# Aquatic macroinvertebrates of an intermittent stream in the arid Hajar Mountains, Oman

*by John Burt*

**Abstract**

Aquatic macroinvertebrates were collected from six habitats in two permanently flowing sites in Wadi Qahfi, northern Oman. A total of 38 taxa were identified, many to taxonomic levels previously unrecorded for aquatic fauna in Arabia. Overall richness was comparable between all habitats sampled. While very little regional information is available for identification of aquatic macroinvertebrates, the combination of regional descriptive information with foreign keys for aquatic stages has proven to be a valuable approach. Recommendations are made for appropriate levels of classification for the major taxonomic groups, and references are provided to assist in identification.

**Keywords:** Oman, Arabia, fauna, freshwater, intermittent stream, wadi

**Introduction**

The Hajar mountain range straddling northern Oman and the eastern United Arab Emirates forms part of the Arabian Highlands. The World Wildlife Fund for Nature has identified this area as part of the Global 200 Ecoregions, making it a priority area for biodiversity research and conservation (Launay and Jungius, 2001). Although the rainfall of the Hajar mountain range is low and relatively infrequent (UNESCO 1979, Boer 1997), there are numerous spring-fed streams throughout the region. A survey of the eastern United Arab Emirates alone found twenty-seven permanent sources of water (Feulner 1998), and more than eighty sites are known in Oman, Yemen, Saudi Arabia and Kuwait (Segars and Dumont 1993). The majority of these streams are spatially and temporally intermittent, with flow alternating between the surface and the hyporheic (alluvial) zone.

These intermittent desert streams, known as wadis (from the Arabic wadian), represent ecosystems chemically and biologically distinct from streams in more temperate climes (Busch and Fisher 1981, Grimm *et* al. 1981, Boulton et al. 1992, Boulton and Stanley 1995, Clinton *et* al. 1996), with spatially infrequent surface flows acting as 'islands' for organisms with aquatic life stages (Brooks 2000).

Unfortunately, knowledge of freshwater fauna in the

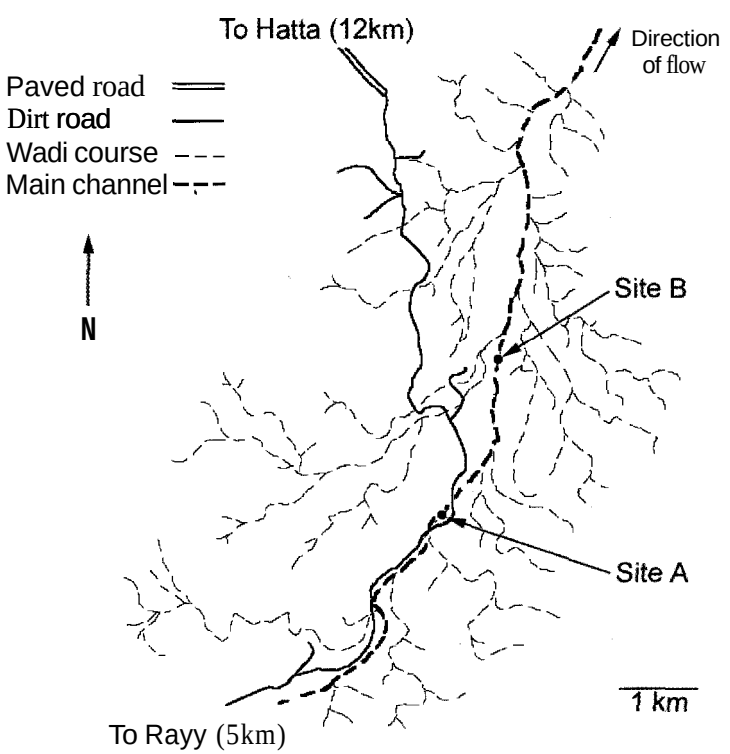


**Figure 1: Map of Wadi Qahfi study area.**

Arabian Peninsula is extremely limited (Victor and Al-Mahrouqi 1996). The purpose of this study was to examine the macroinvertebrate fauna of isolated areas of permanent flow.

