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Fish Species Assemblages in Two Riverine Systems of Mujib Basin in Jordan and the Effects of Impoundment

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Abstract

Mujib and Haidan rivers were sampled in July 2011 to identify fish populations in the riverine system, and to investigate the impact caused by the existence of two dams. Fishes were sampled by electofishing gear through 14 sampling points distributed along the two rivers. The Mujib Dam lake was sampled by gillnets. A total of 2,854 fish specimen were caught during the study of which most consisted of native species but included small numbers of invasive species.
The native *Capoeta damascina* and *Oxynoemacheilus insignis* were found in both rivers but *Garra rufa* was only recorded below their confluence to the west. Four invasive species were recorded. The cichlids *Oreochromis aureus* and *Tilapia zillii* were sampled along Mujib River, and the African Catfish *Clarias gariepinus* and the Common Carp *Cyprinus carpio* were observed only in the lake of Mujib Dam but were not sampled. The construction of the two dams has led to significant changes in the habitats, water flow, and hydrology of the two rivers both upstream and downstream, and enhanced the colonisation of invasive species. There is, therefore, an urgent need to review the management of the system across all stakeholders and to continue monitoring on a regular basis.

Key words: Fish diversity, Conservation, *Oxynoemacheilus insignis*, Invasive, Impact.

1. Introduction

In arid regions, the escalating demands for water have resulted in the substantial modification of many river systems (Propst *et al.*, 2008). In conjunction with the widespread invasion of many rivers by non-native fishes, this has increased the threat of local native fish populations being extirpated and endemic fishes becoming extinct (Kingsford, 2000; Olden and Poff, 2005; Propst *et al.*, 2008).

This situation exists in most of the Jordanian water bodies because Jordan is considered the fourth world poorest country in water (Denny *et al.*, 2008). Damming became a growing activity in the past decades, and major rivers in the country were impounded to allocate water for domestic use. Two of these major rivers are the Mujib and Haidan, both located within the Mujib Basin [Centre coordinates: E 36° 1' 35" N 31° 9' 52"] flowing from east to west before entering the Dead Sea. In 2002 and 2003, two dams were constructed on the Haidan (Waleh Dam) and Mujib (Mujib Dam) rivers, respectively, which caused a concern for the wellbeing and long term survival of their native fish populations. The two dams were constructed to provide a regular and more sustained supply of water year round to charge the aquifer, for drinking and agricultural purposes.

In 2003 when the reservoir was filled for the first time, fish sampling by the author revealed large numbers of introduced cichlids. Seven years later, analyses of water samples showed evidence of contamination by heavy metals (Manasreh *et al.*, 2010), after which fish monitoring was carried out by the Royal Society for the Conservation of Nature (RSCN), to assess the impact caused by the dams using the native fish populations as an indicator of impact level.

Although there are few recent studies on the fresh water fish of Jordan (e.g. Hamidan and Mir, 2003; Hamidan, 2004), none of them addressed the Mujib Basin in particular except for the tentative work jointly performed by RSCN and the Limnology Department in the University of Vienna in 2001, and the Length-weight relationships assessment of the three native species in the basin (Hamidan and Britton, 2012). Details of the fish fauna of Jordan are largely confined to taxonomic revisions provided by Krupp and Schneider (1989) all of which were completed before the above rivers were impounded. The aim of the current study is to establish a baseline data on fish diversity in the two river systems, and to identify the existing and potential threats to their survival posed by changes in water flow and impoundment.

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2. Materials and Methods

2.1. Study Area

The Mujib basin (Figure 1) covers an area of 6,600 km^2 and consists of two major sub-catchments, the Wadi Mujib catchment (4,500 km^2), and the Wadi Wala (or Haidan) catchment (2,100 km^2). The rivers' beds are covered in soft sediments derived from windblown, while, in the downstream area, the slopes are steep due to flush flood erosion and the comparatively more rainfall occurrence (Al-assa'd and Abdulla, 2010). Perennial flow only occurs in downstream reaches where elevations are (- 400 m) lower than the mean sea level. The elevation in Mujib basin ranges from about 950 m a.m.s.l. southern of Karak city to an approximate of 400 m below sea level at the outlet of Wadi Mujib. The two rivers were divided into three sections for the purpose of sampling:

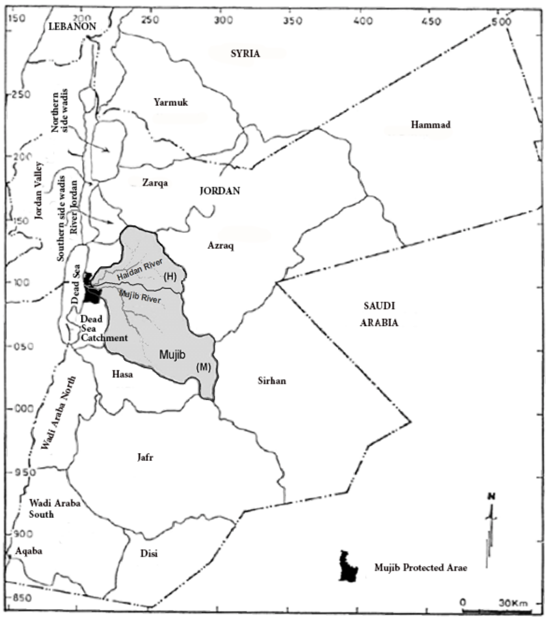

Figure 1. Location of Mujib basin in Jordan according to JICA/WAJ (Japan International Cooperation Agency/Water Authority of Jordan) (1987) Hydrologeological and water use study of the Mujib watershed, appendix (I) Final report. Amman, Jordan. Mujib Protected Area's location was added to the original map. Adapted by the author: Mujib Basin is showing the two sub-catchments: Haidan sub-catchment (H) and Mujib sub-catchment (M).

Section 1: Mujib River: This section starts from the riverhead 20 km east of the dam at Um Al-Rasas (E 35˚53'46" N 31˚23'59"), down to the confluence point locally known as *Malagi* with Haidan River passing through the Mujib dam. Two main wadies drain into the Mujib Dam locally known as Wadi Al-Sawalqah and Wadi Nkhailah where the southern wadi Nkhailah is completely dry, unlike the running northern wadi Al-Sawalqah. The water within the Mujib River is shallow and there are no deep water bodies. The water current ranges between 0.6-0.8 m/s and varied according to the area of water spreading. Most of the river is heavily vegetated with reeds. The river substrate consists of small to medium sized rocks.

In 2010, after the establishment of the dam, Manasrah *et al.* investigated the contamination of water and sediment in Mujib Dam by heavy metals. Manasrah revealed that the sediments are polluted with Cadmium (Cd), relatively contaminated with Nickel (Ni), and Zink (Zn), and uncontaminated with respect to Magnesium (Mn), Led (Pb), and Cupper (Cu).

Section 2: Haidan River: The area is located in upper Haidan River west to the Walah Dam down to the confluence point. Most of the upper wadi is dry, especially the area east to the dam; water appeared west of Walah Dam (due to the recharging process the dame is applying on the aquifer). The water is being utilised for agriculture where local farms exist along this section. Continuing west toward the Dead Sea, water disappeared and the whole wadi became dry through the Mujib Protected Area deep in a basalt canyon until reaching a 45 meter height waterfall, water starts to flow with the aid of side springs supplying the river.

Water depth varies from few centimeters of flowing water to 4 metre deep ponds within the canyon areas. Current speed varies from 0 m/s up to 0.5 m/s. For agricultural purposes, water is being pumped from the river or from the dam pond to irrigate the high water consuming corps. The substrate consists of small sized rock beds to larger sized rocks within the canyon. A few areas downstream are heavily vegetated with reeds that cover the whole river area.

Section 3: Mujib and Haidan: This is the last section where both Mujib and Haidan Rivers meet then drain to the Dead Sea along 3.4 km distance through Mujib canyon, where 12 metres height water fall occurs after 1.2 km to the west of the Mujib canyon entrance. Water is shallow, and the current speed is the highest where it reaches 1 m/s in the canyon. Vegetation is minimal except for the downstream where the canyon is becoming wide (maximum of 8 metres) and vegetation of reeds, Oleander and *Typha* are the most dominant plant species. Before reaching the Dead Sea, water is converted to water treatment station, treated, and pumped for human consumption leaving behind a minimum amount of water drained to the Dead Sea.

