2015

Arabian Peninsula Report

Neil Cumberlidge
Northern Michigan University, ncumberl@nmu.edu

THE STATUS AND DISTRIBUTION OF FRESHWATER BIODIVERSITY IN THE ARABIAN PENINSULA

Compiled by Nieves García, Ian Harrison, Neil Cox and Marcelo F. Tognelli

ARABIAN PENINSULA

The IUCN Red List of Threatened Species™ – Regional Assessment

SSC Species Survival Commission
CONSERVATION INTERNATIONAL
Environment Agency - Abu Dhabi
SENCKENBERG world of biodiversity

About IUCN

IUCN, International Union for Conservation of Nature, helps the world find pragmatic solutions to our most pressing environment and development challenges.

IUCN's work focuses on valuing and conserving nature, ensuring effective and equitable governance of its use, and deploying nature-based solutions to global challenges in climate, food and development. IUCN supports scientific research, manages field projects all over the world, and brings governments, NGOs, the UN and companies together to develop policy, laws and best practice.

IUCN is the world's oldest and largest global environmental organization, with more than 1,200 government and NGO Members and almost 11,000 volunteer experts in some 160 countries. IUCN's work is supported by over 1,000 staff in 45 offices and hundreds of partners in public, NGO and private sectors around the world.

About the Species Survival Commission

The Species Survival Commission (SSC) is the largest of IUCN's six volunteer commissions with a global membership of around 7,500 experts. SSC advises IUCN and its members on the wide range of technical and scientific aspects of species conservation, and is dedicated to securing a future for biodiversity. SSC has significant input into the international agreements dealing with biodiversity conservation.

About Conservation International

Building upon a strong foundation of science, partnership and field demonstration, Conservation International (CI) empowers societies to responsibly and sustainably care for nature and its global biodiversity to promote the long-term well-being of people. Founded in 1987 and marking its 25th anniversary in 2012, CI is head quartered in the Washington, D.C. area. CI employs 900 staff in more than 25 countries on four continents and works with more than 1,000 partners around the world.

About the Environment Agency - Abu Dhabi

The Environment Agency - Abu Dhabi (EAD) is a governmental agency that was established in 1996 with the overall function of protecting and conserving the environment as well as promoting sustainable development in the Emirate of Abu Dhabi, the capital of the United Arab Emirates (UAE). The Agency is responsible for assisting the UAE Ministry of Environment and Water in implementing environmental laws and putting forth regulation orders in the capital.

The IUCN Species Survival Commission and the IUCN Global Species Programme have enjoyed a close working relationship with Abu Dhabi for the last 20 years particularly on issues such as species conservation and re-introduction as well as Red List assessment and training. EAD has been a long-time supporter of the SSC Re-introduction Specialist Group and hosted the meeting of the SSC Specialist Group Chairs in 2008 and 2012.

THE STATUS AND DISTRIBUTION OF FRESHWATER BIODIVERSITY IN THE ARABIAN PENINSULA

Compiled by Nieves García, Ian Harrison, Neil Cox and Marcelo F. Tognelli

Published by: IUCN, Gland, Switzerland, Cambridge, UK, and Arlington, USA

Citation: García, N., Harrison, I., Cox, N. and Tognelli, M.F. (compilers). (2015). *The Status and Distribution of Freshwater Biodiversity in the Arabian Peninsula*. Gland, Switzerland, Cambridge, UK and Arlington, USA: IUCN.

ISBN: 978-2-8317-1706-7

DOI: 10.2305/IUCN.CH.2015.MRA.4.en

Cover design: Chadi Abi Faraj
Cover photo: © Nashat A. Hamidan. The confluence of the two Wadies Tarj and Tarjes in Saudi Arabia, habitat of *Cyprinion mhalensis*

Layout by: Chadi Abi Faraj
Produced by: IUCN-CI Biodiversity Assessment Unit
Printed by: Solprint, Mijas, (Málaga)
Available from: IUCN (International Union for Conservation of Nature)
Environment Agency- ABU DHABI
PO Box:45553
Al Mamoura Building
Murour Road
Abu Dhabi, United Arab Emirates
Tel +971 (2) 4454777
flaunay@ead.ae
www.ead.ae
www.iucn.org/knowledge/publications_doc/publications

The text of this book is printed on 115 gsm environmentally-friendly paper.

Edited by:	Nieves García	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Ian Harrison	CI Center for Environment and Peace, U.S.A.
	Neil Cox	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Marcelo F. Tognelli	IUCN-CI Biodiversity Assessment Unit, U.S.A.
With the support of:	William Darwall	IUCN Species Programme, United Kingdom
	Kevin Smith	IUCN Species Programme, United Kingdom
	Khaldoun Al Omari	IUCN West Asia Middle East Regional Office
	Simon N. Stuart	IUCN Species Survival Commission
	Johannes Els	Breeding Center for Endangerd Arabian Wildlife

Contributors:

Fishes

Chapter authors:	Jörg Freyhof	Centre for Integrative Biodiversity Research, Germany
	Nashat A. Hamidan	Royal Society for the Conservation of Nature, Jordan
	Gary R. Feulner	The Chadbourne & Parke, United Arab Emirates
	Ian Harrison	Center for Environment and Peace, Conservation International, U.S.A.
Reviewers:	Jörg Freyhof	Centre for Integrative Biodiversity Research, Germany
	Gary R. Feulner	The Chadbourne & Parke, United Arab Emirates

Molluscs

Chapter authors:	Eike Neubert	Naturhistorisches Museum der Burgergemeinde, Switzerland
	Zuhair Amr	Jordan University of Science and Technology, Jordan
	Dirk van Damme	University of Ghent, Belgium
Reviewers:	Nieves García	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Mary B. Seddon	IUCN/SSC Mollusc Specialist Group, United Kingdom
	Dirk van Damme	University of Ghent, Belgium

Odonata

Chapter authors:	Wolfgang Schneider	Senckenberg Research Institute, Germany
	Boudjéma Samraoui	University of Guelma, Algeria
Compiler:	Jean-Pierre Boudot	Université de Lorraine, France
Reviewers:	Marcelo F. Tognelli	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Nieves García	IUCN-CI Biodiversity Assessment Unit, U.S.A.

Crabs

Chapter author:	Neil Cumberlidge	Northern Michigan University, U.S.A.
Reviewer:	Anna McIvor	IUCN Species Programme, United Kingdom

Plants

Chapter authors:	Annette Patzelt	Oman Botanic Garden, Sultanate of Oman
	Richard V. Lansdown	Ardeola Environmental Services, United Kingdom
	Sabina G. Knees	Centre for Middle Eastern Plants, United Kingdom
Reviewers:	Marcelo F. Tognelli	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Nieves García	IUCN-CI Biodiversity Assessment Unit, U.S.A.
	Tulia Defex	IUCN-CI Biodiversity Assessment Unit, U.S.A.

Contents

Foreword

Freshwater habitats and biodiversity in the Arabian Peninsula are unique and highly valued for the essential role they play in people's survival, as well as that of its native flora and fauna. Some of the various goods and services provided by the region's freshwater species that benefit people in a direct or indirect way are fisheries, flood prevention and water purification. Also as a consequence of this close relationship between man and freshwater systems, the majority of impacts affecting freshwater taxa have also consequent effects on the economy and people's livelihood.

The Environment Agency - Abu Dhabi (EAD) and the International Union for Conservation of Nature (IUCN) worked together for this project that aims to provide an accurate picture of the present conservation status and distribution of Arabian freshwater species, as well as to identify the main threats that affect them and action requirements for their successful long term conservation.

The Environment Agency - Abu Dhabi expects this document to guide conservation planning, and represent an important step in building capacity for Red Listing and the identification of priority areas for conservation action in the region.

H.E. Razan Khalifa Al Mubarak, Secretary General of the Environment Agency Abu Dhabi (EAD).

Acknowledgements

All of IUCN's global Red Listing processes rely on the willingness of scientists to contribute and pool their collective knowledge to make the most reliable estimates of species conservation status. Without their enthusiastic commitment to species conservation, this kind of regional overview would not be possible.

We would like to thank the following people who gave their time and valuable expertise to evaluate all of the assessments at the workshop held at the *Senckenberg Research Institute and Museum of Nature* in Frankfurt, Germany, asking forgiveness from anyone whose name is inadvertently omitted or misspelled.

The authors of the various chapters, assessors and participants to the workshop: Annette Patzelt (aquatic plants), Boudjéma Samraoui (Odonata), Eike Neubert (freshwater molluscs), Fareed A. Krupp Gary R. Feulner and Jörg Freyhof (freshwater fishes), Wolfgang Schneider and Khaldoun Al Omari (Odonata), Nashat A. Hamidan (freshwater fishes), Neil Cumberlidge (freshwater crabs), Richard Lansdown (aquatic plants), Sabina G. Knees (aquatic plants), and Zuhair Amr (freshwater molluscs). Jean-Pierre Boudot compiled the preliminary assessments for dragonflies and damselflies.

The assessment of the Arabian Peninsula biodiversity was coordinated by Nieves García, Ian Harrison and Neil Cox from the IUCN-CI Biodiversity Assessment Unit, a shared initiative between IUCN Global Species Programme and Conservation International. We received extensive expert advice and assistance from the following IUCN Species Survival Commission (SSC) Specialist Groups: IUCN/SSC Mollusc Specialist Group, IUCN/SSC Dragonfly Specialist Group, IUCN/SSC-Wetlands International Freshwater Fish Specialist Group, IUCN/SSC Freshwater Crab and Crayfish Specialist Group and IUCN/SSC Freshwater Plant Specialist Group. We also thank the IUCN Regional Office for West Asia, and in particular Khaldoun Al Omari for his dedicated support at the workshop.

All analysis was carried out by Marcelo Tognelli from the IUCN-CI Biodiversity Assessment Unit. The species distribution maps were digitalized through the combined efforts of the IUCN-CI Biodiversity Assessment Unit with the technical support of Celia Navarro. Lindsay I. B. Williams and Sophie Neale from the Royal Botanic

شكر وتقدير

تعتمد جميع عمليات القائمة الحمراء العالمية التابعة للاتحاد الدولي لصون الطبيعة على رغبة العلماء ومساهمتهم في جمع معرفتهم الجماعية لجعل التقديرات عن حالة حفظ الأنواع أكثر مصداقية. ومن دون التزامهم وحماسهم للحفاظ على الأنواع فإن هذه النظرة على المستوى الإقليمي لم يكن بالإمكان تحقيقها.

ونود أن نشكر الأشخاص التالية أسماؤهم الذين ضحوا بوقتهم وخبرتهم الثمينة لتقييم جميع التقييمات في ورشة العمل التي عقدت في معهد بحوث سينكنبرج ومتحف الطبيعة في فرانكفورت / ألمانيا، ونعتذر من أي شخص لم يذكر اسمه سهوا أو احتوى اسمه على خطأ إملائي.

ونخص بالذكر مؤلفي الفصول المختلفة والمقيّمين والمشاركين في ورشة العمل: أنيت باتزلت (النباتات المائية) وبودجيما سمراوي (يعسوبيات) وإيك نوبرت (رخويات المياه العذبة) وفريد ا. كروب وغاري ر. فيولنر ويورغ فرايهوف (أسماك المياه العذبة) وفولفغانغ شنايدر وخلدون العمري (يعسوبيات) ونشأت حميدان (أسماك المياه العذبة) ونيل كامبرلدج (سرطانات المياه العذبة) وريتشارد لانسداون (النباتات المائية) وسابينا ج. نييز (النباتات المائية) وزهير عمرو (رخويات المياه العذبة). وقد قام جان بيير بودو بجمع التقييمات الأولية لليعسوبيات ومقترنات الأجنحة.

تم تنسيق تقييم التنوع البيولوجي في الجزيرة العربية من قبل نيفيس غارسيا وإيان هاريسون ونيل كوكس من وحدة تقييم التنوع البيولوجي التابع للإتحاد الدول لصون الطبيعة ومنظمة الحفظ الدولية (IUCN-CI)، وهي مبادرة مشتركة بين البرنامج العالمي للأنواع التابع للإتحاد الدولي لصون الطبيعة (IUCN) ومنظمة الحفظ الدولية (CI). كما تلقينا مشورة ومساعدة واسعة من خبراء المجموعات المتخصصة التالية التابعة للجنة بقاء الأنواع التابعة للاتحاد الدولي لصون الطبيعة والموارد الطبيعية (SSC): المجموعة المتخصصة في الرخويات والمجموعة المتخصصة في اليعسوبيات والمجموعة المتخصصة وهم في أسماك المياه العذبة والمجموعة المتخصصة في سرطان وجراد البحر المياه العذبة والمجموعة المتخصصة في نباتات المياه العذبة. كما نشكر المكتب الإقليمي لغرب آسيا التابع للإتحاد الدولي لصون الطبيعة وعلى وجه الخصوص خلدون العمري لدعمه المتفاني في ورشة العمل.

وقد أجريت جميع التحاليل من قبل مارسيلو توغنللي من وحدة تقييم التنوع البيولوجي التابع للإتحاد الدولي لصون الطبيعة ومنظمة

Garden Edinburgh provided key distributional data and generated maps for the aquatic plants assessment. Mark Mulligan (King's College London) kindly provided data on dams from the DAMS database.

We would like to thank the staff at the *Senckenberg Research Institute and Museum of Nature* in Frankfurt, particularly Wolfgang Schneider, Eike Neubert, and Horst Zetzsche for providing logistical and administrative support and making sure the communications and evaluation workshop ran smoothly. Workshop facilitators in Frankfurt were Nieves García, Ian Harrison, Khaldoun AlOmari.

We also would like to thank Simon Stuart, Chair of IUCN Species Survival Commission, for his good advice and guidance. Experienced support and advice was also provided by Will Darwall, Kevin Smith and David Allen, from IUCN Freshwater Biodiversity Unit, and Johannes Els from the Breeding Center for Endangered Arabian Wildlife. Meryl Cohen and Marion Salaun Fairbanks and Carly Silverman (Conservation International) provided helpful administrative assistance in planning the budget for the project.

Ian Harrison is grateful to the Department of Ichthyology, American Museum of Natural History, New York for granting Research Associate status, and to the staff of the Museum library (in particular Tom Baione [Harold Boeschenstein Director] and Mai Qaraman Reitmeyer [Librarian]), for assisting in locating published materials. Ian Harrison is also grateful to Columbia University, New York for granting Adjunct Research Scientist Status (for Center for Environmental Research and Conservation) and External Affiliate Status (Department of Ecology, Evolution, and Environmental Biology) and allowing access the library facilities.

Ian Harrison, Nieves García and Neil Cox reviewed and text edited this report. Chadi Abi Faraj produced the present project publication. Nashat A. Hamidan helped in editing the Acknowledgments and Executive Summary sections.

The contribution of each expert is fully acknowledged in each of the detailed individual species assessments. Globally completed assessments are available on the IUCN Red List of Threatened Species website (http://www.iucnredlist.org).

This project has been carried out thanks to the generous grant to IUCN by the Environment Agency of Abu

الحفظ الدولية (IUCN-CI). تم تحويل خرائط توزيع الأنواع إلى خرائط رقمية من خلال تضافر جهود وحدة تقييم التنوع البيولوجي التابع للإتحاد الدولي لصون الطبيعة ومنظمة الحفظ الدولية (IUCN-CI) والدعم التقني من سيليا نافارو وقد قدمت ليندسي وليامز وصوفي نيل من الحديقة النباتية الملكية (ادنبره) بيانات التوزيع الرئيسية وأنتجت خرائط لتقييم النباتات المائية. كما قدم مارك موليجان من كينجز كوليدج (لندن) بيانات عن السدود.

ونود أن نشكر الموظفين في معهد سينكنبرج للبحوث ومتحف الطبيعة في فرانكفورت وخصوصا وولفجانج شنايدر وإيك نوبرت وهورست زيتشي لتوفير الدعم اللوجستي والإداري والتأكد من سير ورشة عمل الاتصالات والتقييم على نحو سلس، كما نود أن نشكر نيفيس غارسيا وإيان هاريسون وخلدون العمري ميسّري ورشة العمل في فرانكفورت.

كما نود أن نشكر سايمون ستيوارت رئيس لجنة بقاء الأنواع التابعة للاتحاد الدولي لصون الطبيعة لنصائحه وتوجيهاته الجيدة. وقد تم تقديم الدعم والمشورة أيضا من قبل ويل داروول وكيفن سميث وديفيد ألين من وحدة التنوع البيولوجي للمياه العذبة التابعة للاتحاد الدولي لصون الطبيعة والموارد الطبيعية ويوهانس إلس من مركز تناسل الحياة البرية العربية المهددة بالانقراض. كما تم تقديم المساعدة الإدارية المفيدة للتخطيط لميزانية هذا المشروع من قبل ميريل كوهين وماريون سالاون فيربانكس وكارلي سيلفرمان (منظمة الحفظ الدولية).

كما يشكر إيان هاريسون وزارة علم الأسماك والمتحف الأمريكي للتاريخ الطبيعي في نيويورك لمنحه مرتبة باحث مشارك ولموظفي مكتبة المتحف (ولا سيما توم بايون [مدير هارولد بوشينستاين] وماي قرمان ريتماير [أمينة المكتبة لخدمات البحوث]) للمساعدة في تحديد مكان المنشورات. كما يشكر أيضا جامعة كولومبيا (نيويورك) لمنحه مرتبة مساعد باحث علمي (مركز البحوث البيئية والمحافظة على البيئة) ومرتبة منتسب خارجي (قسم البيئة والتطور وعلم الأحياء البيئي) والسماح له أيضا بالوصول إلى مرافق المكتبة.

تم مراجعة وتحرير نص هذا التقرير من قبل إيان هاريسون ونيفيس غارسيا ونيل كوكس. ويعود انتاج مشروع نشر التقرير الحالي لشادي ابي فرج. نشأت حميدان ساعد في تنقيح النص العربي.

لقد تم ذكر مساهمة كل خبير بالكامل في كل من التقييمات الفردية المفصلة للأنواع. كما تتوفر التقييمات المستكملة عالميا على موقع القائمة الحمراء للأنواع المهددة بالانقراض:
. (http://www.iucnredlist.org)

Dhabi, including its report and workshop in Frankfurt. We are grateful to HE Razan Khalifa Al Mubarak and Frédéric Launay for the Agency´s hugely generous support to IUCN´S Species Survival Commision. Co-funding for data compilation, workshop facilitation and data editing was provided through The Betty and Gordon Moore Center for Ecosystem Science and Economics of Conservation International. Any opinion, findings, denominations and conclusions expressed in this report are those of the authors and do not necessarily reflect the views of the Environmental Agency of Abu Dhabi, the International Union for Conservation of Nature, Conservation International or the project partners.

وقد تم تنفيذ هذا المشروع بفضل المنحة السخية المقدمة من قبل هيئة البيئة في أبوظبي إلى الاتحاد الدولي لصون الطبيعة، بما في ذلك تقريرها وورشة العمل في فرانكفورت.

كما وأننا ممتنون لسعادة رزان خليفة المبارك وفريديريك لوني لدعمهم السخي والكبير إلى لجنة بقاء الأنواع التابعة للاتحاد الدولي لصون الطبيعة وممتنون أيضا الى مركز بيتتي وجوردون مور لعلوم النظام الإيكولوجي والاقتصاد التابع لمنظمة الحفظ الدولية لتقديمه التمويل المشترك لتجميع البيانات وتسهيل ورشة العمل وتحرير البيانات.

إن أي رأي أو نتائج أو تسميات أو استنتاجات واردة في هذا التقرير هي تابعة لآراء كاتبيها ولا تعكس بالضرورة وجهات نظر كل من هيئة البيئة في أبوظبي أو الاتحاد الدولي لصون الطبيعة أو منظمة الحفظ الدولية أو الشركاء في المشروع.

Executive Summary

The Arabian Peninsula Freshwater Biodiversity Assessment addresses the limited information currently available on the status and distribution of freshwater species in the region. The present IUCN Red List publication compiles the results of the project, identifying those species at risk of regional extinction and providing the first overview of their conservation status in accordance with the IUCN regional Red List guidelines. By compiling this existing information and updating it where possible the report provides an important resource for current and future decision-making on the management and conservation of inland waters.

The project evaluates the conservation status of 292 species belonging to five taxonomic groups – 18 fish taxa, 30 molluscs taxa, 59 dragonflies and damselflies taxa (odonates), 3 freshwater crabs taxa and 182 wetland-dependent plants taxa. Freshwater crabs and fish show a high degree of endemism, with 100% and 83% of the species respectively in these groups not being found anywhere else outside of the region. Overall, 17% of the Arabian freshwater taxa assessed are threatened with extinction at the regional scale, with a further 3% assessed as Near Threatened and 20% as Data Deficient.

The limited number and area of wetland systems within the region, and the restricted size of many of them, constrains the distribution of species and the abundance of species in many basins. The greatest numbers of freshwater species and threatened species are found in the mountains of Yemen, the Socotra archipelago, south-west Saudi Arabia and Oman in Dhofar. These areas, identified as centres of freshwater biodiversity and threat, can help focus development and conservation actions in ways that aim to minimise impacts to freshwater species throughout the region.

Habitat loss and degradation due to modification of the natural systems (e.g. unsustainable water abstraction) and agriculture intensification are together with pollution and the current trend of atmospheric temperature increase and rainfall decline, the major causes of species decline in the Arabian Peninsula. The proposed conservation measures to reduce the probability of future declines in freshwater biodiversity in the Arabian Peninsula will be through better, basin-scale programs of landscape management that integrate conservation programs across terrestrial and aquatic systems. This should include increased representation of freshwater ecosystems in networks of protected areas and implementation of Integrated River Basin Management programs. Additional conservation actions should include the use of sustainable agricultural techniques and waste management, law enforcement, habitat protection, action plans for species and environmental education.

Also, the success of conservation planning in order to guarantee the future sustainability of livelihoods, as well as the resources and services provided by functioning wetland ecosystems depends critically on the adequate involvement of communities in the long-term future of freshwater species and habitats across the region.

الملخص التنفيذي

يعالج تقييم التنوع البيولوجي للمياه العذبة في الجزيرة العربية المعلومات المحدودة المتاحة حاليا عن حالة وتوزيع أنواع المياه العذبة في المنطقة. يجمع التقرير الحالي للقائمة الحمراء التابعة للإتحاد الدولي لصون الطبيعة نتائج المشروع وتحديد تلك الأنواع المعرضة لخطر الانقراض إقليمياً وتوفير نظرة أولى عن حالة حفظها وفقا للمبادئ التوجيهية للقائمة الحمراء الإقليمية التابعة للإتحاد الدولي لصون الطبيعة. يقدم هذا التقرير من خلال تجميع هذه المعلومات القائمة وتحديثها -كلما أمكن- موردا هاما لاتخاذ القرارات الحالية والمستقبلية لإدارة وحفظ المياه الداخلية.

يقيّيم المشروع وضع الحفاظ على ٢٩٢ نوعا من الأنواع تنتمي إلى خمس مجموعات تصنيفية - ١٨ من أصناف الأسماك، ٣٠ من أصناف الرخويات، ٥٩ من أصناف اليعسوبيات ومقترنات الأجنحة (odonates)، ٣ من أصناف سرطانات المياه العذبة، ١٨٢ من أصناف النباتات التي تعتمد على الأراضي الرطبة. كما تبين أن لدى سرطانات وأسماك المياه العذبة درجة عالية من التوطن بلغت منها نسبة ٨٣٪ من الموجود أما السرطانات فبلغت نسبة ١٠٠٪ من هذه المجموعات. وعموما، فإن ١٧٪ من أصناف المياه العذبة في الجزيرة العربية التي تم تقييمها مهددة بالانقراض على المستوى الإقليمي مع ٣٪ أخرى اعتبرت تحت التهديد و ٢٠٪ لا يتوفر عنها معلومات.

ان العدد والمساحة المحدودة لأنظمة الأراضي الرطبة في المنطقة والحجم المحدود للكثير منها يحد من توزيع الأنواع ووفرتها في العديد من الأحواض. وقد تم العثور على أكبر عدد من أنواع المياه العذبة والأنواع المهددة بالانقراض في جبال اليمن وفي أرخبيل سقطرى وجنوب غرب المملكة العربية السعودية وفي محافظة ظفار في سلطنة عمان. ويمكن لهذه المناطق التي تم تحديدها كمراكز للتنوع البيولوجي للمياه العذبة ان تساعد على تركيز التنمية وأعمال الحماية بهدف تقليل من الآثار على أنواع المياه العذبة في جميع أنحاء المنطقة.

ان الأسباب الرئيسية لانخفاض الأنواع في شبه الجزيرة العربية هي فقدان الموائل وتدهورها، وذلك بسبب التعديل في النظم الطبيعية (مثل استخراج المياه غير المستدام) وتكثيف الزراعة، بالإضافة إلى التلوث وزيادة درجة حرارة الغلاف الجوي وانخفاض هطول الأمطار. إن تدابير الحماية المقترحة للحد من احتمال انخفاض مستقبلي للتنوع البيولوجي للمياه العذبة في شبه الجزيرة العربية ستكون من خلال تحسين برامج إدارة الأراضي على نطاق الأحواض التي تعمل على دمج برامج المحافظة عبر النظم الأرضية والمائية، وينبغي أن تشمل زيادة في تمثيل النظم الإيكولوجية للمياه العذبة في شبكات المناطق المحمية وتنفيذ برامج الإدارة المتكاملة لأحواض الأنهار. يجب أن تتضمن إجراءات الحفظ الإضافية استخدام التقنيات الزراعية المستدامة وإدارة النفايات وتطبيق القانون وحماية الموائل وخطط عمل للتعليم البيئي والتعرف على الأنواع.

بالإضافة إلى ذلك، فإن نجاح التخطيط لحماية التنوع البيولوجي من أجل ضمان استدامة مستقبلية لسبل العيش، فضلا عن الموارد والخدمات التي تقدمها نظم إيكولوجية فعالة للأراضي الرطبة يعتمد بشكل حاسم على المشاركة الكافية للمجتمعات في مستقبل أنواع المياه العذبة والموائل في جميع أنحاء المنطقة.

Chapter 1. Background

Harrison, I.[1], García, N.[2], Freyhof, J.[3], Neubert, E.[4], Amr, Z.[5], Van Damme, D.[6], and Cumberlidge, N.[7]

1.1 Biophysical characteristics

Cox *et al.* (2012) give a good overview of the geography of the Arabian Peninsula, and much of their information is summarized here. The Arabian Peninsula is defined on political grounds, comprising Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen (including the Socotran archipelago). The area covers more than 3 million km² (see Figure 1.1). Mountains rise steeply from the sea along the western, much of the southern, and the south-eastern coasts, and they shelve more gradually towards the desert interior. The highest part of the Arabian Peninsula is in the western mountains at Jebel An Nabi Shu'ayb (3,666 m)

Figure 1.1 Map showing the Arabian Peninsula region covered in this project and the freshwater ecoregions included within this region (source: Abell *et al.* 2008)

1 Center for Environment and Peace, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA
2 IUCN/Conservation International Biodiversity Assessment Unit, Betty & Gordon Moore Center for Ecosystem Science & Economics, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA
3 Zoological Research Museum Alexander Koenig, Leibniz Institute for Animal Biodiversity, Adenauerallee 160, 53113 Bonn, Germany
4 Naturhistorisches Museum der Burgergemeinde Bern, Bernastr 15, CH-3005 Bern, Switzerland.
5 Jordan University of Science and Technology, P.O. Box 3030, Irbid. 22110, Jordan.
6 University of Ghent, Sint-Pietersnieuwstraat 25, B 9000 Ghent, Belgium
7 Department of Biology, Northern Michigan University. Marquette, MI 49855-5376, USA

in Yemen. The southern part of the western mountains, located in south-west Saudi Arabia and Yemen, receives summer monsoon rainfall, from June to September, and the western escarpment is cut by many steep wadis. The mountains of the Dhofar governorate of southern Oman, extending into the Mahra region of eastern Yemen, attain elevations of 1,400-1,800 m and also receive the summer monsoon. The southwest monsoon that affects southern Oman and adjacent Yemen creates tropical fog that permits the development of a deciduous cloud forest. The forest is also noted as supporting high plant diversity (see chapter 7).

An extensive limestone plateau, the jol, lies between Dhofar and the south-west mountains, and this is deeply incised by the large Wadi Hadhramaut-Wadi Masilah system. The Hajar Mountains stretch for about 700 km between the Musandam Peninsula and Ras al Hadd in the south-east of the Arabian Peninsula, reaching 3,009 m at their highest point at Jebel Al Akhdar. The interior of the Arabian Peninsula comprise sand and gravel deserts, intersected by numerous shallow wadis. Sand dunes occupy about 27% of the Arabian Peninsula, with the extensive Rub al Khali (Empty Quarter) in the southeast itself covering about 640,000 km². Black basalt lava flows (harrat) cover about 30,000 km² in northern Saudi Arabia and extend into Syria and Jordan.

While arid habitats cover most of the Arabian Peninsula, the region has several freshwater systems that are crucial for the survival of people as well as for many animals and plants. The coastal mountainous regions have seaward flowing drainages, otherwise drainages are typically internal and endorheic. Many of the natural streams, wadis and shallow pools are ephemeral, occurring after sporadic rainfall, and the flows frequently do not reach their terminal basins. Permanently flowing freshwater systems also exist, though they tend to be restricted to a few mountain wadis (such as in south west Saudi Arabia and Yemen), and they may show high variation in flow rates that include periodic floods. The deciduous forests of the monsoon regions of southwestern Saudi Arabia , Yeman and Oman support permanent springs and other freshwater bodies. The springs are usually situated in the foothills of the coastal mountains, and offer high quality habitats for all kinds of freshwater organisms Thermal springs are found in some mountainous regions, such as the Jebel Al Akhdar mountains; some of these springs may release brine water. Some of the more notable freshwater systems (with high species numbers) are present in various parts of southern Arabia (e.g. the Wadi Hadhramaut system). Subterranean water systems are widespread in the Peninsula's karstic area, and large caves are known at least in Oman (for example the al-Houta cave near Nizwa).

There are also brackish salt flats (sabkha) along the coasts and in some inland areas, such as the Umm as Samim in Oman. Fresh groundwater mixes with saltwater in the delta areas of larger drainage systems producing more or less brackish water bodies that are inhabited by some species marking the transition to marine systems.

In parts of the Arabian Peninsula, such as Oman, artificial irrigation channel systems, called aflaj or qanats, provide important freshwater habitat for plants and animals, especially where there are no natural wetland areas. In addition to the aflaj, artificial dams form lakes (some of which are large) in the Arabian Peninsula, and these provide freshwater habitats for some species (but the dams and modified geomorphology and hydrology of the river basins represent significant threats to many

Irrigation ditch at Al Ahsa in Saudi Arabia. Photo © Boudjéma Samraoui

species). The FAO (2013) Aquastat database lists 216 dams in the region (29 in Oman, 46 in Yemen, 68 in the United Arab Emirates, and 73 in Saudi Arabia). Several of these do not have geographic coordinates, but the others are shown in figure 1.2, along with data from Mulligan *et al*. (2009). This total number of dams is likely to be an underestimate because even by the end of 2006 the number of dams in Saudi Arabia alone was estimated to be as high as 230. Sixty-one of the dams listed in Aquastat (FAO 2013) qualify as large dams (over 15 m); the highest being the 103 m King Fahad dam in the southwest of Saudi Arabia near Bishah-Khamis Mushayt, with a reservoir size of 325 million m^3. In terms of water impoundment, the 40 m high Ma'areb dam near Ma'areb city in Yemen is the largest, impounding 400 million m^3. Other large reservoirs in the Arabian Peninsula include that behind the Wadi Abhar dam (213 million m^3), the reservoir behind the Wadi Najran dam (86 million m^3), and the reservoir behind the Wadi Jazan dam (51 million m^3); all of which are in Saudi Arabia. Other large artificial water bodies include Al Asfar Lake located east of Al-Hassa, which extends for several kilometers. This artificial lake receives excess drainage water from the surrounding farmland.

The islands of the Socotran archipelago have a continental geological origin but became separated during the Miocene. They are now separated from one another and from Africa by relatively shallow seas and from the Arabian Peninsula to the north by a deep trench of about 2,500 m (Birse *et al*. 1997). Socotra is the largest of these islands (with an area of 3,625 km^2), and lies 240 km east of the Horn of Africa and 480 km south of the Arabian Coast. The second largest island is Abd al Kuri (216 km^2, 850 m above sea level), has low hills rather than mountains, and very little surface water. The other two islands of the archipelago, Samha (45 km^2, 779 m asl) and Darsa (10 km^2, 57 m asl), are both small, arid, and barren. Samha has only a few areas with freshwater, while Darsa has no available freshwater and is uninhabited. The Socotran islands have a summer annual monsoon like other parts of Yemen and Oman (discussed above).

The Arabian Peninsula lies at the junction of three biogeographic realms (using the zoogeographic regions adopted by the Freshwater Animal Diversity Assessment; Balian *et al*. 2008): the western part of the Palearctic, the Afrotropical, and the Oriental. Hence the region has a mixed flora and fauna that includes representatives of both Asian and African groups. The Arabian Peninsula includes all or part of four freshwater ecoregions, as defined by Abell *et al*. (2008): the Southwestern Arabian coast, Oman Mountains, Arabian Interior, and the Lower Tigris and Euphrates ecoregions (Fig. 1.1). The **Southwestern Arabian coast freshwater ecoregion**, which shows affinities with Africa and the Tigris-Euphrates basin, is characterized by high endemism of its fish fauna. Most of the **Oman Mountains freshwater ecoregion** is extremely hot and dry, with few freshwater habitats. The artificial irrigation channels (aflaj or qanats) are important additional habitats for various species (see above). The large **Arabian Interior** freshwater ecoregion has very few freshwater habitats, and the drainages are all internal and endorheic. The ecoregion extends beyond the political boundary of the Arabian Peninsula, north into Jordan and Syria, including the important and highly threatened ecosystems of the Azraq Oasis (not covered in this analysis). The species of the northern part of the Arabian Interior have Palearctic affinities (specifically with the Tigris-Euphrates regions) whereas some of those in the southern part of the ecoregion show Afrotropical affiliations.

The Arabian Peninsula (as defined here) includes only a very small portion of the **Lower Tigris and Euphrates** ecoregion in Kuwait, covering the marine coastal areas of the northeastern part of Al Jahrah district adjacent to Bubiyan Island. Thus, the fish fauna that is typical of the lower Tigris and Euphrates catchments is represented by one species only in the Arabian Peninsula. The Arabian Peninsula as defined here also includes Socotra, however this is not recognized as part of an ecoregion because there were no freshwater fish documented or data available at the time that the ecoregions were delineated (Thieme *et al*. pers. comm.). Nevertheless, the islands are well known for their endemic flora and fauna and were declared a World Heritage site in 2008.

1.2 Aquatic Biodiversity

The overall diversity of freshwater species through the region is relatively low, due to the small volume of permanent water bodies. However, this may be partly an underestimate, due to incomplete surveying. The richness of species tends to be greatest in the mountains that are less arid than the flatter sand dunes and gravel deserts, especially in the interior.

Among the aquatic plants there is a high diversity of species in permanent freshwater systems, with 182 species represented on the Arabian Peninsula (including a small number of endemics). Many of these are

concentrated in southern Arabia, although species diversity is likely underestimated in some areas as it remains quite poorly known. Apart from the freshwater crabs (100% endemic), the aquatic invertebrates studied as part of this report (molluscs, dragonflies and damselflies) also appear to be quite species poor in the region, with only a few endemic species. However further studies are needed for all groups to establish a complete record of the region's freshwater fauna. Perhaps the freshwater fishes are the better known group for the Arabian Peninsula, and of the 19 recognized species many are endemic to the region.

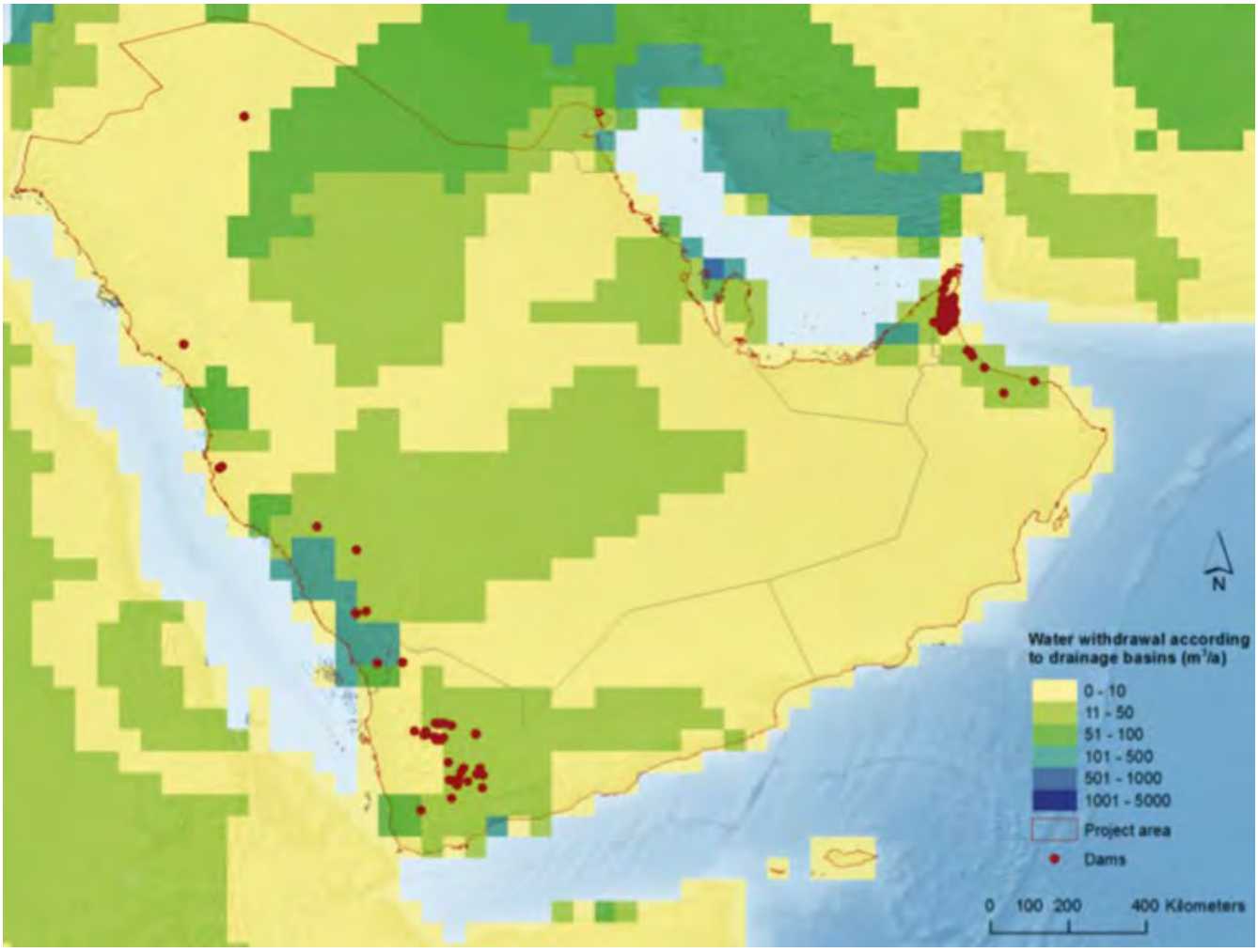
1.3 Regional Threats

Freshwater habitats in the generally dry Arabian Peninsula are notably sensitive to several threats that are often associated with overuse or mismanagement of these resources. Perhaps the overriding threat to freshwater species of the Arabian Peninsula comes from habitat loss and degradation. This is often linked to the drainage of wetlands for conversion to agricultural land or for regional development activities (including increased recreational use). Very much related to habitat loss is the physical modification of water sources and changes to flow regimes, frequently through (but not limited to) either channelization of streams and rivers, or dam construction for either electricity generation or the creation of water storage reservoirs (see Figure 1.2). In addition to the water body itself, associated habitats such as riparian vegetation (essential for many freshwater species) will also be impacted.

Unsustainable abstraction of water, generally to support agricultural or domestic needs, is having a considerable impact on the freshwater species that rely on the region's freshwaters. Both surface and groundwater resources are exploited and perhaps most clearly threaten those species, such as freshwater fishes, that rely on the availability of permanent water-bodies to complete their life-cycles.

The quality of water available to many freshwater organisms is also being compromised. Water pollution is

Fig. 1.2. Dams and water withdrawal in the Arabian Peninsula. Based on data from Alcamo (2002), Mulligan *et al.* (2009), FAO (2013).



a serious issue in many basins, ranging from large waste (plastic bottles etc.) to chemical pollution (for example, anti-malarial biocides (Van Damme and Banfield 2011) and agrochemicals). The eutrophication and reduction in dissolved oxygen for many wadis, springs, rivers and other water-bodies on the Arabian Peninsula can be largely attributed to run-off of fertilizers from irrigated farmed land.

While the impacts of ongoing climate change for the Arabian Peninsula as a whole are difficult to predict, it is clear that the limited freshwater habitats and associated species of the Peninsula will be vulnerable to any lengthening of drought. This may particularly be the case where water-bodies are already heavily affected by over-abstraction of water. While some species may be able to tolerate small increases in dry periods, there will be those (often highly aquatic species such as freshwater fishes) that cannot adapt to these changes.

Invasive species have been recorded in many of the region's freshwaters. It appears that the best documented invasive species are often non-native fishes, and the impact of these aliens on native fish populations is outlined in Chapter 3. Invasive species can be expected to result in habitat loss and degradation, or predation and competition with a variety of freshwater taxa.

1.4 Precautionary Principle

Darwall *et al.* (2009) stated that, even when the economic value of a wetland and its associated biodiversity has been determined as high, it may still remain a difficult task to justify the need to conserve all species in those wetlands. For example, in some circumstances fishery managers may argue that it is easier to focus their management on a few species, or on alien species that are commercially valuable than to try to manage native or all species. However, Darwall *et al.* (2009) showed that this approach may be misguided, especially when we do not know enough about the species-ecosystem interactions to fully understand the effect of loss of a single species, or a group of species, from the system. This is likely to be the case in the wadi systems of the Arabian Peninsula. In those ecosystems, it is important to take a precautionary approach and assume that all species may play a critical role in the ecosystem foodwebs and function.

Hence, the basis of the Precautionary Principle is that, where potential threats could lead to serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. This principle is a critical part of species conservation and should be applied in circumstances where there are reasonable grounds for concern that an activity may cause harm to the environment but where there is uncertainty about the probability of the risk and the degree of harm.

1.5 Objectives

Dryland and desert environments have frequently been overlooked during conservation priority setting exercises; however they contain a wealth of biodiversity adapted to the harsh conditions.

This is particularly the case for the Arabian Peninsula, where assessments of the global conservation status of charismatic species groups such as mammals and birds exist, but are lacking for important species of freshwater taxa. The lack of basic information on species distributions and threatened status in these systems has been a key obstacle facing freshwater ecosystem managers in the region.

The project reported here aimed to address these issues by collating information for assessments of conservation status and distributions of biodiversity throughout the inland waters of the Arabian Peninsula. This report provides a synthesis of the data, with recommendations for conservation priorities. The collated data are stored and made publicly available through the IUCN Species Survival Commission (SSC) data management system, the Species Information Service (SIS) at www.iucnredlist.org.

1.6 References

Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Contreras Balderas, S., Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J., Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D., López, H.L., Reis, R.E., Lundberg, J.G., Sabaj Pérez, M.H., and Petry, P. (2008). Freshwater Ecoregions of the World: a new map of biogeographic units for freshwater biodiversity conservation. *BioScience* **58** (5): 403-414

Alcamo, J., Döll, P., Flörke, M. and Märker, M. (2002). World Water Assessment Programme: Map 4. Water withdrawals according to drainage basins. Center for Environmental Systems Research, University of Kassel. http://www.usf.uni-kassel.de/wwap/results.htm#map4. Downloaded May 28, 2014.

Balian, E.V., Segers, H., Lévêque, C. and Martens, K. 2008a. An introduction to the Freshwater Animal Diversity Assessment (FADA) project. Hydrobiologia 595: 3–8.

