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Relationship of physicochemical factors with fish biomass and production in Shadegan Wetland, Iran

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Abstract. *Hashemi S, Ghorbani R, Kymaram F, Hossini SA, Eskandari G, Hedayati A. 2016. Relationship of physicochemical factors with fish biomass and production in Shadegan Wetland, Iran. Biodiversitas 17: 515-522.* The biomass of fishes was estimate in the Shadegan Wetland with Leslie model. Also the relationships between fish biomass and physic-chemical parameters of were studies. Sampling was carried out seasonally at five stations; include Atish, Khorosy, Mahshar, Rogbe, and Salmane from April 2013 to March 2014. During this study, 2795 specimens were measured and weighed. The highest fish biomass and lowest fish biomass were in spring and winter seasons and Khorosy and Rogbe stations have highest and lowest fish biomass. The mean biomass of fish in four seasons Shadegan, 243±35 (kg/ha) and the amount of biomass in different seasons were not significantly different (P>0.05). Average values of water physicochemical parameters in different seasons were no significant (P>0.05), however average values of salinity stations were significant differences (P<0.05). Fish biomass regressions was estimated as Fish Biomass = 0.41 (temperature) $^{2.56}$. CCA ordination explained temperature, salinity, PH and DO, as the most important variables influencing the variation of fish composition in the Shadegan Wetland. Multi-layer artificial neural network showed four parameters (temperature, salinity, depth and DO) have the greatest impact on fish biomass.

Key words: Artificial neural network, fish biomass, water physic-chemical parameters

INTRODUCTION

The renewal of fish biomass is provided by production which is the "amount of tissue elaborated per unit time per unit area, regardless of its fate". It is thus of interest to fisheries ecologists to know how fish production varies among ecosystems and populations. A first step toward this goal is to determine which characteristics of ecosystems have the greatest impact on this rate of renewal (Downing and Plante 1993). Waters (1997) reviewed and proposed the application of annual production, annual P/B ratio, and eco-trophic coefficient (annual angler harvest/annual production) to management of trout fisheries. Incorporating fish production and it relations physicochemical factors may provide a broader perspective on the dynamics of harvested fishes.

Freshwater resources comprise a mere 2.5% of the earth's water, together with wetlands, around 8% of the land area and contain about 40% of all fish species, but the relative productivity of lakes, reservoirs, rivers, and wetlands is enormous, contributing about 15% of the world fisheries production (Kolding and Zwieten 2006). Shadegan Wetland is located in the very flat territories at the furthermost downstream reach of the Jarrahi River in Khuzestan Province. It is the largest wetland in Iran, and following the recent demise of the Mesopotamian marshes, has become the largest wetland in the Middle East (Kholfenilsaz 2009). Wetlands exist in the terrestrial-aquatic interface and are associated with high nutrient levels, high primary productivity and diversity of structural habitats which are utilized by a variety of organisms (Prince et al. 1992).

Maramazi (1997), Ansari and Mohamadi (2001), Ansari et al. (2009), and Hashemi et al. (2011, 2012) were searched fish stock assessment and capture conditions of Shadegan Wetland. Lotfe et al. (2003) were considered human activity and effect and also diversity and capture situation of Shadegan Wetland. The aim of the present study was twofold: (i) to estimate its stock assessment status and fish production, (ii) to determine, relations of fish production with physicochemical factors. Results will greatly contribute to elaborate management programs for this economically important fish species and preserve other fish species.

MATERIAL AND METHODS

Study area

Estimation of biomass and production of fish species was carried out from April 2013 to March 2014 in the Shadegan Wetland. Samples were collected from at five stations, Mahshar (Doragh)(48˚,45´ E, 30˚,33´ N), Rogbe (48˚,33´ E, 30˚,41´ N), Khorosy (48˚,40´ E, 30˚,39´ N), Salmane (48˚,28´ E, 30˚,40´ N) and Atish (48˚,40´ E, 30˚,54´ N) in the Shadegan Wetland in Khuzestan Provinces (Figure 1).