2.2. Fish Sampling

Fish were sampled in 14 sites along the basin during July 2011. The sampling location was distributed to six sites in Mujib River section, three sites in Haidan River system, and five sites in Mujib-Haidan system downstream of the confluence point (Figure 2).

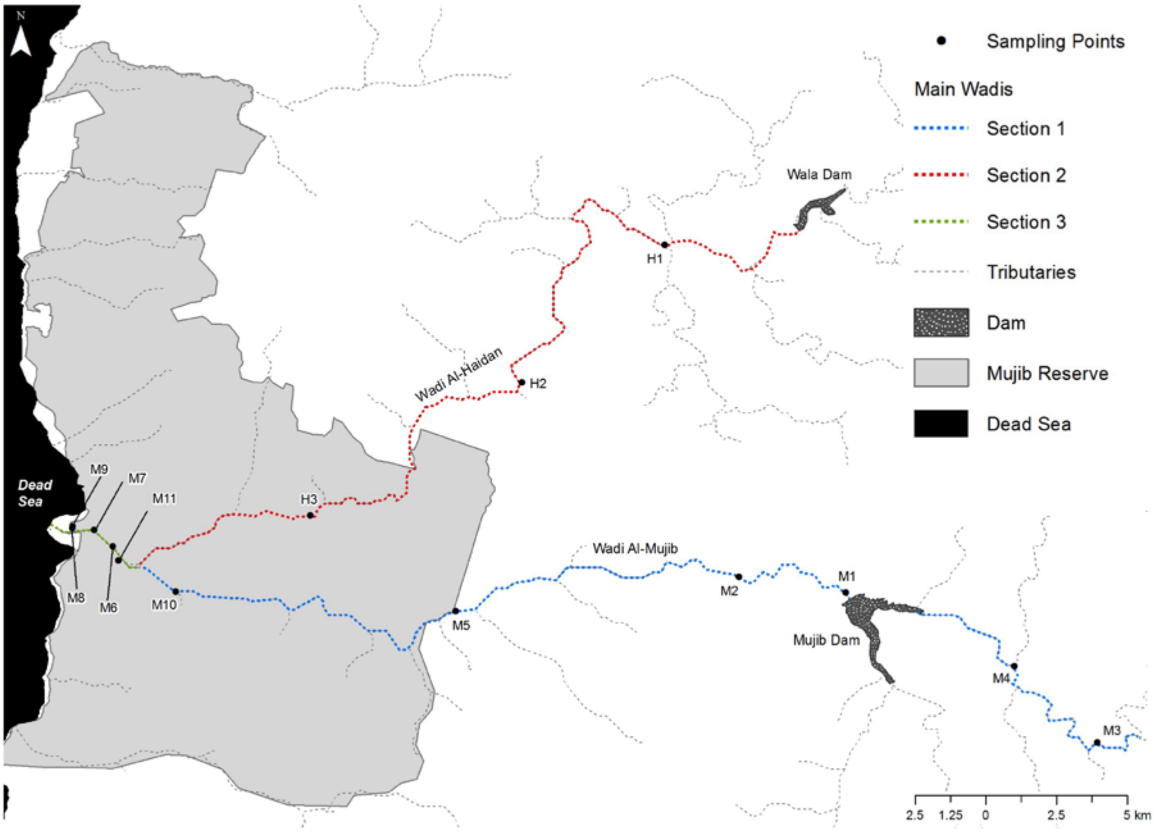

Figure 2. The study area where water was available along the two rivers, including the sampling points.

The sampling sites were designed to reflect a representative sample of habitats along each section. Sampling is comprised by battery-powered, back-mounted electric fishing gear, while gill nets of mesh sizes up to 22 mm was only used in the lake of the Mujib Dam. Once captured, fish were identified to species level, measured (standard length, SL, nearest 1 mm), weighed (to 0.01 g), and immediately released alive at the sampling site. Data on length-weight relationship were reported by Hamidan and Britton (2012). Fish standard length were categorised into 1 cm groups, and plotted against number of fish individuals in the same size group.

