03/10/2022, 04/10/2022

MARINE ECOLOGY (Davide Seveso)

Ecological and Evolutionary principles of Marine Biology
1. Ecology and Ecological Interactions
2. The Ecological Hierarchy
3. Interaction on the scale of Individuals
4. The Population Level
5. The Community Level: Structure and Interspecies Interactions
6. The Ecosystem Level

1. Ecology and Ecological Interactions

<u>INTERACTION</u>

Biological interaction
- Predator-prey interactions
- Biological dependencies
- Parasite-host

Abiotic interaction → Effects of abiotic factors on the functioning of organisms
- geological (basin shape, size, topography)
- physical (temperature, currents, pressure, light)
- chemical (carbon, nitrogen, phosphorus, oxygen, salinity, trace metals)

the two kind of interactions cannot be easily separated, low T could prevent a cold-blooded organism from moving very quickly and this reduce the chance to escape

<u>RESOURSES</u>

A resource is *any material whose abundance in natural environment can limit survival, growth, reproduction*
- <u>Renewable</u>→ continue to become available
- <u>Non-Renewable</u>→ can be depleted and no longer available

2. The Ecological Hierarchy

The ecological processes could be studied at many levels of hierarchy:

With **biological analysis** we study these levels:
- CELL
- TISSUE
- ORGAN
- ORGAN SYSTEM
- ORGANISM (this is also studied with ecological analysis)

<u>Our analysis are mostly focus on higher level of organization of the life, till the biosphere</u>

With **ecological analysis** we study these levels:

- ORGANISM (this is also studied with biological analysis)
- POPULATION
- COMMUNITY
- ECOSYSTEM
- BIOME
- BIOSPHERE

As there are many and different levels, there are many and different questions

- **Individual level**: organism physiologically independent. *How organism can survive under vary physic and chemical conditions?*
- **Population level**: group of individuals of the same species that are responding to the same environmental factors and freely mix. *How large the population must be to produce enough young (hot spring) so the population can persist in time?*
  Species: a single population that is genetically isolated from others
- **Community level**: group of populations belonging to different species and all living in the same place. *How the different species interact and can cause change in the size of the populations?*
- **Ecosystem level**: an entire habitat including all the abiotic features and all the living species within it that interact
- **Biosphere level**: all the living organisms on Earth and the environment with they interact
- Interactions among the levels

3. Interaction on the scale of INDIVIDUALS

ECOLOGICAL NICHE→ is the range of environments (composed by *biological and physicochemical dimensions*) over which a species is found. It is a multidimensional concept which defines a species PLACE in a community in relation to other species because we have to consider the biological facto between the species.

2 species cannot coexist in a community if their niches are identical. This concept was famously documented in the Connell's study called "species overlap between barnacles on intertidal rocks"

- **Fundamental niche**: Niche potentially occupied by the species under ideal conditions. For Chthamalus is all the rocky shore, for Balanus is only the lower part of the substrata
- **Realized niche**: Portion of the fundamental niche actually occupied by the species. For Chthamalus is only the upper strata because in a normal scenario Balanus will win the competition and so Chthamalus can only occupy the upper rocky shore.

e.g.

Connell's study and experiment

Balanus and Chthamalus are 2 different species of barnacles that could live in the same place, but when they are together, they cannot coexist, so Balanus (that is not used to stay outside the water for long time) stays where there is the low tide, instead Chthamalus (that is able to resist for a long time outside the water), stays where high tide arrives, so in the upper part of the intertidal rocks (rocky shore). The fundamental niche for Chthamalus is not only the part of the rocks far from the water, but also the low part of the rocky shore near the water, instead for Balanus the fundamental niche (and so the realized one) is only the rocks' part where the low tide arrives. Balanus is a stronger competitor, so it win and also occupy the lower strata that is a useful substrata also for Chthamalus. If we remove Balanus, Chthamalus is able to occupy its fundamental niche that is bigger than the realized niche.

