What Controls Community Structure?
Top-Down vs Bottom-Up

Note: BU = Bottom-Up = Resource Control, Donor Control
TD = Top-Down Control, Consumer Control

NOTE: ‘TD’ control is not necessary the same as ‘Trophic Cascade’.
1) a cascade invokes indirect effects beyond one trophic level (predators affect plants), while top-down could be a direct effect on the prey trophic level or a cascade; and
2) some trophic cascades affect a subset of a community (species-level TC; see Morin Fig 8.10) and do not control the structure of the entire community (system-level TC).

1. Predators – examples in this class:
   Birds
   Pisaster
   Desert Granivores
   etc.

2. Resources:

   ![Diagram showing relationships between various ecological factors and their effects on community structure.](image-url)
**Pure Donor Control (BU)**

- Each trophic level is controlled by resources
- A smaller resource base can support fewer trophic levels.

**Mechanism:**

- Few resources (deserts)
- More resources + fertilizer, light

**Pure Top-Down control (TD)**

- Top TL is food-limited and competes for resources
- So, the TL below the top is predator-limited
- Alternative TL – food-limited vs predator-limited
- The basal TL – may have very different biomass *even with the same resource base as a similar community with a different number of TLs.*

**Mechanisms:**

- Food-limited
- Predator-limited

**Predictions:**

- HSS**
  - odd # TL
  - even # TL

**Basal TL →**

**NOTES:**

** see herbivory lectures for BU view of plant/herbivore interactions

also see More Fig 4.17 and surrounding text.
**EX 1.** Lakes with different number of Bass as top predators: alternating abundances of adjacent TLs. (Carpenter et al.)

<table>
<thead>
<tr>
<th>Minnows (prey)</th>
<th>Zooplankton</th>
<th>Phytoplankton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Bass Density</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(top predator)</td>
</tr>
</tbody>
</table>

**EX 2:** The Sea Otter system:

**PREDICTIONS:**

- Killer Whales
- Sea Otters
- Urchins
- Kelp

Evidence: Estes et al.

![Diagram showing changes in sea otter abundance over time and concurrent changes in sea urchin biomass, grazing intensity, and kelp density.](image-url)
Cascading effects of overfishing marine systems

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Profused indirect ecosystem effects of overfishing have been shown for coastal systems such as coral reefs and kelp forests. A new study from the ecosystem off the Canadian east coast now reveals that the elimination of large predatory fish can also cause marked cascading effects on the pelagic food web. Overall, the view emerges that, in a range of marine ecosystems, the effects of fisheries extend well beyond the collapse of fish exploited stocks.

Introduction

Although the role of fishing in the collapse of exploited stocks is beyond doubt, it has been less easy to determine whether there are indirect effects on other ecosystem components. Fish are the major predators in most marine systems and one would expect that removing them might have an impact on lower trophic levels. However, assessing the relative impact of predators has long been a difficult problem in ecology.

When do predators make a difference?

The classic dilemma is nicely illustrated by the account of the Italian scientist Lorenzo Capano published in 1880 [1] explaining how naturalists in those days were divided in two categories. According to Capano, the first category reasoned: ‘Birds feed to a great extent on insects; so if we increase the number of birds, the number of insects will decrease’. This is what we now call top-down regulation. The second category had a ‘bottom-up’ perspective: ‘the number of birds is high particularly in those places where insects are very abundant. The number of insects in a region depends essentially on the amount of food found in it. In general, birds have only a small role in destroying insects that might damage crops.