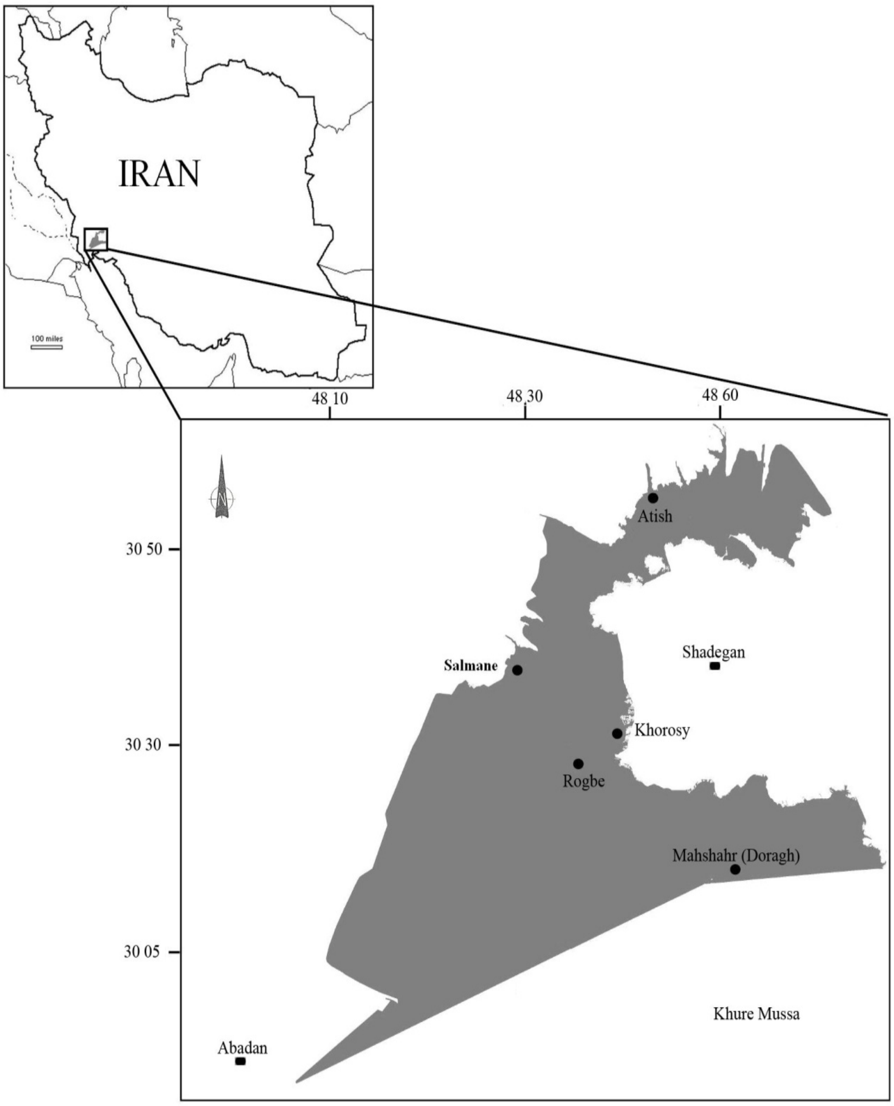

Figure 1. The map of Iran, location of five capture sites was sampled in Shadegan Wetland, Khuzestan Pprovince, South West of Iran

Data collection

Seasonally water samples for analysis of environmental parameters were collected from each station using a Nansen bottle sampler and analyses as per standard analytical procedures (Clesceri et al. 1989). Eighteen environmental parameters (Table 1) were considered in this research and included water temperature (WT), water depth (WD), water salinity (WS) phosphorus (TP), nitrate (TN), pH, biological oxygen demand (BOD) and dissolved oxygen (DO). In each season, 5 stations were selected for sampling. Sampling was carried out by using fixed gill net with 45 mm mesh (100-120 m length and 50-70m width) and then transported to lab with dry ice. Total length with ±l mm and total weight with ±0.01 g were measured for each fish. Amount of 800-1500 m^2 (enclosed area) was changed in different seasons and at each station according to environmental conditions.

Fish biomass

In the Leslie method, the relationship between catch per unit effort and population size is defined by: $Ct/ft = qN$, where t = time period under consideration, q = catchability, N = initial population number. The population at any time t, is equal to the initial population less what has been caught up to time t (cumulative catch), $N_t = N_0 - \sum C$; By substituting N_t from the catch per unit relationship into the above expression, a linear relationship is obtained: $Ct/ft = q(N_0 - \sum C)$. The initial population size can therefore be derived from: $N_0 = a/q$ (Leslie and Davis 1939). The adjusted cumulative catch (x)—the cumulative catch to interval i plus one half of the catch during interval i proposed by Chapman (1961) compensates for the decline in catchability during each time interval (King 2007). Biomass is estimated as: $B = N.\bar{W}$. Where B = estimated biomass (g); N = estimated abundance; and w = mean weight of fish in the population (g) (Anderson and Neumann 1996).

