ترييبلوس

مجلة جمعية الامارات للتاريخ الطبيعي

مجلد 21 - 2013

Volume 21 - 2013

Journal of the Emirates Natural History Group

TRIBULUS

Journal of the Emirates Natural History Group

VOLUME 21-2013

TRIBULUS

Notes for Contributors

TRIBULUS is the Journal of the Emirates Natural History Group and was launched in 1991. The Group, based in Abu Dhabi, was founded in 1976, and is the oldest environmental non-governmental organisation in the United Arab Emirates.

It has two sister groups, the Al Ain ENHG and the Dubai Natural History Group. Between 1976 and 1990, the Group published 42 issues of a thrice-yearly duplicated **Bulletin.**

Copies of **TRIBULUS** and of the Bulletin are available on the website of the Al Ain ENHG, at www.enhg.org

Between 1991 and 2006, **TRIBULUS** was published twice-yearly but from Volume 17 (2007), the number of pages has been increased and frequency has become (near)-annual, rather than bi-annual.

The aim of the publication is to create and maintain in standard form a collection of recordings, articles and papers on topics related to the natural history, heritage, geology, palaeontology, archaeology and history of South-Eastern Arabia, with the focus on the United Arab Emirates and adjacent areas.

Papers, short notes and other contributions are welcomed from both residents of the United Arab Emirates and others, but should not have previously been published elsewhere. Guidelines are set out below.

Information contained in papers is as accurate as can be determined by the Editorial Board, in consultation with the members of the Advisory Panel and other referees, but opinion expressed are those of the authors alone.

All manuscripts received are reviewed by Editorial Board members and appropriate Advisory Panel members and, where appropriate, are also submitted for blind peer review.

Correspondence and enquiries should be sent to:
The Editor
TRIBULUS
P.O. Box 3790, Abu Dhabi, United Arab Emirates

Or by e-mail to:
hellyer@emirates.net.ae

Submission of manuscripts

Manuscripts should be submitted in electronic form. A short abstract may precede the paper, with the address(es) of the authors, including e-mail address, at the end.

Photographs, line drawings and maps should be submitted, in electronic format, and should be of sufficiently high resolution to permit reproduction.

References should give the author's name, with the date of publication in brackets, showing title, publisher and country of publication, in date order. For journal articles, conventional abbreviations of journal titles may be used.

Scientific names should follow customary nomenclature in Latin while the common English names (if any) and local Arabic names (if available) should also be supplied.

تريبيلوس

ملاحظات إلى المساهمين

تريبيلوس هي مجلة تصدر منذ العام 1991 عن جمعية الإمارات للتاريخ الطبيعي التي تأسست في أبو ظبي في العام 1976 لتكون أول منظمة بيئية غير حكومية في دولة الإمارات العربية المتحدة, وتتبع لها كل من جمعية الإمارات للتاريخ الطبيعي في العين وجمعية دبي للتاريخ الطبيعي.

وقد قامت الجمعية خلال الفترة ما بين 1976 و 1990 بإصدار 42 عددا من النشرات الخاصة بها وذلك بمعدل ثلاثة أعداد سنويا.

تتوفر أعداد تريبيلوس والنشرات على الموقع الإلكتروني لجمعية الإمارات للتاريخ الطبيعي في العين: www.enhg.org

بعد ذلك أصبحت تريبيلوس تصدر مرتين سنويا وبقياس ورق الطباعة العادي خلال الفترة الممتدة بين العامين 1991 و 2006, ثم شهدت اعتبارا من العددى 17 (2007) زيادة في عدد صفحاتها وباتت تصدر سنويا.

تهدف المجلة إلى تكوين مجموعة من السجلات والمقالات وأوراق العمل المتعلقة بمواضيع ذات صلة بالتاريخ الطبيعي والتراث والجيولوجيا وعلم الإحاثات وعلم الآثار وتاريخ المنطقة الجنوبية الشرقية من شبه الجزيرة العربية, مع التركيز على دولة الإمارات العربية المتحدة والمناطق المجاورة.

ترحب المجلة بالمقالات والملاحظات والتعليقات القصيرة وغيرها من مساهمات المقيمين بدولة الإمارات العربية المتحدة أو غيرهم, على ألا يكون قد جرى نشرها في مكان آخر, وذلك وفق التعليمات المذكورة أدناه.

إن المعلومات الواردة في المجلة دقيقة بقدر ما يمكن لهيئة التحرير واللجنة الاستشارية أن تحدده, ولا تعبر النصوص الواردة فيها إلا عن رأي مؤلفيها فقط.

تتم مراجعة جميع النصوص المرسلة للمجلة من قبل أعضاء هيئة التحرير والأعضاء المختصين في اللجنة الاستشارية ومختصين آخرين.

الرجاء المراسلة والاستفسار على العنوان التالي:

المحرر

مجلة تريبيلوس

ص. ب. 3790, أبو ظبي, دولة الإمارات العربية المتحدة

أو على العنوان الإلكتروني التالي: hellyer@emirates.net.ae

تسليم النصوص

يجب تسليم نسخة إلكترونية من النص, على أن يسبق النص مقتطف مختصر وأن يذكر في نهايته عنوان المؤلف, بما في ذلك عنوان بريده الإلكتروني.

كذلك يجب تسليم نسخة إلكترونية من الصور والرسومات والخرائط, على أن تكون على درجة عالية من الوضوح لإتاحة الإمكانية لإعادة نشرها.

يجب إدراج المراجع حسب الترتيب الزمني لنشرها, مع ذكر اسم المؤلف وتاريخ النشر بين قوسين إلى جانب العنوان واسم الناشر وبلد النشر, ويمكن في المقالات الصحفية استخدام الاختصارات التقليدية التي تستخدم عادة في العناوين.

يجب ذكر الأسماء العلمية بعد المصطلحات اللاتينية, كما يجب إضافة الأسماء باللغة الإنجليزية واللغة العربية في حال وجودها.

Tribulus

Journal of the Emirates Natural History Group
Volume 21 - 2013

CONTENTS

Corporate Members of the ENHG:

Production of ***Tribulus***, and many other activities of the Emirates Natural History Group, including the grant programme of the Group's Conservation Fund, would not be possible without the generous support of the Group's Corporate Members, many of whom have provided consistent assistance over many years. The Editorial Board and the Group Committee acknowledge, with thanks, the invaluable support of the following companies and bodies, currently Corporate members of the Group, and all past Corporate sponsors without whom publication would be impossible:

Al Mahara Dive Centre

Al Masaood Group

Bin Moosa & Daly

British Petroleum, BP

Crowne Plaza Abu Dhabi – Sheikh Hamdan Street

Dome International L.L.C.

Dolphin Energy

Fugro Survey (Middle East) Ltd.

Mohamed bin Zayed Species Conservation Fund

Nautica Environmental Associates L.L.C.

Park Hyatt Abu Dhabi Hotel and Villas

Partex Oil and Gas

Shell

Readymix Abu Dhabi Limited L.L.C.

URS

We also acknowledge the support and encouragement of our Patron, H.E. Sheikh Nahyan bin Mubarak Al Nahyan, UAE Minister of Culture, Youth and Community Development. ***Tribulus*** is published for members of the three Natural History Groups in the United Arab Emirates, in Abu Dhabi, Dubai, Al Ain and Fujairah, and is also available on subscription inside and outside the UAE. Subscription in the UAE & the Arabian Gulf states is Dh5o per year, including postage. Overseas details on request.

Cover Illustrations:

Front: Mudskippers 'walk' using their muscular pectoral fins as crutches and resting on their modified pelvic fins. Picture by Gary F. Feulner

Back: Pharoah Eagle Owl (*Bubo ascalaphus*). Painted by Beverly McKay

Beverly McKay

Beverly McKay, the Canadian-born artist who painted our back cover illustration of *Bubo ascalaphus*, is an illustrator specialising in paintings of living plants, fungi, animals or their bones, shells and related subjects. With an academic degree in biology and chemistry and a postgraduate qualification in Natural History and Scientific Illustration, she has previously worked as a teacher and as a laboratory assistant. A resident of Ra's al-Khaimah, where her husband teaches at the Higher Colleges of Technology, for over ten years, she has amassed a collection of thousands of images of UAE landscapes and wildlife, some of which are now being turned into paintings. She is currently working on a series of fine art paintings of birds that will have conservation of their habitats as the main theme.
She can be contacted at: bevmckay@hotmail.com

Published by the Emirates Natural History Group. P.O. Box 45553, Abu Dhabi, United Arab Emirates

Designed by Ginny dela Fuente

International Standard Serial Number (ISSN): 1019 - 6919

Printed by Al Amal Printing Press, P.O. Box 38738, Abu Dhabi, UAE

Editorial

Thanks to a number of papers published over the years, ***Tribulus*** has become a key source of accurately-documented information, and photographs, dealing with the dragonflies and damselflies of the UAE and neighbouring Oman. We are pleased, therefore, to start this latest issue with two new papers on the same topic, one, by Gary Feulner, a regular contributor on a wide range of topics, and Jacky Judas, on the remarkable discovery of two new 1st records for the UAE's Odonata and the second presenting the results of a study over 2012 and early 2013, by first-time contributors Elaine and Peter Cowan, of the Odonata of a particular wadi pool in Nizwa, Oman. This not only shows the overlap between the species found in northern Oman and the Emirates, but also the benefits of a detailed study of a particular location over an extended period. Birdwatchers are accustomed to study their 'home patch'. More results of studies of other groups of fauna from such 'home patches' would be welcome.

Reptiles also attract attention, with a report on previously-unknown populations of one of the UAE's rarest lizards from Binish Roobas and Gary Feulner and, a little outside of the geographical area normally covered by the journal, a report on the little-known ghost gecko of Dhofar in southern Oman, by a trio of first-time contributors. A couple of short papers on birds are also included, one a first breeding record for the Emirate of Abu Dhabi and a review of its national status, by Oscar Campbell, and the other a report by John Pereira of Sharjah's EPAA on alien species threats to the collared kingfisher in Khor Kalba, arguably one of the UAE's most important birds, since almost all of the breeding population of this sub-species is to be found at this site, with a few pairs not far away in Oman. These are complemented by reviews on two new bird books, on Kuwait and Oman. A short report by Stephen Lokier on an initial study on sand dune temperature profiles introduces a geological perspective.

The main paper for this issue comes from the duo of the indefatigable Gary Feulner and Binish Roobas, with an exhaustive report on the re-discovery of the mudskipper *Periophthalmus waltoni* in the UAE. First reported decades ago, the species appears to have become locally extinct, for unknown reasons, though habitat disturbance may well have played a contributory role. Now, after many years, a small population appears to have become re-established, albeit in very small numbers, in a location where it had not formerly been recorded. Because of habitat disturbance, its survival is threatened. Through extensive correspondence, the authors have also succeeded in finding evidence of a previously undocumented record from years ago as well as of the probable former presence of a second mudskipper species, now vanished.

The paper demonstrates not only that species can disappear without being noticed or properly recorded, and then may re-appear, but also that habitat disturbance, even at a micro-level, can have a severe impact on the UAE's biodiversity. In drawing attention to this, the authors make a valuable contribution not merely to knowledge of the way in which biodiversity can be reduced, without the fact even being recognised, but also how regular studies of the same location – which Feulner had visited on numerous occasions before finding the mudskippers – can continue to yield new information.

The paper also demonstrates, of course, that plenty of new discoveries remain to be made about the UAE's natural history, even in such well-studied habitats as the shorelines and inter-tidal areas. That will come as no surprise to regular readers of ***Tribulus***.

Some of those discoveries await in scientific orders and families that already receive much attention. Pheasant-tailed Jacana and Cretzschmar's Bunting have been added to the UAE Bird List during 2013, for example, while, as noted above, despite extensive studies over the last few years, there are still new Odonata being found. Is there anyone, though, who is engaged in detailed studies of UAE fungi? Lichens have received some attention, but what about toadstools, mushrooms and puffballs? We look forward to reporting on discoveries in this area, in due course….

Peter Hellyer

First UAE records of two Odonata: the dragonfly *Urothemis thomasi* and the damselfly *Ischnura nursei*

by Gary R. Feulner and Jacky Judas

Abstract

The dragonfly *Urothemis thomasi* and the damselfly *Ischnura nursei* (also known as *Rhodischnura nursei*) were recorded from the United Arab Emirates for the first time in June 2013. The nature of the sites and the observed behaviour of each species are briefly described. The two species were found in very different habitats and their main populations are centered in opposite directions from the East Coast of the UAE, the nearest records being more than 300 kilometres away. Alternative explanations for their newly discovered contemporaneous presence in the UAE are discussed, *viz.*, gradual and previously unnoticed range expansion versus recent (and perhaps episodic) immigration in response to favourable conditions created by regional climatic phenomena.

Introduction

Two Odonata species new to the United Arab Emirates (UAE) were recorded independently within a three-day period in mid-June 2013, from disparate sites in the Hajar Mountains along the Gulf of Oman coast (Fig. 1).

Urothemis thomasi Longfield, 1932 was found at sites in mid and upper Wadi Wurayah, the largest wadi on the East Coast of the UAE. Mating was subsequently confirmed. *U. thomasi* is restricted to eastern Arabia and Somalia; the nominate subspecies is endemic to Oman and, now, the UAE. The paucity of historical records suggests that it is rare throughout its Omani range and it is classified as Endangered in the IUCN Red List (Boudot 2006).

