Water Allocation for Wetland Environmental Water Requirements: The Case of Shadegan wetland, Jarrahi Catchment , Iran

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Abstract
The Shadegan Wetland is a Ramsar-listed wetland in the south-west of Iran at the head of the Persian Gulf. It is the largest wetland of Iran covering about 400,000 hectares. The wetland plays a significant hydrological and ecological role in the natural functioning of the northern Gulf. It also supports a very diverse flora and fauna and is the most important site in the world for Marbled Teal. The water regime is threatened by upstream abstraction of water for irrigation and the saline discharge from sugar cane industries and irrigation schemes. This will result in an overall reduction in wetland water quantity and quality, leading to a change in plant community composition. This paper investigates how much water is required to maintain the wetland health and the best management options to fulfill this requirement. Considering the lack of field data, using remote sensing (NOAA_AVHRR images with 1.1 km resolution), wetland monthly water surface and biomass during the 15 years before dam construction were traced. Then using these data wetland environmental water requirements was determined in 3 levels. Also the best hydrological regime that could conserve minimum requirements of vegetation cover, Marbled Teal, and flooding conditions were set as the hydrological regime with exceedance probability of 60% that is equal to 2766 MCM/y (level 3).
Key word: Shadegan Wetland, Biomass, Reservoir operation

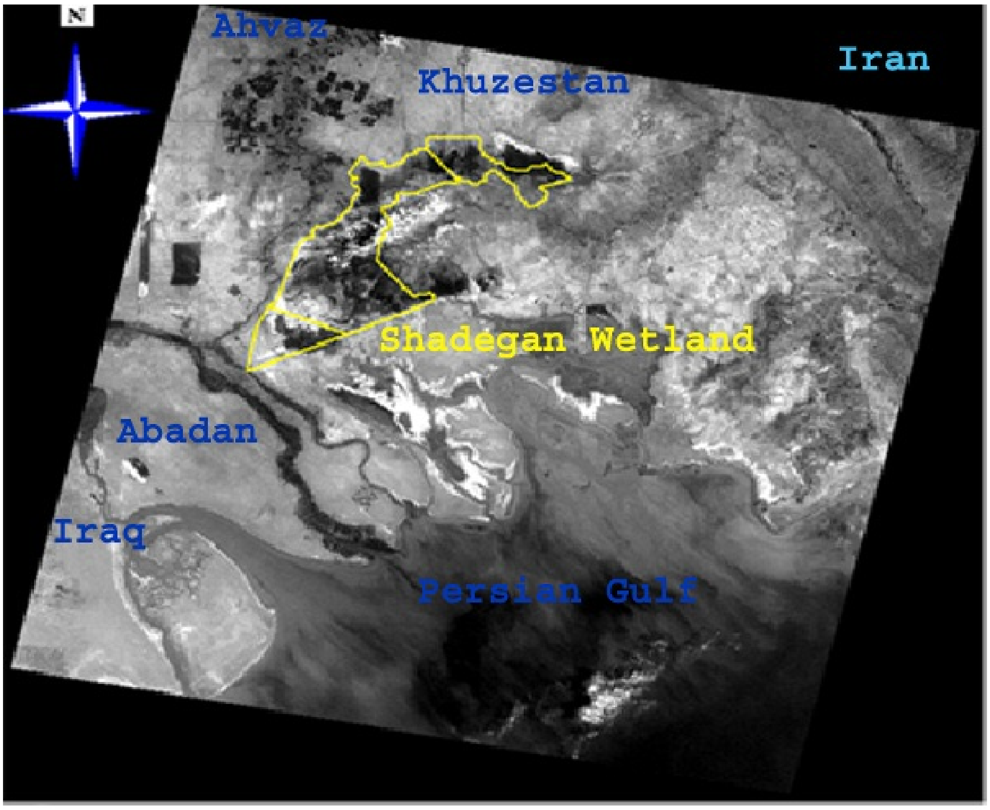
1. Introduction

Water regimes of many wetlands have been altered by regulation, extraction of water for agricultural, domestic and industrial uses, the use of wetlands as areas for water storage, and changes in land use. Human impacts on wetland water regimes can result in both increased and decreased inundation, as well as altered variability in inundation and seasonality (ANCA, 1996). Thus the provision and maintenance of appropriate water regimes is the most important management issue for many wetlands. According to the Ramsar Convention water allocation to a wetland ecosystem is defined as: "the water quantity and quality required to maintain a particular ecological character of the water resources which will sustain selected wetland ecosystem functions and services" (Ramsar Convention, 2004). Generally in the past, environmental water allocation has focused on rivers. Initially the prime motivating concern was improving fish habitat and meeting fish passage