## Methods

### Study Area

Study sites were located in Wadi Qahfi, Oman, 12 km south-east of the village of Hatta, United Arab Emirates, in an area known to expatriate UAE residents as 'the Hatta pools' (Figure *1).* Wadi Qahfi originates on the eastern edge of the Hajar mountain range and travels north-east before merging with Wadi Hatta and travelling east to the Gulf of Oman. Upper tributaries of Wadi Qahfi are permanently dry with the exception of seasonal flooding. Spring-fed hyporheic water flows down the main channel, with periodic zones of permanent surface flow where the hyporheic zone is constricted by bedrock.

The upper tributaries drain sparsely vegetated mountain sides, mainly Upper Cretaceous to Pre-Permian allochthonous gabbro and ultrabasic sediments. The main channel areas contain Pleistocene and Holocene autochthonous fluvial deposits with periodic exposures of cherts and volcanics (UAEU 1993).

The major human activities in the study area are agriculture and recreation. A few small date farms irrigated by traditional channels (aflaj) are located within a few kilometres of the sampling sites. The impact of this diversion is minimal given the small volume of water being extracted (pers. obs.). Swimming in perennial pools is a common weekend pastime, and sport utility vehicles are used for recreation in the wadis.

Two sites containing perennial surface water were selected for sampling. These sites are 2.5 km apart and were designated as Site A (24°42'47" N; 56°11'10" E) and Site B (24°41'56" N; 56°10'24" E). The sampling sites are along a third order stream which represents the main channel, and these sites represent the only accessible areas in the main channel with permanent surface flow (Figure 1).

Site A contains two pools (Figure 2) flowing into a riffle zone followed by a run which eventually disappears into the sediments. The pools are constrained by bedrock walls with sand and gravel bottom, while the riffle and run traverse an unconstrained section of stream bed with gravel and cobble (Figure 3). Site B contains two pools constrained by sheer bedrock walls with a sand and gravel bottom. These pools each end at a gravel bar, where water infiltrates back into alluvial deposits. No riparian vegetation or aquatic macrophytes were present in either sampling site, although algal mats (primarily Spirogyra) were present in the riffle and run of Site A.

### Sampling Methods

Care was taken to sample only in areas with minimal disturbance from vehicular activity. Samples and physiochemical data were collected monthly from April to June 2002 during the last week of each month, between 09:00 and 14:00. Pools and the run were qualitatively sampled by disturbing the bottom for a period of approximately three minutes while sweeping a D-frame net (mesh size 250µm) rapidly through the disturbed area (Boulton 1989). Riffles were sampled in a similar fashion, except that the net was held over the substrate immediately downstream (<50 cm) from the disturbance and flow carried benthos into the net.

Samples were live sorted in the laboratory within 48

**Figure 2: Upper pool of Site A in Wadi Qahfi.**

hours of collection using a Leica GZ4 stereomicroscope following the qualitative methods prescribed by the USGS (Moulton *et al.* 2000). Live sorting was required due to the poor visibility of some organisms following preservation (Boulton and Stanley 1995). Organisms were preserved in 70% ethanol, with the exception of Chironomidae, which were slide mounted in DePeX mounting media.

Identification was attempted to the lowest taxonomic level appropriate for a standard taxonomic assessment as recommended by the USGS (Moulton *et al.* 2000). Taxa were identified to family or higher level using keys from North America (Pennak 1989, Merrit and Cummins 1996). Regional resources specific to taxa of the Arabian Peninsula such as the *Fauna of Saudi Arabia* series, *Tribulus,* the *Insects of Eastern Arabia* field guide (Walker and Pittaway 1987), and *Entomofauna of Saudi Arabia* checklist (Al-Ahmadi and Salem 1999) were used to identify beyond the Family level, in conjunction with other keys. Where morphology deviated from descriptions in keys, individuals remained at the previously established level.

