Department of
Environmental Sciences
and Policy

MARINE SYSTEMS

Lecture 1

2009

Dan Cogalniceanu

Course content

1. Overview of marine systems
2. Goods and services provided
3. Human impact on marine systems
4. Marine fisheries
5. Study case - the Black Sea
6. River influence on enclosed seas: Danube River and the Black Sea
7. Management and conservation of marine systems

LECTURE CONTENT

- Human perception of the oceans
- Water as a medium for life
- Vertical stratification in water
- Ocean diversity compared to terrestrial systems

A PROBLEM OF PERCEPTION

We are a terrestrial species and land is our habitat. The Ocean was until the last 4-500 years only the "mysterious" and dangerous border of our known inhabited world, populated by sea monsters. Now we have the space border, populated in turn by space monsters.

Past **Present**

WHY STUDY THE OCEANS?

Because the oceans:

- Cover 70% of the surface of the planet.
- Contain 97% of all the water.
- Represent 99% of the life supporting habitat of the planet.

The correct name for our planet should be *Water* (instead of *Earth*), or *Aqua* (instead of *Terra*)

Human perception of the oceans

"There are few global issues, even poverty, that are not linked to the oceans"

1998 – International Year of the Ocean

Until recently the world oceans and seas were considered as **unlimited**:

- **providers of resources (goods and services)**
- **waste disposal areas**

Based on the **wrong** perception that **human activities could not impact the ocean**

Marine systems are **limited**, with a **finite capacity**.

Importance of marine systems

- Coastal ecosystems are among the most **productive** (and **threatened)** ecosystems in the world
- Marine systems have a **major role** in regulating climate and the water cycle, provide food and fuel, maintain biodiversity and provide sites for recreation and tourism
- Coastal and marine systems are also **economically** and **socially** important

Marine vs. terrestrial systems 1

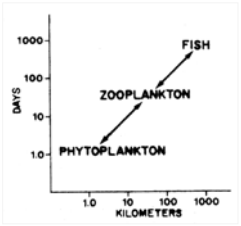
- Terrestrial ecosystems are predominantly **two-dimensional** with most ecological communities located to the earth's surface (area)
- In the marine environment, all habitats are connected by water, and both benthic and water column communities of organisms occur (i.e. **three-dimensional** environment - volume)
- The ocean and coastal habitats are not only connected to each other, they are also linked to land

Marine vs. terrestrial systems 2

- Compared with terrestrial ecosystems that are heterogeneous, highly fragmented and dynamic, the marine systems **appear uniform** and more **stable**. Nevertheless there is a lot of **stratification and heterogeneity** at different time- space scales, unlike terrestrial systems.
- The different oceans and seas are interconnected by horizontal currents and are in fact a **single system**.
- The ocean is **slow in reacting** to changes, but effects can last for long periods of time.

TIME AND SPACE SCALES

LARGE SPATIAL SCALE. Chemical homogeneity of the oceans due to **spatial connectivity**, lacking in terrestrial systems.



LARGE TIME SCALES.

Delayed responses due to the huge thermal capacity of the oceans and the long period of exchange between deep and near surface water.

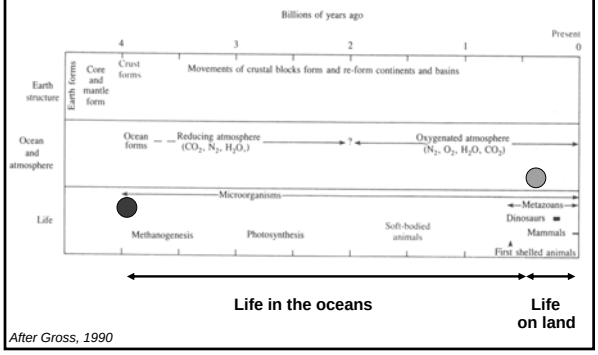
Marine systems are more vulnerable to large scale environmental changes, because they lack the internal adaptability inherent of the more heterogeneous terrestrial systems.