Ischnura nursei Morton, 1907 (also known as *Rhodischnura nursei* (Morton, 1907)) was found at two lakes created by man-made dams along the

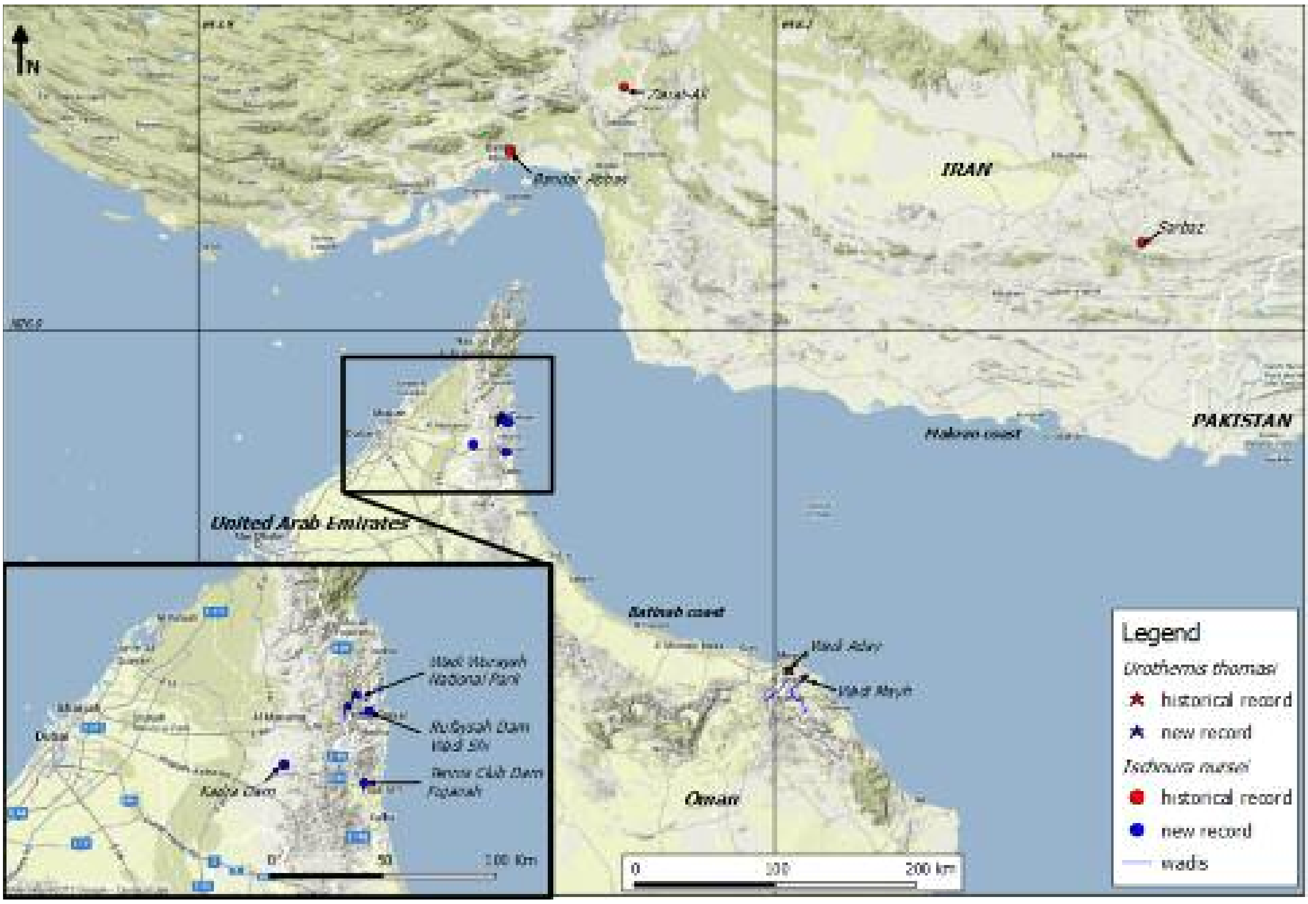


Fig. 1: Map showing the historical and newly-reported distribution of *Urothemis thomasi* and *Ischnura nursei* in the UAE, Northern Oman and Iran.

Fig. 2: *Urothemis thomasi* male, Wadi Wurayah, the first record of this species in the UAE (photo by GRF).

East Coast and at a shallow pond below a dam on the interior flank of the mountains. Both males and females were observed. This species is discussed here as *I. nursei* on the authority of Dumont (Dumont *et al.* 2011, Dumont *in press*). *I. nursei* is a small, playfully coloured damselfly previously known from the semi-arid regions of northern India and southern Pakistan, and more recently recognised from southern Iran (Dumont *et al.* 2011).

***Urothemis thomasi* Longfield, 1932**

On 7 June 2013, investigating the waterfall at Wadi Wurayah with a visiting European naturalist, Judas noticed an unusual red dragonfly and arranged for a photo to be taken. Independently the next day, during a botanical survey of the waterfall area, Feulner encountered and photographed 3-4 red male libellulids of an unknown species with distinctive dark basal wing markings (Fig. 2). They perched at a height of up to 1.5 metres among *Arundo donax* reeds and other, lower hygrophilous vegetation flourishing in the attenuated outflow from the waterfall pool, as well as on nearby wadi cobbles. Another male was found two days later, about six kilometres up the main wadi, floating dead in a *ca*. 20 square metre permanent pool in mid-wadi, without significant fringing vegetation. Subsequently, the photograph taken on 7 June was found to show a similar male.

In the field, these males were thought likely to be *Tramea basilaris*, the only UAE dragonfly species not previously observed by either of the authors, which was known to have been recorded in Wadi Wurayah in 2010 (Reimer *pers. comm.*). However, comparison of available photographs and examination of details, particularly of the wing venation, made it clear that the new dragonfly could not be *T. basilaris*.

Additional research then led to the conclusion that the species in question must be the enigmatic *U. thomasi*, known from a small number of records from the Muscat area and Dhofar, the earliest by Bertram Thomas in 1931 (Waterston & Pittaway 1991, Schneider 1988, Schneider & Dumont 1997, Boudot *pers. comm.*), but the authors could locate no published images of *U. thomasi*. Identification was confirmed from the authors' photographs by Jean-Pierre Boudot and Wolfgang Schneider in e-mail correspondence. Schneider (*pers. comm.*) noted that "Wing spots and short abdomen are (at least in Arabia) good field characteristics". None of the earlier records is accompanied by habitat, behavioural or ecological data.

The overall distribution of *U. thomasi* in Arabia is poorly known. It is evidently rare and populations may be discontinuous. Restricted range coupled with presumed low populations in areas subject to human pressure led the species to be classified as Endangered in the IUCN Red List (Boudot 2006).

The nearest published records to Wadi Wurayah are from the greater Muscat area – Wadi Mayh (Schneider 1988) and Wadi Aday (Boudot *pers. comm.*) – each somewhat more than 300 kilometres away (Fig. 1). In the intervening area, the Hajar Mountains continue unbroken inland of the broad Batinah coast of Oman and feature numerous large wadis containing permanent water, and therefore potentially suitable habitats for *U. thomasi*, but the area remains poorly explored by naturalists. Giles (1998) included *U. thomasi* in his list of Odonata species found in Northern Oman that could occur in the UAE. However, a

Fig. 3: Male and female *Urothemis thomasi* in copula, Wadi Wurayah (photo by Huw Roberts).

reasonable level of attention and sophistication would be required to reliably distinguish it, since *U. thomasi* is one of nine UAE libellulid species having red males, and several of the others also have dark amber basal wing markings.

Waterston & Pittaway (1991) considered *U. thomasi* to be a subspecies of the widespread Asian species *U. signata*, but Schneider & Dumont (1997) followed Schneider (1988) and earlier authors (including Waterston (1981)) in recognising *U. thomasi* as a distinct species. Schneider & Dumont (1997) also followed the recommendation of Schneider (1988) in recognising the Somali populations of *U. thomasi* as a separate subspecies, *U.t. aethiopica*, originally described as *U. signata aethiopica* Nielsen, 1957. The nominate subspecies, *U.t. thomasi*, remains endemic to Arabia, but now to the UAE as well as Oman.

No females of *U. thomasi* were observed when the species was first encountered in Wadi Wurayah or when the waterfall site was visited the following day by Judas. However, Huw Roberts, alerted to the new dragonfly, visited a few days later and obtained photographs of a pair *in copula* (Fig. 3), confirming the presence of at least a small breeding population.

Other Odonata species present at the same time in the immediate vicinity of the *U. thomasi* males were *Arabineura khalidi*, *Pseudagrion decorum*, *Anax imperator*, *Crocothemis erythraea*, *Crocothemis sanguinolenta*, *Orthetrum chrysostigma* and *Trithemis arteriosa*. Further up the main wadi, *Arabicnemis caerulea*, *Ischnura evansi*, *Ischnura senegalensis*, *Orthetrum sabina*, *Pantala flavescens* and *Trithemis kirbyi* were also recorded during the following few days, as well as the dead male *U. thomasi*.

It is impossible to say definitively whether *U. thomasi* has been present in Wadi Wurayah for an extended period or whether it is a recent arrival. The poorly studied mountain wadis of the Batinah coast of Oman could possibly have hosted unrecorded populations that served as stepping stones. Within the UAE, Wadi Wurayah is singular in that it is the only wadi on the East Coast that has significant permanent water, including the UAE's only permanent waterfall. The area at and above the waterfall is the site of the largest UAE population of *Crocothemis sanguinolenta*, a dragonfly otherwise scarce in the UAE and northern Oman. However, the waterfall area has been on the itinerary of numerous dragonfly enthusiasts since *C. sanguinolenta* was first recorded there by Schneider in 2005. The possibility of recent arrival in response to regional meteorological phenomena is considered further in the "Discussion" section below.

Ischnura nursei Morton, 1907

Judas first encountered *Ischnura nursei* on 10 June 2013 at a small dam and lake known to UAE naturalists as Tennis Club Dam, on the north-western outskirts of the expanding Fujairah suburbs. The lake, approximately 5 hectares (55,000 square metres) in area, is almost totally devoid of fringing vegetation (Fig. 4) and is quite unlike the habitat that has been described and depicted in the literature for *I. nursei* (Dumont *et al.* 2011), discussed in more detail below.

Judas visited the dam site in late morning to record and photograph Odonata and had walked 200-300 metres along the north-east bank, when he first observed the new damselfly, with its tri-coloured, red, yellow and black-banded abdomen. His original notes capture the excitement of the occasion: "When I first saw this damselfly, it was coming to sit on an emergent branch, 2-3 metres away from the shore of the lake where I was standing. I could not approach more, and could not properly distinguish what it was. I was not even sure what type of insect it was. From the colour, I thought initially it might be a wasp. It was only when I examined my photo that I realised it was a damselfly of a kind I had never seen before. I tried to take another picture, but it flew away and I couldn't find it again."

Fig. 4: Shoreline of the lake at Tennis Club Dam, mid-June 2013. In the mid-ground are emergent shrubs at the current waterline, where *Ischnura nursei* was recorded (photo by GRF).

Fig. 5: *Ischnura nursei* female, captured specimen from Tennis Club Dam (photo by JJ).

He immediately shared his photograph with a number of regional experts and enthusiasts. It was obviously a female and the consensus was that it was a Coenagrionid, but it was not immediately identified to species. With expert encouragement to try to find a male specimen, Judas visited the site again the next day at the same time. He again found only a single female (at the same place), collected it and took additional photographs of the captured insect (Fig. 5), which has been preserved as a voucher specimen for expert taxonomic reference.

The following day he returned to the dam again for an hour to look for male specimens. After about 30 minutes, he finally saw three specimens of the same species, but only for about 5-10 seconds, exactly at the same place where he had found the original female. They flew together, vanished as quickly as they had arrived, and were not seen again, but their presence established that the original specimen was not simply a vagrant individual.

In subsequent e-mail correspondence, Wolfgang Schneider and Jean-Pierre Boudot independently identified the photographs as being of a female *Rhodischnura nursei*. On the further advice of Henri Dumont (Dumont *et al.* 2011, Dumont *in press*) we refer to this species as *Ischnura nursei* Morton, 1907, its original name, rather than *Rhodischnura nursei* (Morton, 1907), the name by which it has more recently been discussed. Dumont *et al.* (2011) proposed reconsideration of the validity of the genus *Rhodischnura* on molecular genetic grounds and a forthcoming paper, reviewing the molecular phylogeny of oriental *Ischnura* generally, will suppress *Rhodischnura* (Dumont *in press*).

I. nursei has been considered to have its principal range in the semi-arid regions of northern India and southern Pakistan, where its favoured habitat is said to be slow flowing rivers or pools bordered by abundant vegetation (Dumont *et al.* 2011). It is found northward at least as far as Asan Lake, near Dehra Dun, Uttarakhand (Dumont *et al.* 2011), and eastward at least as far as Varanasi (Gilbert 2005). To the west, *I. nursei* has recently been recorded from south and south-east Iran, including near Bandar Abbas, on the Iranian side of the Strait of Hormuz (Dumont *et al*. 2011) (Fig. 1).

The Iranian records are said to stretch almost 1,000 kilometres from earlier Pakistani records to the north-east (Dumont *et al*. 2011), but Dumont *et al*. (2011) find it reasonable to suppose that numerous populations live in the gap, and they believe that “this small and inconspicuous species may be widespread in suitable biotopes of southern and eastern Iran”. The UAE records are some 205-230 kilometres to the south of Bandar Abbas but both Fujairah and Bandar Abbas are more or less equally distant (*ca*. 500 kilometres) from the Iranian record at Sarbaz, near the Makran border of Pakistan. In this area, therefore, the geographic range of *I. nursei* appears to follow that of a number of regional plant and animal species having what has been called an “Omano-Makranian” (Kürschner 1986) or “Omano-Sindian” (Léonard1989) distribution.

The Tennis Club Dam site is an excavated sump having no significant natural watershed. It is understood to have been created in the late 1990s to trap runoff from surrounding foothills areas, which is carried to the site by artificial channels.

At the time of our observations, the water level was some two metres below its recent peak, as shown by a thin layer of silt on the exposed shoreline, which consists principally of bedrock covered by a veneer of angular rubble, much of it evidently bulldozed. The formerly submerged banks were dotted with fewer than twenty species of mostly annual plants. There was extremely little vegetation at the water’s edge (Fig. 4) but the few emergent plants and dead stems, all within metres of the shoreline, were covered with the exuviae of several dragonfly species.

Most of the Odonata at the site, including *I. nursei*, were observed only near the few patches of vegetation on the north-east bank. Other species observed there by the authors during the following week, all in small numbers, included *Ischnura evansi*, *Anax parthenope* (a single pair observed *in copula* and ovipositing), *Crocothemis erythraea*, *Diplacodes lefebvrei*, *Orthetrum sabina*, *Trithemis annulata* and *Trithemis kirbyi*. Inspection of similar sparse vegetation on the south and south-west margins revealed only *Ischnura evansi*.

The nearly simultaneous discovery of populations of *U. thomasi* and *I. nursei* prompted the authors to visit other sites to determine whether those species, or other surprises, might be more widespread. Because *I. nursei* had been observed at a lacustrine site on the East Coast, the authors concluded that it would be useful to pay a visit to the Rufaysah Dam in Wadi Shi, *ca*. 25 kilometres from the Tennis Club Dam. Over the years that site has produced interesting odonate records including a swarm of *Selysiothemis nigra*, breeding *Pseudagrion decorum* (Feulner 2001) and breeding *Anax imperator*, as well as other unusual plant and animal records. In recent years, however, visitation has become increasingly problematic due to restrictions imposed in connection with quarrying and road building operations in the area.

