Productivity and fisheries

Why study production processes?
• Fisheries strongly tied to spatial and temporal variation in primary productivity
• Better understanding of distribution of fishery resources
• Interpret population dynamics

Energy flow
➢ Production begins with plants
➢ Fix carbon and transfer to higher trophic levels
➢ Energy flows through trophic interactions
➢ Food chains of various lengths (affects transfer efficiency)

Biological pyramids

Summer
C₂⁻ Top carnivores
C₂⁻ medium size fish
C₁⁻ large zooplankton, small fish
H⁻ herbivorous fish, small zooplankton
P⁻ phytoplankton, algae

Winter

= ~1000 kcal/m²/year
Sources of marine production

About 90% of net primary production from **phytoplankton** (oceanic and coastal)

Macroalgae accounts for about 5%

Remaining from several sources (mangroves, reef algae, seagrasses, marsh plants)

Variation in marine production

**Fine scale processes**
- sinking
- swimming
- turbulence
- Generate nutrient diffusion

**Large scale processes**
- wind and mixing
- ocean circulation
- upwelling

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The Basics of Coastal Upwelling

No Wind
What are the limiting factors for primary productivity?

1) Light
2) Nutrients
   a. Phosphorous-phosphates
   b. Nitrogen- ammonia, nitrate, nitrite
   c. Potassium
3) Temperature
4) Dissolved gases - carbon dioxide and oxygen

Light limitation:

➢ The sea covers 71% of earth’s surface, but most of it is at depths >1km

➢ Most production occurs over continental shelf waters < 200m deep (only 7-8% of ocean)
What are the limiting factors for primary productivity?

**Light limitation:**
- Available light levels fall rapidly with depth
- Longer wavelengths absorbed at surface
- Photosynthesis restricted to upper water column in turbid coastal areas

**Compensation depth**

Depth at which respiration rate equals photosynthetic rate
- Shallow waters contain ample light, thus photosynthesis exceeds respiration
- Deeper waters have less light penetration, thus respiration exceeds photosynthesis
What are the limiting factors for primary productivity?

**Temperature limitation:**
- In addition to light levels, temperature also decreases with depth
- Formation of thermocline
- Thermocline shifts seasonally depending on wind stress

### Physical structure

<table>
<thead>
<tr>
<th>Percent light (red)</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0°</td>
</tr>
<tr>
<td>25</td>
<td>5°</td>
</tr>
<tr>
<td>50</td>
<td>10°</td>
</tr>
<tr>
<td>75</td>
<td>15°</td>
</tr>
<tr>
<td>100</td>
<td>20°</td>
</tr>
</tbody>
</table>

- Epilimnion
- Metalimnion
- Hypolimnion

### Seasonal variation

Differences in mixing among seasons changes the position of the thermocline
What are the limiting factors for primary productivity?

**Nutrient limitation:**

- **Stratification** prevents plankton from sinking below compensation depth, but also prevents nutrient transfer up from deep waters.

- Leads to **seasonal and spatial variation in production**.

What causes the spring bloom?

- Mixing followed by stratification
- Shallower mixed layer
- Plankton held in **euphotic zone**
- Population growth?

What causes the spring bloom?

- **Rate**
- **Depth**
- **Photosynthesis**
- **Respiration**
- **Compensation depth**
- **Critical depth**
- **Total Production integrated over all depths**
What causes the spring bloom?

- Total production must be > total respiration for population growth to occur.
- Respiration increases with depth, relative to production.
- **Critical depth** (of mixed layer) exists where total production = total respiration.
- Known as **Gran effect** or **Sverdrup mechanism**.
Spatial and temporal variation in primary productivity

- Climate variation (temp, winds) leads to latitudinal variation in production

- Different seasonal patterns at temperate, polar, and tropical latitudes
Change in structure offshore

Global scale variation in primary productivity

- Upwelling affects production by surfacing nutrients
- Generates global patterns of productivity
Transfer of energy (Food webs)

- All organisms ultimately rely upon energy captured by primary producers
- Each step = 1 trophic level
- Carbon lost at each step, based on gross growth efficiency (GGE)
- Transfer Efficiency = $GGE \times \% \text{ of prey eaten}$

Lake food web

Sunlight

Phytoplankton

Zooplankton

Insect Larvae

Predatory Insects

Insect Adults

Omnivore; Sunfish

Predator; Bass

Water

Human; fishing

Predator; Bass

Terrestrial Insects

Insect Adults

Production and fisheries

- Fish production thus depends on:
  1) levels of primary production
  2) length of the food chain
  3) transfer efficiency

- Highest catches (fish production) come from coastal and shelf areas
Production and fisheries

- Five major coastal currents associated with upwelling areas
  - California current (US west coast)
  - Peru current (west coast of South America)
  - Canary current (NW Africa)
  - Benguela current (SW Africa)
  - Somali current (Indian ocean)

- Highly productive clupeid fisheries of major social and economic importance

Table 1.1 Possible mean yields (t/km²/year)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Open ocean (temperate)</td>
<td>0.5</td>
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<tr>
<td>Open ocean (tropical)</td>
<td>0.02</td>
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<tr>
<td>Shallow banks (temperate)</td>
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<tr>
<td>Reefs (tropical)</td>
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<tr>
<td>Continental shelf (temperate)</td>
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<td>Estuaries (tropical)</td>
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<tr>
<td>Upwellings</td>
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