The difficulty with bottom-up and top-down regulation is that they can both be strong at the same time and that their relative roles are not easily inferred from field patterns. Much of the variation in abundances that we see in nature is bottom-up regulated and marine systems are no exception. This is illustrated by a recent study [2] showing a strong correlation between chlorophyll concentration and fish yields along the American west coast. However, although this suggests that primary production largely determines what can be harvested from higher trophic levels, such empirical relationships cannot tell us much about the importance of top-down forces. For instance, correlations between nutrient richness and abundance at all trophic levels are commonly found in lakes [3]. Nonetheless, top-down effects are strong in these ecosystems [4]. This has been convincingly demonstrated by the experimental removal of fish from lakes, and has important management implications [5]. Lake managers have found that such ‘biomanipulation’ can boost large-bodied zooplankton, which then filters the water clear of excessive phytoplankton.

Given that we deplete many marine fish stocks so dramatically, could top-down forces in the oceans be strong enough to imply similar cascading effects? It has been shown that ecosystem effects of overfishing can be strong in coral reefs [6] and other coastal systems [7]. However, with the exception of the replacement of exploited stocks by competing species [8], evidence for indirect effects of overfishing in the open ocean has remained illusive. A recent analysis of historical data from the Scotian Shelf by Kenneth Frank and colleagues [9] changes this situation. The authors have now shown how effects of the decline of cod Gadus morhua and other large predators can cascade down the food web, through small fish, crab and shrimp, zooplankton and phytoplankton to the level of nutrients (Figure 1).

![Figure 1. The cascading effect of the collapse of cod and other large predatory fishes on the Scotian Shelf ecosystem during the late 1980s and early 1990s. The size of the spheres represents the relative abundance of the corresponding trophic level. The arrows depict the inferred top-down effects.](image-url)
Questions:
1. Are trophic cascades more likely in some ecosystems than in others?
2. Is it really either TD or BU?
3. If both, how do these forces interact?

1. Trophic Cascades in terrestrial systems → not many good examples.

Q: Why so few examples of strong TC in terrestrial systems? → where have all the apex predators gone?

a. We didn’t realize something was wrong because we had → Mesopredators
(Prugh et al Bioscience 09)

![Mesopredators](image)

Table 1. Distributional changes of extant terrestrial mammalian carnivores in North America.

<table>
<thead>
<tr>
<th>Type</th>
<th>Family</th>
<th>Species</th>
<th>Common name</th>
<th>Historic range (square kilometers)</th>
<th>Current range (square kilometers)</th>
<th>Range change (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apex predator</td>
<td>Canidae</td>
<td>Canis lupus</td>
<td>Gray wolf</td>
<td>18,500.519</td>
<td>10,983.399</td>
<td>-42.3</td>
</tr>
<tr>
<td></td>
<td>Felidae</td>
<td>Puma concolor</td>
<td>Cougar</td>
<td>10,964.140</td>
<td>6,954.511</td>
<td>-36.6</td>
</tr>
<tr>
<td></td>
<td>Felidae</td>
<td>Panthera onca</td>
<td>Jaguar</td>
<td>2,110.251</td>
<td>586.713</td>
<td>-71.3</td>
</tr>
<tr>
<td></td>
<td>Mustelidae</td>
<td>Gulo gulo</td>
<td>Wolverine</td>
<td>13,041.287</td>
<td>6,129.518</td>
<td>-51.7</td>
</tr>
<tr>
<td></td>
<td>Ursidae</td>
<td>Ursus americanus</td>
<td>Black bear</td>
<td>15,929.861</td>
<td>9,530.070</td>
<td>-39.5</td>
</tr>
<tr>
<td></td>
<td>Ursidae</td>
<td>Ursus arctos</td>
<td>Grizzly bear</td>
<td>11,124.188</td>
<td>5,045.761</td>
<td>-56.4</td>
</tr>
<tr>
<td>Mesopredator</td>
<td>Canidae</td>
<td>Canis latrans</td>
<td>Coyote</td>
<td>12,113.121</td>
<td>16,983.670</td>
<td>40.2</td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Vulpes macrions</td>
<td>Red fox</td>
<td>1,356.361</td>
<td>1,773.415</td>
<td>15.6</td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Vulpes vulpes</td>
<td>Red fox</td>
<td>13,900.681</td>
<td>15,596.352</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Urocyon cinereoargenteus</td>
<td>7,774.945</td>
<td>8,187.349</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Urocyon mansuetus</td>
<td>Channel island fox</td>
<td>824</td>
<td>824</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Alpeyx lagopus</td>
<td>Arctic fox</td>
<td>5,842.376</td>
<td>5,549.225</td>
<td>-5.0</td>
</tr>
<tr>
<td></td>
<td>Canidae</td>
<td>Vulpes velox</td>
<td>Swift fox</td>
<td>1,777.144</td>
<td>711.213</td>
<td>-60.0</td>
</tr>
</tbody>
</table>