The lake behind Rufaysah Dam has only sparse fringing vegetation and the water level was relatively low when the authors visited on 21 June 2013, but a number of Odonata species were present along the silt and rubble banks, including *Ischnura senegalensis* (mating), *Anax imperator*, *Anax parthenope* (attacked and driven off by *A. imperator*), *Crocothemis erythraea* (mating), *Diplacodes lefebvrei* (mating), *Orthetrum sabina*, *Pantala flavescens*, *Trithemis annulata*, *Trithemis arteriosa* and *Trithemis kirbyi*.

In addition, a single male *I. nursei* was found on low shoreline vegetation in an area bordered by a stand of tamarisk trees (*Tamarix* sp.). Initially seen at the water's edge on the creeping grass *Aeluropus lagopoides*, the male moved (evidently spontaneously) along and up the bank to perch on dwarf shrubs, allowing photographs (Fig. 6). The presence of *I. nursei* at two East Coast sites made it harder to dismiss the original records as simply a freak occurrence.

Fig. 6: *Ischnura nursei* male, Rufaysah Dam, Wadi Shi, Khor Fakkan (photo by GRF).

Any doubt in that regard was dispelled by a third record, two months later, on the other side of the Hajar Mountains, some 30 km to the west. On 21 August 2013, Feulner and Binish Roobas inspected a shallow pond in Wadi Isfani below the Kadra Dam (Fig. 7), not far within the mountain front south-east of Dhaid. Roobas recognised a male *I. nursei* in low *Aeluropus lagopoides* grass on damp ground beside the pond. A second male was later found, sheltering in the lee side of a clump of bulrush *Juncus* sp., in association with both males and females of *I. evansi*. Both males may have been less than fully mature, judging by their pale thoracic colours (Fig. 8), suggesting that breeding may have occurred locally.

Fig. 7: The Kadra Dam site where *Ischnura nursei* was observed in late August 2013 (photo by GRF).

Fig. 8: *Ischnura nursei* male, Kadra Dam, sheltering in the lee of a clump of bulrushes *Juncus* sp. Judging by the pale thoracic colours, this specimen is not fully mature (photo by Binish Roobas).

The pond was very shallow and occupied a low spot in the gravel wadi bed, where the profile dipped slightly below the water table. It was drying out and was surrounded by a border zone of damp mud. In its current form, the pond is at least somewhat man-improved, but it is situated in an area where similar ponds existed historically in the wadi bed. The principal vegetation consisted of the cattail *Typha domingensis* growing mostly in damp or inundated areas, patchy ground cover of *Aeluropus lagopoides*, and fringing scattered tamarisk and bulrushes (*Juncus* sp.). Other odonates present were *Selysiothemis nigra*, which was common, and small numbers of *Ischnura evansi*, *Crocothemis erythraea*, *Diplacodes lefebvrei*, *Orthetrum sabina* and *Trithemis kirbyi*.

The association of *Aeluropus lagopoides* and tamarisk at the shoreline is similar to what was observed at Rufaysah Dam and *I. nursei* was again found on *A. lagopoides*. It became evident as we attempted to photograph *I. nursei* that this was probably not entirely a chance association. Instead, we noticed that *I. nursei*, however flamboyantly coloured it may seem, is actually well camouflaged among *A. lagopoides*, whose thin, pale green stems and runners are also regularly banded with yellow and dull red.

As in the case of *U. thomasi*, it is all but impossible to say definitively whether *I. nursei* is newly arrived in the UAE or has been present, permanently or intermittently, for several years (or more). The recent recognition of *I. nursei* in southern Iran, and the suggestion that it may be relatively widespread there, puts a potential source population relatively near at hand and its Omano-Makranian distribution fits a recognised biogeographic pattern.

The Tennis Club Dam was first brought to the attention of local naturalists in early 2010, when it was added to the list of sites for mid-winter waterbird counts, but it has not been regularly monitored for Odonata. Moreover, it does not retain permanent water. It was dry, for example, in January 2011 and 2012 (Judas, *pers. obs.*), and it seems unlikely that it would have been filled to its June 2013 level for most of the past decade (see also the “Discussion” section below).

The Rufaysah Dam retains permanent water, at least in most years, but access has been restricted for a number of years, so it is seldom visited, much less regularly monitored. A visit by Feulner in early June 2010, at an exceptionally low water level, recorded *Ischnura evansi*, *Ischnura senegalensis*, *Anax imperator*, *Anax parthenope*, *Crocothemis* *erythraea*, *Diplacodes lefebvrei*, *Orthetrum sabina*, *Trithemis arteriosa* and *Trithemis kirbyi*. However, *Pseudagrion decorum*, which had been present and breeding on several earlier visits since 2001, was not seen. Nor, of course, was *I. nursei*, which, even more than other *Ischnura*, is a good example of a species that could easily be overlooked if not specifically searched for.

The Kadra Dam site, surrounded on three sides by one of the largest quarries in the area, has probably not been inspected for Odonata since Graham Giles visited in the late 1990s, before either the quarry or the dam existed.

Discussion

What, if anything, are we to make of the contemporaneous first records of the two Odonata species reported here? Is this simply coincidence? The two species occupy very different habitats and they have their provenance in populations centered in opposite directions from the East Coast of the UAE, so it is possible that each has found its way to the UAE for independent reasons and by independent processes, including the possibility of gradual and previously unnoticed range expansion.

The alternative explanation is that the unheralded presence of both species at once is attributable to a more general explanation, the most likely one being climatic phenomena. Because *U. thomasi* and *I. nursei* originate in different geographic areas, their presence cannot reasonably be the result of a single freak storm or event sweeping hapless odonates from one place to another (the "push" hypothesis). More likely is the recruitment or expansion of both species due to the creation of more favourable environmental conditions in the new area, either seasonally or for a longer term (the "pull" hypothesis). The latter hypothesis is arguably favoured by the coincidence of at least a few other unusual UAE Odonata records, including *Pseudagrion decorum* at Wadi Wurayah waterfall (in June); small numbers of *Anax ephippiger* (normally a winter migrant or nomad) seen in August in coastal mangrove habitat on the Arabian Gulf (Feulner, *pers. obs.*); and swarms of *Selysiothemis nigra* at multiple sites along the western mountain front in August and September (Feulner, *pers. obs.*).

The most recent meteorological data have not yet been compiled by local authorities, but the fall, winter and spring of 2012-2013 have been, impressionistically, among the wettest in the UAE in the past 15 years. Major rainfall events caused flooding in the wadis of the East Coast in mid-December, early April and late April to early May. The latter, spanning several days, was exceptional in its volume and its unseasonable timing (Feulner 2006) and may have been due in part to cloud seeding (Scaria 2013). To the authors, these climatic phenomena seem to be the most probable explanation for the singular but contemporaneous records of Odonata having adjacent known ranges, but this can only be tested inferentially, in part by future observations recorded in conjunction with meteorological data.

Climatic conditions could conceivably influence local Odonata populations in at least two ways: (i) by prompting immigration from neighbouring populations to newly congenial habitats – a recognised phenomenon in dragonflies and other taxa; or (ii) by stimulating or suppressing the development, metamorphosis and emergence of nymphs (or even eggs?) that would otherwise remain in the aquatic larval stage pending suitable conditions for emergence of the adult.

Corbet (2004) discusses facultative diapause (suspended development) in odonate larvae, but only in relation to northern species and only in response to photoperiods and temperatures presaging the arrival and departure of winter. Many tropical species residing in seasonal (wet and dry) climates have adapted their normal life cycles to pass all or part of the dry season as non-reproductive adults, or sometimes as eggs (Corbet 2004).

Van Damme & Dumont (1999) demonstrated that at least some dragonflies can suspend their development during the larval (nymph) stage and become dormant, in a completely dry state, in order to survive seasonal drought. They pointed out that this was a powerful adaptation to semi-arid environments that may be more widespread than hitherto believed. This phenomenon may help to explain the regular presence of resident species in seasonal environments, but it is less effective in explaining the seemingly adventitious appearance of rare species intermittently over longer intervals. At least, no Odonata are yet recognised to be able to delay their development and/or emergence for extended periods, in the manner of, e.g., certain desert species of Lepidoptera such as the Desert White butterfly (*Pontia glauconome*), which develops rapidly from egg to pupa but can spend several years in diapause in the pupal stage awaiting climatic conditions suitable for breeding (Larsen 1983).

From a broader ecological perspective, in the UAE the early years of the new millennium have been significantly drier than the two decades that preceded them (Feulner 2006). From this one might reason that, if the East Coast of the UAE is within the historical range of *U. thomasi* and/or *I. nursei*, those species ought to have been present in greater numbers earlier, in the late 20th century, and therefore encountered sooner. However, that reasoning is countered by the fact that few naturalists had paid special attention to dragonflies in the UAE prior to publication of the first illustrated checklist by Giles (1998).

The new records reported here are the latest fruit of the considerable attention that has followed. At the end of his checklist, Giles listed nine species of Odonata found in Northern Oman which he considered could occur in the UAE in the future. *U. thomasi* marks the eighth of those species that has since been recorded within the UAE. *I. nursei* represents the first new UAE species to be encountered that was not forecast by Giles (the Asian *Trithemis pallidinervis* is the exception). These results will doubtless ensure continuing investigation by hopeful enthusiasts.

Acknowledgements

The authors wish to thank Jean-Pierre Boudot and Wolfgang Schneider for their identification of photographs of *Urothemis thomasi* and *Ischnura nursei*; K-D.B. Dijkstra for alerting us to the impending taxonomic revision of *Rhodischnura nursei* (to *Ischnura nursei*); and Henri Dumont for confirming his intention to revise the taxonomy of that species and providing an advance copy of his paper.

Feulner's survey of the flora and vegetation of Wadi Wurayah National Park, which provided the occasion for the discovery of *Urothemis thomasi*, was initiated by Emirates Wildlife Society–WWF and supported by HSBC and Fujairah Municipality. Judas is research manager of Wadi Wurayah National Park for EWS–WWF; his research in Wadi Wurayah National Park and more broadly in the Hajar Mountains of the UAE is likewise supported by HSBC and Fujairah Municipality.

References

Boudot, J.-P. 2006. *Urothemis thomasi*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.1. <>. Accessed 20 September 2013.

Corbet, P.S. 2004. *Dragonflies: Behaviour and Ecology of Odonata* (Revised Edition). 829 pp.

Dumont, H.J. *in press.* Phylogeny of the genus Ischnura with emphasis on the Old World taxa (Zygoptera: Coenagrionidae). **Odonatologica 42(4):** 301-308.

Dumont, H.J., Kiany, M. & Sadeghi, S. 2011. First record of *Rhodischnura nursei* (Morton) from Iran (Zygoptera: Coenagrionidae). **Odonatologica 40(3):** 251-254.

Feulner, G.R. 2001. The damselfly *Pseudagrion decorum* breeding in the U.A.E. **Tribulus 11.1**: 24.

Feulner, G.R. 2006. Rainfall and climate records from Sharjah Airport: Historical data for the study of recent climatic periodicity in the U.A.E. **Tribulus 16.1**: 3-9.

Feulner, G.R. 2011. The Flora of the Ru'us al-Jibal – the Mountains of the Musandam Peninsula: An Annotated Checklist and Selected Observations. **Tribulus 19:** 4-153.

Feulner, G.R., Reimer, R.W. & Hornby, R.J. 2007. An Updated Illustrated Checklist of the Dragonflies and Damselflies of the UAE. **Tribulus 17:** 37-62.

Gilbert, E. 2005. Asia-Dragonfly [online]. Available from World Wide Web:

Giles, G.B. 1998. An Illustrated Checklist of the Damselflies & Dragonflies of the UAE. **Tribulus 8.2**: 9-15.

Kürschner, H. 1986. Omanisch-Makranische Disjunktionen Ein Beitrag zur pflanzengeographischen Stellung und zu den florengenetischen Beziehungen Omans. **Botanische Jahrb¸cher für Systematik 106**: 541-562.

Larsen, T.B. 1983. Insects of Saudi Arabia – Lepidoptera; Rhopalocera (A Monograph of the Butterflies of the Arabian Peninsula). **Fauna of Saudi Arabia 5**: 333-478.

Léonard, J. 1989. *Considerations phytogeographiques sur les phytochores irano-touranienne, saharo-sindienne et de la Somalie-pays Masai. Contribution ‡ l'Ètude de la flore et de la vegetation des deserts d'Iran*. Jardin Botanique Nationale Belgique. 123 pp.

Reimer, R.W., Feulner, G.R. & Hornby, R.J. 2009. Errata and Addenda: Updated Illustrated Checklist of the Dragonflies of the UAE – including a third species of *Ischnura* damselfly. **Tribulus 18:** 28-36.

Scaria, S. 2013. Unseasonal UAE rainfall due in part to cloud seeding. *The 971 Report*, 29 April 2013. <> Accessed 22 August 2013.

Schneider, W. 1988. Dragonflies (Odonata) of the Wahiba Sands and Adjacent Areas, Eastern Oman. **Jour. Oman Studies Special Rept. No. 3**, pp. 377-388.

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

Van Damme, K., and Dumont, H. J. 1999. A drought-resistant larva of *Pantal flavescens* (Fabricius, 1798) (Odonata: Libellulidae) in the LenÁois Maranhenses, NE-Brazil. **International Jour. Odonatology 2(1):** 69-76

Waterston, A.R. 1981. The Dragonflies (Odonata) of Dhofar. **Jour. Oman Studies Special Rept. No. 2**, pp. 149-151.

Waterston, A.R. & Pittaway, A.R. 1991. The Odonata or Dragonflies of Oman and neighbouring territories. **Jour. Oman Studies 10** (for 1989): 131-168.
[NB: *Tribulus*, the journal of the Emirates Natural History Group, Abu Dhabi, is available online at:] http://www.enhg.org/Home/Publications/Tribulus.aspx

Gary R. Feulner
c/o Chadbourne & Parke
PO Box 23927
Dubai, United Arab Emirates
email: grfeulner@gmail.com

Jacky Judas
Emirates Wildlife Society in Association with
World Wide Fund for Nature
P.O. Box 454891
Dubai, United Arab Emirates
email: jjudas@ewswwf.ae

The dragonflies and damselflies of a wadi pool near Nizwa, northern Oman, 2012–2013

by Elaine M. Cowan and Peter J. Cowan

Introduction

Schneider and Dumont (1997) reviewed the literature on previous records of dragonflies and damselflies (Odonata) in Oman, reported on specimens in the national collection in Muscat, and added new observations from two personal visits. They produced a checklist of 40 odonate species for Oman, ten damselflies and 30 dragonflies. The occurrence of some of these species is based on a single individual or on records in the south of Oman. Since then, additional observations and records for northern Oman have been added mainly through the work of odonate enthusiasts visiting from the UAE.