There are different types of interactions among the organisms, using the PLUS-MINUS-ZERO SYSTEM

- Territoriality + -
- Competition + - or - -
- Predation + -
- Parasitism + -
- Mutualism + +
- Commensalism + 0

TERRITORIALITY

- Territoriality is the maintenance of a home range and its defense against intruders (outsiders)
- In most of the cases is INTRA-specific (between organisms that of the same species, they fight because they need to protect different areas)
- Usually these animals want to defend:
    1. **FEEDING AREA**: area di foraggiamento: e.g. *Plectroglyphidodon leucozonus*
    2. **BREEDING SIDE**: area riproduttiva, e.g. *Balistoides viridescens (trigger fish)* is able to produce benthonic eggs that are release on the bottom and attached there, so it controls the water column just above the eggs and can became aggressive, e.g. *Amphiprion frenatus* (clownfish) protected the anemone in which release the eggs, so defense very aggressively the breeding side
    3. **SPECIFIC NEST SIDE**: are dove dormono, il nido

PREDATION

- There are 1 predator and a prey
- Predator may be **stationary** (e.g. cnidarian → sessile) or **mobile** (e.g. fishes, starfish, gastropods → vagile), the mobile predator could be **territorial** or could move for **long distances**.
- The predators have different methods to locate preys and entrap them
- They should be able to adjust their anti-behaviour to optimize the rate of ingestion of the pray. This concept is realized in a theory:

OPTIMAL FORAGING THEORY → *the predator must maximize the amount of energy gained (guadagnata) from the prey and must minimizing the time spent feeding* (nutrendosi). This theory is summarized with these points:

- When food density is high it is better to specialize on food with high nutritional value → if I can choose between different types of foods, I focalized on the food them give me a high level of nutritional values
- The time spent in a patch of prey should increase with an increase of travel time between patches
- Choice of the best-sized prey → e.g. the crab prefer to eat mussels in an intermediate size that represent the higher % of die pray. If the crab spent too much time to end the pray, it became a pray, so is better to feed on pray with the correct dimension → **SELECTION FOR THE INTERMEDIATE SIZE**
- Consider the presence of predators (modulating the frequency of feeding)

PREDATOR AVOIDANCE (how the pray can avoid the predator)

- CRYPSIS or BLENDING WITH THE BACKGROUND:
  1. by **chromatophores** (cells that alter color) to hide themselves and altered the color to became similar to the background. E.g. octopus, crocodile fish…
  2. by **maintaining fixed color similar to the background**. They don't change the color but have fixed color similar to the background. E.g. stone fish, shrimps, seahorse, pipe fish, yellow frog fish… this predator avoidance is called BACKGROUND MATCHING → E.g. *Lutanus sebae* is a red emperor snapper that usually swim close to the lion fish, they discovered that this fish has similar color compared to the lion fish in order to reduce the possibility to became pray and be protecting using the background process.
- CAMOUFLAGE COVERINGS → many organisms cover themselves with sediments or part of the host. E.g. *spider decorator crab* is covered by little rocks and sediments, E.g. *California crab* is covered by bryozoan. E.g. *Candy crab* has a decoration of soft coral
- DECEPTIVE COLORATION AND BEHAVIOUR → sea hare produce dark ink that can create confusion in the predator, e.g. butterfly fish has a coloration as zebra that create confusion to the predator. Also they have false eyes that give them the possibility to escape from the predator that usually attack the eyes.
- ESCAPE RESPONES → not also for the vagile organisms, but also for the sessile ones, e.g. *scallops* when encounter sea star they can escape by clapping the valves rapidly.
- RETREATING TO INACCESSIBLE HABITATS (REFUGE) → e.g. the *trigger fish* has special mechanisms to retreat to an inaccessible habitat (little hole in the reef) and became blocked inside it. e.g. *juvenile blue razorfish* is another example of organisms that when there is a predator, it go completely under the send and disappear, so it became inaccessible to the predator. E.g. in the Maldives there is a gastropod that is very common, but with microscope they note that on the mantle there are little amphipod, so they have seen that shrimps was able to hide themselves inside the mantle of the host producing a lesion to hide themselves inside the tissue, so the shrimps stay is an inaccessible place.
- MIMICRY → use of evolved morphology or behaviour that allows an organism to resemble another species, with the function of reducing attacks by predators. E.g. the frog fish can resemble the sponges. Between this category there is another one:

  BATESIAN MIMICRY→ occur when an animal species harmless against predators resemble to a dangerous species, that live in the same territory, imitating coloration, and behaviour. E.g. *mimic octopus* is able to change color and morphology in order to resemble to dangerous animals, as sea snakes, scorpion fish (=lion fish)…
- MECHANICAL AND CHEMICAL DEFENSES → many marine organisms have these defenses, e.g. *surgeonfish* has a couple of spines, *lionfish* possess spines connected with poison sac, *squirrelfish, stingray, stonefish*… also corals produce mucus full of bacteria that represent a mechanical and chemical defense. There is a category of defenses:

  INDUCIBLE DEFENSES → all defenses that provide an advantage to the pray only when predator is present, but at the expanse of other processes. They obtain defense, but loss efficiencies in term of reproduction or growth. E.g. porcupine fish is able to increase in size and release spines, but it increase the volume by drinking a great amount of water. After 4 time this fish die because is subject to a high stress.

