BIODIVERSITY AND IMPORTANCE OF FLOATING WEEDS OF DARA ISMAIL, KHAN DISTRICT OF KPK, PAKISTAN

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Abstract

The present paper is based on the results of taxonomic research work conducted in Dera Ismail Khan District of KPK, Pakistan, during 2005 - 2007. The area was extensively surveyed in order to collect floating aquatic weeds. From the study area 11 floating aquatic weed species belonging to 9 genera and 9 families were collected and identified in the light of available literature. These plants include Bryophytes: 1 species, *Ricciocarpus natans* (L.) Corda; Pteridophytes: 2 species, *Azolla pinnata* R.Br. and *Marselia quadrifolia* L., and Spermatophytes: 8 species, *Lemna aequinoctialis* Welw., *L. gibba* L., *Marselia quadrifoliata* L. *Nelumbo nucifera* Gaerth., *Nymphoides cristata* (Roxb.) O. Ketze. *Nymphoides indica* (L.) Kuntze:, *Pistia stratiotes* L. *Potamogeton nodosus* Poiret and *Spirodela polyrrhiza* (L.) Schleid. Floating weeds on one hand cause serious problems and on the other hand they are used for various purposes. Data inventory consists of botanical name, family, major group, habit and habitat, flowering period, availability, distribution in D.I.Khan, Pakistan and world, beneficial and harmful effects. Key to the floating aquatic species of the area was developed for easy and correct identification and differentiation.

Key words: Biodiversity, Floating aquatic weeds, Dera Ismail Khan, Pakistan.

Introduction

Aquatic weeds are those unabated plants which grow and complete their life cycle in water and cause harm to aquatic environment directly and to related eco-environment relatively. Water is one of the most important natural resources and in fact basis of all life forms on earth (Lancar and Krake, 2002). Aquatic plants vary greatly in type, with some being quite similar to common land plants while others are quite different. They fall into one of four common class types: algae, floating plants, submerged plants and emerged plants. Grouping is based on the positioning of their roots and leaves (Lichtenstein, 2010). Floating aquatic weeds vary in size from single cell (algae) and may grow up to large vascular plants (Lancar and Krake, 2002). They can be found in fresh or salt water. The leaves of these plants are firm and remain flat in order to absorb more sunlight. (Lichtenstein, 2010)

A diversity of aquatic plants is necessary in water- ways for preventing excessive erosion and turbidity, and for maintaining the delicate nutrient balance in water, hydro-soil and plants. Pond side vegetation provides habitat for water fowl, cover for certain species of fish, and increases the density of planktons, the basis of fish production.

On the other hand, aquatic weeds present a world-wide problem. Such weeds invade aquatic habitats used by man for irrigation, transportation, recreation, drinking and other public purposes. They clog drainage ditches, obstruct navigation channels, limit fishing and boating, provide breeding places for insects and other pests, cause settlement of sediment and present many other problems (Ahmad and Younus, 1979).

Dera Ismail Khan (D.I.Khan) is the southern most district of Khyber Pukhtun Khwa (K.P.K.) lying between 31.15' and 32.32' north latitude and 70.11' and 71.20' east longitude with an elevation of 173 meters from the sea level. It has a total geographical land of 0.896 million hectares out of which 0.300 m.ha. is cultivated (Khan, 2003). The climate is continental with marked temperature fluctuations both seasonal and diurnal, with significant aridity. January is the coldest month of the year and July the hottest. The mean maximum and minimum temperatures during winter are 20.3°C and 4.2°C respectively, compared to 42°C and 27°C during summer. Average annual rainfall is 259 mm (Anonymous, 1998).

Materials and Methods

The research area (D.I.Khan District) was extensively surveyed from 2005 to 2007. Plants specimens were collected at least two times from 15 sites comprising Chashma lake, Badari Dam (at khisore range), Dara Zinda stream, Paharpur sewerage canal, Awaran canal, irrigation channels near Ara, Mandra Kalan, Paharpur and Rangpur Adda, ponds near Bilot Sharif, Dhakki Mor, Basti Dapanwala and Darya Khan Bridge and Baloch Nagar and water spur near Qureshi Mor. The specimens were carefully washed, preserved by using standard herbarium techniques. The following data were recorded in the field i.e. date of collection, collection number, habitat, flowering season and distribution. The collected material was identified

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by using voucher specimens of the herbarium (ISL), dissecting light microscope (Zeis-2000). In major identifications were made with the help of literature such as Jafri (1966); Stewart (1972); Beg and Samad (1974); Qaiser (1977, 1993); Ahmed and Younis (1979); Nazir and Younis (1979); Leghari et al. (1999); Leghari (2004). After correct identification the plants were given voucher numbers and deposited in the herbarium, Department of Plant sciences, Quaid-i-Azam University, Islamabad. Detailed morphological features of each species were compiled.

