FIS 311: AQUATIC FLORA AND FAUNA (2 UNITS)

Ecology

Ecology is the study of environmental systems, or as it is sometimes called, the economy of nature. "Environmental" usually means relating to the natural, versus human-made world; the "systems" means that ecology is, by its very nature, not interested in just the components of nature individually but especially in how the parts interact. Ecology is technically an academic discipline, such asmathematics or physics, although in public or media use, it is often used to connote some sort of normative or evaluative issue as in something is “ecologically bad” or is or is not “good for the ecology”. More properly ecology is used only in the sense that it is an academic discipline, no more evaluative than mathematics or physics. When a normative or evaluative term is needed then it is more proper to use the term “environmental”, i.e., environmental quality or “environmentally degrading”. Most professional ecologists are not terribly unhappy when ecology is used in the normative sense, preferring the wider public awareness of environmental issues today compared to the widespread ignorance of three decades ago.

Utilization of Aquatic Plants

Plants and Breeding Fish

- One of the uses of aquarium plants, both live and artificial, is to encourage the breeding of fish. Many fish, such as tetras (minnow-like fish), practice "egg-scattering." This breeding strategy is exactly what it sounds like: fish lay nonadhesive eggs all over the tank and provide minimal care. In this case, bushy plants can keep the eggs safe from their hungry parents. Similar strategies work with livebearers. Even sophisticated spawners like Bettas use plants; males use them in their bubble nests and females use them for refuge.

Algae Control

- One use of aquarium plants is the control of algae. Plants are basically highly evolved algae, and have the same essential nutritional requirements. However, healthy aquarium plants can do a better job of obtaining nutrients from the water by stripping phosphate

Aesthetics

- The skillful arrangement of aquarium plants can greatly increase the beauty of an aquarium. To achieve the optimal look, arrange larger plants toward the back of a tank and place shorter plants in the foreground. Avoid straight lines of plants and decorations that are parallel to the front of the tank. Lastly - and this takes a little effort to visualize - imagine a tic tac toe grid stretched evenly across the front of your tank. Points of interest should occur where the imaginary lines meet.

Snacks for Fish

- Many fish enjoy plants and algae as a major part of their diet. Cichlids such as Tilapia love plants. A fast-growing plant like duckweed is advisable for such fish, which

More Puppy Pages

How to Feed Duckweed to Tilapia

Duckweed is the common name for plants of the genus Lemna. It is a floating plant found in fresh waters in most temperate and tropical locales in the world. Aquarium hobbyists know it by another word: pest. Duckweed grows quickly, so if it isn't managed...

Duckweed is an aquatic plant that anyone can grow. In fact, it is so easy to grow, that it readily takes over ponds and aquariums unless kept in check. Herbivorous fish, like goldfish and koi, find duckweed a tasty snack, and ducks and geese prefer...

Tilapia, also called St. John's fish, have been raised as a food source since the time of the Egyptians. Tilapia include the tiger, spotted, zebra and Nile varieties. The Nile species remains one of the most available and easy to care for species, often...

Aquatic Plants & Their Predators

Aquatic plants are eaten by turtles and fish. If you want your aquatic plants to thrive you must be careful about the types of creatures that you put in your tank. Some turtles and fish are vegetarians and love munching on plants.

Management of Aquatic Fauna

The notion of sustainable development is sometimes regarded as an unattainable, even illogical notion because development inevitably depletes and degrades the environment.

Ray Hilborn, of the University of Washington, distinguishes three ways of defining a sustainable fishery.

- *Long term constant yield* is the idea that undisturbed nature establishes a steady state that changes little over time. Properly done, fishing at up to maximum sustainable yield allows nature to adjust to a new steady state, without compromising future harvests. However, this view is naive, because constancy is not an attribute of marine ecosystems, which dooms this approach. Stock abundance fluctuates naturally, changing the potential yield over short and long term periods.

- *Preserving intergenerational equity* acknowledges natural fluctuations and regards as unsustainable only practices which damage the genetic structure destroy habitat, or deplete stock levels to the point where rebuilding requires more than a single generation. Providing rebuilding takes only one generation, overfishing may be economically foolish, but it is not unsustainable. This definition is widely accepted.

- *Maintaining a biological, social and economic system* considers the health of the human ecosystem as well as the marine ecosystem. A fishery which rotates among multiple species can deplete individual stocks and still be sustainable so long as the ecosystem retains its intrinsic integrity. Such a definition might consider as sustainable fishing practices that lead to the reduction and possible extinction of some species.

Social sustainability

Fisheries and aquaculture are, directly or indirectly, a source of livelihood for over 500 million people, mostly in developing countries. While biodiversity is important, people need food security.