- TOXIC COMPOUNDS → they can be synthetized by the organisms, e.g. pufferfish produce tetrodotoxin, also they can be acquired through other toxic organisms, e.g. sea hara Aplysia graze in the toxic algae Laurencia, so terpenes became toxic.
- CONSPICUOUS COLOR → is called aposematic coloration, all the organisms that have this coloration are dangerous, the predators think that they are poisoned, e.g. nudibranch
- ALTERATION OF MICROHABITATS → they change the habitats in order to avoid the predators, to refuge, to feed, to reproduce… by altering the microhabitats, an organism can avoid the predator

COMMENSALISM

- Relation + 0, only one species takes advantage, but the other is not damage
- E.g. part of the burrow of the echiurid worm *Urechis caupo* showing the following commensals: the goby *Clevelandia* and the pinnotherid crab *Scleroplax*. There are 3 d9fferent species that use the same burrow created by the worm. The 2 host (fish and crab) obtain protection from predators and feed on detritus and prey in the burrow.
- Could be facultative or obligatory
- There is also a not real commensalism: manta ray present many fishes attached to itself, called *remora*, that use Malta, in order to move without use energy. Malta doesn't have any damage f the number of them is less, but if there are a lot of remora, the Malta have damage, as whale and barnacles → from commensalism to parasitism

MUTUALISM

- Relation ++, all the species involved have benefits
- Usually it began as facultative but genetic variation allowed complete dependence (obligatory)
- Many mutualistic relationships involved the **protection from predators** for almost one of the species and/or **food acquisition** → 2 most important reasons that create mutualism relationship

e.g. *Coral polyps and zooxanthellae*: coral is an organism represented by symbiosis between the animal part (polyp) which host the zooxanthellae (unicellular algae) that with the photosynthesis produce nutrients for the coral polyp. The polyps obtain nutrients and provide refuge and food for the zooxanthellae.

e.g. *Anemone and clownfish*: the anemone is an organisms with a lot of poisoning tentacles (cnidocyte) that can kill some marine organisms, nut not the clownfish. Since the first day of life they have mucus surrounding the body, so is isolated and can live in the anemone. The benefit for the clownfish is to be protected, instead the anemone is protected by the clownfish, also they clean daily the anemone from the send and from the parasite.

e.g. *Goby fish and blind Shrimp*: this is an example of mutualism interaction for protection. The goby fish use the burrow of the shrimps in order to remain save in a refuge, at the same time, the body alert the shrimps if there are predators because the shrimps is blind. This is possible because the shrimps always have an antenna attached to the goby, so with special movement it can transmit an alert signal to the shrimps which go back inside the burrow.

e.g. *Hermit crab and anemone*: this is a species-specific relationship, the crab is able to moves with an anemone of the shoulder, anemone give protection from predators as octopus, instead the anemone is able to be transported on the seabed. If the crab change the shell, the anemone goes with it.

e.g. *cleaning stations*: is a mutualistic relationships created to gain food for almost one of the species. There are special species of fish, *Labroides dimidiatus* which create in the coral ecosystem, areas called cleaning stations. They wait client fishes in order to clean them from the parasite in the gills or in the mouth. Is an intimate relationship between the cleaner fish and the client fish. There is also a mimic species, called *Aspidonotus taeniatus* which is similar in term of color and morphology, it attack fishes which are normally client of the cleaning fishes. There are many other **cleaning organisms** → shrimps, butterflyfish…

PARASITISM

- Is a + - relationship, the parasite obtain benefits, instead the host is damaged by this interaction
- The parasite doesn't kill the host (doesn't consume the host totally) because maintaining it alive is the only way to survive, so the parasite lives at expense of other species and may get nutrients or shelter by damaging the host.
- Parasitic species evolve through cycles of varying virulence:
  TOO INEFFECTIVE: competition with other parasites will occur
  TOO EFFECTIVE: kill the host, extinction of both the species
- **Ectoparasites**: live attached to or embedded within the external body surface
- **Endoparasites**: live within the body, organs, or tissues. Have highly modified morphologies to adapting to life within cavities and to food uptake and absorption of fluids. Have lost locomotory appendages. They invade specific tissues, such as reproductive tissue of the host (*host remain sterile*) Parasitic species evolve through cycles of varying virulence
- In general, a parasite invades the reproductive system of the host:
  - The host lost the gonad functionality
  - A male host can change morphology resembling female and assuming behaviors characteristic of females