Mean abundance of each taxon was categorized qualitatively as present (1-2 individuals), common (3-10 individuals) or abundant (>10 individuals) for each of the habitats over all sampling dates. More detailed quantification would have been inappropriate given the qualitative nature of the sampling methods (Boulton 1989).

Table 1

Table 1. Temperature and conductivity (mean ± SD ) and pH (range) of water at sampling sites (n=3).

| Habitat | Temperature (° C) | PH Range | Conductivity ( S/cm) |
|---|---|---|---|
| Site A Pools | 28.8±1.0 | 8.1 8.9 | 671+33 |
| Site A Run | 29.2±0.6 | 8.3 - 9.1 | 670±34 |
| Site B Pools | 26.7±1.8 | 9.1 - 9.5 | 722±55 |

Figure 3: Riffle and run (right, background) for Site **A** in Wadi Qahfi.

## Results

Mean and standard deviation of water temperature and conductivity and range of pH from Sites A and B are recorded in Table 1. Due to a malfunction with the probe, dissolved oxygen readings were unreliable and are omitted. No measurable differences in these parameters were observed between sites.

Currently there is no regional information regarding freshwater Turbellaria, Oligochaeta, or Hydracarina. These organisms could not be classified beyond these levels. The freshwater amphipods, the insect orders Odonata and Coleoptera, and the dipteran family Tipulidae can be reduced to the family level using North American keys, but cannot be reduced further due to inadequate regional information. Trichoptera larvae can be identified at least to family, with some families reducible to genus. The insect families Ephemeroptera, Hemiptera, Ceratopogonidae, Culicidae, Chironomidae, and Tabanidae can all be reduced to the generic level. Molluscs, at least in the case of Wadi Qahfi, can be identified to the species level using combined regional and international resources (Table 2).

Macroinvertebrates collected from different habitats for the two sampling sites are listed in Table 3. Out of 38 taxa identified, 3 were identified to species, 23 to genera, 9 to family, and 3 to higher levels.

All habitats sampled contained a fairly consistent level of taxa richness. The exception was the upstream pool in Site A, where richness was approximately half of that of the remaining habitats among both sites. Water mites (Hydracarina) (Figure 4), the dragonfly family Libellulidae, small saucer bug adults, Heleocoris, (Figure 5) the chironomid Ablabesmyia, and tipulid craneflies were the only taxa ubiquitous to all sites and habitats sampled. Turbellarian flatworms, oligochaetes, long-toed water beetles (Dryopidae), chironomids Crictopus and Rheotanytarsus, the Tabanus /Atylotus horse flies (Figure 6), and the micro-caddisfly family Hydroptilidae were present in multiple habitats but restricted to Site A. Site B was not as rich in site specific taxa. Only the planorbid snail Gyraulus piscinarum, the mosquito Anopheles and the chironomids Procladius, Paratendipes and Polypedilum were present only at Site B. In all cases, abundance was ranked in the lowest category of 'present' and each was found in only a single pool. Various other taxa were recorded from different habitats within and among sites (Table 3).

## Discussion

Prior to the present study, the only comprehensive examination of benthic macroinvertebrate fauna for the Arabian Peninsula was the study of Wadi Bani Habib of Jebel Akhdar, northern Oman (Victor and Al-Mahrouqi 1996). A comparison between these studies is interesting. Wadi Qahfi water chemistry is similar to that observed in Wadi Bani Habib. Water in Wadi Qahfi was slightly alkaline, perhaps due to the influence of algal mats and limestone deposits in the area. Alkalinity was also observed in Wadi Bani Habib. As the majority of water flow in Wadi Qahfi is subterranean, water temperatures remained relatively consistent over the sampling period due to buffering from sediments. These results are similar to Wadi Bani Habib where periods of high summer air temperatures (>40 ℃), did not significantly alter water temperatures.

