Macroinvertebrates of the Iranian running waters: a review

Macroinvertebrados de águas correntes do Irã: uma revisão

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Abstract: A comprehensive review of macroinvertebrate studies conducted along the Iranian running waters over the last 15 years has been made by providing the most updated checklist of the Iranian running waters benthic invertebrates. Running waters ecosystems are complex environments known for their importance in terms of biodiversity. As part of the analysis, we endeavored to provide the critical re-identification of the reported species by through comparisons with the database of the Animal Diversity Web (ADW) and appropriate literature sources or expert knowledge. A total of 126 species belonging to 4 phyla have been compiled from 57 references. The phylum Arthropoda was found to comprise the most taxa (n = 104) followed by Mollusca, Annelida and Platyhelminthes. Ongoing efforts in the Iranian running waters regarding biomonitoring indices development, testing, refinement and validation are yet to be employed in streams and rivers. Overall, we suggest that future macroinvertebrate studies in Iranian running waters should be focused on long-term changes by broadening target species and strong efforts to publish data in peer-reviewed journals in English.

Keywords: biodiversity; biomonitoring; assessment; freshwater ecosystems.

Resumo: Este trabalho contém uma ampla revisão sobre os estudos de macroinvertebrados realizados em águas correntes iranianas ao longo dos últimos 15 anos com o objetivo de fornecer um checklist de invertebrados bentônicos. Ecossistemas de águas correntes são ambientes complexos e conhecidos por sua importância para a biodiversidade. Como parte da análise, nós nos esforçamos para oferecer uma re-identificação crítica das espécies encontradas comparando-as com o banco de dados da Animal Diversity Web (ADW) e com fontes bibliográficas adequadas ou conhecimento especializado. Um total de 126 espécies de 4 filos foram compiladas em 57 publicações. O filo Arthropoda é o que contém o maior número de taxa (n = 104), seguido de Mollusca, Annelida e Platyhelminthes. Os esforços atuais em ambientes aquáticos do Irã estão relacionados ao desenvolvimento de índices de biomonitoramento, testes, refinamento e validação para serem utilizados em córregos e rios. Em uma visão geral, nós sugerimos que estudos futuros sobre macroinvertebrados em águas iranianas devam ser focados em mudanças de longo prazo, na ampliação do conhecimento de espécies-alvo e em fazer fortes esforços para publicar os resultados em revistas científicas na língua inglesa.

Palavras-chave: biodiversidade; biomonitoramento; avaliação; ecossistemas de água doce.

1. Introduction

Riverine ecosystems are complex environments known for their importance in terms of biodiversity (McCluney et al., 2014). However, human activities (pollution, tourism, commercial fisheries, eutrophication, sediment discharge and sand extraction) have directly and indirectly affected the biodiversity of these ecosystems on a worldwide scale (Wei & He, 2012; Goudie, 2013; Kim et al., 2015; McCluney et al., 2014).

There is a vastly extended network of rivers in Iran most of which seasonally are filled with water. Some permanent rivers run from the Alborz or the Zagros to the Caspian Sea, Persian Gulf and Oman Sea. Some temporary rivers either run into a body of water or get dried before reaching any watershed. The major rivers running into the Caspian Sea in Iranian shorelines flow from the northern Alborz attitudes like: Aras, Sefid Rud, Chalus, Haraz, Sehezar, Babol, Talar, Tajan, Gorgan, Atrak, Qarasu and Neka. The Zagros serves as the main originating headspring of the rivers running into the Persian Gulf and Oman sea watersheds. Among all these rivers, the major ones are: Arvand Rud, Gamasb, Karun, Jarahi, Zohreh, Dalaki, Mend, Shur, Minab, Mehran and Naband (Mehraby, 2010).

The geographical location of Iran shows that about 80% of the total area is located in an arid or semi-arid zone (Aminmansour, 2007). As a result of the following factors, land degradation and desertification have accelerated in Iran during the recent decades: first, the population has doubled over the last 25 years (since 1979); second, increased agricultural and pastoral products have forced people to use land extensively or convert forest and rangelands to cultivated land (Aminmansour, 2007). Therefore, these activities have a major affect on the water quality and diversity of aquatic plants and animals. However, the full extent of the knowledge on river species composition and the distribution of benthic invertebrates in Iranian running waters that has accumulated over the past 15 years (2000-2015) have not been documented in an integrated manner, in spite of the great progress having been achieved during this period of time.

The study of macroinvertebrate assemblages allows the assessment of the ecological quality of river and stream ecosystems (Munné & Prat, 2011; Paller et al., 2014). The macroinvertebrate plays a fundamental role in sediment processes, providing an important measure of the response of a community to environmental stressors (Adámek & Maršálek, 2013; Johnson & Ringler, 2014) and exhibiting the greatest potential for monitoring conditions at a particular station (Sharifinia et al., 2012a; Chang et al., 2014). Given the ability of reflecting water quality, a growing number of tools and methods rely on macroinvertebrate attributes, such as species composition, abundance, biomass and ecological function (Aparicio et al., 2011; Menetrey et al., 2011; Moya et al., 2011; Weigel & Dimick, 2011; Perera et al., 2012).

