

Part II – Trophic System Data: Answers

1. What is the purpose of each figure? Are there unclear terms or confusing aspects to any figure?

Figure 1 is designed to show how different components of the Isle Royale ecosystem changed over time from **1958–1994** and to allow comparisons among trophic levels and environmental conditions.

- **Figure A – Wolves:** Shows the annual winter population of wolves. Wolves are the primary predator of moose in this simplified food web.
- **Figure B – Moose:** Shows the annual winter population of moose, the major herbivore on the island.
- **Figure C – Fir (west):** Shows annual growth-ring width of fir trees at the western end of the island. Wider rings generally indicate greater tree growth, while narrower rings indicate reduced growth.
- **Figure D – Fir (east):** Shows the same ring-width information for fir trees at the eastern end of the island.
- **Figure E – AET:** Shows annual actual evapotranspiration rate (AET) from April–October. AET is being used as an indirect measure of **primary productivity**, because it reflects the amount of water available for plant growth as influenced by temperature and precipitation.

The **blue shaded areas** indicate periods of forage suppression, when interactions among herbivores, plants, and predators may have strongly affected vegetation.

One potentially confusing aspect is that **AET is not itself a direct measurement of plant biomass or growth**. It is being used as a proxy (a substitute) for primary productivity. Also, the fir graphs show ring width rather than total tree growth, so a narrow ring indicates reduced annual growth but does not necessarily mean that the tree stopped growing altogether.

2. How do the maxima and minima of the ring-width indices correspond to changes in moose density? Does this support the primary productivity hypothesis, the trophic cascade hypothesis, or neither?

There is a general **inverse relationship between moose density and fir growth**, particularly during periods when moose populations become large.

For example, from approximately **1965–1972**, the moose population increases substantially, reaching roughly 1,200–1,400 animals. During this same general period, fir ring widths decline. The relationship becomes especially apparent around **1970–1975**, when high moose densities coincide with relatively narrow fir growth rings.

A similar pattern occurs later. Moose populations increase substantially during the late 1980s and early 1990s, while fir growth, particularly at the western end, declines toward the end of the record.

This pattern provides evidence for the **trophic cascade hypothesis**. The proposed cascade is:

Wolves ↑ → **Moose** ↓ → **Browsing pressure** ↓ → **Fir growth** ↑

and conversely:

Wolves ↓ → **Moose** ↑ → **Browsing pressure** ↑ → **Fir growth** ↓

If primary productivity alone were controlling fir growth, we would expect fir growth to correspond more closely to AET. Instead, some periods of reduced fir growth occur when moose densities are high, suggesting that **herbivory by moose is an important control on fir growth**.

The evidence is not perfect, however, because tree growth is influenced by several factors, including climate, precipitation, temperature, tree age, and browsing. Therefore, the data support a trophic cascade but do not demonstrate that predation is the *only* factor affecting plant growth.

3. Do firs from either end of the island (east/west) respond the same way to changes in moose density? How can you account for any observed differences?

No. The fir populations at the eastern and western ends of Isle Royale **do not respond identically** to changes in moose density.

The **western firs** generally show a relatively strong decline in ring width during periods of high moose abundance. The western trees also show relatively low growth toward the end of the study when moose populations become very large.

The **eastern firs** show some similar patterns, but their responses are less consistent. For example, eastern fir growth increases during part of the 1980s even though moose numbers are also relatively high. This indicates that factors other than herbivory are influencing tree growth.

The differences can be explained by the **different environmental conditions on the two ends of the island**. The western end has hardwood forests and generally experiences **warmer, earlier summers and higher AET**, resulting in greater primary productivity. The eastern end is more boreal and has different climatic and ecological conditions.

Therefore, the same moose population density may produce different effects on fir trees depending on **plant productivity, climate, water availability, forest composition, and the availability of alternative forage**. In a more productive environment, trees may be able to tolerate some browsing because they can replace lost tissue more rapidly. In a less productive environment, the same amount of browsing could have a larger effect on tree growth.

This demonstrates an important ecological principle: **top-down effects such as herbivory and predation interact with bottom-up environmental factors such as climate and primary productivity**.

4. How do the maxima and minima of the wolves correspond to changes in moose density? How might you account for this relationship?

The wolf and moose populations show a generally **inverse relationship**, although there is a time lag between changes in the two populations.

During the **mid-1970s through the early 1980s**, wolf numbers increase substantially, eventually reaching approximately 40–45 wolves. During this period, the moose population declines from approximately 1,400 to around 800 animals.

The relationship reverses later. During the **1980s**, wolf numbers decline sharply, while the moose population begins increasing. By the late 1980s and early 1990s, wolves remain relatively low while moose numbers rise dramatically, reaching approximately 1,600–1,800 animals.

One explanation is **predator-prey population dynamics**. When moose populations are high, wolves have greater access to prey and can reproduce successfully, causing the wolf population to increase. As wolf numbers increase, predation mortality on moose increases, causing the moose population to decline. With fewer moose available, food becomes less abundant for wolves, eventually causing the wolf population to decline. Reduced predation then allows the moose population to recover.

This creates a **negative feedback cycle**:

Moose ↑ → **Wolves** ↑ → **Moose** ↓ → **Wolves** ↓ → **Moose** ↑

The relationship is not perfectly synchronized because predator populations typically respond to changes in prey populations with a **time lag**. Wolves require time to reproduce and increase in number after moose become abundant, and wolf numbers may remain high for some time after moose begin declining.

Other factors, such as disease, winter severity, food availability, and changes in vegetation, can also influence both populations.

5. Which hypothesis is supported by the data on annual AET?

The AET data provide stronger support for the **primary productivity hypothesis** as an important bottom-up influence on the ecosystem, but they also demonstrate why AET alone cannot explain all of the variation in fir growth.

AET varies considerably from year to year, with values ranging approximately from **290 to 450 mm**. Because AET reflects water availability in combination with temperature and precipitation, higher AET generally indicates conditions that can support greater **primary productivity**.

However, the fir-growth graphs do not consistently rise and fall in direct correspondence with AET. For example, some years with relatively high AET do not have exceptionally large fir ring widths, while some years with relatively low AET still show substantial growth. This suggests that **climate and primary productivity are important but are not the sole determinants of tree growth**.

Taken together, the data support a model in which **both bottom-up and top-down processes operate simultaneously**:

Climate/precipitation → **AET** → **Primary productivity** → **available forage**

while

Wolves → Moose → Browsing → Fir growth

The AET data therefore support the idea that **environmental productivity influences the trophic system**, but the relationships between wolves, moose, and firs indicate that predator-prey interactions can modify or amplify those bottom-up effects.

Overall conclusion

Figure 1 provides evidence for a **complex interaction between bottom-up and top-down controls** in the Isle Royale ecosystem. AET influences the productivity of the plant community, while wolves influence moose abundance and moose herbivory influences fir growth. The strongest evidence for a trophic cascade is the general pattern that **high wolf abundance is associated with lower moose abundance, which is associated with increased fir growth**, whereas low wolf abundance allows moose populations to increase and fir growth to decline. At the same time, differences between the east and west ends of the island demonstrate that **climate and primary productivity can modify the strength of these trophic interactions**.