Fish production

Production is estimated by the size-frequency method for fishes as (Garman and Waters 1983): P = 0.5×C[W1(N1-N2)+∑W k(Nk-1-N k)+Wc(Nc-1-Nc)] (1/CPI), where P = production for a given population or multispecies group within a specified interval, N = estimated mean density (arithmetic mean of estimates) for a specific length-group, w = estimated mean weight (arithmetic mean of estimates) of individuals in a specific length-group, k = index for length-groups, c = number of length-groups, and CPI = the cohort production interval (average maximum age of fish in the population or multispecies group in years).

Modeling procedure

CANOCO 4.5 (ter Braak and Smilauer 1998) was used to run canonical correspondence analysis (CCA) as in Seilheimer and Chow-Fraser (2006). Canonical correspondence analysis (CCA) was used to explore the distribution of the fish biomass in relation to the environmental variables. Environmental variables selected for the CCA analysis included continuous variables, such as water quality data (e.g., pH and BOD). All continuous environmental variables were log (1 + x) transformed and standardized to have a zero mean and unit variance.

Artificial neural network (ANN) is a form of artificial intelligence that is composed of a network of connected nodes (Rumelhart et al. 1986). In this model, non-linear elements (neurons) are arranged in successive layers, with a one-way flow of information (i.e., weights) from input layer to output layer, through a hidden layer (Lek and Guegan 2000). The ANN models were performed using the same data matrix as the input (environmental variables). The ANN model predicts biomass of fish populations. Correlation coefficient (R) between observed and estimated values in artificial neural network (ANN) training and testing for the fish biomass (Brosse et al. 2001). Comparison of *fish biomass* during different spatial and temporal carried out by analysis of variance (ANOVA). Statistical analyses were performed with SPSS 21 software package and a significance level of 0.05 was adopted.

RESULTS AND DISCUSSION

A total of 2795 fish individuals comprising 26 species from 6 families were sampled from Shadegan Wetland throughout the entire study period (Table 1).

Table 1 showing the list of fish species caught and the percentage composition for fish population in Shadegan Wetland. The gradient of comprises the wetland species are native (N), exotic (E), and introduce (I) and it show in table 1. Maximum and minimum capture was *Carasobarbus luteus* and *Cyprinion macrostomus*, *Cyprinion kais, Barbus luciobarbus*, and *Tenualosa ilisha*, respectively.

Fish biomass

The biomass in each station of the Shadegan Wetland with Leslie model were calculated (Figure 2). The results of fish biomass in Shadegan Wetland stations indicated that maximum and minimum fish biomass was found in Khorosy (mean 409±44 kg/ha) and Rogbe (mean 102±53 kg/ha) respectively. The mean biomass of fish in four seasons Shadegan 243 (kg/ha) and the amount of biomass in different seasons were not significantly different (F = 22, P<0.05).

Average values of fish biomass in each season presented in Table 2. Maximum and minimum fish catch was *Silurs triostegus* and *Acanthopagrus arabicus,* respectively. This could not be attributed to changes in fishing method, or current strength, all of which remained constant. Value Catchability Coefficients (q) differs in each season and each station in Shadegan Wetland. Mean and standard deviation in q values for Leslie model in different stations were 0.007±0.005.

The *S. triostegus* has highest value of biomass to seem than can adapt with Shadegan Wetland condition in different season. The biomass was calculated in each season of the Shadegan Wetland. Maximum and minimum biomass values were spring (479±9) and winter (181±5). A comparison of value biomass between different season is significant (F = 10.22, P<0.05).

Fish production

The maximum and minimum fish production was showed in Table 2. Generally, the maximum and minimum fish production in Shadegan Wetland was *S. triostegus* and *A. arabicus*, respectively. Overall, *S. triostegus*, *Carasobarbus luteus*, *Carassius auratus*, *Cyprinus carpio*, *Mesopotamichthys sharpeyii* are near 90% production of Shadegan Wetland species. P/B ratio of fish species presented in table 2. Average values production and P/B of fish species were 328±31 kg.ha/yr and 0.99 respectively (Table 2).

Environmental parameters and fish biomass

Fish biomass was strongly correlated with temperature (Figure 3) and Fish biomass regressions with one parameter mentioned below (temperature) were obtained (P<0.05). Fish Biomass = 0.41 (temperature) $^{2.56}$. Fish biomass regressions and temperature with different fish species are shown in Table 3 and the highest value of R^2 this regression were observed in *S. triostegus* species. Other species is no significant value of R^2 (P>0.05).

Physic-chemical parameters and different station are shown in Table 4. A comparison of value salinity is significant between different station (F = 18.21, P<0.05) and other parameters is no significant different station (P>0.05).