KEY TO THE FLOATING AQUATIC PLANT SPECIES

1. +Plants flowering ---------- 2
- Plants non-flowering ----------9

2. +Leaves tufted. Plants float freely on the surface of water----------3
- Leaves not tufted. ----------6

3. +Plants with a rosette of leaves, forming a cup shaped structure-----**8.** ***Pistia stratiotes***
- Plants without a rosette of leaves, very small, in the form of fronds. ----------4

4. +Root solitary on each frond. ----------5
- Roots 2-18, never solitary----------**11.** ***Spirodela polyrrhiza***

5. +Frond gibbous beneath; air spaces often larger than 0.3 mm----------**3.** ***Lemna gibba***
- Frond flat beneath; air spaces smaller than 0.3 mm----------**2.** ***Lemna aequinoctialis***

6. +Leaves orbicular, cordate at the base 4 – 70 x 3 – 70 cm----------7
- Leaves not orbicular, elliptic-oblong. 4-16 x 2-5 cm---------**9.** ***Potamogeton nodosus***

7. +Flowers 10-25cm. in diameter; fruits embedded in spongy torus. ----------
----------**5.** ***Nelumbo nucifera***
- Flowers 0.8 – 4.5 cm in diameter; fruiting torus is absent----------8

8. +Flowers 3.5- 4.5 cm in diameter; petals have unusual feathery edges.----------
----------**7.** ***Nymphoides indica***
- Flowers about 0.8 cm in diameter; petals have no feathery edges.----------
----------**6.** ***Nymphoides cristata***

9. +Plant free floating, not rooted in the bed----------10
- Plants fixed, rooted in the bed with floating leaves above the surface----------
----------**4.** ***Marsilea quadrifoliata***

10. +Thallus green lower surface bearing toothed, ribbon-shaped scales----------
----------……**10** ***Ricciocarpa natans***
- Stem branched, roots few, fibrous----------**1.** ***Azolla pinnata***

Results and Discussion

As a result of a detailed taxonomic research work, conducted during 2005–2007 in D.I.Khan District, 11 floating aquatic plant species belonging to 9 genera of 9 families were collected. These plants include 1 species [*Ricciocarpus natans* (L.) Corda] of Bryophyta; 2 species [*Azolla pinnata* R.Br. and *Marselia quadrifolia* L.] of Pteridophyta, and 8 species of Spermatophyta [*Lemna aequinoctialis* Welw. , *Lemna gibba* L., *Nelumbo nucifera* Gaerth., *Nymphoides cristata* (Roxb.) O. Ketze. *Nymphoides indica* (L.) Kuntze:, *Pistia stratiotes* L. *Potamogeton nodosus* Poiret and *Spirodela polyrrhiza* (L.) Schleid]. Data inventory consists of botanical name, family, major group, habit and habitat, flowering period, availability, distribution in D.I.Khan, Pakistan and world, beneficial and harmful effects (Tables 1– 4). Key to the aquatic floating species of the area was developed for easy and correct identification and differentiation. Photographs of 8 plants have been presented in fig.1 and 2 (plates A–J).

Aquatic weeds create situations which are ideal for mosquito growth. The mosquitoes are sheltered and protected from their predators by aquatic weed roots and leafy growth and are responsible for the spread of Malaria, Yellow fever, river blindness and encephalitis. Snails are able to multiply, playing a crucial role in the life-cycle of blood and liver flukes (parasitic worms) as they shelter, and find sustenance among the root zones. Schistosomiasis and fuscioliasis diseases spread as the floating weed carry the snails to new locations. People living close to these areas complain of mosquito problems. Fish production is greatly affected by the presence of floating and submerged aquatic weeds. Isolated weed beds may be tolerated, providing shelter and shade for fish, but when the growth becomes thick and covers entire water body, it can be lethal for fish growth. Fish may suffocate from a lack of oxygen and it may cause death. When floating and submerged aquatic weeds become extremely dense, many fish species are unable to exist in such environments and vanish (Lancar and Krake, 2002).

Genus Azolla is a fern comprising 7 species which are almost cosmopolitan in distribution (Lumpkin, 2010). In different situations Azolla is considered to be an undesirable weed or a beneficial plant (Cook et al., 1974). 1 species *Azolla*

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pinnata is commonly found in D.I.Khan District. It is free floating, heterosporous. It has few fibrous roots. Stem with many crowded branches; the whole plant appears to be triangular in shape (Ahmad and younus, 1979). It harbours symbiotic