requirements. Later, broader issues were considered, such as the maintenance of ecosystem processes (Arthington and Pusey, 1992). Environmental water allocation for wetlands associated with river systems has frequently been incorporated into the flow allocation process for the river system [eg, the Murrumbidgee wetlands (Shields, 1998)]. Approaches to determining the environmental water requirements of wetlands can be divided into two main methodologies; hydrology and ecology driven (Gippel,1996). Hydrology-driven approaches involve first the description then the restoration or partial restoration of the historic (pre-disturbance) water regime of the wetland. It is assumed that the biota is adapted to the predisturbance water regime and that the restoration of this regime will result in a healthy ecosystem. Ecology-driven approaches involve the determination of the water regime requirements of the existing or preferred biota, and the provision of that regime. Ecology-driven approaches may lead to more defensible allocations than those determined by hydrology driven approaches. The Holistic Approach to environmental water allocation assumes that if the essential components of the natural flow regime are incorporated into the modified flow regime, the biota should persist and the ecological integrity of the ecosystem should be maintained (Arthington, 1998). Although developed primarily for rivers, the Holistic Approach to environmental flow determination is also considered applicable to wetlands (Arthington and Pusey, 1992). Essential components of a wetland's water regime include the quantity of water, and the timing, duration and frequency of inundation (McCosker, 1998).
This paper describes a framework for determining environmental water allocations for Shadegan Marshes. It incorporates the determination of management objectives based on both hydrological and ecological characteristics of the wetland and the uses, values and threats associated with it. Relationships between the biota and water regime are used to determine the water allocation required to achieve the management objectives.

2. Study Area

Shadegan Marshes are located on the lower Jarrahi River in the Province of Khuzestan, at the head of the Persian Gulf near Abadan. This is a location at the southern frontier with Iraq on the Gulf (see Figure 1). It is the largest wetland of Iran covering about 400,000 hectares and also recognized under the Ramsar Convention. A wildlife refuge of 296,000 ha, encompassing all the main wetland areas, was established in 1972 and has remained unchanged since then. Shadegan Marshes are an extremely important wintering habitat for a wide variety of waterfowl. The Shadegan Marshes are the most important site in the world for marbled teal *Marmaronetta angustirostris*, regularly supporting 10,000-20,000 in winter, which is 30-60% of the world population. The only flora mentioned are some reeds *Phragmites australis* and reedmace *Typha* sp., extensive *Schoenoplectus* dominated areas in the freshwater marshes in the north, and fresh to brackish sedge marshes north. Autumn and winter rains in the Zagros Mountains cause extensive flooding throughout the delta, creating a vast complex of shallow lagoons with extensive sedge marshes. These dry out gradually during the long, hot summer, and the entire area may be completely dry by the end of the summer. The water level is higher following spring floods, but drains into the Gulf.



Reference Image of Landsat TM(July 2002)

Figure 1. Study area

The area is characterized by extremely high temperatures. Run-off is at its maximum in late winter, when discharge of the Karun River may increase tenfold over late summer levels.

The principal long-term threat to the marshes is diminished water supply as a result of diversion of water for irrigation schemes further north. Maroon storage dam was constructed on the Marun River Upstream of the wetland. Main characteristics of the dam were summarized in Table 1. The main purpose of dam is irrigation of 550,000ha in Behbahan, Jayzan, Khalafabad and Shadegan plains. A schematic overview of the river, irrigation plains and wetland was shown in Figure 2.