Fish biomass and CCA

An ordination of the main fish species and *five stations from* with eight environmental variables produced significant correlations between species, station and variables associated with environmental degradation for AB data (Table 1). The position of a species and station on the CCA tree plot is a reflection of the environmental conditions where it was found. The first axis of the CCA was strongly correlated with environmental conditions, where the positive end of CCA axis 1 was associated with species normally found in degraded conditions, while the negative end was associated with species that are intolerant of water-quality impairment. This location can be interpreted as representing the species' affinity for degraded vs. unimpacted habitat. It seems, distribution of *Carassius auratus* and *Chelon abu* species are associated with temperature; *C. carpio, C. luteus, Hypophthalmichthys molitrix*, *S. triostegus* species are associated with PH and salinity and also, *M. sharpeyii* species with Po4 respectively (Figure 4).

The ANN models yielded correlation coefficients (P<0.05) and in the training procedure and testing procedure value for r for the fish biomass were 90% and %88, respectively. Multi-layer artificial neural network showed four parameters (temperature, salinity, DO and deep) have the greatest impact on fish biomass (Figure 5).

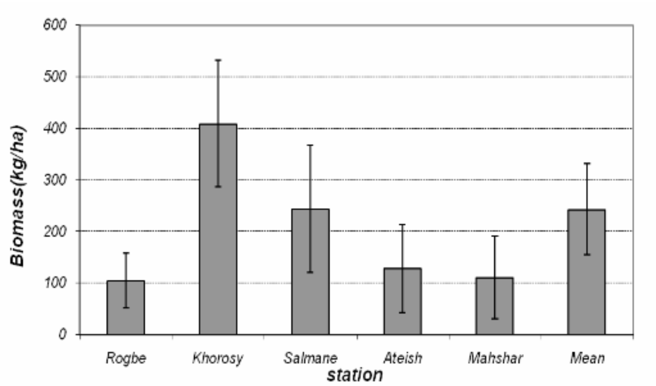

Figure 2. Value fish biomass estimates in different station from Shadegan Wetland (2013-2014)

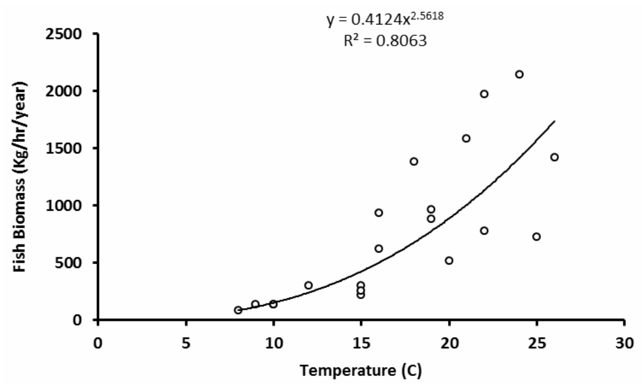

Figure 3. Fish biomass and Temperature in different station from Shadegan Wetland (2013-2014)

Table 1. List of fish species caught and the percentage composition for fish population in Shadegan Wetland (2013-2014)

Family	Species	Status	N	%N
Cyprinidae	*Carasobarbus luteus*	-	634	22.68
	Cyprinus carpio	-	513	18.35
	Carassius auratus	-	417	14.92
	Mesopotamichthys sharpeyii	-	335	11.99
	Leuciscus vorax	-	161	5.76
	Hypophthalmichthys molitrix	-	71	2.54
	Tor grypus	-	70	2.50
	Hypophthalmichthys nobilis	Introduce	51	1.82
	Ctenopharyngodon idella	-	24	0.86
	Luciobarbus pectoralis	Native	14	0.50
	Luciobarbus xanthopterus	-	3	0.11
	Acanthobra mamarmid	-	2	0.07
	Alburnoides bipunctatus	-	2	0.07
	Cyprinion macrostomus	-	1	0.04
	Cyprinion kais	-	1	0.04
	Barbus luciobarbus	-	1	0.04
Clupeidae	*Tenualosa ilisha*	-	1	0.04
	Sardinellas indensis	Exotic	2	0.07
Engraulidae	*Chelon abu*	Native	339	12.13
	Thryssa hamiltonii	Exotic	5	0.18
Mugilidae	*Ellochelon vaigiensis*	-	7	0.25
	Chelon subviridis	Exotic	7	0.25
Mastacembelidae	*Mastacembelus mastacembelus*	Native	21	0.75
Sparidae	*Silurs triostegus*	-	60	2.15
	Acanthopagrus arabicus	Exotic	46	1.65
Siluridae	*Heteropneustes fossilis*	Native	3	0.11

