RESTORATION ECOLOGY

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What can be done to reduce the human effect on earth?

- Ideally the restoration will return normal ecosystem function to an area and hopefully the project will also have social or economic value to humans
- Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed
- Restoration ecology - the full or partial replacement of biological populations and/or their habitats that have been extinguished or diminished

Some Ecological Restoration Terminologies

Restoration - here we attempt to **put back exactly** what existed in the ecosystem prior to the disturbance

Rehabilitation - here we attempt to **put back most** of what existed in the ecosystem prior to the disturbance, but we don't try to put everything back

Reclamation is the general process of **repairing damaged** ecosystems

Recovery or neglect - here we **allow nature to takes it course** - depend upon natural processes of seed dispersal and germination to start plants, natural dispersal of animals to repopulate the area

Replacement - no attempt is made to restore what was lost - here we **replace the original ecosystem with another one**

Creating artificial ecosystems: such as **artificial** wetlands for flood reduction and sewage treatment.

Enhancement - activity designed to **improve the ecosystem**, even if the change is fairly minimal

Restoration Ecology

- Restoration ecology attempts to restore degraded ecosystems to a more natural state
  - The larger the area disturbed the longer the time that is required for recovery
  - Whether a disturbance is natural or caused by humans seems to make little difference in this size-time relationship
- One of the basic assumptions of restoration ecology is that most environmental damage is reversible
- Two key strategies in restoration ecology are:
  1) **Bioremediation**: is the use of living organisms to detoxify ecosystems
  2) **Biological augmentation** uses organisms to add essential materials to a degraded ecosystem

Mitigation

- **Mitigation** is the alleviation of some process
  - Mitigation is related to restoration
  - Mitigation is sometimes required when a group wants to develop a wild area such as a wetland and thus destroy the wetland
- Often the success rate for mitigation projects is fairly low
- Many ecologists fear that if mitigation is seen to be successful we will allow many development projects to proceed with the assumption we can easily recreate nature
  - however there is some question as to how well we can actually restore what is lost or destroyed

Mitigation

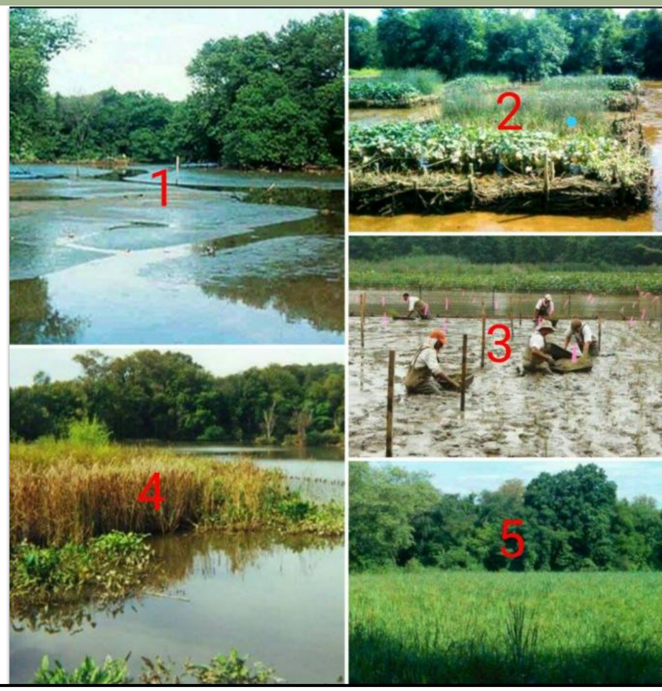
- **Mitigation** is the effort to reduce loss of life and property by lessening the impact of disasters .
- Mitigation has the potential to save and restore the most valuable environmental resources at the least cost .
- The success rate for mitigation projects is fairly low
(mitigation program may currently lead to a net loss in wetlands acres and functions) .
- Mitigation success may be improved by making site selection decisions within the context of a watershed approach .

Cheonggyecheon Stream Restoration Project

Provides flood protection;-Increased overall biodiversity with the number increasing of (plant species , bird species , aquatic invertebrate species, insect species, mammals and amphibians); Reduces the urban heat island effect with temperatures along the stream

Kenilworth Marsh Design-Build Tidal Wetland Restoration (A more complex and typical restoration project)

In 1989, the Metropolitan Washington Council of Governments (COG) recognized the need to coordinate a multi-agency effort to restore the Kenilworth Marsh system to improve its productivity and water quality functions within the watershed.