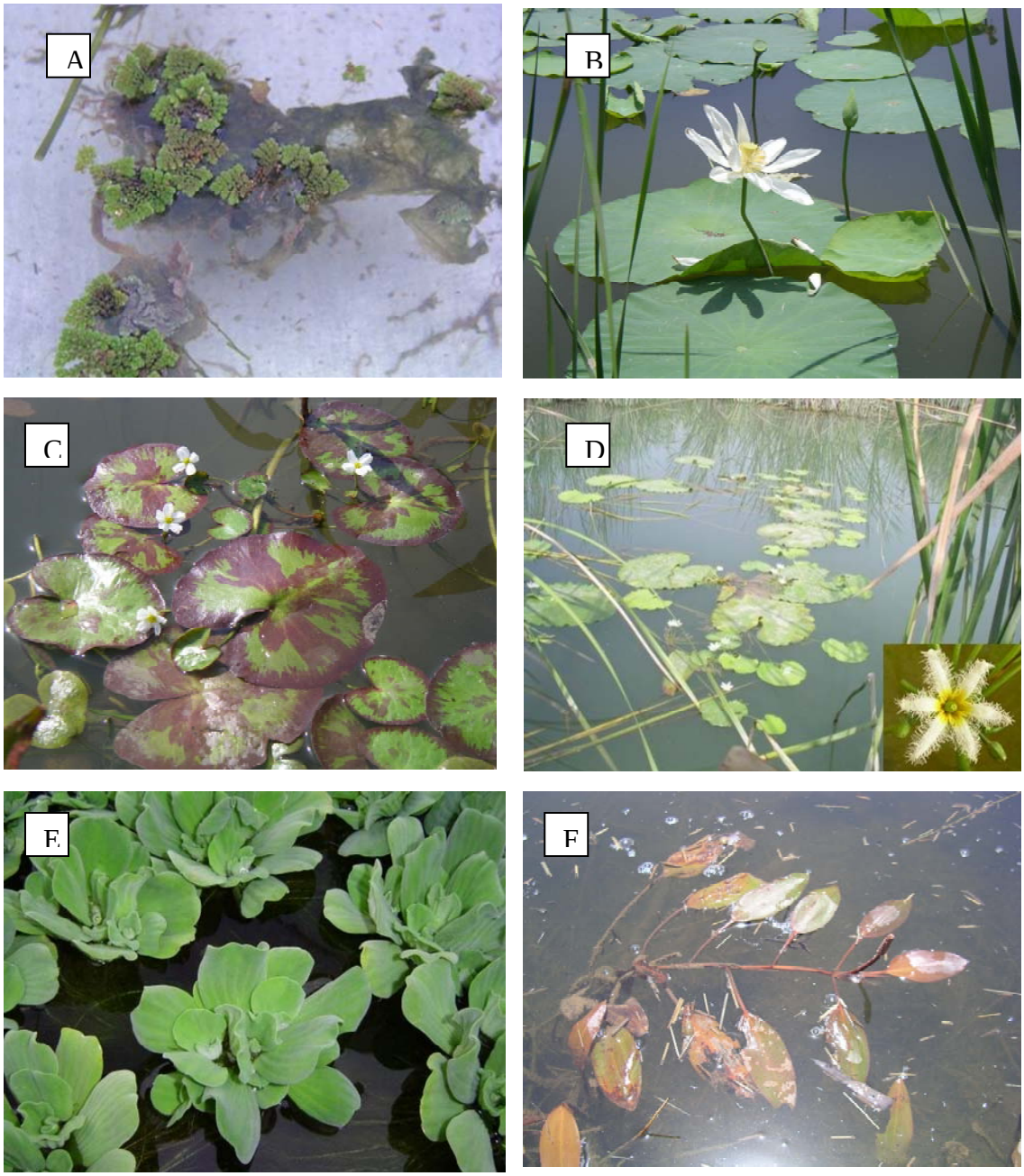

Figure: A. *Azolla pinnata*, **B.** *Nelumbo nucifera*, **C.** *Nymphoides cristata*, **D.** *N. indica*, **E.** *Pistia stratiotes*, **F**. *Potamogeton nodosus*,

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Figure: G. *Ricciocarpus natans*,**H**. *R. natans* (enlarged), **I.** *Spirodela polyrrhiza*, **J.** *S. polyrrhiza* (enlarged)

nitrogen fixing Cyanobacteria, *Anabaena azollae*, and hence luxuriant growth of this fern can increase the fertility of paddy fields. It is calculated that *Azolla* can substitute about 25-30 kg of nitrogen/ha as applied through ammonium sulphate (John et al., 2003).

Hg pollution is a matter of serious concern. A marked reduction in the content of chlorophyll a, protein, DNA and RNA occurs due to toxicity imposed by Hg. *A. pinnata* can remove Hg from industrial effluents by accumulating Hg more efficiently and is thus recommended for removal of Hg from contaminated waters (Rai & Tripathi 2009).