Cox, N.A., Mallon, D., Bowles, P. and Tognelli, M.F. (compilers). (2012). The Conservation Status and Distribution of Reptiles of the Arabian Peninsula. Cambridge, UK and Gland, Switzerland: IUCN, and Sharjah, UAE: Environment and Protected Areas Authority.

Darwall, W.R.T., Smith, K.G., Tweddle, D. and Skelton, P. (eds) (2009). The Status and Distribution of Freshwater Biodiversity in Southern Africa. Gland, Switzerland: IUCN and Grahamstown, South Africa: SAIAB. viii+120pp.

FAO (2013). AQUASTAT – Geo-referenced database on dams in the Middle East. http://www.fao.org/nr/water/aquastat/dams/index.stm. Downloaded September 9, 2013.

Mulligan, M. Saenz-Cruz , L., van Soesbergen, A., Smith,V.T. and Zurita,L (2009) Global dams database and geowiki. Version 1. http://geodata.policysupport.org/dams. Version 1.

Van Damme, K. and Banfield, L. (2011) Past and present human impacts on the biodiversity of Soqotra Island (Yemen): implications for future conservation. *Zoology in the Middle East*. Supplementum 3 (Biodiversity Conservation in the Arabian Peninsula): 31-88.

Chapter 2. Assessment methodology

Harrison, I. J.,[1], García, N.[2], Darwall, W.R.T.[3], and Smith, K.[3]

2.1 Selection of priority taxa

When making an assessment of the condition of biodiversity in freshwater ecosystems, it is important to consider species that are essential to the maintenance of healthy ecological functions as well as those species that are used by human communities to provide food and other ecosystem goods. It is, however, impractical to assess all freshwater species due to financial and knowledge constraints. Therefore, a number of priority taxonomic groups were selected. These groups are: freshwater fishes, freshwater molluscs, odonates (dragonflies and damselflies) and freshwater plants. Assessments have focused on these groups for several reasons. The groups cover a wide range of trophic levels within the foodwebs that underlie and support wetland ecosystems. Given this range of trophic levels and ecological roles encompassed within the four focal taxonomic groups, information on their distributions and conservation status, when combined, will provide a useful indication of the overall status of the associated wetland ecosystems.

The groups were also selected because they include taxa for which there is sufficient existing information and scientific expertise to ensure that comprehensive and accurate assessments can be completed. The selected groups have been assessed for other parts of the world, beyond the Arabian Peninsula, by IUCN's Freshwater Biodiversity Unit (FBU). This has been achieved through several regionally focused assessment projects since 2004 (for example see Darwall *et al.* 2005, 2009, 2011*;* Allen *et al.* 2010, 2012*;* Molur *et al.* 2011). Other freshwater groups (for example, crabs; Cumberlidge *et al.* 2009*),* and freshwater shrimps (IUCN in progress) are being assessed comprehensively at the global scale.

Because the focal groups are relatively well-studied and easily surveyed it will be possible to make repeated assessment of their status, either within any one selected region or globally. These repeated assessments then have the potential to serve as an indicator of the effects of environmental change within the region, where pressures such as rapid development and high population growth can significantly alter wetland systems. Indeed, many of the selected species are particularly good indicators of environmental health in freshwater systems and the adjacent riparian habitat (see information on taxonomic groups in sections 2.1.1-4).

The species in the selected taxonomic groups also provide important services in support of the surrounding ecosystems and human livelihoods (Juffe-Bignoli and Darwall 2012) For example, fishes provide an important benefit to the livelihoods of many people throughout the world, as a source of income or as a valuable source of nutrition. Benefits provided by the other taxa may be indirect and are often poorly appreciated but, nonetheless, are equally important. (eg., water filtration and removal of metals, provision of medicinal materials; Maine *et al*. 2004, Khan *et al*. 2009).

This report focuses on assessment of the four selected groups (fishes, odonates, molluscs, and plants from freshwaters) through the Arabian Peninsula. In addition to those taxonomic groups, freshwater crabs are included here because they have been globally assessed by Cumberlidge *et al* (2009) as part of an earlier stage of IUCN's freshwater-specific biodiversity assessments.

2.1.1 Fishes

Fishes are probably the most important wetland product on a global scale; providing the primary source of protein for nearly one billion people worldwide (FAO 2002) and food security for many more (FAO 2002, UNEP 2010). However, freshwater fisheries in the Arabian Peninsula

1 Center for Environment and Peace, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA
2 IUCN/Conservation International Biodiversity Assessment Unit, Betty & Gordon Moore Center for Ecosystem Science & Economics, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA
3 Freshwater Biodiversity Unit, IUCN Global Species Programme, Cambridge, UK CB3 0DL.

are relatively small and are mainly dependent on the introduced Nile Tilapia *Oreochromis niloticus* (FAO 2012).

For the purposes of this assessment freshwater fishes are defined as those that spend all or a critical part of their lifecycle in fresh waters, or are confined to brackish waterbodies. A total of 21 taxa were selected for this assessment. Fifteen of the species are restricted to the area under consideration (see section 2.2). The remaining taxa are more widespread. The IUCN Red List (IUCN 2012) and FishBase (Froese and Pauly 2012) include some additional brackish water species for the countries of the Arabian Peninsula; however, these are not covered in the current analysis because there is insufficient information to confirm that they are found in the rivers or lakes of the Arabian Peninsula. Only three of the species assessed here had been previously assessed using the IUCN Red List Categories and Criteria at the global scale (IUCN 2012).

2.1.2 Molluscs

The value of molluscs to wetland ecosystems is poorly appreciated. Nevertheless, freshwater molluscs are essential to the maintenance of wetland ecosystems, primarily due to their control of water quality and nutrient balance through filter-feeding and algal-grazing and, to a lesser degree, as a food source for predators including a number of fish species.

Globally, molluscs are one of the most threatened groups of freshwater taxa (Kay 1995, Darwall *et al.* 2011). The impact of developments such as dams, and siltation caused by agricultural practices has not been adequately researched. Many species are also restricted to microhabitats, such as the rapids and riffles (areas of fast current velocity, shallow depth, and broken water surface) between pools and runs (areas of rapid non-turbulent flow) which can be lost through habitat modification.

Thirty species were selected for this assessment (see Chapter 4), following two distinctive biogeographic regions based on the composition of the communities at the beginning of the Holocene (Van Damme 1984); the Palearctic portion in the north of the Arabian Peninsula, and the small Afrotropical portion in the south. However, there is great taxonomic uncertainty surrounding many of the taxa known to be present and some of the more problematic species had to be omitted from this study. Nevertheless, the assessment provides a good representation of the freshwater molluscan diversity across the region.

2.1.3 Odonates

Larvae of almost all of the 5,680 species of the insect order Odonata (dragonflies and damselflies) are dependent on freshwater habitats, with only a few not utilising freshwater. Larvae that develop in water play a critical role with regards to water quality, nutrient cycling, and aquatic habitat structure, whilst also being voracious predators, often considered important in the control of insect pest species. Odonata are unique amongst the groups assessed in not being restricted to the aquatic environment for their entire lifecycle, and this gives them some mobility between habitat types, however they are susceptible to changes in wetland conditions (water flow, turbidity, or loss of aquatic vegetation; Trueman and Rowe 2009) and loss of terrestrial habitat and prey species.

Odonata are relatively easily surveyed (though some expertise is required for correct identification), and a full array of ecological requirements are represented within the group, which has led to their use as a bio-indicator for wetland quality. Fifty-nine species are included in this assessment (see Chapter 5)

2.1.4 Aquatic plants

Aquatic plants are the building blocks of wetland ecosystems, providing food, oxygen and habitats for many other species. They are also a hugely important natural resource, providing direct benefits to human communities across the world. Numerous aquatic and wetland plants are highly valued for their nutritional, medicinal, cultural, structural or biological properties. They are also key species in the provision of wetland ecosystem services, such as water filtration and nutrient recycling.

In this study the definition of an aquatic plant is based on that of Cook (1996), and includes plants "whose photosynthetically active parts are permanently or, at least, for several months each year, submerged in water or float on the surface of water ." However, the definition is adapted also to include species that are restricted to the edges of shallow semi-permanent and permanent water courses (see Chapter 7). According to Cook (1996) aquatic plants represent between one and two percent of the approximately 300,000 species of vascular plants, equivalent to between 2,900 and 5,800 species

(Chambers *et al.* 2008, Vié *et al.* 2008). For this project, the conservation status of 182 aquatic plant species was assessed (see Chapter 7).

2.2 Delineation of the Arabian Peninsula assessment region

The Arabian Peninsula, as defined for this project, includes the political borders according to the United Nations of the countries: Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, Oman and Yemen (including the islands of the Socotra archipelago in the northwestern Indian Ocean) (Fig. 1.1). The boundaries and designations used in this study do not imply any official endorsement, acceptance or opinion by IUCN. The northern part of the Arabian Peninsula is situated within the Palaearctic zoogeographical region, whereas the southern part, including the islands of the Socotra archipelago is in the Afrotropical region. This region includes the Asir Mountains of Saudi Arabia and the highlands of Yemen that are part of the Eastern Afromontane biodiversity hotspot (Mittermeier *et al.* 2004). Among the most important ecosystem services the hotspot provides is fresh water via the major watersheds it houses, and there is a particular need to advance the identification and prioritization of key biodiversity areas in the Arabian part of this hotspot (Birdlife International 2012).

2.3 Data collation and quality control

The biodiversity assessments required sourcing and collating the best information on all known species within the priority taxa (see Section 2.1). Data for the molluscs were compiled by N. García (IUCN-Conservation International Biodiversity Assessment Unit) in consultation with members of the IUCN SSC Mollusc Specialist Group; data for fishes were compiled by I. Harrison (IUCN-Conservation International Biodiversity Assessment Unit and IUCN SSC/Wetlands International Freshwater Fish Specialist Group) in consultation with members of the Freshwater Fish Specialist Group and other international experts; data for odonates were compiled by J.-P. Boudot (IUCN SSC Odonate Specialist Group); data for plants were compiled by R.V. Lansdown (IUCN SSC Freshwater Plant Specialist Group) in consultation with other international experts. All data compilers had experience

Regional and international expert participants at the species assessment review workshop, Senckenberg Research Institute and Museum of Nature, Frankfurt, Germany: Photo © Nieves García.

in use of IUCN's Species Information Service (SIS), application of the IUCN Red List Categories and Criteria (IUCN 2001) to assess a species' risk of extinction in the wild, and in mapping freshwater species distributions using a Geographic Information System (GIS). Initially, lists were compiled of all species of odonates, freshwater fishes, freshwater molluscs, and freshwater plants (according to the criteria discussed in 2.1.4) known to be present within the Arabian Peninsula. These taxon lists were then screened against those species already assessed against the IUCN Red List Criteria and published on the IUCN Red List. The data compilers then collated all available information on each of the selected species, input this to the SIS database, and assessed each species' Red List status. The data compilers also gathered spatial data (species locality data, in decimal degrees latitude/longitude) for the production of species distribution maps (see Section 2.4). The assessments for molluscs, odonates, and plants were then reviewed by a separate group of at least two experts for each taxonomic group at a workshop held from April 30th to May 4th, 2012 at the Senckenberg Research Institute and Museum of Nature in Frankfurt. The information for fishes (which included a small number of species) was reviewed through email consultation with three experts. The purpose of the reviews was to ensure that i) the information presented was both complete and correct; and ii) the Red List criteria had been applied correctly.

Following this review, the data were edited and consistency in the use of the IUCN Red List Categories and Criteria was checked by the IUCN Global Species Programme team. After data gathering, collation and corrections, IUCN experts from the Red List Unit integrated the various data sets in order to draft this regional report.

2.4 Species mapping and analysis

Species global distributions were mapped to river sub-catchments as delineated by the HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) (Lehner *et al.* 2006) (Figure 2.1) using ArcMap GIS software. River sub-

Fig. 2.1 River subcatchments as delineated by HydroSHEDS used to map and analyse species distributions.

catchments were selected as the spatial unit for mapping and analysing species distributions because it is widely accepted that the river/lake catchment is the most appropriate management unit for inland waters. It is recognised that species ranges may not always extend throughout a river sub-catchment, but presence within the river sub-catchment is either 'known' or 'inferred' (either Extant: presence is known from field survey or recent literature, or Probably Extant: presence inferred based on expert opinion).

Where possible, point localities (the latitude and longitude where the species has been recorded), were used to identify which sub-catchments are known to contain the species ('known' sub-catchments). When point localities were not available for some taxa, maps were drawn based on expert knowledge and the literature. Connected sub-catchments, where a species is expected to occur, although presence is not yet confirmed, are labeled as 'inferred catchments.' These inferred distributions were determined through a combination of expert knowledge, course scale distribution records, and unpublished information. The preliminary species distribution maps were digitized and then further edited at the review workshop or during online consultation, and errors or dubious records were deleted from the maps.

For many of the globally widespread plant species there was insufficient information to accurately map the distribution. In these cases, species were mapped coarsely, at the country level (rather than catchment level) for countries that are known to fall inside the species total range.

2.5 Assessment of species threatened status

The risk of extinction was assessed for each species at the global scale, according to the *IUCN Red List Categories and Criteria: Version 3.1* (IUCN 2001; see Figure 2.2), and this information included in the *IUCN Red List of Threatened Species*. In order to avoid an over- or underestimation of the regional risk of extinction, the *Guidelines for Application of the Red List Criteria at Regional Level* (IUCN 2003) were also applied, and the data for each species was used to make an assessment of the regional risk of their extinction, within the boundaries of the Arabian Peninsula. Therefore, this report presents both results, global and regional, of the species risk of extinction.

The categories of threat reflect the risk that a species will go extinct within a specified time period. A species assessed as "Critically Endangered" is considered to be

Figure 2.2 IUCN Red List Categories at the global level.

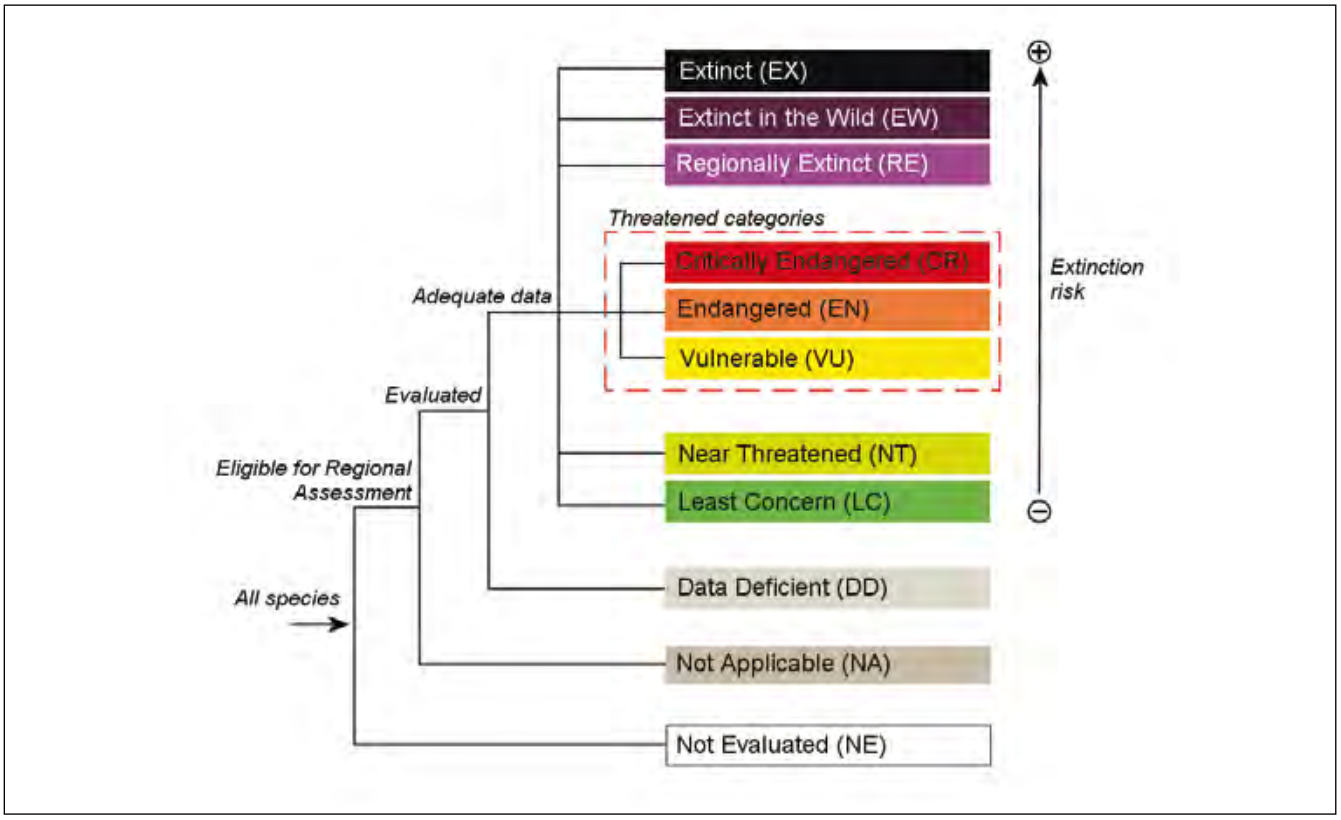


Table 2.1 Summary of the five criteria (A–E) used to determine the category of threat for a species.

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND at least one of C1 or C2			
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):	25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:			
(a) **(i)** Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
(a) **(ii)** % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	**D1.** < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

1 Use of this summary sheet requires full understanding of the *IUCN Red List Categories and Criteria* and *Guidelines for Using the IUCN Red List Categories and Criteria*. Please refer to both documents for explanations of terms and concepts used here.

facing an extremely high risk of extinction in the wild. A species assessed as "Endangered" is considered to be facing a very high risk of extinction in the wild. A species assessed as "Vulnerable" is considered to be facing a high risk of extinction in the wild. All taxa listed as Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) are described as "threatened". To distinguish between the three threatened categories there are five criteria with quantitative thresholds (Table 2.1).

A species is assessed as «Near Threatened» (NT) when it is close to meeting the thresholds for a threatened category either now or in the near future. A species is assessed as «Least Concern» (LC) if it fails to meet, or be close to meeting any of the criteria for the threatened categories. A species is «Data Deficient» (DD) when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on the current knowledge of the species. Species assessed as DD are highlighted as priorities for additional research and are acknowledged as being potentially threatened.

For an explanation of the full range of categories and the criteria that must be met for a species to qualify under each category, please refer to the following documentation: The *IUCN Red List Categories and Criteria: Version 3.1, Version 3.0,* which can be downloaded from www.iucnredlist.org/technical-documents/categories-and-criteria.

The following criteria for the inclusion of a species in the assessment were and were applied in the completion of this Red List assessment:

1. Any species having less than 5% of its range within the project area should not be assessed through this project.
2. Species present in the project area prior to 1500 were treated as being "naturalised" and subject to a Red List assessment. Those species arriving in the region post 1500 were not assessed.

2.6 Overlap with other Red List assessment projects

Some species that are present within the Arabian Peninsula region, and therefore of interest to this project, have already been assessed through other ongoing assessments in adjacent regions of Africa (Darwell *et al.* 2011), the Eastern Himalaya and Western Ghats Biodiversity Hotspots (Allen *et al.* 2010, Molur *et al.* 2011), the HighARCS project (ongoing; www.higharcs.org), and the Sampled Red List Index (SRLI) project (ongoing). In these cases, information that was compiled for the species in the Arabian Peninsula was added to the existing assessment information from elsewhere and, if necessary, any adjustment of the global threat status of the species was made. As noted above, the information that was specific to the Arabian Peninsula was used to make an assessment of the regional risk of extinction within the Peninsula.

2.7 Nomenclature

The taxonomic placement of species and their higher taxonomy often changes as a result of new information from ongoing studies of the species, especially with the introduction of molecular techniques. In addition, the taxonomy of many species is complicated, and different researchers may have different opinions on taxonomic boundaries of those species; i.e., whether some individuals should be recognized as the same or different species, or should be placed in different genera. Therefore, it can sometimes be difficult to find universally agreed taxonomic hypotheses and nomenclatural hierarchy. In the case of this project, the taxonomic nomenclature follows the protocols of the IUCN Red List which, where possible, employs existing published taxonomic authorities as the source of information. Fish classification generally follows the online Catalog of Fishes (Eschmeyer 2012). Odonate classification generally follows the World Odonata List (Schorr and Paulson 2012). There is currently no widely accepted single taxonomy for molluscs, and we therefore follow the standards recommended by the IUCN SSC Mollusc Specialist Group. For plants, where appropriate, we follow the World Checklist of Selected Plant Families hosted by the Royal Botanic Gardens, Kew (WCSP 2010). For more information on the taxonomic standards of the IUCN Red List, visit: http://www.iucnredlist.org/technical-documents/information-sources-and-quality#standards.

2.8 References

Abell, R., Thieme, M.L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Balderas,S.C., Bussing, W., Stiassny, M.L.J., Skelton, P., Allen, G.R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J¸ Armijo, E., Higgins, J.V., Heibel, T.J., Wikramanayake, E., Olson, D.,

Lopez, H.L., Reis, R.E., Lundberg, J.G., Sahaj Pérez, M.H. and Petry, P. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience* **58** (5):403-414.

Allen, D..J., Molur, S., Daniel, B.A. (Compilers). 2010. *The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya.* Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Allen, D.J., Smith, K.G., and Darwall, W.R.T. (Compilers). 2012. *The Status and Distribution of Freshwater Biodiversity in Indo-Burma*. Cambridge, UK and Gland, Switzerland: IUCN. x+158pp+4pp cover.

Birdlife International 2012. *Eastern African Montane Biodiversity Hotspot. Ecosystem Profile*. Critical Ecosystem Partnership Fund. Final Version 24 January 2012. http://www.cepf.net/Documents/Eastern_Afromontane_Ecosystem_Profile_FINAL.pdf

Chambers, P.A., Lacoul, P., Murphy, K.J. and Thomaz, S.M. 2008. Global diversity of aquatic macrophytes in freshwater. *Hydrobiologia* **595**: 9-26

Cook, C.D.K. 1996. *Aquatic Plant Book.* SPB Academic Publishing, Amsterdam/New York.

Cumberlidge, N., Ng, P.K.L., Yeo, D.C.J., Magalhaes, C., Campos, M.R., Alvarez, F., Naruse, T., Daniels, S.R., Esser, L.J., Attipoe, F.Y.K., Clotilde-Ba, F.-L., Darwall, W., Mclvor, A., Ram, M. and Collen, B. 2009. Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. *Biological Conservation* **142**:1665-1673.

Darwall, W., Smith, K., Lowe, T. and Vié J.-C. 2005. *The status and distribution of freshwater biodiversity in eastern Africa.* IUCN SSC Freshwater Biodiversity Assessment Programme. IUCN, Gland, Switzerland and Cambridge, UK.

Darwall, W.R.T., Smith, K.G., Tweddle, D. and Skelton, P. 2009. *The status and distribution of freshwater biodiversity in southern Africa.* Gland, Switzerland: IUCN and Grahamstown, South Africa: SAIAB.

Darwall, W.R.T., Smith, K.G., Allen, D.J, Holland, R.A, Harrison, I.J. and Brooks, E.G.E. (eds.). 2011. *The Diversity of Life in African Freshwaters: Under Water, Under Threat. An analysis of the status and distribution of freshwater species throughout mainland Africa.* Cambridge, United Kingdom and Gland, Switzerland: IUCN.

Eschmeyer, W.N. (ed). 2012. *Catalog of Fishes.* Electronic version. Accessed on 2nd October 2012. http://researcharchive.calacademy.org/research/Ichthyology/catalog/fishcatmain.asp

FAO. 2002. The state of world fisheries and aquaculture 2002. Food and Agriculture Organization of the United Nations Fisheries Department, Rome, Italy.

FAO 2012. Total Fishery Production 1950-2010 (Release date: April 2012). Dataset for FishStat Plus.

Froese, R. and Pauly. D. Editors. 2012. FishBase. World Wide Web electronic publication. www.fishbase.org, version (10/2012).

Holland, R.A., Darwall, W.R.T. and Smith, K.G. 2012. Conservation priorities for freshwater biodiversitv: the key biodiversity area approach refined and tested for continental Africa. *Biological Conservation* **148**,(1): 167-179.

IUCN. 2001. *IUCN Red List Categories and Criteria.* Version 3.1. IUCN, Gland, Switzerland.

IUCN. 2003. Guidelines for application for IUCN Red List criteria at regional levels: version 3.0. IUCN Species Survival Commission, IUCN. Gland, Switzerland and Cambridge, UK.

IUCN. 2012. *IUCN Red List of Threatened Species.* Version 2012.12. http://www.iucnredlist.org.

IUCN and UNEP-WCMC. 2010. *The World Database on Protected Areas (WDPA): Annual Release* [On-line]. Cambridge, UK: UNEPWCMC. Available at: www.wdpa.org. Accessed: 3 November 2010.

Juffe-Bignoli D. and Darwall W.R.T (eds.) 2012. *Assessment of the socio-economic value of freshwater species for the northern African region.* Gland, Switzerland and Málaga, Spain: IUCN. IV + 84 pages

Kay, E.A. 1995. Status Report on Molluscan Diversity. In: *The Conservation Biology of Molluscs.* Proceedings of a Symposium held at the 9th International Malacological Congress, Edinburgh, Scotland, 1986.

Khan, S., Ahmad, I., Shah, M.T., Rehman, S. and Khaliq, A. 2009. Use of constructed wetland for the removal of heavy metals from industrial wastewater. *Journal of Environmental Management* **90**: 3451-3457

Langhammer, P.F., Bakarr, M.I., Bennun, L.A., Brooks, T.M., Clay, R.P., Darwall, W., De Silva, N., Edgar, G.J., Eken, G., Fishpool, L.D., da Fonseca, G.A., Foster, M.N., Knox, D.H., Matiku, P., Radford, E.A., Rodrigues, A.S., Salaman, P., Sechrest, W. and Tordoff, A.W. 2007. *Identification and Gap Analysis of Key Biodiversity Areas .Targets for Comprehensive ProtectedArea Systems.* Gland, Switzerland: IUCN.

Lehner, B., Verdin, K., and Jarvis, A. 2006. HydroSHEDS Technical Documentation. World

Wildlife Fund US, Washington, DC. Available at http://hydrosheds.cr.usgs.gov.

Maine, M.A., Suñé, N.L. and Lagger, S.C. 2004. Chromium bioaccumulation: comparison of the capacity of two floating aquatic macrophytes. *Water Research* **38**, 1494-1501.

Mittermeier, R.A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G., Lamoreux, J. and da Fonseca, G.A.B. 2004. *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions*. Mexico City, Mexico: CEMEX.

Molur, S., Smith, K.G., Daniel, B.A. and Darwall, W.R.T. 2011. *The status and distribution of freshwater biodiversity in the Western Ghats, India.* Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.

Schorr, M. and Paulson, D. 2012. World Odonata List. University of Puget Sound. Available at: http://www.pugetsound.edu/academics/academic-resources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list/

Trueman, J.W.H. and Rowe, R.J. 2009. Odonata. Dragonflies and Damselflies. Version 16 October 2009. http://tolweb.org/odonata.

UNEP 2010. Blue Harvest: Inland Fisheries as an Ecosystem Service. WorldFish Center, Penang, Malaysia

Van Damme, D. 1984. Freshwater Mollusca of Northern Africa. *Developments in Hydrobiology* **25**: 164p. Dordrecht, Netherlands. Dr. W. Junk Publishers.

Vié,J.-C., Hilton-Taylor, C. and Stuart, S.N. 2008. *Wildlife in a changing world: An analysis of the 2008 IUCN Red List of Threatened Species.* Gland, Switzerland. IUCN.

WCSP. 2012. World Checklist of Selected Plants. The Board of Trustees of the Royal Botanic Gardens, Kew. Available at: http://apps.kew.org/wcsp.

Chapter 3. The Status and Distribution of Freshwater Fishes of the Arabian Peninsula

Freyhof, J.[1], Hamidan, N.A.[2], Feulner, G.R.[3] and Harrison, I.[4]

3.1 Overview of the regional fish fauna

3.1.1 Freshwater Fish Diversity

The Arabian Peninsula includes three freshwater ecoregions, as defined by Abell *et al.* (2008): the Southwest Arabian coast, the Oman Mountains and the Arabian Interior ecoregions (see Chapter 1 and Fig. 1). The region includes Socotra, although this is not recognized as part of an ecoregion (see Chapter 1). All fishes found in the freshwaters of Socotra are estuarine or marine species entering the streams and estuaries for foraging, and are not assessed here.

The huge surface of the Arabian Peninsula is almost devoid of freshwater habitats. Saudi Arabia, with a surface cover of more than two million km^2, is inhabited by only eight species of primary freshwater fishes, fewer than in a small catchment in adjacent Iran or Syria. According to this study, 21 species of freshwater fish are present in the Arabian Peninsula. Fifteen species are endemic to the Arabian Peninsula, and six species have a wider distribution.

There are also some marine species which occasionally enter freshwater bodies in the countries of the Arabian Peninsula (e.g, *Acanthopagrus spp., Ambassis gynmocephakus, Megalops cyprinoides, Pellona ditchela, Sillago sihama, Strongylura strongylura*), but freshwater habitats are not an essential element of the life cycle of these species, and they are excluded from the current analysis. The 21 recognized freshwater species are restricted to five families. There is one species of catadromous goby (Gobiidae) and one species of estuarine mullet (Mugilidae), which are found in freshwaters near the coast. There is also one species of euryhyaline killifish (Cyprinodontidae), which occurs all along the coast in marine environments but also ventures relatively far inland. Two species of catadromous eels (Anguillidae) are found locally in freshwaters of the Arabian Peninsula. But by far the majority of species (16 species, or 76% of the total number) are barbs (Cyprinidae). The cyprinid genus *Garra* is the most species rich genus in the region, including 9 of the 21 freshwater species present.

The greatest number of species are found in the Southwest Arabian Coast ecoregion, with 15 taxa (Table 3.1). Eleven of the species present in the Southwest Arabian Coast ecoregion (73%) are endemic to the ecoregion. Despite the fact that the Arabian Interior ecoregion has relatively few freshwater habitats, and the drainages are endorheic and usually intermittent, this ecoregion contains 10 species. Eight species (80% of the taxa present) are endemic to the Arabian Interior ecoregion. The Oman Mountains ecoregion has five species. Two species (40% of the taxa present) are endemic to the Oman Mountains ecoregion. The cyprinid species in this ecoregion show closer affinity to Iranian fauna across the Straits of Hormuz than to the rest of the Arabian Peninsula.

Table 3.1. Species numbers in the three ecoregions (please note that some species may be present in more than one ecoregion)

Ecoregion	Species number	Threatened species	Endemic species
Arabian Interior	10	4	8
Oman Mountains	5	0	2
SW Arabian Coast	15	6	11

1 German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig Deutscher Platz, 5e 04103 Leipzig, Germany
2 The Royal Society for the Conservation of Nature - Conservation Division, P.O.Box 1215, Jubaiha 11941, Jordan. E-mail: nashat.hamidan@rscn.org.jo
3 Chadbourne & Parke, P.O. Box 23927, Dubai, United Arab Emirates. E-mail: grfeulner@gmail.com
4 Center for Environment and Peace, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA. E-mail: iharrison@conservation.org

The impounded water of Qusaiba'a Dam, an ancient dam in Saudi Arabia in Khaibar. One of the few habitats of *Acanthobrama hadiyahensis* (CR) Photo © N. A. Hamidan

3.1.2 Geographical factors affecting the distribution of freshwater fishes

Two taxa are especially widespread in their distribution, mainly along the coastal basins of the Arabian Peninsula. The Arabian Killifish *Aphanius dispar* (LC) is found along the entire coastal part of the Arabian Peninsula; usually it is abundant in numbers. It has been regularly introduced (and re-introduced) into artificial and natural freshwater bodies for mosquito control in the United Arab Emirates and northwestern Oman. Some observers consider that all current populations of *A. dispar* in the mountains of the United Arab Emirates, and along the interior flank of the Oman mountains, are introduced (Feulner 2005).

Some species are regionally relatively widespread across different drainages. For example, *Garra barriemiae* (LC) is found throughout most of the mountains of the United Arab Emirates and Oman. *Garra tibanica* (LC) and *Cyprinion acinaces* (LC) are widespread in western Saudi-Arabia and Yemen. Each of these widespread species is represented by numerous, small populations that are isolated from each other. That isolation means that individual populations can be severely impacted by threats that operate even at a local scale (see section 3.4). The isolation of populations is also likely to promote genetic diversification between them. The extent of isolation and resulting genetic differentiation is still poorly studied. In several instances subspecies have previously been named and several "cryptic" species might yet be discovered (see Section 3.1.3).

Some species seem to be specially adapted to the often extreme conditions in their habitats, but this is only studied well in *G. barreimiae*. This species is typically found in small rock or gravel pools, shallow sections of larger pools with slow-moving water, springs, and fast running perennial rivers. *Garra barriemiae* can survive almost complete disappearance of surface water from its habitat (Feulner 1998) and can travel short distances out of water, even ascending steep, damp rock surfaces (e.g., near waterfalls or during rain). It can tolerate water temperatures up to ca. 40°C and salinity up to one-third that of sea water (Haas 1982). Such physiological and behavior adaptations might be also found in other Arabian freshwater fishes but have not yet been reported.

Some species are restricted to a single river drainage only, like the several endemic species of Wadi Hadramaut (Yemen). For example, *Garra lautior* (EN) is distributed throughout much of the Wadi Hadramaut drainage, but it is restricted to relatively few sites within that range. Such species are very vulnerable to threats like invasive alien species, water extraction and upriver pollution.

There are also a few species that are represented by a single population at a single location where there is almost no opportunity for dispersal. For example, *Garra dunsirei* (EN) is known only from one sinkhole at Tawi Atair, in the Jebel Qara mountains, Dhofar, Oman. This sinkhole is extremely isolated (Banister 1987, Romero and Paulson 2001) and the fish is found in a side passage 200 m down the sinkhole. According to the EPAA (2002) report the population of *G. dunsirei* includes fewer than 250 mature individuals, although this may be an underestimate based on the difficulty of thoroughly exploring the sinkhole.

Wadi Al Ghassah in Saudi Arabia. Photo © N. A. Hamidan

3.1.3 Taxonomic issues

Although there has been a reasonable amount of taxonomic research on the fishes of the Arabian Peninsula, the taxonomy of some species is still not completely resolved. For example, three Arabian cyprinids are often placed in the genus *Barbus*. However, *Barbus apoensis* and *B. exulatus* have been placed in *Carasobarbus* by Ekmekçi and Bănărescu (1998). As to the third species, *B. arabicus*, it has been recognized for decades that it does not belong to *Barbus*. This species has been included in the new genus *Arabibarbus* by Borkenhagen (2014).

Some species (e.g., *Garra barreimiae*, *G. tibanica*, *G. sahilia* and *Cyprinion mhalensis*) have widely separated populations that are totally isolated from each other today. Although during intermittent pluvial intervals, the river network of the Arabian Peninsula was much denser and several species might have been more widespread and individual populations more continuous, it cannot be excluded that there may currently be several "cryptic" species to be discovered, especially in morphologically conservative genera such as *Garra*, as indicated for *G. barreimiae* on opposite flanks of the Oman Mountains by Kruckenhauser *et al.* (2011).

A cave dwelling 'blind' population of *G. barreimiae*, recorded from a single location of less than 10 km^2 by Banister (1984) is often referred to as the 'Omani blind cave fish,' and there has been discussion of its taxonomic status. Kruckenhauser *et al.* (2011) found that it is not genetically removed from adjacent surface dwelling populations of *G. barreimiae*. Because the Omani blind cave fish is not accepted as an independent species, but included in *G. barreimiae*, it is categorized as LC. It has previously been categorized as threatened, but there is no specific threat to the population or indication of decline to justify categorizing it as threatened.

Garra tibanica (LC), is treated as an independent species, distinct from *G. quadrimaculata* from the adjacent African mainland. This judgment is based upon recent morphological and molecular studies (Krupp and Wicker, pers. comm.) despite the earlier suggestion that both might be conspecific (Stiassny and Getahun 2007).

Acanthobrama hadiyahensis, endemic to the Arabian Peninsula and Critically Endangered. Photo © N. A. Hamidan

At the type locality of *Garra longipinnis* in Oman (Jabal al Akhdar) and in areas adjacent to the type locality, only fishes identified as *G. barreimiae* have subsequently been found, all since 2001; fishes agreeing with the long-finned types of *G. longipinnis* were absent. It remains unclear whether *G. longipinnis* has become extinct or whether the original species description (otherwise consistent with *G. barreimiae*) was based on atypical specimens. The species is therefore assessed as Data Deficient due to its unresolved taxonomy.

An additional open taxonomic case comprises the species of the *Cyprinion watsoni* species group. *Cyprinion watsoni* (LC) was described from the Indus drainage in Pakistan and *C. microphthalmum* is a species of neighbouring Iran, Pakistan and Afghanistan. *Cyprinion microphthalmum* is treated as a valid species by Eschmeyer (2013). The Arabian populations have sometimes been treated as a separate species (*C. muscatensis*), as a subspecies of *C. microphtalmum* or sometimes as a synonym of *C. watsoni.* Eschmeyer (2013) lists *C. muscatensis* as a synonym of *C. watsoni*. The authors disagree with this conclusion, since they find that *C. muscatensis* is clearly distinguished by morphology from *C. watsoni* and by (unpublished) molecular data from *C. microphthalmum*. However, there has been no comprehensive review of the genus *Cyprinion*, so we are constrained by IUCN rules to follow the nomenclature set out in Eschmeyer (2013), and therefore to treat *C. muscatensis* as a synonym of *C. watsoni*.

3.1.4 Limitations of data availability and reliability

For most of Arabia, published information is scarce and dates from a decade or more ago, e.g., Krupp (1983) and EPAA (2002). This presents problems in terms of availability and current reliability. Most current information comes from personal communications and recent, but very limited, fieldwork by the authors and Fareed Krupp (Doha). Contemporary fieldwork is strongly recommended to gain up-to-date data on the conservation status of Arabian freshwater fishes. This is also true for threats in the region which seem to be little known in their distribution and severity, especially the extent of water extraction.

Data limitations also were a major problem in attempting to assess the widespread catadromous eels (*Anguilla bicolor*, *A. bengalensis*). The number of records of these eels entering the few streams of the Arabian Peninsula is negligible, although both species have very large global ranges reaching from the East African coast to Southeast Asia. For this reason we leave the regional assessment of these two species as Not Evaluated (NE).

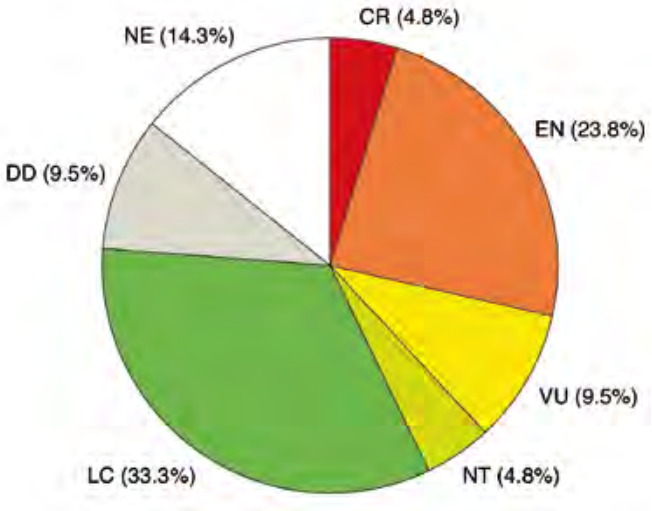
3.2 Conservation status

This assessment considered the global and regional risk of extinction for 21 species of freshwater fishes that are present in the Arabian Peninsula. It is important to note that although several of the species are categorized as Least Concern across the region, many of the isolated populations that are distributed within their range might be facing some serious threats. Data clearly demonstrating this are lacking for Yemen and Saudi Arabia, but from Oman and the United Arab Emirates it is reported that several of the populations of *Cyprinion watsoni* (Oman: Wadi Sharm and Wadi Al-Ramthah; UAE: upper Wadi Hatta watershed) have been impacted by water extraction, habitat modification and the use of pesticides,

to the point of extirpation in some areas (Feulner, own unpublished data).

In Oman, there has been great attention to the 'blind' population of *G. barreimiae*, known as the 'Omani blind cave fish'. This population has been demonstrated genetically to be closely related to adjacent surface dwelling populations of *G. barreimiae* (Kruckenhauser *et al*. 2011). As it does not represent a distinct species, it was assessed against the IUCN Red List criteria together with all other populations of *G. barreimiae*. It has previously been categorized as threatened, but there is no specific threat to the population or indication of decline to justify categorizing it as threatened. Nevertheless, consistent with earlier proposals (EPAA 2002) it is recommended that for conservation purposes, 'Omani blind cave fish' should be protected and managed separately in order to conserve this unique population.

Figure 3.1. The proportions (%) of freshwater fish species in each regional Red List category in the Arabian Peninsula.



Of the 21 species evaluated here, 38% (8 species) are considered threatened (assessed as Critically Endangered, Endangered, or Vulnerable), and 4.8% (1 species) are considered Near Threatened (Table 3.2, Figure 3.1). All eight threatened species are endemic to the Arabian Peninsula. Only one species is assessed as Critically Endangered. That is *Acanthobrama hadiyahensis*, being endemic to Wadi Hadiya in Saudi Arabia (Table 3.2). The species has a very small range and was rediscovered in 2013 after having not been found for 30 years (Hamidan and Aloufi 2014). Within its inferred permanently inhabited range of less than 10 km^2, it faces serious threats due to water extraction and dams, which leave no water downstream.

The most important locality for threatened freshwater fishes in the Arabian Peninsula is Wadi Hadramaut in Yemen.

33.3% (7 species) are assessed as Least Concern, being relatively widespread and often inhabiting many independent streams. 9.5% (2 species) are considered Data Deficient (because there was insufficient information available to make an assessment due to unresolved taxonomic problems).

Table 3.2. The number of freshwater fish species in each Red List Category in the Arabian Peninsula region.

	Regional Red List Category	Regional Assessment	Global Assessment	Number of Regional Endemics
Threatened categories	Critically Endangered (CR)	1	1	1
	Endangered (EN)	5	5	5
	Vulnerable (VU)	2	2	2
	Near Threatened (NT)	1	2	0
	Least Concern (LC)	7	10	6
	Data Deficient (DD)	2	1	1
	Not Evaluated	3	0	0
	Total number of taxa assessed*	**21**	**21**	**15**

3.3 Patterns of species richness in the Arabian Peninsula

3.3.1 All fish species

From a global perspective, the freshwater fish fauna of the Arabian Peninsula is extremely depauperate. At most freshwater sites in Arabia, usually only one or two primary freshwater species are found if the ubiquitous, euryhyaline or catadromous species are not considered. Wadi Hadramaut in Yemen, having six species of primary freshwater fishes, is the most species rich drainage basin of the Peninsula. Several wadis in Yemen and South-west Saudi Arabia host up to five species, but most have a much lower species total (Figure 3.2).