Bioremediation of Exxon Valdez oil spill

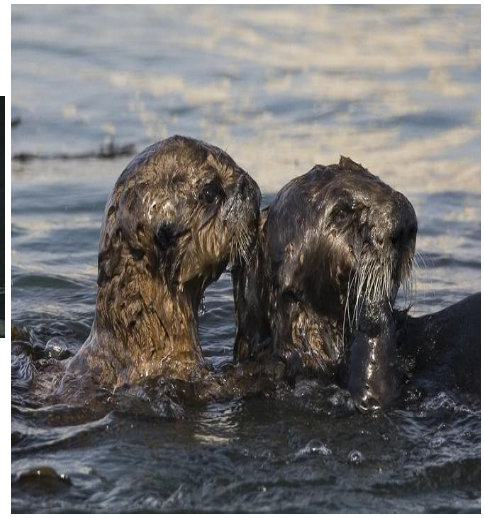
The Exxon Valdez oil, which occurred in 1989 , destroyed Ocean Beach Strait of Prince William leak .

Resulting in a reduction in the number of marine organisms .

The fishing industry in this region faced a sharp decline in fishing.

Exxon Valdez Oil Spill

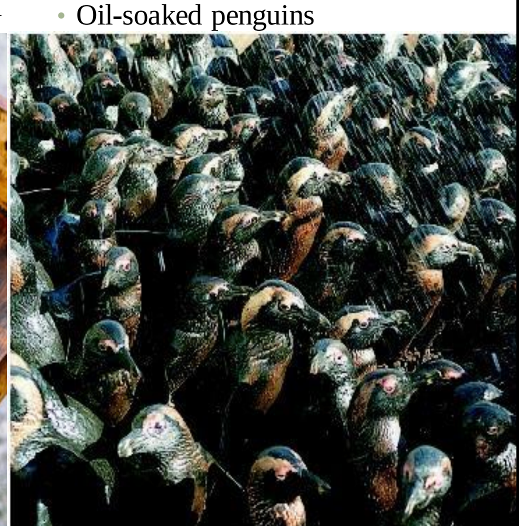
- Otters coated in oil



Exxon Valdez Oil Spill

- Seabirds dead as a result of oil spill

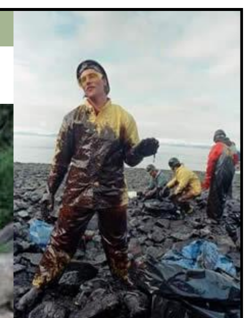
- Oil-soaked penguins



Exxon Valdez Oil Spill

- In 1989, the Exxon Valdez oil spill in Alaska used ***Pseudomonas* species** (oil-degrading bacteria) to clean up the spill through a Federally supported biotechnology demonstration project.
- It was 3x faster & without increased environmental effects

Exxon Valdez oil spill clean efforts



Removing Wastes & Pollution (**Bioremediation**)

- **Bioremediation** is defined as "use of living organisms (e.g., bacteria) to clean up oil spills or remove other pollutants from soil, water, and wastewater”. *Source: United States Environmental Protection Agency, Office of Compliance and Assurance*
  - Another definition :“clean-up of pollution from soil, groundwater, surface water and air, using biological, usually microbiological processes”. *Source: Philp et al., 2001*
- Thus bioremediation is the use of natural process of livings systems to degrade or remove noxious pollutants from the environment.

Why microbes?

- Bioremediation relies largely on the enzymatic activities of living organisms, usually microbes, to catalyze the destruction of pollutants or their transformation to less harmful forms.
- Microorganisms are so important in this process because they have extraordinary metabolic diversity!

Facts bioremediation was built on

1. Huge numbers of bacteria exist naturally in the soil and the rubbish in recycling and landfill sites:
   - Some of those bacteria slowly break down many different types of waste.
   - Some bacteria use oil as a source of nutrients just as we use food.