3. Results

A total of 2,854 specimens representing seven species were caught during the study. These species include *Capoeta damascina* (92% of total catch), *Oxynoemacheilus insignis* (6.1 %), *Garra rufa* (1.15 %), and the alien *Oreochromis aureus* (3.5%) and *Tilapia zillii* (7.02%). The African Sharptooth Catfish *Clarias gariepinus* and the Common Carp *Cyprinus carpio* were both observed in the Mujib dam lake.

Mujib River section: Four species were identified in this section including two native species *C. damascina* and *O. insignis* coexisting with two introduced cichlids *O. aureus* and *T. zillii.* The population structure of *C. damascina* was dominated by Young of the Year (YOY) fish from 10-40 mm length class, while few large specimens of length 230 mm were presented (Figure 3-A). As for *O. insignis* the population structure was dominated by medium sized fish class of 50-70 mm length (Figure 3-B).

Haidan River: large numbers of fishes were found trapped in isolated ponds as a result of flow discontinuity, while others were found dead in other ponds that were dried up completely (Figure 4). Two native species were found to inhabit this river, *C. damascina* and *O. insignis*. No introduced fish were sampled, although local fishermen assured the existence of cichlids in the river. Population structure for the *C. damascina* showed dominance of (YOY) fish of 30-40 mm length class. (Figure 3-C), while for *O. insignis* the population structure showed the dominance of YOY from the 3-4 mm length class (Figure 3-D).

Mujib-Haidan: the native *Garra rufa* appeared after the high waterfall in addition to the two native species *C. damascina* and *O. insignis.* One specimen of *T. zillii* was found close to the river mouth at point M7. *Capoeta damascina* showed a population structure dominated by YOY from 30-50 mm, few individuals from the length class 210-220 were frequently sampled (Figure 3-E). *Oxynoemacheilus insignis* population structure was found to be dominated by larger seized individuals, with few YOY presented, while *G. rufa* population structure showed a population dominated by YOY from the size class of 20-30 mm (Figure 3-F), and (Figure 3-G), respectively.