There are many similarities in faunal composition between Wadi Bani Habib with the results recorded here for Wadi Qahfi.

**Figure 4: Water mites, Hydracarina, were found to be common to abundant in all habitats examined in Wadi Qahfi.**

Table 2. Resources describing adult and larval stages of taxonomic groups of Arabia with aquatic life stages. Reference is made to lowest practical identification level for each group, with resources that can be used to assist in classification.

| Taxonomic Group | Regional Information (Adults) | Regional Information (Larvae) | Lowest Confident Larval Identification Level (Resource) | Comments |
|---|---|---|---|---|
| TURBELLARIA | None | Not applicable | Class (Pennak 1989) | Identification beyond Class should be done carefully as no regional information is available |
| OLIGOCHAETA | None | Not applicable | Class (Pennak 1989) | Identification beyond Class should be done carefully as no regional information is available |
| AMPHIPODA | None | Not applicable | Order/Family (Pennak 1989) | Identification beyond Order should be done carefullv as no regional information is available |
| HYDRACARINA | None | Not applicable | Order (Pennak 1989) | Identification beyond Order should be done carefully as no regional information is available |
| GASTROPODA | Neubert 1998, Feulner and Green 1999 | Not applicable | Genus/ Species (Neubert 1998) | Regional material are descriptive but comprehensive |
| EPHEMEROPTERA | Al-Ahmadi and Salem 1999, Sartori 1991, Sartori and Gillies 1990 | Chorterpesand Cloeon (Sartori and Gillies 1990) | Genus (Merritt and Cummins 1996) | All genera listed for Arabia can be identified |
| ODONATA | Schneider and Dumont 1997, Schneider and Krupp 1993, Waterson 1980,1984 | Unavailable | Family (Merritt and Cummins 1996) | No keys are available to identify larval Platycnemididae |
| HEMIPTERA | Al-Ahmadi and Salem 1999, Linnavouri and Alamy 1982 | Not applicable | Family (Merritt and Cummins 1996); Some Genera (Walker and Pittaway 1987) | Notonectidae incorrectly described as Water Boatmen (Corixidae) instead of Backswimmers by Walker and Pittaway (1987) |
| COLEOPTERA | Gentili 1989, Hebauer 1997, Heinertz 1979, Olmi 1980 | Unavailable | Family (Merritt and Cummins 1996); Some Genera (Nilsson 1996) | Many genera are indigenous to the region making use of foreign keys difficult |
| DIPTERA | Diverse resources; See below | Unavailable for all families | See individual families below | See individual families below |
| Ceratopogonidae | Boorman and van Harten 2002 | Unavailable | Genus (Merritt and Cummins | Larval keys unavailable for Homohelia |

| | | | | |
|---|---|---|---|---|
| | | | 1996) | and Phaenobezzia |
| Culicidae | Roberts and Irving-Bell 1997, Al-Ahmadi and Salem 1999 | Unavailable | Genus (Merritt and Cummins 1996) | Only three genera are known for Arabia. Pesticide use is widespread to combat malarial mosquitoes. |
| Chironomidae | Cranston and Judd 1989 | Unavailable | Genus (Merritt and Cummins 1996) | Of 23 genera Paratrichocladius and Virgatanytarsus can not be identified as larvae using this resource. Conchapelopia can only be identified as a member of the Thienmannimyia group |
| Tipulidae | Hancock 1997 | Unavailable | Family/Subfamily (Merritt and Cummins 1996) | Identify only to subfamily, as only 7 of 12 genera can be identified using Merritt and Cummins (1996) |
| Tabanidae | Leclercq 1982, Al-Ahmadi and Salem 1999 | Unavailable | Genus (Merritt and Cummins 1996) | Atylotus and Tabanus are indistinguishable as larvae and should be grouped together |
| TRICHOPTERA | Malicky 1986, Al-Ahmadi and Salem 1999 | Unavailable | Family; Genera of Philopotamidae, Hydropsychidae, and Leptoceridae (Merritt and Cummins 1996) | Keys for genera of Hydroptilidae unavailable. Ecnomidae, Psychomyiidae, and Limnephilidae have only one genus recorded for each. |