A. pinnata is a food source for waterfowl, fish, shrimp, insects, worms, snails and crustaceans. Mats of Azolla can actually discourage blue-green algal blooms. They restrict the penetration of sunlight into the water, which is essential for algal growth, and take up nutrients from the water column, limiting the availability of this food source for the algae. The mats of Azolla can be a form of biological mosquito control, preventing mosquito larvae surfacing for air. On the other hand, it is possible that thick, complete coverings of Azolla can cause de-oxygenation of the water. This can affect organisms such as fish and other aquatic plants, and the decay of the latter can lead to a strong odour (Anon., 2010).

Genus Lemna has about 15 species distributed in both the hemispheres of the world, represented in Pakistan by 5 species (Hashmi and Omer, 1986). These species are mostly small and rarely exceeding 5mm in length. Usually gregarious and often forms green floating mats on the surface of still or slowly flowing water (Cook et al., 1974). In D.I.Khan district 2 species (*Lemna aequinoctialis* Welw. *a*nd *L. gibba* L.) were found during investigation.

Spirodela, duckweed with 4 species (Cook et al., 1974), is mostly distributed in temperate and tropical zones as represented in Pakistan by 1 species (Hashmi & Omer, 1986). In D.I.Khan district it is also found on the surface of water.

Note: *Lemna gibba* resembles *L. aequinoctialis* but it is easily differentiated from the later in being gibbous beneath. *L. aequinoctialis* is flat on both surfaces.

Spirodela polyrrhiza may be confused with *Lemna* spp. which are smaller and have only a single root per frond. In *Spirodela polyrrhiza* roots are 2-18 per frond.

Duckweeds can accumulate large amount of mineral nutrients in their tissues. Concenteration as high as 7% N in dry mass of *Lemna gibba* and 2.9 % P in dry mass of *Spirodela polyrrhiza* obtained under laboratory conditions has been reported. When growing in wastewater, concentration of N may reach the values up to 7.3% and concentration of P may exceed 2.5%. However, concentration higher than 4% N and 1% P on dry mass basis are commonly found in natural wetlands (Vymazal and Kröpfelová, 2008)

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Table 1: Showing the number of floating aquatic weed species of each genus.

S.#./ Name of genus and family	Distribution		Number of species of each genus				
	Pakistan	Research area (D.I.Khan district)	World	Pakistan		D.I.Khan	
				Total	FP*	Total	FP*
1. Azolla (Azollaceae)	Punjab University, Badian Road, Ravi Ntional Park Lahore, and is expected in Mian Wali District, Dera Ghazi Khan District. Bakar Lake	Pahar pur sewrage canal, Common in water canal near Awan Petrol Pump c. 30kilometer from D.I.Khan towards north-east.	7	1	1	1	1
2. Lemna (Lemnaceae)	Peshawar; Pubi, Hazara, Shogran, Rawalpindi; Lahore; D.I.Khan; Quetta, Rohri, Karachi, Kashmir.	Very common in ponds and still water of waste places of the area.	15	5	5	2	2
3. Marsilea (Marsileaceae)	Common in ponds,irrigation channels water channels.	Common in ponds,irrigation channels water channels.	c.65	2	2	1	1
4. Nelumbo (Nelumbonaceae)	Lahore: D.I.Khan, Bakar Lake, Keenjhar Lake	Found in ponds, standing water, near DIKhan bridge.	2	1	1	1	1
5. Nymphoides (Menyanthaceae**)**	Attock district: Hattian Bridge; Thatta district: Haleji Lake; D.I.Khan.	D.I.Khan: Found in standing water, 2kilometer from Qureshi More on way to Bhakkar	20	3	3	2	2
6. Pistia (Araceae)	Dera Ismail, Khan District; Lahore district	Ponds near Dhappan Wali Basti, canal near Awan petrol pump, Pahar pur canal,Syed Alian, D.I.Khan Bridge	1	1	1	1	1
7. Potamogeton (Potamogeotnaceae)	Pakistan south-ward to Sind and Baluchistan; Swat: Dir; Hazara District; Karakorum Highway; Skardu, Baltistan; Hangu; Phoosna Lake, Bakar Lake, Rawal Dam, Wah Garden Keenjhar Lake	Common in Badari Dam at Khaisore Range; ponds near Darya, Khan Bridge	c.100	11	2	5	1
8. Ricciocarpus (Ricciaceae)	D.I.Khan; Bakar Lake	Common in Pahar pur sewrage canal	1	1	1	1	1
9. Spirodela (Lemnaceae)	Phoosna Lake, Bakar Lake, Rawal Dam, Wah Garden, Keenjhar Lake	Common in ponds near Dhappan Wali Basti.	3	1	1	1	1

* FP = Floating Plant

Ricciocarpus, a liverwort, comprises 1 species, *Ricciocarpus natans* (L.) Corda, found free floating on surface of water in the warmer parts of the world (Cook et al., 1974). In our research area it is very common growing with duckweeds (*Lemna* spp., *Spirodela* sp.).