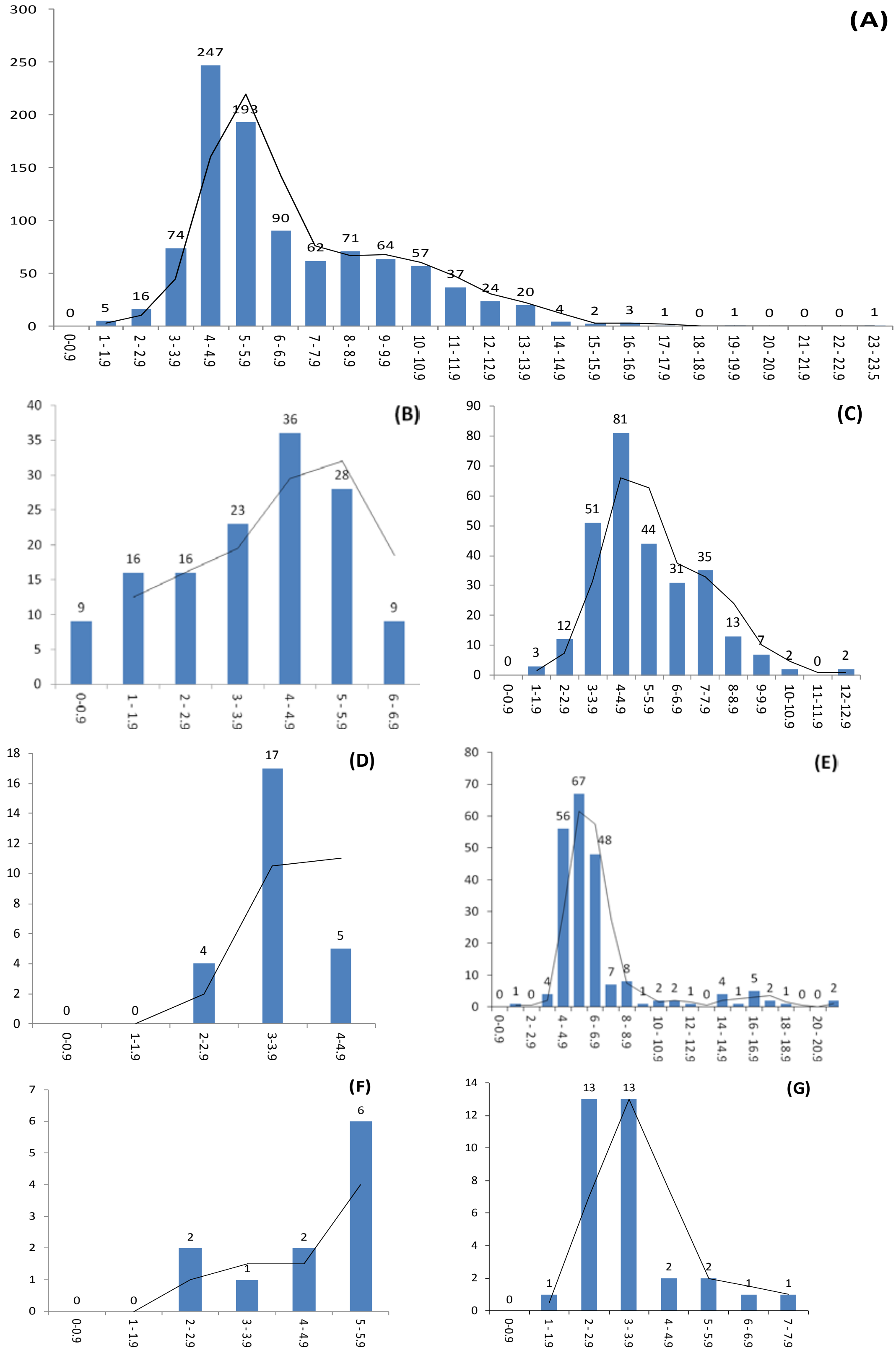

Figure 3. Population structures of native fishes in each section of the study area. Standard length is plotted on the X-axis in centimetre, and the number of individuals in each category at Y-axis. **(A)** Population structure of *C. damacina* in Mujib River (n=972), **(B)** Population structure of *O. insignis* in Mujib River (n=137), **(C)** Population structure of *C. damacina* in Haidan River (n=281), **(D)** Population structure of *O. insignis* in Haidan River (n=26), **(E)** Population structure of *C. damacina* in Mujib-Haidan River section (212), **(F)** Population structure of *O. insignis* in Mujib-Haidan River section (n= 11), and **(G)** Population structure of *G. rufa* in Mujib-Haidan River section (n=33).

4. Discussion

This study assures the importance of Mujib basin in hosting three populations of native species of the Jordanian ichthyofauna, including *G. rufa* at its southern most edge of distribution in Jordan, represented by an isolated population down to the Mujib River close to the Dead Sea. Mujib Dam is known for its high catch of fish in general among fishermen (Hamidan, Per. Comm., 2010). The low number of fish in the dam is probably due the recent introduction of the Catfish *Clarias gariepinus*, and the accumulative impact caused by the Common Carp, *Cyprinus carpio*, while *Clarias gariepinus* is well known for its predation of fish fry and even juveniles (Tawwab, 2005); *Cyprinus carpio* is the third most frequently introduced species in the world "known to be the keystone ecosystem engineer that altering habitats for native fish and other native aquatic species" as stored on the Global Invasive Species Database.

In Walah Dam, the system is different than Mujib, since the dam receives water from the rain water runoff; the water then recharges the aquifer, and no permanent rivers feed into the dam. As a result the dam lake is not a favourable habitat for native or introduced species. In addition, the dam lake dries regularly, and is mechanically cleaned. In addition to the limited accessibility to the dam, these factors reduce the chance of introducing invasive fish species. The extensive water pumping from the Haidan River over a long distance from Walah Dam west to the entrance of the river into the protected area clearly resulted with discontinuity of the water flow. A large number of fish was found dead in groups due to the gradual drying of their isolated water bodies where they were trapped (Figure 4). This, happening prior to the spawning season, resulted in the removal of breeding adults which will consequently cause the population declining at long run. This was not the case in Mujib River where the fish content and structure were healthier.

Figure 4. Number of native fish found dead along Haidan River because of drought.

In terms of the fish compositions in the river, the introduced cichlids start to appear in low numbers, where the numbers became lower when moving west. This is due to the nature of those cichlids since they are not well adapted to the fast running water, although they are well known for their great breeding potential and the explosive increases in population (Buntz and Manooch, 1968). The number of juveniles was very limited and restricted to the stagnant water on river banks, where this kind of water is regularly washed off in the seasonal floods and cause drifting of those cichlids down to the Dead Sea.