In the last decade, an excellent field guide was published for the dragonflies and damselflies of Europe including western Turkey and northwestern Africa (Dijkstra & Lewington 2006), which includes some of the species occurring in Arabia. In addition, annotated checklists of the dragonflies and damselflies of the UAE illustrated by photos have been produced (Giles 1998, Feulner *et al.* 2007, Reimer *et al.* 2009). The photos of UAE damselflies and dragonflies on Tommy Pedersen's website (www.uaebirding.com) and the Arkive website (www.arkive.org) are also useful. Together these resources facilitate the study of northern Oman's Odonata.

To assess the status of the various species in Oman, Schneider and Dumont (1997) suggested that "frequent collecting in all seasons over several years by resident naturalists is most important". The present paper describes the odonatofauna of a wadi pool near Nizwa, based on repeated visits over more than a year, though armed with a digital camera rather than a collecting net.

Occasional visits to this wadi pool between 2009 and 2011 were followed up with more frequent visits and observations March 2012 to June 2013. Apart from exuviae, no odonates were physically handled on any visit. All species observations for this paper are based on digital photos taken at the pool, allowing for later deliberation and confirmation of ID. All photos were by EMC, using a lightweight handheld Sony Cybershot compact camera with 30× optical zoom (except Figure 22, taken with an earlier model).

Fig. 1. The pool in August 2012.

Fig. 2. The pool in March 2013.

Fig. 3. The *falaj* and cave seepage site, May 2012.

Fig. 4. The dam upstream of the pool, overtopped by floodwaters, August 2012.

The pool habitat

The observation pool (GPS: 23° 4.533 N, 57° 21.567 E, 680 m asl) is between Al Hamra and Tanuf, in upper Wadi al Abyad (El-Baz 2004) that 'flows' eastwards through the southern foothills of the Jebel Akhdar range towards Wadi Tanuf and then on towards Nizwa. It is a few kilometres from the Al Hoota cave tourist attraction. The pool changes in size dramatically over time (Figures 1 to 4) due to variations in rainfall and evaporation. It is also fed by seepage from a small mountain-side cave which has a very short *falaj* at its exit (Figure 3). A short distance 'upstream' of the pool is a small dam which in September 2012 and April 2013 was overtopped by flood waters (Figure 4). The pool has a variety of typical wadi vegetation on its northern side with larger shade trees mainly on the southern side. The immediate area on the southern side is a popular picnic site at weekends with an associated play area for children and carpark. Litter drifts into the pool.

Systematic list

Two damselfly and eight dragonfly species were observed. Evidence of breeding at the pool was obtained for one damselfly (*Pseudagrion decorum*) and five dragonfly (*Anax imperator*, *Orthetrum chrysostigma, O. sabina, Crocothemis erythraea, Trithemis annulata*) species. Scientific nomenclature, authority citations and species sequence follow Schneider and Dumont (1997). Notes on behaviour and breeding are given below while field characteristics that aid identification are presented in the photograph captions. Identification of females and recently emerged males is far more challenging than that of typical males.

ZYGOPTERA Damselflies
Coenagrionidae

Evans' Bluetail *Ischnura evansi* Morton, 1919 (Figure 5). Males were observed on twigs and basking on stones in the pool but mating was not observed. Female bluetail *Ischnura* ovipositing (Figure 6) in June 2013, unaccompanied by a male (typical of this genus), were presumably *I. evansi* and males were present at the pool then.

Elegant Sprite *Pseudagrion decorum* (Rambur, 1842). This is the common damselfly of the pool (Figure 7). Female bluetails ovipositing were definitely observed on rare occasions e.g. in March and April 2013, during and after mating (Figures 8 and 9).

Fig. 5. Male Evans' Bluetail *Ischnura evansi*, February 2013. Note the green face and thorax, posterior blue 'tail-light' on segment 8 of abdomen with dark brown beyond. The plain green colouration on abdominal segment 2 is a distinguishing character from *I. senegalensis* (Feulner *pers. comm.*).

Fig 6. Females, apparently Evans' Bluetails *Ischnura evansi*, ovipositing, June 2013. Another photo showed that the more male-like individual on the right had greenish eyes and a pale 'tail light'. The female on the left had reddish eyes and orange legs (cf. Feulner *et al.* 2007).

Fig. 7. Male Elegant Sprite *Pseudagrion decorum*, January 2013. Vivid blue face, eyes and thorax. Blue underside of abdomen with blue dorsal marking on front of each segment. Blue double band at posterior of abdomen.

Fig. 8. Elegant Sprite *Pseudagrion decorum* mating wheel (female below), March 2013. Female: green face and upper thorax; underside of abdomen, lower face and sides of lower thorax pale blue-grey.

ANISOPTERA Dragonflies

Aeshnidae

Blue Emperor *Anax imperator* Leach, 1815. This large bright-blue male dragonfly patrols the pool and surrounding area (Figure 10). Females are less brightly coloured. Females were observed in October 2012 and on several occasions in March to June 2013, laying eggs in the largely submerged patches of plants close to the northern, more shaded side of the pool (Figure 11). On one occasion three females were laying in the same area of 'weed'. After the wadi flood of May 2013, three females were also seen ovipositing in sugar-grass stems and floating debris. Large exuviae, presumably of this species, were found on steep rock faces above water level, February to April 2013.

Gomphidae

Sinai Hooktail *Paragomphus sinaiticus* (Morton, 1929). There is no mistaking this dragonfly (Figure 12). Males sometimes basked in groups of up to three or more individuals on the tops of larger sunny boulders around the pool, returning to the same spot if disturbed. Females are less obviously black and white and were only seen occasionally, e.g. in late afternoon perched on small branches in trees near the pool.

Libellulidae

Girdled Skimmer *Orthetrum chrysostigma* (Burmeister, 1839). Males of this dragonfly are pale blue (Figure 13), tend to be solitary and bask on twigs, stones, the shore or the *falaj* walls. The female (Figure 14) was only identified at the pool when mating (Figure 15) or laying eggs in the pool with a male on guard.

Slender Skimmer *Orthetrum sabina* (Drury, 1773). This distinctive dragonfly perches on twigs or stones in and around the pool (Figure 16). Male and female are similar in appearance as seen in this mating wheel (Figure 17).

Carmine Darter *Crocothemis erythraea* (Brullé, 1831). Usually two or three individual males frequent the pool and bask on twigs or surrounding stones (Figure 18). The brownish females were seen much less frequently (Figure 19). A mating wheel was photographed, January 2013.

Purple-blushed Darter *Trithemis annulata* (Beauvais, 1807). One or two males were seen at the pool on almost every visit. Individuals commonly bask on rocks and waterside twigs, often in the abdomen-up obelisk position (Figure 20). The yellow-brown females were identified only when mating or ovipositing with male on guard (Figure 21).

Gulley Darter *Trithemis arteriosa* (Burmeister, 1839). Only seen infrequently at the pool, the male has a slender abdomen, scarlet in colour with black markings along its sides (Figure 22). Males perch on rocks or twigs around the pool. The slender females were seen in deep shade, e.g. in the *falaj* area (Figure 23).

Orange Darter *Trithemis kirbyi* Sélys, 1891. This dragonfly is very common at the pool and ten or more individuals were visible on most visits. It is smaller than *Crocothemis erythraea* and the abdomen is slightly heavier set than *Trithemis arteriosa*. Unlike *T. arteriosa* the male has no black on the abdomen dorsally or laterally except at segments 9 or 10 (Figure 24). Males spend much of their time basking around the pool on rocks or stones but are also quite aggressive to one another and other dragonflies. On very hot days they hug the shade near the larger rock faces. Females were seen less frequently (Figure 25) and, on the hottest days, perch in shade up in the trees. We did not observe mating or laying for this species.

Fig. 9. Elegant Sprites *Pseudagrion decorum* in tandem (female below) after mating, April 2013. Flew in tandem returning to the mating twig, then slowly inched down into the water with the partly immersed female presumably laying eggs. The female did not fully immerse, unlike observed by Feulner (2001).

Fig. 10. Male Blue Emperor *Anax imperator* in flight, April 2012. Large dragonfly with blue eyes, bowed blue abdomen and strong patrolling flight.

Fig. 11. Female Blue Emperor *Anax imperator* laying eggs, April 2013. Blue on frons (forehead), pale bluish-green eyes, greenish colour on thorax and blue on abdomen. Note reddish colouration dorsally on the abdomen. No male present during ovipositing (typical for this species).

Fig.12. Male Sinai Hooktail *Paragomphus sinaiticus* in obelisk position, April 2013. Widely separated eyes, white frons, black and white diagonal stripes on sides of thorax, slim black and white banded abdomen with large yellow hooks at posterior of abdomen.

Fig.13. Male Girdled Skimmer *Orthetrum chrysostigma*, May 2013. Blue eyes, blue/black legs, blue thorax and blue abdomen with 'girdle' formed by narrowing of abdominal segments 3 and 4 into a 'waist'.

Fig. 14. Female Girdled Skimmer *Orthetrum chrysostigma* in flight, April 2013. Note the bluish eyes and diagonal whitish stripe faintly edged in black on the side of the thorax. This individual was observed ovipositing, dipping her abdomen into the pool while male guarded her from above.

Fig. 15. Girdled Skimmer *Orthetrum chrysostigma* mating wheel, May 2013. Female, underneath, bluish in colour, perhaps an old female. Another mating female seemed greyish rather than brown or blue.

Fig. 16. Male Slender Skimmer *Orthetrum sabina* perching on twig, October 2012. Eyes dark green, thorax with green stripes, abdomen greenish-white and black bands merging into a central black line dorsally. Black posterior segments (8–10) thicker than anterior segments. White terminal appendages.

Fig. 17. Slender Skimmer *Orthetrum sabina* mating wheel (male above), January 2013. The female was then observed ovipositing, dipping her abdomen into the pool while the separated male guarded her from above. The whitish stripe on the female's thorax is in reality probably greenish.

Fig. 18. Male Carmine Darter *Crocothemis erythraea*, January 2013. Red dragonfly with broad red abdomen, red eyes and legs. The pterostigma are pale yellow-brown and amber patches at base of rear wings are very small.

Fig 19. Female Carmine Darter *Crocothemis erythraea*, October 2012. This female was greyish-brown with dorsal line on abdomen and small proximal amber patches on rear wings.

Fig. 20. Male Purple-blushed Darter *Trithemis annulata*, October 2012. Maroon eyes, bright purple thorax and abdomen. Orange patches on rear wings and dark pterostigma.

Fig. 21. Female Purple-blushed Darter *Trithemis annulata* in flight, April 2013. Yellowish-brown with black dorsal line along the abdomen becoming thicker on terminal segments and amber patch on rear wings. This female was seen laying eggs with male on guard.

Fig. 22. Male Gulley Darter *Trithemis arteriosa*, September 2009. Very slim red abdomen, with black markings at terminal segments and black colouration just visible along both sides of abdomen. Small proximal amber wing patches on both front and rear wings and dark pterostigma.

Fig. 23. Female Gulley Darter *Trithemis arteriosa*, May 2013. Yellowish abdomen with black markings along the sides, extensive black around the posterior segments. The two females observed on this date had obvious nodal and apical wing patches but on previous occasions these were not always evident (*cf.* Walker and Pittaway 1987).

Fig. 24. Male Orange Darter *Trithemis kirbyi*, February 2013. Orange red abdomen with black only on terminal segments. Large bright orange patches at base of all four wings and dark pterostigma.

Fig 25. Female Orange Darter *Trithemis kirbyi*, April 2013. Yellowish with black dashes along the abdomen sides and at the final two segments dorsally. Some females at the pool have much smaller and paler wing patches with a second, separate, pale amber patch at base of rear wings.

Acknowledgements:

EMC thanks Professors Henri Dumont (Belgium) and Jean-Pierre Boudot (France) for their encouragement and helpful advice at an early stage of her dragonfly photographic studies. Gary Feulner (UAE) made very helpful comments and suggestions on a draft of this paper.

References:

Dijkstra, K-D.B. and Lewington, R. (2006). *Field Guide to the Dragonflies of Britain and Europe*. British Wildlife Publishing, Dorset, UK.

El-Baz, F. (*Ed*). (2004). *Wadis of Oman: Satellite Image Atlas***.** Office of The Adviser to His Majesty The Sultan for Cultural Affairs, Muscat.

Feulner, G.R. (2001). The damselfly *Pseudagrion decorum* breeding in the U.A.E. **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.

Giles, G.B. (1998). An illustrated and annotated checklist of the Dragonflies of the UAE. **Tribulus 8(2)**: 9-15.

Reimer, R.W., Feulner, G.R. and Hornby, R.J. (2009). Errata and addenda: Updated illustrated checklist of Dragonflies of the UAE—including a third species of *Ischnura* damselfly. **Tribulus 18**: 28-36.

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.

Walker, D.H and Pittaway, A.R. (1987). *Insects of Eastern Arabia***.** Macmillan, London.