These aquatic weeds (as mentioned above) are responsible for lowering quantity as well as quality of water. They cause taste and odour problems and also increase biological oxygen demand because of organic loading (Lancar and Krake, 2002).

Marsilea, a fern, has about 65 species distributed throughout the warmer regions of the world. The species are aquatic and semi aquatic (Cook et al., 1974). Seedlings remain submerged and adults float as emergent plants (John *et al*., 2003). Several species are regarded as troublesome weeds in rice fields and irrigation ditches (Cook et al., 1974). In D.I.Khan district it is represented by 1 species, *Marsilea quatrifoliata* L. It is perennial, rooted at the bottom of the soil, leafy, heterosporous floating fern (Ahmad and Younus, 1979).

Nelumbo is a single genus of family Nelumbonaceae. It has 2 species, *N. pentapetala* (Walt) Fernald and *N. nucifera* Gaerth. The latter is distributed in the West Indies, C. America, Southern and Eastern parts of N. America and the other in S. E. Asia, India and Iran (Cook et al., 1974). In Pakistan 1 species, *N. nucifera* (lotus) is found. The flowers are very large and showy and considered sacred by Hindus. Whole plant is holy to Budhists (Qaiser ,1993). Although the flowers and buds of lotus are of great demand in the market it is a weed which obstructs the fishing activity. The periphytonic algal growth on this plant can support several fresh water fishes as their food (John *et al*., 2003).

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The lotus (*N. nucifera*) is a very beautiful plant cultivated for food purpose in D.I.Khan on small scale near Indus River. The seeds are eaten. The rhizomes (locally known as *bhen*) are often sold in the market. These are commonly sliced and cooked with or without meat.

Table 2. Taxonomic information of floating weeds of Dera Ismail Khan District.

S.#.	Botanical Name	Common Name	Major groups	Flowering period	V. No.*	Availability
1.	*Azolla pinnata*	Water velvet	Pteridophyta	Produces sporocarp in winter months	230	Common
2.	*Lemna aequinoctialis*	Duckweed	Spermatophyta (Monocotyledons)	April - May.	349	Common
3.	*Lemna gibba*	Duckweed	Spermatophyta (Monocotyledons)	April – August	414	Common
4.	*Marsilea quadrifoliata*	Pepperwort. water clover	Pteridophyta	Produces Sporocarp in winter months	65	Common
5.	*Nelumbo nucifera*	Lotus, sacred lotus,	Spermatophyta (Dicotyledons)	Sept. - Nov.	55	Not common
6.	*Nymphoides cristata*	Crested floating heart.	Spermatophyta (Dicotyledons)	March - June.	129	Common
7.	*Nymphoides indica*	Water snowflake	Spermatophyta (Dicotyledons)	August - October	415	Not common
8.	*Pistia stratiotes*	Water lettuce	Spermatophyta (Monocotyledons)	July – November	202	Common
9.	*Potamogeton nodosus*	Indian Pondweed.	Spermatophyta (Monocotyledons)	April - August	192	Common
10.	*Ricciocapus natans*	Purple-fringed riccia	Bryophyta	Fruiting period occurs in spring	283	Not common
11.	*Spirodela polyrrhiza*	Giant duck weed	Spermatophyta (Monocotyledons	Sept. – Oct.	204	Common

* V.No. = Voucher Number

Nymphoides a genus with about 20 species distributed in temperate and topical regions of both the hemispheres. It is represented in Pakistan by 3 species. 2 species (*Nymphoides cristata* and *N. peltatum*) were recorded in flora of Pakistan (Qaiser, 1977) and 1 species (*Nymphoides indica*) reported by the author as a new record for Pakistan
(Marwat et al., 2009). Represented in D.I.Khan district by 2 species (*Nymphoides indica* and *N. cristata*). Both the species are quick growing rooted floating emergent. Due to the fast growth rate large scale biomass synthesis takes place during the post monsoon period. As it is a weak plant it can be very easily mulched into the soil which then provides a high quality organic matter to the soil (Sanil and John, 2010).
Note: *Nymphoides indica* (L.) Kuntze is closely related to *N. cristata* (Roxb.) O. Ketze, but differs from the latter in having petals of unusual feathery edges. In *N. cristata* to be continued.
(Roxb.) O. Ketze the petals have no feathery edges (Marwat et al., 2009).
Charm of boating, swimming, bathing and other recreations in water is minimized due to infestation of water bodies' with such floating weeds (Lancar and Krake, 2002).