In Mujib-Haidan section, the water velocity starts to increase since the elevation is decreasing, and the well adapted bottom dweller *G. rufa* starts to appear after the natural barrier, represented by the Mujib Waterfall. The relative abundance of *O. insignis* was found to be lower than those of *G. rufa* and this could be linked to the fact that *G. rufa* is well adapted to fast running water due to its specialised mental desk. *Capoeta damascina* is still dominating the whole system since it is widely distributed in the basin and is being well adapted to both stagnant and running water.

The population structure of *C. damascina* showed healthy population dominated by YOY, which confirms the breeding success in the past season. *Oxynoemacheilus insignis* did not present such type of structure except in Haidan, however, for this species, in particular, there is almost nothing known about its biology (Krupp and Schneider, 1989); this is challenging the judgment on the species' population structure.

Several threats were identified during the present survey and earlier when the Mujib dam in particular was in operation. The first and most important impact causing factor is the controlling of the natural flow regime resulting in unexpected flooding.

Flow regime is an important determinant of the reproductive success of native and non-native fish species in regulated rivers (Brown and Ford, 2002). Controlling the flow enhances the growth of reed along the river, where it used to be washed out annually. Reed, in some location, is in high density covering the river and minimising the fish utilised habitats and forming a natural barrier along the river. The unexpected floods in summer due to cleaning processes in the dam causes significant removal of fish fry and YOY by washing them down to the Dead Sea, knowing that the period of May to June is the breeding season of the dominant *C. damascina* (Asadollah, 2011).

The dam lakes also promotes "invasive friendly receiving environment" since the introduced species, including one of the globally worst invaders, the Common Carp, which cannot adapt to the fast running water in Mujib, and/or the regular flooding cycle. The Lake of the dam makes such environment suitable for introduced species, and induces a 30-40 meters deep pool that is not known along the river system. Having no native species in the dam is only an indicator that those species (native) could be overstepped by the new invading species mainly the Common Carp and the Catfish. On the other hand, cichlids leaked to the river system out of the dam, but they did not succeed to establish a viable population because they are not adapted to such an environment.

The risk of the river has been invaded by more invasive species that can adapt to the running water and the flood cycle is not excluded. The potential expansion of catfish down the river is possible since this species is found in other running water bodies, like Zarqa River (Hamidan, personal observation, 2011). On the other hand, pollution will be - if not already is - transferred to the native and introduced fish in the dam, and consequentially to the river system down to the Dead Sea. Notes from the protected area staff show a high number of dead fish downstream from time to time.

Fishing is being practiced in and around the Mujib dam, where it is strictly illegal in the dam lake due to safety considerations. This fishing practice encouraged fishermen to introduce more high fish meat contents like Carp and Catfish, although the native *C. damascina* is well known to fishermen for its local name *Haffaf* and its taste, and is still targeted. As a result, productive individuals from the populations have been removed annually. Both dams and the surroundings are located in the "allow-hunting" area, where hunters used to target wildfowl species using the lead shots. In Mujib Dam, hunting is not allowed by the dam authority, and the lake of the dam is designed not to have any shoreline, where hunters cannot bring their hunts. A number of ducks was found dead in the dam after being shot, where they deteriorated, enriching the organic matter concentration in the impounded water. Furthermore, the type of shots that were used in hunting also enhanced the lead content in the lake of the dam, and this will eventually be transferred to fish and birds.

In conclusion, this survey confirmed the importance of Mujib-Haidan basin for three native species of Jordanian ichthyofauna. However, establishing the dams of Mujib and Walah has modified the natural water system, and blocked large amount of water behind. This water used to flow down to the Dead Sea without being controlled. In addition, the dam controls the annual flooding cycle that forms one of the major determinant features in this kind of river system. The dam indirectly facilitates the introduction of alien species including the globally third introduced species *C. carpio*. Currently, none of the invasive species has managed to establish viable population out of the dam lake. But potential coming threats are still possible if "fast running water" adaptive species are introduced, or if the catfish manages to escape into the river.