Table 2. Average values catch, total biomass and production of fish species from the Shadegan Wetland (2013-2014)

Species	Spring (kg/ha)	Summer (kg/ha)	Autumn (kg/ha)	Winter (kg/ha)	Mean biomass (kg/ha/yr)	Production (kg/ha/yr)	Production per biomass (P/B)
Acanthopagrus arabicus	0.2	6.8	1.1	-	2±3	2±1	1.39
Aspius vorax	-	17.8	55.1	14.3	21±2	16±5	0.75
Carasobarbus luteus	167.4	43.9	27.7	11.5	62±7	65±1	1.05
Carassius auratus	22.8	62.4	24.1	12.7	30±2	41±7	1.35
Chelon abu	22.8	7.1	8.1	7.9	11±7	9±1	0.81
Cyprinus carpio	57.4	74.8	40.1	14.6	46±2	66±2	1.43
Mesopotamichthys sharpeyii	63.3	53.7	32.7	29.4	44±2	44±6	1.00
Silurs triostegus	93.3	141.2	13.1	90.8	84±5	71±3	0.85
Tor grypus	21.5	-	-	0.5	5±1	4±2	0.76
Others	31.1	7	-	-	9.5±1.5	4±0.5	0.52

Table 3. Fish biomass and temperature in different species from Shadegan Wetland (2013-2014)

Fish species	Regression formula	R^2
Cyprinus carpio	$y = -0.6215x^2 + 38.854x-319.88$	0.5059
Hypophthalmichthys molitrix	$y = 0.8108x^2-21.582x + 132.01$	0.4256
Mesopotamichthys sharpeyii	$y = 0.0296x^2 + 6.6605x-52.136$	0.3641
Silurs triostegus	$y = 1.3568x^2-27.411x + 153.68$	0.5434
Tor grypus	$y = 0.6235x^2-17.028x + 111.21$	0.5155

Table 4. Physic-chemical parameters in different station from Shadegan Wetland (2013-2014)

Variable	Value	Atish	Khorosy	Mahshar	Rogbe	Salmane	P-values
	Max	8.1	10	8.05	6.2	7.1	>0.05
DO	Min	4.5	3	2	2	4.5	
	Mean	6.8±1.6	6.9±3.3	5.2±3.2	3.3±1.8	6.4±1.3	
BOD	Max	4.6	6.6	3.1	2.6	3.4	>0.05
	Min	2.5	4	2	1	2.5	
	Mean	3.7±0.8	4.7±0.9	2.4±0.4	1.7±0.6	2.9±0.4	
pH	Max	8.2	8.8	7.6	8.4	8.1	>0.05
	Min	8	7.2	7.2	8	7.5	
	Mean	8.1±0.1	7.9±0.6	7.3±0.1	8.1±0.1	8.1±0.1	
Tem.	Max	22	21	24	25	22	>0.05
	Min	8	15	9	10	10	
	Mean	16±6.2	18.2±2.6	16.7±6.3	17.5±6.2	16.5±5.2	
Sal.	Max	6	8	50	17	40	< 0.05
	Min	5	2	10	6	6	
	Mean	5.25±0.5	3.68±2.9	18.75±10.2	10.5±4.8	23±2	
NO_3	Max	8.5	8	5.5	5	4.5	>0.05
	Min	4	4.5	4	4.5	3	
	Mean	5.7±1.4	6.7±1.3	4.8±1.1	4.6±0.4	4±0.7	
PO_4	Max	0.7	1.2	0.8	0.6	0.8	>0.05
	Min	0.3	0.2	0.2	0.1	0.2	
	Mean	0.4±0.1	0.6±0.2	0.5±0.2	0.5±0.3	0.5±0.2	
Depth	Max	2.7	2.1	2.6	2.5	2.3	>0.05
	Min	2.1	1.4	1.4	1.4	2	
	Mean	2.4±0.2	1.7±0.3	1.9±0.5	1.9±0.4	2.1±0.1	