This review is an attempt to make our data on the macroinvertebrate richness of the Iranian running waters available to global comparisons. In the present study, we first aimed to update the list of benthic macroinvertebrates found in the Iranian running waters, being supported by critical taxonomy of the previously reported taxa. Accordingly, the spatial and temporal distribution of benthic macroinvertebrates could be overviewed in terms of biogeography, by highlighting faunal assemblages that reflects a habitat classification. In particular, the habitat classification based on species occurrences toward regional distribution characteristics are carefully addressed in semi-quantitative manner. Finally, the outlook for future researches supporting the sound science toward ecosystem-based management of the Iranian running waters was suggested, by emphasizing the socio-ecological value of river benthic diversity.

2. Data Collection and Analysis of the Macroinvertebrates in Iran

To provide a list of the macroinvertebrate species reported in the Iranian running waters, the occurrence and distribution were analyzed based on the data collected from previous works. A total of 57 peer-reviewed articles on macroinvertebrate assemblages in river and stream ecosystems of Iranian running waters, have been published since 2000 (Figure 1).

Taxa identified to genus or species level are categorized in phyla, to fully update the list of riverine macroinvertebrates. A total of 126 species belonged to 158 genus, 97 families, 25 orders and 7 classes are reported in the Iranian running waters. As part of the analysis, we endeavored to provide the critical re-identification of the reported species by comparisons with the database of the Animal Diversity Web (ADW) and appropriate literature sources or expert judgment (Table 1).