Elaine M. Cowan
School of Education
University of Aberdeen
Scotland, UK
(presently Nizwa)
e-mail: desertlarksgirl@hotmail.com

Peter J. Cowan
Department of Biological Sciences and Chemistry
University of Nizwa
Sultanate of Oman
e-mail: desertmammal@yahoo.com

A population of Bosk's fringe-toed lizard *Acanthodactylus boskianus* (Daudin, 1802) in the Hajar Mountain foothills of the UAE

by Binish Roobas and Gary R. Feulner

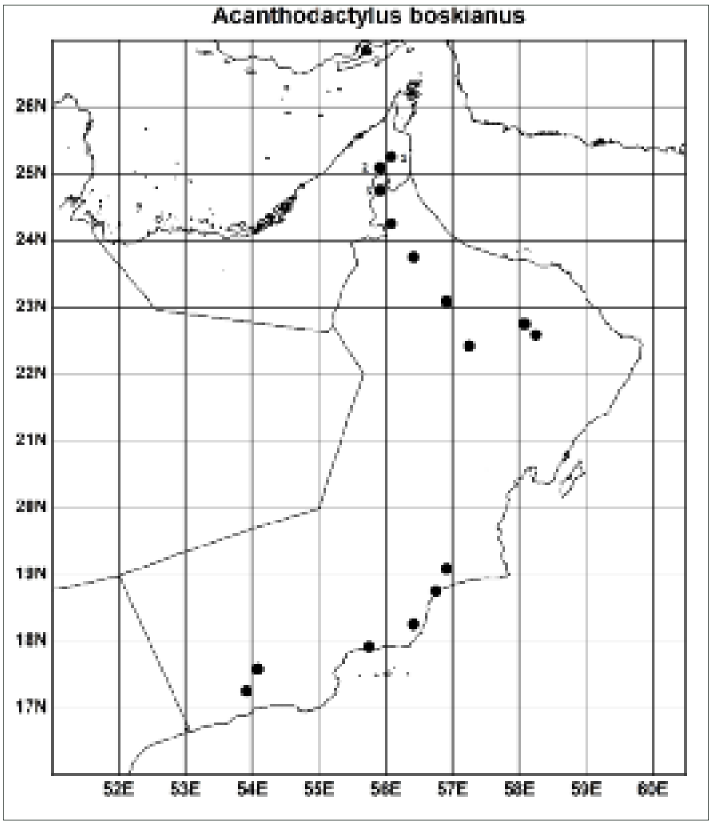


Fig. 1: Records of *Acanthodactylus boskianus* from the UAE and Oman (courtesy of A.S. Gardner). Point 1 represents the two sites discussed in this paper. Point 2 shows the approximate location of the first UAE reports of *A. boskianus* (Arnold 1984). Point 3 represents unpublished records from Peter L. Cunningham, described as being "in the area between Ash-Shu'ayb [Shuwayb or Shwaib] and [the] general Hatta direction" (Cunningham, *pers. comm.*). The map is not an authorityon international borders.

Abstract

A localised population of *Acanthodactylus boskianus* lizards (n 50 ± 10) has been identified along a wadi in the foothills of the Hajar Mountains of the United Arab Emirates (UAE). Photographs of adult male, adult female, juvenile and adolescent individuals are presented for reference. This constitutes only the second report of *A. boskianus* from within the UAE and expands the habitat for that species from what has been described on the basis of most earlier records from the UAE and neighbouring northern Oman.

The newly recognised *A. boskianus* population is associated with abandoned and eroded fields bordering a gentle wadi. Observation of foraging and foraging behaviour suggests that ants constitute the principal prey of this population, although termites were actively dug for and eaten and other, larger prey is probably taken opportunistically. The lizards are active primarily in the morning but some, particularly adolescents, also forage in late afternoon. Population evidence indicates that the reproductive season is extended but may be centered in fall and winter. Winter dormancy is possible but not confirmed.

Our successful effort to find *A. boskianus* at a second, similar location leads us to suggest that the species has heretofore probably been overlooked and under-recorded, being more common than was previously thought. Ironically, however, its foothills wadi habitat is today under severe threat throughout the UAE.

Introduction

Bosk's fringe-toed lizard *Acanthodactylus boskianus* (Daudin, 1802) is the most widespread species in the Saharo-Sindian lacertid genus *Acanthodactylus*, which includes about 30 species (Arnold 1980, Rastegar-Pouyani 1999). It is also the largest *Acanthodactylus* species throughout its range (Arnold, 1980, Sahara-Nature), which includes all of Saharan North Africa and the Middle East, i.e., Arabia, the Levant and Mesopotamia (including the Turkish border), as well as north-western Iran (Rastegar-Pouyani 1999). A recent account of the systematics of *A. boskianus* is given in Rastegar-Pouyani (1999).

A. boskianus is said to be present in all regions of the Sahara and to "frequent a range of stony and sandy environments such as the edges of routes, channels, wadi beds [and] palm groves" (Sahara-Nature). Jongbloed (2000) has mentioned that outside the UAE it is known from elevations up to 2000 metres. In Egypt, it is said to be common and found in a variety of habitats throughout the country (Khanoon 2009).

In the UAE, *A. boskianus* is one of six *Acanthodactylus* species, and one of the only two that have been recorded on other than sand substrates (Hornby 1996, Jongbloed 2000, Gardner 2005b, Gardner 2008, Gardner *in press*). *A. boskianus* has also been considered one of the rarest of the UAE's *Acanthodactylus* lizards. The only prior UAE records are those of Arnold (1984), believed to be from eastern Sharjah emirate, in the area between Dhaid and Madam (Gardner *pers. comm.*, Gardner *in press*), not far from the border with northernmost Oman (Fig. 1). The habitat was described as the interface between the gravel outwash plains along the west flank of the mountains and the active sand dunes still farther west (Arnold 1984).

It was therefore a considerable surprise when the authors encountered a small population of *A. boskianus* in early December 2012 in a lower tributary of Wadi Isfani, in the foothills south of Siji, on the west flank of the Hajar Mountains (Fig. 1). Our surprise was all the greater because extensive quarrying, road-building, power lines, private construction and weekend picnicking have severely disrupted the natural environment in that general area.

Nevertheless, within less than an hour we were able to observe and photograph an adult male, adult female and juvenile, each showing different and distinctive colour patterns (Rastegar-Pouyani 1999), in what was evidently a relatively concentrated local population. We also made some preliminary behavioural observations.

This population represented not only an extension of the known geographic range of *A. boskianus* within the UAE and Oman, but also an expansion of the range of habitats within which it is known to occur. We therefore made follow-up visits in mid and late December 2012, and again in early and mid-August 2013, to try to better

Fig. 2: An adult male *Acanthodactylus boskianus*, early December 2012. [BR]

Fig. 3: A young adult male *Acanthodactylus boskianus*, mid-August 2013, showing a relatively high proportion of vivid intermittent dark scales, retained from juvenile colouration. [BR]

Fig. 4: An adult female *Acanthodactylus boskianus*, early December 2012. [BR]

assess the size of the population and understand more about its ecology. This report describes and discusses our observations.

Identification

Comparison of our original photographs with literature sources (Rastegar-Pouyani 1999, Jongbloed 2000, Gardner 2008) permitted a tentative identification as *A. boskianus*, a species not previously encountered by either of the authors. That identification was confirmed by Gardner (*pers. comm.*) and Cunningham (*pers. comm.*). It is worth noting that images of *A. boskianus* available on the internet were inconclusive for purposes of identification, owing to the diversity of colour patterns found at other locations.

Description

The adult *A. boskianus* we observed were relatively large – larger (in our estimation) than *A. schmidti*, the UAE's most common *Acanthodactylus*, with which we are familiar. Relative size was one of the factors in favour of a tentative identification as *A. boskianus*. However, size remains a qualitative assessment. Because we wanted to be able to study the ecology of the population and wished to habituate the lizards to our presence, we did not attempt to capture and measure any specimens.

Jongbloed (2000) states maximum snout-vent length for *A. boskianus* as 95mm, versus a range of 60-100mm for snout-vent length in *A. schmidti*, but Arnold (1980) has pointed out that the sizes of both *A. boskianus* and *A. schmidti* vary with geography (and suggests that this is due to character displacement resulting from sympatry with other species). Like other *Acanthodactylus* lizards, *A. boskianus* has a very long tail, longer than the body length. Tail colour evidently varies with maturity and, in adults, with season.

Males. In adult males (Figs. 2 and 3), the ground colour is bronze, mottled with intermittent darker scales and marked with three faint pairs of pale, longitudinal stripes, residual from the juvenile colour pattern. A horizontal line of four irregular dark spots, separated by white, is present under the eye. Depending on light conditions, the overall bronze colour may appear slightly grayish or greenish. The belly is yellowish. Tail colour is dull blue-grey.

Females. Adult females (Fig. 4) have a medium to light brown ground colour with three distinct pairs of thin, pale, longitudinal stripes, retained from the juvenile colour pattern. The belly is pale. Tail colour in December was bluish-grey, similar to the male. Tail colour in August was dull pinkish-tan. In all cases the base of the tail was marked by subdued, darker transverse piping, fading out distally.

Juveniles. Juvenile *A. boskianus* (Fig. 5) were observed in both early December 2012 (n = 2) and mid-August 2013 (n = 1). They are distinguishable from adults not only by their much smaller size but also by their colouration, which features a boldly striped body with a pale, turquoise-blue tail. Length was measured indirectly at *ca*. 9cm, including the long tail. The trunk displays a pattern of contrasting

Fig. 5: A juvenile *Acanthodactylus boskianus*, early December 2012, showing the blue coloured tail. [BR]

Fig. 6: An adolescent *Acanthodactylus boskianus*, early August 2013. [GRF]

dark and pale longitudinal stripes from the base of the skull to the base of the tail. A dark central dorsal stripe (dark brown, appearing almost black) is flanked by three thin, pale cream-coloured stripes alternating with three slightly broader dark stripes. The belly is pale. A dagger of pale colour divides the central dorsal stripe from the base of the skull to the shoulder girdle. As in adults, the posterior surface of the legs is spotted white on very dark brown.

The pattern of a boldly striped trunk and a colourful tail is common to juveniles of a number of *Acanthodactylus* and other lizards, e.g., *A. opheodurus* (Arnold 1980). In this instance it created particular confusion initially, not only because *A. boskianus* was unexpected but because its juvenile colour pattern (black-and-white striped trunk and pale blue tail) closely resembles that of another juvenile lacertid found in the UAE, *Omanosaura cyanura*, a Hajar Mountain endemic (Feulner 2013). The latter would normally have been found only deeper in the mountains, in habitats characterised by narrower, bedrock wadis, but in the field we were forced to consider at the outset whether the juvenile form we encountered was conspecific with the undoubtedly 'new' male (*A. boskianus*) or whether it was an errant *O. cyanura*.

<u>Adolescents</u>. Adolescent *A. boskianus* (Fig. 6) were observed only in August 2013, when they constituted a majority of the individuals seen. They are intermediate in size between juveniles and adults. They continue to display the juvenile colour pattern of contrasting parallel longitudinal stripes, but the dark stripes are much less vivid and the tail is no longer turquoise blue but pale, slightly dull pink, as described for females. Closer inspection shows that the colour change to the trunk results because the dark stripes no longer consist of uniformly dark scales. Instead, in adolescents the dark stripes contain only intermittent dark scales, with lighter brown scales in between. A continuation of this process, i.e., reduction in the number of dark scales in favor of light brown ones, would result in what we have called the adult female colour pattern.

Several larger and less contrastingly striped adolescents displayed a diffuse but distinct reddish patch dorsally at the base of the tail, behind the hips (Fig. 7*)*. Its significance is unknown, but sexual signalling is an obvious possibility. The evidence for late summer egg laying (see "Reproductive cycle" below) makes the hypothesis of sexual signalling more plausible, but if it is correct, it would mean that at least some of the lizards that we have characterised as adolescents are in fact sexually mature, notwithstanding that they still retain some of the dark scales seen in juveniles.

Fig. 7: A late adolescent or young adult female *Acanthodactylus boskianus*, early August 2013, one of several individuals showing a diffuse red patch dorsally at the base of the tail. The significance of the red patch is unknown. [GRF]

Habitat

The *A. boskianus* population we have studied is associated with accumulations of silty soil along the low banks of a gentle wadi, representing former cultivated fields now eroding and exposing coarse gravel beneath. *A. boskianus* has been found along a 0.6 kilometre stretch of the wadi but the concentration of lizards is greatest where the silt is most continuous and dotted with small trees and shrubs, especially *Pulicaria glutinosa* (Family Asteraceae, a very common Hajar Mountain foothills shrub not browsed by quadrupeds). In a few places, the soil cover has been bulldozed in the past, for unknown reasons; we always found lizards near the resulting low, bulldozed piles of soil, perhaps because they created preferred substrate or more diverse small scale habitat.

No other reptiles were recorded among our *A. boskianus* population. Other UAE lizard species which might reasonably be expected at or near such a site include the diurnal lacertid *Mesalina adramitana* and the nocturnal gecko *Bunopus spatalurus* (*pers. obs.*, Gardner *in press*). A single semaphore gecko *Pristurus rupestris* was found at a second, smaller *A. boskianus* locality (described below), on dead wood covering the mouth of a cistern; *P. rupestris* would normally be found in a somewhat more rocky or stony environment than *A. boskianus*. A single *Pseudotrapelus sinaitus*, the Sinai agama, was found on stony ground near bedrock outcrops not far from the second *A. boskianus* locality.

The only prior records of *A. boskianus* from the UAE are from the gravel outwash plains bordering the Hajar Mountains, and more specifically from the interface between the gravel plains and the active sand dunes to the west (Arnold 1984). Arnold (1984) considered it probable that *A. boskianus* was limited to that habitat. That view was repeated by Jongbloed (2000) and has gone unchallenged by most other authors. Hornby (1996) described the habitat of *A. boskianus* as “Desert, wadis, coast” but the reference to coast was based on a photo record since reckoned to show an unusually well striped *Mesalina adramitana* (Hornby *pers. comm.*, Gardner *pers. comm.*). The foothills wadi environment therefore represents an expansion of the generally accepted habitat of *A. boskianus* within the UAE.

Reviewing this point with the benefit of hindsight, it is evident that, by design, Arnold largely excluded the foothills environment from the scope of his UAE field investigations. His pioneering study was focused on the ecology of “desert lizards”, then understudied in Arabia, and he expressly distinguished “really desertic regions” from “the more mesic, peripheral areas, such as the mountains of northern Oman”, which he considered had already received a measure of scientific attention (Arnold 1984). Cunningham’s data, previously unpublished, bridges the gap to some extent; he reports “seeing [*A. boskianus*] in lower foothills and gravel plains, often in association with vegetated small ephemeral drainage lines” (Cunningham, *pers. comm.*).

Descriptions from other countries indicate that *A. boskianus* is an environmentally plastic species (Jongbloed 2000, Khanoon 2009). In Egypt, for example, it has been called a “sand lizard” (El-Masry & Hussein 2001) and in north-western Iran it has been collected from under spiny *Astragalus* bushes on a sand hill (Rastegar-Pouyani 1999). Its general restriction to firmer substrates in the UAE may be an example of character displacement resulting from niche competition with other *Acanthodactylus* species. Arnold (1980) has previously suggested character displacement as an explanation for the larger size of *A. boskianus* in Arabia, where it is often sympatric with the smaller *A. opheodurus*, than in North Africa, where it is not.