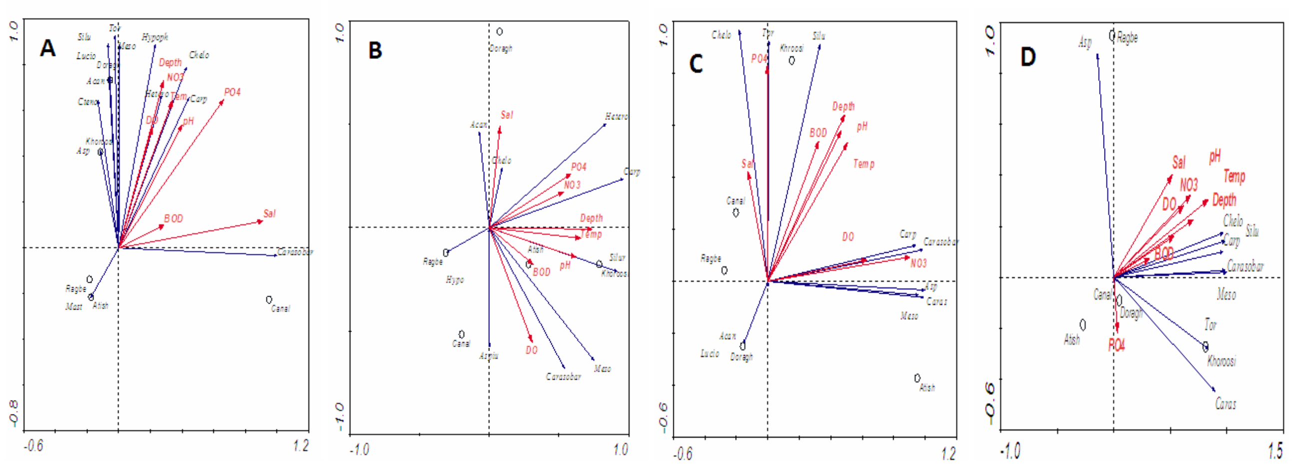

Figure 4. Ordination three plot of main fish species (see Table 1 for species numbers) and five stations from canonical correspondence analysis (CCA) with 8 environmental variables in Shadegan Wetland (A = Spring, B = Summer, C = Autumn, D = Winter).

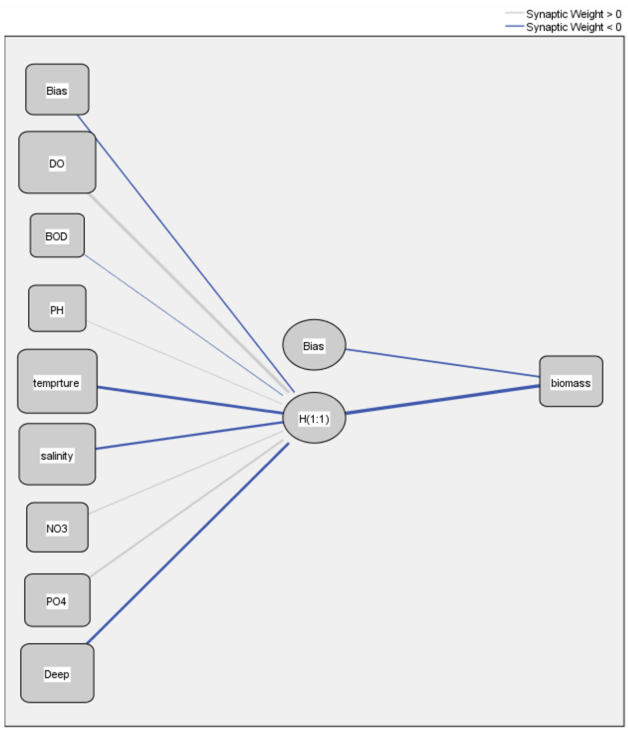

Figure 5. Artificial neural network (ANN) with one input layer corresponding to the input (independent), one hidden layer and one output layer to estimate the output (dependent). Solid lines show connections between neurons. Bias neurons are also shown their input value is biomass

Discussion

The native marshland fish populations were originally dominated by Cyprinid fish of the genus *Barbus*. Overall, *B. luteus, M. sharpeyii, C. carpio, C. carasus, A. vorax* and *Chelon abu* are included over 70% biomass and fish main species of Shadegan Wetland species (Hashemi et al. 2015). The dominance of cyprinids in tropical reservoirs has been observed in Sri Lankan reservoirs, where the family formed over 50% of the species present (Amarasinghe 1992). Abundance of fish populations in river, lake with river source and reservoirs widely changed from year to year and the relative frequency of different species is different in population. The increasing area and flood flow time is improved spawning, growth and survived rate (Welcomme 2001). Bias associated with fishing gear types can greatly influence comparisons of aquatic habitats, especially when meaningful community information is desired for habitat restoration research (Jackson and Harvey 1997).