e.g. *invasion of the parasitic barnacle Sacculina (barnacle, crustacea) into the reproductive organs of a crab* → this is a strange parasitism relationship. The cypris is the first stage of live of the barnacle, it attached the crab using a soft tissue of the pray injecting a chitinous dart called KENTROGON. Through the kentrogon they are able to inoculate same cells of the body, then they start to multiply and invade the body of the host. So Sacculina takes the totally control of the crab and if the crab is a male, it unfeminized it. after same months, the barnacle is able to produce an external rigid bag placed ventrally under the abdomen of the crab, where the eggs are incubated. The crabs take care of the external bags, there are 2 small holes that open when the eggs inside are ready, so the male cyprid enters and fertilize the eggs, when the eggs are ready, the crab helps the eggs to come out and with moving up and down it favorites the dispersal of the eggs, so the cycle can continue.

Other parasites have COMPLEX LIFE CYRCLE, with:

- Different morphologies
- Different functions
- Different hosts
- Different microenvironments

In the intermediate host the parasite can only do **asexual reproduction**
In the definitive host the parasite can do the **sexual reproduction**

PARTICULAR PARASITISM IN FISH

1. **The castration barnacle & *Anelasma squalicola*** → The Anelasma barnacle specifically targets deep-water sharks and will bury themselves directly into the fish's back. Once it is comfortable in its new home, the barnacle then sends out a number of small roots past the shark's spine and into tissue pockets taking nutrients from the shark. Moreover, Anelasma can shut down the shark's reproduction system
2. **Fish lice & Argulidae**→ Usually characterized by a flat, rounded body protected by a carapace, these unsightly parasites attach themselves to fish and feed on internal fluids. In some cases, fish lice will even eat the fish's scales for nutrients.

3. **The tongue-eating louse** & ***Cymothoa exigua***→ Protoandric hermaphrodite, the female enter from the gills and eat the tongue
4. **The face-biting Snuffbox & *Epioblasma triquetra***→ Unlike many other mussels, the snuffbox begins life as a parasite during its larval stage. In 2004, researchers discovered that female snuffboxes will lure in unsuspecting fish and then clamp down on their mouth with its shell, which are lined with small "teeth." The mussel will then pump its parasitic young straight into the fish's face, hoping to propel most of them into its victim's gills. The snuffbox often do so with such force that the host fish is unintentionally killed. It's most common victim is the common logperch, which is strong enough to survive the initial contact.

4 - The POPULATION Level

Population: is a group of individuals of the same species that are responding to the same environmental factors and can freely mix.
Most ecological problems require knowledge of a variety of numerical aspects of natural populations, when we study the population, we should know:

- *Population Size*→ number of organisms in a defined area
- *Population Density (crowding)*→ number of organisms per unit of area or unit of volume. This parameter give as an idea of the degree of crowding or access to the resources by the organisms
- *Biomass*→ mass of individuals per unit of area or of volume

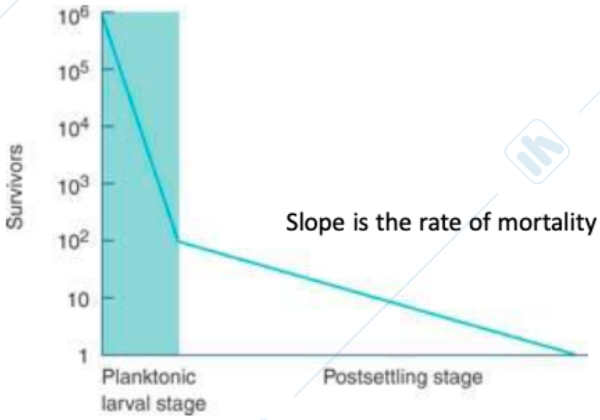
Marine populations are very dynamic, they can change in the time and in the space. Marine populations are **more** dynamic **than the terrestrial populations** because there are **less barrier**, so the organisms can move and change more, so:

1. TEMPORAL PATTERNS
2. SPATIAL PATTERNS

TEMPORAL PATTERNS

- We have to consider these different elements: **Survival of adults** (major factor in the population change: if survival is high, the current population size play a major role in explaining the population size in the future), **Reproduction** (they can produce hundred or thousand eggs per female), **and successful survival of young**, **Immigration**, **Emigrations** (they affect the change in population abundance.
- The growth of population could follow different curves considering the temporal variations: **SURVIVORSHIP CURVE**