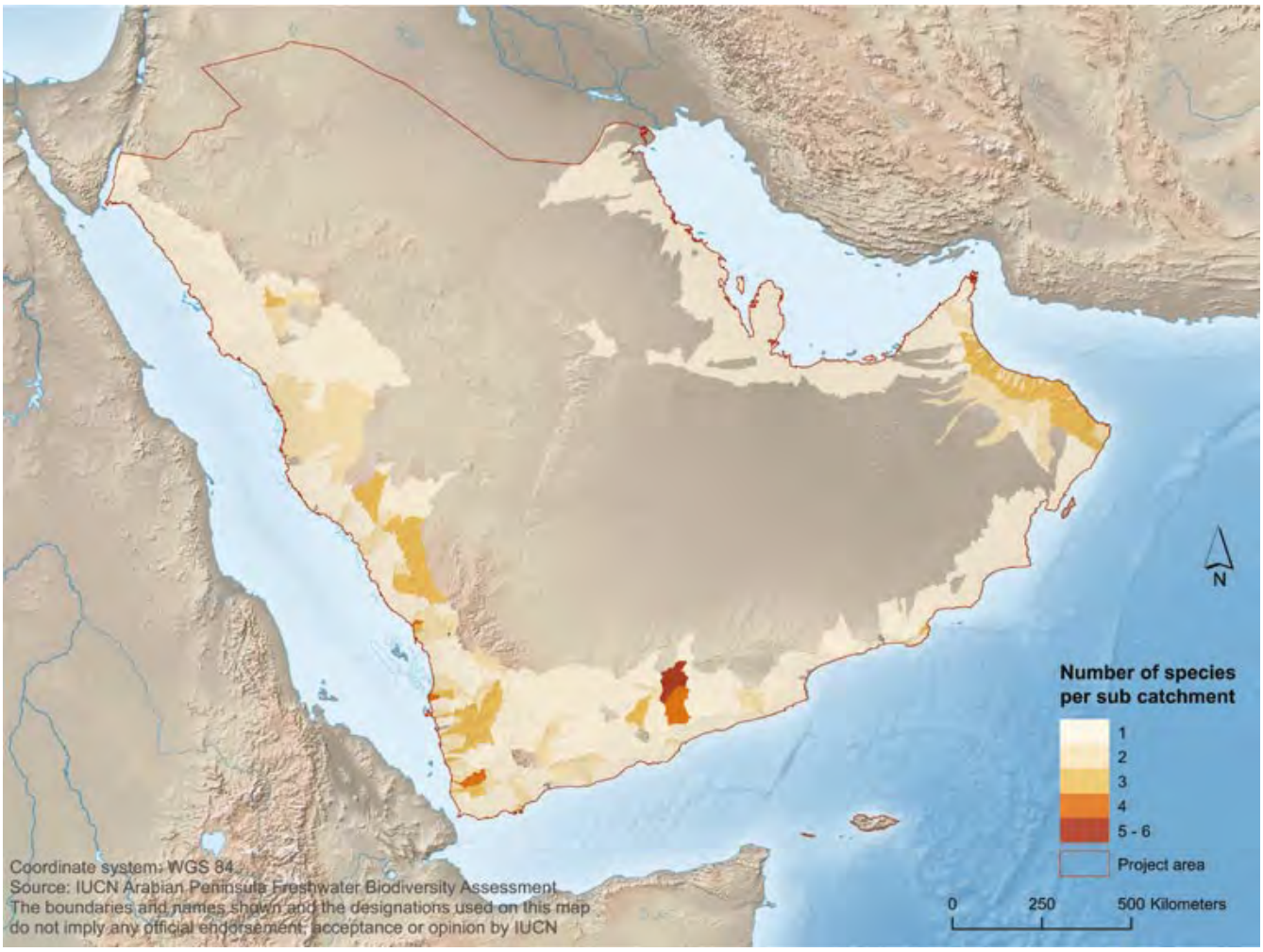
3.3.2 Threatened species

The most important hotspot for threatened freshwater fishes in the Arabian Peninsula is Wadi Hadramaut in Yemen (Figure 3.3). All three species endemic to that Wadi (*Carasobarbus exulatus*, *Garra mamshuqa*, *G. lautior*) have been assessed as Endangered. While Wadi Hadramaut is large and has a lot of water seasonally, it is a single wadi (hence its fishes are assessed to exist in only one independent site when it comes to the threats active in the area). Furthermore, during dry seasons, almost all freshwater bodies dry out, so that the area of occupancy permanently occupied by the species is estimated as being more than 10 km^2 but less than 500 km^2. Krupp (pers. comm. 2012) found a single pool of about 10 km length inhabited by native fishes in Wadi Hadramaut. Although the fish stocks there were reported as being still healthy in 2011-2012 (Krupp, pers. comm.), there is strong evidence that the habitat is threatened by water extraction (EPAA 2002) and pollution by pesticides from the intensive agriculture in the wadi.

3.3.3 Restricted range and endemic species

Besides the species endemic to Wadi Hadramaut mentioned above, there are three more species with very limited distribution (Figure 3.4). *Acanthobrama hadiyahensis* (CR) is endemic to Wadi Hadiya in Saudi Arabia where it faces severe threats. There are two range restricted species endemic to the Dhofar region of Oman.

Figure 3.2. The distribution of freshwater fish species across the Arabian Peninsula region.



The tiny global population of the subterranean *Garra dunsirei* (EN) is known from only a single sinkhole at Tawi Atair, in the Jebel Qara (Jebel Samhan) mountains, and the dwarf *Garra smarti* (VU) is restricted seasonally to few permanent pools in Wadi Hasik. Both local endemic species of Omani *Garra* seem to inhabit pristine or only little impacted waters and seem not to be of major conservation concern. They are mostly vulnerable due to the very tiny area inhabited and could be the victim of unexpected accidents. However, the development of water use and evolution of climate change in the Dhofar Region of Oman is poorly understood and the populations of both species should be carefully monitored.

3.3.4 Data Deficient species

Garra longipinnis and *Awaous aeneofuscus* have been assessed as DD in the region due to unresolved taxonomic problems.

3.3.5 Extirpated /Extinct species

None known.

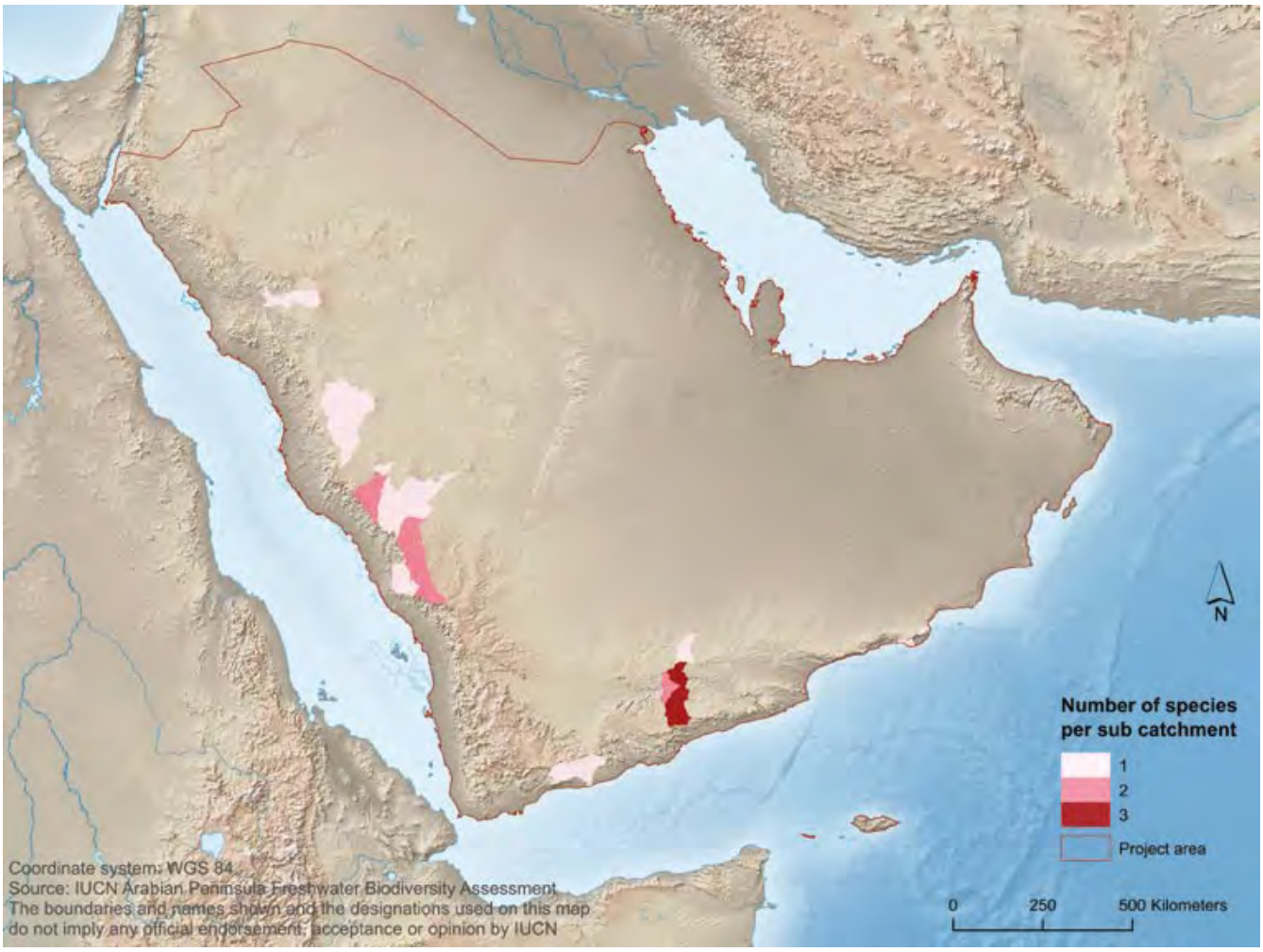
3.4 Major threats to freshwater fishes

There are a number of threats to the freshwater fishes of the Arabian Peninsula (see below), most of them coming from human development (Figure 3.5). The threats include increased water extraction, the development of dams, habitat loss, and increased pollution of freshwater systems from domestic effluent (washing etc.) and from local agricultural runoff. Although the threats are not particularly intense in many parts of the region, they are acting upon populations that are frequently small, and isolated from each other. Even relatively low environmental stress on these small populations can significantly impact their overall condition and likelihood of survival.

Water extraction and dams

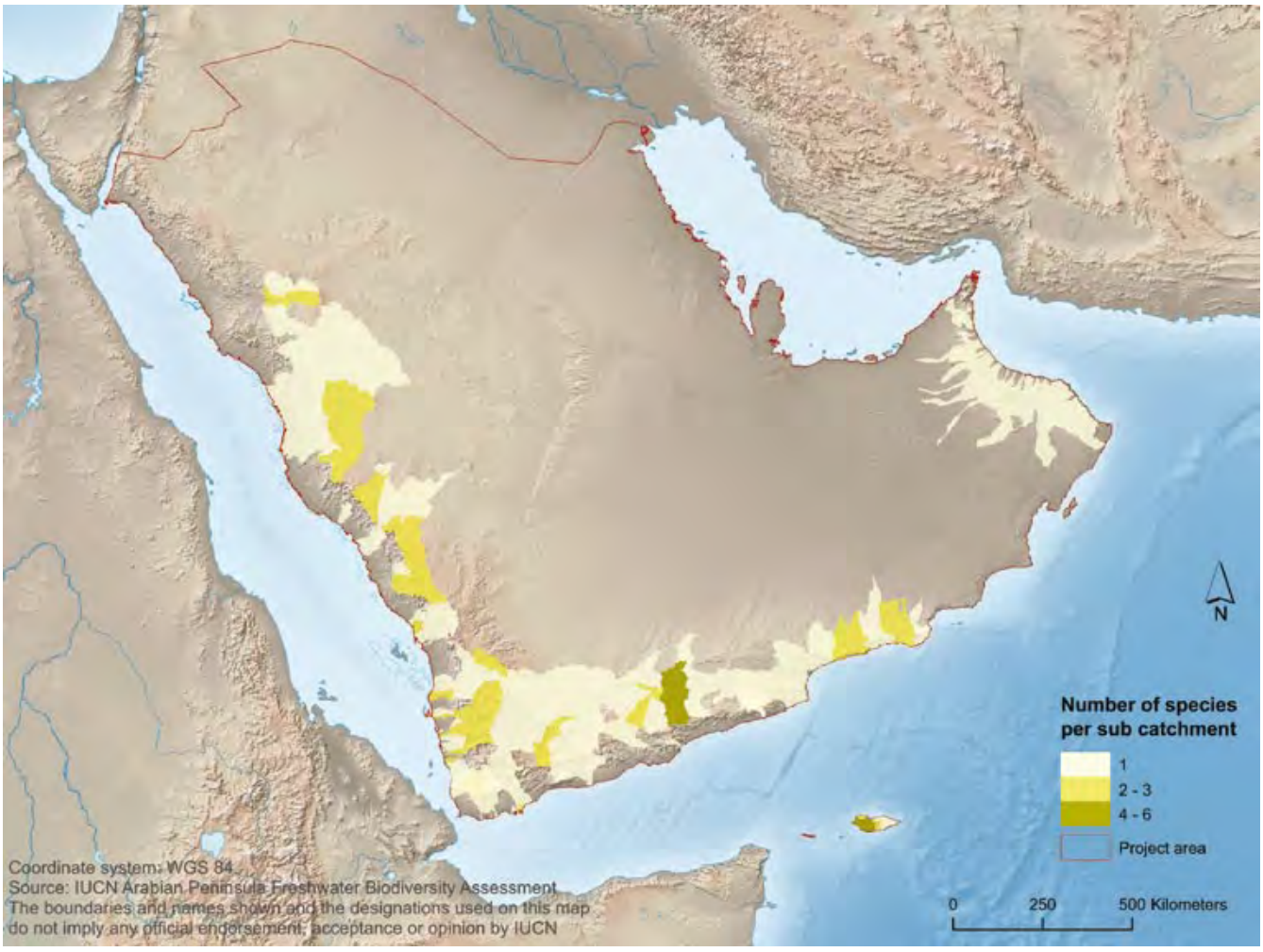
Water extraction is a significant threat for many of the freshwater fishes in arid and semiarid landscapes, mainly because many of the wadis are ephemeral or have periods of low flow, and any additional extraction can result in significant loss of habitat. Water extraction results not only in lowering the amount of surface water in the wadis, in some areas pumping can lower the water table to the

Figure 3.3. The distribution of threatened freshwater fish species across the Arabian Peninsula



Dam construction in Wadi Turabah, Saudi Arabia. Photo © N. A. Hamidan

Figure 3.4. The distribution of endemic freshwater fish species across the Arabian Peninsula.



extent that springs don't flow anymore. For example, Yemen is facing a severe water crisis, with some estimates suggesting the capital, Sanaa, could run dry in 10 years. With little being done to harness rainfall in the country, farmers are drilling deeper than ever for water without any government regulation. Agriculture uses around 90% of the country's water resources and fast growing human population will soon take all available water resources. There are no current assessments dealing with water and biodiversity. In the past, water extraction for domestic use may have caused a reduction of up to 50% in available habitat for *Carasobarbus apoensis* (EPAA 2002). The available habitat is estimated to have decreased in area by 21-50% in the five years prior to 2002, due to water extraction for domestic use (EPAA 2002).

If dams are constructed to capture runoff that would otherwise be unavailable for human use, rivers often run dry below the dams leaving no water behind for freshwater biodiversity. Such dams reduce the area of occurrence of freshwater fishes even in ecosystems which are adapted to seasonal droughts and survival of fishes in small refuge pools. Less and less water leads to the desiccation of those refuge pools and finally to the extirpation of the fishes. Locally, dams are thought to be hindering the recruitment into rivers of species that have a marine dispersal phase, such as *Anguilla bengalensis* (Scott 1995) and *Awaous aeneofuscus* (Feulner 2006). For example, Wadi Hajr, the only site where *Anguilla bengalensis* is known in Arabia, is dammed 3-4 km from its mouth, creating a small lake with marsh vegetation (Scott 1995). The dam might prevent immigration of the eels further upstream.

All Arabian freshwater fish species are adapted to periods of droughts and floods, but the impacts of floods and droughts become most severe when the local populations have already been compromised by other threats (such as water extraction). Under these circumstances the populations might be too small, or the individuals too stressed, for them to recover normally from a period of flood and drought.

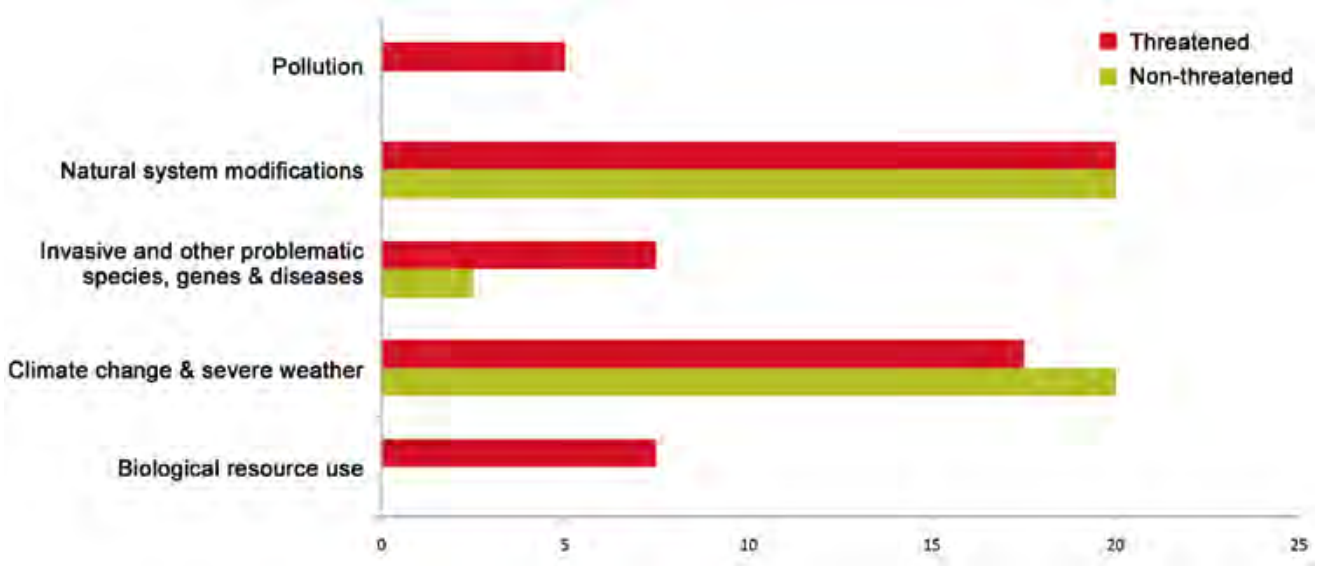
Habitat loss and degradation.

Unsurprisingly, habitat loss is a particular problem adjacent to areas of human development. For example, the main habitat of *Cyprinion watsoni* is deep wadi pools, and these are usually found in the lower courses of wadis where human settlement is not only well established but is also increasing. Consequently, these pools are becoming extensively modified and degraded (G. Feulner, own unpublished data). Extensive clearance of native trees for firewood and agriculture is reported from Wadi Hajr (Scott 1995) and may be a widespread problem.

Pollution

There seem to be no comprehensive data available about chemical and biological water quality. Furthermore, there is no continuous monitoring system about the quality and quantity of open surface waters. Therefore, little is known about the extent and intensity of industrial and rural pollution across the Arabian Peninsula. Local observations confirm that pollution from agriculture and human settlements is a problem, which is locally serious, especially in relatively densely inhabited wadis such as Wadi Hadramaut and others. As water is a scare resource,

Figure 3.5. Percentage of freshwater fish in the Arabian Peninsula affected by major categories of threat



water in the wadis is extensively used for all kinds of purposes. Some wadis in Oman, and perhaps elsewhere, are sprayed or powdered with pesticide to control mosquito larvae. Local residents themselves attribute short-term declines in the fish populations to the effects of pesticides (G. Feulner, own unpublished data).

Climate impacts

Global climate change seems not to have been a major problem on the Arabian Peninsula generally until the new millennium, but recent studies show temperature increases and less rainfall in some areas. AlSarmi and Washington (2011) have examined trends in temperature and precipitation parameters for the Arabian Peninsula during the last 2 to 3 decades at 21 stations. The mean annual temperature trend is one of warming, with 14 of 21 stations showing statistically significant warming. The highest statistically significant mean annual warming trends are found in Oman and the UAE. Trends in mean annual precipitation are significant at only two stations, which show a decrease in precipitation.

Almazroui *et al.* (2012) analysed the rainfall and temperature climatology over Saudi Arabia from its 27 stations from 1978–2009. Over Saudi Arabia, the observed annual rainfall showed a significant decreasing trend (47.8 mm per decade) since the mid-1990s, although with a relatively large inter-annual variability. The effects of climate change to the unique and highly endemic freshwater biodiversity of the Arabian Peninsula should be carefully monitored to be able to react to changes in rainfall before tiny fish populations go extinct.

Introductions

At least 11 species of alien freshwater fishes are reported to be introduced and naturalized to the Arabian Peninsula. These are mostly common "global invaders" such as the cyprinids *Carassius auratus*, *Cyprinus carpio* and *Pseudorasbora parva*, the cichlids *Coptodon zillii*, *Oreochromis mossambicus*, *O. spilurus* and *O. niloticus*, and the poecilids *Gambusia holbrooki*, *Poecilia latipinna*, *P. reticulata* and *Xiphophorus maculatus.* Although there are no specific reports of impacts of these species on the native fauna, it must be expected that they will compete with them, at least in certain circumstances. Research on the effects and distribution of alien species is strongly recommended to better understand their impacts, their behavior and how to limit their dispersal. *Aphanius dispar*, a native to the Arabian Peninsula, might represent a threat to other fishes where it has been introduced to ecosystems within the region for mosquito control. While it usually feeds near the surface and is an efficient

Wadi Turabah stream. Photo © N. A. Hamidan

Garra buettikeri (VU) an endemic species to Saudi Arabia. Photo © N. A. Hamidan

predator on mosquito larvae (Haas 1982), it will readily shift to become a mid-water or bottom feeder if suitable near-surface food resources are not available. Under those circumstances it might compete strongly with other freshwater species (EPAA 2002).

Harvesting

Relatively few native freshwater fish species are harvested in the Arabian Peninsula; and this does not generally represent a significant risk to biodiversity. Two species which reach larger body sizes than many of the other species present are *Arabibarbus arabicus* (reaching 34.5 cm standard length; Banister and Clarke 1977) and *Carasobarbus apoensis* (reaching 21.3 cm standard length). Both used to be popular game fishes (EPAA 2002) but are now very rare, hard to find, and no longer targeted. At least one species may have been impacted by the habitat modification and/or indiscriminate harvesting that is associated with artisanal fisheries. Improved vehicular access to some of the sites in Oman where the goby *Awaous aeneofuscus* had been found resulted in increased fishing activity (although not targeted at the goby), with damming and channeling of the streams, and construction of fish weirs occurring contemporaneously with the disappearance of the goby population (Feulner 2006).

3.5 Uses and Livelihood values

Freshwater fishes are seldom directly used by humans in the countries of the Arabian Peninsula. The larger species, such as *Arabibarbus arabicus* and *Carasobarbus apoensis* used to be taken as game and food fishes by local human populations and this might threaten those species, but the situation has been little explored. In areas of northernmost Oman and the UAE, local mountain residents catch wadi fish using channels and weirs, but only *Garra barreimiae* is eaten, being part of the traditional local diet (Feulner 1998, 2006; EPAA 2003). However, there is no evidence that this small scale fisheries is a real threat to the local fish populations. In most areas of the Arabian Peninsula, local human populations appreciate having fish in their waters not as a source of food but for the enjoyment of seeing living creatures, which are sometimes interpreted as a sign of good water quality and ecosystem health. In other areas, fish are just ignored and seem to have no value for local people.

3.6 Conservation actions and recommendations Conservation actions

In-situ conservation actions for most of the threatened species had earlier been suggested by EPAA (2002, 2003, 2004), but to date there seem to be few specific conservation actions in place for the species listed as threatened by this Red List assessment. Legal protection for the fishes themselves is in place in most areas, but this helps little to protect freshwater habitats from the threats described above. At the Breeding Centre for Endangered Arabian Wildlife (Sharjah, UAE), conservation breeding programs are in place for four species assessed as threatened (*Garra buettikeri*, *G. dunseri*, *G. smarti*, *Carasobarbus apoensis*). All these species have bred continuously since 2009, without the need to supplant new specimens into the captive stock from the wild or from other institutions. No captive broodstocks of threatened Arabian species seem to exist outside of the Breeding Centre for Endangered Arabian Wildlife and it is strongly recommended to establish such stocks to

reduce the risk of species extinction should the existing captive populations fail, especially for *Garra dunseri* and *G. smarti*, where only single, small wild populations seem to exist. Great care must be given to maintain genetic diversity in the captive broodstocks and to avoid genetic bottlenecks.

Recommendations

Recommendations for in-situ conservation actions for most of the threatened species, including management of habitat, and monitoring and management of populations, have been detailed by EPAA (2002). This IUCN Red List assessment reveals how many gaps remain in the exploration and understanding of the freshwater fish fauna of the Arabian Peninsula. Although there are so few native species in the area, they are still very poorly known. Among the resources generally lacking are accessible identification literature and accessible, comprehensive data on species distribution and environmental threats.

Exploration and taxonomic studies

Field surveying is essential in order to provide up-to-date knowledge on the overall distribution of species and threats, and the abundance of populations and connectivity between them. That a species like *Acanthobrama hadiyahensis* (CR) had not been recorded for 30 years best demonstrates that freshwater fishes are a forgotten part of biodiversity in the Arabian Peninsula. The taxonomy of the few freshwater fish species should be resolved by applying an integrated molecular and morphological approach by well-trained taxonomists.

Public data availability

It is strongly recommended to bring together all site scale records of all Arabian freshwater fish species in a public database like the Global Biodiversity Information Facility (GBIF) to make them available for analysis and all conservation activities. To do so, an active data mobilization strategy should be worked out. Data and metadata should also be published in open access data journals.

Documentation

The freshwater fish biodiversity of the Arabian Peninsula is poorly documented and much information is no longer valid. As a complement to further exploration and taxonomic study, we strongly recommend publication of an online field guide of the freshwater fishes of the Arabian Peninsula. In such an online field guide, photographs of fishes and sites, and information about the distribution, ecology, identification characters and threats are made publicly available. The online guide should be directly linked to GBIF, to have up-to-date distribution data. Furthermore, a citizen scientists recording system for freshwater fishes based on smart-phone technologies could be implemented, to allow local scientists and citizens to add their own data. The IUCN-SSC/Wetlands International Freshwater Fish Specialist Group is already coordinating an online portal (via iNaturalist) for the public to upload photographs and locality information on freshwater fishes in the wild. These data will be added to GBIF. For more information see the Global Freshwater BioBlitz (www.iucnffsg.org).

Key Biodiversity Areas

Ideally a network of Freshwater Key Biodiversity Areas (KBAs) should be developed in the Arabian Peninsula following IUCN methodology and reviewed by regional stakeholders and experts. These efforts to identify sites of critical biodiversity will be a collaborative activity with national protected area authorities and should be integrated with landscape management. From these data, conservation management should be implemented comprehensively, and following standardized methods, at the whole ecosystem scale that includes management of the habitats around the wadis. Here, analysis and maintenance of natural flow regimes are essential, because even small anthropogenic disruptions of the often sporadic flows can have devastating effects on the populations present.

Monitoring

Critical sites for freshwater fish biodiversity and threatened species such as Wadi Hadiya in Saudi Arabia, Wadi Hadramaut in Yemen, Wadi Hasik in Oman as well as the sinkhole at Tawi Atair in Oman, must be visited regularly and fish populations have to be monitored following standardized protocols. Sites assessed as KBAs should also be included in the monitoring. Such sites should be regularly visited to assess the population status of freshwater fishes and to collect long term population trend data.

Impact studies

Regular monitoring will lead to concrete questions about limiting factors for fish populations such as the spread of alien species, pollution, water extraction or habitat modification. These questions are fertile ground for research.

Training and Dissemination

Primary research should be facilitated, and studies of direct interest to the local people should be translated into local languages and distributed freely. Too frequently,

the results of studies are not made widely available, and are therefore never used to benefit conservation. In the context of biodiversity conservation there is an urgent need to train specialists in 'secondary' taxonomy. That is, we need scientists to train others in identification, and write local identification tools (including translation into local languages), thereby making identification of species possible for researchers in a variety of disciplines. At key sites (as Wadi Hadiya, Wadi Hadramaut, Wadi Hasik as well as the sinkhole at Tawi Atair), local awareness raising is strongly recommended and local conservation projects can focus on raising awareness of the endemic fishes of these sites.

Acknowledgements

Special thanks are due to Dr. Fareed Krupp (Qatar Natural History Museum, Doha; and former Regional Chair for Southwest Asia, IUCN-SSC/WI Freshwater Fish Specialist Group), who assisted in compiling and reviewing the information on which the assessments are based. We are also pleased to thank: Dr. Mohammed Shobrak, from Taif University, who facilitated and guided the field trip of NAH and made full resources available; Taif University, which funded the work of NAH in KSA and provided him with laboratory and other facilities; Saudi Wildlife Authority and especially Dr. Ahmed al Bouq, and Mr. Abdullah al-Shihri, who facilitated the trip of NAH to the south of the country; Dr. Abdulhadi al-Aoufi and Tabuk University who facilitated and funded the trip of NAH to Taouk; Fujairah Municipality and especially H.E. Eng. Mohammed Saif al-Afkham, and Ms. Aseelah al-Mua'allah, who funded and facilitated field work in Wadi Wurayah National Park; Mr. Maral Al-Shuraiqi, who coordinated logistics for the work by NAH on *G barreimiae*, participated in all field trips and made many independent collections; the Breeding Centre for Endangered Arabian Wildlife in Sharjah, and especially Ms. Hana Suwaidi, Mr. Paul Vercammen, and Mr. Johannes Els, for their contribution of information.

3.7 References

Abell, R., M. Thieme, C. Revenga, M. Bryer, M. Kottelat, N. Bogutskaya, B. Coad, N. Mandrak, S. Contreras-Balderas, W. Bussing, M. L. J. Stiassny, P. Skelton, G. R. Allen, P. Unmack, A. Naseka, R. Ng, N. Sindorf, J. Robertson, E. Armijo, J. Higgins, T. J. Heibel, E. Wikramanayake, D. Olson, H. L. Lopez, R. E. d. Reis, J. G. Lundberg, M. H. Sabaj Perez, and P. Petry. 2008. Freshwater ecoregions of the world: A new map of biogeographic units for freshwater biodiversity conservation. *BioScience*, 58:403-414

Almazroui, M., Nazrul Islam, M., Athar, H., Jones, P. D., Ashfaqur Rahman M. 2012. Recent climate change in the Arabian Peninsula: annual rainfall and temperature analysis of Saudi Arabia for 1978–2009. *International Journal of Climatology*, 32: 953–966. DOI: 10.1002/joc.3446

AlSarmi, S. and Washington, R. 2011. Recent observed climate change over the Arabian Peninsula. *Journal of Geophysical Research: Atmospheres*, 116: DOI: 10.1029/2010JD015459

Banister, K.E. 1984. A subterranean population of *Garra barreimiae* (Teleostei: Cyprinidae) from Oman, with comments on the concept of regressive evolution. *Journal of Natural History* 18(927-938)

Banister, K.E. 1987. Two new species of *Garra* (Teleostei-Cyprinidae) from the Arabian peninsula. *Bulletin of the British Museum of Natural History (Zoology Series)* 52(1): 59-70.

Banister, K. E. and Clarke, M. A. 1977. The freshwater fishes of the Arabian Peninsula. Pp.: 111-154 In: The scientific results of the Oman flora and fauna survey 1975. Journal Oman Studies (Special Report).

Ekmekçi, F. G. and P. M. Bănărescu 1998 A revision of the generic position of *Barynotus* (*Systomus*) *verhoeffi*, and the validity of the genera *Carasobarbus*, *Kosswigobarbus* and *Mesopotamichthys* (Pisces, Cyprinidae). *Folia Zoologica: international journal of vertebrate zoology*. v. 47 (suppl. 1): 87-96.

Environment and Protected Areas Authority (EPAA). 2002. Conservation Assessment and Management Plan (CAMP) for the Threatened Fauna of Arabia's Mountain Habitat. BCEAW/EPAA, Sharjah; UAE.

Environment and Protected Areas Authority (EPAA) 2003. Fourth International Conservatio Workshop for the Threatened Fauna of Arabia. Final Report. BCEAW/EPAA, Sharjah; UAE.

Environment and Protected Areas Authority (EPAA) 2004. Fifth International Conservatio Workshop for the Threatened Fauna of Arabia. Final Report. BCEAW/EPAA, Sharjah; UAE.

Eschmeyer, W. N. (ed). Catalog of fishes: Genera, Species, References. (http://research.calacademy.org/research/ichthyology/catalog/fishcatmain.asp). Electronic version accessed 14 November 2013.

Feulner, G.R. 1998. Wadi fish of the UAE. *Tribulus* 8(2): 16-22.

Feulner, G.R. 2005. Freshwater fishes. In: Hellyer, P., and Aspinall, S. (eds), *The Emirates – A natural History*. pp. 257-259. Trident Press.

Feulner, G.R. 2006. Goby Gone for Good? *Tribulus* 16.2: 34

Haas, R. 1982. Notes on the ecology of *Aphanius dispar* (Pisces, Cyprinodontidae) in the Sultanate of Oman. *Freshwater Biology* 12: 89-95.

Hamidan, N. A. and Aloufi, al A., Rediscovery of *Acanthobrama hadiyahensis* (Cyprinidae) in Saudi Arabia. J Fish Biol. 2014 Mar 7. doi: 10.1111/jfb.12315. [Epub ahead of print]

J Fish Biol. 2014 Mar 7. doi: 10.1111/jfb.12315. [Epub ahead of print]

Kottelat, M. and Freyhof, J. 2012. *Mugil cephalus*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. www.iucnredlist.org. Downloaded on 20 September 2013.

Kruckenhauser, L., Haring, E., Seemann, R., and Sattmann, H. 2011. Genetic differentiation between cave and surface dwelling populations of *Garra barreimiae* (Cyprinidae) in Oman. *BMC Evolutionary Biology* 11: 172-186.

Krupp, F. (1983). "Fishes of Saudi Arabia. Freshwater fishes of Saudi Arabia and adjacent regions of the Arabian Peninsula" *Fauna of Saudi Arabia* 5:568-636.

Romero, A. and Paulson, K.M. 2001. It's a Wonderful Hypogean Life: A Guide to the Troglomorphic Fishes of the World. *Environmental Biology of Fishes* 62: 13-41.

Scott, D.A. 1995. A Directory of Wetlands in the Middle East. Gland, Switzerland; and Slimbridge, U.K.IUCN and IWRB.xvii + 560pp. http://www.wetlands.org/RSIS/WKBASE/MiddleEastDir/Title1.htm

Stiassny, M.L.J. and Getahun, A. 2007. An overview of labeonin relationships and the phylogenetic placement of the Afro-Asian genus *Garra* Hamilton, 1922 (Teleostei: Cyprinidae), with the description of five new species of *Garra* from Ethiopia, and a key to all African species. *Zoological Journal of the Linnean Society* 150(1): 41-83.

Chapter 4. The status and distribution of freshwater molluscs in the Arabian Peninsula

Neubert, E.[1], Amr, Z.[2] and Van Damme, D.[3]

4.1 Overview of the regional fauna

Molluscs are found in many of the permanent freshwater bodies such as wadis, oases, highland creeks and thermal springs that are distributed through the Arabian Peninsula region, but mainly in the southwestern part of the peninsula (see Chapter 1 for further discussion of the distribution of these freshwater systems).

The subterranean water systems that are widespread in the Peninsula's karstic areas (for example the al-Houta cave near Nizwa in Oman) represent one of the potential habitats particularly for hydrobiid snails, also known as mud snails. However, additional fieldwork is required to document more precisely the freshwater mollusc fauna that might be present in these systems. The Socotran Archipelago (Yemen), known for its endemic flora and fauna, harbors a few endemic freshwater molluscan species. The ancient al-Aflaj irrigating system in Oman forms a man-made habitat for freshwater molluscs, and many species survive even periods of drought in small water pockets (Neubert pers. obs. 2012). Additionally, this system transports and displaces molluscs over larger distances in the mountains down to the oases in the foothills.

The lakes formed behind artificial dams (see Chapter 1) are also suitable habitats for freshwater molluscs. For example, three dams were constructed in the Ha'il area (Saudi Arabia) and attracted several species of freshwater snails including *Bulinus truncatus*.

The populations of the brackish water molluscs of the Arabian Peninsula are known to be in decline due to the rapid disappearance of the mangal (a saline woody tree and shrub environment) biotopes and swamps along the coastline of the Emirates. At the same time, the ever increasing abstraction of freshwater in wadi systems means that the volume of freshwater reaching the coast has declined and salinity is increasing and moving inland. This, in turn, threatens the freshwater species in the downstream parts of drainages.

On one hand, scarcity of suitable freshwater habitats explains the small number of freshwater molluscan species being recorded from the Peninsula. From its area

Ancient al-Aflaj irrigation channels in Misfah al Abriyyin, Jebel Akhdar, Oman. Photo © R. Bonifer

The oasis of Nizwa, Oman. Photo © R. Bonifer

1 Naturhistorisches Museum der Burgergemeinde Bern, Bernastr 15, CH-3005 Bern, Switzerland.
2 Jordan University of Science and Technology, P.O. Box 3030, Irbid. 22110, Jordan.
3 University of Ghent, Sint-Pietersnieuwstraat 25, B 9000 Ghent, Belgium.

of 3,237,500 km^2 only 30 species are known so far, and only nine of them are considered to be endemic. On the other hand, many probably suitable areas remain under-explored, and even in easily accessible (and clearly promising) regions like the mountain systems in Oman, there have been no systematic research activities focusing on freshwater molluscs so far. This is quite astonishing, because some gastropod species in particular are well known vector species for serious diseases like schistosomiasis (= bilharziosis). The known value of molluscs as helpful indicator species for sustainable water management has not being reviewed anywhere on the Peninsula.

4.2 The taxonomic and ecological impediments

Although there are relatively few freshwater species living on the Arabian Peninsula, almost all are seriously underexplored (Brown and Wright 1980, Brown and Gallagher 1985, Neubert 1998). The taxonomic impediment is well exemplified by the putative species *Hydrobia lactea*. Although described by Mousson in 1874, this species has not being subject to any serious, subsequent taxonomic research, and remains affiliated to the genus *Hydrobia* only due to a lack of research. Though this species undoubtedly belongs to another hydrobiid genus, there have been no efforts to collect living specimens from its type locality in Mossul, Iraq to address this problem, nor was there ever any investigation whether specimens collected from the Arabian Peninsula and assigned to this species are correctly identified. Thus, the taxonomic status remains unchanged since 1874 and is probably incorrect.

By 'ecological impediment' we mean that there has been no focused investigation on the autecology and biology of the Arabian populations of freshwater molluscs so far. No data are available on population sizes and trends, and long term monitoring projects yielding data for a trend analysis are missing as well.

4.3 Conservation status (IUCN Red List Criteria: Regional scale)

Data for 30 species are presented in this summary. Large areas of the Peninsula are still hard to access, barrages as artificial systems are usually not checked for molluscs, and even for the highlands of Jebel Akhdar in Oman or in Yemen and southwestern Saudi Arabia, no systematic research for freshwater molluscs has been conducted. For this reason, we consider the assessments presented here to be preliminary baseline ones that should be updated on a regular basis.

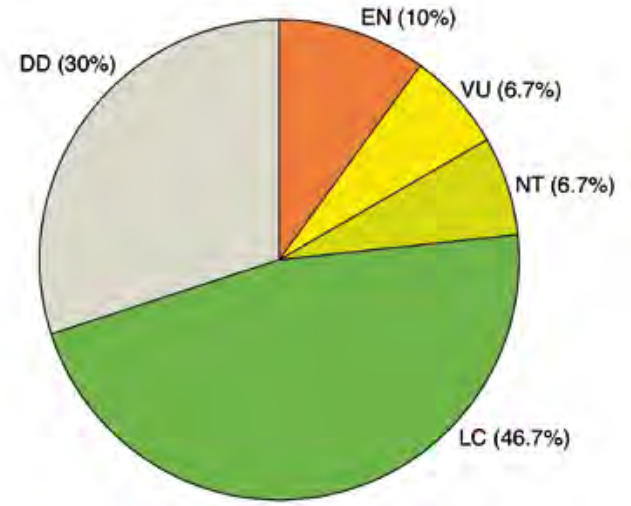
Only a small proportion (16.7 %) of the freshwater molluscs fall into one of the IUCN threatened categories (Table 4.1 and Fig. 4.1). Almost half of the species are considered to be LC (Least Concern). This could be considered a positive result, but might also be biased by

Table 4.1. The number of freshwater mollusc species in each Red List Category in the Arabian Peninsula region.

	IUCN Red List Categories	Regional Assessment	Global Assessment	Number of Regional Endemics
Threatened Categories	Critically Endangered	0	0	0
	Endangered	3	1	1
	Vulnerable	2	1	0
	Near Threatened	2	1	1
	Least Concern	14	23	3
	Data Deficient	9	4	4
	Not Applicable	9	0	0
	Total*	**30**	**30**	**9**

* The total figure does not include NA (Not Applicable) species. The following species were assessed as NA because they are not native to the region (*Helisoma duryi, Cerithidea decollata* and *Pseudosuccinea columella*) or belong to marine habitats (*Cerithidea cingulata, Iravadia quadrasi, Pirenella conica, Potamides conicus, Telescopium telescopium* and *Terebralia palustris*).
All species assessed as regionally threatened that are endemic to the region are also globally threatened

Figure 4.1. The proportions (%) of freshwater mollusc species in each regional Red List category in the Arabian Peninsula.

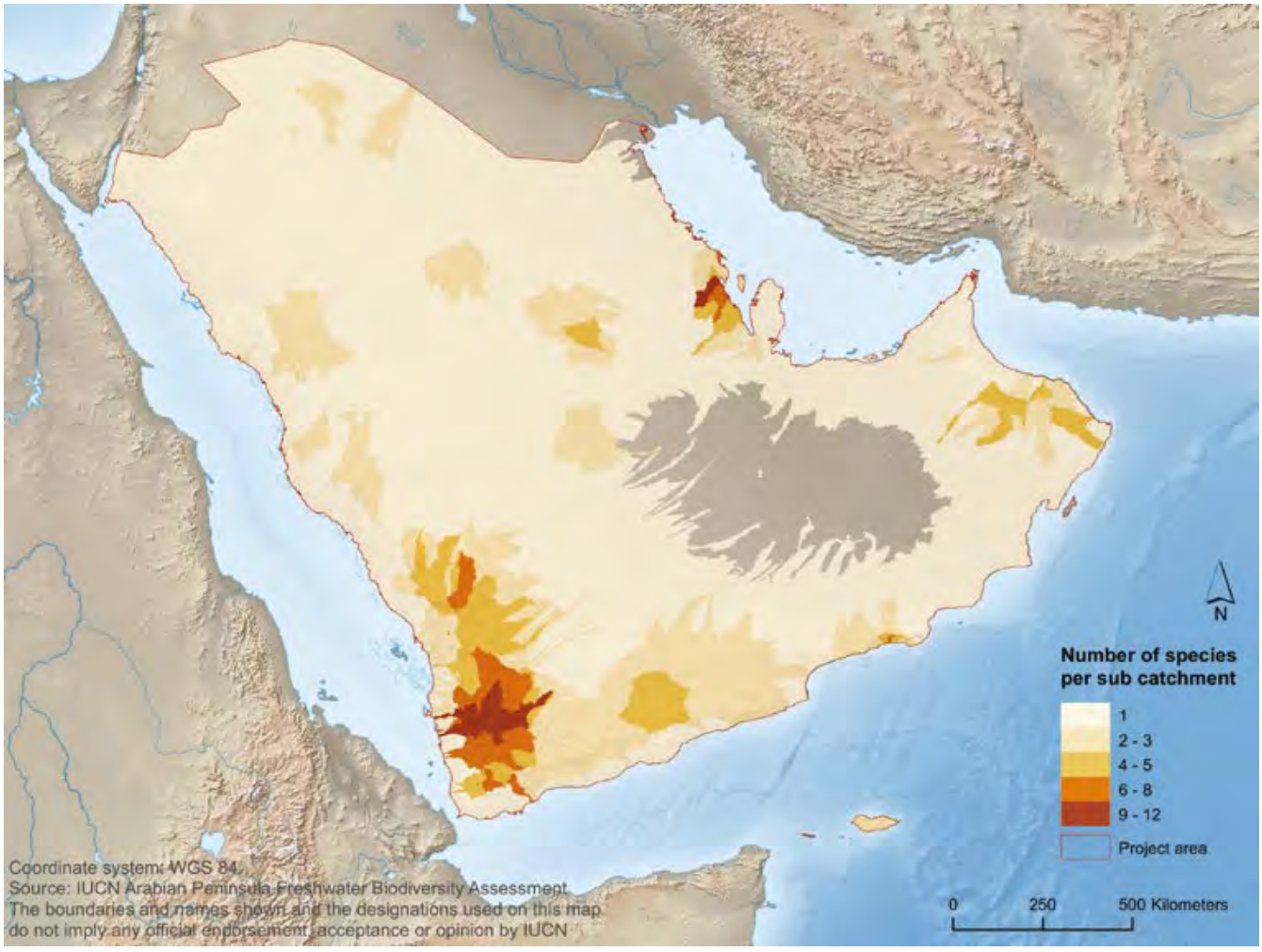


personal estimation rather than the result of targeted scientific research. This may explain the differences with the much more dramatic situation of freshwater systems in other regions, where Europe with 43.7 % of threatened species is a quite contrasting example. The value of ~30 % DD species (Data Deficient) is consistent with results from other parts of the world (Cuttelod *et al*. 2011, Köhler *et al*. 2012).