Table 1. Characteristics of the Maroon Dam

Reservoir volume(MCM)	1200
Annual supply(MCM)	1556
Normal operation level (m)	505
Minimum operation level (m)	440
Regulated volume(MCM)	723
Dead storage(MCM)	121

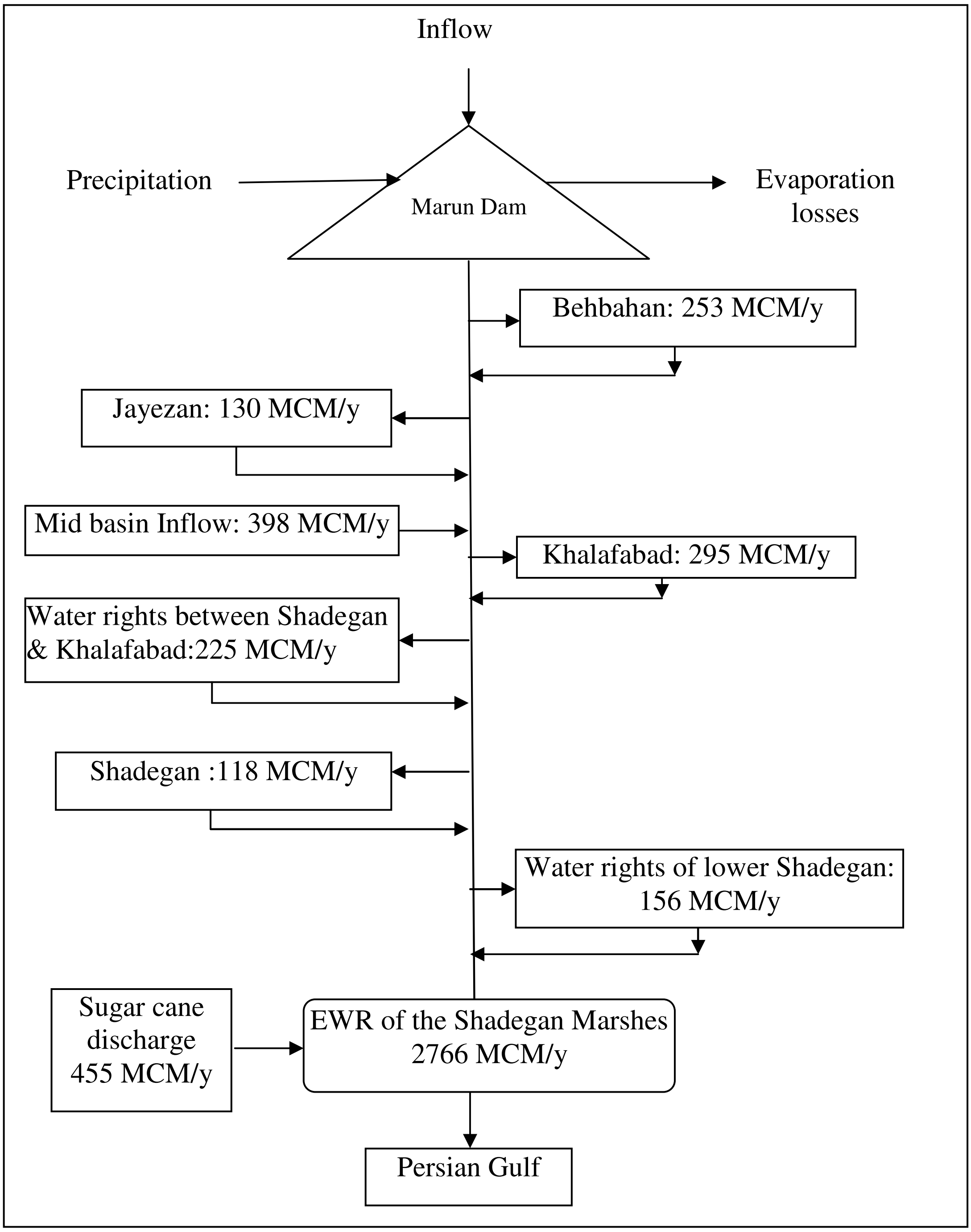


Figure 2. An overview of the reservoir, river and wetland system

3. Methodology

In the determination of a suitable water regime for Shadegan Marshes, a holistic methodology was applied. An outline of the frame work used to determine environmental water allocations to the Shadegan Marshes is given in Figure 3.As the north part of the wetland is the most important freshwater habitat for many endangered species, it was selected as the study area. Because of the north and south part interaction it was assumed that, if the desired condition for north part water quantity and quality can be provided, the whole wetland would be conserved. Using remote sensing data the water regime requirements of vegetation were first examined with an objective of maintaining the existing distributions. These requirements were then compared with the requirements of aquatic invertebrates and waterbirds, for the determination of Environmental Water Requirements (EWR).