EARTH - THE WATER PLANET

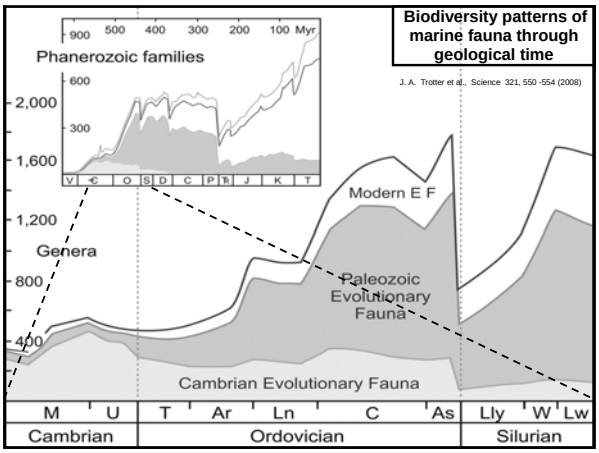
- Life originated in water about 4 billion years ago but only 0.5 billion years ago colonized the land. Organisms usually contain 60% to 90% water (lowest: plant seed -20%, and highest: jellyfish - 99%).

  Despite being a terrestrial species, our existence is still water-conditioned. By studying the ocean we learn not only about how much of life **originated** in the ocean, but about how much of life on this planet continues to **depend** on it.

A TIME HISTORY OF LIFE ON EARTH



After Gross, 1990



Water as a medium for life

The life of aquatic organisms differs from that of terrestrial organisms due to the physico chemical properties of water and to the special adaptations of living organisms after 3.5 4billion years of existence in the ocean **(ocean footprint):**

1. **The high density of water**
2. **The lack of salt in freshwater**
3. **The high solubility of water for chemical compounds**
4. **The development of vertical profiles in water**

Water as a medium for life 1

THE HIGH DENSITY OF WATER

Water is 775 denser than air and since the specific gravity of the organisms is just slightly higher, water is capable of supporting them very well.

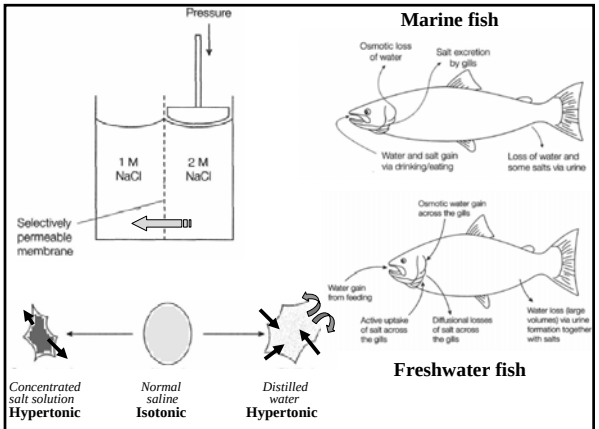
- **The entire volume of a water body can be permanently colonised by organisms.**
- **Supporting tissues or supporting organs are unnecessary.**
- **Aquatic plants are almost entirely edible, and aquatic primary production is rapidly recycled.**
- **Movement in water requires more energy than in air, many aquatic organisms depending on water currents for movement.**

Water as a medium for life 2

THE LACK OF DISSOLVED SALTS IN FRESHWATER

The tissues and body fluids of all organisms are hypertonic, i.e. contain a much higher concentration and a different composition of electrolytes than freshwater.

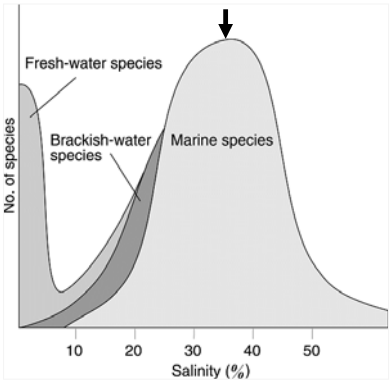
- Osmoregulation is easily achieved in marine organisms and does not need specific adaptations.
- In freshwater organisms osmoregulation is extremely difficult to achieve and requires high amounts of energy, thus limiting the diversity of animal life in freshwaters comparative to marine environments.