Q: Why might communities dominated by mesopredators differ from those dominated by ‘real’ apex predators?
Recent evidence:
b. Compare time ± predators: Apex predators in the past

![Graph showing comparison between wolves and cougars in different areas over time.](image)

Yrs trees were established – by decades

c. Compare areas ± predators: Apex predators NOW
Cottonwoods

![Graph showing cottonwood trees over time for common and rare cougars.](image)

Fig. 3 – Cottonwood age structure for (a) the North Creek area where cougars are common and (b) Zion Canyon where they are rare. Both areas are within Zion National Park. The exponential function (dashed line) was fitted to measured tree frequencies for North Creek study reaches; this same relationship has been plotted along with tree frequencies for the Zion Canyon study reaches illustrating a general cessation of cottonwood recruitment (i.e., missing age classes) since ~1940. Error bars represent standard errors.

→ Is there a trophic cascade?
Fig. 7 - Native fish densities from two “cougars common” areas (North Creek and East Fork of the Virgin River) and one “cougars rare” area (North Fork of the Virgin River). Species include flannelmouth sucker (Catostomus latipinnis), desert sucker (Catostomus clarki), speckled dace (Rhinichthys osculus), and Virgin spinedace (Lepidomeda melliapinis). Error bars represent standard errors for all species combined. Sources: Morviltus et al. (2006) and Utah Division of Wildlife Resources (unpublished data).
2. Does it have to be either TD or BU??

a) Wootton & Power 1993: **TD & BU forces can act at the same time. (Morin: p200)**

<table>
<thead>
<tr>
<th>Trophic Level</th>
<th>Abundance determined by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predators</td>
<td></td>
</tr>
<tr>
<td>Grazers</td>
<td></td>
</tr>
<tr>
<td>Algae</td>
<td></td>
</tr>
</tbody>
</table>

**Pure BU**

**Pure TD**

**Conclusion:**
Ex 2: Central California coast: both TD and BU – spatial and temporal differences: Upwelling events vs annual patterns

- + Fe
- ○ o Control

Low N
Low Fe

High N
High Fe

North of Monterey Bay
- strong upwelling (late Spring thr Summer)
- rivers
- continental shelf
- rich in NO₃, Fe, etc.
- high productivity
- large phytoplankton
- high fish production
- short food chain

→ BU control (during upwelling)
→ TD rest of year

South of Monterey Bay
- weak upwelling
- low nutrient levels
- low productivity
- small phytoplankton
- long food chain

→ TD control (but nutrient-limited, so also BU?)

Open ocean
- nutrient limited
- low nutrient levels
- low productivity
- small phytoplankton
- long food chain

→ TD control (but nutrient-limited, so also BU?)

Summary:
Coastal ocean (N of MB): seasonal changes in TD vs BU controls (strong upwelling: 0.1% of oceans, produce >20% of fish landings)

Coastal ocean (S of MB) AND open ocean: TD control throughout year.
**Overall Conclusions:**

1. Trophic Cascades that give Top Down control can occur in both terrestrial and aquatic systems.

2. Trophic Cascades may be rare (now) in terrestrial systems because the top predators are often missing or rare.

3. Pure BU and TD controlled systems occur in nature.

4. But, in many systems: TD and BU control work together or sequentially over time and space.