4.4 Patterns of species richness

The distribution of freshwater molluscs is shown in Fig. 4.2. As can be expected from the geomorphological structure of the Peninsula, the highest species richness is found in mountainous regions which capture enough moisture during the year. The regions with the highest diversity are the highlands of Yemen and the Jebel Akhdar area in Oman. Two other regions are of particular interest: in eastern Saudi Arabia, the large Oasis of al-

Figure 4.2. The distribution of freshwater mollusc species across the Arabian Peninsula region, mapped to river sub-catchments.



Galba truncatula is a common snail in the mountainous areas of the Arabian Peninsula. This amphibious snail can frequently be found in mud along irrigation canals. It is listed as Least Concern. Photo © Z. Amr and E. Neubert

The snail *Haitia acuta* is associated with slow running water and can often be found along with *Bulinus truncatus*. It is listed as Least Concern. Photo © Z. Amr and E. Neubert

Melanoides tuberculatus lives usually in freshwater, but can also inhabit brackish waters. It is a common species all over the Arabian Peninsula, listed as Least Concern. Photo © Z. Amr and E. Neubert

Plotia scabra can often be found associated with *M. tuberculatus*, but it is less common. It is listed as Least Concern. Photo © Z. Amr and E. Neubert

Hufuf collects the groundwater of the Central Arabian Plate and thus supports a large freshwater system; and the summer monsoon area of Dhofar, Oman.

4.4.1 All species

With 30 species recorded, the region is poor in the number of freshwater molluscs reflecting the fact that drylands form the most extensive environments on the Peninsula, and thus cannot compete with tropical freshwater systems. Species richness is highest in the catchment of the central mountains of Yemen and the al-Hufuf Oasis, where nine to 12 species have been recorded. The Jebel Akhdar area is less rich with a maximum of four or five species, while in Dhofar six to eight species are recorded. It must be stressed that in the last case, catchment areas are extremely restricted with some permanent springs feeding small and usually short creeks, which are heavily used for agricultural and other purposes.

Table 4.2. Threatened freshwater mollusc species in the Arabian Peninsula region.

Family	Species	Regional Red List Category	Red List Criteria	Endemic?
PLANORBIDAE	*Gyraulus cockburni*	EN	B2ab(ii,iii)	Yes
ASSIMINEIDAE	*Assiminea nitida*	EN	B2ab(iii)	No
MELANOPSIDAE	*Melanopsis costata*	EN	B2ab(iii)	No
LYMNAEIDAE	*Stagnicola palustris*	VU	D2	No
PLANORBIDAE	*Gyraulus convexiusculus*	VU	B2ab(iii)	No

4.4.2 Threatened species

The threatened freshwater molluscs from the Arabian Peninsula are listed in Table 4.2. The only endemic taxon qualifying as Endangered (EN) is the Socotran species *Gyraulus cockburni*.

This species was found in two small creeks on Socotra Island that are highly threatened due to unsustainable water management practices and the uncontrolled use of insecticides (Van Damme and Banfield 2011). Two species with the category Endangered (EN) live in the oasis of Oasis of al-Hufuf in Saudi Arabia, which is also

The Endangered species *Gyraulus cockburni* from Socotra Island, Yemen. Photo © NHMUK

Melanopsis costata is known from many places in the Middle East. The shell exhibits different colour patterns that range from light brown to deep dark. It is listed Endangered in the Arabian Peninsula. Photo © Z. Amr and E. Neubert

Figure 4.3. The distribution of threatened freshwater mollusc species across the Arabian Peninsula, mapped to river sub-catchments.

Assiminea nitida collected in a freshwater course of the Al-Qatif oasis, Eastern Province, Saudia Arabia. Threatened by changes in irrigation schemes and eutrophication as a consequence of the use of fertilizers in the Arabian region, this species is assessed Endangered. Photo © E. Neubert

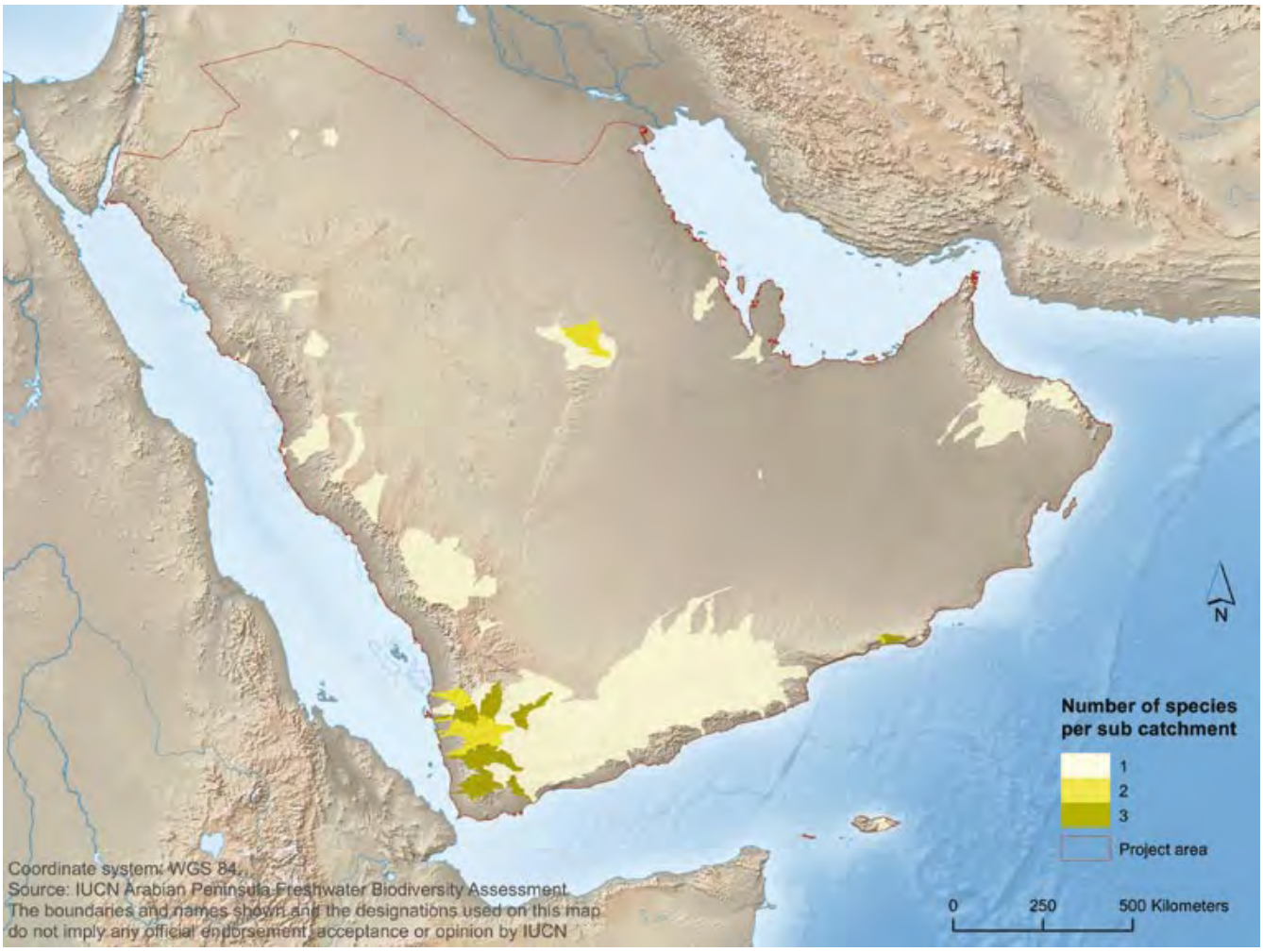
under pressure due to water extraction and use of pesticides. The areas with the highest water withdrawal clearly coincide with the areas where threatened species of molluscs are living.

4.4.3 Endemic freshwater molluscs

Endemic species are concentrated in areas with the highest species richness (compare Figs 4.2 and 4.4). In continental Yemen, three endemic planorbid freshwater species can be found, namely *Bulinus arabicus*, *Bulinus beccarii*, and *Bulinus wrighti*. On the Socotran Archipelago, only a few permanent running water bodies are present (exclusively on the main island of Socotra), which harbour two planorbid species, *Gyraulus cockburni* and ?*Ceratophallus socotrensis*. A third species, "*Hydrobia*"

Wadi Kilisan in the southeast of Socotra Island, habitat of the Endangered (EN) species *Gyraulus cockburni*; Socotra, February 1999. Photo © E. Neubert

Figure 4.4. The distribution of endemic freshwater mollusc species across the Arabian Peninsula, mapped to river sub-catchments.



balfouri, has not been observed or collected since its description by Godwin-Austen in 1881, and there are doubts whether this might be a freshwater, brackish or even marine species. In Oman, "*Hydrobia*" *glaucovirens* from the Dhofar region can be considered a local endemic freshwater species.

?*Ceratophallus socotrensis* has only been found once in the 19th Century and has not been collected since, though surface and underground waters on Socotra were systematically sampled during the last decades. It is, therefore, considered to probably be extinct.

The Arabian Peninsula endemic species ?*Ceratophallus socotrensis* from Socotra Island (Yemen), where only the figured type specimen is known. Photo © NHMUK

Clouds from the Red Sea and the Tihama plain transporting moisture to the highlands of the south-western Arabian Peninsula; view to the escarpment West of Abha, Saudi Arabia. Photo © E. Neubert

Figure 4.5. The distribution of Data Deficient freshwater mollusc species across the Arabian Peninsula, mapped to river sub-catchments.

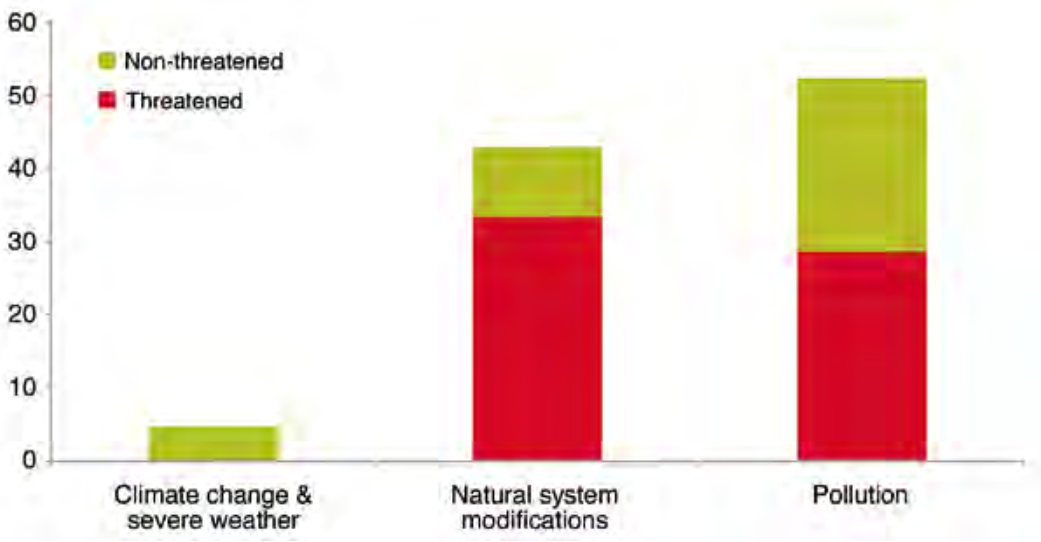
4.4.4 Data Deficient species

Nine species match this category, which is almost a third of the total number of species recorded from the area. The main reasons for such a classification are serious doubts on the correct identification of the species (see also chapter 4.2), or the lack of any additional records since their description.

4.5 Major threats to freshwater molluscs

Natural freshwater habitats in arid areas are a pivotal subject to human use since ancient times, and their value can be estimated from the fact that many of these localities have had a religious status. However, in times of human population increase combined with significant changes in water use and technical capabilities for extraction, these

Figure 4.6. Percentage of freshwater mollusc species known to be affected by each threat. Note that many species may have more than one threat listed.



Small pond in the Oasis of al-Hufuf in Saudi Arabia. Photo © E. Neubert

resources are often overexploited. Unsustainable use of all types of water bodies including ground water, landscape modifications and damage by increasing livestock and agriculture drives many freshwater species towards extinction (Strong *et al*. 2008). Taking this evolution into account it is no wonder that the recently published European Red List of non-marine molluscs lists freshwater molluscs as one of the most endangered organism groups with a proportion of 43.7 % species having a threatened status (Cuttelod *et al*. 2011).

The major threat to freshwater molluscs on the Arabian Peninsula is the overexploitation of surface and ground waters, e.g. for irrigation and for the ever increasing water demand of the fast growing cities. Next to the complete extraction of water from wells and water courses, the countless artificial alterations such as drains, culverts, channels and dams reduce the habitat suitability for the species. Large amounts of freshwater are withdrawn from the mountains in the southwestern region of Saudi Arabia, the southern Hijaz and Jizan area, and the al-Hufuf oasis in the Eastern province (Saudi Arabia), where several of the threatened species like *Assiminea nitida* and *Melanopsis costata* are living.

Pest control activities may destroy complete freshwater ecosystems, as has been exemplified quite recently on Socotra, where an uncontrolled malaria prevention program has contaminated highly sensitive creeks on the island, eradicating several endemic freshwater organisms (Van Damme and Banfield 2011).

Other threats concern accumulation of agricultural fertilizers that change the water chemistry, resulting in algal blooms and subsequent de-oxygenation during decomposition of the algal masses. Occasionally, raw sewage may be discharged into freshwater systems, or wells and karstic sinkholes are used as garbage dumps for all kinds of household and industrial waste.

4.6 Conclusions and conservation recommendations

For the future it is strongly recommended to develop management plans for the sustainable use of the remaining natural water resources on the Arabian Peninsula. Their exploitation should not only be economically driven but the welfare of all freshwater organisms should also be take into consideration as these are the best indicators for good water quality.

More research is needed to explore the freshwater diversity on the Peninsula. It is highly recommended to put in place a monitoring system that is able to follow the changes in the aquatic biotopes and to develop strategies towards sustainable water management in the area.

4.7 References

Brown, D.S. and Gallagher, M.D. (1985). Freshwater snails of Oman, South Eastern Arabia. *Hydrobiologia*, 127: 125–149.

Brown D.S. and Wright, C.A. (1980). Freshwater Mollusks, *Fauna of Saudi Arabia*, 2: 341–358.

Cuttelod, A., Seddon, M. and Neubert, E. (2011): *European Red List of Non-marine Molluscs*. 96 pp.; Luxembourg: Publications Office of the European Union.

Köhler, F., Seddon, M., Bogan A. E., Tu, D. V., Sri-Aroon, D. and Allen, D. J (2012): The status and distribution of freshwater molluscs of the Indo-Burma region. In: Allen, D. J., Smith, K. G. and Darwall, W. R. T. (Eds): The status and distribution of freshwater biodiversity in Indo-Burma: 66–88.

Mousson, A. (1874): Coquilles terrestres et fluviatiles recueillies par M. le Dr Alex. Schlæfli en Orient. *Journal de Conchyliologie* 22: 5–60.

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

Strong, E. E., Gargominy, O., Ponder, W. F. and Bouchet, P. (2008): Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. *Hydrobiologia*, 595: 140–166.

Van Damme, K. and Banfield, L. (2011) Past and present human impacts on the biodiversity of Soqotra Island (Yemen): implications for future conservation. *Zoology in the Middle East*. Supplementum 3 (Biodiversity Conservation in the Arabian Peninsula): 31–88.

Chapter 5. The status and distribution of dragonflies and damselflies (Odonata) in the Arabian Peninsula

Schneider, W.[1] and Samraoui, B.[2]

5.1 Introduction

Dragonflies and damselflies (Odonata) are a fascinating order of insects with a complex lifecycle (Corbet 1999). Their displays of contrasting colours and aerial acrobatics have endeared them to scientists and laymen alike. The close dependence of Odonata on wetlands has made them worthy ambassadors of freshwater conservation (Riservato *et al.* 2009, Clausnitzer *et al.* 2012). As guardians of the watershed (Clausnitzer and Jödicke 2004), dragonflies help us monitor global changes sweeping past our planet (Hooftman *et al.* 2003, Crick 2004). This is particularly true in an excessively arid region undergoing strong anthropogenic pressure that is a cause of much concern (Krupp *et al.* 1990).

The odonatofauna of the Arabian Peninsula and the Socotra Archipelago was not well known until the twentieth century (McLachlan 1903, Longfield 1931, 1932) and systematic studies were initiated much later by Waterston (1980, 1981, 1984, 1985) and extended by Schneider (1987, 1988). Recent decades have witnessed a steady progress of our knowledge of the Odonata of Yemen (Waterston 1984, 1985, Al-Safadi 1990, Dumont and Al-Safadi 1991, 1993, Carfi *et al.* 1995, Schneider and Parr 1998, Krupp *et al.* 2006) and Socotra (Kimmins 1961, Schneider and Dumont 1998, Schneider and Nasher 2013), Oman (Waterston 1981, Schneider 1988, Schneider and Dumont 1995, 1997, Waterston and Pittaway 1991, van der Weide and Kalkman 2008), United Arab Emirates (Feulner 1999, 2001, Feulner *et al.* 2007, Giles 1998, Reimer 2008, 2009, Reimer *et al.* 2009, Wilson 2008), Saudi Arabia (Waterston 1980, 1985; Pittaway, 1983; Schneider and Krupp 1993; Lambret and Boudot 2009) and Kuwait (Al-Houty 1985). The status of the Odonata of the region was previously assessed by Jödicke *et al.* (2004) who provided an initial list of critical species and conservation priorities.

5.1.1 Number of Odonata taxa within the area of the Arabian Peninsula

The number of dragonflies and damselflies of the Arabian Peninsula and the Socotra Archipelago amounts to 59 taxa with 5 additional species, *Pseudagrion niloticum*, *Anax tristis*, *Sympetrum sinaiticum*, *Trithemis pallidinervis*, and *Tramea basilaris* not evaluated. *Pseudagrion niloticum* has not been assessed because it was only recently discovered in Wadi Hadhramout (Schneider and Nasher 2013). For *Sympetrum sinaiticum* there is only a single record in northern Saudi Arabia at the southernmost border of the species' distribution. Although a female was collected during oviposition, its

Anax parthenope (LC) is often on patrol across the numerous canals and wadi of the region. Photo © Boudjéma Samraoui

1 Senckenberg Research Institute, Entomology II, Senckenberganlage 25, 60325 Frankfurt (Germany).
2 Laboratoire de Recherche et de Conservation des Zones Humides, University of Guelma, Guelma, Algeria/Center of Excellence for Research in Biodiversity, King Saud University, Riyadh, Saudi Arabia

An artificial canal that crosses the arid eastern part near Al Ahsa in Saudi Arabia. Photo © Boudjéma Samraoui

true status is unknown. The same holds true for the remaining three species: *Anax tristis* and *Tramea basilaris* are common migrants often spotted in the desert plains or far offshore. In Arabia *Trithemis pallidinervis* is only known from a single specimen collected in northern Oman. It is likely that the occurrence of this Indian species originated from a windborne migration. The species has obviously not established stable populations in Arabia.

The validity of some taxa and their precise distribution deserves further investigation, with the larvae of several species insufficiently described or even unknown (Jödicke *et al.* 2004).

The highest diversity of Odonata in the region is concentrated in the southern Arabian Peninsula, including parts of Yemen (67.2%), Saudi Arabia (64.1%) and Oman (64.1%) (Table 5.1, Fig. 5.1). The south-west of Saudi Arabia, a hotspot of Odonata diversity in the region, contrasts sharply with the much drier rest of the country.

Figure 5.1. The distribution of Odonata across the Arabian Peninsula region, mapped to river sub-catchments.

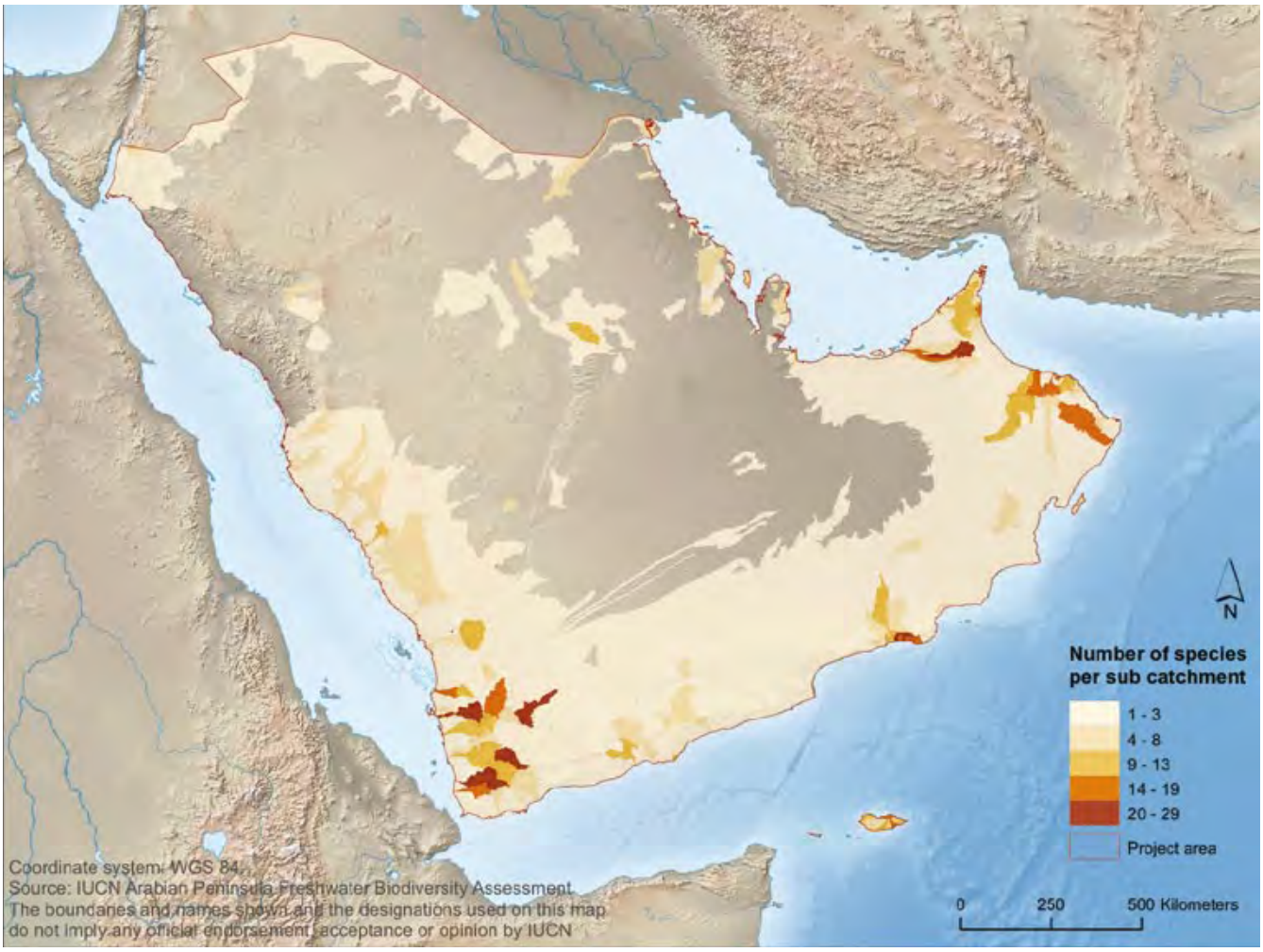


Table 5.1. Number of Odonata taxa within different countries of the Arabian Peninsula[1].

Countries	Number of recorded species	% of total
Yemen[2]	43	67.2
Saudi Arabia	41	64.1
Oman	41	64.1
UAE	23	35.9
Qatar	13	20.3
Kuwait	12	18.8
Bahrain	6	9.4

1 Including five species recorded but not evaluated: P*seudagrion niloticum, Anax tristis, Sympetrum sinaiticum, Trithemis pallidinervis*, and *Tramea basilaris*.
2 Including the Socotra Archipelago with two species not recorded from mainland Yemen: *Azuragrion granti* (endemic) and *Tramea basilaris*.

5.2 Overview of the Regional Odonata

The huge Arabian land mass connects the two continents Asia and Africa. With 3.2 million km², it has the same size as India and may be regarded as a subcontinent of its own. Despite the fact that, as a continuation of the Saharan desert belt, Arabia predominantly consists of semiarid to hyperarid lands, its odonatofauna is comparatively rich with 64 taxa recorded so far (compared to 83 in northern Africa, Samraoui *et al.* 2010) and seven endemics (similarly seven endemics in northern Africa). High species densities are found in pluvial refugia, the high mountains in the southwestern Saudi Arabia, Yemen) and the southeast (northern Oman), and in intercalated Afrotropical relict pockets of Dhofar (Oman) and the neighbouring al-Mahra region in Yemen, which are both influenced by the monsoon rains. It was suggested that the faunas of these regions were formed during the same moist period (Schneider 1987), probably the early Holocene pluvial phase, approx. 12,500 – 10,000 years BP (Samraoui *et al.* 1993).

Ceriagrion glabrum (LC) is an African species found on Socotra and in the Southwest and Southeast of Arabia. Photo © Friedhelm Krupp

Recent progress in African odonatology has included revision and taxonomic changes for east African species (Dijkstra *et al.* 2011) and this has direct implications on the status and known ranges of several Arabian odonate populations. Prominent examples are the species pairs *Orthetrum taeniolatum* versus *O. kollmanspergeri*, *Brachythemis leucosticta* versus *Brachythemis impartita*, and *Trithemis donaldsoni* versus *Thrithemis dejouxi*.

With more than 60% of all recorded species also found on the African continent, the odonatofauna of Arabia has to be classified as predominantly Afrotropical. In addition six out of the seven regional endemics evolved from African lineages, including the monotypic genus *Arabicnemis* (Gassmann 2004).

There is a striking similarity between dragonfly assemblages in perennial mountain springs in Namibia (Suhling *et al.* 2006, Martens *et al.* 2010) and southwestern Arabia, in terms of the species present and their ecological characteristics. These habitats sustain a number of perennial stream dwellers: *Crocothemis*

Wadi Hanifa just south of Riyadh , in Saudi Arabia. Photo © Boudjéma Samraoui

sanguinolenta, *Orthetrum julia*, *Trithemis stictica* (replaced by *T. dejouxi* in Arabia), *Zosteraeschna minuscula* (replaced by *Pinheyscha yemenensis* in Arabia), *Anax speratus*, and *Pseudagrion kersteni* (plus *P. arabicum* in Arabia).

There is a weak but remarkable penetration of Oriental/ south-east Asian species in the extreme east of the

A male of *Pseudagrion decorum*, an Oriental element in the odonate fauna of Arabia. It is categorized by IUCN as Near Threatened in the Arabian Peninsula and Least Concern at global level. Photo © Friedhelm Krupp

Arabian Peninsula, e.g. *Agriocnenis pygmaea*, *Pseudagrion decorum*, and *Macrodiplax cora*.

Besides *Arabicnemis*, the other endemic and monotypic genus for Arabia, *Arabineura* remains an enigma: *Arabineura khalidi* is the only protoneurid known between south-east Asia and Africa (Schneider 1988). It may represent the relict of an older but yet unrecognised faunal exchange between Asia and Africa.

Due to the huge and arid desert belt in the north of Arabia, the influx of Palearctic species is rather weak. Only two of them, *Selysiothemis nigra* and *Lindenia tetraphylla*, have penetrated deep into Arabia. This is explained by their capacity to migrate and to breed in different types of stagnant waters, even in ephemeral and brackish ones. Other Palearctic species, like *Orthetrum coerulescens*, *Orthetrum taeniolatum*, and *Sympetrum sinaiticum* are restricted to suitable habitats with enough permanent freshwaters in the north of Arabia, as around the Shat al-Arab on the Iraq/Iran border and the Jabal Lauz mountains of the northern Hijaz in Saudi Arabia.

Compared to other oceanic islands and considering its large size (3,625 km²), Socotra has an impoverished odonatofauna with a total of 21 species and only one endemic, *Azuragrion granti*. Afrotropical and migrant species predominate. It is striking that the genus *Pseudagrion* is obviously not represented on Socotra, but is on other western Indian Ocean islands. A major freshwater crisis on Socotra in the past, with species' extinctions, is a possible explanation. The absence of primary freshwater fish and amphibians points in the same direction (Schneider and Nasher 2013)

Tandem oviposition of the endemic (genus and species) Threadtail *Arabineura khalidi* (EN), the only known protoneurid between the Indian subcontinent and Africa. The male is only supported by his grip on the female's prothorax. Photo © Robert W. Reimer

Selysiothemis nigra (LC) is a well known migrant, even found far offshore. This female was part of a migrating swarm along the Red Sea coast in Jordan. Photo © Wolfgang Schneider

5.3 Conservation Status (IUCN Red List Criteria: Regional Scale)

Of the 59 assessed taxa (i.e., not including 'Not Applicable and Not Evaluated' species) of the Arabian Peninsula, one species is assessed as Regionally Extinct and 15 (25.4%) are classified as threatened (CR, EN, VU).

5.3.1 Regionally Extinct species

One species *Azuragrion vansomereni*, known from a single site in Saudi Arabia is now considered to be Regionally Extinct (RE), following the demise of its habitat, the Laila lakes (Krupp *et al.* 1990, Kempe and Dirks 2008, Jennings 2010).

The Layla Lakes in al-Aflaj (Central Saudi Arabia) were the only known natural freshwater lakes in Arabia. The Afrotropical species *Azuragrion vansomereni*, collected here in the 1980s, is now listed as Regionally Extinct. The two pictures represent the situation of the main lake in 1992 (top) and 1995 (bottom). Photos © Michael C. Jennings

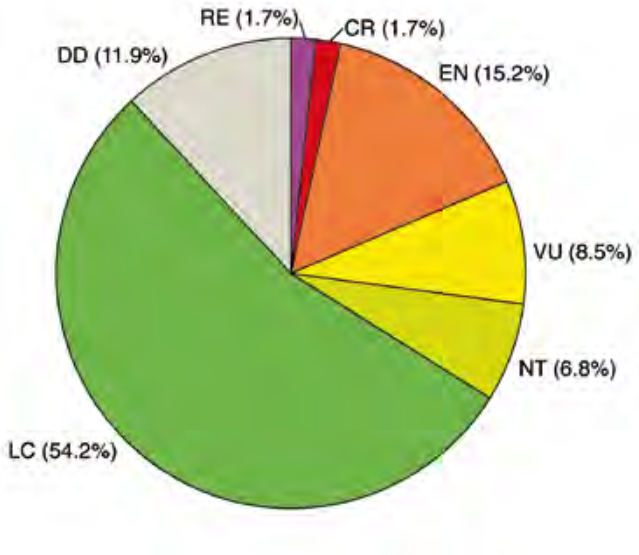
5.3.2 Threatened taxa

1.7% of the assessed taxa are Critically Endangered (CR), 15.2% are Endangered (EN) and 8.5% are Vulnerable (VU) (Table 5.2, Fig. 5.2).

5.3.3 Near Threatened taxa

Four species (6.8%) are considered as Near Threatened (NT). Although the status of these species could not fit the criteria of threatened species, further monitoring, especially of *Azuragrion granti*, may uncover a decline if no conservation steps are adopted to halt habitat losses.

Figure 5.2. The proportions (%) of Odonata taxa in each regional Red List category in the Arabian Peninsula.



Irrigated palm grove, home of *Crocothemis chaldaeorum* (DD). Photo © Boudjéma Samraoui

Table 5.2. The number of Odonata taxa in each Red List Category in the Arabian Peninsula.

	Regional Red List Category	Regional Assessment	Global Assessment	Number of Regional Endemics
	Regionally Extinct (RE)**	1	0	0
Threatened categories	Critically Endangered (CR)	1	0	0
	Endangered (EN)	9	0	3
	Vulnerable (VU)	5	0	2
	Near Threatened (NT)	4	1	1
	Least Concern (LC)	32	57	1
	Data Deficient (DD)	7	1	0
	Not Applicable	4	0	0
	Not Evaluated	1	0	0
	Total number of taxa assessed*	**59**	**59**	**7**

* Taxa considered Not Applicable (*Anax tristis*, *Sympetrum sinaiticum*, *Tramea basilaris*, *Trithemis pallidinervis*) and Not Evaluated (*Pseudagrion niloticum*, see Schneider and Nasher 2013) are excluded from total.
All species assessed as regionally threatened which are endemic to the region are *de facto* globally threatened.

** The species *Azuragrion vansomereni* is listed Regionally Extinct in the Arabian Peninsula.

5.3.4 Data Deficient taxa

Not enough is known about the distribution and/or population trend of seven taxa (11.9%) which were evaluated as Data Deficient (DD). Fig. 5.4 indicates that more effort needs to be devoted to the southern part of the Arabian Peninsula, where the DD taxa tend to be concentrated.

5.3.5 Least Concern taxa

A total of 32 taxa (54.2%) were considered as widespread with no hint of pending threats leading to their assessment as Least Concern (LC).

5.3.6 Not Applicable species

A total of 4 species were considered as Not Applicable (*Anax tristis*, *Sympetrum sinaiticum*, *Tramea basilaris*, *Trithemis pallidinervis*). Because Arabian records of *Pseudagrion niloticum* were published only after the assessment process, it could not be evaluated.

The conservation status of threatened taxa is almost evenly split between the two sub-orders, with eight Zygoptera and seven Anisoptera. The threatened zygopterans are made up mainly by the family Coenagrionidae (six taxa) while the Libellulidae (six taxa, all listed as EN) dominate the other sub-order (Table 5.3). It is important to bear in mind that due to the fast rate of local development, especially in the southern part of the Arabian Peninsula where the overall species richness and number of threatened species are greatest (Figs. 5.1 and 5.3), this evaluation may change rapidly and many species, actually assessed as LC, may become threatened.

The range of *Trithemis kirbyi* (LC) has changed fast in the Mediterranean region and its distribution may be worth monitoring in the Arabian Peninsula. Photo © Boudjéma Samraoui

The impact of freshwater reservoirs like Jisan Dam in southwest Saudi Arabia on the regional biodiversity deserves a thorough investigation. It is the only known locality in Arabia of the African species *Palpopleura deceptor* (DD in the Arabian Peninsula and LC globallly). Photo © Boudjéma Samraoui

Trithemis annulata (LC), common in palm groves and irrigation ditches. Photo © Boudjéma Samraoui

Crocothemis erythraea (LC) is common outside the palm groves. Photo © Boudjéma Samraoui.

Figure 5.3. The distribution of threatened Odonata across the Arabian Peninsula region, mapped to river sub-catchments.

Table 5.3. Threatened Odonata in the Arabian Peninsula.

Family	Taxon	Regional Red List Category	Criteria	Endemic
COENAGRIONIDAE	*Agriocnemis pygmaea*	CR	B2ab(iii)	
COENAGRIONIDAE	*Azuragrion nigridorsum*	EN	B2ab(iii)	
COENAGRIONIDAE	*Pseudagrion arabicum*	EN	B2ab(iii)	yes
LIBELLULIDAE	*Acisoma panorpoides* ssp. *ascalaphoides*	EN	B1ab(i,ii,iii)+ 2ab(i,ii,iii)	
LIBELLULIDAE	*Orthetrum abbotti*	EN	B2ab(iii)	
LIBELLULIDAE	*Rhyothemis semihyalina*	EN	B1ab(i,ii,iii,iv,v)+ 2ab(i,ii,iii,iv,v)	
LIBELLULIDAE	*Trithemis dejouxi*	EN	B2ab(iii)	
LIBELLULIDAE	*Urothemis edwardsii*	EN	B1ab(iii)+2ab(iii)	
LIBELLULIDAE	*Urothemis thomasi* ssp. *thomasi*	EN	B2ab(iii)	yes
PROTONEURIDAE	*Arabineura khalidi*	EN	B2b(iii,iv)	yes
AESHNIDAE	*Pinheyschna yemenensis*	VU	B1ab(iii)+2ab(iii); D2	yes
COENAGRIONIDAE	*Azuragrion somalicum* ssp. *amitinum*	VU	B2ab(iii); D2	yes
COENAGRIONIDAE	*Pseudagrion kersteni*	VU	B2ab(iii)	
COENAGRIONIDAE	*Ischnura fountaineae*	VU	B2ab(iii)	
LESTIDAE	*Lestes pallidus*	VU	B2ab(iii)	

Figure 5.4. The distribution of Data Deficient Odonata across the Arabian Peninsula region, mapped to river sub-catchments.

5.4 Patterns Of Species Richness

Male of *Orthetrum ransonnetii* (LC) in Wadi Rum (Jordan). Photo © Friedhelm Krupp

5.4.1 Species richness

The diversity of dragonflies in the Arabian Peninsula is mainly explained by the effect of climate (rainfall due to monsoons) and the proximity to the African and Asian plates. Hotspots of species richness are coastal areas (south-west Saudi Arabia, Yemen and Oman). Elsewhere, the region receives little rainfall and has low species diversity.

5.4.2 Distribution of endemic taxa

The Arabian Peninsula holds seven taxa endemic to the region (10.9% of all taxa recorded for the region), including five Zygoptera and two Anisoptera. The Coenagrionidae with three taxa dominate all other zygopteran families (Table 5.4). Endemics are mainly found in the mountains along the southeastern and southwestern coasts of Arabia (Fig. 5.5).

5.4.3 Distribution of threatened species richness

The distribution of threatened species richness mirrors that of high species diversity represented by the mountain forests of southwestern Saudi Arabia and Yemen, the mountains of northern Oman and the Afrotropical relict pockets of Dhofar (Oman and Al Mahra (Yemen).

Tandem oviposition of the Arabian Featherleg *Arabicnemis caerulea* (LC), an endemic genus and species of Southern Arabia. Photo © Friedhelm Krupp

Table 5.4. Number of endemic taxa and total number within each Odonata family.

Suborder	Family	Number of taxa	Number of endemic taxa
Zygoptera	Lestidae	1	0
	Coenagrionidae	14	3
	Platycnemididae	1	1
	Protoneuridae	1	1[1]
	Sub-total – Zygoptera (damselflies)	**17**	**5**
Anisoptera	Aeshnidae	5	1
	Gomphidae	3	0
	Libellulidae	34	1[2]
	Sub-total – Anisoptera (dragonflies)	**42**	**2**
Total – Odonata		**59**	**7**

[1] With the endemic genus *Arabineura* Schneider and Dumont, 1995

[2] The status of *Urothemis thomasi* Longfield, 1932 as an Arabian endemic would be challenged if *Urothemis aethiopica* Nielsen, 1957 is considered as its east African subspecies (Schneider 1988), or if *U. thomasi* is regarded as a subspecies of *U. signata* (Rambur, 1842) (Waterston and Pittaway 1991).

Figure 5.5. The distribution of endemic Odonata across the Arabian Peninsula region, mapped to river sub-catchments.

5.5 Major threats to Odonata of the Arabian Peninsula

5.5.1. General overview of threats

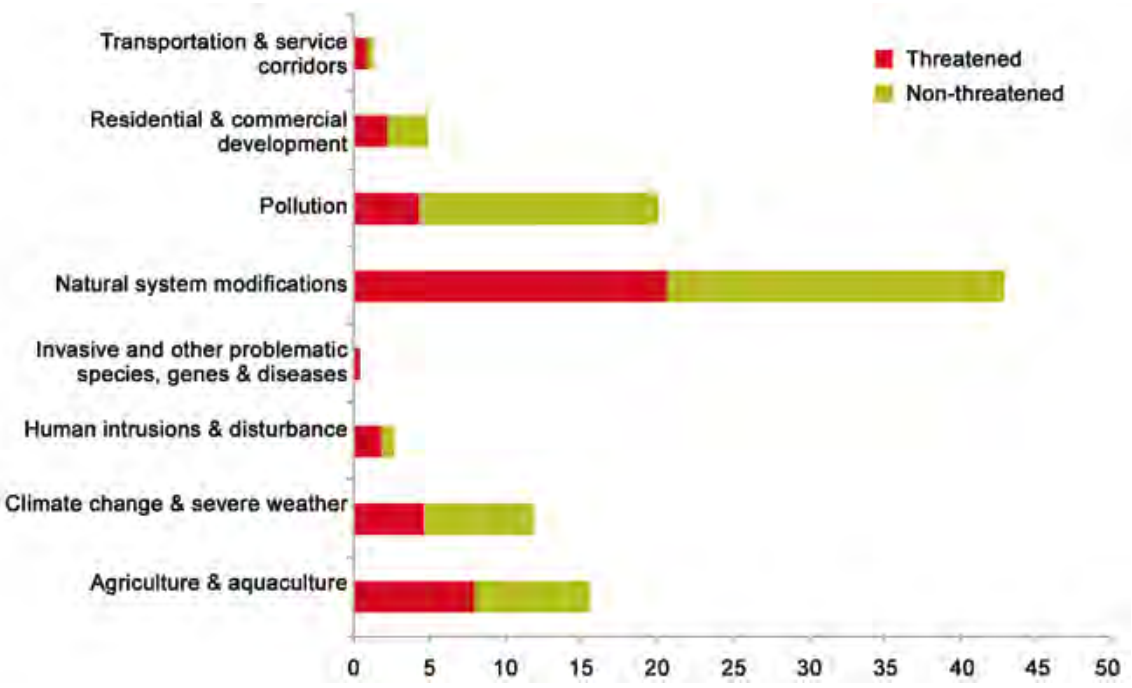
The main threats to Odonata and their habitats in the Arabian Peninsula are summarized in Fig. 5.6. Over the last century, rapid development has transformed the whole of the Arabian Peninsula and, unsurprisingly, modifications to natural systems (in terms of physical modification of the habitat by dams, water abstraction, channelization, or destruction of riparian habitat??) stand out as the dominant threats. Pollution, agriculture and a burgeoning aquaculture industry (e.g. shrimp farms) also rank high in the threats list. Unfortunately, the advent of global warming will probably exacerbate such pressure and the steady sprawl of residence and commercial development will only add to the plight of already vulnerable and increasingly fragmented wetlands.

5.6 Conservation Recommendations

Freshwater habitats in the region are under a several anthropogenic pressures (see section 5.5.1) due to water extraction, habitat degradation and urban development. Thus, the conservation of wetland biodiversity in the Arabian Peninsula faces a tough challenge and will need to draw upon a wide spectrum of local and regional actions spread over different domains: protection, monitoring, research, management and education. Databases, atlases (Boudot *et al.* 2009) and Red Lists are useful tools that will help to select highly threatened species and hotspots of high conservation values. Extensive surveys are needed to fill the gaps in our knowledge of the distribution of several species and complete the present checklist. More work is also needed to clarify the taxonomic status of a number of taxa (e.g. *Urothemis thomasi*, *Orthetrum kollmannspergeri*, and *Crocothemis chaldaeorum*) and to describe their larvae and exuviae. Likewise, our knowledge of the ecology of

Wadi Baish in southwest Saudi Arabia which hosts a large population of *Pseudagrion hamoni* may be threatened by dam construction and water extraction. Photo © Boudjéma Samraoui

Figure 5.6. Percentage of Odonata in the Arabian Peninsula affected by major categories of threat.