2. These bacteria can be used to break down oil spills at sea or on the shore.

3. There is a strong tie to microbial biotech (since many microbes are helpful for this area).

Fundamentals of cleanup reactions

- Bacterium uses some other carbon and energy source to partially degrade contaminant (organic aromatic ring compound)

- Aerobic metabolism
  - Microbes use O2 in their metabolism to degrade contaminants

- Anaerobic metabolism
  - Microbes substitute another chemical for O2 to degrade contaminants as ***Nitrate, Iron, Sulfate, Uranium, Technetium***,..etc

What Makes Bioremediation a Promising Approach?

- Permanence
  - Contaminant is degraded
- Potentially low cost
  - 60-90% less than other technologies

Treating petroleum sludge and oil spills

- Biological treatment techniques fall into two categories:
  1. **Biostimulation:** refers to the addition of specific nutrients to a waste situation with the hope that the correct, naturally occurring microbes are present in sufficient numbers and types to break down the waste effectively.
  2. **Bioaugmentation:** refers to adding living microorganism to break down the waste.

WHY ADD MICROBES (Bioaugmentation)?

1. It involves the **addition** of specifically formulated microorganisms to a waste situation.
2. It allows one to **control** the nature of the biomass.
3. It ensures that the proper team of microbes is present in the waste situation in **sufficient** type, number, and compatibility to attack the waste constituents effectively and break them down into their most basic compounds.

Bio-remediation

adding nutrients to stimulate growth of bacteria to clean up oil spill

Some microbes of those hydrocarbon Degrading ones

- *Pseudomonas* sp.
  - ***P. putida***
  - ***P. fluorescens***
  - *P. stutzeri*
  - *P. vesicularis*
  - *P. aeruginosa*
- *Bacillus* sp.
  - *B. subtilis*
- ***Alcaligenes*** sp.
- *Corynebacterium* sp.
- *Flavobacterium* sp.
- *Micrococcus roseus*
- *Acinetobacter lwoffi*

- This large community of microorganisms made it possible to try bioremediation and made it unnecessary to introduce microbes.
  - But they needed to find what was limiting the activity of the microbe in order to speed up the process.
- "Several investigators have reported that concentrations of available nitrogen and phosphorous in seawater are severely limiting to microbial hydrocarbon degradation" .
  - The results showed that biodegradation can be enhanced about two to three fold. This means that an oil spill that would take five to ten years to degrade can be degraded in as little as two to five years.

Challenge

- In the 1970s, the first U.S. GMO patent was granted to a scientist for a strain of bacteria capable of degrading components in crude oil.

- Researchers are working to have "genetically engineer very effective oil – digesting bacteria" that are:
  - Well suited to the environmental conditions of the ocean
  - Can speed up the bioremediation process even more at the time of any future oil spill disaster.

Future of Bioremediation

- The ideal result is a **bacterium genetically custom-made** to clean up a specific problem waste at a particular site under defined conditions. These bacteria should be:
  - A common, harmless bacterium that can be easily mass-produced
  - Able to break down some specific hazardous waste
  - Able to withstand wide temperature ranges, lack of oxygen or another environmental extreme.
- One of the largest hurdles with bioremediation is the difficulty in controlling the factors for the microorganism growth.
  - The development of a microorganism is affected by temperature, pH, humidity, and availability of an energy source.
- It is relatively simple to culture bacteria in a laboratory under controlled conditions, but outside in changing environmental conditions, the process is more difficult.

Future of Bioremediation

- Biotechnology is establishing a constructive partnership with bioremediation to engineer more efficient microorganisms that are less dependent on environmental conditions.
  - For instance, transferring genes from thermophilic (heat-loving) bacteria to one that can decompose insecticides would allow the transgenic microorganisms to be used in areas in more extreme temperatures.

- Several research groups are now developing genetically modified bacteria that have enhanced capacity for cleaning areas polluted with heavy metals, radioactive elements, chemical fertilizers, insecticides, herbicides, and other toxic elements

Other Bioremediation agents

- The further exploration of microbial diversity is likely to lead to the discovery of many more organisms with unique properties useful in bioremediation

- Different categories of bioremediation agents that can be used:
  1. **Microorganisms (bacteria and fungi)** are nature's original recyclers that able to transform natural and synthetic chemicals into sources of energy and raw materials.
  2. **Plants (Phytoremediation)**: it is an emerging research area where the plants are used to concentrate pollutants.
  3. **Organism dead cells**: the organisms cell walls can be useful in bioremediation technologies (Biobeads).