| | (Site A) | | | | (Site B) | |
|---|---|---|---|---|---|---|
| | Upper pool | Lower Pool | Riffle | Run | Upper Pool | Lower Pool |
| TURBELLARIA | | + | + | + | | |
| OLIGOCHAETA | | | ++ | +++ | | |
| AMPHIPODA | | | | | | |
| Gammaridae | | ++ | | | | |
| HYDRACARINA | ++ | +++ | ++ | ++ | +++ | +++ |
| GASTROPODA | | | | | | |
| Thiaridae | | | | | | |
| Melanoides tuberculata | | | | + | | |
| Lymnaeidae | | | | | | |
| Lymnaea natalensis | | | +++ | +++ | + | |
| Planorbidae | | | | | | |
| Gyraulus piscinarum | | | | | + | |
| EPHEMEROPTERA | | | | | | |
| Caenidae | | | | | | |
| Caenis | ++ | ++ | | ++ | ++ | ++ |
| Leptophlebiidae | | | | | | |
| Chorterpes | +++ | ++ | | ++ | ++ | +++ |
| ODONATA | | | | | | |
| Gomphidae (indet). | | + | | + | + | + |
| Paragomphus [t] | | | | + | | + |
| Libellulidae (indet.) | ++ | + | + | ++ | + | ++ |
| Coenagrionidae (indet.) | + | | | | + | |
| HEMIPTERA | | | | | | |
| Veliidae (indet.) | | + | | | | |
| Naucoridae | | | | | | |
| Heleocorus (A) | + | + | +++ | +++ | + | + |
| COLEOPTERA | | | | | | |
| Carabidae (indet. A) | | | + | | | + |
| Hydrochidae | | | | | | |
| Hydrophilidae (indet.L) | | + | | + | + | |
| Arabhydrus (A) | | | + | | | |
| Dryopidae (indet. A) | | | | + | | |
| Dryops (L) | | + | | | | |
| DIPTERA | | | | | | |
| Ceratopogonidae | | | | | | |
| Sphaeromias | | | + | | | |
| Bezzia | | + | + | + | + | + |
| Culicidae | | | | | | |
| Anopheles | | | | | + | |
| Chironomidae | | | | | | |
| Procladius | | | | | | + |
| Ablabesmyia | +++ | +++ | + | ++ | + | ++ |
| Paramerina | + | + | | + | + | + |
| Thienemannimyia group (Conchapelopia [t]) | + | + | | | + | |
| Cricotopus | | + | + | | | |
| Dicrotendipes | | | | + | | + |
| Stictochironomus | | + | | | | + |
| Paratendipes | | | | | + | |
| Polypedilum | | | | | | + |
| Neozavrelia | | + | | | | |
| Rheotanytarsus | | + | | + | | |
| Tipulidae | + | + | ++ | ++ | + | + |
| Tabanidae | | | | | | |
| Tabanus / Atylotus | | + | + | + | | |
| TRICHOPTERA | | | | | | |
| Philopotamidae | | | | | | |
| Chimarra | | | + | | | |
| Psychomyiidae (indet.) | | + | | | | |
| Abaria [t] | + | | + | ++ | + | + |
| Hydropsychidae (indet.) | | | + | | | |
| Hydroptilidae (indet.) | | + | | + | | |

Table 3. Taxa recorded at sites in Wadi Qahfi, Oman. Qualitative abundance categories represent mean number collected at each habitat over three sampling dates (+ = present (1-2 individuals), ++ = common (3-10 individuals), +++ = abundant (>10 individuals)). Life stage is denoted as L (larval) or A (adult) where relevant, and tentative classification is indicated by ( t ).