Wadi Hanifa is very much "tamed" across the Saudi capital Riyadh. Photo © Boudjéma Samraoui

Crocothemis chaldaeorum (DD) is thought to have originated within the extensive and ancient palm groves of the eastern part of the Arabian Peninsula. Photo © Boudjéma Samraoui

endemic species (e.g., *Pinheyschna yemenensis*, *Arabineura khalidi*,and *Azuragrion granti*) and relict species (*Rhyothemis semihyalina*, *Urothemis edwardsii*) is limited and there is ample scope for improvement (Samraoui *et al.* 2003). There is thus clearly a need for capacity building in the area both for odonatological and environmental training. There is a close similarity between the conservation status of freshwater species of the Arabian Peninsula and that of Northern Africa (Samraoui and Menai 1999, Jödicke *et al.* 2004). Conservation priorities identified by a panel of experts for the latter region may be applicable to the Arabian Peninsula (García *et al.* 2008). Conservation measures include research designed to provide reliable information on status and trends of species and their habitats (as noted above), the development of Integrated River Basin Management (IRBM) programs, the use of sustainable agricultural techniques and waste management, law enforcement, habitat protection, and action plans for species, and environmental education.

5.7 References

Al-Houty, W. 1985. Some Odonata from Kuwait. *Entomologist's Monthly Magazine* **121**: 62.

Al-Safadi M.M. 1990. Dragonflies (Odonata) of the Yemen Arab Republic. *Fauna of Saudi Arabia* **11**: 18–30.

Boudot, J-P, Kalkman, V., Azplicueta Amorin, M., Bogdanovic, T., Cordero Rivera, A., Degabriele, G., Dommanget, J.-L., Ferreira, S., Garrigos, B., Jovic, M., Kotarac, M., Lopau, W., Marinov, M., Mihokovic, N., Riservato, E., Samraoui, B. and W. Schneider 2009. Atlas of the Odonata of the Mediterranean and North Africa. *Libellula*, *Supplement* **9**: 1–256.

Carfì, S., Vittoria, R. and Terzani, F. 1995. Some dragonflies from the north of the Republic of Yemen. *Bolletino della Società entomologica italiana* **126**: 195–199.

Clausnitzer, V. and Jödicke, R. (eds) 2004. Guardians of the Watershed. Global status of dragonflies: critical species, threat and conservation. *International Journal of Odonatology* **7**: 111–430.

Clausnitzer, V., Dijkstra, K-D, Koch, R., Boudot, J-P., Darwall, W.T.T., Kipping, J., Samraoui, B., Samways, M.J., Simaika, J.P. and Suhling, F. 2012. Focus on African freshwaters: hotspots of dragonfly diversity and conservation concern. *Frontiers in Ecology and the Environment* **10**: 129–134.

Corbet, P.S. 1999. Dragonflies: Behaviour and biology of Odonata. Harley Books.

Crick, H.Q.P. 2004. The impact of climate change on birds. *Ibis* **146**: 48–56.

Dijkstra, K.-D.B., Boudot, J_P., Clausnitzer, V., Kipping, J., Kisakve, J.J., Ogbogu, S.S., Samraoui, B., Samways, M.J., Schütte, K., Simaika, J.P., Suhling, F. and Tchibozo, S. 2011. Dragonflies and Damselflies of Africa (Odonata): history, diversity distribution and conservation. In: Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A., Harrison, I.J. and Brooks, E.G.E. (Editors). The diversity of life in African Freshwaters. Under Water, Under Threat An analysis of the status and distribution of freshwater species throughout mainland Africa. IUCN, 128–177.

Dumont, H.J. and Al-Safadi, M.M. 1991. Additions to the dragonfly fauna of Yemen. *Notulae odonatologicae* **3**: 114–117.

Dumont, H.J. and Al-Safadi, M.M. 1993. Further additions to the dragonfly fauna of the Republic of Yemen (Odonata). *Opuscula zoologica fluminensia* **109**: 1–8.

Feulner, G.R. 1999. Two new UAE Damselflies: *Ceriagrion glabrum* and *Pseudagrion decorum*. *Tribulus* **9**: 31.

Feulner, G.R. 2001. The damselfly *Pseudagrion decorum* breeding in the UAE. *Tribulus* **11**: 24.

Feulner, G.R., Reimer, R.W., and Hornby, R.J. 2007. An updated illustrated checklist of dragonflies and damselflies of the UAE. *Tribulus* **17**: 37–62.

Garcia, N., Abdul Malak, D. and Cuttelod, A. 2008. The status and distribution of freshwater biodiversity in North Africa. Gland, Switzerland, Cambridge, UK, and Malaga, Spain: IUCN.

Gassmann, D. 2004. The phylogeny of Southeast Asian and Indo-Pacific Calicnemiinae (Odonata, Platycnemididae). *Bonner zoologische* Beiträge **53**: 37–80.

Giles, G.B. 1998. An illustrated and annotated checklist of the dragonflies of the UAE. *Tribulus* **8**: 9–15.

Hooftman, D.A., van Kleunen, M. and Diemer, M. 2003. Effects of habitat fragmentation on the fitness of two common wetland species, *Carex davalliana* and *Succisa pratensis*. *Oecologia* **134**: 350–359.

Jennings, M.C. 2010. Atlas of the breeding birds of Arabia. *Fauna of Arabia* **25**: XI + 751.

Jödicke, R., Boudot, J-P., Jacquemin, G., Samraoui, B. and Schneider W. 2004. Critical species of Odonata in northern Africa and the Arabian Peninsula. *International Journal of Odonatology* **7**: 239–253.

Kempe, S. and Dirks, H. 2008. Layla Lakes, Saudi Arabia: The world-wide largest lacustrine gypsum tufas. *Acta carsologica* **37**: 7–14.

Kimmins, D.E. 1961. The Odonata and Neuroptera of the Island of Socotra. *Annals and Magazine of Natural History* **13**: 385–392.

Krupp, F., Schneider, W., Nader I.A. and Khushaim, O. 1990. Zoological survey in Saudi Arabia, spring 1990. *Fauna of Saudi Arabia* **11**: 3–9.

Krupp, F. Appel, M., Hamoud, A., Schneider,W. and Zajonz, U. 2006. Zoological survey in the Red Sea coastal zone of Yemen. **Fauna of Arabia 21** : 11–32.

Lambret, P. and Boudot, J-P. 2009. *Nesciothemis farinosa* (Förster, 1898) et *Orthetrum ransonnetii* (Brauer, 1865) nouveaux pour l'Arabie Séoudite et autres observations d'Odonates sur les reliefs côtiers de la Mer Rouge. *Martinia* **25**: 153–155.

Longfield, C. 1931. Dragonflies. In: Thomas, B. "A camel journey across the Rub' al Khali". *Geographical Journal* **78**: 209-242; pp. 230–231.

Longfield, C. 1932. A new species of the genus *Urothemis* from southern Arabia and some remarks on the species of Odonata inhabiting the Qara mountains. *Stylops* **1**: 34–35.

Martens, A., Richter, O. and Suhling, F. 2010. The relevance of perenial springs for regional biodiversity and conservation. In: Schmiedel U., Jürgens, N. (eds): Biodiversity in southern Africa 2: Patterns and processes at regional scale. Klaus Hess Publishers, Göttingen: 70–74.

McLachlan, R. 1903. The dragonflies of Sokotra. In: H.O. Forbes (ed.), The Natural History of Sokotra and Abd-el-Kuri: being the report upon the results of the conjoint expedition to these islands in 1898-9. Special Bulletin of the Liverpool Museum, London, XLVII + 598pp.

Pittaway, A.R. 1983. The dragons of Al-Hasa (Odonata). *ARAMCO World Magazine* **2**: 2–3.

Reimer, R.W. 2008. An extraordinary confluence of events in the study of UAE and Oman Odonata. *Agrion* **12**: 55.

Reimer, R.W. 2009. Additional records for Oman. *Agrion* **13**: 45–47.

Reimer, R.W., Feulner, G.R. and Hornby, R.J. 2009. Errata and Addenda: Updated illustrated checklist of dragonflies of the UAE – uncluding a third species of *Ischnura* damselfly. *Tribulus* **18**: 28–36.

Riservato, E., Boudot, J-P., Ferreira, S., Jovic, M., Kalkman, V.J., Schneider, W., Samraoui, B. and Cuttelod, A. 2009. The status and distribution of dragonflies of the Mediterranean Basin. Gland, Switzerland and Malaga, Spain.

Samraoui, B., Benyacoub, S., Mecibah, S. and Dumont, H.J. 1993. Afotropical libellulids in the lake district of El Kala, NE Algeria with a redescription of *Urothemis e. edwardsii* (Selys) and *Acisoma panorpoides ascalaphoides* (Rambur) (Anisoptera: Libellulidae). *Odonatologica* **3**: 365–372.

Samraoui, B., Boudot, J.-P., Riservato, E., Ferreira, S., Jovic, M., Kalkman, V.J. and Schneider. 2010. The status and distribution of dragonflies. In García, N., Cuttelod, A. and Abdul Malak, D. (eds.). The Status and Distribution of Freshwater Biodiversity in Northern Africa. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga, Spain: xiii+141pp.

Samraoui, B. and Menai, R. 1999. A contribution to the study of Algerian Odonata. *International Journal of Odonatology* **2**: 145–165.

Schneider, W. 1987. The genus *Pseudagrion* Selys, 1876 in the Middle East. A zoogeographic outline (Insecta: Odonata: Coenagrionidae). *Proceedings of the Symposium on the Fauna and Zoogeography of the Middle East, Mainz* 1985, pp. 114–123.

Schneider, W. 1988. Dragonflies (Odonata) of the Wahiba Sands and adjacent areas, eastern Oman. *Journal of Oman Studies. Special Report* **3**: 377–388.

Schneider, W. and Dumont, H.J. 1995. *Arabineura* n. gen., a new protoneurid genus from Arabia, with the description of the hitherto unknown female of *Arabineura khalidi* (Schneider, 1988) comb. nov. (Insecta: Odonata: Protoneuridae). *Biologisch Jaarboek Dodonaea* **62**: 114–120.

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

Schneider,W. and Dumont, H.J. 1998. Checklist of the dragonflies and damselflies of Socotra island (Insecta:

Odonata). In: H.J. Dumont (ed.); Proceedings of the First International Symposium on Socotra Island: Present and Future, Aden 1996 1: 83–105. United Nations Publications, p. 219–232, New-York.

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

Schneider, W. and Nasher, A. 2013. Dragonflies from mainland Yemen and the Socotra Archipelago. Additional records and novelties. *IDF Report* **57**: 1–13.

Schneider, W. and Parr, M.J. 1998. *Orthetrum julia falsum* Longfield 1955, new to the dragonfly fauna of Yemen and the Arabian Peninsula (Anisoptera: Libellulidae). *International Journal of Odonatology* **1**: 155–158.

Suhling, F., Sahlén, G., Martens, A., Marais, E. and Schütte, C. 2006. Dragonfly assemblages in arid tropical environments : a case study from western Namibia. *Biodiversity and Conservation* **15**: 311–332.

van der Weide, M.J.T. and Kalkman, V.J. 2008. Some new records of dragonflies from Oman. *Agrion* **12**: 52–54.

Waterston, A.R. 1980. Insects of Saudi Arabia. Odonata. *Fauna of Saudi Arabia* **2**: 57–70.

Waterston, A.R. 1981. The dragonflies (Odonata) of Dhofar. In: "The scientific results of the Oman flora and fauna survey 1977 (Dhofar)". *Journal of Oman Studies*, Special Report **2**: 149–151.

Waterston, A.R. 1984. A new genus and species of platycnemidid dragonfly from the Arabian Peninsula. *Odonatologica* **13**: 139–146.

Waterston, A.R. 1985. Insects of southern Arabia. Odonata from the Yemens and Saudi Arabia. *Fauna of Saudi Arabia* **6**: 451–472.

Waterston, A.R. and Pittaway, A.R. 1991. The Odonata or dragonflies of Oman and neighbouring territories. *Journal of Oman Studies* **10**: 131–168.

Wilson, K. 2008. A brief trip to United Arab Emirates and Northern Oman. *Agrion* **12**: 56–57.

Chapter 6. The status and distribution of freshwater crabs

Cumberlidge, N.[1]

6.1 Overview of the regional fauna

The entire Arabian Peninsula lacks freshwater crabs, except for Socotra, the largest island in the Socotran archipelago. Socotra is home to three species of freshwater crabs that belong to two genera, *Socotra* Cumberlidge and Wranik, 2002, and *Socotrapotamon* Apel and Brandis, 2000, that are all assigned to the Potamidae Ortmann, 1896 (Ng *et al*. 2008, Cumberlidge *et al.* 2009). All of these species (*Socotra pseudocardisoma* Cumberlidge and Wranik, 2002, *Socotrapotamon socotrensis* (Hilgendorf, 1883), and S*ocotrapotamon nojidensis* Apel and Brandis, 2000, have a stable taxonomy (Ng *et al.* 2008). The Potamidae is easily the largest of all of the freshwater crab families, and includes 95 genera and more than 505 species in two subfamilies, the Potaminae Ortmann, 1896, and the Potamiscinae Ortmann, 1896 (Ng *et al.* 2008, Cumberlidge and Ng 2009). The Potamidae has a wide distribution throughout the southern Palaearctic and Oriental zoogeographical regions from Morocco as far east as Japan and as far south as Indonesia (Ng *et al.* 2008, Yeo *et al.* 2008, Cumberlidge *et al.* 2009). The three Socotran potamids are the only members of this family found in the Afrotropical region (Yeo *et al.* 2008, Cumberlidge 2008). All three Socotran species belong to the subfamily Potamiscinae, whose members are otherwise found from northeast India to as far as east China and Japan, and in southeast Asia as far as Indonesia and the Philippines. The Socotran potamids are not closely related to the geographically closest potamids (species of the Palaearctic genus *Potamon* (Potamidae: Potaminae)) that are found in North Africa, the Mediterranean coastal region (including Egypt), the Middle East, and the western Himalayas (Bott 1967, Brandis *et al.* 2000; see section 6.3 for further discussion). Furthermore, the Socotran freshwater crabs are not closely related to the geographically close freshwater crabs of Somalia, despite the fact that Socotra lies closer to the coast of Africa than to the coast of the Arabian Peninsula (Reed and Cumberlidge 2004, 2006; see section 6.3 for further details).

The three species of Socotran freshwater crabs are similar in terms of their breeding strategy (they all have direct development from egg to hatchling crabs, and they all lack larval stages) but they differ in their choice of habitat within freshwater ecosystems on the island (streams, waterfalls, and rock crevices) (Apel and Brandis 2000, Cumberlidge and Wranik 2002). These freshwater crabs are omnivores that mostly consume plant matter and scavenge detritus, and are found wherever year round water is present.

6.1.1 Crab Distribution and Ecoregions

The Socotra archipelago comprises a chain of four islands: Socotra, Abd al Kuri, Samha, and Darsa that have a combined area of about 4,000 km^2. This archipelago is an extension of the Horn of Africa and at its closest point is only 90 km from the coast of Somalia (see also Chapter 1). Socotra is the only island in the archipelago that has freshwater crab populations, all of the other islands lack freshwater crabs (Cumberlidge and Wranik 2002).

Topographically Socotra can be divided into three main zones: a lowland coastal plain of variable width, a limestone plateau (300 to 700 m asl) that extends over most of the island, and the granitic Haghir mountains in the center of the island (up to 1,519 m asl). The vegetation of Socotra is sparse and is dominated by plants adapted to a semi-arid climate although more luxuriant vegetation is found in the sheltered valleys and on mountain slopes (Kingdon 1989, Mies and Zimmer 1993, Mies *et al.* 1995). In general about one-third of the plants and animals found on Socotra are endemic at both the species and generic levels, but the genera and species of freshwater crabs are 100% endemic.

1 Department of Biology, Northern Michigan University. Marquette, MI 49855-5376, USA.

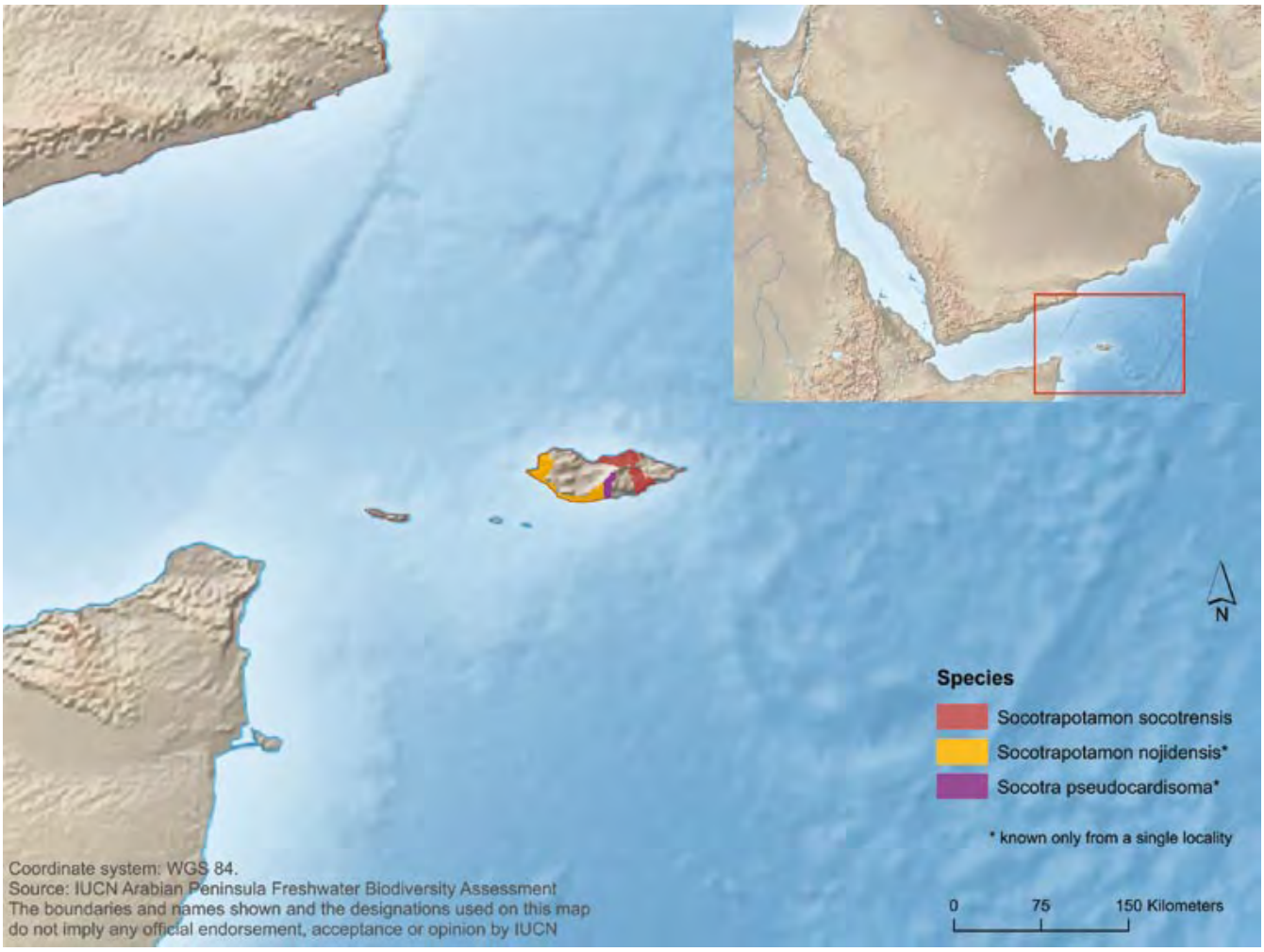
6.2. Assessment of species threatened status (IUCN Red List Criteria: Regional Scale)

The conservation status of the Arabian Peninsula's freshwater crab fauna has been assessed using the IUCN Red List Criteria at the regional scale (IUCN 2003, Cumberlidge *et al.* 2009). All three species of freshwater crabs found in the Arabian Peninsula have a restricted extent of occurrence and, as noted above, are all endemic to Socotra. Therefore, the assessment of threat status at the regional scale is also representative of a global assessment.

Socotra pseudocardisoma is a large and secretive semi-terrestrial air-breathing species that is restricted to rock crevices, karst, and an underground cave system in an inland locality in the Haghir mountains far away from permanent freshwater sources and far away from the coast (Cumberlidge and Wranik 2002). *Socotrapotamon socotrensis* is a locally common stream-living species found in shallow streams and wadis throughout the

Wadi Daneghan, Socotra is one of the locations where *Socotrapotamon socotrensis* (LC) is known to occur. Photo©Friedhelm Krupp

Figure 6.1 Distribution map of the freshwater crabs *Socotra socotrensis*, *Socotrapotamon nojidensis* and *S. pseudocardisoma* in the Arabian Peninsula.



island including the northern lowland coastal areas and the streams draining the central mountain range. This species is often found living in burrows that it digs into the banks of rivers (Apel and Brandis 2000). The third Socotran species, *S. nojidensis*, is found only in the shallow waters of a series of waterfalls and rock pools at the base of the escarpment in the western part of the Nojid plain on the south coast of Socotra, living between rocks and plants (Apel and Brandis 2000).

Most of the aquatic ecosystems of Socotra are either actually or potentially affected by increasing development for the tourist industry with its associated demands on freshwater sources, and this may adversely affect freshwater crab populations in the future. The conservation status of each of the three species of freshwater crabs found in the Arabian Peninsula is summarized in Table 6.1 and is discussed briefly below.

6.2.1 Case Studies

Socotra pseudocardisoma Cumberlidge and Wranik, 2002 (LC)

This semi-terrestrial species grows as large as 90.5 mm across the carapace at its widest point. Living specimens of *S. pseudocardisoma* have a dark-purple dorsal carapace with a light brown margin, cream carapace sides, a pale sternum, and light yellow chelae and walking legs. *Socotra pseudocardisoma* lives only in the Haghir massif, and is a semi-arid zone crab with terrestrial habits found in temporary aquatic freshwater habitats in granite and limestone (sinks, underground streams, caverns, hollows and crevices) located far from conventional freshwater sources. These crabs can not only move rapidly on level surfaces they can also climb quickly up and down rock surfaces and so escape into inaccesible crevices. The Haghir massif where this species lives is an ancient mountainous area that has remained above sea level for millions of years (since the Mesozoic) and has served as a refuge for a number of Socotra's terrestrial species during past changes in sea levels that flooded lower-lying parts of the island. The Haghir mountains receive Socotra's highest rainfall totals and are frequently shrouded in clouds and heavy mists. Other sources of water for aquatic animals living on these mountains include permanent springs and the year-round streams that run down the northern slopes of the massif. However, at lower elevations these streams become sporadic and only flow freely after rain (Wranik 1999). Crabs produce eggs and release their hatchlings during the wettest part of the year when plant and animal populations on Socotra are at their highest levels. The present population levels of

Socotra pseudocardisoma (LC) lives in an inaccessible limestone karst system in the highlands of Socotra, Yemen, which provide this large semiterrestrial species with a level of protection. Photo©Friedhelm Krupp

Table 6.1 The number of freshwater crab species, and the number of endemics, in each regional IUCN Red List Category in the Arabian Peninsula (IUCN 2003, Cumberlidge *et al.* 2009).

	Regional Red List Categories	Regional Assessment	Global Assessment	Number of Regional Endemics
Threatened Categories	Critically Endangered	0	0	0
	Endangered	0	0	0
	Vulnerable	0	0	0
	Near Threatened	0	0	0
	Least Concern	2	2	2
	Data Deficient	1	1	1
	Total*	**3**	**3**	**3**

* Excluding species that are considered Not Applicable.

S. pseudocardisoma are estimated to be stable based on the number of individuals known and field reports made at different times. *Socotra pseudocardisoma* is currently listed as Least Concern because there are no known long-term threats that may result in a decline in the extent and quality of its habitat. Its extent of occurrence is very restricted (less than 500 km²) because all individuals are found in a single locality (Diksam located on a limestone plateau in the Haghir mountains) that is part of an extensive karst system whose inaccessible crevices undoubtedly protect this species from threats by predators, including humans. In addition, the Haghir mountains are a UNESCO World Heritage Site, and this designation may afford some level of protection for this species in the future.

Socotrapotamon socotrensis (Hilgendorf, 1883) (LC)

This species is endemic to Socotra island where it is common in freshwater streams and wadis throughout the island from the low coastal areas in the north to the mountainous parts of the Haghir mountains where it is found either in shallow water or in burrows dug into river banks. *Socotrapotamon socotrensis* is known from five different localities on Socotra: Kerignigi, Wadi Daneghan, Wadi Fahuh, a wadi near Hadibo, and Wadi Ayhaft. *Socotrapotamon socotrensis* is listed as Least Concern in view of its island-wide distribution, its apparent tolerance of low-scale habitat modification, and its presumed large population based on its occurrence in multiple localities. However, this stream-living species is not found in a protected area and no conservation measures are known to be in place. Potential long-term threats to *S. socotrensis* include habitat loss and pollution arising from the increased demands for water imposed by the tourist industry.

Socotrapotamon nojidensis Apel and Brandis, 2000 (DD)

This species is endemic to Socotra where it is known only from a series of waterfalls and rock pools at the base of the escarpment in the western part of the Nojid plain

Socotrapotamon socotrensis (LC) is endemic to Socotra island where it is common in streams and wadis living either in shallow water or in burrows dug into river banks. Photo©Friedhelm Krupp

on the south coast of the island. This species lives in the shallow waters between rocks and plants. Living specimens of *S. nojidensis* have a dark-colored carapace that is cream on the sides and pale underneath and its chelae and walking legs are bright orange. This is a medium-sized species with adults measuring 36.6 mm across the carapace at its widest point. This species is listed as Data Deficient because it is known only from a single locality in Socotra, was last collected in 1999, and because very little is known about its extent of occurrence, ecological requirements, population size, population trends, and long-term threats. This species is not found in a protected area.

6.3 Patterns of species richness

The unique character of Socotra is due in part to its great age and long isolation. Geologically, Socotra is part of the African-Arabian tectonic plate that became separated from the African mainland in the Tertiary. The result is that the majority of the island's fauna and flora is more closely related to African species rather than to those from the Arabian Peninsula. It is, therefore, interesting that the affinities of *Socotrapotamon* and *Socotra* lie with members of the Oriental freshwater crab subfamily Potamscinae rather than with the Palaearctic Potaminae or the Afrotropical Potamonautidae (Cumberlidge 2008, 2009, Cumberlidge *et al.* 2008).

The geographically closest potamids to Socotra are not close relatives and belong to a different subfamily (the Potaminae; see above) whose members are found north of the Arabian Peninsula, the closest being the widespread species *Potamon potamios* that is found in the Sinai peninsula in Egypt, Israel, Jordan and Syria. Other species of this genus are distributed throughout the Middle East as far east as the Himalayas (Brandis *et al.* 2000, Cumberlidge 2010). Although Socotra is geographically much closer to Somalia than it is to the Arabian Peninsula the two species of freshwater crabs found in Somalia (*Potamonautes obesus*, Potamonautinae and *Deckenia imitatrix* Deckeniinae) and the freshwater crabs found in the Seychelles are not closely related to the Socotran freshwater crabs, and belong to a different family, the Potamonautidae Bott, 1970 (Reed and

Socotrapotamon nojidensis (DD) is endemic to a waterfall in the western part of the Nojid plain in Socotra, Yemen. Photo©Friedhelm Krupp

Cumberlidge 2004, 2006, Daniels *et al.* 2006, Ng *et al.* 2008, Cumberlidge and Ng 2009, Cumberlidge *et al.* 2009). The taxonomic isolation of the Socotran freshwater crabs is further emphasized by the fact that there are no species of Potamidae found either in Somalia or anywhere else in subsaharan Africa (Bott 1955, Cumberlidge 1999, Reed and Cumberlidge 2006). Because of the above anomalies all three of Socotra's endemic species of freshwater crabs, *S. pseudocardisoma*, *S. socotrensis* and *S. nojidensis* are of extreme biogeographical and phylogenetic interest.

Although the two Socotran genera are not known to be closely related to any of the extant potamid genera, *Socotra* and *Socotrapotamon* are closely related to each other despite their morphological differences, because they group together as sister taxa in molecular phylogenies of the Potamidae (Daniels *et al.* 2006, Shih *et al.* 2009). A Gondwanan origin for the Socotran freshwater crab genera is unlikely because the potamoid freshwater crab ancestors probably originated in the late Cretaceous or early Cenozoic, long after the fragmentation of the southern supercontinent (Klaus *et al.* 2011). The date of origin for the potamoid freshwater crabs is supported by molecular phylogenetic studies (Daniels *et al.* 2006) and by the fossil record for freshwater crabs that dates back only as far as the Miocene (Glaessner 1929, Bachmayer and Pretzmann 1971). It is therefore more likely that the ancestors of the Socotran freshwater crabs reached the island by overseas dispersal from somewhere in Asia, given the lack of any close taxonomic relationship with the crabs found in Europe, the Middle East, continental Africa, the Seychelles, and Madagascar (Daniels *et al.* 2006, Cumberlidge 2008). The relatively close proximity of the Indian peninsula to the Socotran archipelago raises the possibility of an Indian peninsula origin for the ancestors of the Socotran freshwater crabs. However, this is unlikely because of the complete absence of any species of potamid freshwater crabs in the Indian subcontinent south of the Ganges basin (Cumberlidge *et al.* 2009). The possibility of the Socotran freshwater crabs originating during the Miocene from an Asian potamiscine ancestor that reached the island via the eastern Arabian mainland remains an open question (Apel and Brandis 2000).

Species diversity of freshwater crabs within the Arabian Peninsula clearly depends on the availability of permanent surface water. Hence, the lack of records of freshwater crab specimens from all parts of the mainland Arabian Peninsula (in Saudi Arabia, Kuwait, Bahrain, Qatar, United Arab Emirates, Oman and mainland Yemen; Table 6.2) over the past 100 years is because these aquatic crustaceans are genuinely not found there (presumably because of a lack of suitable habitat) rather than because of a lack of zoological interest and collection effort. This is not an unexpected finding because freshwater crabs are also absent from other extremely arid parts of Africa (e.g., the Sahara including Libya, Western Sahara, and the desert regions of Morocco, Algeria, and most of Egypt away from the Nile) (Cumberlidge 2010).

There is a high degree of endemism in Socotra at the species level (3 out of 3, 100%), and at the genus level (2 out of 2, 100%), but not at the family level (Cumberlidge *et al.* 2009) (Table 6.2).

Table 6.2 Number of species and genera (in parentheses) of freshwater crabs found in each country of the Arabian Peninsula

Country	Number of Species and Genera	Family, Subfamily	Species
Bahrain	0	-	-
Kuwait	0	-	-
Oman	0	-	-
Socotra Island, Republic of Yemen	3(2)	Potamidae, Potamiscinae	*Socotra pseudocardisoma* *Socotrapotamon socotrensis* *Socotrapotamon nodijensis*
Qatar	0	-	-
United Arab Emirates	0	-	-

6.3.1 Extirpated species

No species of freshwater crab from the Arabian Peninsula is known to have been extirpated and none are either Extinct (EX) or Extinct in the Wild (EW).

6.4 Major threats to crabs in the freshwater ecosystems of the Arabian Peninsula

Threats to crabs in Socotran freshwater ecosystems are mainly from changes in hydrology and habitat destruction driven by the demands of increasing tourism (Collen *et al.* 2008, Cumberlidge *et al.* 2009). *Socotrapotamon socotrensis* inhabits aquatic systems some of which are associated with population centers, and these are localities where pollution by sewage and general waste may become threat factors. The two range-restricted species of Socotran freshwater crabs (*Socotra pseudocardisoma*, in karst formations; and *Socotrapotamon nodijensis*, around waterfalls) depend on the careful management of both their habitats and the associated water resources, because these factors are most likely to have the biggest impact on their long-term survival.

Recent information on additional threats to the Socotra's aquatic ecosystems and their invertebrates comes from Belgian biologist Kay van Damme (pers comm.) who carried out field investigations there in March 2010. One such threat comes from the application of anti-malarial biocides in 1999 that polluted many of Socotra's river systems with toxic chemicals. These chemicals accumulate in the food chain, although their effects on the freshwater crab populations have still to be investigated. Other threats to Socotra's aquatic ecosystems include alterations of hydrological flow patterns caused by global climate change that could negatively impact the island's aquatic invertebrates. Field investigations in Socotra in March 2010 by Kay van Damme noted dramatic declines in some of the island's surface water systems and in the abundance of both species of *Socotrapotamon*. These sharp declines in crab populations warrant further investigation because these charismatic island endemics are not found anywhere else in the Arabian Peninsula. The threats to the species need more thorough investigation, and the species certainly require careful re-assessment to determine whether they are at risk of extinction. However, at present there is not enough field data to determine the full extent of any threats and the status of the populations.

6.5 Conservation recommendations

None of the three species of Socotran freshwater crabs are currently assessed as threatened (Tables 6.1, 6.3). Hence, the region's freshwater crab fauna does not appear to be in immediate trouble when compared with other assessed freshwater groups, such as fish, molluscs, and dragonflies found in the same freshwater habitats. The two Socotran freshwater crabs assessed as Least Concern have so far proved to be relatively tolerant of changes in land-use affecting the freshwater ecosystems where they are found. Nevertheless, all three species could suffer catastrophic declines should there be abrupt changes in hydrology, and there is at least some evidence that this might occur (see section 6.4 above). Human-induced loss of habitat is a primary cause for concern for the long-term survival of Socotra's unique freshwater crab fauna. There is an urgent need for new surveys to discover new species, refine species distributions, define specific habitat requirements, describe population levels and trends, and identify specific threats to Socotra's important endemic freshwater crab fauna.

Table 6.3 Summary of the Red List categories and the distribution of the species of freshwater crabs found in the Arabian Peninsula.

Species	RL Category	Range (km^2)	# Loc	PA
Socotra pseudocardisoma	LC	< 100	1	N
Socotrapotamon socotrensis	LC	< 1,000	4	N
Socotrapotamon nodijensis	DD	~ 10	1	N

RL = Red List, LC = Least Concern, DD = Data Deficient, Range = estimation of species distribution range based on distribution polygon of all known specimens, #Loc = number of discontinuous localities from which the species was collected, PA = protected area, N = not found in a PA.

6.6 References

Abell, R., Thieme, M. L., Revenga, C., Bryer, M., Kottelat, M., Bogutskaya, N., Coad, B., Mandrak, N., Balderas, S. C., Bussing, W., Stiassny, M. L. J., Skelton, P., Allen, G. R., Unmack, P., Naseka, A., Ng, R., Sindorf, N., Robertson, J., Armijo, E., Higgins, J. V., Heibel, T.J., Wikramanayake, E., Olson, D., López, H.L., Reis, R. E., Lundberg, J. G., Pérez, M. H. S., and Petry, P. 2008. Freshwater Ecoregions of the World: A New Map of Biogeographic Units for Freshwater Biodiversity Conservation. *BioScience* **58(5):** 403–414.

Apel, M. and Brandis, D. 2000. A new species of freshwater crab (Crustacea: Brachyura: Potamidae) from Socotra Island and description of *Socotrapotamon* n. gen. *Fauna of Arabia* **18**: 133–144.

Bachmayer, F. and Pretzmann, G. 1971. Krebsreste aus den altpliozanen Susswasserablagerungen des Eichkogels bei Modling, Niederosterreich. *Annalen des naturhistorischen Museums Wien* **75**: 283–291.

Bott, R. 1955. Die Süßwasserkrabben von Afrika (Crust., Decap.) und ihre Stammesgeschichte. *Annales du Musée du Congo belge* (*Tervuren, Belgique*) *C-Zool. Sér.* 3(III): 209–352.

Bott, R. 1967. Potamidae (Crustacea, Decapoda) aus Afghanistan, Westasien und dem Mittelmeerranum (Eine Revision der Untergattung *Potamon* s str.). Videnskabelige Meddelelser Naturhistorisk Forening i København, **130**: 7–43.

Bott, R. 1970. Betrachtungen über die Entwicklungsgeschichte und Verbreitung der Süßwasser-Krabben nach der Sammlung des Naturhistorischen Museums in Genf/Schweiz. *Revue suisse de Zoologie* **77**: 327–344.

Brandis, D., Storch, V. and Türkay, M. 2000. Taxonomy and zoogeography of the freshwater crabs of Europe, North Africa and the Middle East. *Senckenbergiana biologica* **2**: 5–56.

Collen, B., Ram, M., Dewhurst, N., Clausnitzer, V., Kalkman, V., Cumberlidge, N. and Baillie, J. E. M. 2008. Broadening the coverage of biodiversity assessments. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart (eds). *The 2008 Review of The IUCN Red List of Threatened Species*. IUCN Gland, Switzerland.

Cumberlidge, N. 1999. *The freshwater crabs of West Africa. Family Potamonautidae*. Faune et Flore Tropicales 35, Institut de recherche pour le développement (IRD, ex-ORSTOM), Paris, 382 pp.

Cumberlidge, N. 2008. Insular species of Afrotropical freshwater crabs (Crustacea: Decapoda: Brachyura: Potamonautidae and Potamidae) with special reference to Madagascar and the Seychelles. *Contributions to Zoology* **77(2)**: 71–81.

Cumberlidge, N. 2009. Chapter 27, Freshwater Crabs and Shrimps (Crustacea: Decapoda) of the Nile Basin. In H. J. Dumont (ed), The Nile. Origin, Environments, Limnology and Human Use. Monographiae Biologicae, Vol. **89** (Springer, New York), pp.547–561.

Cumberlidge, N. 2010. Chapter 6. The status and distribution of freshwater crabs, pp. 71–78. *In*: García, N., Cuttelod, A. and Abdul Malak, D. (eds.). *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. IUCN, Gland, Switzerland, Cambridge, UK, and Malaga, Spain: xiii+141pp.

Cumberlidge, N. and Ng, P. K. L. 2009. Systematics, evolution, and biogeography of the freshwater crabs. *In*: Crustacean Issues: Decapod Crustacean Phylogenetics, CRC, Leiden, 491–504.

Cumberlidge, N. and Wranik, W. 2002. A new genus and new species of freshwater crab (Potamoidea: Potamidae) from Socotra Island, Yemen. *Journal of Natural History* **36(1)**: 51–64.

Cumberlidge, N., R. v. Sternberg, S. R. Daniels. 2008. A revision of the higher taxonomy of the Afrotropical freshwater crabs (Decapoda: Brachyura) with a discussion of their biogeography. *Biological Journal of the Linnean Society* **93(2)**: 399–413.

Cumberlidge, N., Ng, P. K. L., Yeo, D. C. J., Magalhaes, C., Campos, M. R., Alvarez, F., Naruse, T., Daniels, S. R., Esser, L. J., Attipoe, F. Y. K., Clotilde-Ba, F.-L., Darwall, W., McIvor, A., Ram, M., and Collen, B. 2009. Freshwater crabs and the biodiversity crisis: importance, threats, status, and conservation challenges. *Biological Conservation* **142**: 1665–1673.

Daniels, S. R., Cumberlidge, N., Pérez-Losada, M., Marijnissen S. A. E., and Crandall, K. A. 2006. Evolution of Afrotropical freshwater crab lineages obscured by morphological convergence. *Molecular Phylogenetics and Evolution* **40**: 225–235.

Glaessner, M. 1929. Dekapodenstudien. *Neues Jahrbuch fur Mineralogie* etc., Beilagenband **LXIII**, **Abt. B**: 137–176.

Hilgendorf, F., 1883. Dans Taschenberg, Beitrage zur Fauna der Insel Sokotra, *Zeitschrift für Naturwissenschaft Halle* **11**(4):171–173.

IUCN. 2003. Guidelines for Application of IUCN Red List Criteria at Regional Levels: Version 3.0. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

Kingdon, J., 1989. *Island Africa* (Princeton University Press, Princeton, New Jersey) 287.

Klaus, S. Yeo, D. C. J., and Ahyong, S. T. 2011. Freshwater crab origins-Laying Gondwana to rest. *Zoologischer Anzeiger* **250**: 449–456.

Mies, B. and Zimmer, H. 1993. Die Vegetation der Insel Sokotra im Indischen Ozean, **Natur und Museum 123**: 253–264.

Mies, B., Behyl, F. E. and Printzen, C. 1995. Die Waldformationen der Insel Sokotra (Indischer Ozean), *Natur und Museum* **125**: 122–133.

Ng, P. K. L., Guinot, D. and Davie, P. J. F. 2008. Systema Brachyurorum: Part I. An annotated checklist of extant brachyuran crabs of the world. *Raffles Bulletin of Zoology Supplement* **17**: 1–286.

Ortmann, A. 1896. Das system der Decapoden-Krebse. *Zool. Jabh. (Syst.)* **9**: 409–453.

Reed, S. K. and Cumberlidge, N. 2004. Notes on the taxonomy of *Potamonautes obesus* (A Milne-Edwards, 1868) and *Potamonautes calcaratus* (Gordon, 1929) (Brachyura: Potamoidea:Potamonautidae) from eastern and southern Africa. *Zootaxa* **418**: 1–20.

Reed, S. K., Cumberlidge, N. 2006. Taxonomy and biogeography of the freshwater crabs of Tanzania, East Africa (Brachyura: Potamoidea: Potamonautidae, Platythelphusidae, Deckeniidae). *Zootaxa* **1262**: 1–139.

Shih, H.-T., Yeo, D. C. J. and Ng, P. K. L. 2009. The collision of the Indian plate with Asia: molecular evidence for its impact on the phylogeny of freshwater crabs (Brachyura: Potamidae). *Journal of Biogeography* **36**: 703–719.

Thieme, M. L., Abell, R. A., Stiassny, M. J. L., Skelton, P. A., Lehner, B. 2005. Freshwater ecoregions of Africa and Madagascar: A conservation assessment. Island Press, Washington, DC, USA.

Wranik, W. 1999. Sokotra, Mensch und Natur, J*emen Studien* 258.

Yeo, D. C. J., Ng, P. K. L, Cumberlidge, N., Magalhaes, C., Daniels, S. R., Campos, M. 2008. Global diversity of crabs (Crustacea: Decapoda: Brachyura) in freshwater. In: *Freshwater Animal Diversity Assessment. Hydrobiologia* **595**: 275–286.

Chapter 7. The status and distribution of wetland-dependent plants in the Arabian Peninsula

Patzelt, A.[1], Lansdown, R.V.[2], Knees, S.G.[3]

7.1 Introduction

Wetland-dependent plants provide a wide range of functions in freshwater ecosystems. They supply water with oxygen, fix atmospheric carbon, recycle nutrients, regulate water temperature and light, as well as protecting against erosion. They also provide vital habitat and food for fish and aquatic invertebrates, which themselves support other animals and humans. Many species of wetland-dependent plants, such as rice (*Oryza sativa*) and water-chestnut (*Trapa natans*) are eaten by people, while others have been used for a variety of purposes, such as papyrus (*Cyperus papyrus*) for writing and the Socotran *Exacum affine*, or the Persian Violet, which is now widely cultivated as an indoor ornamental plant. Many still are used for construction, such as common reed (*Phragmites australis*). Plants that are dependent upon wetlands are vulnerable to many anthropogenic pressures, from direct habitat loss through drainage and conversion to other land-uses to pollution and the secondary effects of hyper-eutrophication such as algal blooms.

The aim of this project was to assess the conservation status of vascular plant species occurring in wetlands in the Arabian Peninsula. The definition of which plants may be considered aquatic is not straightforward. The following definition was considered the most clear and unambiguous available: "Vascular aquatic plants are interpreted as all Pteridophytina and Spermatophytina whose photosynthetically active parts are permanently or, at least, for several months each year submerged in water or float on the surface of water" (Cook 1996). However, the decision was taken to extend the range of taxa included to cover species such as *Nerium oleander*, which is restricted to the edge of shallow semi-permanent and permanent water courses, as well as *Utricularia striatula* which grows as an epiphyte in the drought-deciduous *Anogeissus dhofarica* forest in southern Oman. Thus, the project considered the conservation requirements of all plants occurring in the Arabian Peninsula which are dependent upon wetlands; these are species which would not occur if there were no wetlands.

A fundamental principle of these assessments was not to pre-judge the conservation condition, such as by selecting species known or believed to be of conservation concern, as this approach is likely to support existing areas of concern, but overlook taxa which are not already known to be at risk. Therefore all plants occurring in the region which might be considered dependent upon wetlands were assessed.