Plants in Bioremediation-Depolluting

- It was noticed the capability of some plants to absorb heavy metals from polluted soil and water.
- Plants used for bioremediation should mobilize the metal; absorb the metal with its roots; transport the metal from roots to the canopy; and retain the metal in its tissue
- This is what we call it **phytoremediation**

Phytoremediation

- Naturally occurring bioremediation and phytoremediation have been used for centuries (desalination of agricultural land by **phytoextraction**).
- Phytoremediation is useful in cleaning soil from **heavy metals** (such as ***cadmium*** , ***zinc, nickel, chromium lead*** and ***mercury)*** , because natural plants or transgenic plants are able to bioaccumulate these toxins in their above-ground parts, which are then harvested for removal.

Advantages

1. **The low cost**: phytoremediation is lower than that of traditional processes both *in situ* and *ex situ*
2. Can be employed in **inaccessible areas** without excavation
3. The plants can be **easily monitored**
4. The possibility of the **recovery** and re-use of valuable metals (by companies specializing in "***phyto mining***")
5. It is potentially "**the least harmful**" method because it uses naturally occurring organisms and preserves the environment in a more natural state

Phytoextraction

- Naturally occurring bioremediation and phytoremediation have been used for centuries (desalination of agricultural land by **phytoextraction**).
- **Phytoextraction** (or *phytoaccumulation*) uses plants or algae to remove contaminants from soils, sediments or water into harvestable plant biomass (organisms that take larger-than-normal amounts of contaminants from the soil are called **hyperaccumulators**).

Hyperaccumulators

- A hyperaccumulator is a plant capable of growing in soils with very high concentrations of metals , absorbing these metals through their roots, and concentrating extremely high levels of metals in their tissues.
- The plant *Thlaspi caerulescens*, commonly known as **Alpine pennycress** has naturally occurring populations in the UK, Belgium and France.
- These plants, known as **hyperaccumulators**, can take up hundreds or thousands of times more metal in their above ground parts than normal plants.
- *Thlaspi* possess genes that regulate the amount of metals taken up from the soil by roots and deposited at other locations within the plant.

Alpine pennycress doesn't just thrive on soils contaminated with zinc and cadmium it cleans them up by removing the excess metals.

Alpine pennycress (*Thlaspi caerulescens*)

Alpine pennycress has been cited in phytoremediation to have special phytoextractional properties and is known to absorb cadmium with very good results and in certain instances is said to have absorbed zinc as well .

Alpine pennycress doesn't just thrive on soils contaminated with zinc and cadmium it cleans them up by removing the excess metals.

Sunflowers

These plants have the ability to take up large amounts of toxic materials from their environment.

In fact, sunflowers were planted around the Chernobyl region to remove some of the radioactive isotopes released by a nuclear plant meltdown

How Plants Clean Up

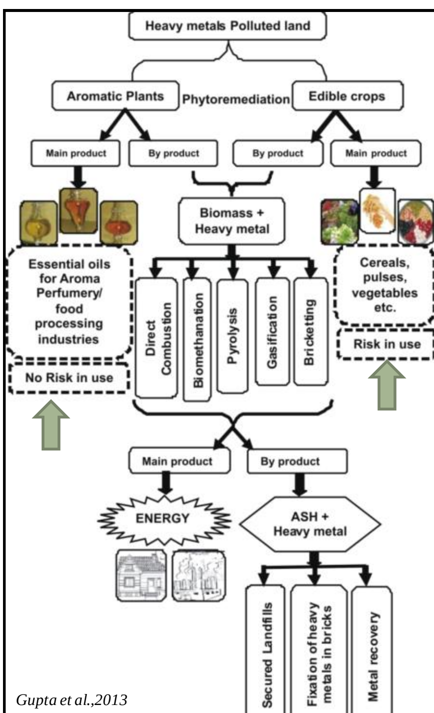
- "Hyperaccumulators like *Thlaspi* are a marvelous model system for elucidating the fundamental mechanisms of —and ultimately the genes that control— **metal hyperaccumulation**"
- "There are a number of sites in the plant that could be controlled by **different genes** contributing to the hyperaccumulation trait".
  - "These genes govern processes that can increase the solubility of metals in the soil surrounding the roots as well as the transport proteins that move metals into root cells.
  - From there, the metals enter the plant's vascular system for further transport to other parts of the plant and are ultimately deposited in leaf cells."