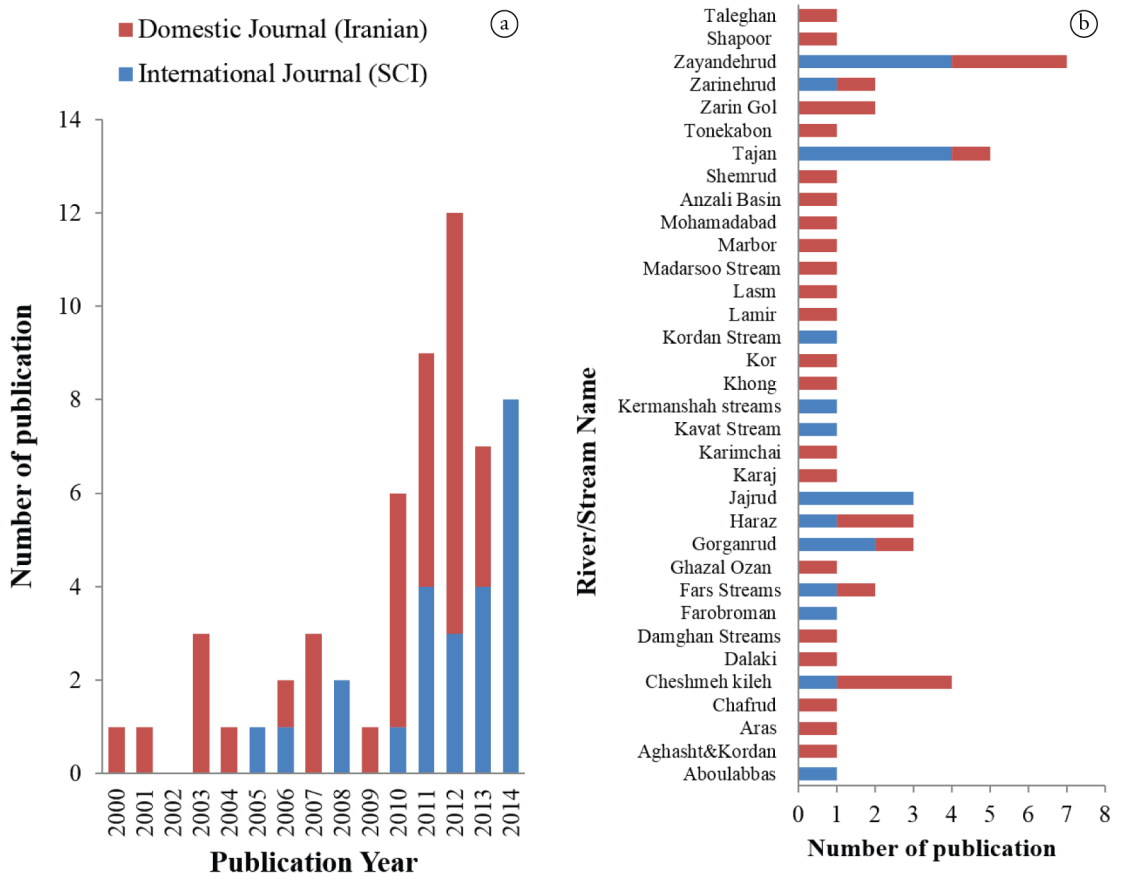

Figure 1. The overview on macroinvertebrate studies conducted at the Iranian running waters; (a) yearly number of publications over the past 15 years, and (b) the number of publications referring to 35 rivers and streams with corresponding references, a total of 57 reviewed articles. References: Abbasi et al. (2013a, b), Abbaspoor et al. (2011), Abbaspoor et al. (2013a, b), Abbaspoor et al. (2012), Abbaspour et al. (2013), Ahmadi et al. (2000), Ahmadi et al. (2012), Aliyev & Ahmadi (2010), Amri et al. (2014), Ardalan et al. (2011), Babapoor et al. (2011), Bashti & Ostovan (2014), Ebrahimnejad (2003a, b), Ebrahimnejad & Nikoo (2004), Ebrahimnezhad & Fakhri (2005), Farasat & Sharifi (2014), Farhangi & Taimoori Yansari (2012), Gahane et al. (2006), Ghasemi & Kamali (2014), Hafeziyeh (2001), Haffar et al. (2010), Hatami et al. (2011a, b), Hosyni et al. (2012), Hosyni & Nejad (2014), Jorjani et al. (2008), Kamali & Esmaeilisari (2009), Kamali et al. (2010), Kamali & Tatina (2010), Khatami & Shayegan (2006), Khatami et al. (2007), Mesgarankarimi et al. (2012a, b), Mirrasouli et al. (2012a, b), Mirzajani et al. (2008), Montajami et al. (2012), Naderi Jolodar et al. (2011), Nadushan & Ramezani (2011), Namin et al. (2013), Navan Maghsoodi (2012), Navan Maghsoodi et al. (2003), Ostovan & Niyakan (2007), Pazira et al. (2008), Raoshan Tabari et al. (2013), Shapoori et al. (2010), Sharifinia et al. (2012a, b), Shokri et al. (2014), Soltani et al. (2012), Soofiani et al. (2012), Toosi et al. (2011), Varnosfaderany et al. (2010), Yazdian et al. (2014).

3. Scientific Efforts as to Macroinvertebrate Studies in Iran

An analysis is done as to yearly number of publications, the study area of interest, and the area of interest per locality (35 river and streams along 13 provinces). Such a combinatorial analysis will help the understanding of the Iranian running water macroinvertebrates in terms of species diversity and biogeography in a historical manner.

With regard to the number of studies (Figure 1), only two articles had been published until the 2003. Since the first report in 2000, then publications rapidly increased afterwards. The increasing trend in publishing articles in the recent years, indicate the increased scientific efforts given on the river and stream ecology in Iranian running waters. Indeed more than half of the studies were published from 2010 onwards. During the relevant period (2000-2010), the majority of these studies have been published in the local journals hence could not be available to the international audiences. Only 4 articles were published in internationally journals (Figure 1). This first published article in 2005

Table 1. List of suggested identification for macroinvertebrates found in the Iranian running waters, being updated based on the Animal Diversity Web (ADW) and appropriate literature references.

Phylum	Class	Order	Family	Genus	Species
Annelida	Oligochaeta	Opisthopora	Lumbricidae	Aporrectodea	*A. rosea*
				Eiseniella	*E. tetraedra*
	Clitellata	Arhynchobdellida	Erpobdellidae	Erpobdella	
		Rhynchobdellida	Piscicolidae	Piscicola	
			Glossiphoniidae	Glossiphonia	
				Helobdella	
				Hemiclepsis	
		Lumbriculida	Lumbriculidae	Limnodrilus	
				Lumbriculus	
				Stylodrilus	
		Haplotaxida	Haplotaxidae	Haplotaxis	
			Naididae	Pristina	
			Naididae	Nais	*N. communis*
					N. elinguis
			Tubificidae	Peloscolex	
				Tubifex	
Mollusca	Gastropoda	Basommatophora	Planorbidae	Planorbis	
		Mesogastropoda	Bithyniidae	Bithynia	*B. tentaculata*
		Hygrophila	Physidae	Physa	*P. concolor*
					P. hordacea
				Costatella	*C. acuta*
		Basommatophora	Lymnaeidae	Lymnaea	*L. glabra*
					L. truncatula
					L. auricularia
					L. stagnalis
		Heterostropha	Valvatidae	Valvata	*V. mergella*
					V. sincera
					V. cristata
		Littorinimorpha	Hydrobiidae	Potamopyrgus	*P. antipodarum*
		Pulmonata	Planorbidae	Planorbis	
			Lymnaeidae		
			Ancylidae		
		Stylommatophora	Succineidae	Succinea	
		Caenogastropoda	Thiaridae	Melanopsis	*M. tuberculata*
	Bivalvia	Veneroida	Corbiculidae	Corbicula	*C. fluminea*
			Sphaeriidae	Pisidium	*P. amnicum*
				Sphaerium	*S. corneum*
					S. rivicola
			Dreissenidae	Dreissena	*D. polymorpha*
Platyhelminthes	Turbellaria	Tricladida	Planariidae	Polycelis	*P. felina*
				Phagocata	
			Dendrocoelidae		
		Seriata	Planariidae		

Phylum Arthropoda						
Class Malacostraca						
Order	**Family**	**Genus**	**Species**			
Amphipoda	Gammaridae	Gammarus	*G. daiberi*			
Class Insecta						
Order	**Family**	**Genus**	**Species**	**Family**	**Genus**	**Species**
Diptera	Athericidae	Atherix	*A. basilica*	Tanytarsus		
	Blephariceridae	Bibiocephala	*B. grandis*	Tvetenia		

Table 1. Continued...