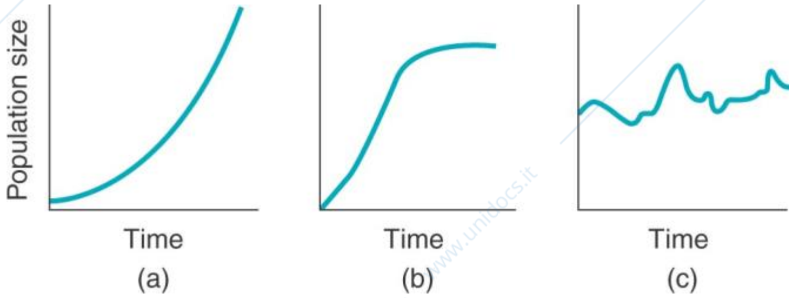
We can repot the probability of survival of different stage (class of age) by using a graph (named below). E.g. Survivorship curve for a marine invertebrate specie with planktonic larvae: the survivors are plotted on a logarithmic abundance scale, the slope of the line represent the rate of mortality, in fact high mortality rate is recorded for the larval stage.



Also to calculate the population size for the future, we use the POPULATION MODEL, is a formula → N is function of different factors: mortality (M), number of birth (R), immigration (I), and emigration (E) → dN/dT= f (N,M,R,I,E).

$$N(t+1)= N(t) + B(t) + I(t) – D(t) – E(t)$$

How a population can change in size in the time? 3 DIFFERENT MODES OF POPULATION TEMPORAL VARIATIONS:



1. **Exponential growth**: the population increase with the same proportion during the time, it might continue indefinitely if the space, light, food… are limitless.
2. **Resources-limited growth**: the majority of population shows this mode. The carrying capacity is maximum population size that the environment can sustain. The rate of population growth starts to decrease and involve intraspecific competition for the resources
3. **Random growth**: in many cases the populations change randomly, the factors that regulate the size of population are too complex to show any simple pattern. Such fluctuations in time can cause extinction, especially when the population size became small.

SPATIAL PATTERNS

Spatial Distribution How individuals are spaces in an area? 3 CATEGORIES:

The organisms could follow 3 different spatial distribution:

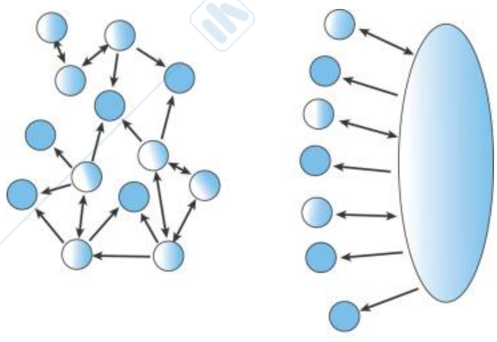
1. **Random distribution**: an indivudal has the same chance to be located in a spot or in another spot in the area, is very rare
2. **Uniform distribution**: there is a uniform spatial distribution of the organisms if every equal sub area contains a constant number of individuals, it maximizes the distance between the neighbor.
3. **Aggregate, patchy distribution**: if more individuals occur in a given sub area than is expected. We can see this distribution if there is a meeting process, protection against the predator…

Metapopulation

- *most of marine population are often metapopulation which are a series of interconnected sub population*
- It's a group of populations (or subpopulations) that are living in separate habitats but are connected by dispersal of larvae, it's a group of interconnected subpopulations

- There are 2 TYPE OF SUB-POPULATION
    - **Sink**: sub-population that *only receives immigrants* from the source
    - **Source**: sub-population that contributes more individuals to the metapopulation, in this there is high reproduction and dispersal rate. *Is able both to receive and donate individuals*
- There are 2 WAYS TO STRUCTURING A METAPOPULATION INTO SUB-POPULATION:

1. **Equally sized sub-populations** that composed the metapopulation, where there is a series of equally sized subpopulation with a connection by means of dispersal thanks to sink and source
2. There is one big mainland (is a source of organisms) and a lot of small islands with the same size, following the **island-mainland scheme**. It is similar to those that we can observe in the coral reef when there are patches.