Cell behavior in different solutions

There are few species that can tolerate a wide range of salinity, the majority is limited to a narrow range.

The high number of freshwater species is due to the high degree of geographical isolation in freshwater ecosystems.



Water as a medium for life 3

THE HIGH SOLUBILITY OF WATER FOR CHEMICAL COMPOUNDS

Water *is know as 'The Universal Solvent'*

- Aquatic plants and micro organisms can take up dissolved chemicals across their entire body.
- The importance of the roots for aquatic plants is greatly reduced.
- Biogeochemical cycles are much faster in water.

Water as a medium for life 4

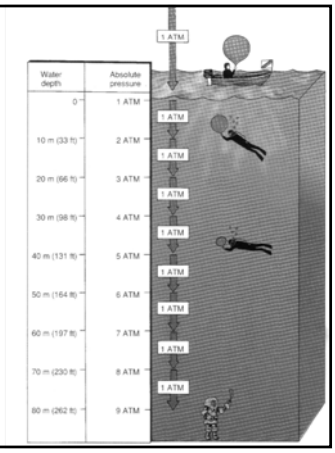
THE DEVELOPMENT OF VERTICAL PROFILES IN WATER

- **Vertical gradients in respect to hydrostatic pressure, temperature, salinity, light penetration, oxygen, nutrients, microelements, etc. divide the water mass into water bodies of varying degrees of attractiveness.**
- **This causes an uneven distribution of organisms that migrate periodically between water bodies of different characteristics.**
- **Major role of water currents in structuring aquatic communities.**

VERTICAL PROFILES

INCREASE OF HYDROSTATIC PRESSURE WITH DEPTH

On land or at sea surface the atmosphere (i.e. air) is the only thing above. Below the sea surface all organisms are under the pressure caused by the weight of the water column, the higher the water column (i.e. the deeper) the greater the pressure.



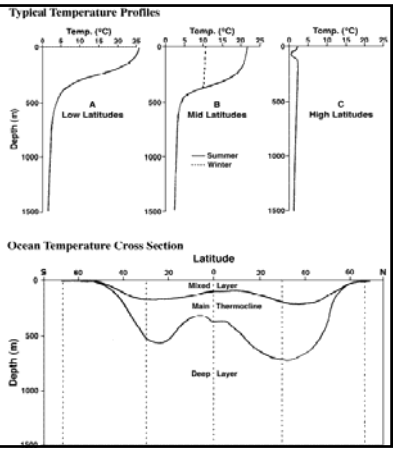
VERTICAL PROFILES

Water has the highest density at 4^{0}C, in the liquid state, not in the solid state as most other chemical compounds.

Freezing point:

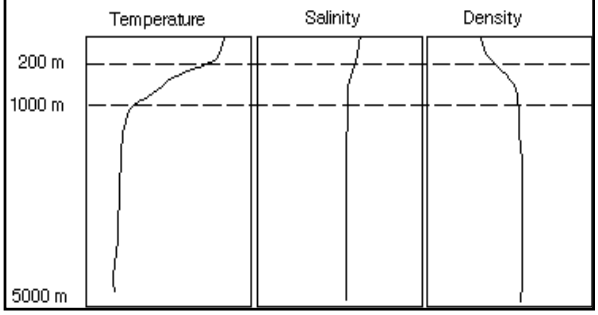
0^{0}C freshwater

-1.9^{0}C marine water

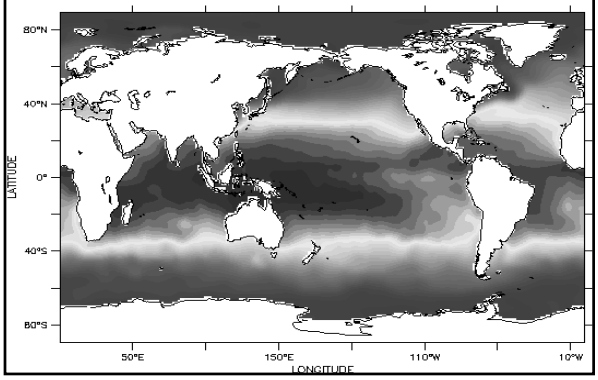


VERTICAL PROFILES

THE LINK BETWEEN WATER TEMPERATURE AND SALINITY ON DENSITY

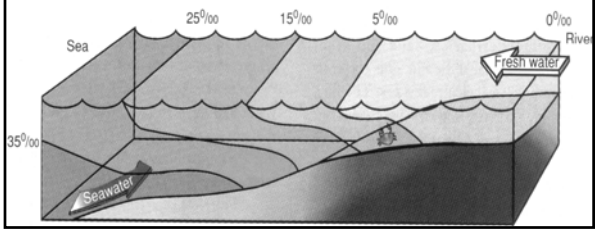


SEASONAL SEA SURFACE TEMPERATURE CYCLE



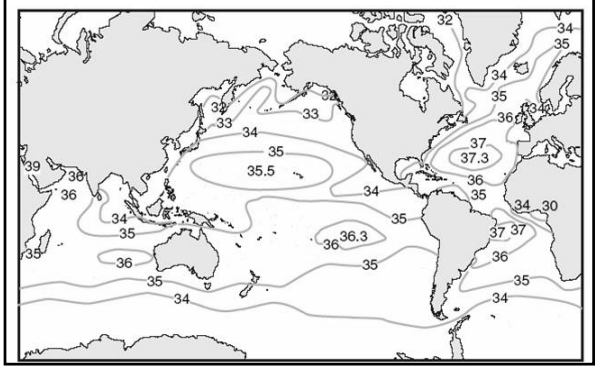
VERTICAL PROFILES

SALINITY GRADIENT NEAR A RIVER MOUTH

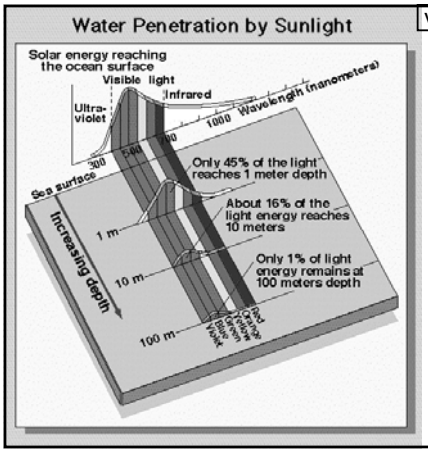


VERTICAL PROFILES

Variation in surface water salinity



VERTICAL PROFILES



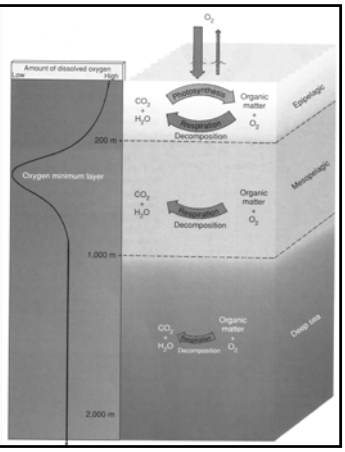
UV and IR radiations are absorbed entirely after 1-2 m

Only visible light (blue component) can reach 100 m in depth

VERTICAL PROFILES

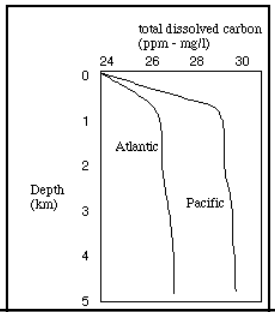
OXYGEN STRATIFICATION

Surface waters are rich in oxygen, both entering from the atmosphere and released by **photosynthesis**. Below surface, oxygen concentration depends on the rates of photosynthesis and **decomposition**. Below 200 m there is no entering of oxygen but extensive decomposition, resulting in an oxygen minimum layer. Below the oxygen minimum layer, most of the organic matter has already decayed and oxygen remains dissolved in the water.