Order	Family	Genus	Species	Family	Genus	Species
			B. infuscate	Tanytarsus		
			B .minor	Tvetenia		
		Liponeura		Simuliidae	Simulium	*S. damnosum*
	Chironomidae	Aagaardia	*A. longicalcis*			*S. venustum*
			A. oksanae	Psychodidae	Telmatoscopus	*T. aberrans*
			A. protensa			*T. advenus*
			A. sivertseni		Pericoma	
		Abiskomyia	*A. paravirgo*	Empididae	Chelifera	*C. accomodata*
		Ablabesmyia	*A. digitata*			*C. caliga*
			A. ensiceps		Hemerodromia	*H. acutata*
		Tanytarsini	*T. antennata*			*H. basalis*
			T. atridorsum	Dixidae	Dixa	*D. abiettica*
			T. dimidiatus			*D. cincta*
		Clunio	*C. tuthill*	Stratiomyidae	Euparyphus	*E. apicalis*
		Doithrix	*D. barberi*			*E. mutabilis*
		Chironomus		Tabanidae	Tabanus	*T. abaculus*
		Ablabesmyia				*T. atratus*
		Brillia		Tipulidae	Tipula	*T. absona*
		Cardiocladius				*T. paludosa*
		Cladotanytarsus			Antocha	*A. aculifera*
		Cricotopus				*A. biacus*
		Cryptochironomus			Dicranota	
		Demicryptochironomus			Nephrotoma	
		Dicrotendipes		Culicidae	Culicidae	*C. cuprinervis*
		Kiefferulus		Ceratopogonidae	Allohelea	*A. annulata*
		Lapposmittia				*A. fruticosa*
		Microchironomus			Bezzia	
		Microtendipes		Dolichopodidae	Acropsilus	*A. albitibia*
		Nanocladius				*A. maprik*
		Orthocladius		Mycetophilidae	Rhymosia	
		Parametriocenemus		Cecidomyiidae	Parepidosis	
		Paraphaenocladius		Chamaemyiidae	Cecidomyia	
		Paratanytarsus		Pediciidae	Dicranota	
		Paratendipes		Stratiomyidae		
		Phaenopsectra		Rhagionidae		
		Polypedilum		Dolichopodidae		
		Procladius		Chaoboridae	Chaoborus	*C. crystallinus*
		Rheopelopia				*C. punctipennis*
		Rheotanytarsus		Thaumaleidae		
		Tanypus				
Order	**Family**	**Genus**	**Species**	**Order**	**Family**	**Genus**	**Species**
Plecoptera	Capniidae	Capnia	*C. arensi*	**Ephemeroptera**	Baetidae	Baetis	*B. adonis*
			C. bicornata				*B. bicaudatus*
			C. barberi				*B. alius*
	Chloroperlidae	Chloroperla	*C. acuta*				*B. magnus*
			C. stenoptila				*B. notos*
			C. zhiltzovae				*B. persecutor*
			C. tripunctata				*B. tricaudatus*
	Perlodidae	Isoperla	*I. acula*				*B. rhodani*
		Isogenoides	*I. olivaceus*			Cloeon	*C. Simile*
			I. zionensis				*C. dipterum*
			I. colubrinus				*C. cognatum*
			I. doratus			Heterocloeon	
			I. hansoni			Centroptilum	
			I. krumholzi		Heptageniidae	Epeorus	*E. albertae*

Table 1. Continued...