- Metapopulation model is very appropriate for marine systems where dispersal of larvae between relatively isolated subpopulations is common

5 - The COMMUNITY Level: Structure and Interspecies Interactions

Ecological communities consist of a *series of coexisting species that interact by means of biological processes*

Factors that determine the community structure:

a. Structural habitat (es. hard substrate of a rocky shore usually precludes soft bottom organisms)

b. Foundation species (habitat-determining species those species that contribute substantially to the structure of a local habitat determining many of physical and chemical proprieties, e.g. mangroves are foundation species because they protect tropical shore, provide habitats for animals and plants, on them depend on the live and the presence of other organisms. Such habitat-determining species are also called ecosystem engineers → are able to alter and create the structural habitat, upon which other species depend.

c. Interacting species

d. Environmental parameters (T°C, salinity, O2…)

e. **Processes between species**:
- Dispersal of larvae (for animals), spores (for vegetable)
- Competition for limiting resources
- Predation and herbivory
- Disturbance by environmental factors that create ecological succession
- Disease and parasitism
- Facilitation

DISPERSAL OF LARVAE, SPORES

- Most of the species of fish and invertebrates have *planktonic larvae*, which can disperse great distances
- The larval settlement can be a limiting factor in the composition of marine community
- In most marine habitats there are «good» (the recruitment is more succession then other) and «bad» recruitment years (wide variation in adult population size)
- Some of this variation may result from the effects of local currents
- Feeding larvae may be short of food in some years, with a consequent reduction in successful settlement

INTERSPECIFIC COMPETITION

- Usually occur when individuals of different species exploit the same limiting resource (space / food)
- A **guild** is a group of species that exploit the same resource
- Competition between species can proceed in several different ways: 3 MECANISMS OF COMPETITION
  - DIRECT DISPLACEMENT→ when the space is the limiting resource, one specie may succeed directly thought displacement of the other one
  - PREEMPTION→ the priority in arrival give the precedence, the species able to colonize first, avoid other species to invade it
  - EXPLOITATION COMPETITION/SCRUMBLE COMPETITION→ the more efficient species might gain more food and gradually increase in the population size at the expenses of the other species
- **Competition affects abundance where resources are limiting.** E.g. the mussel My*tilus californianus* competes for space with the barnacle *Balanus cariosus* on an intertidal rock near Bamfield, British Columbia
- **The intraspecific competition usually occur for SPACE** → in the hard substrata the space is the most important limiting factors

  There are different mechanisms of competition for space:
  1. **Overgrowth of neighbors** (species with the most rapid growth rate are the most successful competitors): The species with the most rapid growth rate, usually are the most successful competitors because growing faster are able to overgrowth the neighbors.
  2. **Shading of competitors** (in photosynthetic organisms): an organism growing can reduce the amount of light that can reach he other species. The species with the most rapid growth rate, usually are the most successful competitors because growing faster are able to shade the competitors
  3. **Secretion of poison**: sponges are able to do this
  4. **Presence of special aggressive structures**

The intraspecific competition due to 2 different outcomes:

- COMPETITIVE EXCLUSION: one species is stronger than the other, so this species will survive (ONLY ONE WINNER), instead the other could die or must change the place. There is a dominance of a single species that monopolize the habitat indefinitely

- CO-EXISTANCE: some process allows more than one species to exploit same resources WITHOUT DISPLACMENT, they can live together, in this case is necessary to know that there are:
  - ***Habitat complexity*** (*microhabitats* and *niche structure* produce the habitat complexity and can give the possibility to coexist): habitat complexity allows species to coexist by specializing on slightly different microhabitat, so **environmental heterogeneity** promotes coexistence of many species by providing several distinct microhabitats within which species may exploit unique resources (if the habitat is very heterogenous, I can divide it in different microhabitat which give the possibility to many species to use the same resources without competitions). Competition combined with differential success in different microhabitat results in **niche structure**: any partitioning by coexisting species of a habitat into sub-habitats, involving a differential utilization of limiting resources. E.g. different species of carnivorous snail *Conus*: in a coral reef habitat (located in very low longitude), Conus shows a very high number of species, but *if we consider intertidal smooth limestone (without a great heterogeneity), the number of species is more or less the same* in we consider all the longitude because there isn't a heterogeneous habitat. If we focus *on subtidal complex reef, there is a very high heterogeneity of environments* , so a lot of microhabitats with strong niche structure, *the number of species increase*, especially in the low latitude where there is coral reef, so can produce a *higher coexistence*.
  - ***Complex networks of competition****:* In a simple competition hierarchy (LINE), one species is superior to all others and any given species is superior to another at a lower level. (in this case the *co-existence is impossible because the space A monopolizes the habitat*). In a network (TRIANGLE), it is possible that species A is competitively superior to species B but inferior to species C, leading to different outcomes of dominance depending upon which species come into contact (in this case the *co-existence is possible between B and C*)
  - ***Adult extinctions and recolonizations****:*
  - ***Complex patterns of disturbances***: PREDATION AND DISTURBANCE: *both the phenomenon may prevent the domination by superior competitors over inferior species.* Disturbance generally is any physical process (storm, wave action, unstable sediments, change temperature) and usually operates on larger spatial scales, removing patches of the community. Mobile animals may also cause mortality unrelated to predation (biological disturbance). E.g. while moving along rocky surfaces, limpets often bulldoze newly settled barnacle larvae from the rocks