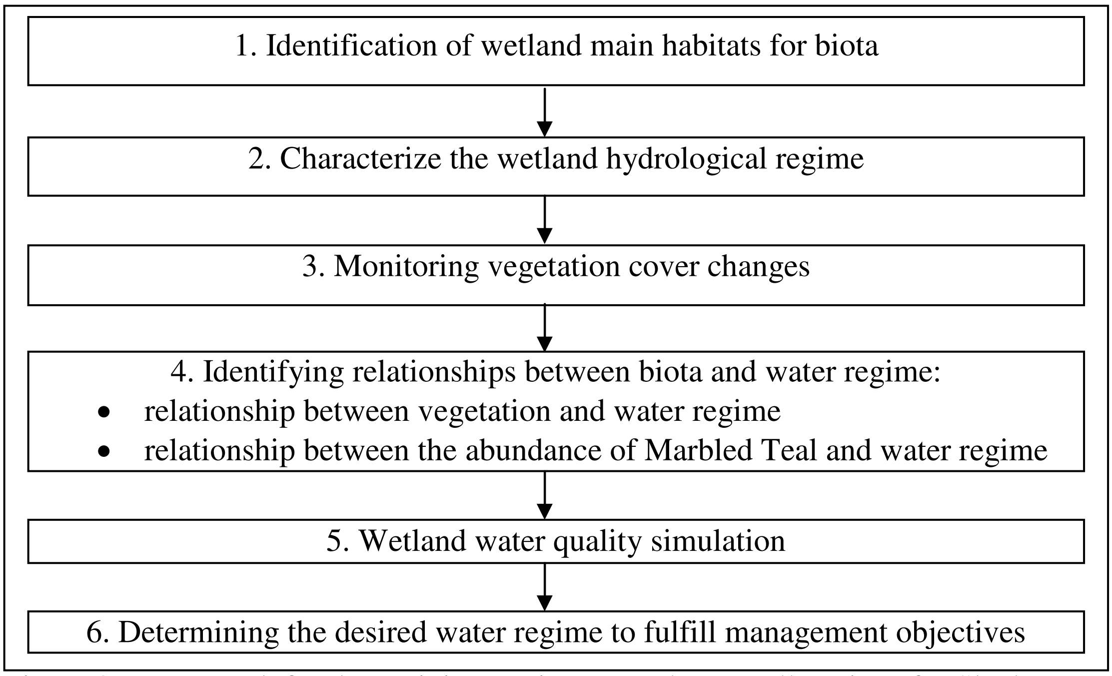


Figure 3. Framework for determining environmental water allocations for Shadegan Marshes

3.1. Remote sensing data

Considering the lack of field data using satellite images of NOAA_AVHRR (LAC) with 1.1Km resolution, wetland monthly water surface and biomass during 1989-2001 were traced .For each month, just a cloudless image was chosen and georeferenced with a TM Land sat reference image of the study area. Only 8 months of this time series (approximately 3% of data) had no cloudless images so their relevant data were estimated through interpolation.

3.1.1. Monitoring vegetation covers of the wetland

In order to quantify vegetation cover density NDVI maps of NOAA-AVHRR were used. Fatehi et al., 2003 note that there is a strong relationship between NDVI values and wetland biomass. They developed and calibrate an empirical equation for Shadegan Marshes region as follows:

$$\text{Biomass } (kg/km^2) = 1.13\text{NDVI} - 22.68 \qquad (1)$$

So, wetland monthly biomass in Kg/Km^2 was calculated from NDVI maps. Calculations showed the vegetation cover increases in spring so that the maximum biomass takes place in June. Then it decreases in early autumn. It can be said that in the flood seasons when the wetland fully inundates, vegetation growth state starts and at the end of spring, that sunlight radiation increases, it reaches to its maximum. In summer, increased evaporation leads to biomass reduction in the way that in autumn biomass dire and reaches to its minimum.