Social sustainability can conflict with biodiversity. A fishery is socially sustainable if the fishery ecosystem maintains the ability to deliver products the society can use. Major species shifts within the ecosystem could be acceptable as long as the flow of such products continues. Humans have been operating such regimes for thousands of years, transforming many ecosystems, depleting or driving to extinction many species.

According to Hilborn, the "loss of some species, and indeed transformation of the ecosystem is not incompatible with sustainable harvests. For example, in recent years, barndoor skates have been caught as bycatch in the western Atlantic. Their numbers have severely declined and they will probably go extinct if these catch rates continue. Even if the barndoor skate goes extinct, changing the ecosystem, there could still be sustainable fishing of other commercial species.

At the Fourth World Fisheries Congress in 2004, Daniel Pauly asked, "How can fisheries science and conservation biology achieve a reconciliation?", then answered his own question, "By accepting each other’s essentials: that fishing should remain a viable occupation; and that aquatic ecosystems and their biodiversity are allowed to persist."

Overfishing

Overfishing can be sustainable. According to Hilborn, overfishing can be "a misallocation of societies' resources", but it does not necessarily threaten conservation or sustainability".

Overfishing is traditionally defined as harvesting so many fish that the yield is less than it would be if fishing were reduced.[1] For example, Pacific salmon are usually managed by trying to determine how many spawning salmon, called the "escapement", are needed each generation to produce the maximum harvestable surplus. The optimum escapement is that needed to reach that surplus. If the escapement is half the optimum, then normal fishing looks like overfishing. But this is still sustainable fishing, which could continue indefinitely at its reduced stock numbers and yield. There is a wide range of escapement sizes that present no threat that the stock might collapse or that the stock structure might erode.[1]

On the other hand, overfishing can precede severe stock depletion and fishery collapse.[12] Hilborn points out that continuing to exert fishing pressure while production decreases, stock collapses and the fishery fails, is largely "the product of institutional failure."

Today over 70% of fish species are either fully exploited, overexploited, depleted, or recovering from depletion. If overfishing does not decrease, it is predicted that stocks of all species currently commercially fished for will collapse by 2048.

A Hubbert linearization (Hubbert curve) has been applied to the whaling industry, as well as charting the price of caviar, which depends on sturgeon stocks.Another example is North Sea cod. Comparing fisheries and mineral extraction tells us that human pressure on the environment is causing a wide range of resources to go through a Hubbert depletion cycle.

The global continental shelf, highlighted in cyan
See also: Environmental effects of fishing and Destructive fishing practices

Nearly all the world's continental shelves, and large areas of continental slopes, underwater ridges, and seamounts, have had heavy bottom trawls and dredges repeatedly dragged over their surfaces. For fifty years, governments and organizations, such as the Asian Development Bank, have encouraged the fishing industry to develop trawler fleets. Repeated bottom trawling and dredging literally flattens diversity in the benthic habitat, radically changing the associated communities.[17]

Fishing with a lift net in Bangladesh. Coastal fishing communities in Bangladesh are vulnerable to flooding from sea-level rises.[18]
Main article: Fisheries and climate change

Rising ocean temperatures[19] and ocean acidification[20] are radically altering aquatic ecosystems. Climate change is modifying fish distribution[21] and the productivity of marine and freshwater species. This reduces sustainable catch levels across many habitats, puts pressure on resources needed for aquaculture, on the communities that depend on fisheries, and on the oceans' ability to capture and store carbon (biological pump). Sea level rise puts coastal fishing communities at risk, while changing rainfall patterns and water use impact on inland (freshwater) fisheries and aquaculture.

Island with fringing reef in the Maldives. Coral reefs are dying around the world.[22]
Main article: Marine pollution

A recent survey of global ocean health concluded that all parts of the ocean have been impacted by human development and that 41 percent has been fouled with human polluted runoff, overfishing, and other abuses.[23] Pollution is not easy to fix, because pollution sources are so dispersed, and are built into the economic systems we depend on.

The United Nations Environment Programme (UNEP) mapped the impacts of stressors such as climate change, pollution, exotic species, and over-exploitation of resources on the oceans. The report shows at least 75 percent of the world's key fishing grounds may be affected.[24][25][26]

Diseases and toxins

See also: Fish diseases and parasites, Harmful algal blooms, and Mercury in fish

Large predator fish contain significant amounts of mercury, a neurotoxin which can affect fetal development, memory, mental focus, and produce tremors.

Separately, the release of wastewater polluted with microbes, hormones, human and animal medicines and other contaminants can kill fish, reducing sustainable harvests.

