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Full Length Research Paper

Alien and exotic *Azolla* in northern Iran

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Azolla filiculoides **a planktonic fern found floating on the surface of wetlands, ponds and rivers. Because of its ability to fix nitrogen through symbiotic cyanobacteria, it causes more rice production in paddy fields and is used as a green fertilizer. *A. filiculoides* was introduced from Philippine as a green fertilizer for rice crop to Iran, at 1986. The climatic condition of paddy fields, ponds and rivers of north of Iran was the best habitats for its regeneration and growth. *Azolla* has been distributed and has grown very fast in three Northern provinces of Iran, over 20 years. Now, this useful exotic plant, is a harmful weed in waters of the northern region of Iran because its fast regeneration, fast growth and high distribution.**

Key word: *Azolla filiculoides*, cyanobacteria, exotic plant, mosquito fern.

INTRODUCTION

Azolla filiculoides Lam. a small aquatic and planktonic fern is found floating on the surface of canals, Lakes, wetlands, ponds and slow-moving streams. In shaded conditions the leaves are green, whilst in direct sunlight they become reddish. The plants are small, 1.5 - 2.5 cm long. The roots have fine lateral rootlets and a feathery appearance in the water. The leaves are minute, 1 - 2 mm long, overlapping in 2 ranks, upper lobe that is green, brown green or reddish, and lower lobe that is translucent brown (Figure 1). When fertile, round sporocarps 1 - 1.5 mm wide can be seen on the under side at the bases of the side branches. The leaves often have a maroon-red tinge and the water can appear to be covered by red velvet from the distance. The upper surface of the leaves is totally water-repellant, and if completely submerged, the plants quickly re-float with the right side up (Sweet and Hills, 1971; Konar and Kapoor, 1972, 1974; Croft et al., 1985). Azolla is propagated vegetatively and by spores; it is placed on US noxious weed list. It forms a symbiotic pair of *A. filiculoides* and a heterocystous blue-green alga *Anabaena azollae*, taking advantage of their ability to fix nitrogen and its usefulness as soyabean plants in rice fields. It is sometimes introduced and used by farmers as a natural fertilizer for this reason (Ripley et al., 2003) and it has been used as a fertilizer in botanical gardens because of its nitrogen-fixing ability (Peters and Meeks, 1989; Moore, 1969; Lumpkin and Plucknett, 1980). Azolla species can often grow on nitrogen poor water due to its ability to fix nitrogen. Native range of *A. filiculoides* are found in Africa, Madagascar, India, South-east Asia, China and Japan, Malaya, the Philippines, the New Guinea mainland and Australia (Reed, 1965; Johns, 1981; Croft et al., 1985).

The Caspian is the largest lake in the world and 3 northern provinces of Iran, Gilan, Mazandaran and Golestane are on south of this lake (Caspianenviroment.org). Indigenous species of Azolla have not been found in Iran. In 1986 the Ministry of Agriculture initiated the importation of *Azolla* from the Philippines into Bandar Anzali, in northern Iranian province of Gilan for studies on its nitrogen fixation capacity and *Azolla* was then distributed in North of Iran. While in August 1990 only a few scattered plants were seen in Anzali lagoon, in November 1990 and again in April 1991 some channels and open waters in the eastern basin became covered with extensive mats of *Azolla*. In October–November 1991, the *Azolla* invaded the entire lagoon except for its western basin, where wind prevented its growth. At present almost all sheltered open-water areas in the southern and eastern basins are covered by a dense mat of this fern which also penetrated deeply into the *Phragmites* stands. Some channels of the southern basin are completely covered by *Azolla*, and in

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Figure 1. *Azolla filiculoides*

Figure 2. Azolla in east of Gilan. **a**. Soostan wetland of Lahijan; **b**. Langrood River.

sheltered places, it forms thick carpets up to 20 cm deep making boat passage very difficult. *Azolla* is being continuously washed down from the lagoon into the sea where it may be found along the beach several kilometres eastward and westward from Bandar Anzali (Fao, 2005). We researched Azolla distribution in these 3 provinces of Iran.