3.1.2. Monitoring wetland water surface

To estimate wetland monthly water surface before dam construction band 2, 3, 4 of NOAA_AVHRR (LAC) images were applied. Using thresholding method of band 2, wetland water surface in each month through the study years were recognized. Then wetland monthly water volumes were calculated using histograms of the maps and the wetland volume-surface equation. Results showed that water surface increases from mid-autumn so that in the winter months its maximum occurs. The water level is higher following spring floods, but drains into the Gulf. In summer as evaporation increases significantly wetland water surface decreases, resulting in a fully dry land in some years. According to wetland volume-surface-level curves, water surface of more than 1000 Km^2 indicates inundation, whereas water surface of less than 150 Km^2 represent dry condition. As it can be seen in Tables 2 and 3, prior to regulation in more than 70% of the times wetland was fully inundated for at least 1 month in the flood seasons; while more than half of the time series inundation frequency increase to 2 subsequent months. Furthermore in 30% of the times wetland fully dried out at least one month at end of summer or early autumn. But it just lasted to 5 sequent months in the dry year 2000. Table 4 represents the results of the statistical analysis which were made on predevelopment water regime data.

Table 2. Frequency of the wetland inundation and drought during the wet and dry months respectively from 1987-2001

	Drought frequency	Inundation frequency
Number of years	5	11
Percent of years	33	73

Table 3. Duration of the wetland inundation and drought during the wet and dry months respectively from 1987-2001

	Duration of wetland drought		Duration of wetland Inundation		
	More than 1 month	1 month	More than 3 sequent months	More than 2 sequent months	More than 1 month
Number of years	1	4	6	8	11
Percent of years	7	27	40	54	73

Table 4. Wetland water surface with different exceedance of probability

Probability (%)	October	November	December	January	February	March	April	May	June	July	August	September
90	75	307	393	534	687	692	753	658	601	187	211	131
80	159	340	466	615	748	764	810	721	655	290	244	167
70	244	377	538	696	809	837	868	783	709	394	281	208
60	329	419	611	777	870	909	926	845	763	498	324	256

3.1.3. Relationship between water surface and vegetation cover

Figure 4 illustrates time variation of the wetland water surface and biomass from 1997 to 2001.According to this Figure there is an approximately 2 month lag between the peak of biomass and maximum water surface. Thus by drawing maximum biomass and water surface data of each year, minimum water surface threshold in relation to vegetation can be recognized. As shown in Figure 5 if the maximum water surface (that occurs in April) decrease to less than 800 Km^2, a significant decline occurs in the peak of biomass (at June). Considering the data of Table 4, this water surface corresponds to the hydrological regime with the probability exceedance of 80%.