Order	Family	Genus	Species	Order	Family	Genus	Species
		Perlodes					*E. fragilis*
	Perlidae	Caroperla	*C. Pacifica*				*E. Hesperus*
		Perla					*E. grandis*
		Đsoperla	Đ. grammatica			Rhithrogena	*R. exilis*
	Leuctridae	Leuctra	*L. aculeata*				*R. ingalik*
			L. albida			Maccaffertium	
			L. alpine			Heptagenia	
			L. alta			Rhithrogena	
			L. balcanica		Caenidae	Caenis	*C. tardata*
			L. alosi			Brachycercus	
		Capnia			Leptophlebiidae	Paraleptophlebia	*P. adoptiva*
	Dytiscidae	Laccophilus					*P. clara*
	Elmidae	Narpus					*P. debilis*
	Nemouridae	Protonemura			Oligoneuriidae	Lachlania	*L. fusca*
		Nemoura					*L. lucida*
		Amphinemura	*A. sulcicollis*				*L. iops*
	Taeniopterygidae	Taeniopteryx				Oligoneuriella	
Hemiptera	Veliidae	Velia	*V. heteroptera*		Ephemeridae	Ephemerella	*E. doris*
	Corixidae	Micronecta					*E. ignita*
		Corixa				Ephemera	*E. danica*
		Sigara	*S. dorsalis*		Ecdyonuridae	Ecdyonurus	
	Gerridae				Polymitarcyidae	Campusurus	*C. notatus*
	Nepidae	Nepa	*N. cinerea*		Potamanthidae		
		Ranatra	*R. linearis*	**Trichoptera**	Hydropsychidae	Cheumatopsyche	
	Hydrometridae	Hydrometra				Hydropsyche	
	Pleidae					Ceratopsyche	
Odonata	Coenagrionidae	Argia	*A. adamsi*			Potamyia	
		Ischnura			Rhyacophilidae	Rhyacophila	
		Coenagrion mercuriale	*C. mercuriale*		Sericostomatidae	Sericostoma	
			C. hastulatum		Hydroptilidae	Agraylea	
	Aeshnidae	Aeshna	*A. affinis*			Hydroptila	
			A. athalia			Oxyethira	
	Cordulegastridae	Cordulegaster			Philopotamidae	Chimarra	
	Gomphidae	Gomphus	*G. vulgatissimus*			Philopotamus	
	Calopterygidae				Phryganeidae	Agrypnia	
	Corduliidae	Somatochlora			Polycentropodidae	Polycentropus	
	Libellulidae				Brachycentridae	Brachycentrus	
	Agriidae	Agrion	*A. splendens*		Leptoceridae	Adicella	
	Platycnemididae				Ecnomidae		
Hymenoptera	Formicidae	Formica			Glossosomatidae	Glossossoma	
						Agapetus	
					Limnephilidae	Limnephilus	*L. lunatus*
							L. flavicornis
					Psychomyiidae		
						L. flavicornis	

was about on macroinvertebrates in Iranian rivers aiming to estimate biomass and productivity in the Aghasht and Kordan Rivers (Ahmadi et al., 2000).

The analysis has shown that most of the studies have been conducted in provinces where universities where research was done in this field of Fisheries and Aquatic Ecology are existed, such as in the provinces of Tehran, Guilan, Mazandaran and Esfahan (Figure 2). Most of these studies are focused on the bioassessment and the effect of human activities on rivers and streams based on biotic indices. All of these studies have been done

on a local scale (Case studies). Only two studies at a large-scale (20 and 17 headstreams across the entire province) have been conducted on the distribution and diversity of macroinvertebrates in Fars and Kermanshah provinces (Khatami & Shayegan, 2006; Hafeziyeh, 2001). Finally looking at the study intensity cross the regional locality (Figures 1 and 2); the Zayandehrud River (Esfahan province) and Tajan River (Mazandaran province) seemed to be most intensively targeted with 7 and 5 publications, respectively. The high degree of study efforts given to this locality would be explained by the fact that it encompasses the most important rivers of the Iranian running waters. A further reason would be the increasing and continuing concerns on the Zayandehrud and Tajan Rivers, which has been a long standing issue of the environmental pollution and human activities.

4. Chronological Studies on the Macroinvertebrates in Iranian Running Waters

The study of the macroinvertebrate from the Iranian running waters based on published articles is dated back to the 1990s. In the 1990s (1995-96) one investigation was made on the determination of the biomass and production of macroinvertebrates in Aghasht and Kordan Rivers, in the Tehran province (see Ahmadi et al., 2000). Ahmadi et al. (2000) were reported 35 genera belonging to 30 families from the Aghasht and Kordan Rivers, whit aquatic insect larvae being the most frequent (98.68% of the total abundance). Later, Hafeziyeh (2001) investigated aquatic insecta community in the Fars headstreams and provided a list of 48 identified genera. So, in 2003 two investigations were conducted to assess the production potential using benthic abundances and diversity in Siahkal Shemrood River and macroinvertebrate diversity and abundance and biotic indices in Zayandehrud River, were identified respectively 28 and 26 genera belong to aquatic insecta (Ebrahimnejad, 2003a; Navan Maghsoodi et al., 2003). The latter study conducted in 2003-04 addressed the taxonomic identification and distribution of macroinvertebrates in Marbor River (Ebrahimnejad & Nikoo, 2004). To be noted, all the above studies were published in domestic journals, hence being expected a limited access to international audience. These pioneering studies would be regarded as the birth of macroinvertebrate research in the Iranian running waters, and in inland aquatic ecological history.