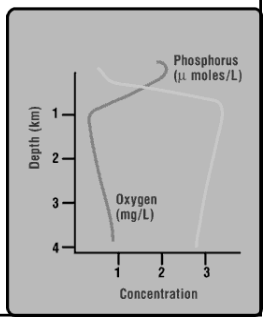


VERTICAL PROFILES

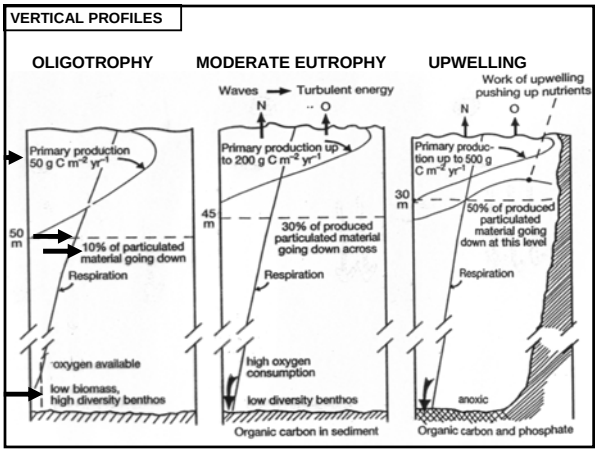
Vertical distribution of carbon along a depth profile



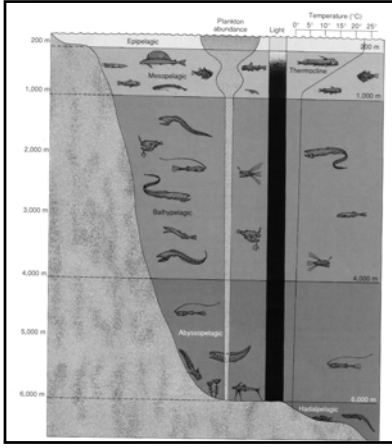
Vertical distribution of oxygen and phosphorus along a depth profile



VERTICAL PROFILES



VERTICAL PROFILES

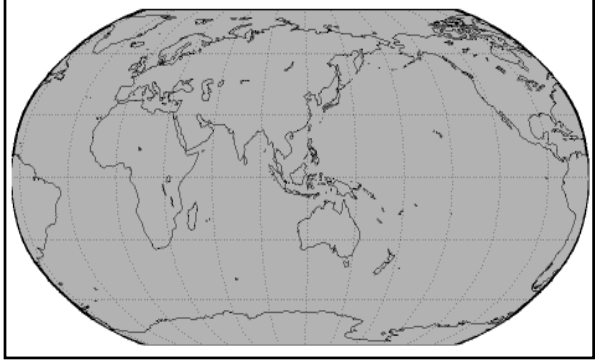


Vertical distribution of fish according to environmental conditions

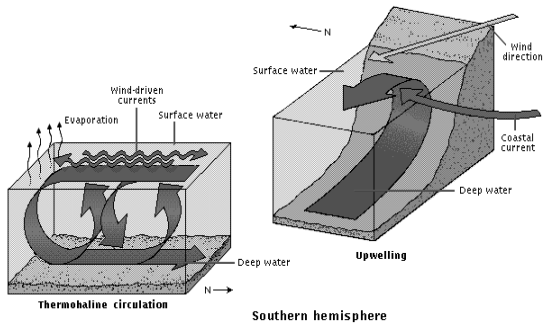
Links between the biota and physical environment

- A strong correspondence exists between physical features in the ocean's environment and biodiversity
- The more complex and heterogeneous the physical environment, the more productive and diverse the marine food webs