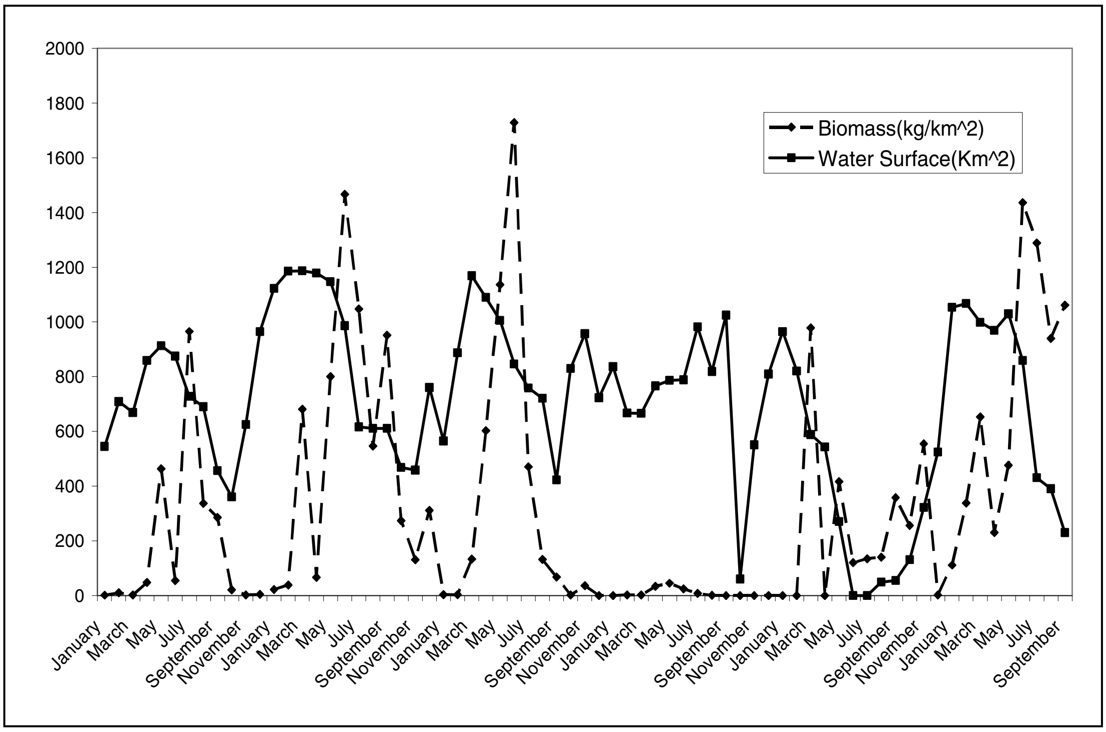


Figure 4. Time variation of wetland Biomass and water surface

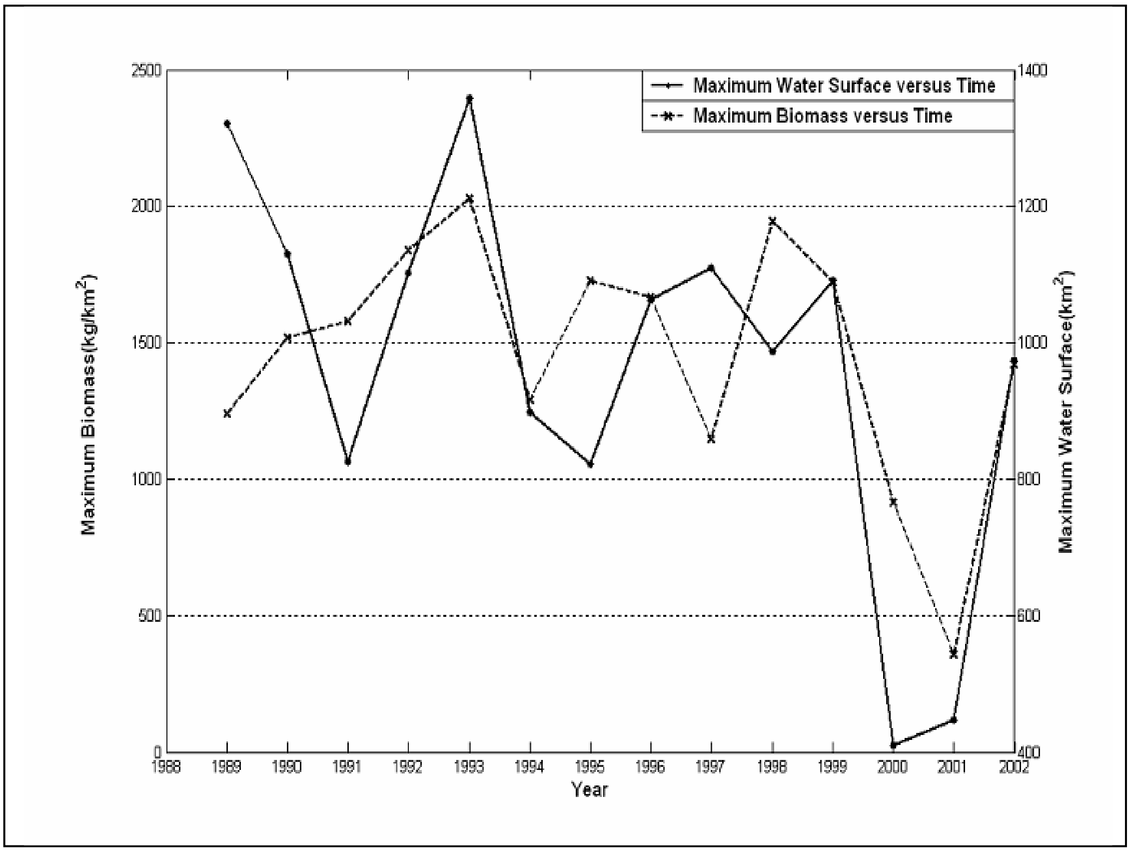


Figure 5. Relationship between peak of the wetland biomass and maximum water surface

3.1.4. Relationship between water surface and the abundance of Marbled Teal

Most of the world population of Marbled Teal congregates on only one site, the Shadegan Marshes in Iran (IUCN). Abundance of this endangered species strongly depends on the duration of wetland inundation especially in the flood seasons. As shown in Figure 6, number of Marbled Teal exponentially correlates with water surface of the wetland in the previous month (December).