The running waters ecological studies in Iran further included the anthropogenic influences, primarily pollution, as a response to environmental pressure by rapid industrialization. The most controversial issue was the decline in water quality due to the construction of fish farms, sand extraction from rivers and sewage discharge (Abbaspoor et al., 2012; Soltani et al., 2012; Namin et al., 2013;

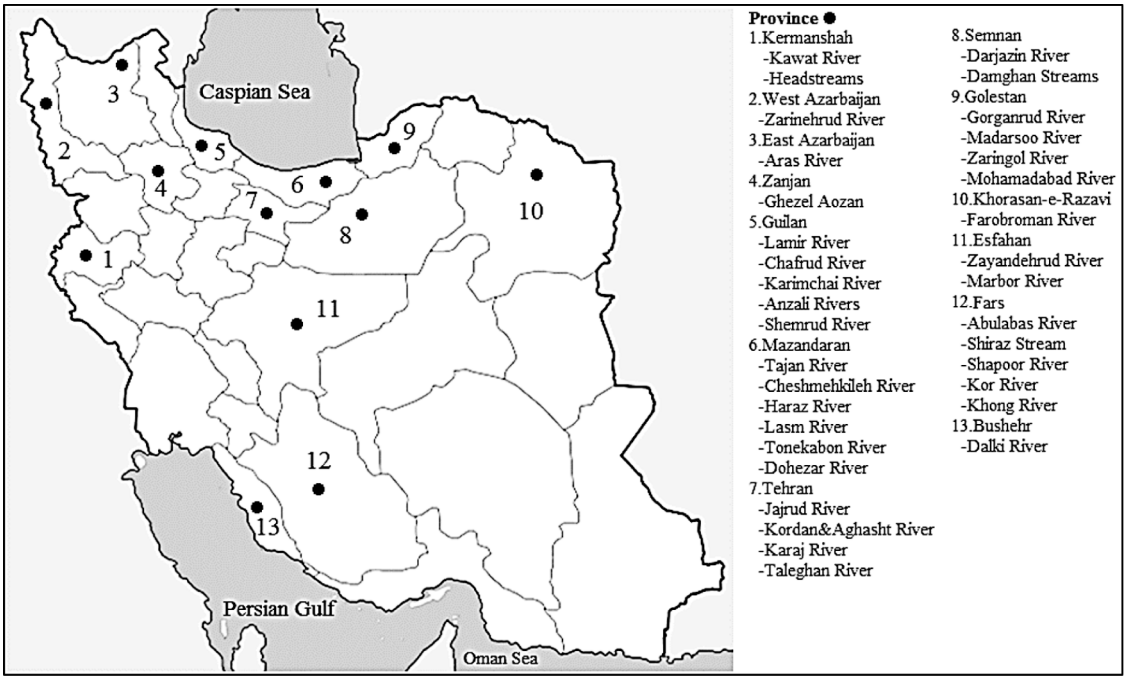

Figure 2. Map of Iran, showing the name of total rivers and streams in each province that recorded species composition of the macroinvertebrate.

Raoshan Tabari et al., 2013; Shokri et al., 2014). A set of studies also endeavored to address pollution issue and assessment of water quality based on biotic indices and physico-chemical parameters (Gahane et al., 2006; Abbaspoor et al., 2013a; Bashti & Ostovan, 2014). Such environmental studies looked for the benthic faunal responses against physicochemical variations and pollution loads. For instance, Nadushan & Ramezani (2011) and Soofiani et al. (2012) reported the macrobenthic communities of the Kordan Stream and the Zayandehrud River, respectively. Furthermore, a set of studies also investigated the biological assessment of rivers based on the population and community structure of benthic macroinvertebrate species (Varnosfaderany et al., 2010; Naderi Jolodar et al., 2011; Sharifinia et al., 2012a; Sharifinia et al., 2012b).

5. International Significance of the Macroinvertebrate Assemblages

The macroinvertebrate assemblages of Iran's freshwaters differs from that in other parts of the world in several respects. Some groups of macroinvertebrates that are common in the Northern Hemisphere are absent from or poorly represented in Iran. For instance, the stonefly fauna is dominated by large species belonging to the northern hemisphere families Perlodidae and Perlidae, and there are none of the small Gripopterygidae and Notonemouridae stoneflies that are commonly encountered in southern hemisphere countries. Furthermore, the number of dragonfly species is very small for a country the size of Iran, and many predominantly lotic families of Hemiptera, Gastropoda and Crustacean are poorly represented. In contrast, the Diptera and Ephemeroptera faunas are diverse in Iran, and caddis flies at least. Our hypothesis for the higher diversity of these invertebrates is that speciation process has been facilitated by the abundance and variety of streams and rivers.

6. Characteristics of the Macroinvertebrate Assemblages in the Iranian Running Waters

Included in the list of the macroinvertebrate species found in Iranian running waters are taxa which have been previously documented to the genus or species level (Table 1). A total of 158 genera and 126 species belonging to 97 families are primarily composed of three major faunal groups: Arthropoda (n = 104 species; 129 genera), Mollusca (n = 19 species; 14 genera) and Annelida (n = 2 species; 13 genera). The phylum Arthropoda was found to be the richest taxonomic group with 104 species, accounting for 82% of the total macroinvertebrate species and genera (Figure 3). The number of species (n = 103) and genera (n = 128) in the insecta class were counted and presented in Figure 4. The highest percentage of genera (46%) and species (40%) were belonging to Diptera order, with the rest including: Ephemeroptera, Plecoptera, Odonata, Hemiptera, Thrichoptera and Hymenoptera (Figure 4).