Fisheries management

Fisheries management draws on fisheries science to enable sustainable exploitation. Modern fisheries management is often defined as mandatory rules based on concrete objectives and a mix of management techniques, enforced by a monitoring control and surveillance system.

- Ideas and rules: Economist Paul Romer believes sustainable growth is possible providing the right ideas (technology) are combined with the right rules, rather than simply hectoring fishers. There has been no lack of innovative ideas about how to harvest fish. He characterizes failures as primarily failures to apply appropriate rules.

- Fishing subsidies: Government subsidies influence many of the world fisheries. Operating cost subsidies allow European and Asian fishing fleets to fish in distant waters, such as West Africa. Many experts reject fishing subsidies and advocate restructuring incentives globally to help struggling fisheries recover.

- Economics: Another focus of conservationists is on curtailing detrimental human activities by improving fisheries' market structure with techniques such as salable fishing quotas, like those set up by the Northwest Atlantic Fisheries Organization, or laws such as those listed below.

- Sustainable fisheries certification: A promising direction is the independent certification programs for sustainable fisheries conducted by organizations such as the Marine Stewardship Council and Friend of the Sea. These programs work at raising consumer awareness and insight into the nature of their seafood purchases.

V. MANAGEMENT OF AQUATIC WEEDS

Considering the losses caused by aquatic weeds, their management is of utmost importance to improve the availability of water from the source to its end users. This does not only improve availability but also the conveyance efficiency. Irrigation and drainage systems provide favorable conditions for the growth of aquatic weeds which interfere with the storage and delivery systems of irrigation water, maintenance of canals, drains, barrages, lakes, ponds etc. These systems often get choked with the weeds and cause environmental pollution. On low lying areas, adjoining irrigation and drainage channels, soil salinity and alkalinity problems do arise. Management of aquatic weeds consists of two approaches viz. preventive and control of existing infestation.

1. Preventive approaches
2. Control

Type of aquatic weeds flora and their intensity influence the damage caused by them. The habitat and the type of aquatic weed flora influences the technique of weed control. In broader sense, weed "control" means keeping the weeds at a level where they do not cause economic damage. Aquatic weed can be brought under control to manageable limits by various methods. Broadly, these methods can be grouped under four groups: -

(1) Physical or Mechanical methods
(2) Biological methods
(3) Chemical methods, and
(4) Cultural and physiological methods

There is rarely a situation when weeds can be 'eradicated' but often can be 'prevented' from infesting other areas. Prevention can be useful for a certain weed species or may include a group of aquatic weeds in a given aquatic environment. Once prevention fails the next step is to eradicate it, i.e., treating them in a way that they do not emerge again.

PREVENTIVE APPROACHES

Quarantines are legislative tools that may be used to mitigate the effect of weeds. Quarantine is defined as the restriction imposed by duly constituted authorities whereby the production, movement or existence of plants, plant products, animals, animal products, any other article or material or the normal activity of persons is brought under regulation in order that introduction or spread of a pest may be prevented or restricted. If a pest has already been introduced and established in a small area, a quarantine is necessary so that it may be controlled or eradicated or dissemination stopped in newer areas, thereby reducing the losses that would other wise occur through damage done by pest (Sand, 1987). The success of preventive weed management programs varies with weed species, its biology, means of dissemination and the amount of effort needed to be applied. Preventive weed programs usually require community action through enactment and enforcement of appropriate laws and regulations (Day, 1972).

It was found that the irrigation water in Nebraska was the significant source of weed seeds (Aldrich, 1984). In India, irrigation canals appear to be a potential source for spreading water hyacinth (Sushil Kumar and Bhan, 1994). Recently preventive weed management approach has been reviewed and discussed by Walker (1995). When prevention and eradication fail to give desired results under aquatic environment, the only alternative left is to keep aquatic weeds under manageable limits so that water use efficiency with respect of water storage in reservoirs and transportation through canals is not reduced. Management of aquatic weeds in water reservoirs, canals, drainage systems, ponds etc. consists of following systems approach of aquatic weed management i.e., following prevention, eradication and control techniques based on the habitat and type of weed flora present in a given situation. These situations may result in serious reduction in water flow in irrigation and drainage systems which may result in flooding, salinity and alkalinity. Under specific situations it may adversely influence navigation and operation of turbines in hydro electric projects.

CONTROL OF AQUATIC WEEDS IN PONDS

Physical or mechanical control methods

a) **Mechanical Control of aquatic weeds**:

Mechanical control of aquatic weeds primarily consists of removing the weeds of any group physically from the water body. It may also involve any physical power which may directly or indirectly inhibit the growth and development of aquatic weeds. This could be done manually by hand, using hand tools or machine power. It may also consist of altering the environment or creating conditions/situations which may inhibit or do not permit growth and development of weeds.