The vascular plant taxa covered by this assessment can be grouped as follows:

- Always completely submerged (obligate submerged aquatics) such as the naiads (Najadaceae).
- Submerged with sexually reproductive parts emergent (held above the water or at the surface), such as *Potamogeton natans*.
- Emergent, the roots and base of the plant are submerged, but some photosynthetic parts and sexually reproductive parts are held above the water, such as *Eleocharis*, *Marsilea*, *Schoenoplectus* and *Typha* species.
- Floating, without roots or with roots hanging in the water column, such as hornworts (*Ceratophyllum* sp.) and duckweeds (Lemnaceae).
- Amphibious, growing from the land over the water or adopting a variety of the above forms, such as some *Persicaria* species.

1 Oman Botanic Garden, Diwan of Royal Court, P.O. Box 808, Muscat 122, Sultanate of Oman.
2 Ardeola Environmental Services, 45 The Bridle, Stroud, Glos. GL5 4SQ, UK.
3 Centre for Middle Eastern Plants (CMEP), Royal Botanic Garden Edinburgh, 20A Inverleith Row, Edinburgh, EH3 5LR, UK.

- Marginal plants and those associated with ephemeral wetlands.

The following taxa were excluded from the assessment:

- Taxa known or suspected not to be native to the region; however, this distinction is not always straightforward, particularly when considering long-established cultivated plants.
- Hybrids and taxa below species level.

The availability of information on plants in the region is not uniform. Recent intensive research combined with conservation assessment of plants on Socotra and neighbouring islands (Miller and Morris 2004) means that an accurate picture of the conservation status of wetland-dependent plants in the archipelago can be established. Similarly, as a result of recent conservation assessments for plants in Oman (Patzelt in press.), there is generally good information for Oman. Most of the available information for the rest of the Peninsula is either sparse or out of date and this is particularly the case for some mountainous areas.

Where the information was available, the taxonomic treatment by The World Checklist of Selected Plant Families (The Board of Trustees of the Royal Botanic Gardens, Kew 2013) was followed. In cases where names had not yet been treated by this checklist, The Plant List

Exacum aff. *affine* (Gentianaceae) from southern Oman. The species is restricted to a small number of limestone springs at the foothills of the mountains. The closely related *Exacum affine* (LC), known commercially as the Persian Violet, is endemic to Socotra. Photo © Annette Patzelt

(2010) was followed. Data were derived from field observations and records, a range of published sources, including mainstream and the "grey" literature, the National Herbarium in Oman (ON), the herbarium at Oman Botanic Garden, and the Royal Botanic Garden Edinburgh (E) databases.

There are areas of taxonomic uncertainty affecting wetland-dependent plants, in particular, the taxonomy of *Ranunculus* subgenus *Batrachium* is very poorly elucidated and the subject of a number of different concurrent treatments (Lansdown 2007). Equally, there

Wadi Daykah in northern Oman is one of the largest permanent water bodies in the country. Photo © Annette Patzelt

are populations of a species of *Exacum* (Gentianaceae) occurring in the southern region of Oman that resemble *Exacum affine*, a species endemic to Socotra (Knees and Miller 2006), but which are considered to be distinct (Patzelt in press.). The populations in Oman are threatened, but because they have yet to be formally described, they have been considered here as part of *E. affine*. Once this taxon has been formally described, it will be possible to assess its conservation status separately.

Maps have been produced showing the distribution of species in relation to catchments (using HydroSHEDS spatial data layers; see Chapter 2). However, in the Arabian Peninsula the distribution of wetland-dependent plants is not strongly linked to catchments and consequently these maps give the impression that many species occur over a larger area than is actually the case.

Permanent or semi-permanent pools in wadi systems are usually very small in size and localised in their distribution. Photo © Annette Patzelt

7.2 Overview of the regional aquatic flora

While the Arabian region mainly comprises dry, arid habitats, there are also several permanent freshwater systems with high species diversity including endemic and threatened species (see Chapter 1). Large numbers of species of freshwater plants are found in southern Oman, the Hajar mountains of northern Oman, the mountain chain in south-western Yemen, the Asir and Al Hijaz mountain ranges in Saudi Arabia, and the Haggeher and Hager ranges on Socotra Island (Yemen).

Areas of higher species richness are found in central Saudi Arabia, the United Arab Emirates, Bahrain, Qatar and Kuwait. Species diversity is likely to be underrepresented in remote areas, because the aquatic flora of areas difficult to reach is poorly known.

Species richness is relatively low in much of the northern part of the Arabian Peninsula, where the freshwater

Limestone seepages on the southern coast of Socotra provide a unique habitat for Critically Endangered species such as *Scaevola socotraensis.* Photo © Sabina G. Knees CMEP/RBGE

flora is characterised by a lower number of widespread pantropical species. In the central Arabian Peninsula, covered by the vast sand desert of the Rub Al Khali, there are very few wetland-dependent plants. Throughout the Arabian Peninsula, overgrazing and disturbance as well as surface water abstraction has led to severe degradation of the vegetation of many permanent water bodies.

Many natural water bodies in the region are seasonal and the region contains a few permanent water bodies such as in the mountain areas of Oman, and on the inner slope of the Asir Mountains in Saudi Arabia. The main habitats supporting wetland dependent plants are small pools in wadis, small marshes and localised water bodies. Not surprisingly, most wetland vegetation in the region is characterised by plants which are able to tolerate drought and which grow on the margins of pools, in irrigated areas and on damp, disturbed ground.

Throughout much of the Peninsula, apart from the coastal mountainous regions, drainages are typically internal and endorheic or intermittent and do not reach their terminal basins. Natural streams and wadis tend to be very "flashy" in that they respond rapidly to the erratic rainfall, such that water-levels and flow velocity vary considerably. Only a few wetland dependant plant species are able to cope with these conditions.

The small number and scale of permanent water bodies means that the region supports few obligate wetland-dependent plant species; those which do occur are typically species with a wide global distribution such as hornworts (*Ceratophyllum* species), duckweeds (*Lemna* species) the grass *Isachne globosa*, naiads (*Najas* species), pondweeds (*Potamogeton* species) and water-crowfoots (species of *Ranunculus* subgenus *Batrachium*). Floating plants such as *Lemna* species and rare *Utricularia* species are less abundant than other life-forms.

A number of species grow along the margins of wadis in shallow water, but not in deep standing water. These may also be considered wetland plants, but their relationship is with the readily available water in the soil, rather than surface water. These include species such as *Arundo donax* (LC), *Nerium oleander* (LC), *Salix acmophylla* (LC), which is rare in the Peninsula, and grasses such as *Saccharum kajkaiense* (LC), *S. ravennae* (LC) and *S. spontaneum* (LC). The margins of pools, irrigated areas and moist, disturbed ground are dominated by sedges (Cyperaceae) and grasses (Poaceae), but also include a range of bistorts or water-peppers (*Persicaria* species) and rushes (Juncaceae) among other species. These species also dominate the vegetation in marshy areas, which occur along the Red Sea Escarpment in Yemen and Saudi Arabia.

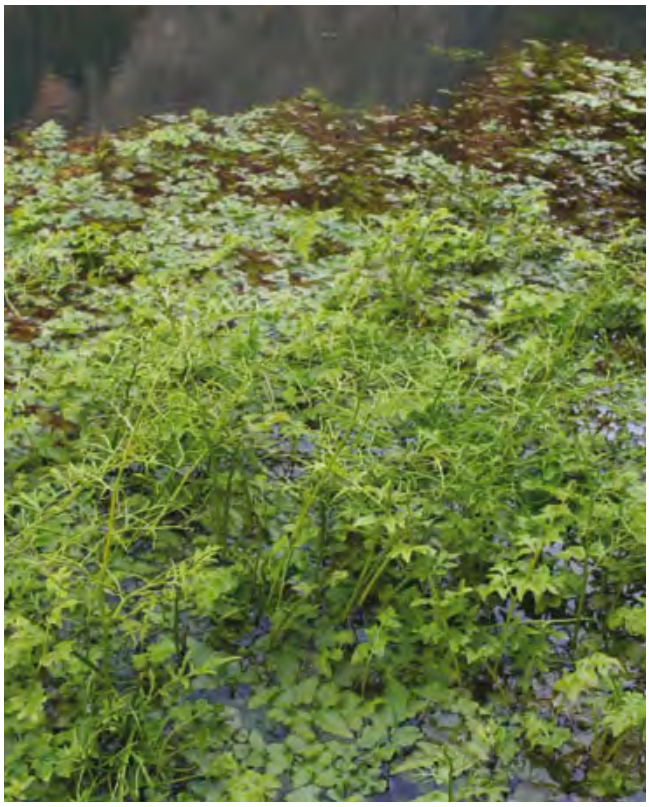
Very localised limestone springs in southern Arabia provide a rare habitat for the aquatic fern *Ceratopteris cornuta* (Water lettuce, Water sprite), assessed Critically Endangered in the Arabian Peninsula. Photo © Annette Patzelt

Seasonally inundated depressions are a particularly important habitat for local wetland plant species on the Red Sea Escarpment, in Oman and on the islands of the Socotra archipelago. This habitat typically supports species capable of surviving as annuals, but which persist during dry periods in the seed-bank, including a number of rare or local taxa, such as *Exacum socotranum* (CR), *Panicum socotranum* (CR) and *Bergia polyantha* (VU).

A number of both submerged and emergent species of plant are found at the edge of permanent water bodies or in shallow water. Typical elements at the edge of water pools and slowly moving water in wadi systems include *Schoenoplectus lacustris* (LC), *S. litoralis* (VU), *Bolboschoenus maritimus* (LC) and *Juncus* species. The aquatic fern *Ceratopteris cornuta* (CR), usually rooting in mud, is restricted to a few isolated swamps and springs in southern Arabia.

The mountains of southern Oman and adjacent Yemen are influenced by the southwest monsoon, which creates a tropical fog-oasis in an arid environment. The area is an outstanding example of an island-like refugium: a seasonal cloud-forest in an otherwise arid environment (Miller 1994, Hildebrandt and Eltahir 2006, Patzelt

The fertile fronds of *Ceratopteris cornuta* (CR) are erect, longer, narrower and more divided than the sterile floating fronds. The species always occurs in small populations and is threatened by ecosystem modifications. Photo © Annette Patzelt



The Pondweed *Potamogeton nodosus* (Potamogetonaceae) (LC) is common and widespread and can be found in permanent water bodies in Oman, Saudi Arabia and Yemen including Socotra. Photo © Annette Patzelt

2011). This mountain chain has a unique climate which is reflected in high plant species diversity with high levels of endemism, where endemic palaeo-African relict forest communities, dominated by the endemic *Anogeissus dhofarica* are found (Kürschner *et al.* 2004). In this semi-deciduous cloud-forest, the rare *Utricularia striatula* (EN) is found as an annual epiphyte on the bark of trees (Miller and Cope 1996; Patzelt, in press.). This plant community also includes larger permanent water bodies.

The mountains in northern Oman are part of an arid subtropical mountain system extending from southern Arabia to Southwest Asia, with a strong element of endemism and remarkable relict species. Above 1,500 m, the vegetation is dominated by *Olea europaea* subsp. *cuspidata* and *Juniperus excelsa* subsp. *polycarpos*; here, wetland-dependent plants are mostly restricted to man-made structures, as almost no permanent or semi-permanent natural water bodies occur in this arid environment. Occasionally, the hygrophilous Maidenhair fern (*Adiantum capillus-verneris*) (LC) and the orchid *Epipactis veratrifolia* (EN) are found in small springs, seepages, rock cavities with dripping water, and on moist man-made terrace walls.

The Maidenhair fern *Adiantum capillus-veneris* (Adiantaceae) (LC) is common and widespread on the Arabian Peninsula. It often may be seen growing on moist, sheltered and shaded limestone formations, and in gorges and wadis, in springs and seepages. Photo © Annette Patzelt

The rare Eastern marsh helleborine *Epipactis veratrifolia* (Orchidaceae) (EN) is restricted to small populations and is threated by recreational activities, natural system modifications such as changing hydrology and drought. Photo © Annette Patzelt

Wetland dependent plants, particularly ferns such as *Adiantum capillus-veneris* (LC) and *Pteris vittata* (LC) may also occur in areas which do not permanently hold water, but remain humid due to the topography. Where waterfalls or seepages further increase humidity, rock faces and walls may support other species such as *Poa schimperiana* (LC) and local endemics, including *Festuca yemenensis* (VU) and *Scaevola socotraensis* (CR) (Cope 2007).

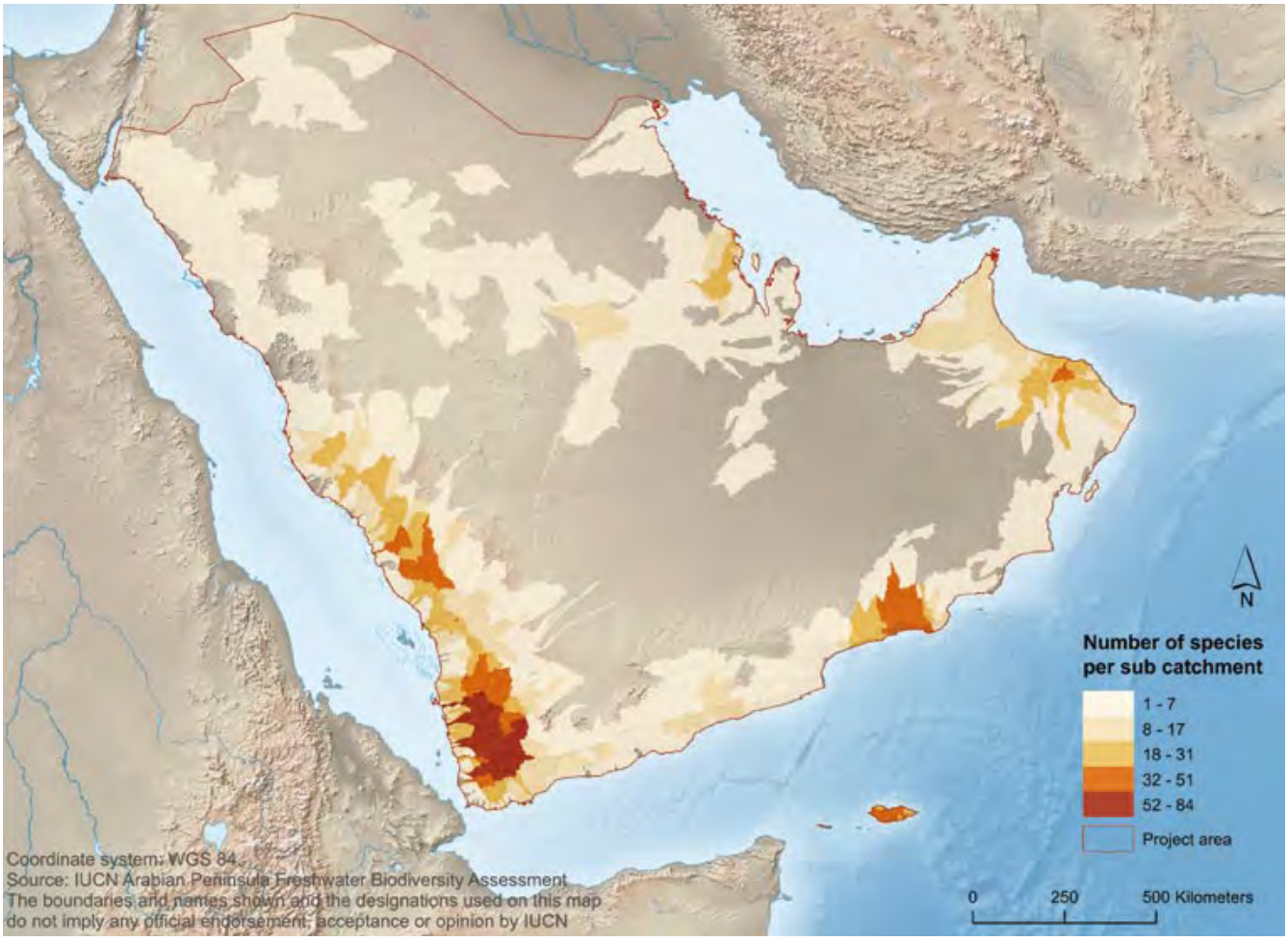
In parts of the region, irrigation channel systems, called "aflaj" (singular "falaj") in Oman and qanats in other countries, represent an important habitat in areas where there are no natural water bodies. Especially around leaks of old and less-well maintained water channels, plants dependant on wet or moist soil, such as *Lindenbergia indica* (LC), and *Bacopa monnieri* (LC) occur. As a traditional water supply, the water channels are variously maintained or abandoned for pump wells. Wetland-dependent plants are typical found in artificial habitats such as irrigated land, damp areas around settlements and along the irrigation channels (Patzelt 2010).

The comparison of the total species richness of wetland-dependent plants per country (Figure 7.1) shows that Yemen, including the Socotra archipelago, has the highest species richness of wetland dependant plants, followed by Oman and Saudi Arabia. The UAE, Bahrain, Qatar and Kuwait support fewer wetland-dependent species, because aquatic habitat structures and permanent freshwater systems are less common.

In the Arabian Peninsula, mountain ranges typically support more wetland-dependent plants than the lowlands. There are many reasons for this, but the most important are:

1. Mountains typically support complex geology and topography with high peaks, deep ravines, wadis and springs. As a result there many different habitats for species to occur, with pockets of high humidity, where water may not be lost quickly through evaporation.
2. Many habitats occur as small isolated patches whilst at the same time, many species are altitude or habitat specific. This leads to increased speciation.

Figure 7.1. The distribution of wetland-dependent plant species across the Arabian Peninsula region, mapped to river sub-catchments



A falaj in Oman refers to water that runs through a channel dug in the earth or built by stones and rock. Leaks and holes in the irrigation system support wetland plant life. This irrigation system is deep-rooted in Oman's land and history. Photo © Annette Patzelt

3. The southern Arabian Peninsula is at a biogeographical crossroad between Africa and Asia and many species characteristic of one or other region occur, particularly in south-western Yemen and southern Oman.
4. The mountain systems function in a similar way to islands, isolated from similar habitats by the surrounding desert.

7.3 Conservation status (IUCN Red List criteria: regional scale)

The status of a total of 182 species of wetland-dependent plants was assessed at a regional level. Within the Arabian Peninsula, 12.6% of the species assessed (23 species) are considered threatened with extinction, with 3.8% of them being Critically Endangered, 3.8%

Table 7.1. The number of wetland-dependent plant species in each Red List Category in the Arabian Peninsula.

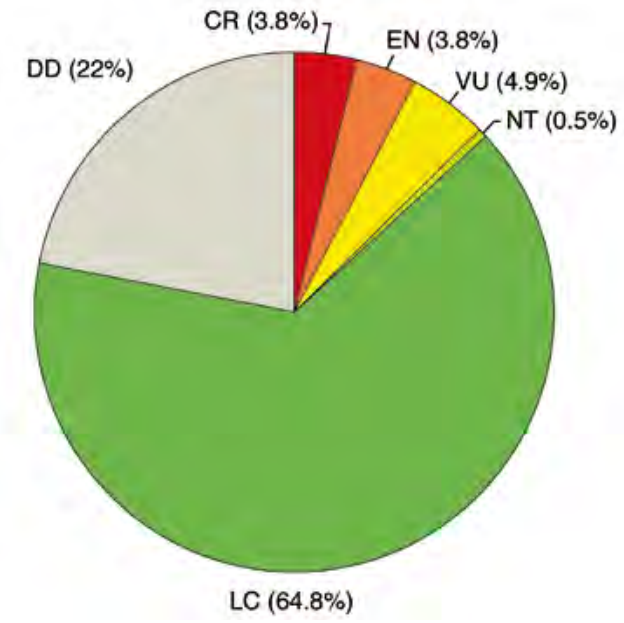
	Regional Red List Category	Number of species	Number of Regional Endemics
Threatened categories	Critically Endangered (CR)	7	3
	Endangered (EN)	7	0
	Vulnerable (VU)	9	2
	Near Threatened (NT)	1	0
	Least Concern (LC)	118	2
	Data Deficient (DD)	40	0
	Not Evaluated	-	0
	Total number of taxa assessed*	**182**	**7**

* All species assessed as regionally threatened which are endemic to the region are also globally threatened

Table 7.2 Threatened wetland-dependent plant species in the Arabian Peninsula.

Family	Species	Regional Red List Category	Criteria	Endemic
CONVOLVULACEAE	*Stictocardia tiliifolia*	CR	D	
CYPERACEAE	*Pycreus dwarkensis*	CR	B2ab(iii)	
GENTIANACEAE	*Exacum socotranum*	CR	B2ab(iii)	yes
GOODENIACEAE	*Scaevola socotraensis*	CR	B2ab(iii)	yes
GRAMINEAE	*Panicum socotranum*	CR	B2ab(iii)	yes
PARKERIACEAE	*Ceratopteris cornuta*	CR	B2ab(iii)	
PTERIDACEAE	*Acrostichum aureum*	CR	D	
CRASSULACEAE	*Crassula hedbergii*	EN	B2ab(iii)	
CYPERACEAE	*Cyperus alulatus*	EN	B2ab(iii)	
CYPERACEAE	*Fimbristylis bisumbellata*	EN	B2ab(ii,iii)	
GRAMINEAE	*Odontelytrum abyssinicum*	EN	B2ab(iii)	
LENTIBULARIACEAE	*Utricularia minor*	EN	B2ab(iii)	
LENTIBULARIACEAE	*Utricularia striatula*	EN	B2ab(iii)	
ORCHIDACEAE	*Epipactis veratrifolia*	EN	B2ab(ii,iii,v)	
ELATINACEAE	*Bergia polyantha*	VU	D2	
GRAMINEAE	*Festuca yemenensis*	VU	D2	yes
CYPERACEAE	*Fuirena felicis*	VU	D2	yes
UMBELLIFERAE	*Hydrocotyle sibthorpioides*	VU	D2	
POLYGONACEAE	*Persicaria senegalensis*	VU	D2	
COMPOSITAE	*Pulicaria arabica*	VU	B2ab(iii)	
CYPERACEAE	*Schoenoplectiella proxima*	VU	D2	
CYPERACEAE	*Schoenoplectus lacustris*	VU	B2ab(iii)	
CYPERACEAE	*Schoenus nigricans*	VU	B2ab(ii,iii)	

Figure 7.2. The proportions (%) of wetland-dependent plant species in each regional Red List category in the Arabian Peninsula

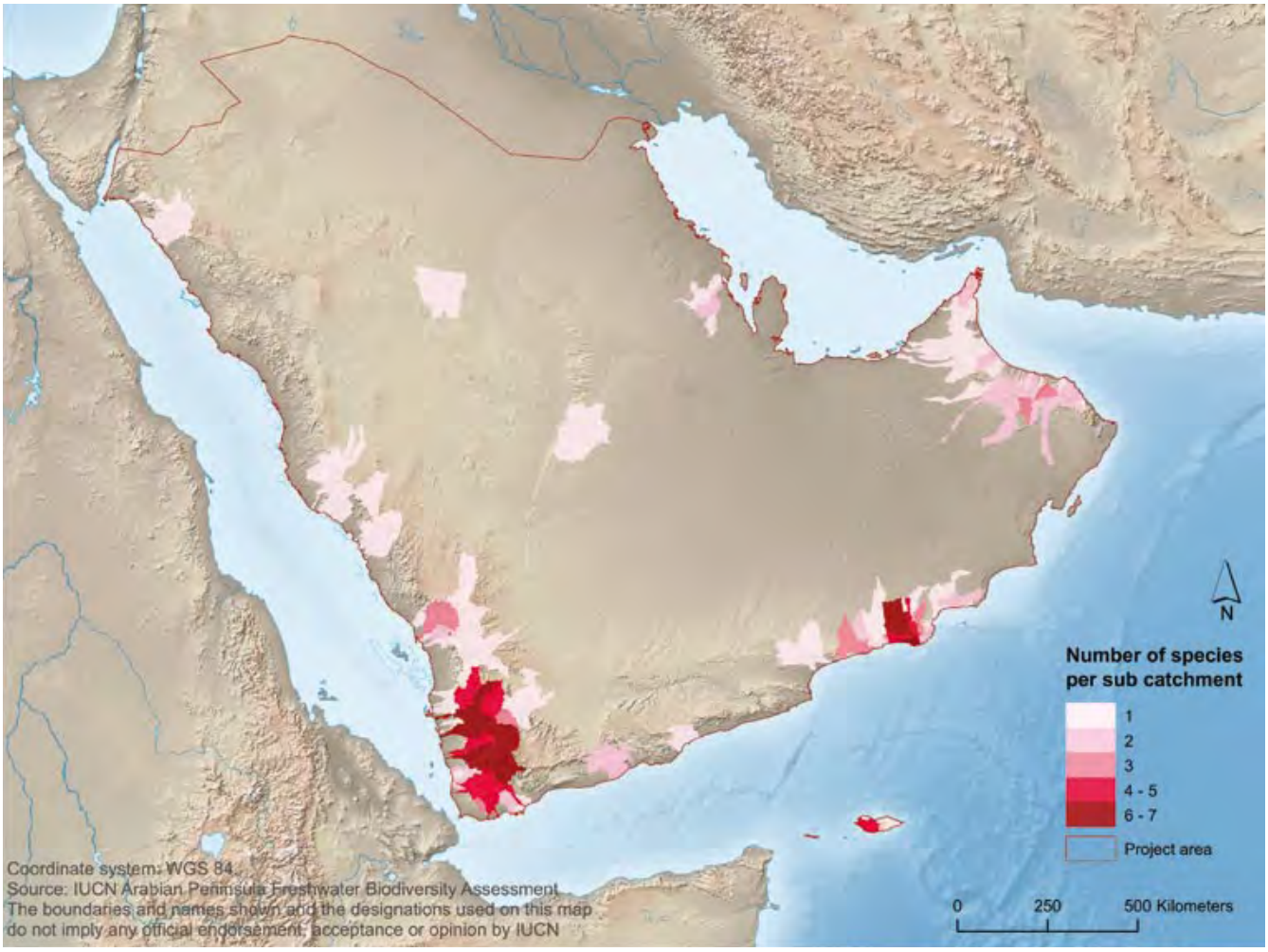


Endangered and 4.9% Vulnerable (Tables 7.1 and 7.2, Figures 7.2 and 7.3); one species is classed as Near Threatened.

The threats to the wetland-dependent plants of the Arabian Peninsula are fundamentally caused by the conflict between supply and demand for natural resources. The species assessed are therefore mainly affected by habitat loss and degradation induced by human activities, such as development and agriculture, and natural system modifications resulting from unsustainable human mismanagement of the environment.

The majority of threatened wetland-dependent plants in the region are found in montane areas (Figure 7.3) and the patterns of abundance closely follow the areas of species diversity (Figure 7.1) as well as the areas of endemic species (Figure 7.4). The main areas of threat include the Yemen highlands, where springs are being

Figure 7.3. The distribution of threatened wetland-dependent plant species across the Arabian Peninsula region, mapped to river sub-catchments



converted to facilitate abstraction and the vegetation is removed to improve the 'cleanliness' of the off-take area. In Oman, threatened species mainly include species dependent upon springs and permanent pools, of which several have been altered to cemented structures.

In the Asir mountains (Saudi Arabia), in northern and southern Oman, in the Yemen highlands and on Socotra, building development and recent road construction has had a severe effect on local hydrology, causing the loss of springs and many small bodies of semi-permanent water, as well as severely affecting permanent water bodies in larger wadi systems. The high degree of threat to montane wetland-dependent plant populations is partly because the mountains are species rich, but also partly due to the level of threat imposed by man. There is massive pressure due to the increasing urbanisation of the region, especially on the highlands of mainland Yemen and north-eastern Socotra, the Asir mountains in Saudi Arabia, as well as in mountain areas in Oman and the UAE, in relation to the growing human population and the on-going expansion of the tourist infrastructure. Even small-scale disturbance, such as a single road, can destroy the habitat of narrow-range endemic and rare aquatic species, and there is little chance of recovery from neighbouring areas.

Adapting springs to use for water supply for animals and as recreational area by concreting the spring is a major threat to rare plant species. The fringing vegetation and all aquatic plant life are usually eradicated during the construction process. Photo © Annette Patzelt

Natural limestone springs are found at the foothills of the mountain systems in southern Oman. The fringing vegetation holds rare and threatened species. Photo © Annette Patzelt

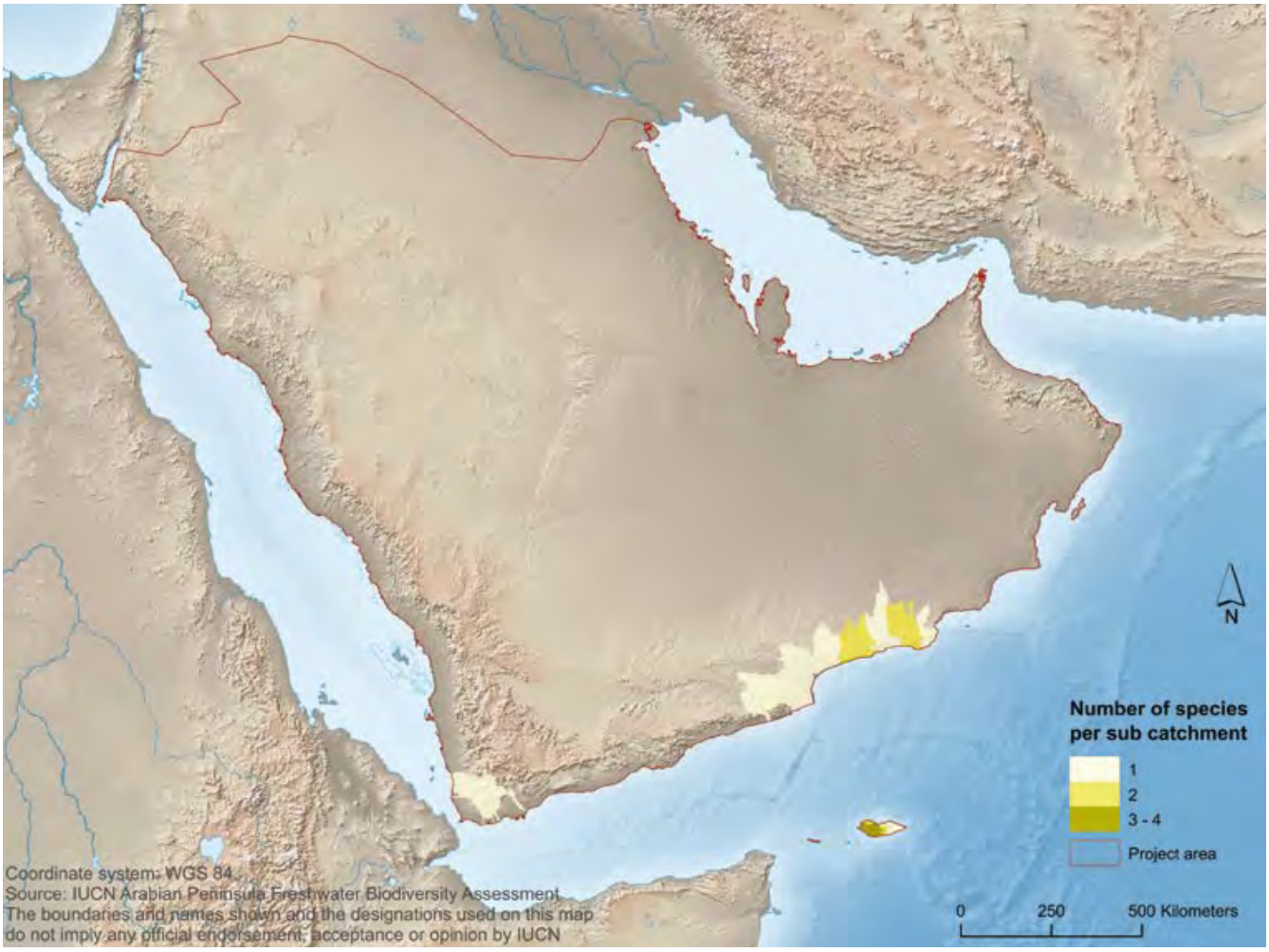
Seasonally wet pools are common in the deeply cut gorges in central Socotra. Photo © Sabina G. Knees CMEP/RBGE

Areas with high levels of endemism among wetland-dependent plants in the Peninsula (Figure 7.4) reflect the areas of high species diversity, with an increase in endemism from north to south and high levels of endemism in the southern Arabian Peninsula. The islands of Socotra as well as southern Oman hold a significant proportion of narrow-range endemic species, some of which are listed as threatened either at a national or global level. The Socotra archipelago has the highest number of endemics found in aquatic habitats and many of these are confined to wet refugia, in areas usually mountainous, which typically catch monsoon precipitation. These vary in size from just a few square kilometres, such as the north-facing limestone escarpment on Samha or the limestone plateau on Abd al Kuri, to several hundred square kilometres such as the granitic central highlands and the adjacent limestone plateaux on Socotra.

In general, both southern Oman and Socotra show regions that have high taxonomic diversity as well as high numbers of endemic species (Miller and Nyberg

In Yemen, several permanent pools occur on the limestone plateaux such as this at Hamadero, Socotra, providing good habitats for marginal wetland species including *Juncus socotranus*. These water bodies also provide habitats for freshwater crabs and dragonflies. Photo © Sabina G. Knees CMEP/RBGE

Figure 7.4. The distribution of endemic wetland-dependent plant species across the Arabian Peninsula region, mapped to river sub-catchments.



1991, White and Léonard 1991, Miller and Morris 2004, Patzelt in press). The montane areas of the Red Sea escarpment in Yemen and Saudi Arabia support only few aquatic endemics, because most aquatic species found there represent range extensions of species with a larger, more northern distribution.

Generally, three endemism hotspots can be identified as follows:

1. The south-west monsoon-affected regions in southern Oman and southeast Yemen, a regional centre of plant endemism with a vegetation unique on a global scale.
2. South-western Saudi Arabia and the adjacent Yemen highlands.
3. Socotra Archipelago, with seven principal "wet refugia" identified:
   - Granitic central highlands and adjacent limestone plateaux in north-central Socotra
   - Limestone plateaux and escarpments (principally Riqadrihon and Hamaderoh) in north-eastern Socotra
   - Jebel Ma'alih in north-western Socotra
   - Hager, limestone ridge above Ras Shu'ub in western Socotra
   - Qatariyah limestone plateau in south-western Socotra
   - North-facing limestone escarpment on Samha
   - Limestone plateau and cliffs of Jebel Saleh on Abd al Kuri

A large proportion (22%; 40 species) of the species assessed are classed as Data Deficient (Table 7.3). In general, the distribution of these species (Figure 7.5) follows that of the threatened and endemic species apart from only very small numbers occurring on Socotra, because of the intensive research which has recently been carried out (Miller and Morris 2004). However the limits to data availability in the highlands of Yemen and Saudi Arabia are evident in the high proportion of Data Deficient species there, compared to other regions.

These species, although often widely distributed outside the region, are frequently only known from one or two

Figure 7.5. The distribution of Data Deficient wetland-dependent plant species across the Arabian Peninsula region, mapped to river sub-catchments

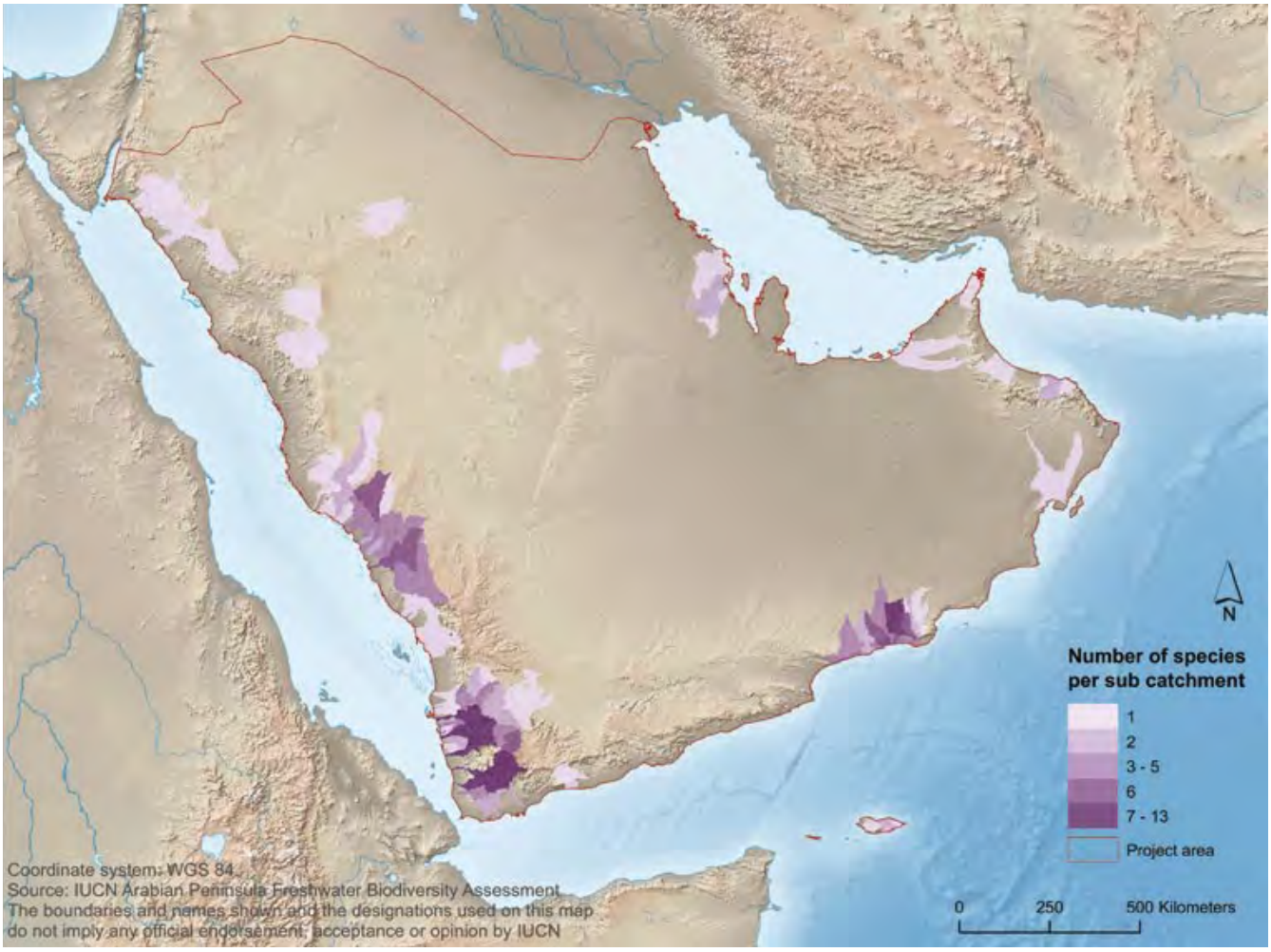


Table 7.3. Data Deficient wetland-dependent plant species in the Arabian Peninsula. None of the species are endemic to the region.

Species	Regional Red List Category	Global Red List Category
Anagallis serpens	DD	DD
Bolboschoenus glaucus	DD	DD
Bolboschoenus maritimus	DD	LC
Brachiaria mutica	DD	LC
Ceratophyllum submersum	DD	LC
Cyperus compressus	DD	LC
Cyperus difformis	DD	LC
Cyperus esculentus	DD	LC
Cyperus fuscus	DD	LC
Cyperus iria	DD	LC
Cyperus longus	DD	LC
Cyperus nutans	DD	LC
Cyperus wissmannii	DD	DD
Echinochloa pyramidalis	DD	LC
Eleocharis marginulata	DD	LC
Eleocharis uniglumis	DD	LC
Fimbristylis dichotoma	DD	LC
Fimbristylis turkestanica	DD	LC
Hemarthria altissima	DD	LC
Isachne globosa	DD	LC
Limosella macrantha	DD	LC
Myriophyllum spicatum	DD	LC
Najas graminea	DD	LC
Osteospermum muricatum	DD	LC
Phragmites karka	DD	LC
Polypogon schimperianus	DD	DD
Potamogeton coloratus	DD	LC
Potamogeton lucens	DD	LC
Pycreus polystachyos	DD	LC
Pycreus sanguinolentus	DD	LC
Ranunculus rionii	DD	LC
Ranunculus sphaerospermus	DD	LC
Ranunculus trichophyllus	DD	LC
Schoenoplectus corymbosus	DD	LC
Schoenoplectus mucronatus	DD	LC
Sebaea microphylla	DD	LC
Sebaea pentandra	DD	LC
Utricularia australis	DD	LC
Veronica anagalloides	DD	LC
Veronica beccabunga	DD	LC

gatherings within the Peninsula and in many cases these collections do not provide sufficient information on which to base a thorough assessment. Until more studies of these taxa can be made they have been listed here as Data Deficient.

7.4 Major threats to wetland dependent plants of the Arabian Peninsula

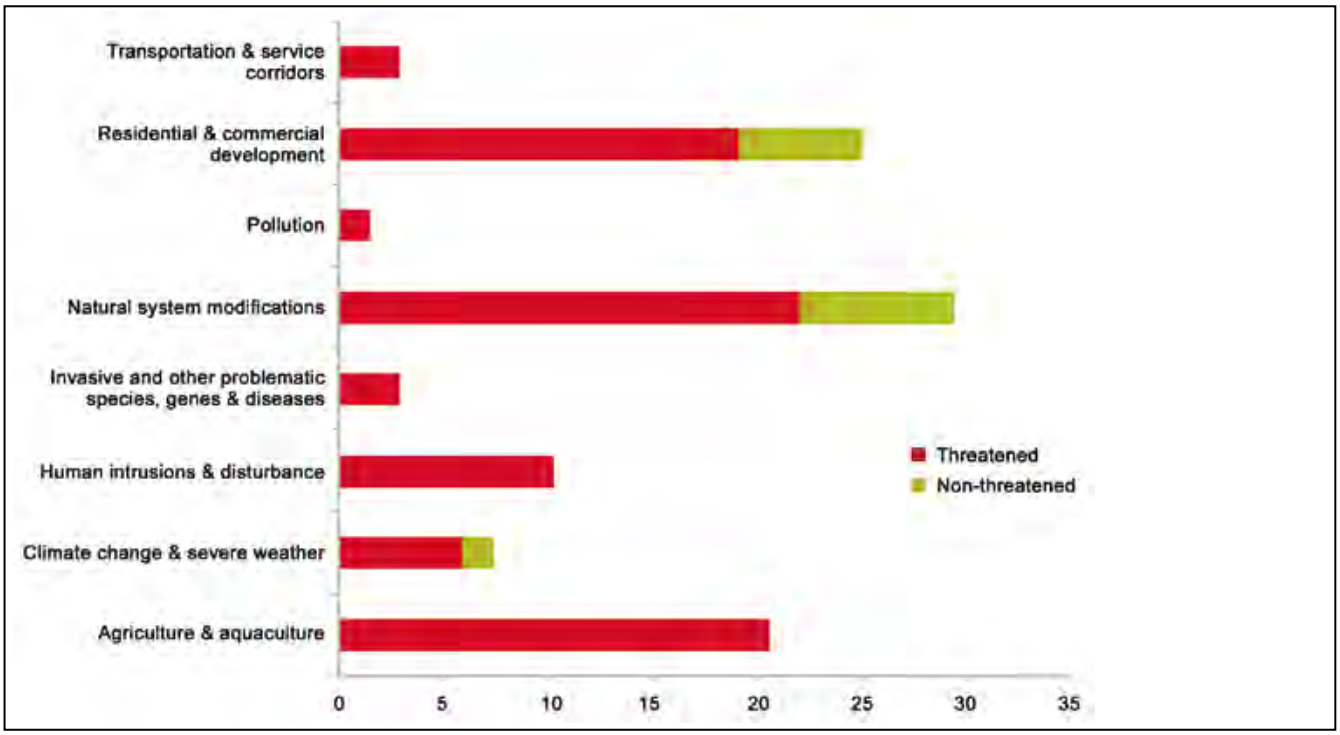
7.4.1 General overview of threats

Habitat loss and degradation through natural system modifications, residential and commercial development and through agriculture are the main threats to wetland-dependent plants in the Arabian Peninsula (Figure 7.6). Natural system modifications affect 30% of the threatened wetland-dependent plant species, residential, commercial development 25%, and agriculture 22%.