7. Threats to Running Waters Macroinvertebrates

Processes that threaten the biodiversity in freshwater species have been classified into three categories (Collen et al., 2014): habitat loss/degradation, water pollution and

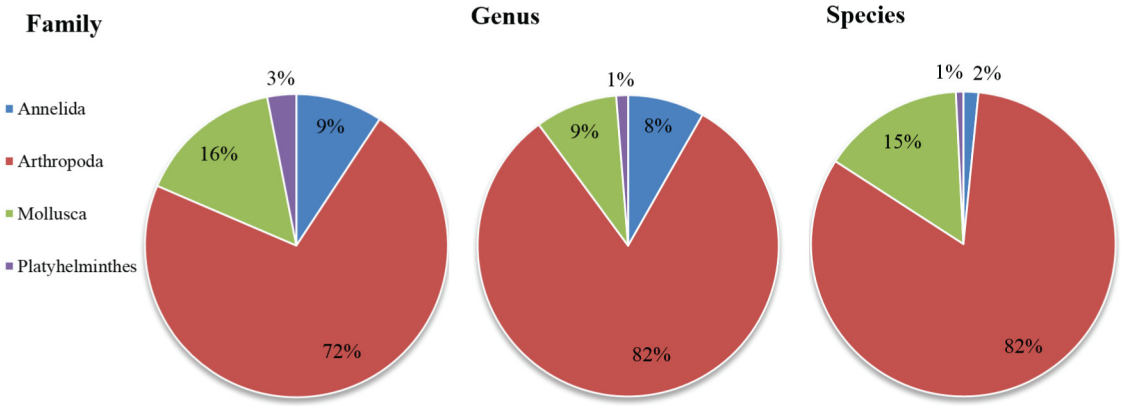

Figure 3. Macroinvertebrate recorded in the Iranian running waters, showing the species, genus and family composition; a total of 4 phyla encompassing 126 species, 158 genus, 97 family, 25 order and 7 classes identified from the meta-data extracted from 57 articles listed in Table 1 and Figure 1.

over-exploitation. In addition to this factors, invasion of alien species and climate change are also affecting on biodiversity of species in running waters. Of these, the main proximate drivers of habitat loss and degradation were agriculture, urbanization, infrastructure development (particularly the building of dams) and logging (Collen et al., 2014). Up to now, the main factors threatening the aquatic macroinvertebrates in Iran could be including: household sewage, urban waste water, agricultural effluents and habitat degradation by human-induced modifications to the catchment and changes to water quality and river flows. Development of catchments to improved pasture, and associated changes in water temperature and level of enrichment, were identified as important factors influencing the composition of benthic macroinvertebrate assemblages. Channelisation of rivers may also lead to marked changes in macroinvertebrate assemblages, and abstraction of water or altered flow regimes have been found to cause depletion of the macroinvertebrate assemblages in some rivers.

Aquatic invertebrates play a key role in many ecosystem processes such as nutrient cycling and organic matter decomposition. Thus, they are widely used as an indicator of the ecological status of running waters ecosystems. A recent study showed that particularly aquatic invertebrates are at risk from effects of toxicants in the EU, with pesticides playing a dominant role (Malaj et al., 2014). Many studies have reported adverse effects of pollutants on runnig waters macroinvertebrate species or assemblages. These include point source pollutants from agriculture (e.g., Sharifinia et al., 2015), organic effluents (e.g., Álvarez-Cabria et al., 2011), mine drainage (He et al., 2015), and herbicides and pesticides (Magbanua et al., 2013; Bunzel et al., 2015). However, it unlikely that any river-dwelling species has been driven extinct by chemical pollution alone, although this may be a serious problem for species with highly restricted ranges that are also threatened by other factors such as habitat degradation. Few studies have quantitatively documented the impacts of alien aquatic plants and animals on the native fauna of Iran's freshwaters, but it is likely that these have had some adverse effects through predation, competition for food or space, and through habitat degradation.

8. Future Research Directions

Running waters macroinvertebrates are recognized as a group of freshwater organisms that have ecological importance as food sources in rivers and streams. Macroinvertebrates studies have a long tradition in freshwater science, with a publication history of over 50 years worldwide existing, with mainstream topics of assemblage, dynamics, production and food web. As part of the present work, the comparative analysis, between worldwide and Iranian studies, on the status quo of scientific publications were provided and briefly discussed, to identify and narrow down the future research directions. However, we analyzed the