METHODS

The wetlands of Gilan, Mazandaran and Golestan comprise an almost unbroken chain of freshwater lakes and marshes, brackish lagoons, irrigation ponds and rice paddies stretching for some 700 km along the shores of the Caspian Sea from the border with the Republic of Azerbaijan in the west to the border with Turkmenistan in the east. Two of the most important wetlands in these lowlands are Anzali lagoon in the west and the Gorgan Bay/Miankaleh complex in the east.

We traveled from west of Gilan province at Grid reference 36° 36′ N and 48° 25′ E to the east of Golestane province at Grid reference 36° 50′ N and 56° 32′ E, three times in summer of 2006 and the waters in three provinces (Gilan, Mazandarn and Golesane) were observed in this pathway. Samples waters were collected and *A. filiculoides* determined in these waters by Chromophytes of Iran (Ghahraman, 1996). Data was recorded using a handy camera.

RESULTS

The climatic condition of paddy fields, ponds and rivers of north of Iran is best habitats for Azolla regeneration and growth. Azolla is distributed and has grown very fast in the three north provinces of Iran, for 20 years. Our observations showed these provinces have high distribution of Azolla. Frequency of Azolla in Gilan (at Grid reference 36° 36′ - 38° 27′ N and 48° 25′ – 50° 34′ E) is the highest and it exist in all nature slow waters of this province. Our observations showed ferny Azolla water velvet on surface of all marsh of paddy fields, lakes, ponds, wetlands, lagoons and rivers of Gilan. Examples of waterland from west to east Gilan includes: marsh of Anzali lagoon, Langrood lagoon, Kiashahr lagoon, Amirkalieh lagoon and Soostan wetland of Lahijan (Figure 2a), Astar Abad lagoon, and slow waters of Langrood River (Figure 2b). All ponds and paddy fields waters were covered on surface by Azolla.

The plant has penetrated from Gilan as an additive to rice cultivation and eventually reached the rivers, lagoons, lakes, wetlands and ponds of Mazandaran (at Grid reference 35° 55′- 36° 20′ N and 50° 25′ – 52° 53′E). Azolla is on surface of some paddy fields and waters marsh of Sarandoon and Balandoon Wetlands of Sari, Darab-Kola Waterfall, Nov water storage, Abbas-Abad Lake, Zangat waterfall, Gol-Paba Lake, Saboon Lake, Shahandash waterfall in Larijan, Savasareh waterfall in Baladeh, Kandoochal Wetland (Figure 3), Valasht Lake in kelardasht, Khezrini Lake in the north of Nowshahr, Akapol and Herijan waterfalls, Lapoo-Palangan wetland east of Neka, in Ramsar Azarak, Rishboraz, Chardar waterfalls, slow waters of Babolsar river (Figure 4a), and in all ponds paddy fields of Mazandaran but its frequency is less than of Gilan. Azolla frequency in Golestane pro-

Figure 3. Azolla in Kandoochal wetland.

Figure 4. **a**. Azolla in slow waters of Babolsar river; **b**. in rice paddy fields of Mazandaran

vince is light and exists in paddy field of rice crop (Figure 4b). Weather condition of this province is doughtier and warmer than Mazandaran and Gilan and paddy fields and rice crop is less too. Azolla existed in all rice crops of Gilan, Mazandaran and Golestane.

DISCUSSION

Biological invasion is regarded as one of the primary menaces to biodiversity. Invasive exotic species, when outside their natural range, can jeopardize native fauna and flora. The invasion has disturbing outcomes not only for a country's nature, but also for its economy. One example is the introduction of a floating fern called Azolla from the Philippines into Bandar Anzali, in northern Iranian province of Gilan. The fern was first imported in 1986 for studies on its nitrogen fixation capacity, making it an ideal fertilizer for paddy fields and an additive to cattle feed. However, given the fern's ability to travel on people's shoes, vehicles, or by wind, water and animals, it eventually found its way into the Anzali Wetland in early 1990s. The invasive plant colonized rapidly and formed into dense mats covering vast expanses of surface water.