The advantages of mechanical methods include- utilization of available manpower resources, environmental friendly and target specific, yields immediate results, non selective (under specific situations) and provides fewer chances of permitting ecological shifts in aquatic flora. Mechanical methods often reduce massive nutrient load of eutropic water bodies, helping indirectly in diminishing the future weed population. Harvested weeds may have various utilities such as feed, manure, energy source etc. and most importantly mechanical methods can be exercised in any localized area of water bodies. The limitations include limited effectiveness as in some cases aquatic weed regrow up from their rootstocks, rhizomes and the like; physical removal especially with machines may help spreading weeds to new areas; and sometimes removal of aquatic weeds may deplete water bodies of their nutrients limiting growth of plantation. A vegetation survey of Pening Lake in 1989 revealed the presence of 4 submerged and rooted species, 6 emergent species and 10 floating species. The most common aquatic plant, which occupied 410 ha of the fluctuating lake area of 1760-2770 ha in 1988, was water hyacinth (*Eichhornia crassipes*), followed by *Hydrilla verticilatta, Salvinia molesta* and *Mimosa pigra*. Two potentially noxious weeds were recorded in the lake for the first time. Two trials were conducted in 1988 and 1989, during which 14 ha and 30.8 ha respectively of *E. crassipes* were manually removed from the lake and left to decompose on dryland (Tjitrosoedirdjo, 1991).

23 Controlling weeds in an aquatic environment is greatly complicated because of lack of ownership of waterbodies. Most of these are places of public interest. Often frequent approvals are needed from public health Dept., water surveyor, fish and other wildlife agencies before weed control works may be carried out. In many developing and under developed countries there is no control on water use. In many Asian countries a water body can be used for a number of purposes including bathing, drinking, stock watering and irrigation.

b) **Manual Cleaning**:

In areas sparsely infested, weeds can be removed by hand. This could apply to the removal of floating weeds like water hyacinth. Generally, this method is applied to emergent weeds eg. *Typha spp*.,*Phragmites spp., Justicia spp*. (Willow), where men cut the vegetative growth with heavy knives and hooks. In shallow water the propagules, rhizomes and other underground reproductive organs can be removed.

c) **Cutting**:

This method consists of physically cutting the biomass over and under the water with the help of heavy knives, or mechanical weed cutters. In the case of *Typha*, it has been observed that if plants are cut under the water and remain submerged for more than a week to 10 days, control is possible This may also hold good for *Phragmites, spp*. Also mechanical cutting of water hyacinth and other submersed aquatic weeds like *Chara spp*. Filamentous *algae*, *Potamogeton* spp. will give temporary relief from weed infestations A mechanical weed cutter is used to cut floating and submersed weed at 1-1.5 m depth in water reservoirs. It consists of sharp cutter bar and operates from a boat. The harvested weeds are collected and water is squeezed from them to hasten dehydration and desiccation.

d) **Chaining**:
Chaining consists of a heavy iron dragchain attached between two tractors, which is dragged down a densely weed infested ditch or medium canal. The chain tears the rooted weeds and loosen them from the bottom. This method has been found effective where there is dominance of emergent and submersed weeds. The practice of chaining should be followed when new shoots of weed are around 30-50cm above water level. Dragging the chain up and down the stream may be effective in dislodging most of the weeds. For effective weed control the practice should be repeated at frequent intervals if found successful. One of the limitations of this method is that ditches need to have uniform width, accessible from both the sides with tractors and free from trees and other such obstructions. The debris thus collected at the end should be removed to avoid reinfestation by plant proagules further downstream

e) **Water weed cutters and harvesters**:
In high discharge canals and very large water bodies weed cutters/harvesters are used to control rooted submerged weeds.
i) Under water cutters: These are normally attached to a motorboat. The equipment consists of sharp and strong cutter bars with heavy reciprocating blades, sliding against a fixed blade.
ii) Harvesters: Machine that cut and picks up the weeds from water body and convey these to shore simultaneously. Under water weed cutters were employed at Kota (India) to clear Chambal canal from aquatic weeds (Gupta, 1973). At the Central Institute of Fisheries Technology (CIFT), a portable machine gadget has been developed which can clear both floating and submersed weeds at the rate of 1-1.5 ha area per day (Mukhopadhyay, 1995).