Pistia comprises only 1 species (*Pistia stratoites* L.) distributed throughout the tropical and subtropical regions of the world (Nasir, 1978), also commonly found in our area (D.I.Khan). It is a free floating plant that grows in a wide variety of aquatic habitats. In many regions it has become a serious pest (Cook et al., 1974).
P. stratoites is one of the most problematic weeds in the world and along with *Salvinia* to be continued.
molesta is particularly troublesome in regions with subtropical climate (Lancar and Krake, 2002). *P. stratiotes* mats clog waterways, making boating, fishing and almost all other water activities impossible. Its mats degrade water quality by blocking the air-water interface and greatly reducing oxygen levels in the water, eliminating underwater animals such as fish. Water lettuce mats greatly reduce biological diversity: mats eliminate native submersed plants by blocking sunlight, alter emerged plant communities by pushing away and crushing them, and also alter animal communities by blocking access to the water and/or eliminating plants the animals depend on for shelter and nesting (Ramey and Peichel, 2001).
Potamogeton has about 100 species which are cosmopolitan. It occurs in large variety of habitat (Cook et al., 1974). About a dozen of species are reported from Pakistan (Aziz and Jaferi, 1975). Five species were recorded from D.I.Khan district during extensive survey of the area out of which 4 species are submerged and 1 species, *Potamogeton nodosus* Poiret is rooted with both floating and underwater leaves (Aziz and Jaferi,1975). *P. nodosus* has been reported to be a nuisance in canals and ditches (Cook et al., 1974). The plant is used medicinally by local people. Plant is boiled in water and its poultice is applied

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on dislocated joint to make it soft and then properly adjust in original position easily. The seeds are eaten by birds (Marwat et al., 2008).

Table 3: Phytogeography and harmful effects of floating aquatic weeds.

Worldwide Distribution	**Occurrence**	**Harmful effects**	**Sources**
1. *Azolla pinnata* R.Br.			
Asia, Tropical America, Tropical Africa and Australia.	Ponds and tanks, deep water rice infestation, lakes, irrigation canals and drainage ditches.	Azolla weevil, *Stenopelmus rufinasus*, uses the *A. pinnata* as a host plant, but it is an inferior host and unlikely to support field populations of the weevil. It is possible that thick, complete covering of Azolla can cause de-oxygenation of the water. This can affect organisms such as fish and other aquatic plants. The decay of the plants can lead to a strong odour.	Pemberton and Bodle, 2009; Anonymous, 2010
2. *Lemna aequinoctialis* Welw. (Syn. *L. paucicostata* Hegelm**.)**			
Throughout all the warmer regions of both the hemispheres.	Ponds, pools and swamps, natural water bodies for storage.	High intensity invasion lead to fish mortality and decrease in invertebrate diversity, due to invasive nature of Lemma spp.	Lancar and Krake, 2002
3. *Lemna gibba* Linn.			
Europe, S.W. Asia, India, Ceylon,N.E & S. Africa and S. America.	Natural water bodies for storage, aquatic sports and aesthetic value	High intensity invasion lead to fish mortality and decrease in invertebrate diversity, due to invasive nature of Lemma spp.	Lancar and Krake, 2002
4. *Marsilea quadrifoliata* Linn.			
Cosmopolitan	Pond, ditches, swamps and paddy fields, lakes.	It is regarded as troublesome weed in rice field and irrigation ditches.	Cook *et al.*, 1974
5. *Nelumbo nucifera* Gaerth. (Syn: *Nelumbium nelumbo* (L.) Druce, *N. speciosum* Wild.)			
N. temperate zone, Europe and Asia.	Cultivated; wild in Ponds and lakes.	Charm of boating, swimming, bathing and other recreations in water is lost due to infestation of water bodies with such aquatic weeds.	Lancar and Krake, 2002
6. *Nymphoides cristata* (Roxb.) Ketze. (Syn. *Menyanthes cristata* Roxb.)			
Malaya, China, India and Pakistan	Lakes and tanks growing fishes, irrigation ditches and drainage system.	Causing floods, damages irrigation and drainage systems	Lancar and Krake, 2002
7. *Nymphoides indica* (L.) Kuntze (Syn: *Menyanthes indica* L.)			
Australia,Cambodia, India, Indonesia, Malaysia,Vietnam; Myanmar, Japan; Korea,Nepal,India Pakistan,SriLanka, Pacific,Islands,	Lakes and tanks growing fishes, irrigation and drainage system.	Causing floods; damages irrigation and drainage systems	Lancar and Krake, 2002
8. *Pistia stratiotes* Linn.			
Pantropical, India, Sri Lanka and Pakistan.	Water-bodies, canals and lakes, irrigation and drainage system. shallow water areas, eutrophied areas.	Influences fishing, power generation, navigation, recreation, waste disposal, water flow problems in irrigation canals	Lancar and Krake, 2002
9. *Potamogeton nodosus* Poiret			
Warmer regions of Europe, N.and Cent. America, Africa and Asia.	Lakes and tanks, water storage reservoirs for city water supply system, fisheries development, irrigation canals and drainage system.	Damaging irrigation canals, and drainage system, ponds, lakes, fisheries areas and rivers	Lancar and Krake, 2002