In fact, any indigenous species of *Azolla* has not been found in Iran. *Azolla* was distributed first in Anzali lagoon and after, in north waters of Iran (FAO, 2005). The *Azolla* invasion is important in its positive and negative impact on the Northern Iran ecosystem. It lives in symbiosis with blue-green algae (cyanobacteria), taking advantage of their ability to fix nitrogen. It is some times introduced and used by farmer as a natural fertilizer for this reason. *Azolla* represents a significant contribution to food resources for the herbivorous fish. It is useful in de-creasing weed seed germination of rice crop. *Azolla* has been shown to be able to effectively adsorb Pb, Cd, Cu and Zn from the wastewater (Khosravi et al., 2005; Taghi ganji et al., 2004; Cohen-Shoel et al., 2002; Sanyahumbi et al., 1998; Zhao et al., 1999) and removal of gold (III) from aqueous solution (Antunes et al., 2001). Now, this useful exotic plant, is a harmful weed in waters of north of Iran because of high fast regeneration, high fast growth and high distribution. *A. filiculoides* spread rapidly and it survives on moist soil in and around rivers, ditches, and ponds. This may allow the plant to survive periods of drought. It forms dense surface mats, interfering with boating, fishing and recreational activities as well as degrading water quality by reducing oxygen levels.

Azolla fern has an adverse effect on the Northern Iran ecosystem by increasing the nutrient load and thus contributing to eutrophication of rivers, lagoons, lakes, wetlands and ponds. Dense *Azolla* mats prevent light penetration in open-water areas, which causes oxygen deficiency in the waters of the already poor life conditions for fish there. Anzali lagoon is an international lagoon in Khazar Sea (Caspian), on Giulan province of Iran. Azolla formed dense surface mats of 25% waters of this lagoon and 20% marsh waters of Giulan and Mazandaran. In most water bodies, Azolla is considered ornamental, but in waters of Giulan and Mazandaran province of Iran, it has caused problems by blocking pump inlets and filters, entering drinking water tanks, and limiting recreational use of dams and degrading drinking waters. The most problems include blocking of water surface and limiting the marine plants and animal. It can cause changes in biodiversity in these waters, because *A. filiculoides* can spread very quickly forming dense vegetative masses on areas of still water. This in turn limits light available to other aquatic plants and oxygen used by other aquatic life. The formed dense mats can choke out other species. *A. filiculoides* is on the US noxious weed list. In New Zealand, this plant has replaced a native floating fern, *Azolla rubra*, over most of northern New Zealand (Webb, 1988; Owen, 1997). Controlling its reproduction has been deemed necessary in some *Azolla*-abundant areas like South Africa (Hill and Cilliers, 1999; Ashton and Walmsley, 1976) and the north part of Iran. In this regard,

the development of an *Azolla*-based biosorbent for wastewater treatment, especially in developing countries, may benefit environmental problems, by removing heavy metals from water using this weed (Zhao et al., 1999). The devastating consequences of Azolla infestation are numerous. It can interfere with fishing and boating activities and block irrigation channels and waterways. The colonies also serve as havens for mosquito larvae. The thick mats prevent light from penetrating submerged species. Azolla masses compete with other species for nutrients and suppress flora which serve as food for waterfowls. The invasive carpet also prevents fish from migrating to and laying eggs in the wetland, and the fingerlings from returning to the Caspian Sea. Iranian experts recently warned that *Azolla* has already covered about 20 percent of the 20,000 hectare wetlands. Fern infestation coupled with excessive sedimentation has decreased the water depth, reducing the wetland's rainwater storage capacity and increasing flood risks. Each year, thousands of fish perish in the wetland as a result of oxygen deficiency. The Anzali lagoon natural attraction has always been a landmark of Gilan province, with its breathtaking views drawing thousands of sight-seers to the region, thus making significant contribution to local tourism revenues (Iran –Daily, 2006).

In May 2005, the then director of Gilan Department of Environment vowed that prompt action was underway to remove the invasive plant from the Anzali lagoon and bring it under control. Half to one year later, larger expanses of the wetland is now carpeted with *Azolla*. Experts have proposed chemical, biological and mechanical methods for controlling *Azolla* (Caspianenviroment.org). Considering the probable harmful impacts of chemicals on the ecosystem, and the lengthy process of biological techniques, it seems that mechanized procedures using engine-operated equip-ment provide the quickest option for harvesting Azolla (FAO, 2005; Iran- Daily, 2006).

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