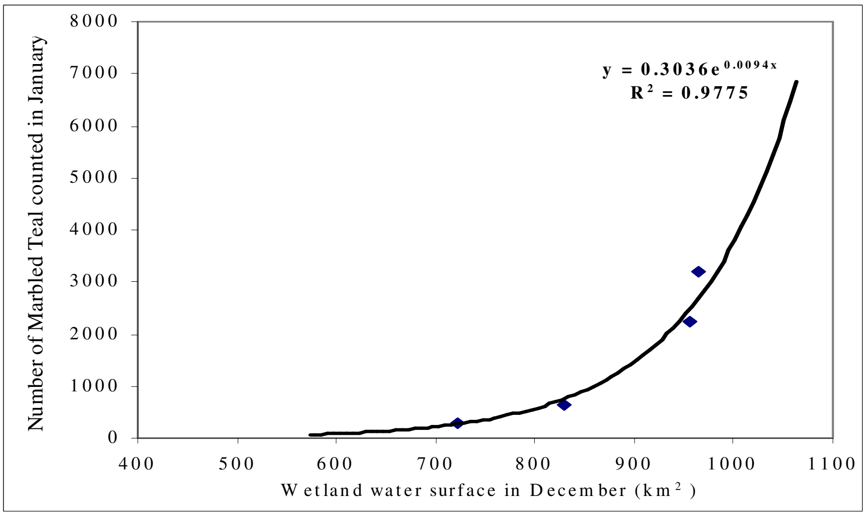


Figure 6. Relationship between water surface and the abundance of Marbled Teal

Therefore the desired water regime that can meet the requirements of the Marbled Teal existence should be determined in the way that at least the water surface of 600 km^2 in December can be supplied. This equals to the hydrological regime with the probability exceedance of 60%.

4. Environmental Water Requirements of Shadegan Marshes

With regards to the mentioned analysis the three level of supply for Environmental Water Requirements (EWR) of Shadegan Marshes were determined as followed:
Level 1: Minimum requirements of hydrological regime
Level 2: Minimum requirements of vegetation cover
Level 3: Minimum requirements of vegetation, Marbled Teal and suitable inundation
Table 5 gives the water surface and volume of the wetland in each level of the supply. According to these data, increasing supply from level 1 to 3, corresponding to hydrological regime with the probability of exceedance equal to 90 to 60 percent respectively, it is possible to meet both hydrological and ecological values. Thus the best hydrological regime that can meet minimum requirements of vegetation cover, Marbled Teal and suitable inundation was set at the probability exceedance of 60% 2766 MCM/year).

Table 5. Environmental Water Requirements (EWR) of Shadegan Marshes

EWR Supply Level	Probability	Parameter	October	November	December	January	February	March	April	May	June	July	August	September	Mean Annual Volume (MCM)
Level 1	90	Water Volume	14	48	84	144	229	233	275	227	144	82	32	0	1513
		Water Surface	75	307	393	534	687	692	753	658	601	187	211	131	
Level 2	80	Water Volume	30	66	127	198	273	286	317	268	186	103	47	16	1917
		Water Surface	159	340	466	615	748	764	810	721	655	290	244	167	
Level 3	60	Water Volume	69	112	212	306	360	392	401	350	269	155	83	57	2766
		Water Surface	329	419	611	777	870	909	926	845	763	498	324	256	

5. Summary and Conclusions

In this paper how much water is required to maintain wetland desired water quantity and quality were investigated. Using a holistic approach, three levels of supply were assigned for wetland environmental water requirements where the best hydrological regime was set at the probability of exceedance equal to 60%.So it is strongly recommended to consider different levels of wetland water requirements in the operation of development schemes.

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