However, due to the difficulty in locating appropriate taxonomic resources, all groups were identified only to family level or higher in that study (Victor and Al-Mahrouqi 1996). Information regarding freshwater invertebrate fauna from the Arabian region is scarce. Aside from molluscs, few studies have examined the composition of aquatic communities in the region (Victor and Al-Mahrouqi 1996, Roberts and Irving-Bell 1997, Victor and Victor 1997), and aquatic taxonomy remains an area in need of substantial development. There is very little information on the larval stages of aquatic insects in the Fauna of Saudi Arabia series, the primary taxonomic resource for the region, and a common naturalist guide, Insects of Eastern Arabia (Walker and Pittaway 1987), only has an incorrectly identified larval dragonfly (Schneider and Dumont 1997).

Widespread sampling of aquatic habitats in Arabia has been conducted in separate surveys in the 1990's, but these have focused on distinct taxonomic groups (Rotifera: Segars and Dumont 1993) or on subterranean habitats (Stygofauna of Oman series: ex. Magniez and Stock 1999, Martinez-Ansemil et *al.* 2002), which are known to differ significantly from benthic habitats (Boulton et *al.* 1992).

Despite challenges in several taxa, the results of this study show that the integration of comprehensive keys from other locales with regional taxonomic information allows for a relatively detailed survey of the aquatic invertebrate fauna. The inclusion of larval information when creating taxonomic checklists should be considered a priority for taxonomists working in the Arabian Peninsula. While larval identification keys could be developed from existing literature for a number of taxa in the region, others will require significant research. The development of a rearing programme for positive identification from mature adults would be an essential step forward in the understanding of freshwater fauna in the region.

**Figure 5: Saucer bugs, *Heleocoris* (Naucoridae), were collected in all habitats in Wadi Qahfi, and were abundant in the riffle and run of Site A.**


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## References


Al-Ahmadi, **A.Z.** and Salem, M.M.. 1999. *Entomofauna of Saudi Arabia: General Survey of Insects in the Kingdom of Saudi Arabia.* King Saud University Press, Riyadh, KSA.

Boer, B. 1997. 'An introduction to the climate of the United Arab Emirates'. **Journal of Arid Environments. Vol. 35:** 3-16.

Boorman, J. and van Harten, A. 2002. 'Some Ceratopogonidae (Insecta: Diptera) from the Arabian Peninsula, with particular reference to the Republic of Yemen'. **Fauna of Arabia. Vol.** 19: 427-462.

Boulton, A.J. 1989. 'Over-summering refuges of aquatic macroinvertebrates in two intermittent streams in central Victoria'. **Transactions of the Royal Society of Southern Australia. Vol.** 11**3:** 23-34.

Boulton, A.J. and Stanley, E.H. 1995. 'Hyporheic processes during flooding and drying in a Sonoran Desert stream. II. Faunal dynamics'. **Archiv fur Hydrobiologie. Vol.** 134 (1): 27-52.

Boulton, A.J., Valett, H.M, and Fisher, S.G. 1992. 'Spatial distribution and taxonomic composition of the hyporheos of several Sonoran Desert streams'. **Archiv fur Hydrobiologie. Vol.** 125 (1): 37-61.

Brooks, R.T. 2000. 'Annual and seasonal variation and the effects of hydroperiod on benthic macroinvertebrates of seasonal forest ("vernal") ponds in central Massachusetts, USA'. **Wetlands. Vol. 20 (4):** 707-715.

Busch, D.E. and Fisher, S.G. 1981. 'Metabolism of a desert stream'. **Freshwater Biology. Vol. ▮▮**: 301-307.

Clinton, S.M., Grimm, N.B., and Fisher, S.G.. 1996. 'Response of a hyporheic invertebrate assemblage to drying disturbance in a desert stream'. **Journal of the North American Benthological Society. Vol.** 15 **(4):** 700-712.