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10. *Ricciocapa natans* (L.) Corda			
Occur nearly worldwide	Shallow water of ponds, pools. Often found growing with duckweeds (*Lemna* spp., *Spirodela* sp.)	Fish production is greatly affected by the presence of these weeds. As they cause oxygen depletion, and accumulation of Carbondioxide, gases like hydrogen sulphide and methane are formed; these gases are harmful to the fishes. Decomposing weeds omit offensive odor.	Lancar and Krake, 2002
11. *Spirodela polyrrhiza* (L.) Schleid.			
Tropcal America, Europe, Asia.	Lakes, ponds, marshes and slow streams in areas sheltered from wind.	These aquatic weeds are responsible for lowering quantity as well as quality of water. These weeds cause taste and odour problems and also increase biological oxygen demand because of organic loading.	Lancar and Krake, 2002

Table 4. Floating weeds and their Beneficial effects collected from literature.

Habit and habitat	**Beneficial effects**	**Sourcess**
1. *Azolla pinnata* R.Br.		
Free floating, hetersporous, small aquatic fern	Hg pollution is a matter of serious concern. A marked reduction in the content of chlorophyll a, protein, DNA and RNA occurs due to toxicity imposed by Hg. *A. pinnata* can remove Hg from industrial effluents by accumulating Hg more efficiently and is thus recommended for removal of Hg from contaminated waters.	Rai & Tripathi 2009.
	Sewage effluents for cultivation of *A. pinnata* are evaluated so that the biomass production can be used for different applications as well as recycle wastewater. The study has recommended that cultivation of *A. pinnata* can facilitate wastewater management through recycling and reuse of municipal wastewater and is a fruitful strategy for sustainable and ecofriendly agriculture	Rai and Kumar, 2007
	The absorption of iron, copper, cadmium, nickel, lead, zinc, manganese and cobalt by *A. pinnata* and subsequent utilization of this biomass for production of biogas (methane), have been investigated.	Jain et al., 1992
	A. pinnata has fame as a promoted component of rice culture in China because of the nitrogen fixing symbiotic bacteria that live in its leaves.	Pemberton and Bodle, 2009
2.*Lemna aequinoctialis* Welw. (Syn. *L. paucicostata* Hegelm**.)**		
Annual, often forms floating mats on the surface of still or slowly flowing water.	The duckweeds are important in the process of bioremediation because they grow rapidly, absorbing excess mineral nutrients, particularly nitrogen and phosphates. A cover of duckweeds can reduce evaporation of water compared to a clear surface.	Robil, 2010.
	Lemna is recommended for assessing the toxicity of textile dye wastewaters	Sharma et al., 2005
3. *Lemna gibba* Linn.		
Annual, often forms floating mats on thesurface of still or slowly flowing water.	It has been investigated that *L. gibba* can significantly accumulate the toxic elements, arsenic, uranium, and boron. So, it can be used as a practical and effective method to remove toxic elements from waste water.	Sasmaz and Obek,2009.
	Duckweeds are important food source for waterfowl. Some duckweeds are used in freshwater aquariums and ponds. The plants can provide nitrate removal (if cropped).	Robil, 2010.
4.*Marsilea quadrifoliata* Linn.		
Perennial, floating fern, rooted at the bottom of the soil.	It can be used for lack of breast milk after childbirth.The whole plant of *M. quadrifoliata* including roots is crushed with whole plant of *Centella asiatica* including roots and made into a paste. The paste is applied twice daily for 7 days around the nipple.	Nawaz, 2009
	Whole plant paste is soaked in hot water and is used for toothache.	Anisuzzaman et al., 2007
5. *Nelumbo nucifera* Gaerth. (Syn. *N. speciosum* Willd; *Nelumbium nelumbo* (L.) Druce)		