The major impact on the river system and the consequences of the impoundment are classified as anthropogenic factors mainly for agricultural practice, fishing, and hunting. Management of Mujib Protected Area needs to consider the integrated approach in watershed management including multi-sectorial involvement of stakeholders, while promoting both the upstream management concept, and environmental friendly and agriculturally sustainable practices.

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References

Al-Assa'd T and Abdulla F. 2010. Artificial groundwater recharge to a semi-arid basin: case study of Mujib aquifer, Jordan. *Environ Earth Sci.*, **60**:845–859

Asadollah S, Soofiani N, Keivany Y and Shadkhastz M. 2011. Reproduction of Capoeta damascina (Valenciennes, 1842), a cyprinid fish in Zayandeh-Roud River, Iran. *J Applied Ichthyol.*, **27**:1061-1066.

Bagenal TB and Tesch FW. 1978. Age and growth. In: T. Begenal (Ed.), **Methods for Assessment of Fish Production in Fresh Waters,** 3rd Edn. IBP Handbook No. 3, Blackwell Science Publications, Oxford: 101- 211 – 216

Bolger T and Connolly P L. 1989. The selection of suitable indices for the measurement and analysis of fish condition. *J Fish Biol*., **34**:171-182.

Brown L and Ford T. 2002. Effects of flow on the fish communities of a regulated California River: implications for management native fishes. *River Res Applications*,**18**: 331–342.

Buntz J and Manooch CS. 1968. *Tilapia aurea* (Steindachner), a rapidly spreading exotic in south central Florida. Proc. SE Assoc. *Game Fish Comm*., **22**: 495-501

Denny E, Donnelly K, McKay R, Ponte Gand Uetake T. 2008. Sustainable Water Strategies for Jordan. *University of Michigan, Ann Arbor*.

Froses R and Pauly D. 2000 **FishBase: Concepts, Design and Data Sources**. ICLARM, Los Baños, Laguna, Philippines. 344 p.

Global Invasive Species Database, at: http://www.issg.org/ database/species/search.asp?sts=sss&st=sss&fr=1&sn=common+carp&rn=&hci=-1&ei=-1&lang= EN

Hamidan N. 2004. The freshwater fish fauna of Jordan. *Denisia*, **14**: 385 – 394.

Hamidan N and Britton J R. 2013. Length-weight relationships for three fish species (*Capoeta damascina, Garra rufa, and Oxynoemacheilus insignis*) native to the Mujib Basin, Jordan. *J Appl Ichthyol*.,, **29** : 480-481.

Hamidan N and Amir S. 2003. The status of *Garra ghoronsis* in Jordan: distribution, ecology and threats. *Zool Middle East*, **30**: 49-54

Jackson P B N. 1989. Prediction of regulation effects on natural biological rhythms in south-central African freshwater fishes. *Regulated Rivers: Research and Management*, **3**: 205-220.

Kingsford RT. 2000. Ecological impacts of dams, water diversions and river management on floodplain wetlands in Australia. *Austral Ecol*.,**25**: 109-127.

Krupp F and Schneider W. 1989. The fishes of Jordan River drainage Basin and Azraq Oasis. *Fauna of Saudi Arabia*, **10**: 384-410.

Manasreh W, Hilat I and El-Hansan T. 2009. Heavy metal and anionic contamination in the water and sediments in Al-Mujib reservoir, central Jordan. *Environ Earth Sci*., **60**:613– 621

Moutopoulos DK and Stergiou KI. 2002. Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). *J Appl Ichthyol.*, **18**: 200–203.

Olden JD and Poff NL. 2005. Long-term trends in native and non-native fish faunas of the American Southwest. *Animal Biodiversity and Conservation*,**28**: 75-89.

Propst DL, Gido KB and Stefferud JA. 2008. Natural flow regimes, nonnative fishes and native fish persistence in arid-land river systems. *Ecological Applications*,**18**: 1236-1252.

Tawwab M. 2005, Predation efficiency of Nile Catfish, *Clarias gariepinus* (Burchell, 1822) on Fry Nile Tilapia, *Oreochromis niloticus* (Linnaeus, 1758): Effect of prey density, predator size, feed supplementation and submerged vegetation. *Tur J Fisheries and Aquatic Sci.*, **5**: 69-74 .