Average fish biomass in spring and summer of 1997, 70.2 kg/ha, 109.2 kg/ha, and in 2001, 186.5 kg/ha and 269.4 kg/ha and in 2009, 249 kg/ha, 216 kg/ha was calculate, respectively (Maramazi 1997; Ansari et al. 2001; Hashemi et al. 2012). In spring and summer were increased of biomass comparing 1997, 2001 and 2009. It seems, climate change and wetland nutrient elements are very effective factor that influenced on biomass. The Khorosy stations in different seasons have high amount of fish biomass. It seems, that entering the Jarahi river for east side of the wetland and location of Khorosy station in near the river month and entering of nutrition element was caused to increase phytoplankton and phytobentozic production that caused to increase fish biomass in these areas (Kholfenilsaz 2009). The dynamics of wetland fish communities are determined by periodically changing abiotic factors, especially water temperature and water level, and biotic factors, especially food availability. Water level fluctuations have several important functions and result in pulses of nutrient input and fish abundance. Wetland fish stocks can usually be sustained as long as the pristine flood regime is retained, but disruption of the flooding pattern interferes with fish breeding and nutrient flow (Bruton and Jackson 1983).

Mean ± S.D fish production values were 325±33 kg ha/yr. Productive reservoir fisheries have developed in small reservoirs in Africa with yields of up to 329 kg ha/yr, in Latin America and the Caribbean with yields up to 125 kg ha and in Asia with yields up to 650 kg ha/yr (SOFIA 2002). Fish production estimates are valuable statistics for understanding population dynamics and elucidating ecological relationships and have great potential for improving fisheries management.

Based on P/B value were as 0.52-1.43. Typical values of P/B for freshwater invertebrates range from 2.5 to 5, with a mean of 3.5. Values for fishes generally are lower. (Waters et al. 1990) The P/B (per year) ratio indicates how quickly biomass is potentially changing. For fish populations in lakes, most P/B ratios varied between 0.2 and 5.0, and were inversely related to maximum size of the fish in the populations and positively related to lake productivity (Downing and Plante 1993).

In the CCA ordination, axes 1 and 2 together explained a high percentage of variance of the species-station-environment tree plot, with temperature, salinity, PH and DO, as the most important variables influencing the variation of fish composition in the Shadegan Wetland (Figure 5). It seems in multivariate indices; depth and Po4 have low affect associated with species distribution (Hashemi et al. 2015). Thus, the fish assemblage of the freshwater-influenced habitat was characterized by the presence of numerous species that are tolerant to low-salinity conditions, and enter the system mainly for food and protection. The fish assemblage of the marine-influenced habitat was characterized by the presence of occasional and seasonal species (Simon 1999).

Fish biomass regressions and ANN model was showed four parameters (temperature, salinity, DO and depth) have the greatest impact on fish biomass. Among the physic-chemical factors, water salinity, temperature, dissolved oxygen, and their regular or irregular fluctuations at different time scales, have been identified as determinants in fish ecology (Blaber 2000). The associations between fish biomass and water quality variables owing to a complex array of stochastic and/or deterministic effects, long-term studies are ideal because they incorporate both annual and seasonal variation (Leash and Pigg 1990).

The successful application of ANN at various spatial scales, and for a range of aquatic ecosystems (lakes and rivers), organisms (invertebrates and fish), and ecological descriptors (abundance, Shannon diversity index, and community composition) demonstrated in this study opens new fields for the application of ANN in aquatic ecology (Lek and Guegan 2000). Due to their ability to mimic non-linear systems, ANNs proved far more effective in modeling the distribution of these species in the marine ecosystem (Brosse et al. 2001). The ANN models could be developed using information measured in undisturbed reference sites (environmental parameters and fish biomass), and deviations between reference and test sites may be interpreted with respect to potential anthropogenic impacts.

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REFERENCES

Amarasinghe US. 1992. Recent trends in the inland fishery of Sri Lanka. In: Baluyut EA (ed.) Indo-Pacific Fishery Commission, FAO Fishery Report No. 458 Supplement, Rome, 84-105 pp.

Anderson RO, Neumann RM. 1996. Length, weight, and associated structural indices. Pages 447-482 in BR. Murphy and DW. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Ansari H, Mohammadi GH. 2001. Capture fishing status in Shadegan Wetland. South of Iran Aquaculture Fishery Research Center, Ahwaz, Iran.

Ansari H, Hashemi SAR, Eskandari GH. 2009. Survey fishing status and Biomass fish in Shadegan Wetland. The 1th Scientific Conference of Iranian Wetland, 3-4 March 2009, Ahwaz.

Blaber SJM. 2000. Tropical Estuarine Fishes. Ecology, Exploitation and Conservation. Fish and Aquatic Resources Ser. 7, Blackwell Science, New York.