Cranston, P.S. and Judd, D.D. 1989. 'Diptera: Fam. Chironomidae of the Arabian peninsula'. **Fauna of Saudi Arabia. Vol 10:** 236-289.

Feulner, G. 1998. 'Distribution of wadi fish in the UAE and northernmost Oman'. **Tribulus:. Vol. 8:** 16-22.


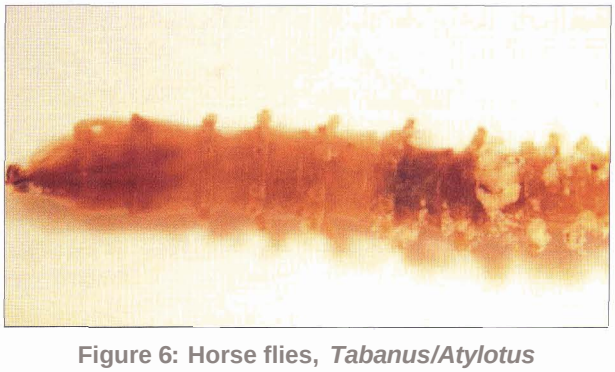

**Figure 6: Horse flies, *Tabanus/Atylotus* (Tabanidae), were observed in pool, riffle, and run habitats of Site A.**

Feulner, G.R. and Green, S.A. 1999. 'Freshwater snails of the UAE'. **Tribulus: Vol. 9:** 5-9.

Gentili, E. 1989. 'The Laccobius (Coleoptera, Hydrophilidae) of the Arabian Peninsula and Sinai'. **Fauna of Saudi Arabia. Vol. 10:** 95-102.

Grimm, N.B., Fisher, S.G. and Minckley, W.L. 1981. 'Nitrogen and phosphorus dynamics in hot desert streams of the southwestern USA'. **Hydrobiologia. Vol.** 83: 303-312.

Hancock, E.G. 1997. 'Craneflies (Diptera: Tipulidae and Limoniidae) of Saudi Arabia and Oman'. **Fauna of Saudi Arabia. Vol. 16:** 341-352.

Hebauer, F. 1997. 'Annotated checklist of the Hydrophilidae and Helophoridae (Insecta: Coleoptera) of the Arabian Peninsula with description of a new genus and species'. **Fauna of Saudi Arabia. Vol. 16:** 255-276.

Heinertz, R. 1979. 'Insects of Saudi Arabia – Coleoptera: Fam. Carabidae'. **Fauna of Saudi Arabia. Vol. 1:** 140-155.

Launay, F and Jungius, H. 2001. *Biodiversity Conservation in the UAE.* World Wildlife Fund for Nature.

Leclercq, M. 1982. 'Insects of Saudi Arabia - Diptera: Fam. Tabanidae'. **Fauna of Saudi Arabia. Vol. 4:** 447-449.

Linnavouri, R.E. and Alamy, K.T. 1982. 'Insects of Saudi Arabia: Hemiptera'. **Fauna of Saudi Arabia. Vol. 4:** 89-98.

Magniez, G.J. and Stock, J.H. 1999. 'Consequences of the discovery of Stenasellus (Crustacea, Isopoda, Asellota) in underground waters of Oman (Arabian Peninsula)'; Stygofauna of Oman, 4. **Contributions to Zoology. Vol. 68:** 173-179.

Malicky, H. 1986. 'The caddisflies of Saudi Arabia and adjacent regions (Insecta, Trichoptera)'. **Fauna of Saudi Arabia. Vol. 8:** 233-245.

Martinez-Ansemil, E, Giani, N, and Sambugar, B. 2002. 'Oligochaetes from underground waters of Oman with descriptions of two new species of Phreodrilidae (Oligochaeta): *Antarctodrilus arabicus* n. sp. and *Phreodrilus stocki* n. sp.'; Stygofauna of Oman, 7. **Contributions to Zoology. Vol. 71:** 147-158.