PREDATORY AND HERBIVORY AND DISTURBANCE BY ENVIRONMENTAL FACTORS THAT CREATE ECOLOGYCAL SUCCESSION

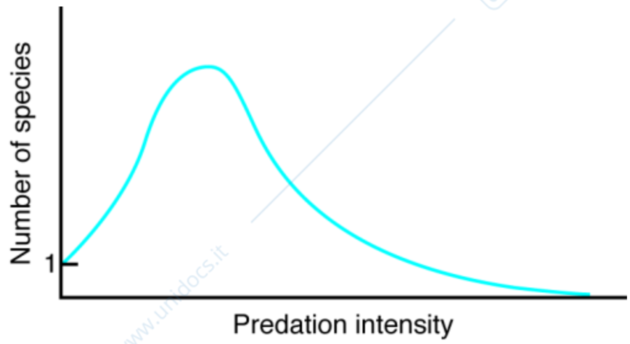
- Both the phenomenon may prevent the domination by superior competitors over inferior species
  - *Predation and herbivory*: biological process that acts on singular individuals, so it is a one-at-a-time removal processes → they act on singular individual, they don't affect all the whole population, but remove e.g. only one individual
  - *Disturbance*: generally is any physical process (storm, wave action, unstable sediments, change temperature) and usually operates on larger spatial scales removing patches of the community → can affect all the community, all the population in a specific space, in not one at a time removal process, but is a physical process that affect the whole community.

- Often initiates a **sequence of dominance by different species over time** known as SUCCESSION: often starts after a disturbance event

Succession is a predictable ordering of appearance and dominance of species, usually following an initial disturbance. A predictable final state is called **climax community → FINAL EQUILIBRIUM**. *Succession of different species can occur over the time*; it could be a trend toward a more stable assemblage of species or the simple sum of colonization and persistence of the species.

E.g. of *ecological successional events in patch recolonization in a mussel bad*: where was a **bare rock** that could be created by the wave actions, storms… all the organisms die and so we start a new ecological succession with bare rock. The patches initially are colonized by **opportunistic algae** (diatoms, Ulva, Porphyria…). The first colonize species usually have high reproductive rate and short generation time. They are adapted to colonized newly disturbed environment (e.g. bare rock), they are not specialized. These species might facilitate the appearance of other species or prevent other species from colonizing. There are then **perennial algae** (corallines) that are more resistance and produce compounds that can deter herbivore and grazer. Then there are **acorn barnacles** that displaced algae and finally we have **mussels**, they became the dominant species that colonize the substrate and displace all the other species, in order to became dominant competitor, they require secondary space that is represented by algae and barnacles that are useful for larval settlement. So the mussels became completely dominance, monopolize the habitat, and became the most important competitor until some specific events: grazing, storms, physical damage that eliminate the dominance species and permit further colonization, so everything can start again from this stage.

The effect of the rate predation and disturbance on the number of species in the ecological community can be represented by this curve →



If we look at the effect of the rate of predation and disturbance on the number of species, we know that:

- **Low levels of disturbance or predation**: only 1 competitive dominant species that displace all the competitive inferior species, no species diversity.
- **Intermediate levels of disturbance or predation**: more resource space opened; more competing species allowed to coexist. We will reach the highest species diversity, in particular **Species diversity tends to be maximized at intermediate level of predation / disturbance**. if the disturbance and the predation intensity is too high all the individual of the species will be removed (extremely strong) and the species diversity will decline.
- **High levels of disturbance or predation**: all the individuals of all species removed, reduces total number of species

This trend is what we can see in nature, BUT this relationship occurs with the large requitement rate of new individual because with low requitement the coexistent might occur even at very low-level of disturbance because there would not be a sufficient influx of larvae, competitive dominant to recruit and displace other species

DISEASE AND PARASITES

- Diseases are a major cause of massive and widespread mortality, caused by **microorganism** (protist, virus, bacteria). Unfortunately, the knowledge about
- The parasites have complex life cycle with sometimes several hosts
- Interesting issues of marine disease is the mechanism (vectors) and rate of spread
- *Environmental factors may increase the spread and virulence of disease and the host susceptibility.*
- We have disease that can affect all the marine environment from mollusk, coral, bivalve… but the knowledge about marine pathogens is very limited.