f) **Dredging**:
Dredging is one of the techniques by which the weed vegetation along with excess silt is removed from drains and ditches. A Dredger is a machine equipped with a forked bucket which can be opened and closed on command. The machine could operate from the ground or from a boat in water. Dredging is done in large water bodies, canals and drains. It is a common method of cleaning ditches but slow, time consuming and is a costly operation. Small lakes, water reservoirs etc. get silted if area surrounding them is under cultivation or surrounded by erodable lands with poor aforestation. When silts gets sedimented at bottom the water retention gets decreased and emergent weeds (*Typha, Scirpus* spp. etc.) establish. Such a situation demands the use of dredging facilities to remove silt and increase the water capacity of lakes. This also reduces the problem of emergent weeds. Fig.7. Dredging essentially meant for desilting along shores also helps in removal of aquatic weed vegetation

g**) Mowing**

This process consists of cutting the weeds close to the ground with the help of manual or power operated mowing machines. Mowing is effective on tall growing plants. Repeated mowing not only prevents seed production of emergent weeds but may also starve the under ground parts which store carbohydrate reserves and provides energy to vegetative reproductive organs. The best time to mow is when carbohydrate reserves are low. For many species it is when the active growth phase is over and the time of flowering initiation starts. Repeated mowing hastens carbohydrate depletion and slow death of plants. Generally, this practice effectively controls emergent weeds on canals, water reservoirs etc banks. Where gradient in ditches is smooth and not too steep the under water cutters can be used to control emergent and submerged weeds. The effect of mowing is short lived. The operation needs to be done frequently to exhaust carbohydrate resources. Therefore this process does not give any effective control on long term basis. Pasturing is the economical and effective way in controlling marginal grasses, weeds etc. A good legume grass mixture if properly managed and grazed will give a lawn like appearance. A good sod shall also protect banks of canals, drains and dams against erosion Excessive movement of animals may destroy the banks and make water muddy and may also degrade the quality of the water.

h) Netting:
Scattered floating weeds can be skimmed out of small water bodies using nets usually made of 3 mesh coir ropes.
i) Barriers:
Bamboo or inflatable rubber boom fencing is used to restrain the drift of free floating aquatic weeds. The barriers are made to allow water to pass through them and to sustain the wave and wind action.

j) Checking weeds seeds through irrigation water:
Irrigation water often carries the seeds of aquatic weeds such as *Eichhornia crassipes, Pistia stratiotes* and *Salvinia molesta*. It is important to control weeds near and in reservoirs and irrigation canals to prevent them form shedding seeds into the water. Weed seeds can be collected by screens and removed from the source of supply. The screens should be made of woven plastic cloth of less then 1.0 mm mesh supported on rigid metal 1.5 cm screens. Allowing a square meter of screen for each 0.05 m3 per second of water flow with the fine screen tightly stretched to encourage vibration and self cleaning as water falls on it. Fig.8. Lining of canals helps in reducing weed vegetation (Yamuna Canal Haryana, India).

k) Burning/Fire/Heat treatment:
Aquatic weeds especially emergent bank weeds can also be brought under control with the help of fire. The general thermal death point of most of the weeds is in between 45-550C. Higher temperature treatment than this results in coagulation of cell protoplasm which inactivates the enzymic process resulting in the death of the plant. The heat treatment required for weed control is provided with the help of fire through flame throwers. Burning may be used to control bank weeds in irrigation canals, ditches etc. Usually green plants are also given preliminary shearing and after two to three weeks vegetation may be dry enough to be successfully re-burnt. Burning can be combined with herbicides and mowing to increase its efficiency. Often mowing followed by burning or burning followed by herbicide application on regrowth will help the efficacy of each other treatment.

Eco-physiological alterations:

a) **Drying or water level manipulations:**

This method is a simple and effective way of controlling submerged weeds. Most of the aquatic weeds respond quickly to changes in water level. Control is achieved by either dehydration of the vegetation or by exposure to low temperatures. In tanks, fish ponds and canals emptying the water periodically to kill the weeds susceptible to desiccation is practiced. To kill submersed weeds in the canals of Bhakra Canal System in Haryana (India) (Malhotra, 1976) and in Chambal Command Area (India) in Rajasthan (Brezney, 1970) exposure to sun is given by draining the water and this practice prevents regrowth for nearly six months. Cutting of the aerial shoots of *Typha spp.* at flowering stage and keeping the stubble submerged under the water for four weeks controlled *Typha* (Singh, 1976). Under such cases, there may be disadvantages in lowering the water level as it may induce production of vegetative propagules or sexual reproduction. Therefore, in such cases, weeds should be removed quickly and the sediments should be dried completely. Planting of trees on the banks of canals may create shade to reduce light intensity hence checking the weed growth. However care should be taken that trees or their appendages do not impede. water flow. Light intensity can also be checked by adding dyes to the water. This type of control is more effective in static water such as ponds or tanks where dye remain suspended for a longer time. Drying or water level manipulation is generally practiced in flowing water system like irrigation canals, drainage ditches. In some cases where facilities exists, in tanks and ponds. During the process the water is removed and the base of the tanks, canals etc. is made dry by exposing the land to sun & air. This totally changes the eco environment, which is very adverse to the eco-environment required for growth and development of submerged weeds. Frequent drying and wetting for several days may control the growth of roots and propagules in the bottom soil. This method is not effective for control of emergent weeds. The Irrigation and Power Research Institute, Amritser (India) has developed a weed cutter operative from banks of the canals (Singh et.al. 1987). Thereafter, applied drying method i.e., plants were exposed to the sunlight for 7 days by affecting closure in canals. Following the exposure water was delivered for 2 weeks. Four such cycles were necessary. The weeds were disintegrated after the fourth cycle. This method has the limitation of alternate closure and operation of the canals.

b) **Light**:

Light is an essential component of the photosynthetic process, which is necessary for the growth and development of aquatic plants, especially submersed aquatic weeds. Growth of submerged aquatic plants in small tanks and ponds can be checked by reducing light penetration . Use of fiber glass screen is popular in some countries. Coloring chemicals have also been tried for intercepting solar radiation reaching the water.

Ponds that are adequately fertilized develop millions of tiny plants which give the water a cloudy appearance (bloom). If this water is nearly 75 cm deep, submerged aquatic weeds have almost no chance to grow (KLINGMAN, 1961). This is due primarily to shading the submerged plants.

A 8-8-8 or similar fertilizer is suggested at about 150 kg/ha. A light colored object should not be visible at around 50 cm below the surface. This practice should be followed where there is little loss of water from the pond. Some object to it as unclean water but that is not the case. The bloom induced by fertilizer application is not considered as bad for health.

The proper construction of a tank is very important for controlling pond weeds. Many rooted aquatic plants do not establish in deep water. Therefore tanks should generally be deeper than 1m. The slope, at the bank should not be more than 2m i.e. the angle of slope should be steep i.e.

around 3:1 and this will help in reducing the area where infestations of *Typha, rushes* and *sedges* could establish. This may be dangerous for access but flatter separate slopes can be provided at one or two location in the pond for general access. In an experiment conducted at Irrigation and Power Research Institute of Amritser (India) in small plastic trough of 45cm dia meter and 22.5 cm height with silt added at base for little more than 7.5cm. The weeds were transplanted and allowed to stabilize. Nutrition was provided through well decomposed Farm Yard Manure. When new sprouts started emerging, the polyethylene film was used to cover troughs for 1,2,3,4,5 i.e. up to 15 days the leaves started falling after six days.

c) **Breaking of anchorage**:

Submerged aquatic weeds can only survive if there is optimum sunlight. In shallow water, optimum light may penetrate to the bed level allowing plants to anchor and take root at the base of the distributary, water course, shallow pond etc. In case of canals, barrages, tanks with deeper water levels, the light may not reach the bed level. Under such situation weeds may form anchorage on the inside banks of the irrigation system. In an experiment conducted at Nirwan Branch near Patiala (India). A canal was heavily infested with submerged weeds. Divers cleared the bed of weed. Thereafter a plough was lowered in the canal along with wooden floats which were connected with a tractor and pulled upstream of canal. However no weed could be brought out from the bed. It is important to check where the weeds are anchored and growing from so that they can be successfully managed. Alternatively side walls may be covered with colored polyethylene to exclude all light penetration and facilitate early decomposition of the plant materials.

d) **Sub-mergence**:

Typha is one of the most important emergent weed growing all along the unlined canals margins of the water bodies and shallow submersed area s along canals. Cutting *Typha* close to the ground followed by subsequent submergence or cutting *Typha* under the water provides effective control of this weed.

e) **Competitive displacement**:

The approach of replacing harmful vegetation by relatively less harmful and beneficial vegetation needs more research. Planting of Paragrass (*Brachiaria mutica*) in drainage ditches in the Chambal Irrigation Project eliminated *Typha angustata* after 10 to 12 months and yielded green fodder (Mehta and Sharma, 1975). Besides direct competition, growth is also suppressed by some plants by shading effect. For example, the growth of *Azolla* in rice fields effectively controls the growth of other weeds.