Merritt, R.W. and K.W. Cummins. 1996. *An Introduction to the Aquatic Insects of North America* (Third Edition). Kendall Hunt Publishing, Iowa, USA.

Moulton, S.R., Carter, J.L., Grotheer, S.A., Cuffney, T.F. and Short, T.M. 2000. *Methods of analysis by the US Geological Survey National Water Quality Laboratory - processing, taxonomy, and quality control of benthic macroinvertebrate samples.* US Geological Survey Open-File Report 00-212.

Neubert, E. 1998. 'Annotated checklist of terrestrial and freshwater molluscs of the Arabian Peninsula with descriptions of new species'. **Fauna of Arabia. Vol. 17:** 333-461.

Nilsson, A.N. 1996. *Aquatic insects of North Europe - A taxonomic Handbook.* Apollo Books, Denmark.

Olmi, M. 1980. 'Insects of Saudi Arabia - Coleoptera: Fam. Dryopidae'. **Fauna of Saudi Arabia. Vol. 2:** 122-123.

Pennak, R.W. 1989. *Freshwater Invertebrates of the United States: Protozoa to Mollusca.* John Wiley and Sons, New York, USA.

Roberts, D.M. and Irving-Bell, RJ. 1997. 'Salinity and microhabitat preferences in mosquito larvae from southern Oman'. **Journal of Arid Environments. Vol. 37:** 497-504.

Sartori, M. 1991. 'The mayfly fauna (Insecta: Ephemeroptera) of the Arabian Peninsula (Part 3)'. **Fauna of Saudi Arabia. Vol. 12:** 242-245.

Sartori, M and Gillies, M.T. 1990. 'Further records of mayflies (Insecta: Ephemeroptera) from the Arabian Peninsula: Leptophlebiidae and Baetidae'. **Fauna of Saudi Arabia. Vol. 11:** 10-17.

Schneider, W. and Dumont, H.J. 1997. 'The dragonflies and damselflies (Insecta: Odonata) of Oman. An updated and annotated checklist'. **Fauna of Saudi Arabia. Vol. 16:** 89-110.

Schneider, W. and Krupp, F. 1993. 'Dragonfly records from Saudi Arabia, with annotated checklist of species from the Arabian Peninsula (Insecta: Odonata)'. **Fauna of Saudi Arabia. Vol. 13:** 63-78.

Segars, H and Dumont, H.J. 1993. 'Rotifera from Arabia, with descriptions of two new species'. **Fauna of Saudi Arabia. Vol. 13:** 3-26.

Stanley, E.H., Buschman, D.L., Boulton, A.J., Grimm, N.B. and Fisher, S.G. 1994. 'Invertebrate resistance and resilience to intermittency in desert streams'. **American Midland Naturalist. Vol. 131**: 288-300.

UAEU. 1993. *The National Atlas of the United Arab Emirates.* United Arab Emirates University, Al Ain, UAE.

UNESCO. 1979. *Map of the World Distribution of Arid Regions.* MAB Technical Notes 7. United Nations Educational, Scientific and Cultural Organization, Paris.

Victor, R, Al-Mahrouqi, A.I.S. 1996. 'Physical, chemical and faunal characteristics of a perennial stream in arid northern Oman'. **Journal of Arid Environments. Vol. 34:** 465-476.

Victor, R. and Victor, J.R.. 1997. 'Some aspects of the ecology of littoral invertebrates in a coastal lagoon in Southern Oman'. **Journal of Arid Environments. Vol.** 37:33-44.

Walker, D.H. and Pittaway, A.R. 1987. *Insects of Eastern Arabia.* MacMillan, London, UK.

Waterson, A.R. 1980. 'Insects of Saudi Arabia: Odonata'. **Fauna of Saudi Arabia. Vol. 2:** 57-70.

Waterson, A.R. 1984. 'Insects of southern Arabia: Odonata from the Yemens and Saudi Arabia'. **Fauna of Saudi Arabia. Vol. 6:** 451-472.

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