NO PREP

Nutrient Limitation Across Ocean Zones

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

Name: Period: Date:

Nutrient Limitation Across Ocean Zones

What Is Nutrient Limitation?

In marine ecosystems, nutrient limitation occurs when the growth of organisms, especially phytoplankton, is restricted by the availability of key nutrients such as nitrogen, phosphorus, or iron. While sunlight and carbon dioxide are usually abundant at the surface, nutrients can quickly become scarce. Without these essential building blocks, productivity slows, no matter how much light or CO_2 is available. Different regions

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Nutrient Patterns Across Ocean Zones

The ocean is not uniform; nutrient levels vary widely depending on depth, circulation, and biological activity. Surface waters often run short on nutrients because phytoplankton consume them rapidly during photosynthesis. In contrast, deeper waters are often nutrient-rich because decomposition of sinking organic matter releases nitrogen and phosphorus back into solution. This creates a paradox: the sunlit surface, where photosynthesis is possible, often lacks nutrients, while the deep ocean, where nutrients are abundant, is too dark for photosynthesis. The cycle depends on upwelling, where deep, nutrient-rich waters are brought to the surface, fueling massive phytoplankton blooms. Upwelling zones, such as along the coasts of Peru and California, are among the most productive ecosystems in the world. Regional

differences also matter. For example, the North Atlantic often has enough nitrogen and phosphorus but can be limited by iron. Meanwhile, subtropical gyres (vast rotating currents in the open ocean) tend to be nutrient deserts, with very low productivity. These contrasts show how nutrient availability defines the productivity of each ocean zone.

Implications for Climate and Ecosystems

Nutrient limitation does not only influence marine life—it also affects the global carbon cycle. In regions where nutrients are scarce, phytoplankton absorb less CO_2, reducing the ocean's role as a carbon sink. Conversely, nutrient-rich upwelling zones absorb large amounts of CO_2, linking nutrient cycles directly to climate regulation. Human activity can further disrupt natural nutrient limitation. Fertilizer runoff delivers excess nitrogen and phosphorus to coastal waters, fueling algal blooms and oxygen depletion. On the other hand, climate change may reduce nutrient supply by strengthening ocean stratification, making it harder for deep, nutrient-rich waters to mix upward. These challenges show that nutrient limitation is not just a scientific curiosity—it is a powerful force shaping Earth's climate, ecosystems, and even human economies.

Key Information: Table: Nutrient Limitation Across Ocean Zones

Ocean Zone/Region	Limiting Nutrient	Resulting Effect on Productivity
Subtropical Gyres	Nitrogen	Very low productivity
Coastal Upwelling Zones	Few limitations	High productivity
Southern Ocean (HNLC)	Iron	Nutrients unused, low productivity
Deep Ocean	Light (not nutrients)	Nutrient-rich but no photosynthesis
Global Long-Term Scale	Phosphorus	Ultimate limiting nutrient

Case Study: High-Nutrient, Low-Chlorophyll (HNLC) Regions

Scientists once assumed that wherever nutrients like nitrogen and phosphorus were plentiful, phytoplankton would thrive. However, in parts of the Southern Ocean, equatorial Pacific, and North Pacific, researchers found something puzzling: nutrient levels were high, but phytoplankton growth remained low. These areas became known as High-Nutrient, Low-Chlorophyll (HNLC) regions. The missing piece was iron, a micronutrient required for photosynthesis and nitrogen fixation. In HNLC waters, iron is scarce because it primarily enters the ocean through dust carried by winds from land. Without sufficient iron, phytoplankton cannot fully use available nitrogen and phosphorus, leaving these nutrients unused. When scientists conducted experiments adding small amounts of iron, phytoplankton blooms rapidly expanded, confirming the importance of iron as a limiting nutrient. This case study illustrates how nutrient limitation is not simply about abundance but about balance. Even trace elements like iron can determine whether ecosystems flourish or remain barren, despite having plenty of other nutrients.

1. Why do HNLC regions remain unproductive even when nitrogen and phosphorus are available?

2. How did iron fertilization experiments help scientists understand nutrient limitation?

Multiple Choice

1. Which nutrient is considered the ultimate limiting nutrient over geologic time?

    a) Atmospheric nitrogen

    b) Carbon

    c) Iron

    d) Phosphorus

2. Why are upwelling zones highly productive?

    a) They bring nutrient-rich deep water to the surface

    b) They have higher salinity than other regions in the sea

    c) They mix cold and warm waters

    d) They receive more sunlight

3. What factor explains why HNLC regions remain unproductive?

    a) Low oxygen

    b) Iron deficiency

    c) Lack of sunlight

    d) Excess salinity

Matching

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

Term	Definition
1. ___ Nutrient-rich but photosynthesis cannot occur here	A) Subtropical gyres
2. ___ Nutrient deserts with low productivity	B) Iron fertilization
3. ___ Regions with high nutrients but low phytoplankton	C) Upwelling
4. ___ Experimental addition that triggered blooms	D) HNLC regions
5. ___ Process that fuels high surface productivity along coasts	E) Deep ocean

Fill-in-the-Blank

1. In most oceans, the primary limiting nutrient is _____.

2. Areas with high nutrients but little chlorophyll are known as _____ regions.

3. The process that brings deep, nutrient-rich water to the surface is called _____.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why does nutrient limitation vary across different parts of the ocean?

_____

_____

_____

2. How can human activities alter natural nutrient limitation patterns?

3. Why is iron considered just as important as nitrogen and phosphorus in certain ocean zones?