Brosse S, Lek S, Townsend CR. 2001. Abundance, diversity, and structure of freshwater invertebrates and fish communities: An artificial neural network approach. N Z J Mar Freshw Res 35 (1): 135-145.

Bruton MN, Jackson PBN. 1983. Fish and fisheries of wetlands. J Limnol Soc Southern Africa 9 (2): 123-133.

Chapman DG. 1961. Statistical problems in dynamics of exploited fisheries populations. Proc Berkeley Symp Math Stat Probab 4: 153-168.

Clesceri LA, Greenberg AE, Trussel RR. 1989. Standard Methods for the Examination of Water and Wastewater. 17th ed, APHA-AWWAWAPCF, Washington.

Downing JA, Plante C. 1993. Production of fish population in lakes. Can J Fish Aquat Sci 50: 110-120.

Garman GC, Waters TF. 1983. Use of the size-frequency (Hynes) method to estimate annual production of a stream fish population. Canadian J Fish Aquat Sci 40: 2030-2034.

Hashemi S, Eskandary Gh, Ansary H, Yooneszadeh M. 2011. Stock assessment and production of fish species in the Shadegan Wetland, Iran. World J Fish Mar Sci 3 (6): 502-508.

Hashemi S, Eskandary Gh, Ansary H. 2012. Biomass of fish species in the Shadegan Wetland, Iran. Res J Recent Sci 1 (1): 66-68.

Hashemi S, Ghorbani R, Kymaram F, Hossini S A, Eskandari G, Hedayati A. 2015. Fish species composition, distribution and abundance in Shadegan Wetland. Fish Aquac J 6: 128. DOI: 10.4172/2150-3508.1000128.

Jackson DA, Harvey HH. 1997. Qualitative and quantitative sampling of lake fish communities. Can J Fish Aquat Sci 54: 2807-2813.

Kholfenilsaz M. 2009. Survey frequency and diversity planktonic in Shadegan Wetland. Sci J Mar Biol 1 (1): 1-12.

King M. 2007. Fisheries biology, assessment and management. Fishing News Books, Oxford.

Kolding J, Zwieten PAM van. 2006. Improving productivity in tropical lakes and reservoirs. Challenge Program on Water and Food-Aquatic Ecosystems and Fisheries Review Series 1. Theme 3 of CPWF, C/o World Fish Center, Cairo, Egypt.

Lek S, Guegan JF. 2000. Artificial Neuronal Networks, Applications to Ecology and Evolution. Springer-Verlag, Berlin.

Leslie PH, Davis DHS. 1939. An attempt to determine the absolute number of rats on a given area. J Anim Ecol 8: 94-113.

Lotfe A, Ghafari H, Behrozirad B, Savari A, Kawosi K. 2003. Human activity and their affect in Shadegan Wetland. Conselor Engining Publisher No. 2, Iran.

Maramazi Gh. 1997. Fish stock assessment in Shadegan Wetland. South of Iran Aquaculture Fishery Research Center, Ahwaz, Iran.

Prince HH, Padding PI, Knapton RW. 1992. Waterfowl use of the Laurentian Great Lakes. J Great Lakes Res 18: 673-699.

Randall R.G., Minns CK. 2000. Use of fish production per unit biomass ratios for measuring the productive capacity of fish habitats. Can J Fish Aquat Sci 57: 1657-1667.

Reash L, Pigg J. 1990. Physicochemical Factors Affecting the Abundance and Species Richness of Fishes in the Cimarron River. Proc Oklahoma Acad Sci 70: 23-28.

Rumelhart DE, Hinton GE, Williams RJ. 1986. Learning internal representations by error propagation. Nature 323: 533-536.

Seilheimer TS, Chow-Fraser P. 2006. Development and use of the wetland fish index to assess the quality of coastal wetlands in the Laurentian Great Lakes. Can J Fish Aquat Sci 63: 354-366.

Simon TP. 1999. Assessing the suitability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.
SOFIA. 2002. The State of World Fisheries and Aquaculture 2002. FAO Fisheries Department, Rome.
Ter Braak CJF, Smilauer P. 1998. CANOCO reference manual and user's guide to CANOCO for windows: software for canonical community ordination. Version 4. Microcomputer Power, Ithaca, New York.
Waters TF. 1997. Secondary production in inland waters. Adv Ecol Res 10: 91-164.
Waters TF, Doherty MT, Krueger CC. 1990. Annual production and production: biomass ratios for three species o stream trout in Lake Superior tributaries. Trans Am Fish SOC 119: 470-474.
Welcomme R. 2001. Inland fisheries ecology and management. Food and Agriculture Organization and Fishing News Books, Blackwell Science Ltd., New York.