Climate change and severe weather, especially droughts and strong high flow events severely affect some freshwater species and have a direct effect on wetland-dependent plant populations. These threats are expected to worsen in the future due to the increasing effects of climate change (Botkin *et al.* 2007, Dawson *et al.* 2011).

In the Arabian Peninsula, *Stictocardia tiliifolia* (Convolvulaceae) (CR) is only found in one location, occurring in small numbers. It is threatened by infrastructure and tourism development. Photo © Annette Patzelt

Figure 7.6. Percentage of wetland-dependent plants in the Arabian Peninsula affected by major categories of threat



7.4.2 Habitat loss and degradation

The greatest threat to the wetland-dependent plants of the region is the loss and degradation of suitable habitat mainly through drainage of wetlands for development or for agriculture. This is mainly due to encroaching urbanisation, tourism and recreational activities. For example, the rare *Stictocardia tiliifolia* is only found in one location on the Arabian Peninsula (in southern Oman), where it is Critically Endangered as a result of planned recreation and tourism infrastructure development.

Some threatened or endemic species are directly affected by the increasing number of visitors to sites where infrastructure development such as the building of paths, tracks and roads affects their habitat. This is, for example, the case of *Salix acmophylla* (LC) and *Epipactis veratrifolia* (EN). Some species are vulnerable to human disturbance as they can be easily destroyed by trampling, including delicate herbaceous plants such as *Myosotis laxa* (LC) and *Hydrocotyle sibthorpioides* (VU) only found in swampy areas close to areas of cultivation in the Yemen highlands.

Plant populations that occur on islands are extremely vulnerable to genetic erosion as they often do not have any neighbouring populations, which could work as a source genepool. An additional pressure on island populations is the degradation and fragmentation of their habitats due to an increasing human population combined with the development of tourism and recreation, especially in coastal areas. This is particularly true for Socotra, where the few fragile coastal lagoons are becoming increasingly polluted. The potential for subsequent loss of marginal species is high. However, the coastal development in Oman, the UAE, Qatar, Bahrain and Kuwait is also substantial and habitat loss occurs at an alarming rate.

7.4.3 Modification of water sources and changes to flow regime

Water bodies in the Arabian Peninsula are modified in a variety of ways for a wide range of reasons. Typical examples of water body modifications which adversely affect wetland-dependent plants include:

- Realignment of water courses for road construction
- Concreting the beds of natural water flows
- Adapting springs to abstract water to supply local villages and their livestock, removing fringing vegetation, and concreting spring beds

Dams and their associated reservoirs adversely affect freshwater biodiversity and change ecosystems. Photo © Annette Patzelt

- Adapting thermal springs to use the water for swimming and washing, again removing fringing vegetation, and concreting spring beds
- Construction of dams

These practices have increased in frequency and impact in the last three decades. Although there are a relatively small number of permanent larger water systems in the region, an increasing number have been highly regulated by dams built in recent years, and more dams are planned.

Most of the wetland-dependent plants in the region are dependent upon the draw-down zones of permanent water bodies (fringing parts of permament water bodies as well as areas further downstream that may vary from being inundated to dry based on natural draw down). Consequently, they are extremely vulnerable to stabilisation of water levels, which allows colonisation by more aggressive plants dependent upon the permanent availability of water. Stabilisation of water levels also permanently inundates the seed bank of ephemeral species which cannot grow in water, but are typical for moist ephemeral wetlands. Much of the stabilisation of water levels is the result of dams blocking flowing water or the conversion of springs and seasonal pools to structures that permanently hold water.

Dams are built in permanently wet wadi systems for electricity generation and for industrial and domestic supplies. Damming to create water storage reservoirs affects the upper reaches of water systems. In general, data indicate biodiversity loss through dam construction, ultimately resulting in common species replacing rare ones (McAllister *et al.* 2001). An overall increase in species numbers hides a real decline in 'natural' plant diversity. Dams and their reservoirs form barriers that

will modify the hydrological landscape by altering the fluctuations in water level, and changing in water-chemistry, temperature, oxygen content and sediment load, and thus potentially affecting sensitive species.

7.4.4 Over-abstraction of water

Large-scale habitat destruction due to excessive water abstraction is a threat that has reached critical proportions, especially in the Yemen highlands, one of the most water-stressed countries on earth. The human population has grown alongside water corridors and the intensification of agriculture has led to loss of natural wetlands due to surface and groundwater abstraction. In Yemen, production of the recreational drug, qat (*Catha edulis*) has doubled in the last two decades, consuming 90% of Yemen's water (Sullivan 2012). Overuse of underground water has resulted in an increase of underlying saline waters and has led to the disappearance of surface water bodies. The 21 aquifers that surround the capital city Sana'a are drying up very rapidly and the water table is recorded as falling by c. 2m per year (Brown 2008).

Permanent water bodies are now becoming seasonal in many parts of the Arabian Peninsula and are no longer suitable for most species that require a constant availability of water for their survival. The water table of many natural streams is also being lowered by groundwater abstraction for irrigation.

7.4.5 Water pollution

Water pollution is a problem throughout the Arabian Peninsula and in general it is a consequence of the unregulated discharge of waste water from agriculture, industry and domestic human activities, such as high concentrations of detergents from washing clothes, into natural water bodies. However, some countries, e.g. Oman and the UAE, have invested substantially in water treatment plants and unregulated discharge of waste is much reduced, littering however remains a major problem. In Yemen, most streams and small standing water bodies around human populations are very polluted, a problem exemplified by the recent accumulation of litter and rubbish in Khor Qalansiyah (see photo), a large lagoon on the west of Socotra (Van Damme and Banfield 2011). This was free of macro-waste up until the late 1990s but now there is a serious risk to human health as well as the potential reduction in biodiversity in these rare freshwater habitats.

Pollution through waste and biocides may pose a threat to the freshwater fauna and flora (photo from Khor Qalansiyah, Socotra). Photo © Kay Van Damme

The human population is increasing along freshwater systems and so is the degree of contamination. The main impacts of pollution on wetland-dependent plants are as a consequence of the secondary effects of hyper-eutrophication, such as algal blooms which often lead to catastrophic declines in dissolved oxygen. However, lower levels of eutrophication can enable aggressive species such as *Phragmites australis* and *Typha* species to out-compete less robust species.

The main impacts of pollution on wetland-dependent plants are as a consequence of the secondary effects of hyper-eutrophication, such as algal blooms, which often lead to substantial decline in dissolved oxygen. Lower levels of eutrophication can enable aggressive species such as *Phragmites australis* (Common Reed) and *Typha* species (Reed-mace) to out-compete less robust species.

Wadi Darbat, southern Oman in full spate following unseasonal rain in 2007. Delicate marginal herbaceous species with restricted distributions are easily lost following catastrophic weather events such as this. Photo © Sabina G. Knees CMEP/RBGE

7.4.6 Climate change and extreme weather events

It is very difficult to predict the potential effects of climate change on wetland-dependent plants in the Arabian Peninsula. It seems likely that water availability will become an issue for wetland plant conservation: the existing impacts of over-abstraction, combined with poor water management are having a devastating effect on wetlands in the region and extreme climatic events are only likely to exacerbate this. Based on the current climate change scenarios, the increased frequency and intensity of droughts as well as tropical hurricane events may become another major threat (Delany *et al*. 2008, Lenton *et al.* 2008). In certain areas of the Arabian Peninsula, springs are already seeing declines in recharge during drought events.

7.4.7 Invasive alien plants

Although a number of non-native wetland-dependent plant species are established in the region, there is as yet no evidence to suggest that they are adversely affecting native wetland-dependent plant populations. However, there is a need to monitor the import as well as the spread of non-native plant species.

7.5 Conservation

In the face of the on-going threats to wetland habitats in the region and the species they support, there is an urgent need to implement conservation action. The following section presents priorities for conservation of wetland-dependent plants in the Arabian Peninsula.

7.5.1 Develop Action Plans for the conservation of wetland-dependent plants

Data from this publication provide information on the status of and threats to wetland-dependent plants in the Arabian Peninsula. However, there is a need to convert this information into a comprehensive tool that sets out the steps required to meet the conservation needs of these species. The first step is, therefore, to use the data compiled through this project to prepare an Action Plan for the conservation of wetland-dependent plants in the Arabian Peninsula. This action plan will set out the conservation action necessary for each species and will bring these species-specific actions together to provide regional and strategic plans for conservation action that can be adopted by different national governments..

7.5.2 Incorporate plant conservation requirements and actions into national strategies and legislation

The countries of the Arabian Peninsula are signatories to a number of important conventions aimed at conserving biodiversity, most importantly the 1992 Convention on Biological Diversity. Being signatories to the CBD, the Arabian Peninsula countries have made the commitment to conserve the biodiversity within the Peninsula. This means that not only should extinctions be prevented, but population decline should also be stemmed or reversed. The GSPC (Global Strategy of Plant Conservation) targets for 2010 were not met, but the data generated by this publication will support efforts to meet the new targets for 2020.

However, there is currently no legislation specifically for the protection or conservation of wetland-dependent plant species and the only legislative tools available for protection of these species relate to general habitat and site protection. There is an overwhelming need to improve enforcement of existing legislation to control development and the impacts of agricultural intensification. In particular, Environmental Impact Assessment (EIA) is a tool designed to control the adverse effects of development on the environment. There is a need to review the adequacy of existing legal requirements for EIA's in the region, and propose a tightening of the legislation if this is required, e.g. such as adding a requirement for EIA for small dams, tourism and wetland development projects, to ensure that the legislation for EIA is applied. In addition, there is a need to introduce new legislation to protect both the most threatened wetland-dependent plant species and the sites which support them. There is also a need to identify and conserve man-made structures e.g. the aflaj system in Oman, which need careful and skilled restoration and use of appropriate materials in order to not destroy the associated aquatic flora.

7.5.3 Follow a landscape and catchment level approach

There is a need to lobby governments to adopt a catchment-based approach to management of natural resources, including water. The protection of freshwater biodiversity is a conservation challenge as the influences of the upstream drainage network, and the surrounding land on springs and pools need to be taken into consideration. Such catchment approaches are rarely met; however action is required to set aside intact aquatic habitats with large managed areas.

Conservation of aquatic habitats must address sustainable development, by the integrated management of habitats and natural resources, combining the rational use of resources, particularly water, with the conservation of biodiversity. This can be achieved by each country applying its own existing legislation in order to reduce habitat loss and by strengthening existing protection measures such as increasing protected areas and the creation of further reserves. The increasing threat to aquatic flora and habitats merits a regional initiative and agreement.

7.5.4 Develop capacity building and public awareness campaigns

Any attempt to improve the legislative controls on actions affecting wetland-dependent plants in the region must be coupled with a programme of capacity building and awareness. In particular, the dissemination of information on water management and its effect on biodiversity at the household and village levels as well as on the governmental level could have a dramatic effect on the condition and use of natural wetlands. Such a programme needs to involve collaboration between experts and NGO's with the expertise to monitor species to support the relevant governmental institutions.

7.5.5 Conduct research to expand the knowledge on wetland-dependent plants of the Arabian Peninsula

There is a need to undertake research to fill gaps in the information available on the conservation status of wetland-dependent plants in the Arabian Peninsula. This report identifies Data Deficient species (for which information is inadequate to achieve an informed conservation assessment), and areas in which there are concentrations of Data Deficient species, where there is therefore a need to carry out research into wetland plant conservation.

Such survey programmes should also be used to identify additional sites for conservation through the strengthening of research on wetland-dependent plant distribution, population sizes and population trends. There is also a need to commence research into the potential impacts of climate change, which presents a new level of threat, especially to fragmented and small populations.

7.5.6 Improve information management

There is a need to strengthen the network of Arabian Plant experts by improving communication and providing training. This includes the mobilisation of appropriate financial support. The IUCN Species Survival Commission's Arabian Plant Specialist Group plays a vital role in this regional network.

7.5.7 Establish *ex-situ* conservation programmes

Ex situ conservation programmes should be used to ensure the continuing presence of viable populations of highly threatened species. These collections will serve as a back-up measure through conservation in botanic gardens and gene banks. Inter- and intra-specific species diversity should be systematically targeted.

The Oman Botanic Garden, currently under construction, already holds the largest documented collection of Arabian plants on a global scale (Patzelt *et. al*. 2008, 2009). The garden has the unique aim of propagating and displaying the complete indigenous flora of the Sultanate of Oman, and aims to address the urgent need for conservation solutions to the biodiversity crisis. Actively addressing targets of the 'Global Strategy for Plant Conservation' (GSPC), a program of the UN Convention on Biological Diversity, the Oman Botanic Garden represents a new model for botanic gardens in the 21st century and is a ground-breaking initiative of *ex situ* conservation in Arabia. The experience gained is vital for other major new initiatives in plant conservation across the Arabian Peninsula. Smaller scale projects are also underway in other parts of the Peninsula, including a fledgling botanic garden in Hadibo on the island of Socotra. Established with help from the Ministry of Agriculture, Yemen, this family run garden and nursery are growing 37% of Socotra's 308 endemic plants and have a seed collection of over 80 species, including several threatened wetland dependent species. It has since received support from the Socotra Conservation Fund (SCF), Socotra Conservation and Development Programme (SCDP), Arid Lands and Sustainable Communities Trust (ALSCT) and the Royal Botanic Garden Edinburgh (RBGE). This is a vital project which is helping to conserve the unique flora of the island and will eventually be key to future reintroduction programmes. Further botanic gardens are becoming established in the Peninsula and these are summarised by Al Farhan *et al.* (2008).

7.7 References

Al Farhan, A.H., Aldjain, I.M.N., Thomas, J. Miller, A.G., Knees, S.G., Lewellyn, O. and Akram, A. 2008. Botanic Gardens in the Arabian Peninsula, Sibbaldia 6:189–203

Botkin, D.B., Saxe, H., Araújo, M.B., Betts, R., Bradshaw, R., Cedhagen, T., Chesson, P., Davis, M.B., Dawson, T.P., Etterson, J., Faith, D.P., Ferrier, S., Guisan, A., Skjoldborg, A., Hansen, D.H., Kareiva, P., Loehle, Margules, C., New, M., Skov, F., Sobel, M.J., Stockwell, D., and Svenning, J-C., 2007. Forcasting effects of global warming on Biodiversity, BioScience 57, 227–236.

Brown, LR. 2008. Plan B 3.0: Mobilizing to Save Civilization. W.W. Norton and Company, New York,

Cook, C.D.K. 1996. Aquatic and wetland plants of India. Oxford University Press, Oxford

Cope, T. 2007. Flora of the Arabian Flora of the Arabian Peninsula and Socotra. Vol. 5 part 1. Edinburgh University Press, Edinburgh.

Dawson, T.P., Jackson, S.T., House, J.I., Prentice, I.C. and Mace, G.M., 2011, Beyond Predictions: Biodiversity Conservation in a Changing Climate, Science Vol. 332 no. 6025, 53–58.

Delany S., Seddon, M., Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H.J. 2008. Tipping elements in the Earth's climate system. Proceedings of the National Academy of Sciences of the United States of America 105(6): 1786–1793.

Hildebrandt, A., Eltahir, E.A.B. 2006. Forest at the edge: Seasonal cloud forest in Oman creates its own ecological niche. Geophysical Research Letters 33.

Knees, S.G. and Miller, A.G. 2006. Soqotra – land of the dragon's blood tree. The Plantsman, new series 5: 146–152.

Kürschner, H., Hein, P., Kilian, N. and Hubaishan, M. A. 2004. The *Hybantho durae-Anogeissetum dhofaricae* ass. nova – phytosociology, structure and ecology of an endemic South Arabian forest community. Phytocoenologia 34(4): 569–612.

Lansdown, R.V. 2007. The identity of *Ranunculus* subgenus *Batrachium* in the River Itchen. Environment Agency, Southern Region.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W,; Rahmstorf, S., Schellnhuber, H.J. 2008. Tipping elements in the Earth's climate system. www.pnas.org/cgi/content/full/0705414105/DC1.

McAllister, D.E., Craig, J.F. and Davidson, N. 2001. Biodiversity Impacts of Large Dams - Background Paper, IUCN / UNEP / WCD.

Miller, A.G. 1994. CPD Site SWA 1. Dhofar Fog Oasis. Oman and Yemen. In: Davis, S. D. and Heywood, V. H. (eds.) Centres of Plant Diversity, vol. 1, pp. 143–155, Cambridge: IUCN.

Miller, A.G. and Cope T.A. 1996. Flora of the Arabian Peninsula and Socotra. Vol. 1. Edinburgh University Press, Edinburgh.

Miller, A.G. and Morris, M. 2004. Ethnoflora of the Socotra Archipelago. Royal Botanic Garden Edinburgh, Edinburgh.

Miller, A.G. and Nyberg, J.A. 1991. Patterns of endemism in Arabia. Flora et Vegetatio Mundi 9: 263–279.

Patzelt A. 2010. Plant Communities, Endemism and Conservation – History and Heritage. In: Bürkert, A. and Schlecht E. (eds.) Oases of Oman – Livelihood Systems at the Crossroads, p. 30–33. Al Roya Press & Publishing House, Sultanate of Oman.

Patzelt, A. 2011. The *Themeda quadrivalvis* tall-grass savannah of Oman at the crossroad between Africa and Asia. Edinburgh Journal of Botany, 68 (2): 301–319.

Patzelt, A., (in press.) Oman Plant Red Data Book. Oman Botanic Garden, Diwan of Royal Court: Muscat, Oman.

Patzelt, A., Morris, L., Al Harthi, L., Al Rashdi, I., Spalton, A. 2008. The Oman Botanic Garden (1): The Vision, early plant collections and propagation. Sibbaldia 6: 41–77.

Patzelt A., Morris L.M., Al Farsi K., Spalton A. 2009. The Oman Botanic Garden (2): Collections Policy, Nursery Construction, Expanded Plant Production and Initial Tree Translocation. Sibbaldia 7: 83–97

Sullivan, P. 2012. Water, Food, Energy, Qat and Conflict: Yemen. Associate Paper, Future Directions International, 1–6.

The Board of Trustees of the Royal Botanic Gardens, Kew 2013. World Checklist of Selected Plant Families. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://apps.kew.org/wcsp/ (accessed January 31, 2013).

The Plant List 2010. Version 1. Published on the Internet; http://www.theplantlist.org/ (accessed January 31, 2013).

Van Damme, K. and Banfield. L. 2011. Past and present human impacts on the biodiversity of Socotra Island (Yemen): implications for future conservation. Biodiversity Conservation in the Arabian Peninsula. Zoology in the Middle East, Supplementum 3, 2011: 31–88.

White, F. and Léonard, J. 1991. Phytogeographical links between Africa and Southwest Asia. Flora et Vegetatio Mundi 9: 229–246.

Chapter 8. Regional synthesis for all taxa

García, N.[1], Harrison, I.[2] and Tognelli, M.[1]

This chapter provides the results and analysis of the combined data for freshwater fishes, molluscs, wetland-dependent plants, crabs and odonates. It presents an overview of the current status and distribution of freshwater species, and valuable base-line knowledge to be taken into consideration in environmental and development planning throughout the region.

8.1 Red List status

Out of the 292 species assessed, 17.5% are categorized as regionally threatened (in the Red List Categories Critically Endangered, Endangered or Vulnerable), almost 3% Near Threatened and 20% Data Deficient. One taxon is Regionally Extinct, the odonate *Azuragrion vansomereni*, known from a single site in Saudi Arabia (see chapter 5). The number of introduced or wandering species (Not Applicable) identified as non-native to the region reaches 13, including mainly mollusc and Odonata taxa.

Forty-one taxa (14% of the species assessed) are endemic to the Arabian Peninsula region, i.e., they do not exist anywhere else in the world, and therefore their regional Red List status corresponds also to their risk of extinction at the global level. Almost half of these endemics (19 species) are threatened with extinction: four Critically Endangered, nine Endangered and six Vulnerable (Table 8.1 and Figure 8.1)

8.2 Patterns of species richness

8.2.1 Centres of species richness

Species richness patterns were identified by combining the number of species contained in sub-catchments for each focal taxonomic group (freshwater fishes, molluscs, crabs, dragonflies and wetland-dependent plants). Fifty-five Data Deficient species could not be mapped and were, therefore, excluded from the analysis.

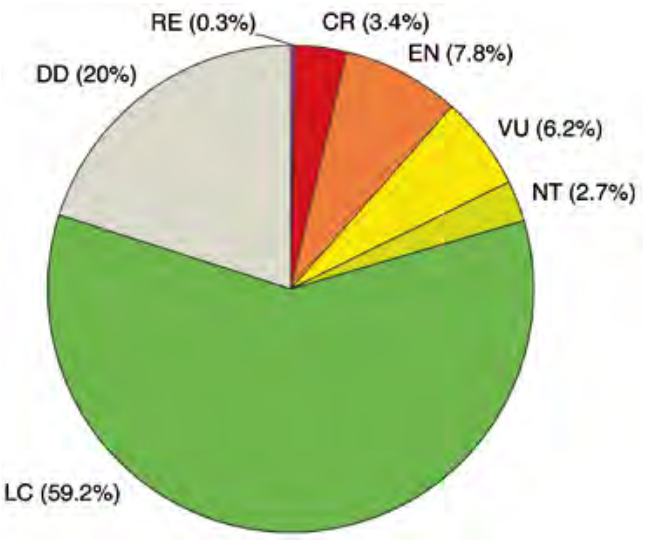
Table 8.1 Summary of Red List Category classifications at the regional scale by taxonomic groupings.

Taxon	Total*	RE	CR	EN	VU	NT	LC	DD	NA
Fishes	18	0	1	5	2	1	7	2	0
Odonata	59	1	1	9	5	4	32	7	4
Molluscs	30	0	1	2	2	2	14	9	9
Aquatic Plants	182	0	7	7	9	1	118	40	0
Crabs	3	0	0	0	0	0	2	1	0
Total	**292**	**1**	**10**	**23**	**18**	**8**	**173**	**59**	**13**

IUCN Red List Categories: RE – Regionally Extinct, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient, NA – Not Applicable (e.g. vagrant species, introduced species). * Excludes those species classified as Not Applicable (NA) and Not Evaluated (NE).

1 IUCN/Conservation International Biodiversity Assessment Unit, Betty & Gordon Moore Center for Ecosystem Science & Economics, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA
2 Center for Environment and Peace, Conservation International, 2011 Crystal Drive, Suite 500, Arlington, VA 22202, USA

Figure 8.1 The proportion (%) of freshwater species in each regional IUCN Red List Category in the Arabian Peninsula.

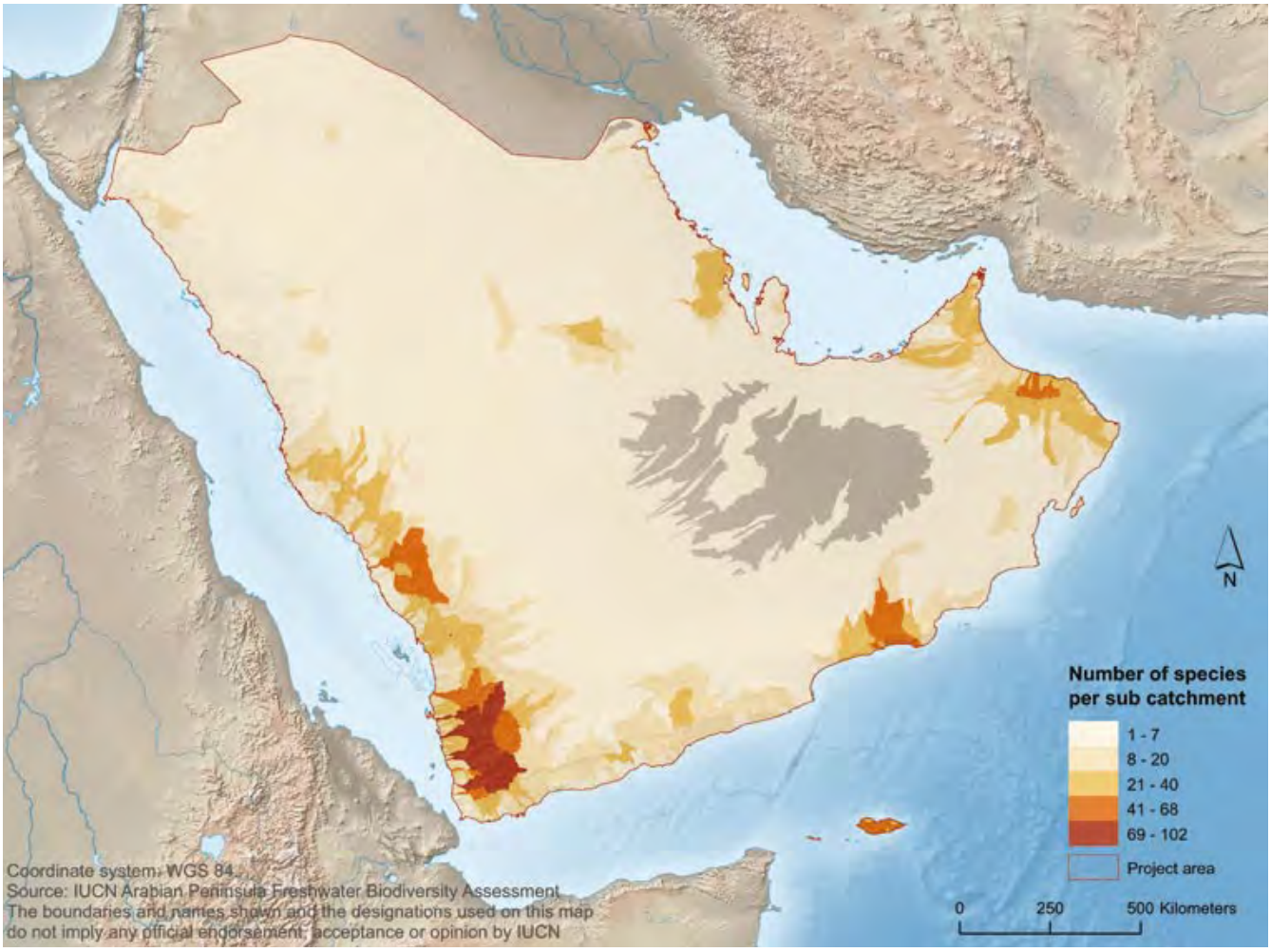


The highest concentration of freshwater species assessed was found in wadis of central mountain ranges in Yemen, including the Socotra archipelago, and south-west Saudi Arabia and Oman in Dhofar (Figure 8.2). These regions mainly fall in the Southwest Arabian Coast freshwater ecoregion, but also in some of the neighboring, peripheral parts of the Arabian Interior freshwater ecoregion.

8.2.2 Distribution of threatened species

The areas with highest concentration of threatened freshwater species in the Arabian Peninsula are in Oman, the northern mountains and Afrotropical relict pockets of Dhofar, and the highlands of southern Saudi Arabia and Yemen. These are also Southwest Arabian Coast freshwater ecoregion, and in the southern part of the Arabian Interior freshwater ecoregion where it overlies

Figure 8.2. Arabian Peninsula species richness for freshwater fishes, molluscs, odonates, crabs and wetland-dependent plants, mapped to river sub-catchments.



Oman. Some freshwater taxa present in the Socotra Island are also highly threatened due to unsustainable water management practices and pollution (Figure 8.3).

8.2.3 Distribution of endemic species

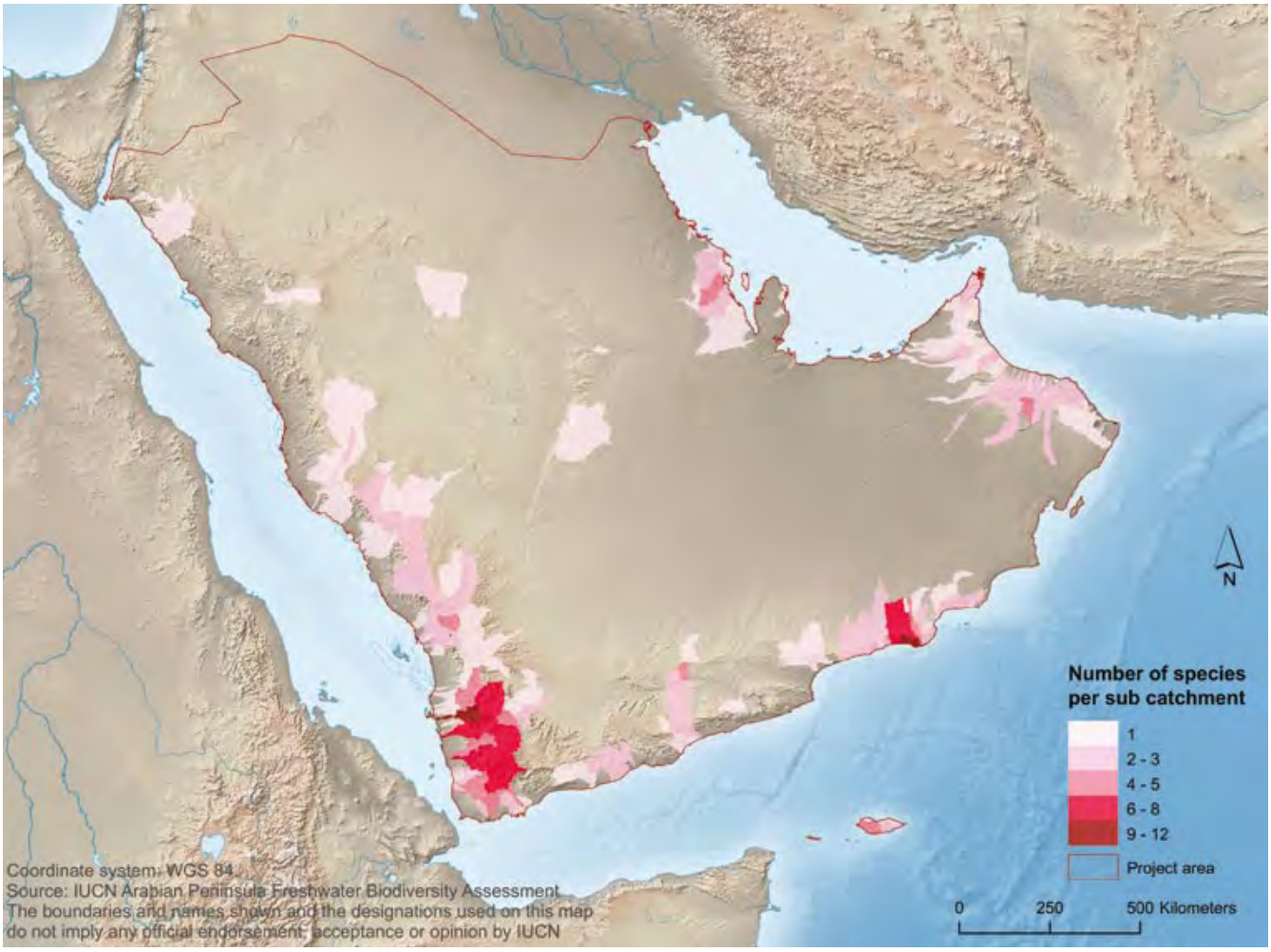
The mountains along the southeast and southwest of the Arabian Peninsula are hotspots of freshwater endemic species. Particularly for wetland-dependent plants, southern Oman and southeast Yemen are regional centres of plant endemism with unique vegetation at global scale. Also, all freshwater crabs and some freshwater molluscs known from the region are exclusive to the Socotra Islands. Other areas holding high concentrations of endemic freshwater taxa are Wadi Hadramaut in Yemen, Wadi Hadiya in Saudi Arabia, and the Dhofar region in Oman (Figure 8.4).

8.2.4 Distribution of Data Deficient species

The pattern of Data Deficient species follows the general pattern of species richness, and highlights the areas where

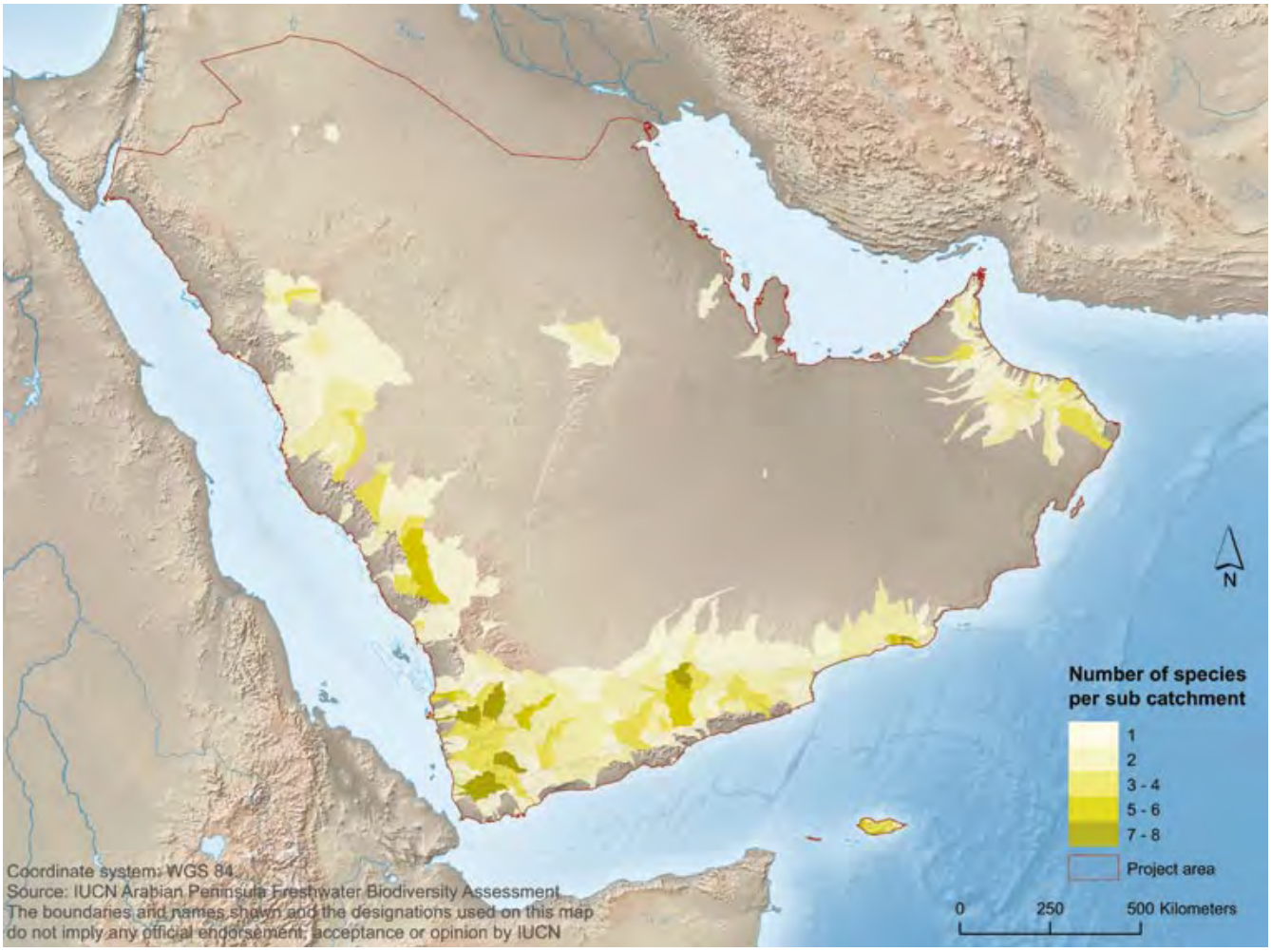
Research on freshwater fish at Wadi Wurrayah, UAE. Photo © N. A. Hamidan

Figure 8.3. The distribution of regionally threatened species of freshwater fishes, molluscs, odonates, crabs and wetland-dependent plants within the Arabian Peninsula, mapped to river sub-catchments.



Kids swimming at Layla Lakes in Saudi Arabia (summer 1976). Photo © Michael C. Jennings

Figure 8.4. Number of species of freshwater fishes, molluscs, odonates, crabs and wetland-dependent plants endemic to the Arabian Peninsula, mapped to river sub-catchments.



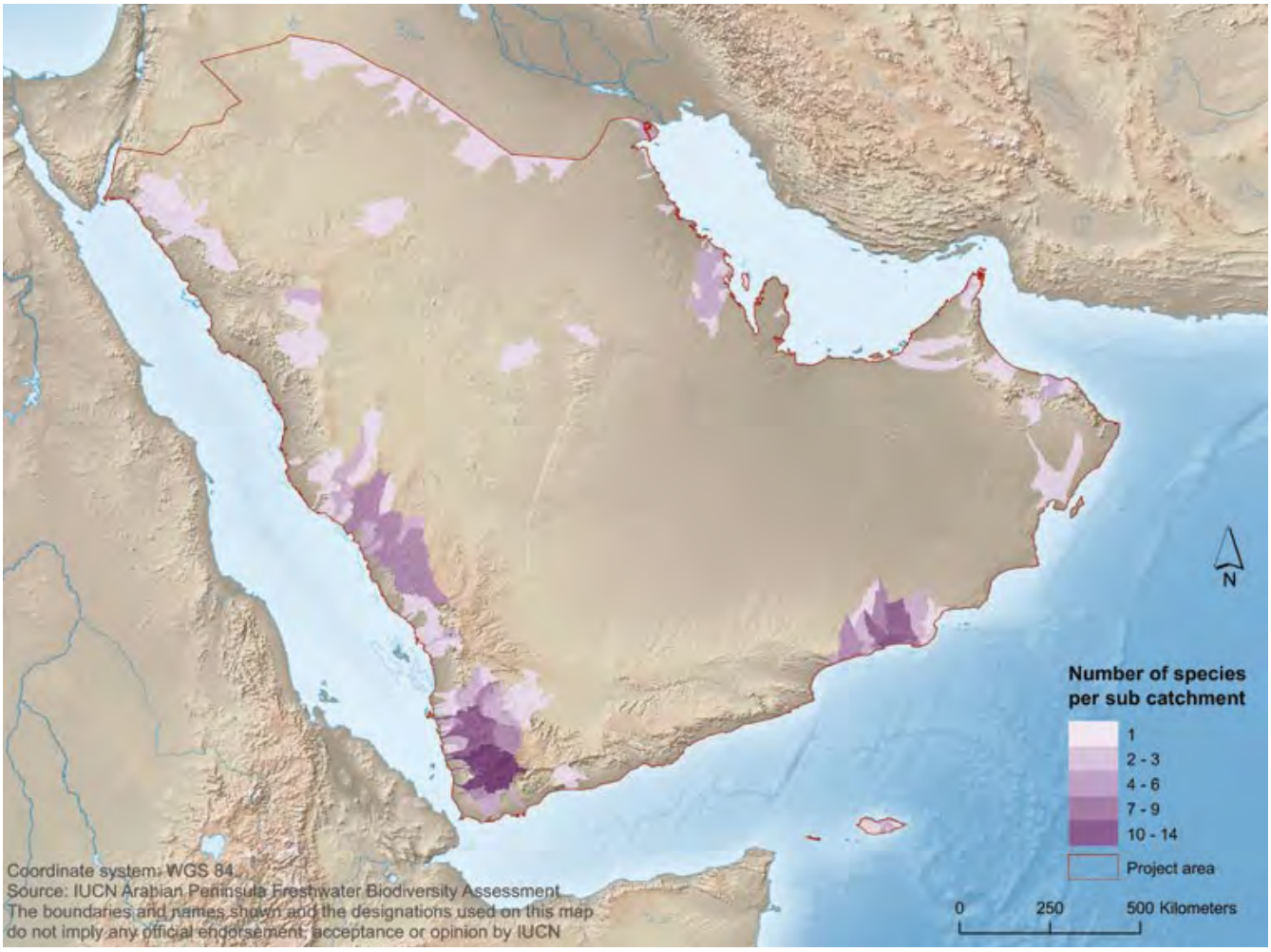
more research is needed to determine their conservation status. The highest concentration of species categorized as DD is in the south west and south of the Arabian Peninsula, although a few species also appear in the northern portion of the region (Figure 8.5).

8.3 Threats to freshwater biodiversity in the Arabian Peninsula

The Arabian Peninsula includes some of the most water stressed countries in the world, with high temperatures and low rates of precipitation. This low availability of water, coupled with a growing population with increasing water needs, is placing considerable stress on freshwater ecosystems (Jungius 1988, Wishart *et al.* 2000). The main threats to freshwater biodiversity in the region are related to natural system modifications, including dams, water abstraction and riparian habitat loss due to fires, which affects more than 40% of the assessed species. Water pollution due to domestic and agricultural activities is the second largest threat known, impacting more than 50% of the molluscs and 20% of the odonates. Particularly, the uncontrolled use of pesticides for malaria pest control is attributed to be a major cause of decline and eradication of freshwater species populations in the region.

The current trend of atmospheric temperature increase and rainfall decline, particularly in Oman and the UAE (chapter 3) is known to be major threat to the assessed freshwater species, particularly 23% of the freshwater fish. Habitat degradation and modification due to agriculture intensification are also important threats for approximately 21% of the assessed wetland-dependent plants and 16% of the odonates. Residential and commercial development is a major cause of decline for 25% of the water-dependent plants. Additional impacts to freshwater biodiversity assessed for the region are included in Figure 8.6.

Figure 8.5. Distribution of freshwater fishes, molluscs, odonates, crabs and wetland-dependent plants classified as Data Deficient, mapped to river subcatchments. Only those species with locality information could be mapped.



8.4 Conclusions

8.4.1 Patterns of species richness and endangerment

With sparse rainfall only occurring during monsoons, the regional climate determines the low diversity of freshwater fauna and flora in the Arabian Peninsula. As this reports shows, even though the region may not be exceptional in terms of the number of species, the distribution pattern of these species shows important hotspots of richness in the Dhofar region of Oman, the wadis of the central Yemeni mountain ranges, south-west Saudi Arabia and the Socotra archipelago. Rainfall elsewhere in the region is very scarce and has resulted in low species diversity.

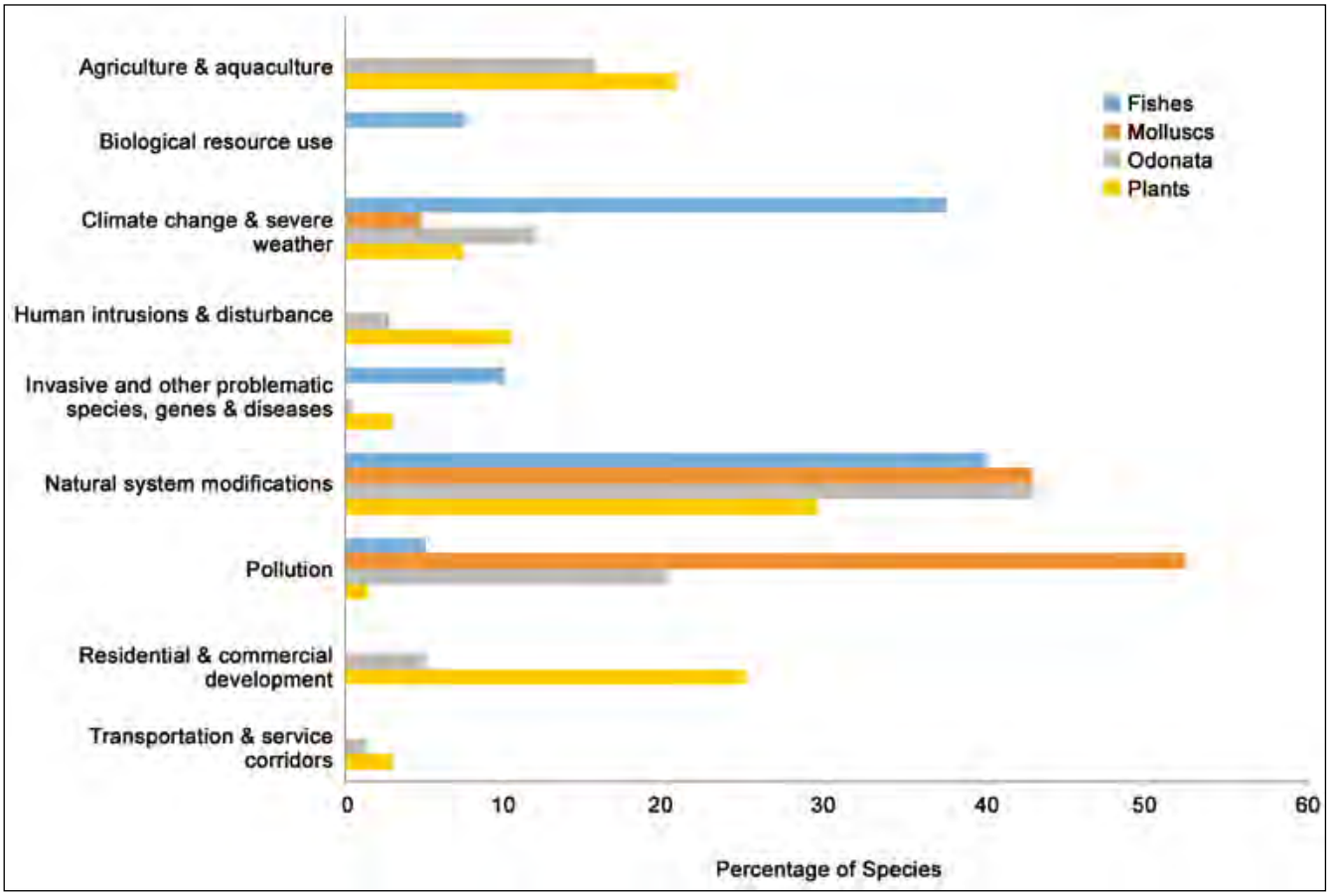
Also, freshwater habitats in the region are under great anthropogenic pressure associated to urban, agricultural and industrial development activities, such as habitat modification from water extraction and degradation from pollution.