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Perennial, rooted in the soil, floating	The extracts of rhizomes, seeds, flowers and leaves have been reported to have varied therapeutic potential. Several bioactive compounds have been derived from these plant parts belonging to different chemical groups, including alkaloids, flavonoids, glycosides, triterpenoid, vitamins etc.,	Mukherjee et al., 2010
	Tender rhizomes, stems and leaves of lotus are edible and its seeds are rich in protein as well as minerals. Petals are useful as garnish, while the stamens are used in flavoring the tea and the roasted seeds can be used as coffee substitute. Powdered popped seeds are eaten dry and useful in bread preparation. Seeds are raw material for Ayurvedic and folk medicines to treat many ailments such as tissue inflammation, cancer, diuretics, skin diseases and as poison antidote. Lotus plants provide several bioactive ingredients like alkaloids, flavonoids, antioxidants, antisteroids, antipyretic, anticancerous, antiviral and anti-obesity properties.	Sridhar and Bhat, 2007.
6. *Nymphoides cristata* (Roxb.) Ketze. (Syn. *Menyanthes cristata* Roxb.)		
Annual, with long floating stem, rooting at the nodes, leaves floating	The hepatoprotective effect of *N. cristatum* was investigated in an experimental model. The albino rats were treated with 50 percent ethanol extract of the whole plant and callus of *N. cristatum* extracts at a dose of 500 mg/kg body weight orally. These results evidence/ demonstrated that *N. cristatum* has a protective effect against experimental liver damage.	Niranjan et al., 2010.
7. *Nymphoides indica* (L.) Kuntze (Syn: *Menyanthes indica* L.)		
Annual, with long floating stem, rooting at the nodes, leaves floating	Plant paste is applied as bandage in cut and injuries as coolant and for early healing. Dried rhizome paste along with little honey is taken in diuresis.	Jain et al., 2007
	Whole plant juice (20-35ml) is taken on empty stomach twice daily for a week, for curing fever and jaundice in India.	Das et al., 2005
8. *Pistia stratiotes* Linn.		
Perennial, stemless, free floating herb with rosette of leaves.	Nutrients such as N and P can be removed from wastewater by *P. stratiotes.*	Olguin and Gloria,2010
	Plant paste is applied in boils and burns.	Jain et al., 2007
	Leaves are used in the traditional medicine for the treatment of ring worm infection of the scalp, syphilitic, eruption, skin infection, boils and wound. The oil extract is in the treatment of worm infestation, tuberculosis, asthma, dysentery, and externally applied to treat skin diseases, inflammations piles, ulcers, syphilitic infections and burns.	Premkumar and Shyamsudar, 2005
	The results of one study indicated that *P. stratiotes* methanolic extract was the most active against the dermatophytes, *Trichophyton rubrum*, *T. mentagrophytes* and *Epidermophyton floccosum.*	Premkumar and Shyamsudar, 2005
	The ethanolic extract of the plant *P. stratiotes* was investigated for activity against Indian earthworms *Pheretima posthuma* and nematode *Ascardi galli*. The study indicated the potential usefulness of *P. stratiotes* against earthworm infections.	Kumar et al., 2010
	Arsenate uptake by aquatic plant water lettuce (*Pistia stratiotes* L.) was studied in the laboratory condition to investigate a low cost natural aquatic treatment system for pollutant removal. The removal efficiency was, however, noted to be maximum (87.5%). The effect of biomass quantity has also been investigated along with some metabolic parameters.	Mukherjee and Kumar, 2005
9. *Potamogeton nodosus* Poiret		
Perennial, rooted with both floating and underwater leaves	2-Hydroxyheptane-3,5-dione was obtained from the petrol soluble fraction (PE) of the ethanol extract of *P. nodosus*. Biological screening of PE revealed antibacterial activity and cytotoxicity. Compound showed only antibacterial activity.	Alam et al., 1999
	A new furanoid diterpene, 15,16-epoxy-12-oxo-8(17),13(16),14-labdatrien-20,19-olide was isolated from an ethanolic extract of *P. nodosus*. Its structure was elucidated by the usual spectroscopic methods, including 2D NMR techniques. Compound was found to exhibit moderate inhibitory activity against a number of both Gram-positive and Gram-negative bacteria.	Qais et al., 1998
	Provides important food and cover for aquatic animals. Tubers of long-leaf pondweed are an important waterfowl food.	Hamel et al., 2001
10. *Ricciocapus natans* (Linn.) Corda (Syn. *Riccia natans* Linn.)		

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Free floating, liver wort, growing with *Lemna* spp., *Spirodela* sp.	Food for ducks and birds; provides habitat for aquatic insects and invertebrates.	Hamel et al., 2001
11. *Spirodela polyrrhiza* (Linn.) Schleid. (Syn. *Lemna polyrrhiza* Linn.)		
Annual, free floating, Often grows with other members of Lemnaceae.	*S. polyrhiza* shows profound ability to take up Cd from ambient medium.	Noraho, and Gaur, 1996.
	S. polyrhiza is recommended for assessing the toxicity of textile dye wastewaters.	Sharma et al., 2005
	Provides a high protein food source for ducks and geese, also eaten by certain fish. In Africa and Asia, giant duckweed has been harvested for cattle and pig feed. Has been used to reduce nutrients in sewage effluent.	Hamel et al., 2001
	Duckweeds are important food source for waterfowl. Some duckweeds are used in freshwater aquariums and ponds. The plants can provide nitrate removal (if cropped). The plants are used as shelter by pond water species, such as bullfrogs and bluegills. The duckweeds are important in the process of bioremediation because they grow rapidly, absorbing excess mineral nutrients, particularly nitrogen and phosphates. A cover of duckweeds can reduce evaporation of water compared to a clear surface.	Robil, 2010.

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