Accounts for the present distributions in terms of interactions between organisms and their physical and biotic environments.
Ecological Biogeography

**Definition**

Why is a species confined to its present range in space?

What enables it to live where it does?

What prevents it from expanding into another areas?

What roles do water, climate, latitude, topography and interactions with other organisms play in limiting its distribution?
How do we account for the replacement of species as one moves from one environment to another?

Why are there more species in the tropics than in cooler environments?

What controls the diversity of organisms that is found in any particular region?

Short-term periods of time, with local, within-habitat, intracontinental questions, with species and subspecies living organisms.
No two species are identical in their patterns of distribution. Causes of patterns also vary with the spatial scale.
Ecological Biogeography  PATTERNS

Factors in patterns of distribution

Geological history

Availability of food

Chemistry of Environment
Factors in patterns of distribution

- Geological history
- Availability of food
- Chemistry of Environment
- Climate
- Competition

Global Warming Predictions

Expected changes in the abundance of the cod stocks with a temperature increase above current levels.

1°C

Expected changes in the abundance of the cod stocks with a temperature increase above current levels.

2°C

Expected changes in the abundance of the cod stocks with a temperature increase above current levels.

3°C
Expected changes in the abundance of the cod stocks with a temperature increase above current levels.

Ravinet et al. PloS One in press

Spatial and temporal isolation leads to speciation

Migratory movements

SCALE
• **Spatial and temporal dimension of sampling and observation**
  
  – **Extent**: size of the study area or the duration of time under consideration
  
  – **Grain**: level of spatial resolution

Variations in the world ocean: North Atlantic Oscillation, Pacific Decadal Oscillation, recurring phenomena such as ENSO.
Level of spatial resolution

Duration

1 week

1 month

1 year

Schematic drawing showing the dominant space- and time-scales in the marine environment for physical processes and biological population.
WHAT IS BIODIVERSITY

WHAT COMES TO OUR MIND?

“A definition of biodiversity that is altogether simple, comprehensive, and fully operation (i.e., responsive to real-life management and regulatory questions) is unlikely to be found”

Noss (1990)
“The total variability of life on earth”
(Heywood et al. 1995)

“More useful than a definition, perhaps, would be a characterisation of biodiversity that identifies the major components at several levels of organisation”
Noss (1990)

“The variety and variability among living organisms and the ecological complexes in which they occur”
OTA (1987)

“The variability of life from all sources, including within species, between species, and of ecosystems”
Whitaker and Fernandez-Palacios (2007).
“... the variety of life and its processes; ... the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.”

Keystone Center (1991)

“Biodiversity, simply stated, is the total expression of life on Earth”

Conservation International

Biodiversity means the full range of life on earth
Knowledge on global diversity must be established to appreciate the increasing extinction rate of species

- Since there is no absolute idea on how many species existed in the first place, extinction rates are vaguely estimated.
- Little is known about extinction rates of microorganisms.
- We can rarely be sure that a species is actually lost, that no isolated members remain.
Ask yourself why do you think there is a higher concentration of biodiversity at the equator than at the poles?

Tintensor et al. 2010
Primarily coastal taxa have peaks of diversity in the western Pacific and show clear latitudinal gradients along the coasts of continents (Fig. a–g).

Primarily oceanic taxa tended to show pantropical or circumglobal distributions with diversity peaking at latitudes between 20° and 40° in all oceans (Fig. h–m).
**WHAT** do you measure?

**WHEN** and **WHERE** do you measure it?

**HOW** do you compare different types of measurement?

---

**Alpha diversity**

The number of species per unit.

The more species present in a sample, the ‘richer’ the sample.
Evenness is a measure of the relative abundance of the different species making up the richness of an area.

Shannon-Wiener index (H)

Species richness (S) +

Proportion of each species within a zone (E)

1.5 > H < 3.5

Relation between Evenness, Heterogeneity and Species richness:

E = H/log(S)
H = E/log(S)

**Ecological Biogeography**

### DIVERSITY

**Alpha diversity**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Species 1</th>
<th>Species 2</th>
<th>Species 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>99</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>33</td>
<td>33</td>
</tr>
</tbody>
</table>

**Beta diversity**

Distribution of the numbers of individuals among the species counted

**Beta diversity**

To what extent do species turnover between different sites or along a gradient?