8.4.2 Conservation priorities

The species distribution information generated through this project has been compared with the existing on protected areas in the region (Figure 8.7). Spatial information on Ramsar sites (Wetlands of International Importance) also available at the Ramsar website in the form of point localities (full details at www.ramsar.org), was included in this figure. According to this information, there are very few sites in the Arabian Peninsula (five in United Arab Emirates, two in Bahrain, and one each in Yemen [Socotra] and Oman), most of these being coastal wetlands. However, there are two important inland wetland sites in the United Arab Emirates: Al Wathba Wetland Reserve and Wadi Wurayah National Park. The latter site is an important spawning ground for several species of fishes.

In general for the Arabian Peninsula, freshwater biodiversity habitat lacks suitable protection, with the exception of the Island of Socotra and some small areas in south and southeastern Oman and United Arab

Figure 8.6 Major current threats to freshwater species in the Arabian Peninsula



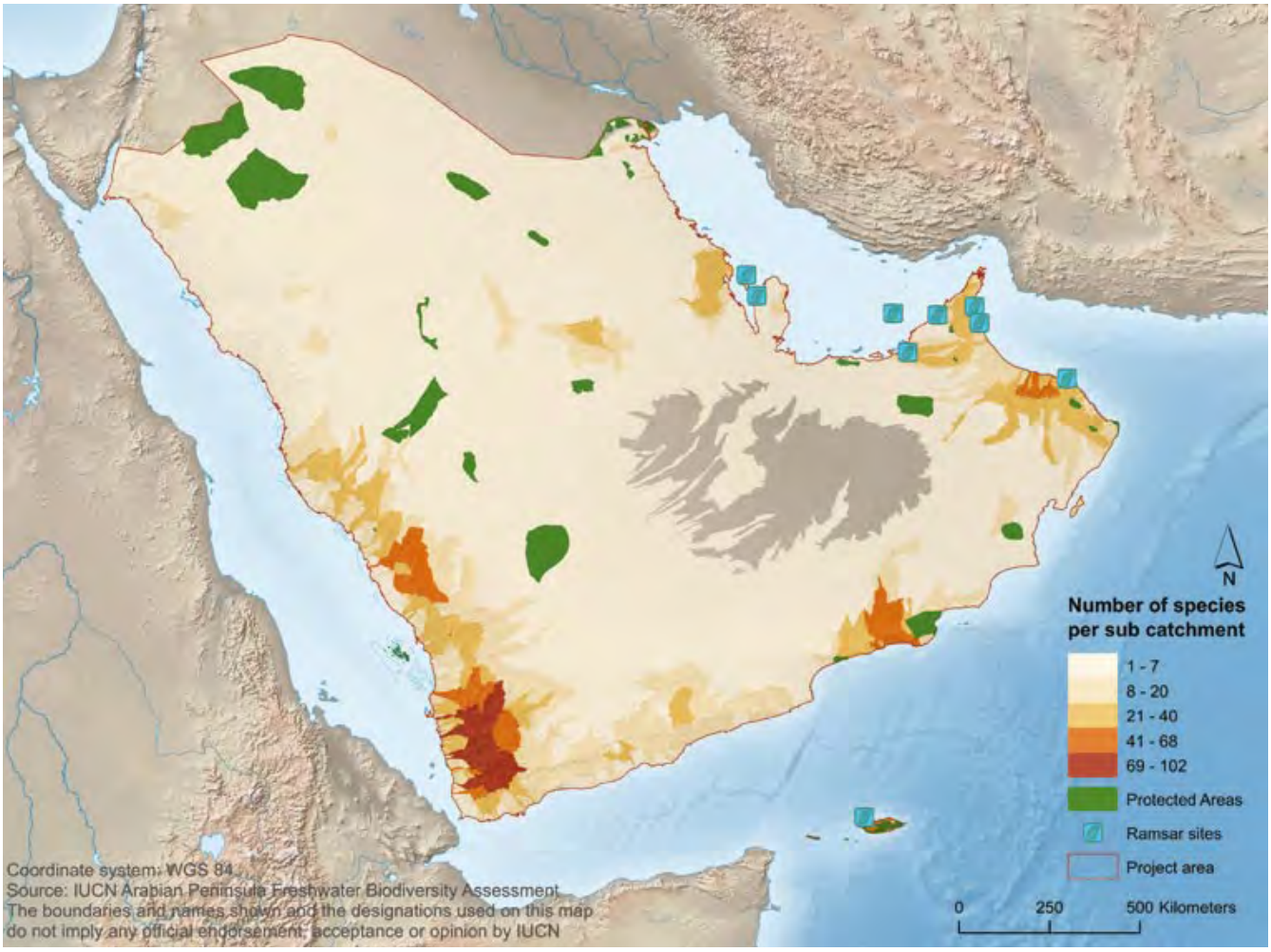
Emirates. This may be related to the fact that protected areas in the region are mainly designed to cover terrestrial species. Therefore, there is a need to update the protected areas system to integrate this newly disclosed information.

It is also worth highlighting that half of the freshwater species endemic to the region are threatened with extinction, and that a fifth of all assessed species are Data Deficient, and therefore potentially threatened if future updated data changes our current knowledge about their conservation status. Additional fieldwork to fill the knowledge gaps and update the status of these taxa, particularly those endemic to the region, is a priority to ensure adequate conservation of these species.

Finally, conservation priorities of freshwater biodiversity in the Arabian Peninsula are very similar to those identified for the Northern Africa region (García *et al.* 2008), which include the development of Integrated River Basin Management (IRBM) programs, the use of sustainable agricultural techniques and waste management, law enforcement, habitat protection, action plans for species, and environmental education. Because many of the rivers in the Arabian Peninsula experience regular cessation of flow, it will be essential to develop conservation priorities that recognize the importance of perennial systems in maintaining aquatic biodiversity (Wishart *et al.* 2000). Faunal comparison of temporary and perennial systems will be important in developing networks of protected and managed areas that support the species diversity across connected basins.

As noted by Jungius (1988), the establishment of protected areas in the Arabian Peninsula should include appropriate policies and management for enforcing legislation and supporting conservation. In addition, it is important to ensure that local and nomadic communities are engaged in the planning of implementation of these protected areas, to ensure that there is a sense of ownership and governance of the protected areas. For

Figure 8.7. Overlay of protected areas and freshwater species in the Arabian Peninsula. Protected area layer developed from World Database on Protected Areas, with additional new information for the region (adapted from Al Omari 2011), and including Ramsar sites (www.ramsar.org).



maximum efficiency, conservation planning for the freshwater ecosystems of the Arabian Peninsula should be integrated with existing terrestrial programs and spatial prioritization for the region. For example, AGEDI (2013) have completed an important systematic study for the Arabian Peninsula which has produced a stakeholder and expert database, spatial data, and measures of ecosystem threat status and ecosystem protection level that will be valuable to basin scale conservation planning.

8.4.3 Application of project outputs

All data generated by this project and summarized in the present report are freely available. The global assessments of all species included in this project are available on the IUCN Red List website (www.iucnredlist.org) and freely available to the public, and all regional assessments can be found in the physical CD attached at the end of this publication.

This information is a base resource to assist in the prioritization of sites that contribute significantly to the global persistence of biodiversity at both regional and international levels, such as Key Biodiversity Areas (Langhammer *et al.* 2007) and Alliance for Zero Extinction sites (Ricketts *et al.* 2005). In addition, this information can guide decision makers in future development and environmental planning.

8.4.4 Future work

A strong and collaborative network of experts has been built through this project, which is essential for keeping the collated information regularly up-to-date and its effective integration within development and environmental planning processes.

Efforts should be directed to keep and strength the links between IUCN and its partners, policy makers, regional decision makers and related organizations to use, maintain and strengthen this freely available knowledge and integrate it into future planning.

Lessons learned from the process of integrating biodiversity information need to be disseminated to all stakeholders in a practical format that makes it easy to replicate the most successful methodologies.

8.5 References

AGEDI. 2013. Systematic Conservation Planning Assessments and Spatial Prioritizations for the Emirate of Abu Dhabi, the United Arab Emirates and the Arabian Peninsula. Pp. 80. Available from www.agedi.ae.

Al Omari, K. 2011. Protected Areas in he Arabian Peninsula. *Zoology in the Middle East (Supplementum 3)*: 21-26.

García, N., Cuttelod, A. and Abdul Malak, D. (eds.) (2010). *The Status and Distribution of Freshwater Biodiversity in Northern Africa*. Gland, Switzerland, Cambridge, UK, and Malaga, Spain : IUCN, 2010. xiii+141pp.

Jungius, H. 1988. The national parks and protected areas concept and its application to the Arabian Peninsula. *Fauna of Saudi Arabia* 9: 3-11.

Langhammer, P. F., Bakarr, M. I., Bennun, L. A., Brooks, T. M., Clay, R. P., Darwall, W., De Silva, N., Edgar, G. J., Eken, G., Fishpool, L. D. C., da Fonseca, G. A. B., Foster, M. N., Knox, D. H., Matiku, P., Radford, E. A., Rodrigues, A. S. L., Salaman, P., Sechrest, W. and Tordoff, A. W. 2007. *Identification and gap analysis of key biodiversity areas: targets for comprehensive protected area systems*. Gland, Switzerland: IUCN (Best Practice Protected Area Guidelines Series 15).

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. 2005. *Pinpointing and preventing imminent species extinctions. Proceedings of the National Academy of Sciences* 51: 1849718501-.

Wishart, M.J., Gagneur, J. and El-Zanfaly, H.T. 2000. River conservation in North Africa and the Middle East. In: Boon, P.J., Davies, B.R. and Petts, G.E. (eds). *Global perspectives on river conservation: science, policy, and practice*. Pp. 127154-. John Wiley & Sons.

Appendix 1. Freshwater Fishes of the Arabian Peninsula

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/No)
ANGUILLIFORMES	ANGUILLIDAE	*Anguilla bengalensis*	NT		NE		No
ANGUILLIFORMES	ANGUILLIDAE	*Anguilla bicolor*	NT		NE		No
CYPRINIFORMES	CYPRINIDAE	*Acanthobrama hadiyahensis*	CR	B2ab (i,ii,iii,iv);	CR	B2ab (i,ii,iii,iv);	Yes
CYPRINIFORMES	CYPRINIDAE	*Arabibarbus arabicus*	LC		LC		Yes
CYPRINIFORMES	CYPRINIDAE	*Carasobarbus apoensis*	EN	B2ab (i,ii,iii,iv)	EN	B2ab (i,ii,iii,iv)	Yes
CYPRINIFORMES	CYPRINIDAE	*Carasobarbus exulatus*	EN	B2ab(iii)	EN	B2ab(iii)	Yes
CYPRINIFORMES	CYPRINIDAE	*Cyprinion acinaces*	LC		LC		Yes
CYPRINIFORMES	CYPRINIDAE	*Cyprinion mhalensis*	LC		LC		Yes
CYPRINIFORMES	CYPRINIDAE	*Cyprinion watsoni*	LC		NT		No
CYPRINIFORMES	CYPRINIDAE	*Garra barreimiae*	LC		LC		Yes
CYPRINIFORMES	CYPRINIDAE	*Garra buettikeri*	VU	B2ab(iii)	VU	B2ab(iii)	Yes
CYPRINIFORMES	CYPRINIDAE	*Garra dunsirei*	EN	D	EN	D	Yes
CYPRINIFORMES	CYPRINIDAE	*Garra lautior*	EN	B2ab(iii)	EN	B2ab(iii)	Yes
CYPRINIFORMES	CYPRINIDAE	*Garra longipinnis*	DD		DD		Yes
CYPRINIFORMES	CYPRINIDAE	*Garra mamshuqa*	EN	B2ab(iii)	EN	B2ab(iii)	Yes
CYPRINIFORMES	CYPRINIDAE	*Garra sahilia*	LC		LC		Yes
CYPRINIFORMES	CYPRINIDAE	*Garra smarti*	VU	D2	VU	D2	Yes
CYPRINIFORMES	CYPRINIDAE	*Garra tibanica*	LC		LC		Yes
CYPRINODONTIFORMES	CYPRINODONTIDAE	*Aphanius dispar*	LC		LC		No
MUGILIFORMES	MUGILIDAE	*Liza abu*	LC		NE		No
PERCIFORMES	GOBIIDAE	*Awaous aeneofuscus*	LC		DD		No

Appendix 2. Freshwater Molluscs of the Arabian Peninsula

Order	Family	Taxon	IUCN Red List Category	Red List Criteria	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/No)
VENEROIDA	CORBICULIDAE	*Corbicula fluminalis*	LC		LC		No
VENEROIDA	SPHAERIIDAE	*Pisidium casertanum*	LC		LC		No
HYGROPHILA	LYMNAEIDAE	*Galba truncatula*	LC		LC		No
HYGROPHILA	LYMNAEIDAE	*Lymnaea natalensis*	LC		LC		No
HYGROPHILA	LYMNAEIDAE	*Radix auricularia*	LC		LC		No
HYGROPHILA	LYMNAEIDAE	*Stagnicola palustris*	LC		VU	D2	No
HYGROPHILA	PHYSIDAE	*Haitia acuta*	LC		LC		No
HYGROPHILA	PLANORBIDAE	*Ancylus fluviatilis*	LC		LC		No
HYGROPHILA	PLANORBIDAE	*Biomphalaria arabica*	LC		LC		Yes
HYGROPHILA	PLANORBIDAE	*Bulinus beccarii*	LC		LC		Yes
HYGROPHILA	PLANORBIDAE	*Bulinus truncatus*	LC		LC		No
HYGROPHILA	PLANORBIDAE	*Bulinus wrighti*	LC		LC		Yes
HYGROPHILA	PLANORBIDAE	*Ceratophallus socotrensis*	DD		DD		Yes
HYGROPHILA	PLANORBIDAE	*Gyraulus cockburni*	EN	B2ab(ii,iii)	EN	B2ab(ii,iii)	Yes
HYGROPHILA	PLANORBIDAE	*Gyraulus convexiusculus*	LC		EN	B2ab(iii)	No
HYGROPHILA	PLANORBIDAE	*Gyraulus piscinarum*	LC		DD		No
HYGROPHILA	PLANORBIDAE	*Indoplanorbis exustus*	LC		LC		No
HYGROPHILA	PLANORBIDAE	*Planorbis planorbis*	LC		DD		No
HYGROPHILA	PLANORBIDAE	*Segmentorbis angustus*	LC		DD		No
LITTORINIMORPHA	ASSIMINEIDAE	*Assiminea nitida*	LC		EN	B2ab(iii)	No
LITTORINIMORPHA	BITHYNIIDAE	*Bithynia badiella*	VU	B1ab(iii,iv)	DD		No
LITTORINIMORPHA	HYDROBIIDAE	*Hydrobia balfouri*	DD		DD		Yes
LITTORINIMORPHA	HYDROBIIDAE	*Hydrobia glaucovirens*	DD		DD		Yes
LITTORINIMORPHA	HYDROBIIDAE	*Hydrobia lactea*	NT		NT		Yes
LITTORINIMORPHA	STENOTHYRIDAE	*Gangetia miliacea*	LC		NT		No
LITTORINIMORPHA	STENOTHYRIDAE	*Stenothyra arabica*	DD		DD		Yes
SORBEOCONCHA	MELANOPSIDAE	*Melanopsis costata*	LC		EN	B2ab(iii)	No
SORBEOCONCHA	PALUDOMIDAE	*Cleopatra bulimoides*	LC		DD		No
SORBEOCONCHA	THIARIDAE	*Melanoides tuberculata*	LC		LC		No
SORBEOCONCHA	THIARIDAE	*Plotia scabra*	LC		LC		No

Appendix 3. Dragonflies and Damselflies (Odonata) of the Arabian Peninsula

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
ODONATA	AESHNIDAE	*Anax ephippiger*	LC	LC		No
ODONATA	AESHNIDAE	*Anax imperator*	LC	LC		No
ODONATA	AESHNIDAE	*Anax parthenope*	LC	LC		No
ODONATA	AESHNIDAE	*Anax speratus*	LC	LC		No
ODONATA	COENAGRIONIDAE	*Agriocnemis pygmaea*	LC	CR	B2ab(iii)	No
ODONATA	COENAGRIONIDAE	*Azuragrion nigridorsum*	LC	EN	B2ab(iii)	No
ODONATA	COENAGRIONIDAE	*Azuragrion vansomereni*	LC	RE		No
ODONATA	COENAGRIONIDAE	*Ceriagrion glabrum*	LC	LC		No
ODONATA	COENAGRIONIDAE	*Ischnura evansi*	LC	LC		No
ODONATA	COENAGRIONIDAE	*Ischnura fountaineae*	LC	VU	B2ab(iii)	No
ODONATA	COENAGRIONIDAE	*Ischnura senegalensis*	LC	LC		No
ODONATA	COENAGRIONIDAE	*Pseudagrion decorum*	LC	NT		No
ODONATA	COENAGRIONIDAE	*Pseudagrion hamoni*	LC	LC		No
ODONATA	COENAGRIONIDAE	*Pseudagrion kersteni*	LC	VU	B2ab(iii)	No
ODONATA	COENAGRIONIDAE	*Pseudagrion sublacteum sublacteum*	LC	LC		No
ODONATA	GOMPHIDAE	*Lindenia tetraphylla*	LC	LC		No
ODONATA	GOMPHIDAE	*Paragomphus genei*	LC	LC		No
ODONATA	GOMPHIDAE	*Paragomphus sinaiticus*	NT	LC		No
ODONATA	LESTIDAE	*Lestes pallidus*	LC	VU	B2ab(iii)	No
ODONATA	LIBELLULIDAE	*Acisoma panorpoides ascalaphoides*	LC	EN	B1ab(i,ii,iii)+ 2ab(i,ii,iii)	No
ODONATA	LIBELLULIDAE	*Brachythemis impartita*	LC	LC		No
ODONATA	LIBELLULIDAE	*Crocothemis chaldaeorum*	DD	DD		No
ODONATA	LIBELLULIDAE	*Crocothemis erythraea*	LC	LC		No
ODONATA	LIBELLULIDAE	*Crocothemis sanguinolenta*	LC	LC		No
ODONATA	LIBELLULIDAE	*Crocothemis servilia*	LC	DD		No
ODONATA	LIBELLULIDAE	*Diplacodes lefebvrii*	LC	LC		No
ODONATA	LIBELLULIDAE	*Macrodiplax cora*	LC	NT		No
ODONATA	LIBELLULIDAE	*Nesciothemis farinosa*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum abbotti*	LC	EN	B2ab(iii)	No
ODONATA	LIBELLULIDAE	*Orthetrum caffrum*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum chrysostigma*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum coerulescens anceps*	LC	DD		No
ODONATA	LIBELLULIDAE	*Orthetrum julia falsum*	LC	DD		No
ODONATA	LIBELLULIDAE	*Orthetrum kollmannspergeri*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum ransonnetii*	LC	LC		No

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
ODONATA	LIBELLULIDAE	*Orthetrum sabina*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum taeniolatum*	LC	LC		No
ODONATA	LIBELLULIDAE	*Orthetrum trinacria*	LC	DD		No
ODONATA	LIBELLULIDAE	*Palpopleura deceptor*	LC	DD		No
ODONATA	LIBELLULIDAE	*Pantala flavescens*	LC	LC		No
ODONATA	LIBELLULIDAE	*Rhyothemis semihyalina*	LC	EN	B1ab(i,ii,iii,iv,v)+ 2ab(i,ii,iii,iv,v)	No
ODONATA	LIBELLULIDAE	*Selysiothemis nigra*	LC	LC		No
ODONATA	LIBELLULIDAE	*Sympetrum fonscolombii*	LC	LC		No
ODONATA	LIBELLULIDAE	*Tholymis tillarga*	LC	DD		No
ODONATA	LIBELLULIDAE	*Tramea limbata*	LC	NT		No
ODONATA	LIBELLULIDAE	*Trithemis annulata*	LC	LC		No
ODONATA	LIBELLULIDAE	*Trithemis arteriosa*	LC	LC		No
ODONATA	LIBELLULIDAE	*Trithemis dejouxi*	LC	EN	B2ab(iii)	No
ODONATA	LIBELLULIDAE	*Trithemis furva*	LC	LC		No
ODONATA	LIBELLULIDAE	*Trithemis kirbyi*	LC	LC		No
ODONATA	LIBELLULIDAE	*Urothemis edwardsii*	LC	EN	B1ab(iii)+2ab(iii)	No
ODONATA	LIBELLULIDAE	*Zygonyx torridus*	LC	LC		No
ODONATA	LIBELLULIDAE	*Urothemis thomasi thomasi*	LC	EN	B2ab(iii)	Yes
ODONATA	COENAGRIONIDAE	*Azuragrion somalicum amitinum*	LC	VU	B2ab(iii); D2	Yes
ODONATA	COENAGRIONIDAE	Pseudagrion arabicum	LC	EN	B2ab(iii)	Yes
ODONATA	AESHNIDAE	*Pinheyschna yemenensis*	LC	VU	B1ab(iii)+2ab(iii); D2	Yes
ODONATA	PLATYCNEMIDIDAE	*Arabicnemis caerulea*	LC	LC		Yes
ODONATA	PROTONEURIDAE	*Arabineura khalidi*	LC	EN	B2b(iii,iv)	Yes
ODONATA	COENAGRIONIDAE	*Azuragrion granti*	LC	NT		Yes

Appendix 4. Freshwater Crabs of the Arabian Peninsula

Order	Family	Taxon	IUCN Red List Category	Regional IUCN Red List Category	Endemic to Arabia (Yes/No)
DECAPODA	POTAMIDAE	*Socotra pseudocardisoma*	LC	LC	Yes
DECAPODA	POTAMIDAE	*Socotrapotamon nojidensis*	DD	DD	Yes
DECAPODA	POTAMIDAE	*Socotrapotamon socotrensis*	LC	LC	Yes

Appendix 5. Wetland Dependent Plants of the Arabian Peninsula

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
EQUISETALES	EQUISETACEAE	*Equisetum giganteum*	LC	LC		No
MARSILEALES	MARSILEACEAE	*Marsilea aegyptiaca*	LC	LC		No
MARSILEALES	MARSILEACEAE	*Marsilea coromandelina*	LC	LC		No
PTERIDALES	ADIANTACEAE	*Adiantum capillus-veneris*	LC	LC		No
PTERIDALES	PARKERIACEAE	*Ceratopteris cornuta*	LC	CR	B2ab(iii)	No
PTERIDALES	PTERIDACEAE	*Acrostichum aureum*	LC	CR	D	No
PTERIDALES	PTERIDACEAE	*Pteris vittata*	LC	LC		No
ARALES	LEMNACEAE	*Lemna gibba*	LC	LC		No
ARALES	LEMNACEAE	*Lemna minor*	LC	LC		No
COMMELINALES	COMMELINACEAE	*Commelina benghalensis*	LC	LC		No
COMMELINALES	COMMELINACEAE	*Commelina diffusa*	LC	LC		No
CYPERALES	CYPERACEAE	*Bolboschoenus glaucus*	LC	DD		No
CYPERALES	CYPERACEAE	*Bolboschoenus maritimus*	LC	DD		No
CYPERALES	CYPERACEAE	*Carex distans*	LC	LC		No
CYPERALES	CYPERACEAE	*Carex stenophylla*	LC	LC		No
CYPERALES	CYPERACEAE	*Cladium mariscus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus alopecuroides*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus alternifolius*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus alulatus*	LC	EN	B2ab(iii)	No
CYPERALES	CYPERACEAE	*Cyperus articulatus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus compressus*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus difformis*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus dilatatus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus dubius*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus esculentus*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus fuscus*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus iria*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus laevigatus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus longus*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus nutans*	LC	DD		No
CYPERALES	CYPERACEAE	*Cyperus rigidifolius*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus rotundus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus schimperianus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus squarrosus*	LC	LC		No
CYPERALES	CYPERACEAE	*Cyperus wissmannii*	DD	DD		No

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
CYPERALES	CYPERACEAE	*Eleocharis caduca*	LC	LC		No
CYPERALES	CYPERACEAE	*Eleocharis geniculata*	LC	LC		No
CYPERALES	CYPERACEAE	*Eleocharis marginulata*	LC	DD		No
CYPERALES	CYPERACEAE	*Eleocharis palustris*	LC	LC		No
CYPERALES	CYPERACEAE	*Eleocharis uniglumis*	LC	DD		No
CYPERALES	CYPERACEAE	*Fimbristylis bisumbellata*	LC	EN	B2ab(ii,iii)	No
CYPERALES	CYPERACEAE	*Fimbristylis complanata*	LC	LC		No
CYPERALES	CYPERACEAE	*Fimbristylis cymosa*	LC	LC		No
CYPERALES	CYPERACEAE	*Fimbristylis dichotoma*	LC	DD		No
CYPERALES	CYPERACEAE	*Fimbristylis ferruginea*	LC	LC		No
CYPERALES	CYPERACEAE	*Fimbristylis sieberiana*	LC	LC		No
CYPERALES	CYPERACEAE	*Fimbristylis turkestanica*	LC	DD		No
CYPERALES	CYPERACEAE	*Fuirena ciliaris*	LC	LC		No
CYPERALES	CYPERACEAE	*Fuirena felicis*	VU	VU	D2	Yes
CYPERALES	CYPERACEAE	*Fuirena pubescens*	LC	LC		No
CYPERALES	CYPERACEAE	*Isolepis setacea*	LC	LC		No
CYPERALES	CYPERACEAE	*Kyllinga brevifolia*	LC	LC		No
CYPERALES	CYPERACEAE	*Kyllinga microstyla*	LC	LC		No
CYPERALES	CYPERACEAE	*Pycreus dwarkensis*	LC	CR	B2ab(iii)	No
CYPERALES	CYPERACEAE	*Pycreus elegantulus*	LC	LC		No
CYPERALES	CYPERACEAE	*Pycreus flavescens*	LC	LC		No
CYPERALES	CYPERACEAE	*Pycreus polystachyos*	LC	DD		No
CYPERALES	CYPERACEAE	*Pycreus pumilus*	LC	LC		No
CYPERALES	CYPERACEAE	*Pycreus sanguinolentus*	LC	DD		No
CYPERALES	CYPERACEAE	*Schoenoplectiella proxima*	DD	VU	D2	No
CYPERALES	CYPERACEAE	*Schoenoplectus corymbosus*	LC	DD		No
CYPERALES	CYPERACEAE	*Schoenoplectus lacustris*	LC	VU	B2ab(iii)	No
CYPERALES	CYPERACEAE	*Schoenoplectus litoralis*	LC	LC		No
CYPERALES	CYPERACEAE	*Schoenoplectus mucronatus*	LC	DD		No
CYPERALES	CYPERACEAE	*Schoenus nigricans*	LC	VU	B2ab(ii,iii)	No
CYPERALES	CYPERACEAE	*Scirpoides holoschoenus*	LC	LC		No
CYPERALES	GRAMINEAE	*Agrostis lachnantha*	LC	LC		No
CYPERALES	GRAMINEAE	*Arundo donax*	LC	LC		No
CYPERALES	GRAMINEAE	*Brachiaria mutica*	LC	DD		No
CYPERALES	GRAMINEAE	*Brachiaria reptans*	LC	LC		No
CYPERALES	GRAMINEAE	*Brachiaria scalaris*	LC	LC		No
CYPERALES	GRAMINEAE	*Desmostachya bipinnata*	LC	LC		No
CYPERALES	GRAMINEAE	*Echinochloa colona*	LC	LC		No
CYPERALES	GRAMINEAE	*Echinochloa crusgalli*	LC	LC		No
CYPERALES	GRAMINEAE	*Echinochloa pyramidalis*	LC	DD		No

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
CYPERALES	GRAMINEAE	*Eriochloa meyeriana*	LC	LC		No
CYPERALES	GRAMINEAE	*Festuca yemenensis*	VU	VU	D2	Yes
CYPERALES	GRAMINEAE	*Hemarthria altissima*	LC	DD		No
CYPERALES	GRAMINEAE	*Isachne globosa*	LC	DD		No
CYPERALES	GRAMINEAE	*Leptochloa fusca*	LC	LC		No
CYPERALES	GRAMINEAE	*Odontelytrum abyssinicum*	LC	EN	B2ab(iii)	No
CYPERALES	GRAMINEAE	*Panicum socotranum*	CR	CR	B2ab(iii)	Yes
CYPERALES	GRAMINEAE	*Paspalidium flavidum*	LC	LC		No
CYPERALES	GRAMINEAE	*Paspalidium geminatum*	LC	LC		No
CYPERALES	GRAMINEAE	*Paspalum scrobiculatum*	LC	LC		No
CYPERALES	GRAMINEAE	*Paspalum vaginatum*	LC	LC		No
CYPERALES	GRAMINEAE	*Pennisetum macrourum*	LC	LC		No
CYPERALES	GRAMINEAE	*Phragmites australis*	LC	LC		No
CYPERALES	GRAMINEAE	*Phragmites karka*	LC	DD		No
CYPERALES	GRAMINEAE	*Poa schimperiana*	LC	LC		No
CYPERALES	GRAMINEAE	*Polypogon schimperianus*	DD	DD		No
CYPERALES	GRAMINEAE	*Polypogon viridis*	LC	LC		No
CYPERALES	GRAMINEAE	*Saccharum kajkaiense*	LC	LC		No
CYPERALES	GRAMINEAE	*Saccharum ravennae*	LC	LC		No
CYPERALES	GRAMINEAE	*Saccharum spontaneum*	LC	LC		No
CYPERALES	GRAMINEAE	*Sporobolus consimilis*	LC	LC		No
CYPERALES	GRAMINEAE	*Urochloa panicoides*	LC	LC		No
HYDROCHARITALES	HYDROCHARITACEAE	*Najas graminea*	LC	DD		No
HYDROCHARITALES	HYDROCHARITACEAE	*Najas marina*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus bufonius*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus fontanesii*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus inflexus*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus punctorius*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus rigidus*	LC	LC		No
JUNCALES	JUNCACEAE	*Juncus socotranus*	LC	LC		No
NAJADALES	POTAMOGETONACEAE	*Potamogeton coloratus*	LC	DD		No
NAJADALES	POTAMOGETONACEAE	*Potamogeton lucens*	LC	DD		No
NAJADALES	POTAMOGETONACEAE	*Potamogeton natans*	LC	LC		No
NAJADALES	POTAMOGETONACEAE	*Potamogeton nodosus*	LC	LC		No
NAJADALES	POTAMOGETONACEAE	*Potamogeton pusillus*	LC	LC		No
NAJADALES	ZANNICHELLIACEAE	*Zannichellia palustris*	LC	LC		No
ORCHIDALES	ORCHIDACEAE	*Epipactis veratrifolia*	LC	EN	B2ab(ii,iii,v)	No
TYPHALES	TYPHACEAE	*Typha domingensis*	LC	LC		No
TYPHALES	TYPHACEAE	*Typha elephantina*	LC	LC		No
APIALES	UMBELLIFERAE	*Apium graveolens*	LC	LC		No

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
APIALES	UMBELLIFERAE	*Apium nodiflorum*	LC	LC		No
APIALES	UMBELLIFERAE	*Berula erecta*	LC	NT		No
APIALES	UMBELLIFERAE	*Centella asiatica*	LC	LC		No
APIALES	UMBELLIFERAE	*Hydrocotyle sibthorpioides*	LC	VU	D2	No
ASTERALES	COMPOSITAE	*Adenostemma caffrum*	LC	LC		No
ASTERALES	COMPOSITAE	*Gnaphalium unionis*	LC	LC		No
ASTERALES	COMPOSITAE	*Osteospermum muricatum*	LC	DD		No
ASTERALES	COMPOSITAE	*Pulicaria arabica*	LC	VU	B2ab(iii)	No
ASTERALES	COMPOSITAE	*Pulicaria inuloides*	LC	LC		No
CAMPANULALES	GOODENIACEAE	*Scaevola socotraensis*	CR	CR	B2ab(iii)	Yes
CARYOPHYLLALES	AMARANTHACEAE	*Alternanthera sessilis*	LC	LC		No
CARYOPHYLLALES	PORTULACACEAE	*Talinum portulacifolium*	LC	LC		No
EUPHORBIALES	EUPHORBIACEAE	*Chrozophora tinctoria*	LC	LC		No
GENTIANALES	APOCYNACEAE	*Nerium oleander*	LC	LC		No
GENTIANALES	ASCLEPIADACEAE	*Kanahia laniflora*	LC	LC		No
GENTIANALES	GENTIANACEAE	*Centaurium erythraea*	LC	LC		No
GENTIANALES	GENTIANACEAE	*Centaurium pulchellum*	LC	LC		No
GENTIANALES	GENTIANACEAE	*Exacum affine*	LC	LC		Yes
GENTIANALES	GENTIANACEAE	*Exacum arabicum*	LC	LC		Yes
GENTIANALES	GENTIANACEAE	*Exacum socotranum*	CR	CR	B2ab(iii)	Yes
GENTIANALES	GENTIANACEAE	*Sebaea microphylla*	LC	DD		No
GENTIANALES	GENTIANACEAE	*Sebaea pentandra*	LC	DD		No
HALORAGALES	HALORAGACEAE	*Myriophyllum spicatum*	LC	DD		No
LAMIALES	BORAGINACEAE	*Heliotropium ovalifolium*	LC	LC		No
LAMIALES	BORAGINACEAE	*Myosotis laxa*	LC	LC		No
LAMIALES	VERBENACEAE	*Phyla nodiflora*	LC	LC		No
MALVALES	STERCULIACEAE	*Melhania phillipsiae*	LC	LC		No
MYRTALES	LYTHRACEAE	*Ammannia auriculata*	LC	LC		No
MYRTALES	LYTHRACEAE	*Ammannia baccifera*	LC	LC		No
MYRTALES	LYTHRACEAE	*Lythrum hyssopifolia*	LC	LC		No
MYRTALES	ONAGRACEAE	*Epilobium hirsutum*	LC	LC		No
MYRTALES	ONAGRACEAE	*Ludwigia octovalvis*	LC	LC		No
MYRTALES	ONAGRACEAE	*Ludwigia palustris*	LC	LC		No
NYMPHAEALES	CERATOPHYLLACEAE	*Ceratophyllum demersum*	LC	LC		No
NYMPHAEALES	CERATOPHYLLACEAE	*Ceratophyllum submersum*	LC	DD		No
POLYGONALES	POLYGONACEAE	*Persicaria amphibia*	LC	LC		No
POLYGONALES	POLYGONACEAE	*Persicaria barbata*	LC	LC		No
POLYGONALES	POLYGONACEAE	*Persicaria glabrum*	LC	LC		No
POLYGONALES	POLYGONACEAE	*Persicaria lapathifolia*	LC	LC		No
POLYGONALES	POLYGONACEAE	*Persicaria maculosa*	LC	LC		No

Order	Family	Taxon	IUCN Red List Category	Regional Red List Category	Regional Red List Criteria	Endemic to Arabia (Yes/ No)
POLYGONALES	POLYGONACEAE	*Persicaria salicifolia*	LC	LC		No
POLYGONALES	POLYGONACEAE	*Persicaria senegalensis*	LC	VU	D2	No
POLYGONALES	POLYGONACEAE	*Polygonum argyrocoleon*	LC	LC		No
PRIMULALES	PRIMULACEAE	*Anagallis serpens*	LC	DD		No
PRIMULALES	PRIMULACEAE	*Samolus valerandi*	LC	LC		No
RANUNCULALES	RANUNCULACEAE	*Ranunculus multifidus*	LC	LC		No
RANUNCULALES	RANUNCULACEAE	*Ranunculus rionii*	LC	DD		No
RANUNCULALES	RANUNCULACEAE	*Ranunculus sphaerospermus*	LC	DD		No
RANUNCULALES	RANUNCULACEAE	*Ranunculus trichophyllus*	LC	DD		No
ROSALES	CRASSULACEAE	*Crassula hedbergii*	LC	EN	B2ab(iii)	No
ROSALES	CRASSULACEAE	*Crassula tillaea*	LC	LC		No
RUBIALES	RUBIACEAE	*Pentodon pentandrus*	LC	LC		No
SALICALES	SALICACEAE	*Salix acmophylla*	LC	LC		No
SCROPHULARIALES	LENTIBULARIACEAE	*Utricularia australis*	LC	DD		No
SCROPHULARIALES	LENTIBULARIACEAE	*Utricularia minor*	LC	EN	B2ab(iii)	No
SCROPHULARIALES	LENTIBULARIACEAE	*Utricularia striatula*	LC	EN	B2ab(iii)	No
SCROPHULARIALES	SCROPHULARIACEAE	*Bacopa monnieri*	LC	LC		No
SCROPHULARIALES	SCROPHULARIACEAE	*Limosella macrantha*	LC	DD		No
SCROPHULARIALES	SCROPHULARIACEAE	*Lindenbergia indica*	LC	LC		No
SCROPHULARIALES	SCROPHULARIACEAE	*Mimulus gracilis*	LC	LC		No
SCROPHULARIALES	SCROPHULARIACEAE	*Veronica anagallis-aquatica*	LC	LC		No
SCROPHULARIALES	SCROPHULARIACEAE	*Veronica anagalloides*	LC	DD		No
SCROPHULARIALES	SCROPHULARIACEAE	*Veronica beccabunga*	LC	DD		No
SOLANALES	CONVOLVULACEAE	*Cressa cretica*	LC	LC		No
SOLANALES	CONVOLVULACEAE	*Ipomoea aquatica*	LC	LC		No
SOLANALES	CONVOLVULACEAE	*Stictocardia tiliifolia*	LC	CR	D	No
THEALES	ELATINACEAE	*Bergia polyantha*	LC	VU	D2	No

Appendix 6. CD

Please find the CD on the inside cover of the back of the book, including the species summaries, distribution maps and spatial data.

IUCN Red List of Threatened Species™ – Regional Assessment Project Reports

Freshwater Africa

The Status and Distribution of Freshwater Biodiversity in Eastern Africa. Compiled by W.R.T. Darwall, K.G. Smith, T. Lowe, J.-C. Vie. 2005.

The Status and Distribution of Freshwater Biodiversity in Southern Africa. Compiled by W.R.T. Darwall, K.G. Smith, D. Tweddle and P. Skelton, 2009.

The Status and Distribution of Freshwater Biodiversity in Western Africa. Compiled by K.G. Smith, M.D. Diop, M. Niane and W.R.T. Darwall. 2009.

The Status and Distribution of Freshwater Biodiversity in Northern Africa. Compiled by N. Garcia, A Cuttelod, and D.A. Malak. 2010.

The Status and Distribution of Freshwater Biodiversity in Central Africa. Compiled by D.J. Allen, E.G.E. Brooks, and W.T. Darwall. 2010.

The Diversity of Life in African Freshwaters: Underwater; Under Threat. An Analysis of the Status and Distribution of Freshwater Species Throughout Mainland Africa. Edited by W.R.T. Darwall, K.G. Smith, D.J. Allen, R.A. Holland, I.J. Harrison, and E.G.E. Brooks. 2011.

Freshwater Asia

The Status and Distribution of Freshwater Biodiversity in the eastern Himalaya. Compiled by D.J. Allen, S. Molur, and B.A. Daniel. 2010.

The Status and Distribution of Freshwater Biodiversity in the Western Ghats. Compiled by S. Molur, K.G., Smith, B.A. Daniel, and W.R.T Darwall. 2011.

The Status and Distribution of Freshwater Biodiversity in Indo-Burma. Compiled by D.J. Allen, K.G. Smith, and W.R.T Darwall. 2012.

Mediterranean

The Status and Distribution of Freshwater Fish Endemic to the Mediterranean Basin. Compiled by K.G. Smith and W.R.T. Darwall. 2006.

The Status and Distribution of Reptiles and Amphibians of the Mediterranean Basin. Compiled by N. Cox, J. Chanson and S. Stuart. 2006.

Overview of the Cartilaginous Fishes (Chondrichthyans) in the Mediterranean Sea. Compiled by R.D. Cavanagh and C. Gibson. 2007.

The Mediterranean: A Biodiversity Hotspot Under Threat. A. Cuttelod, N. Garcia, D.A. Malak, H. Temple, and Katariya, V. 2008.

The Status and Distribution of Dragonflies of the Mediterranean Basin. Compiled by E. Riservato, J.-P. Boudot, S. Ferreira, M. Jovic, V.J. Kalkman, W. Schneider and B. Samraoui. 2009.

The Status and Distribution of Mediterranean Mammals. Compiled by H.J, Temple and A. Cuttelod. 2009.

Overview of the Conservation Status of the Marine Fishes of the Mediterranean Sea. Compiled by D.A. Malak, S.R. Livingstone, D. Pollard, B.A. Polidoro, A. Cuttelod, M. Bariche, M. Bilecenoglu, K.E. Carpenter, B.B. Collette, P. Francour, M. Goren, M.H. Kara, E. Massutí, C. Papaconstantinou, and L. Tunesi. 2011.
Marine Mammals and Sea Turtles of the Mediterranean and Black Seas. IUCN. 2012.

The Status and Distribution of Freshwater Biodiversity in the Eastern Mediterranean. Compiled by K.G. Smith, V. Barrios, W.R.T. Darwall, and C. Numa. 2014.

Europe
The Status and Distribution of European Mammals. Compiled by H.J. Temple and A. Terry. 2007.

European Red List of Amphibians. Compiled by H.J. Temple and N. Cox. 2009.

European Red List of Reptiles. Compiled by N. Cox and H.J. Temple. 2009.

European Red List of Saproxylic Beetles. Compiled by A. Nieto and K.N.A. Alexander. 2010.

European Red List of Butterflies. Compiled by C. van Swaay, A. Cuttelod, S. Collins, D. Maes, M.L. Munguira, M. Šašić, J. Settele, R. Verovnik, T. Verstrael, M. Warren, M. Wiemers and I. Wynhoff. 2010.

European Red List of Dragonflies. Compiled by V.J. Kalkman, J.-P. Boudot, R. Bernard, K.-J. Conze, G. De Knijf, E. Dyatlova, S. Ferreira, M. Jović, J. Ott, E. Riservato and G. Sahlen. 2010.

European Red List of Vascular Plants. Compiled by M. Bilz, S.P. Kell, N. Maxted, and R.V. Lansdown. 2011

European Red List of Non-marine Molluscs. Compiled by A. Cuttelod, M. Seddon, and E. Neubert. 2011.

THE IUCN RED LIST
OF THREATENED SPECIES™

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

WORLD HEADQUARTERS
Rue Mauverney 28
1196 Gland
Switzerland
Tel: +41 22 999 0000
Fax: +41 22 999 0020
www.iucn.org/species
www.iucnredlist.org