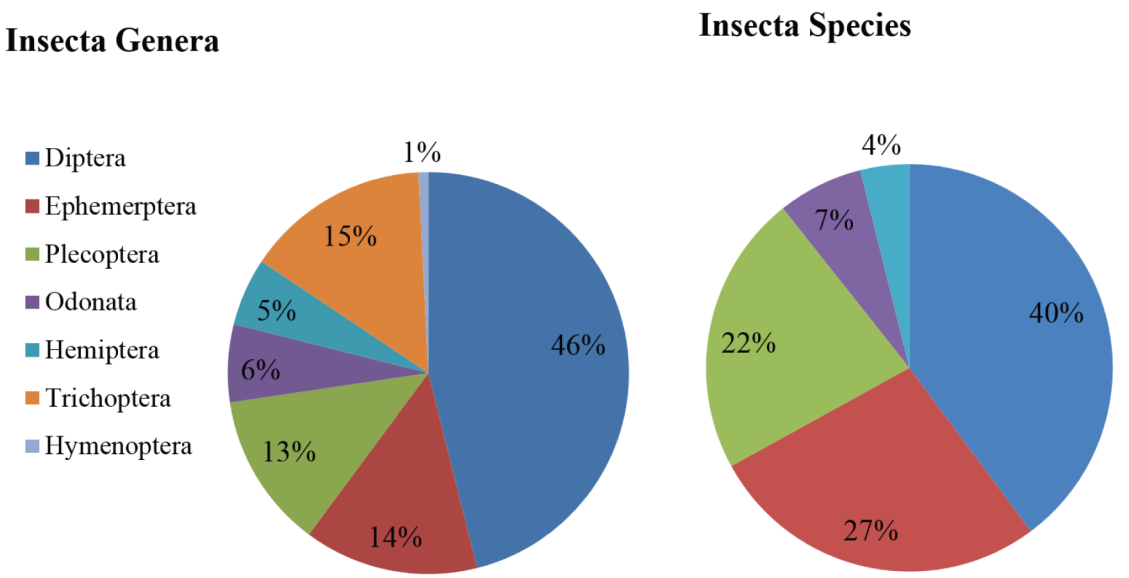

Figure 4. Percentage of genera and species belonging to insecta class recorded by 14 regions and identified from the meta-data extracted from 57 articles.

most recent 15 years of domestic and international publications only to focus on recent development and limitations, which might be appropriate to identify future challenges in Iran. Furthermore, the scientific papers are highly biased toward the fundamental understanding of macroinvertebrates structure changes in assemblages more than half of the total publications. One major weakness of macroinvertebrates studies in Iran would be a lack of scientific community with widespread but limited group(s) or individuals, and further lesser cooperation between Iranian scientists compared to those in Europe and North America would have blocked the scientific development and published articles in journals with high quality. Nevertheless, individual scientific efforts in Iran's are continuously growing with wider range of topics, in parallel to an appropriate increase in the total number of international publications.

9. Conclusions

In the present review, a set of 57 macroinvertebrate studies conducted at the rivers and streams of Iran over the past 15 years has been revisited by an analysis combined with a taxonomic re-identification. A provisioning of comprehensive Iranian macroinvertebrate checklist was first provided as partial outcome of the present review (Table 1). Ongoing efforts in the Iranian running waters regarding biomonitoring indices development, testing, refinement and validation are yet to be employed in streams and rivers. Apart from few ecological and taxonomical studies conducted in patches of the Iranian running waters, there is no effort that has led to the development of biomonitoring indices for the Iranian river and stream ecosystems. The presence of technical, financial and logistical constraints have hindered the potential use of macroinvertebrate communities as indicators of water quality and thus, making biomonitoring programs a remote possibility in the Iranian running waters.

The main threats to freshwater macroinvertebrates in Iran now and in the feature could be including: habitat degradation by catchment clearance and removal of riparian vegetation, wetland drainage, channel engineering works, diffuse and point source pollution, mining and the regulation of flow volumes and patterns. The impacts of alien organisms may also have had significant impacts on some aquatic macroinvertebrates through predation, competition and habitat alteration. Macroinvertebrate species with large, slow-moving larval or adult stages may be particularly susceptible to predation by alien invertebrates, fish and birds. Predation by alien species and the effects of climate change may become increasingly important threats to freshwater invertebrates in the future.

We recommend the following suggestions for future study in the Iranian running waters, (I) technical efforts to develop field standard operating protocols and procedures as well as the establishment of reference conditions for Iranian rivers and streams by a recognized governing body or certified by ISO protocols, covering benthic organisms, (II) balancing efforts to investigate for a more even distribution of species and localities along the Iranian running waters, and finally (III) strong efforts to publish data in peer-reviewed journals.

Because of the lack of information on distribution and ecology of many aquatic macroinvertebrates, I advocate a habitat- rather than a species-based approach to freshwater macroinvertebrate conservation. With endangered species, short-term management usually requires species-based approaches, but longer term conservation success requires a habitat-based approach addressing the needs of that species across its lifetime and that of subsequent generations. Physically undamaged sections of large, unmodified lowland rivers and small streams are now rare in most parts of the country, and numbers of relatively unmodified coastal streams and freshwaters without alien species are also diminishing. If we are to protect remaining examples of these endangered habitats and the aquatic fauna that colonizes them, potentially high-value stations in different regions of the country will need to be identified, given protection, and, if practical, rehabilitated.

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