Biological control of weeds:

Biological management of aquatic weeds is a broad term for the exploitation of living organisms or their products to reduce or prevent the growth and reproduction of weeds. The organisms that are used for biological control are diverse e.g. insects, pathogens, nematodes, parastic and competing plants Biological control involves the deliberate use of organisms such as insects or fungi to control weeds. Biological control is more complex than chemical control because it requires (a) long term planning (b) multiple tactics and (c) manipulation of cropping system to interact with the environment. Julien (1989) has attempted to work out the total releases made against weeds by biological agents. He found that after 13 releases of agents for classical control of weeds in the first decade of this century, the number of releases per decade increased nearly exponentially. The rate of effectiveness declined from 29% of all releases up to 1980 to 25% of all releases up to 1985. The various approaches of biological control are briefly discussed as below:

i) **Biocontrol agents**:
Owing to the increasing awareness about ill effects of herbicides and no control on use of water, lately emphasis is being given to research for non-chemical approaches. Biological control is considered to be one of the most safest approaches. Any plant feeding organism may be used to control aquatic weeds provided, it does not harm plants of economic value or create undesirable imbalances in the plant community. Some of the natural enemies have been considered for control of submersed, floating and emergent weeds.
ii) **Pathogens**:
Weeds can be controlled by pathogens like fungi, bacteria, virus and virus like agents. Among the class of pathogens, fungi has been used to a larger extent than bacterial, viral and nematode pathogens. In some cases, it has been possible to isolate, culture, formulate and disseminate fungal propagules as mycoherbicides. Several books and reviews detail the history, development prospects and technical aspects of the use of plant pathogens (Julien, 1992). Pathogens may have many advantages like (i) most pathogens of plants are fungi (ii) they are destructive (iii) they are widely prevalent (iv) most of them can be easily mass cultured, and, (v) they can be integrated into organized pest management systems. Most specificity is the fundamental feature. Pathogens with broad host range are unsuitable simply because they may attack the cultivated plants. Formulations of fungi applied as inundative inoculum in a manner similar to that of chemical herbicides have been termed “myco-herbicides”. It involves mass-culturing, standardization, formulation and application of fungi inoculum to weeds. Already two mycoherbicides have been registered in USA for use as herbicides. They are De-Vine and Collego.
iii) **Use of aquatic mammals and rodents**:
Introduction of Manatee (*Trichechus inunguis*), and the rodent *Coypus* (*Myocastou coypus*) both known to feed on aquatic vegetation had earlier been suggested as possible biocontrol agents against aquatic weeds, but the slow reproductive rate of the former and the omnivorous feeding of the latter have discarded their trials.
iv) **Use of fish**:
Hickling (1965) has dealt in detail the use of fish in biological control of aquatic vegetation. Among the several species of herbivorus fishes which feed on aquatic weeds, the more important are ; *Tilapia melanoplaura; T. zilli; T nilotica;* and *Puntiase gonianatus*. Verigin (1963) tried *T. Zilli* in the cooling ponds of a power station in Moscow and found it to be a great consumer of weed *Vallisneria*, but this fish cannot survive below 55oF. The Russians who consider fish as more valuable and more permanent agent for weed control than mechanical or chemical, are using the grass carp *Clenopharyngodon idella* and *Hypophthal michthys molitrix*. The former is said to be the more effective species. It feeds on a wide range of aquatic weeds such as (*Potamogeton*; *Lemna; Ceratophyllum; Elodea; Hydrocharis*; *Vallisneria*; and *Myriophyllum)*. The *C. idella* fish has been employed for weed control in China, Hungary and Japan and has shown promise in other regions. It feeds on a range of submerged and floating weeds, but prefers plants having soft tissues. Its rate of growth and development varies with the source of food. The white amur displays good performance in high and low temperatures and is not known to reproduce naturally outside its native water.
Grass carp (Ctenopharyngodon idella), voracious feeder of submerged aquatic weeds Spencer (1994) used a computer program to simulate the growth of *Potamogeton pectinatus* and plant consumption by the herbivorous fish *Ctenopharyngodon idella* (triploid grass carp) under environmental conditions of Northern California Irrigation System. The program was executed using several initial fish densities ranging form 0 to 300 kg fish/ha. It was concluded that for

temperature of 12-24o C would require more fish (50 or 250 kg vegetated/ha). It is also concluded that *C. idella* may be an effective and economically feasible option for *P. petinatus* control in cool water irrigation systems. Santha et.al. (1994) studied the control of the submersed weeds in water lily production ponds in Georgia USA, under enclosed condition. Complete control of *Hydrilla; Myriophyllum*; *Ceratophyllum, Utricularia* and *Najas* was observed at 1 and 2 fish (triploid grass carp) per enclosure. When weeds were controlled, there was some damage to water lilies in 2 of the enclosures.