THE GLOBAL OCEAN CONVEYOR BELT CIRCULATION

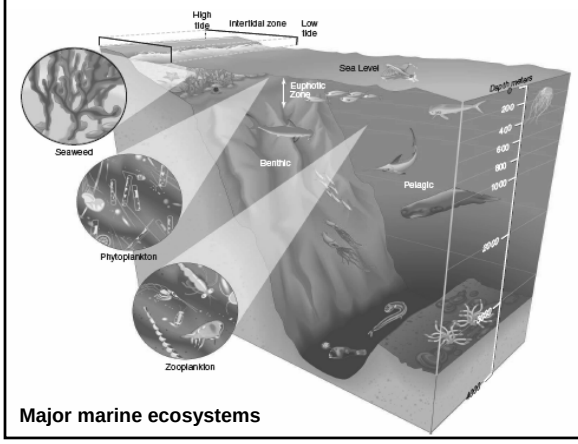


Vertical Ocean Circulation



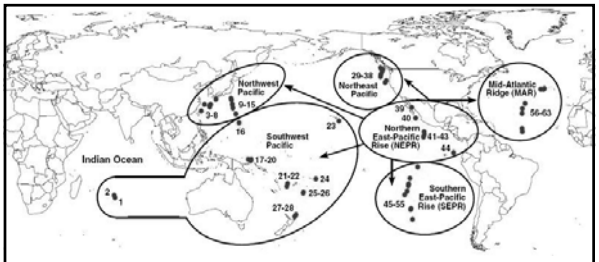
MAJOR MARINE ECOSYSTEM TYPES

- **OPEN OCEAN (pelagic)**
- **CONTINENTAL SHELF WATERS (coastal ocean, about 1% in volume and ~30% in fish landings)**
- **UPWELLING REGIONS (fertile areas with productive fisheries – 0.1% in area and ~30% in fish landings)**
- **DEEP SEA (including hydrothermal vents)**
- **ESTUARIES (coastal bays, salt marshes etc.)**



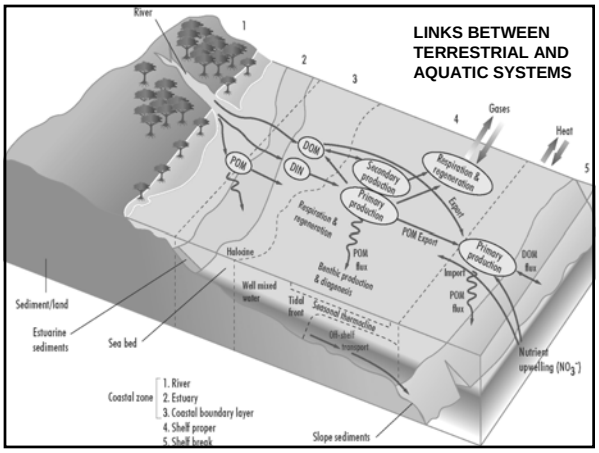
Major marine ecosystems

HYDROTHERMAL VE



A survey of hydrothermal vent life reveals six distinct 'provinces' of animals, with the East Pacific Rise as the likely centre of dispersal