**Ecological Biogeography**

### DIVERSITY

**Alpha diversity**

Changing levels of alpha diversity along an environmental gradient that creates a series of different habitats (H1, H2, H3) reflect beta diversity (average number of species in different habitats).

**Beta diversity**

(low alpha (1 species per box))

(low beta (1 type of box))

(high beta (3 different boxes))

(high alpha (3 species per box))

(low beta (1 type of box))

(high alpha (3 species per box))

(low beta (1 type of box))
Ecological Biogeography

**DIVERSITY**

**Rate of species change with distance (geographical replacement of species = gamma diversity)**

**Distance across landscape**

- **Number of species**
  - **Gamma diversity**
    - Measured over a large scale, same concept as alpha-diversity.
    - Number of species in a region where there are no barriers to dispersal.

**Alpha-diversity**
- Measured locally, at a single site.
- Number of species in a local homogenous community.

**Beta-diversity**
- Measures the uniqueness; the difference between two sites.
- Species distributions among different habitats.

**Gamma-diversity**
- Measured over a large scale, same concept as alpha-diversity.
- Number of species in a region where there are no barriers to dispersal.

---

**Ecological Biogeography**

**DIVERSITY**

**Alpha-diversity**

*Measured locally, at a single site.*

Number of species in a local homogenous community.

**Beta-diversity**

*Measures the uniqueness; the difference between two sites.*

Species distributions among different habitats.

**Gamma-diversity**

*Measures over a large scale, same concept as alpha-diversity.*

Number of species in a region where there are no barriers to dispersal.

---

Original concept from Whittaker (1976)
Beta diversity (Whittaker, 1960)

"the extent of change in community composition, or degree of community differentiation, in relation to a complex-gradient of environment, or a pattern of environments”.

[the effective number of distinct compositional units in the region (Tuomisto, 2010)]


Beta diversity quantifies the number of different communities in the region. So it’s clear that beta diversity does not only account for the relationship between local and regional diversity, but also informs about the degree of differentiation among biological communities. This is because alpha and gamma diversities are different if (and only if) the biological communities within the region are different.
Ecological Biogeography

DIVERSITY

Maximum differentiation

1
2
3

Ecological Biogeography

DIVERSITY

Maximum differentiation

\[ \alpha = 5 \]
\[ \gamma = 15 \]
\[ \beta = N = 3 \]

Ecological Biogeography

DIVERSITY

A. Species Richness by ecoregion

- 1 - 4
- 5 - 9
- 10 - 19
- 20 - 29
- \( \geq 30 \)

B. Endemism Richness by ecoregion

- 1 - 4
- 5 - 9
- 10 - 19
- 20 - 29
- \( \geq 30 \)

NUMBER OF SPECIES
### Estimates of Species Numbers

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of described species</th>
<th>Estimated total no. of species</th>
<th>% Described</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td>4 000</td>
<td>400 000</td>
<td>1</td>
</tr>
<tr>
<td>Bacteria</td>
<td>4 000</td>
<td>1 000 000</td>
<td>0.4</td>
</tr>
<tr>
<td>Fungi</td>
<td>72 000</td>
<td>1 500 000</td>
<td>4.8</td>
</tr>
<tr>
<td>Protozoa</td>
<td>40 000</td>
<td>200 000</td>
<td>20</td>
</tr>
<tr>
<td>Algae</td>
<td>40 000</td>
<td>400 000</td>
<td>10</td>
</tr>
<tr>
<td>Plants</td>
<td>270 000</td>
<td>320 000</td>
<td>84.4</td>
</tr>
<tr>
<td>Nematodes</td>
<td>25 000</td>
<td>400 000</td>
<td>6.2</td>
</tr>
<tr>
<td>Crustaceans</td>
<td>40 000</td>
<td>150 000</td>
<td>26.7</td>
</tr>
<tr>
<td>Arachnids</td>
<td>75 000</td>
<td>750 000</td>
<td>10</td>
</tr>
<tr>
<td>Insects</td>
<td>950 000</td>
<td>8 000 000</td>
<td>11.9</td>
</tr>
<tr>
<td>Mollusks</td>
<td>70 000</td>
<td>200 000</td>
<td>35</td>
</tr>
<tr>
<td>Vertebrates</td>
<td>45 000</td>
<td>50 000</td>
<td>90</td>
</tr>
<tr>
<td>Others</td>
<td>115 000</td>
<td>250 000</td>
<td>46</td>
</tr>
<tr>
<td>Totals</td>
<td>1 750 000</td>
<td>13 620 000</td>
<td>12.8</td>
</tr>
</tbody>
</table>
Why is biodiversity important to biogeography?