In a study testing the preference of grass carp (triploid) on submersed aquatic weeds; Pine and Anderson, (1991) based on experimental value triploid grass carp preference was determined as *Potamogeton pectinatus* > *Chara* > *Myriophyllum spicatum*. A filamentous alga *Cladophora sp*. disappeared the area not surrounded by enclosure 9 months after fish introduction. The efficiency of controlling *Hydrilla verticillata* using grass carp was studied in three trials during 1993-94 in Costa Rica (Rojas and Aguero, 1996). 987 kg/ha of grass carp reduced *H. verticillata* biomass in nearly 62 m3 with in 21 days. In another trial 1264 and 2042 kg/ha of the fish completely eliminated the weed after 30 days. In third case 1000 kg/ha of carp only reduced *H. verticillata* volume in 19 m3 after 66 days. The ration of kg of carp initial volume of *H. verticillata* was more important than kg/ha of carp. When this was <0.02, the carp did not satisfactorily control *H. verticillata,* while ratio of >0.05 resulted in the significant reduction of the weed. The equilibrium point between weed regrowth and biomass consumed by the carp occurred at a ratio close to 0.03. Jhingran (1968) reported grass carp to feed voraciously on *Hydrilla, Azolla, Nechamandra* and *Lemna spp*. In India. Ponds choked with *Hydrilla* have been cleared within a month by stocking 300 to 375 grass carps (weighing 78 to 173 kg per hectare.) White Amur is a poor breeder in the warm water, therefore, for weed control purposes it is bred artificially and released in the water when fingerling are 100g each. About 1500 fingerlings must be released per hectare area of water. Fry and fingerlings of the carp are being distributed to different states in India by Central Inland Fisheries Research Institute, Barrackpore,

v) **Use of Snails**:

Promising results have also been obtained utilizing snails *Pomade canaliculata Lamer*, against the aquatic weed, *Anachaares alensa* in Brazil and *Marisa cornuarietis* in Florida (Seaman and Porterfield, 1964). Good results have also been observed against aquatic weeds like *Ceratophyllum demersum, Najas guadalupensis* and *Potamogeton illinoensis* which were controlled completely. *Pistia stratoites* and *Alternanthera philoxeroides* were partially controlled while *Eichhornia crassipes* was not completely eaten but its growth and flowering were greatly retarded by root pruning action of the snail. The snail *Marisa cornuarietis* feeds on a number of aquatic plants and was considered to have weed control potential. However, its usefulness was limited because of its ability to feed on young rice plants and poor tolerance to water temperature below 10oC. On the other hand, its ability to destroy the breeding sites of the snail vector of *bilharzia* may allow its introduction in non rice areas. *Pomacea australis*, a South American snail is also being considered for weed control.

vi) **Use of insects**:

Water hyacinth (*Eichhornia crassipes*) remains the world's most important aquatic weed. It is spreading at an alarming rate in Africa and Papua New Guinea and is a major problem in the Indian Subcontinent and South-East Asia. Successful biological control can significantly reduce this weed cover in 3 to 10 years after establishment of an agent and has achieved excellent control in number of countries. (Julien et.al., 1996). The use of curculionid *Neochetina bruchi* for controlling water hyacinth was investigated in Karnataka (India) in 1984. Between February and July, a total of 7 releases consisting of 1700 beetles was made into a 20 ha tank fully infested with water hyacinth. Releases were than confirmed to an area of about 1 ha and observations on establishment and dispersal of the beetle were made at 2 month interval. By March 1985, up to 5 adults were present per plant in the release area, and the insects had started dispersing to other parts of the tank. The beetle was present throughout the tank by Sept. 1985. By September 1987, about 90% control of water hyacinth had been achieved and the remaining plants were stunted with reduced vigor The curculionid coexists with *N. eichhorniae* which was also released in India from USA for biological control of this weed (Jayanth, 1988). Over 7500 adults of *Neohydronmus affinis* were released in Florida between April 1987 and July 1988 for biological control of *Pistia stratiotes*. Periodic observations from June 1987 to Sept. 1988 indicated establishment and dispersal of bioagent. At some sites, *N. affinis* infested plants exhibited symptoms typical of plants in other countries where *N. affinis* has been used successfully to control this weed (Day et.al., 1990). The potential of North American aquatic weevil *Euhrychiopsis lecontei* to serve as a bioagent for an exotic weed *Myriophyllum spicatum* which is currently found throughout USA and Southern provinces of Canada was evaluated. This weevil was found on *M. spicatum* in lakes where population of the exotic weed have declined.