FACILITATION

- Is another important process that can affect the structure of the community
- Many species cannot invade an environment unless another species appears first
- Facilitation is the necessity of a form of cooperation among species.
- *The species that benefits may eventually displace then the facilitating species*. Many small colonial animals (hydrozoan, bryozoan…) cannot live on a bare mud bottom, they require the grow of seabed of seagrass on which they can colonize.
- FACILITATION IS THE USE OF ANOTHER SPECIES AS SUBSTRATUM, A WAY TO LIVE
- **Foundation species** (e.g. seagrass) are those species that create the habitat for other species, they often alter the structural environment, which facilitates the presence of many other species

DIRECT AND INDIRECT EFFECTS of all these processes

- **Direct effects**: Predator consumes prey, so the prey population decreases (e.g. if we focus on the kelp ecosystem there are 3 actors: Sea otter, sea urchins and kelp → The sea otter consumes sea urchins that decrease)
- **Indirect effects**: Effects propagated to other species of the communities (e.g. sea otter consumes urchins, as a consequence, prey of urchins (seaweeds: Kelp) increases in population size → we involve a third species). Indirect effect in a community can involve two different types of indirect effects:

A. **Density-mediated indirect effect (DMII) →** Density at one feeding level increases, reducing the density of another species (second) and resulting in an increase of the prey of the second species. E.g. if we have more sea otters, the density of the sea urchins decreases, and at the end there is an increase of the kelp dimension.

B. **Trait-mediated indirect effect (TMII) →** the presence of a predator causes prey (second species) to be active less and feed less on their own prey. So, the prey of second species increase in abundance, even though the second species did not decline in size, but the feeding activity declined. If we have more sea otters, sea urchins change their behaviour, their activity and start to feed less on the pray (kelp), this behaviour trait does not result in a decrease of sea urchins, but it would result in less feeding by urchins on the kelp → CHANGE OF BEHEVIOUR

6 – The ECOSYSTEM Level

- The ecosystem *is a group of communities that interact with the physical-chemical environment within a specific geographic area*.
- An ecosystem is not necessarily independent from other ecosystems,
- All ecosystems exchange nutrients and organisms with other ecosystems
- It is crucial to determine the boundaries of an ecosystem
- All the ecosystems have primary produces: **autotrophic organisms** (phytoplankton, seaweed, cyanobacteria, bacteria…) that can manufacture organic substance with the sun energy or energy from inorganic chemical.

At the base of this trophic pyramid we have always the primary producers with use the sun energy to create organic material starting from inorganic nutrients, there are different levels of consumers which are heterotroph organisms. At first there are herbivorous consumers that feed on the primary producers Different levels of carnivores (heterotroph)
Not all the material produced is consumed by herbivore and carnivore, but if fall in the water column till the sea floor and if decomposed by bacteria and fungi producing dissolve inorganic nutrients available again for primary producers (DECOMPOSITION CYCLE)

- PRODUCTIVITY: in general is the amount of living material produced per unit area per unit time (g/m2/y)
  - **Primary** → the amount of living material produced in the photosynthesis per unit area per unit time (g/m2/y)
  - **Secondary** → productivity of the primary consumers (herbivorous) per unit of area per unit time
  - **Tertiary** → productivity of carnivores per unit of area per unit time

Always **the primary productivity is higher than the secondary productivity, that is higher than the tertiary productivity**.

- **Food chain**: a set of connected feeding levels of primary, secondary, and tertiary sources of productivity, each organism occupied a trophic level
- **Food web**: in more complicated systems, a simple chain cannot be constructed. Food web has many links and complex branching between and among the various trophic levels

Keystone species: species at the top of the food web. A predator at the top of a food web which exert (cause) strong effects on competitive interactions and on the entire ecosystem. Their removal could cause a **trophic cascade,** a change in the equilibrium of the ecosystem.

TROPHIC LEVELS:
1. CARNIVORE
2. HERBIVORE
3. VEGETATION

Food webs may be controlled by:

- **top-down processes** where top predators have strong effects on the lower levels, they control the trophic chain. *If the predator is removed, there is an increase of forage fish, that produce a strong decrease of the zooplankton which produce a strong increase of phytoplankton*
- **bottom-up processes** where changes in primary production drive changes in food web*. If there is an increase in phytoplankton productivity, there is an increase in zooplankton, in forage fish and in predator*.

Strong top-down linkages or bottom-up linkages generate a tropic cascade through the food web