Kochian, 2013

Researches on hyperaccumulator plants

- Plants with such a large accumulation of heavy metals typically produce relatively small amounts of biomass and have no economic value.
- Identification of hyperaccumulator new plant species that having these characters:
  1. a high biomass
  2. a robust growth habit
  3. ability to tolerate and accumulate multiple metals
  4. can take up large amounts of heavy metals
  5. accumulate high concentrations in their above ground tissues
  6. accumulation has no adverse effects on their growth.

Baker et al. 1994; Chaney et al. 1997; Reeves and Baker 2000



Gupta et al.,2013

Candidate plants

- Aromatic plants which are ecologically feasible and viable:
  - Vetiver (*Vetiveria zizanioides*),
  - Palmarosa (*Cymbopogon martinii*),
  - Lemon grass (*Cymbopogon flexuosus*),
  - Citronella (*Cymbopogon winterianus*),
  - Geranium mint (*Mentha* sp.),
  - Tulsi (*Ocimum basilicum*)
- Some aromatic grasses which are stress tolerant and perennial in nature:
  - lemon grass, palmarosa, citronella, vetiver, etc.…

How Plants Clean Up

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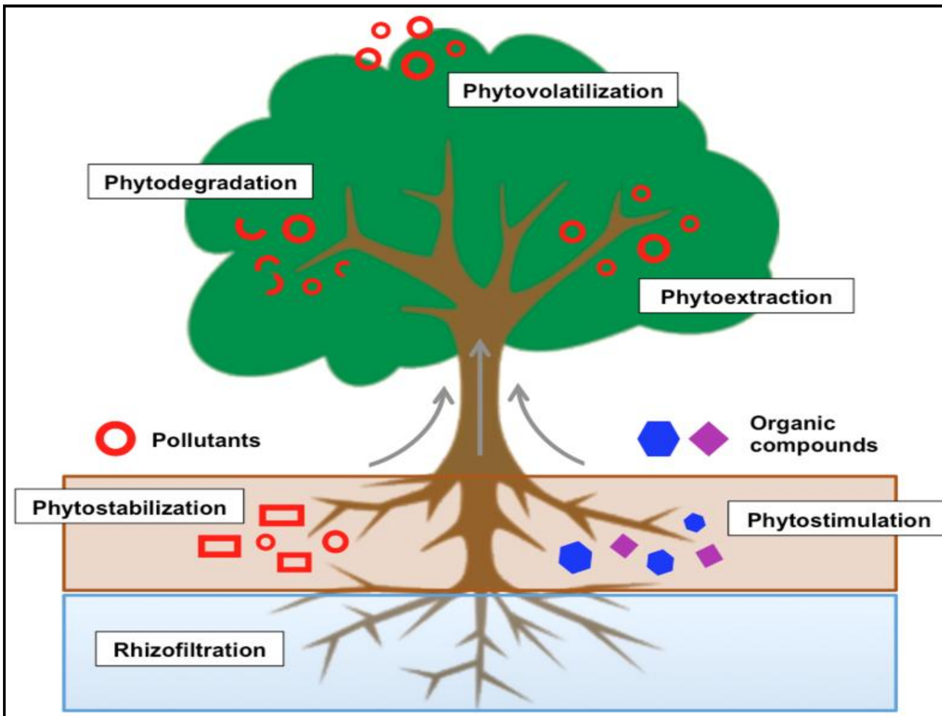

Will Restoration Encourage Further Destruction?

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- There is some concern that ecological restoration could promote further environmental destruction and degradation.
  - Suggesting that any ecological harm can be undone.

- Preventing ecosystem damage is far cheaper than ecological restoration

REMEMBER WHAT FRANK EGLER SAID:

"*Ecosystems are not only more complex than we think, Ecosystems are more complex than we can think*"