Population size, density and structure

The core area of the study population appears to be near the upstream extremity of the site, where continuous soil cover is most extensive (Fig. 8). There, at mid-morning in early August 2013, we recorded 14 individuals within a rectangular area of approximately 55 by 40 metres, or 2200 square metres. Only one lizard was an adult male (as determined by size and colour pattern); four were adult females (as determined by light brown ground colour and pale longitudinal stripes, with darker stripes extremely subdued or absent); and eight were adolescent (as determined by size and residual dark longitudinal stripes bordering the pale ones). Three more individuals (an adult female and two adolescents) were observed within about 20-30 metres of the core area.

Those observations permit us to calculate, very roughly, an average density in the core area of one lizard per 157 square metres, equivalent to a 12.5 metre (41 foot) square per individual. By way of comparison, Cunningham (2001) estimated a home range of roughly 200 square metres per individual in his study of *Acanthodactylus opheodurus* on sand and gravel plains north of Jebel Hafit, in Al Ain, UAE, with individuals typically being found 10-20 metres from each other.

Fig. 8: A view of the core zone of the *A. boskianus* site reported in this paper. [GRF]

The following morning we surveyed the downstream extension of our area and observed an additional 11 individuals over approximately 500 metres, in similar but somewhat more discontinuous and more heavily treed habitat. These included one adult male and an estimated two adult females and eight adolescents, all of the adolescents approaching adult female colouration and several showing a reddish patch dorsally at the base of the tail, as described above.

In all, we observed 28 individual lizards foraging along *ca*. 600 metres of wadi. From this we estimate the total population in the area to be approximately 50 ± 10 individuals. The lizards were not difficult to observe and, given the limited scale of the area of preferred habitat, we believe it is reasonable to suppose that we observed approximately 50% or more of the total population. The areas upstream and downstream of our site are disturbed by construction and do not preserve similar habitat.

The apparent scarcity of adult males seems anomalous, but more information about the social structure of *A. boskianus* (or other *Acanthodactylus* species) might suggest an explanation. It is known, for example, that *A. boskianus* is territorial and that males acquire dominance hierarchies in captivity (Khanoon 2009). If social dominance can regulate the expression of male breeding colours, then it is possible we have been mistaken in some of our field determinations of adult gender.

Reproductive cycle

A summary account of reproduction by *A. boskianus* in North Africa says that, "This lizard lives in a burrow of 30 to 40 cm in depth which it excavates at the foot of a clump of vegetation. The female deposits 2 to 4 eggs which incubate for 75 days, hatching taking place in August" (Sahara-Nature).

At our UAE site, our observations provide circumstantial evidence for an annual life cycle featuring egg-laying in late summer to mid-winter (late August to perhaps as late as February) and hatching in mid-autumn to early spring (late October to perhaps as late as early May), as elaborated below. However, the presence of juvenile lizards in both early December and mid-August leaves open the possibility that reproduction could be multi-seasonal or relatively continuous, or, even if reproduction is generally seasonal, that the potential exists for opportunism.

The predominance of adolescent lizards in August 2013 may reflect enhanced breeding success as the result of above average rainfall during the preceding autumn, winter and spring. The autumn of 2012 was probably somewhat wetter than normal, with (anecdotally) some rain having fallen in each of September, October and November. At the time of our initial visit to the site in early December 2012, a grove of flowering and seeding *Datura stramonium* was flourishing in silt where flood water had backed up at a road crossing. Subsequently, major rainfall events occurred over mountain areas of the UAE in mid-December 2012 (*pers. obs.*), early April 2013 and late April into early May 2013 (J. Judas, *pers. comm.*).

Development and maturation times for *A. boskianus* are not known, but Arnold (1984) has reasoned from field evidence in the UAE that the similar sized *A. schmidti* matures within one year: *A. schmidti* "are common as adults in the spring, but virtually no juveniles are present until eggs laid that year hatch, so these presumably reach full size by the next spring."

Assuming that a minimum of approximately 75 days are spent as a juvenile (equivalent to the reported North African incubation period), the many *A. boskianus* lizards we observed as adolescents in early August must have hatched no later than mid-May. Adding the reported 75-day incubation period, mating and egg laying would have occurred no later than end-February. But the adolescents seen in August 2013 were variable in size and the largest of them, at or near adult size, could reasonably correspond to the juveniles seen in December 2012; some may even have reached sexual maturity, as possibly indicated by the reddish patches at the base of the tail. In turn, the juvenile lizards present in early and mid-December 2012, *ca*. 9cm in size, must have hatched by mid

Fig. 9: An adult male *A. boskianus* anticipates making a meal of a large ant, *Cataglyphis* sp. This individual exhibits a re-grown tail. [BR]

or late November, and therefore, if we accept the reported 75-day incubation period, from eggs laid by early September 2012. These estimates dovetail nicely to frame an annual cycle commencing with egg-laying in late summer through mid-winter, followed by hatching and maturation in time for first-year individuals to participate in egg-laying at the next annual cycle.

Arnold found that for many species of UAE lizards, dates of egg carrying are spread over two months or more (his dates for *A. schmidti* span five months, from January through May), suggesting that breeding is repetitive and several clutches are laid (Arnold 1984). We did not directly investigate reproductive status or observe reproductive activity in our study population of *A. boskianus*, but our observations of population structure are consistent with an extended breeding season. However, Arnold (1984) also generalised that most egg carrying in UAE lizard species takes place in the spring. That generalisation is not well supported by our study population, for which, as indicated, our data instead suggest a breeding season centered on autumn and winter. We cannot assess, from observations within a single year, whether this represents the normal pattern for *A. boskianus* in the UAE or whether, perhaps, in the context of the relatively unpredictable UAE rainfall regime, the breeding period can be shifted facultatively to take advantage of unseasonably clement conditions.

Unfortunately, we were unable to make field observations during spring 2013 and our field time in late summer 2013 was devoted to the search for additional *A. boskianus* sites. In hindsight, additional observations during either or both of those periods might have helped to better resolve the timing of breeding activity.

Behaviour: foraging and tail movements

All *A. boskianus* were observed principally on relatively firm, silty soil with scattered rocks and shrubs. If approached too closely or too rapidly, they retreated to the cover of shrubs, mostly *Pulicaria glutinosa*, which grows in more or less cushion-like clumps and spreads close to the ground.

When not taking cover, the lizards foraged actively on the firm soil, moving, pausing, watching, waiting, then moving again. Sometimes they stopped on local high points (minimally so, on relatively flat ground) as if to have a better view. Forward movement was generally purposeful and sometimes rapid. Upon stopping, the lizards normally exhibited the tail swishing movement characteristic of at least some other *Acanthodactylus* spp., e.g., *A. schmidti* and *A. gongrorhynchatus* (*pers. obs.*) and *A. opheodurus* (Arnold 1980, Cunningham 2001). The tail was swung to one side or the other, ± 90°, with a modest but distinct extra flourish of the tip. In this position the lizard is alert, with head up. On one occasion when we watched a lizard stop with its head down, to examine the ground beside a small stick, it did not swish its tail. A lizard digging for termites moved its tail regularly, but evidently primarily to counterbalance frequent changes of body position.

Why do the lizards swish their tails? Flexing the tail perpendicular to the body probably facilitates rapid acceleration by conferring a mechanical advantage, which may explain why alert lizards do this and preoccupied lizards do not. But there seems to be more to the movement than simply positioning the lizard on the starting block.

Many *Acanthodactylus* spp. and other lacertids are known to exhibit tail autotomy (i.e., tail shedding) in response to attack (Arnold 1984, Jongbloed 2000, Cunningham 2001). This appears to be the case for *A. boskianus* as well. At least one of our adult lizards exhibited a re-grown tail (Fig. 9); so does the adult *A. boskianus* shown in Gardner (2005a) (at p. 234). In such species, tail swishing behaviour has been tentatively interpreted as a defence mechanism to mislead would-be predators (Cunningham 2001). This makes intuitive sense. In case the movement of the lizard on open ground attracts the attention of a nearby predator, it is advantageous if the predator is promptly misdirected to the disposable tail rather than the head or body. By the same token, a single initial swish may be optimal, since the likelihood that the lizard has been observed and will be attacked probably diminishes with the passage of time, and further movement only increases the risk of attention.

Notwithstanding the appeal of the foregoing logic, since different sympatric species of *Acanthodactylus* have different tail colours (a useful field characteristic to discriminate among them), a sexual signalling function for tail movements cannot be ignored, as has been documented for other regional diurnal lizard species (Arnold 1980, Ross 1990, Feulner 2004).

Shelter

A North African account generalises that *A. boskianus* "lives in a burrow of 30 to 40 cm in depth which it excavates at the foot of a clump of vegetation" (Sahara-Nature). At our own site, we saw numerous examples of probable *A. boskianus* burrows (Fig. 10) under clumps of vegetation; not many other species are present that are likely to have constructed them. More generally, the availability of a substrate suitable for burrowing suggests itself as one of the principal factors localising our UAE population.

Fig. 10: An *A. boskianus* burrow entrance under a *Pulicaria glutinosa* shrub. This burrow was thought to have at least two entrances. [GRF]

Sometimes we saw multiple burrow entrances under the same small shrub. We watched one adolescent lizard retire to such a burrow at the end of a late afternoon sortie. But we also saw another type of burrow, an inconspicuous slot in flat, open ground. We saw two adolescents stationed near such burrows (Fig 11), each 1-2 metres from small shrubs, while out in late afternoon, and we watched one of those lizards actually retire to the nearby burrow, only about 15 minutes before darkness. Thus we suggest that, in addition to burrows used for breeding and or permanent residence, *A. boskianus* (at least immature lizards) may also excavate more rudimentary burrows for temporary use. The entrance to some of these latter burrows appeared to be partly blocked, whether by accident or design.

Diet

We observed at least a half dozen individuals catch and eat ants, mostly very small ants. The one adult male found in the core zone was especially active and fed on several ants, including larger ones, in the space of less than a minute. An adolescent foraging in late afternoon ate an estimated dozen ants in an hour of observed foraging. One small adolescent attempted to take a very large and robust ant, apparently the soldier

Fig. 11: An adolescent *A. boskianus* in late afternoon, beside its simple burrow on open ground. [GRF]

Fig. 12: This adolescent lizard, the same individual shown in Fig. 11, revealed an unsuspected talent when the piece of wood at left was tossed towards it, about 30 cm away. Instead of fleeing, the lizard tracked its trajectory and "caught" the stick in its mouth at the instant of contact with the ground. [GRF]

caste of an unknown species (possibly *Camponotus sp.*), but released it after a brief attempt.

At least six types of ants were distinguishable: (i) the common large black *Cataglyphis* workers (Fig. 9); (ii) the still larger soldier ant mentioned immediately above; (iii) a medium-sized but robust red-orange ant; (iv) a similar-sized but more delicate red-orange ant; (v) a medium-sized, thin ant with a red head and thorax and a short, heart-shaped black abdomen; and (vi) a very small, thin black ant. Only (i) and (vi) were common, and (vi) appeared to be the principal prey item. The only other ground insects we observed were a few Tenebrionid beetles, probably of the genus *Adesmia* (the so-called Pitted Beetles).

Our observation of repeated predation on ants, the fact that all of the lizards foraged on open ground, and the relative scarcity of other suitable prey, all point to ants as a principal prey of our *A. boskianus* population. That is consistent with Arnold's (1984) assessment for *A. schmidti* and Cunningham's (2001) generalisation that ants seem to be the favoured diet of *Acanthodactylus* species generally, notwithstanding anecdotal evidence of other prey items. Nevertheless, the dietary contribution of other prey items may be important, although less frequently documented.

We watched one adult male lizard dig for and consume small termites. The male, which had already travelled *ca*. 10 metres from where we had first seen it, took shelter at one point under an accumulation of twigs in the shade of low branches of a *Pulicaria glutinosa* shrub. There it soon began to scrape purposefully in the dirt with its forefeet and snout, picking at and gobbling up something we could not discern. When it had moved on, we investigated and found, just below the surface, a few very small white termites of a kind we had noticed half an hour before at a piece of discarded lumber. On another occasion we watched an adolescent lizard dig repeatedly and unsuccessfully, probably for suspected termites, at the spot where a thin branch from a dead and toppled small tree poked into the soil.

Still another adolescent was seen to taste a small piece of potato crisp that we had inadvertently dropped nearby. The lizard briefly masticated one corner but did not ingest the crisp; we speculate that it was probably licking the surface salt.

A casual experiment revealed an unsuspected talent with dietary implications (Fig. 12). An adolescent lizard had been alert but motionless for some time on open ground in late afternoon. One of the authors tossed a small piece of dead wood in front of it, about 30 cm away. Instead of fleeing, as expected, the lizard darted forward, evidently following and foreseeing the descent trajectory, and seized the stick in its mouth at the instant of contact with the ground. It was only then that we realised that the piece of wood was, coincidentally, about the same size, shape and colour as a medium-sized local grasshopper (e.g., *Sphingonotus* spp.). From this we infer that geophilous grasshoppers and other insects alighting on bare ground in the vicinity of *A. boskianus* are in danger of being tracked and caught by waiting lizards.

The UAE's most common fringe-toed lizard, *A. schmidti*, is known on occasion to hunt and eat juveniles of other lizards, including other *Acanthodactylus* species (Baha El Din 1996). Since *A. boskianus* is the largest of the UAE's *Acanthodactylus* species, we cannot rule out the possibility that it too may sometimes take other, smaller lizards. As mentioned above, we have recorded no other reptiles within the area of our *A. boskianus* population.

It should be noted that the behaviour, foraging habits and diet of *A. boskianus* in North Africa have been described somewhat differently (in translation from French): "*Acanthodactylus boskianus* is active by day, especially in the morning, it hibernates until April. . . . [It] feeds on small insects, beetles, flies, it hunts visually and is very agile, it likes to climb and perch in bushes" (Sahara-Nature).

Predators and predator avoidance

A relatively dense population of lizards would seem to present a tempting opportunity for predators. However, the study population is limited in extent and, as far as we have been able to determine, is singular, so it may not be worth the while of local predators to specialise in predation on *A. boskianus*. That reasoning will have to be revisited if, as we suspect, *A. boskianus* proves to have been, in the recent past, more common and widespread than previously recognised.

