1 Proportion of woodlots of each size class in which the species indicated were found (Robbins 1980).

Fig. 5.2 Worm-eating warbler.
Ecological Consequences of Fragmentation

• Reduction in habitat area - reduction in population sizes; decreased habitat heterogeneity.

• Reduction in Patch Size - Increasing edge effects

• Patch Isolation - Less exchange of organisms
How prevalent is fragmentation among ecosystem types?

• Ecosystem Properties – Biomass Accumulation
Biomass Accumulation Hypothesis

High Biomass Ecosystem

2. Microclimate (e.g., wind speed)
1. Vegetation biomass
3. Species Guild Abundances

Magnitude
Low
High

Early Seral Patch Edge Later Seral Patch

Low Biomass Ecosystem

2. Microclimate (e.g., wind speed)
1. Vegetation biomass
3. Species Guild Abundances

Magnitude
Low
High

Early Seral Patch Edge Later Seral Patch

Hansen et al. in review
Aboveground Biomass of Major Forest Ecosystem Types.

![Biomass Average Graph](image)

- **Boreal Forests/Taiga**: 20.25, n=12
- **Tropical and Subtropical Coniferous Forest**: 60.91, n=2
- **Mediterranean Forests, Woodlands, and Scrub**: 88.39, n=2
- **Tropical and Subtropical Dry Broadleaf Forest**: 71.95, n=9
- **Temperate Broadleaf and Mixed Forest**: 61.50, n=5
- **Tropical and Subtropical Moist Broadleaf**: 92.08, n=18
- **Temperate Coniferous**: 247.13, n=3

Hansen et al. in review
**Microclimate Results**

**Light Intensity**

\[ y = 0.0006 \times \text{AGB} + 0.7068 \]

\[ R^2 = 0.44 \]

**Humidity**

\[ y = 0.0006 \times \text{AGB} + 0.0221 \]

\[ R^2 = 0.86 \]
Variation in Interior Species with Biomass

Birds
\[ y = 0.07x - 0.6979 \]
\[ R^2 = 0.6782 \]

Beetles
\[ y = 0.0771x + 2.3499 \]
\[ R^2 = 0.6457 \]

Mammals
\[ y = 0.0664x - 5.7805 \]
\[ R^2 = 0.8958 \]

Percent of Species Specializing on Forest Interiors vs. Biomass
Discussion

How do the three drivers of landscape pattern (biophysical, disturbance, land use) interact to influence the effects of fragmentation?

What are implications for managing various ecosystem types?