NO PREP

Trophic Levels and Energy Transfer Efficiency

Includes: Student reading, case study, differentiated questions, teacher key

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The Structure of Trophic Levels

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Marine ecosystems are organized into distinct trophic levels, or feeding steps, that describe how energy flows from one group of organisms to another. At the base are producers, like phytoplankton, that capture sunlight and convert it into chemical energy. The next step is occupied by primary consumers such as zooplankton that feed directly on producers. Above them are secondary consumers like small fish, followed by tertiary consumers such as tuna, and at the very top are apex predators, including sharks and orcas. Each level is connected by the transfer of energy through feeding. The number of levels in a food chain is limited by the efficiency of energy transfer. Unlike matter, which cycles continuously, energy moves in a single direction and diminishes at each step. This structure explains why ecosystems support many producers but far fewer top predators.

The 10% Rule and Energy Loss

Ecologists often summarize energy transfer with the "10% rule." On average, only about 10% of the energy available at one trophic level is passed on to the next. The remaining 90% is lost to heat, respiration, growth, and daily activities like movement and reproduction. For example, phytoplankton capture solar energy, but much of it is used for their own cellular processes. When zooplankton consume them, only a small portion of that energy becomes new biomass that can be eaten by small fish. This inefficiency means that the biomass pyramid of the ocean has a wide base of producers, fewer herbivores, even fewer carnivores, and a narrow top of apex predators. This pyramid shape can shift depending on local conditions, but the principle of energy loss remains constant.

Ecological Implications of Energy Flow

Because energy transfer is inefficient, food chains rarely exceed four or five trophic levels. Longer chains would leave too little energy at the top to sustain predators. This principle has major ecological consequences. It means that protecting producers is critical for maintaining entire ecosystems, and that declines in lower trophic levels can rapidly affect higher ones. For example, a collapse in sardine populations can impact tuna, seabirds, and marine mammals that rely on them as food. The efficiency of energy transfer also determines the carrying capacity of each level. Large populations of top predators require enormous amounts of prey and, in turn, an even larger base of producers. When this balance is disrupted, ecosystems can lose stability.

Measuring Efficiency in Marine Systems

Energy transfer efficiency varies by species and ecosystem. Some fish convert food into body mass more efficiently than others, while warm-blooded animals like whales and seals require more energy for heat regulation. Seasonal cycles, nutrient availability, and climate conditions also affect transfer rates. Understanding these efficiencies helps managers predict how many individuals can be supported at each trophic level and guides conservation of threatened predators.

Key Information: Table: Examples of Trophic Levels and Energy Efficiency

Trophic Level	Example Organisms	% Energy Passed On
Producers	Phytoplankton	100% (base energy)
Primary consumers	Zooplankton	~10%
Secondary consumers	Small fish	~1%
Tertiary consumers	Tuna	~0.1%
Apex predators	Sharks, orcas	~0.01%

Case Study: The Decline of Atlantic Cod (Excerpt)

For centuries, cod were so abundant in the North Atlantic that sailors claimed one could lower a basket into the sea and pull it out brimming with fish. Cod occupied the role of a top predator among secondary and tertiary consumers, feeding on herring, capelin, and invertebrates. But by the late 20th century, heavy fishing pressure began to deplete stocks at an alarming rate. As cod numbers fell, the energy flow through the ecosystem shifted. Prey species that cod once controlled, like small fish and shrimp, increased dramatically, while dependent fisheries collapsed. This case illustrates how removing a high-level consumer can alter energy dynamics across multiple trophic levels. With cod reduced, mid-level consumers expanded, disrupting the food web and preventing recovery. Scientists now understand that sustainable fishing must respect the limits of energy transfer. Without sufficient biomass at lower levels, top predators cannot rebuild, and ecosystems remain imbalanced. The decline of cod serves as a warning about the fragile efficiency of marine energy transfer.

1. Why does the loss of cod populations illustrate the importance of energy flow in ecosystems?

2. How did the removal of cod alter the balance of other trophic levels?

Multiple Choice

1. What is the average percentage of energy passed from one trophic level to the next?

    a) 10%

    b) 50%

    c) 1%

    d) 25%

2. Which of the following is an apex predator in marine ecosystems?

    a) Krill

    b) Shark

    c) Zooplankton

    d) Tuna

3. Why are food chains usually limited to four or five trophic levels?

    a) Producers cannot survive longer chains

    b) Decomposers recycle all the energy

    c) Predators stop eating at that level

    d) Too much energy is lost at each step

Matching

Write the letter of the correct definition on the line next to each term.

Term	Definition
1. ___ Producers	A) Zooplankton feeding on phytoplankton
2. ___ Primary consumers	B) Microscopic algae using photosynthesis
3. ___ Secondary consumers	C) Tuna or other large predatory fish
4. ___ Tertiary consumers	D) Large carnivores such as sharks
5. ___ Apex predators	E) Small fish that eat zooplankton

Fill-in-the-Blank

1. The _____ rule states that only about 10% of energy is passed on to the next trophic level.

2. The shape of biomass in marine ecosystems is usually described as a _____ pyramid.

3. Removing a predator like cod can cause a _____ cascade.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why is energy transfer efficiency lower in warm-blooded animals like whales than in cold-blooded fish?

_____

_____

_____

2. How does the 10% rule explain why there are fewer apex predators than producers?

_____

_____

_____

3. Give one example of how human activity has disrupted trophic levels in the ocean.

_____

_____

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