Red foxes are probably the most likely terrestrial predators. They might also be attracted to the area in winter by the litter left by picnickers, although we saw no fox prints or droppings at any time. Avian predators are also a possibility, but birds have not been much in evidence when we have been present at the site. The only species we have seen that might be possible predators on *A. boskianus* are the Southern Grey Shrike *Lanius meridionalis* and the Indian Roller *Coracias benghalensis*. Tracks of ground birds were most likely those of Grey Francolin *Francolinus pondicerianus*, heard at a distance. The presence of owls along the foothills, e.g., the Desert or Pharaoh Eagle Owl *Bubo ascalaphus*, may be one reason why our lizards retired to their burrows before dark (see below, "Diurnal schedule").

Like other *Acanthodactylus* species (Arnold 1980, Cunningham 2001), *A. boskianus* probably relies principally on vigilance, speed and vegetation cover to avoid predators. As noted above, the lizards normally responded to potential threats by retreating to the shelter of a low shrub, usually *Pulicaria glutinosa*. There they remained motionless, evidently relying on their camouflage. We did not observe the "doubling up" posture reported by Cunningham (2001) for *A. opheodurus*, but we never attempted to actively alarm any lizards.

Reactions can be very cautious, however. In one instance, a small piece of litter (*ca*. 1 cm square) was accidentally dropped above a lizard that had approached at close range to where we stood on open ground. The lizard reacted instantly to this small object falling vertically, about 7-10 cm in front of it. It shot off to the rear, but stopped only about 60 cm away, still on open ground.

Diurnal schedule

Like most *Acanthodactylus* species, *A. boskianus* is diurnal. In early December, we found lizards active until at least midday. In early and mid-August, the first lizards were observed at 0700-0800 hrs on generally slightly overcast mornings, at air temperatures of *ca*. 32°C (90°F). More were observed, and they became more active, as the sun broke through at *ca*. 0830 hrs. Observations declined after about 1000 hrs (with sightings then often in shade and air temperature at 38°C (100°F)) and we saw no lizards after 1100 hrs, by which time the air temperature had reached 40°C (104°F). Cunningham (2001) likewise observed that *A. opheodurus* in the UAE retreated to its burrows when air temperatures approached 40°C.

Where it has been studied in North Africa, *A. boskianus* is active principally in the morning; it does not have a bimodal activity pattern (Cunningham 2001, citing Perez-Mellado 1992; Sahara-Nature). The same is true of at least two other *Acanthodactylus* species that have been studied in the UAE, *A. schmidti* (Cunningham 2001, citing Haas 1957) and *A. opheodurus* (Cunningham 2001). In contrast, *A. gongrorhynchatus*, studied in eastern Saudi Arabia and Abu Dhabi, is reportedly active in both morning and late afternoon (Baha El Din 1996).

We paid a late afternoon visit to our site in mid-August and found three individuals, all adolescents, active in the core zone beginning from at least 1700 hrs (when we commenced observations) until 1900 hrs, at a temperature of *ca*. 32°C (90°F). One lizard, the largest, foraged relatively actively, traversing and re-traversing open ground and circling small shrubs, eating an estimated dozen small ants. The other two were largely motionless but alert on open ground; one was the individual which "caught" a tossed piece of wood, as described above under "Diet". The most active individual retired to its burrow at the base of a bush at *ca*. 1815 hrs. The wood-catcher retired at *ca.*1900 hrs (only 10-15 minutes before darkness) to its simple slot burrow in open ground (Fig. 11). From these observations we generalise that although *A. boskianus* is active principally during the morning, some individuals, particularly adolescents, may also forage in late afternoon. In

Fig. 13: In pleasant weather, the *A. boskianus site* is shared on weekends with local picnickers. Litter is an aesthetic problem but more serious habitat damage is probably done by vehicles and destruction of plants for firewood. [GRF]

addition, there may be a tendency for the afternoon hunting strategy to shift from active hunting to "sit and wait".

Thermoregulatory behaviour

As has been reported for other *Acanthodactylus* species (Arnold 1984, Cunningham 2001), *A. boskianus* was increasingly seen in the shade of shrubs and trees as air temperatures increased during its activity period. But, with a single exception, we saw no other examples of postures or behaviours (e.g., climbing shrubs) that we interpreted as thermoregulatory.

The exception was the adolescent lizard, mentioned above, which dug repeatedly, probably for suspected termites, at the spot where a branch from a fallen tree poked into the silty soil. Roobas took a video of that effort, in partial shade at about 0845 hrs, which records a number of furious but unsuccessful bouts of excavation, using both forelimbs. Studying the video at leisure, we saw that in the course of its exertions, the lizard paused twice to rest for a few seconds in the disturbed soil, lying on its belly with its forelegs and head in the air, and its hind legs splayed and weightless.

Arnold (1984) noted that, as surface temperatures rise, some diurnal desert lizard species dig into the substrate so that they can place their bodies in contact with cooler layers beneath. We tentatively interpret the behaviour we observed as an effort by the lizard to reduce its body temperature, elevated due to physical activity, by lying in cooler, subsurface soil exposed by digging. Cunningham (2001) recounted a similar phenomenon in *A. opheodurus*: "When actively pursuing prey on warm surfaces they often rested their bodies on the ground and raised their forelegs momentarily."

Does *A. boskianus* hibernate in the UAE?

In Egypt, *A. boskianus* undergoes hibernation (perhaps better termed winter dormancy in ectotherm species) from December through February, triggered by reduced photoperiods (El Masry & Hussein 2001). Our observations leave open the question whether *A. boskianus* also hibernates in the UAE.

A morning visit in mid-December 2012 turned up no lizards in the core zone and only one juvenile overall, at the downstream extremity of the population, but the weather that day was breezy, mostly cloudy and there was some drizzle. A late December visit encountered no lizards at all; the day was sunny, but also cool and extremely windy. In both cases, our observations (or lack of them) are consistent with the hypothesis of winter dormancy beginning in mid-December, but they could also be attributable to the weather conditions prevailing at the time of our visits.

Other commitments made it impossible for us to re-visit the site during the winter and spring to resolve the question definitively, but the presence of juvenile lizards in early December, particularly if that reflects the normal annual reproductive cycle as suggested above, is arguably evidence against hibernation, since it would be unusual for hatching to closely precede seasonal dormancy.

A second site: Has *A. boskianus* been overlooked and under-recorded?

In mid and late August 2013 we undertook to see if, making use of our experience, we could find *A. boskianus* at other, similar sites. This exercise was not as straightforward as it may sound, because a great deal of the potential *A. boskianus* habitat in foothills wadis for *ca*. 20 kilometres to the north and south of our site has been not merely disturbed, but totally destroyed by quarrying or by the construction of dams, highways, pipelines and/or power lines (see also “Conservation concerns” below). In the end, our results were mixed. We were able to find another *A. boskianus* site within the Wadi Isfani watershed almost immediately, but we found no evidence of these lizards at three other search areas to the south.

We knew of a promising area in mid-Wadi Isfani, only about 3 kilometres distant as the crow flies, but some 9 kilometres away along wadi beds. Scouting by car, we found a lizard almost immediately at our second vehicle stop, evidently a young male (Fig. 3) – not very large but with full male colouration, except that it still retained a relatively high proportion of vivid intermittent dark scales. At our third stop, in and adjacent to recently cultivated fields, we encountered an adolescent and a boldly striped, blue-tailed juvenile, both foraging actively on silty soil. We also found occasional tracks probably made by *A. boskianus* among the natural wadi bank vegetation (*Saccharum griffithii*, *Tamarix* sp. and *Juncus* sp.) bordering the fields in this area.

We saw no other *A. boskianus* there, however (and only a single *Pristurus rupestris*), despite patient inspection before mid-morning (1000 hours). We asked ourselves why there were not more, in what seemed like congenial habitat. Tree cover was similar but the ground level vegetation was different from our main *A. boskianus* site. *Pulicaria glutinosa* was all but absent; the main shrubs were *Fagonia indica* and *Rhazya stricta*, the latter indicative of overgrazing by camels and goats (of which we saw approximately 4 dozen in 3 small herds during our visit). But we also took note that almost the entire width of the broad wadi bed and its lower banks was covered with a thin layer of fresh silt, and flotsam debris draped almost every shrub on the upstream side, the result of a major recent inundation.

Later in the day, an interested local resident directed our attention to the same phenomenon. In a discussion of the fish species that were (and were not) then present at a permanent pool in the wadi, he emphasised the need to take account of the massive flooding that had occurred just a few months earlier (S.M.S. Al Qaydi, *pers. comm.*), probably corresponding to an April 30 to May 1 rainfall event on the UAE’s East Coast (J. Judas, *pers. comm.*). The headwaters of Wadi Isfani drain *ca*. 40 kilometres of mountain ridges that also drain, in the opposite direction, to the East Coast. They rise in a few places to more than 1000 metres. Our local acquaintance described the flooding in Wadi Isfani as unprecedented in his lifetime of some thirty years. We were left to contemplate the possibility that the *A. boskianus* population in mid-Wadi Isfani was perhaps temporarily depressed owing to mortality and habitat destruction occasioned by that event.

The discovery of a relatively dense local population and the fact that we were able to predict and find additional lizards elsewhere inevitably calls into question whether *A. boskianus* is (or was) quite as rare or as restricted as has heretofore been accepted. Our local resident acquaintance did not regard the striped adolescents we showed him as exceptional (Al Qaydi, *pers. comm.*) and there are no local species with which they could be readily conflated.

We therefore extended our search to other wadis along the western mountain front, taking advantage of relatively detailed local geographical knowledge. We searched fruitlessly, however, in abandoned fields along wadi banks above the dams in Wadi Shawkah and Wadi Baraq. In the latter, we found that small animal husbandry stations have proliferated, relying on the ability to pump ground water from depths of more than ten metres. One result is that overgrazing by camels and goats has effectively removed almost all of the small shrubs from the wadi bank terraces, eliminating both the cover and burrowing sites favoured by *A. boskianus* at our principal site. In Wadi Qawr, a historical transit route across the mountains, agricultural development on an industrial scale has transformed any suitable wadi bank habitat that might have existed.

Fig. 14: A quarry in the Hajar Mountain Foothills south of Siji. [GRF]

We conclude from these results that any new-found optimism about the historical or current status of *A. boskianus* must be countered by grounds for considerable pessimism concerning conservation of its foothills wadi habitat generally.

Conservation concerns

It is interesting to contemplate that humans may have unwittingly promoted the creation of favourable habitat for *A. boskianus* at the principal site reported here, and at other foothills wadi sites, by constructing the fields whose remains the lizards now exploit (and even by limited bulldozing in more recent times). But humans are surely now degrading that same habitat. A paved road runs through our main site and power lines parallel the road; a 4-metre high bulldozed berm blocks the view of the wadi from the road for some 30 metres; in winter, local picnickers occupy prime *A. boskianus* habitat, driving large vehicles onto the limited remaining field areas, and harvesting and cutting brush and trees for campfires.

More alarmingly, foothills habitats for tens of kilometres to the north and south along the mountain front, across the borders of several emirates, have been obliterated by extensive and indiscriminate quarrying and dam construction. The cumulative assault is massive, especially when these are added to multiple highway, pipeline and power line routes. The mountain front and foothills environment is probably the second most threatened environment in the UAE, after the coastal zone. This diminishes the possibility that *A. boskianus* can survive at historical levels in that habitat.

The discovery reported here, of a large and previously unsuspected population of a rare lizard, epitomises the more general problem that environmental destruction continues in ignorance of what is being lost. Other examples of lost or threatened natural heritage along the mountain front and foothills of the UAE are unique fossil localities such as the Palaeozoic Kub Melange (Robertson *et al*. 1990), Palaeolithic stone tool sites, representing evidence of the earliest human inhabitants of Arabia (Green 1999, Scott-Jackson *et al*. 2008), and the only UAE sites for the native freshwater minnow *Cyprinion microphthalmus*.

Acknowledgements

The authors wish to thank Dr. A.S. (Drew) Gardner and Peter L. Cunningham for confirming the identification of *A. boskianus* and for sharing their records and experience. Dr. Gardner kindly reviewed a draft of this paper and adapted his distribution map of *A. boskianus* for our use.

References

Arnold, E.N. 1980. The Reptiles and Amphibians of Dhofar, Southern Arabia. *Jour. Oman Studies Spec. Rep. No. 2: The Scientific Results of the Oman Flora and Fauna Survey 1977 (Dhofar)*: 273-332.

Arnold, E.N. 1984. Ecology of lowland lizards in the eastern United Arab Emirates. **Jour. Zool. London 204**: 329-354.

Baha El Din, S. 1996. Terrestrial Reptiles of Abu Dhabi. In P. Osborne (ed.) *Desert Ecology of Abu Dhabi*. National Avian Research Center. Pisces Publications, Newbury, UK. pp. 124-147.

Cunningham, P.L. 2001. Notes on some aspects of the ecology of *Acanthodactylus opheodurus* Arnold, 1980, from the United Arab Emirates. **Herpetozoa** 14 (1/2):15-20.

El-Masry, A.A. & Hussein, H.K. 2001. Thermal Relations, Metaabolism and Winter Dormancy of the Sand Lizard, *Acanthodactylus boskianus*. **Pakistan Jour. Biol. Sci. 4(4)**:492-497.

Feulner, G.R. 2004. Tail Signalling in the Semaphore Gecko *Pristurus celerrimus*. **Tribulus 14.1**: 18-22.

Feulner, G.R. 2013. Dressed for Success? **Gazelle** (monthly newsletter of the Dubai Natural History Group) 28(4): 6.

Gardner, A.S. 2004. Reptiles. In S. Aspinall & P. Hellyer (*eds.*) *Jebel Hafit, A Natural History*. Emirates Natural History Group, Abu Dhabi, UAE. pp. 149-168.

Gardner, A.S. 2005a. Terrestrial Reptiles. In P. Hellyer & S. Aspinall (*eds.*) *The Emirates – A Natural History*. Trident Press. pp. 229-241.

Gardner, A.S. 2005b. Blanford's fringe-toed lizard (Lacerta: *Acanthodactylus blanfordii* Boulenger, 1918): a new species record for the United Arab Emirates. **Tribulus 15.2**: 25-26.

Gardner, A.S. 2008. The Terrestrial Reptiles of the United Arab Emirates: Herpetological History, Zoogeography and Conservation. In R.J. Perry (ed.), *Terrestrial Environment of Abu Dhabi Emirate*. Environment Agency – Abu Dhabi. pp. 281-307.