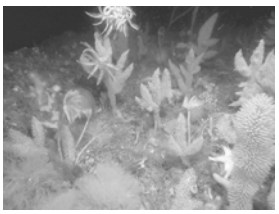
Schrope, M. 2008. Nature

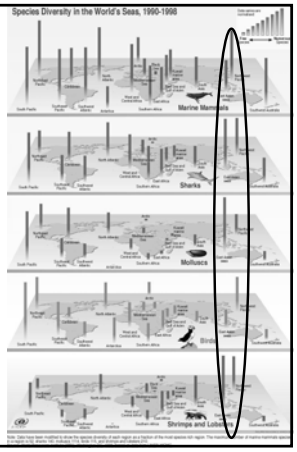


MAJOR FEATURES OF THE COASTAL AND OPEN OCEAN

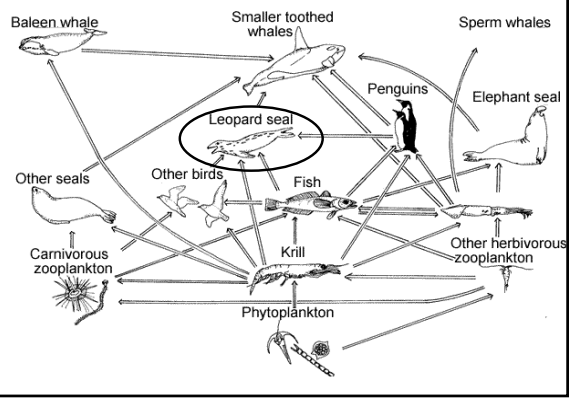
Feature	Coastal ocean	Open ocean
Depth	Up to 100-1000 m	Up to 4-6 km
Distance	Tens of km from coast	Hundreds of km from continental slope
Surface currents	Seasonal, parallel to coastline	Little change, circular gyres
Salinity	**Variable**, river discharges dominate	Variation only in surface zone, **constant** below
Temperature	**Varies** seasonally, affects bottom	Variation only in surface zone, **constant** below
Sediments	River discharge dominates	Atmospheric deposition dominates

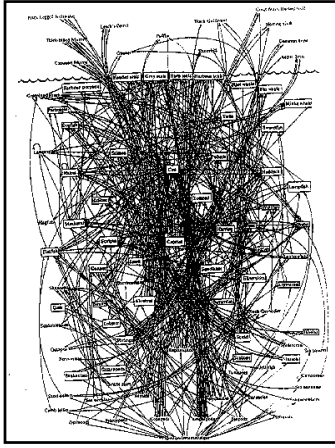
Species diversity in the oceans



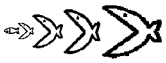


THE ANTARCTIC FOOD WEB





A food web from the northwest Atlantic showing the high complexity of trophic links.



A COMPARISON BETWEEN MARINE AND TERRESTRIAL SYSTEMS

Parameter	Marine	Terrestrial
Area (%)	70	30
Inhabitable volume (%)	99	1
Total biomass (ratio)	1	200
Number of described species (ratio)	1	6
Number of phyla described (ratio)	3	1
Age of life forms (billion years)	4	0.5

ENERGY FLUXES THROUGH PRIMARY PRODUCERS

Ecosystem	NPP ($g\ m^{-2}yr^{-1}$)	Biomass ($g\ m^{-2}$)	Transit time (years)
Tropical rain forest	2,000	45,000	22.5
Temperate deciduous forest	1,200	30,000	25
Boreal forest	800	20,000	25
Temperate grassland	500	1,500	3
Desert scrub	70	700	10
Wetland	2,500	15,000	6
Lake and stream	500	20	15 days
Algal beds and reefs	2,000	2,000	1
Open ocean	125	3	9 days

COMPARISON BETWEEN TROPHIC RELATIONSHIPS

Community	NPP (kcal m^{-2} yr^{-1})	Predator ecological efficiency (%)	Number of trophic levels
Open ocean	500	25	7.1
Coastal area	8000	20	5.1
Temperate grassland	2000	10	4.3
Tropical forest	8000	5	3.2

COMPARISON BETWEEN ECOSYSTEMS

CHARACTERISTIC	MARINE	TERRESTRIAL
Described by	Faunal types	Vegetation types
Geodiversity	High	Low
Primary producers	Small, often mobile	Large, sessile
Consumers	High reproductive output	Low reproductive output
Symbioses	Mainly concern primary production	Mainly concern consumption
Trophic interactions	Very high between habitats	Low between habitats
Biodiversity interactions	Over large distances: danger of extinction lower	Rarely over large distances: danger of extinction high

COMPARISON BETWEEN FAUNAS

CHARACTERISTIC	MARINE	TERRESTRIAL
Species described	**250,000**	**1,450,000**
Unique phyla	**13-18**	**0-1**
Speciation rate	**Slow (1-5 million years)**	**Fast (10-50,000 years)**
Species discrimination	**Mainly by internal characters High differences between taxa**	**Mainly by external characters Often similar between taxa**
Species description	**Difficult, high technical equipment, long time**	**Easier, low technical equipment, short time**
Amateur scientists	**No significant role (except conchology)**	**Significant role (except for very small animals)**
Degree of knowledge of biodiversity	**Extremely poor**	**Poor**