The Census produced the first all-taxon maps of global marine species using the distributions of more than 65,000 species from the Ocean Biogeographic Information System.

Finally, “biogeography” summarizes the distribution of life, marine or terrestrial. Census researchers compared the distributions of 65,000 species of marine animals, plants, and protists to produce the first all-taxa map of global marine species diversity. These analyses distinguished 30 biogeographic regions worldwide.
Ecological Biogeography

SPECIES

Coral Triangle

Safeguarding a diverse coral habitat

Regional governments are announcing a new plan to protect the Coral Triangle from land-erosion runoff, coral harvesting and fishing by dynamiting reefs. Coral already is dying there due to warming water.

Coral Triangle

Sources: Coral Triangle Center; World Wildlife Fund; ESRI
Ecological Biogeography

The Coral Triangle is a 6 million km² area covering parts of the entirety of 6 countries.

76% of the world’s coral species are found in the Coral Triangle.

6 of the world’s 7 marine turtle species are found in the Coral Triangle.

The Coral Triangle has more coral reef fish diversity than anywhere else in the world.

37% of the world’s coral reef fish species, and

56% of the Coral Reef fishes in the Indo-Pacific region.
Coral triangle: the centre of maximum marine biodiversity

(A) Briggs’ (1974) Indo-Malayan centre of marine biodiversity depicted as the “East Indies Triangle” (Briggs, 1987). His later version (Briggs, 2005a) is slightly larger, including all of Sumatra, and therefore more similar to the Coral Triangle indicated by Allen (2002; Fig. 1B). Kulbicki et al. (2004) refer to a centre of fish diversity, which they call “the Philippines–South China Sea–Indonesia triangle”;

(B) The centre of maximum diversity presented as coral triangles (Paine, 1988; Allen, 2002). The centre of reef-associated pennatulacean octocorals is also presented as a triangle (Williams, 1993).

Reef stomatopods in the IWP

Reaka et al. Patterns of biodiversity and endemism on Indo-West Pacific coral reefs. PNAS (2008), 105:11474
IN RED:
Shallow-water marine habitats (down to the -130 m contour) are highlighted in red, showing the maximum extent of seaway constriction during extreme low-stands in sea level.

Black lines:
The present day course of the Indonesian Throughflow is represented by black arrows, after Oppo and Rosenthal (2010).

Center of origin
The theory suggests that species originate in the Indonesian archipelago, thereby causing high species diversity there. The species diversity gradient is hypothesized to be due to diffusion of species from the center-of-origin into the rest of the Pacific.

Center of overlap
The theory suggests that the high species diversity in Indonesia is because of the overlapping of several adjacent biogeographic provinces (Ekman 1953).

Center of accumulation
Species are formed in the periphery of the Indo-West Pacific on isolated archipelagoes like the Hawaiian or Society Islands. The high species diversity in Indonesia is due to current patterns in the Pacific that tend to transport species there from the periphery.
Concepts by Linneus, Darwin and Wallace

1. species originate in “centers of origin”
2. speciation follows
3. new species evolve and disperse, thus displacing more primitive species to the periphery of the center of origin.
4. organisms disperse as far away as permitted by their abilities and their physical conditions.
Ecological Biogeography

**outline**

- DEFINITION
- PATTERNS
- SCALE
- WHAT IS BIODIVERSITY
- DIVERSITY MEASUREMENTS
- NUMBER OF SPECIES
- CORAL TRIANGLE

THE END