Gardner, A.S. in press. *The Amphibians and Reptiles of Oman and the UAE*. Chimera Publishing.

Green, S.E. 1999. A Possible Stone Age Flint Site Found Near Fili, Sharjah. Unpublished report, January 1999.

Hornby, R.J. 1996. A Checklist of Amphibians and Reptiles of the UAE. **Tribulus 6.1**: 9-13. [The photo on the back cover is now thought to show *Mesalina adramitana*.]

Jongbloed, M. 2000. *Wild About Reptiles*. Bakers Trident Communications. 116 pp.

Khanoon, E.R.R. 2009, Comparative chemical ecology, behaviour, and evolutionary genetics of *Acanthodactylus boskianus* (Squamata: Lacertidae). Ph.D. Thesis, Dept Biol. Sci., Univ. of Hull.

Rastegar-Pouyani, N. 1999. First Record of the Lacertid *Acanthodactylus boskianus* (Sauria: Lacertidae) for Iran. **Asiatic Herpetological Research 8**: 85-89.

Robertson, A.H.F., Blome, C.D., Cooper, D.W.J., Kemp, A.E.S. & Searle, M.P. 1990. Evolution of the Arabian continental margin in the Dibba Zone, Northern Oman Mountains. In A.H.F. Robertson, M.P. Searle and A.C. Ries (*eds.*), *The Geology & Tectonics of the Oman Region*, Geological Society Special Publication 49 (1990), pp. 251-84.

Ross, W. 1990. Notes on the Behaviour of *Pristurus rupestris* (Reptilia: Gekkonidae) with Special Reference to Tail Signalling. **Fauna of Saudi Arabia 11**: 300-305.

Sahara-Nature. [Accessed 19 December 2012]

Scott-Jackson, J., Scott-Jackson, W., Rose, J.I. & Jassim, S. 2008. Investigating Upper Pleistocene stone tools from Sharjah, UAE: Interim report. In **Proceedings of the Seminar for Arabian Studies 38 (2008)**: 43-54

Binish Roobas
Trivandrum, Kerala, India
email: johanruphus@hotmail.com

Gary R. Feulner
Dubai, U.A.E.
email: grfeulner@gmail.com

Potential alien species threat for the Arabian Collared Kingfisher at its only UAE breeding locality

by John Pereira

Fig 1. Reconyx camera trap images indicating a Black Rat and Common Mynas inspecting an artificial nest box after installation, March 2013 (John Pereira)

There has been continuing concern regarding the population status of the Collared Kingfisher *Todirhamphus chloris* in the UAE, where it is represented by the endemic subspecies *kalbaensis*. A census in 1995 established no more than 44 to 55 pairs within the Emirate of Sharjah's Khor Kalba mangrove system. One or two individuals are known to have wandered south to to Khor Liwa, Oman although no confirmed breeding is known from that site (Boer *et al*. 2005)

More recent surveys have indicated a decline in the kingfisher's population. Counts in 2011 produced an estimate of 26 – 35 pairs, pointing towards a 20 – 36% decline from records in 1995. This decline, if accurate, is clearly unsustainable; a report published in 2012 suggests that the main cause of the drop is as a result of habitat destruction and deterioration (Campbell *et al*. 2012). The Collared Kingfisher is a cavity nester, and nests in the hollows of older, larger mangrove trees. It has been generally believed that the decline in population numbers is likely due to the lack of nesting cavities owing to continuous die-off and previous destruction of the older mangrove trees, with few intermediate trees providing adequate nesting sites as replacement.

Khor Kalba has been proclaimed a protected area since 2012, and received Ramsar status in 2013 (Ramsar 2013), Initial indications are positive for the recovery and rehabilitation of the mangrove, as extensive new growth is visible in previously heavily trampled areas and the destruction and browsing of mangrove trees has been completely eliminated.

Recently the Environment & Protected Areas Authority, EPAA, of the Emirate of Sharjah initiated an experimental artificial nest box project; the aim of the project is to determine if the Kingfishers would show interest in artificial nest boxes with the ultimate aim being to promote breeding in mangrove zones with little or no potential natural breeding sites. These nest boxes were equipped with Reconyx camera traps to monitor activity around the boxes.

After four months of camera trapping from March to June 2013, results have delivered little evidence of Kingfisher interest in the nest boxes, but have provided insight into possible additional threats faced by the species. Reconyx images have provided indications that the mangroves are inhabited by Black Rat (*Rattus rattus*), a species previously unknown to inhabit the mangrove, and by House Crow *Corvus splendens.* The latter species is often seen around the Khor but, until the present study, it was unknown whether they foraged within mangrove trees. Both species are listed under the Global Invasive Species Database (Invasive Species Specialist Group, 2013), and are considered pest species within the UAE. The Reconyx cameras have provided images of both species visiting and inspecting the artificial nest boxes; see Figures 1 and 2.

The presence of House Crows near the nest boxes was not anticipated as the boxes were situated deep in the mangroves with extensive canopy cover overhead, limiting detection from above. However, Reconyx images have indicated multiple crows inspecting a nest box simultaneously. This is a probable indication that crow flocks could actively hunt and scavenge in the mangroves and could represent a possible threat to nesting kingfishers. House Crows are well known for their aggressive and opportunistic hunting methods, and various studies globally have indicated that large populations of this species have a significant impact on native species numbers and distribution (Archer 2001, Ryall Lim *et al*. 2003).

According to Meier (2013), it has been observed in that both the Pied Kingfisher *Ceryle rudis* and Mangrove Kingfisher *Halcyon senegaloides* are harassed on a regular basis by House Crows, and so it is clearly feasible that Collared Kingfishers at Kalba could suffer predation and mobbing pressure from that species. Large flocks of House Crows have been counted within the mangroves at Kalba, and it is possible that their numbers will increase. Multiple roosts have been identified in the mangroves, but exact numbers vary. On-going weekly counts, initiated in March 2013, of House Crows in the Kalba mangroves have delivered the following average per count: March: 29, April: 29.25, May: 8.25, June: 7.2. The crows counted in Kalba were mostly foraging, but two nests have been located within the mangrove. These weekly counts have revealed the House Crow as the most numerous terrestrial species at Kalba.

The presence of Black Rats is of great concern, as rats triggered the Reconyx cameras more than any other species and were the only species triggering the traps at night. The Black Rat has directly caused or contributed to the extinction of numerous species of wildlife, including birds, small mammals, reptiles, invertebrates and plants, especially on islands. They are omnivorous and capable of eating a wide range of plant and animal foods (Innes 1990) and also prey on the eggs and young of forest birds (Innes *et al*., 1999). The Black Rat is frequently identified with catastrophic declines of birds on islands. The best documented examples in the Pacific region are Midway Island in the Leeward Islands of Hawai'i (Johnson, 1945; Fisher & Baldwin, 1946) and Lord Howe Island (Hindwood, 1940; Recher & Clark, 1974). Atkinson (1977) brought together circumstantial evidence suggesting that Black Rats, rather than disease, were responsible for the decline of many species of Hawaiian native birds during the 19th Century.

Fig 2. A House crow adjacent to a nest box. (John Pereira)

Currently there are no direct indications that Collared Kingfishers at Kalba are under pressure from Black Rats or House Crows, yet it is of utmost concern that these potentially devastating species inhabit the mangroves and their impact across the species spectrum should be considered. Currently the EPAA is conducting a nest cavity survey within the mangroves, the aim of the survey being; to determine the general availability of viable nesting cavities, and identify areas in the mangrove that is cavity poor. The survey also aims to determine the extent of occupation by other species especially Black Rat and Common Myna *Acridotheres tristis*. During the survey multiple kingfisher nests with eggs and chicks have been located and these are being monitored by Camera traps to indicate if any interference from alien species are present.

Another invasive species that has established itself within the mangrove is the Common Myna. This species has established itself successfully within the UAE and surprisingly could prove a very direct threat to the Collared Kingfisher; global observations suggest mynas could directly compete with the kingfisher for already scarce nest cavities. According to the Invasive Species Specialist Group (ISSG) (Anonymous 2011), in French Polynesia, Common Mynas predate the critically endangered Marquesan Kingfisher *Todiramphus godeffroyi*. Further, studies in Australia and some oceanic islands suggest that mynas can reduce the breeding success of several hole-nesting species. Species affected include the Laughing Kookaburra *Decelo gigas*, Sacred Kingfisher *Todiramphus sanctus* and Galah *Cacatuaro seicapilla*.

The ISSG also advise that Common Myna poses a particular threat to Mangaia's endemic Mangaia Kingfisher *Todiramphus ruficollaris*, classified as Vulnerable by the IUCN. Anecdotal evidence indicates that the kingfisher cannot breed successfully outside the small areas of *Barringtonia asiatica* forest on Mangaia because of interference from the myna. In New Zealand, hole nesting species affected by mynas again include Sacred Kingfisher. Mynas are omnivorous and circumstantial observations suggest that they frequently kill reptiles and consume birds' eggs and young. Most recorded bird predations by mynas are from New Zealand and include eggs and nestlings of Tui *Prosthemadera novaeseelandiae*, Grey Warbler *Gerygone igata* and Grey Fantail *Rhipidura fuliginosa*, as well as Sacred Kingfisher.

From the discussion above, it is evident that Collared Kingfisher could potentially be under greater pressure and threat from invasive species than previously understood. Given that it occurs as a tiny population in a severely fragmented and limited habitat, the additional pressure that these foreign species impose circumstances that need immediate attention and proactive intervention.

The eradication of the foreign species from the protected area and its immediate surrounds should be considered. Unfortunately all three foreign species mentioned above are renowned for their abilities to endure most eradication methods, and the only effective means of reducing numbers and populations has been by the use of chemical control. This method is generally nervously approached yet under appropriate management and well controlled methods, chemical control has proven effective globally. Currently the EPAA is formulating strategies to control and remove foreign species from the protected area, most likely starting with the extensive trapping of rats.

A lack of action from the relevant authorities might lead to the extinction of an iconic UAE bird, and a flagship species of Khor Kalba. It is suggested that further research be conducted on the impact of these species on the Collared Kingfisher, focusing on breeding success of the species in the presence of exotic species pressure.

Acknowledgements

The author would like to thank Ahmed Al Ali from the EPAA and Kevin Budd from the Breeding Centre for Endangered Arabian Wildlife for their support and counsel on this report and providing the much needed equipment and resources.

References

Archer, A.L., 2001. Control of the Indian House **Crow** *Corvus splendens* in eastern Africa**. Ostrich Supplement, 15**:147 – 152.

Atkinson, I. A. E., 1977. A reassessment of factors, particularly *Rattus rattus* L., that influenced the decline of endemic forest birds in the Hawaiian Islands. **Pacific Science 31**: 109–133.

Boer, B. and Aspinall, S.J. 2005. Life in the Mangroves. In: *The Emirates: a Natural History.* Eds. P. Hellyer and S. Aspinall, Trident Press, London, 133 -137.

Campbell, O. Al Ali, A. & Tovey, N., 2012.The status of Collared Kingfisher in the United Arab Emirates, with comments on the status of Sykes's Warbler and Indian Pond Heron. **Tribulus 20:** 62-66.

Fisher, H. I. and Baldwin, P. H., 1946. War and the birds on Midway Atoll. **Condor 48**: 3–15.

Hindwood, K. A., 1940. The birds of Lord Howe Island. **Emu, 40**: 1–86.

Innes, J. G., 1990. Ship Rat. The Handbook of New Zealand Mammals. King, C. M. (*ed.*) Oxford University Press: 206-225.

Innes, J., Hay, R., Flux, I., Bradfield, P., Speed, H. and Jansen, P., 1999. Successful recovery of North Island kokako *Callaeascinerea wilsoni* populations, by adaptive management. **Biological conservation 87**: 201-214.

Global Invasive Species Database 2005.
http://www.issg.org/database.
Accessed 11/03/2013

Jackson, C. & Cowburn, B., 2010. *Control of the alien pest: House Crow. A Summary of the situation in Kenya and the proposed solution*. A Rocha Kenya/National Museums of Kenya.

Johnson, M. S., 1945. Rodent control on Midway Islands. **US Naval Medical Bulletin 45**: 384–398.

Lim Haw Chuan, Navjot S. Sodhi, Barry W. Brook and Malcom C. K. Soh., 2003. Undesirable aliens: factors determining the distribution of three invasive bird species in Singapore. **Journal of Tropical Ecology 19**: 685-695.

Meier, Guntram G., 2007 "*Corvus splendens*." *Ed*. Colin Ryall. Global Invasive Species Database. ISSG, n.d. http://www.issg.org/database, accessed 11/03/2013

The Ramsar convention on wetlands, 2013. http://www.ramsar.org/cda/en/ramsar-news-archives-2013-uae-kalba/main/ramsar/1-26-45-590%5E26113_4000_0.
Accessed on 03/04/2013

Recher, H. F. and Clark, S. S., 1974. A biological survey of Lord Howe Island with recommendations for conservation of the island's wildlife. **Biological Conservation 6**: 263-273

Ryall, C. 1992. The pest status of the Indian House Crow *Corvus splendens* in Mombasa and a survey of its expansion of range in coastal Kenya; In: L. Bennun (*Ed*). **Proc. VIIth Pan.African Ornith. Congress**. Nairobi, Aug 1988.

Anonymous 2011 "*Acridotheres tristis* (bird)." IUCN/SSC Invasive Species Specialist Group (ISSG). ISSG,.
http://www.issg.org/database.
Accessed 11/03/2013

John Pereira
Breeding Centre for Endangered Arabian Wildlife, P. O. Box 29922 Sharjah
email: john.pereira@bceaw.ae

Re-Discovery of the Mudskipper *Periophthalmus waltoni* Koumans, 1941 in the United Arab Emirates

by Gary R. Feulner and Binish Roobas

Abstract

A small, localised population (n ≈ 15) of the upper intertidal mudskipper *Periopthalmus waltoni* was recognised in February 2012 in a lagoon on the Arabian Gulf coast of the UAE. *P. waltoni* is locally common on mudflats in northern Kuwait and along the Iranian shores of the Strait of Hormuz, but this was the first UAE record in nearly 20 years.

The site was monitored over the course of 20 months, at intervals of 1 to 6 months, until October 2013. During that time the population dipped to *ca*. 8 fish in January and March 2013, but rose to *ca*. 30 individuals following the arrival of seagoing larvae in mid-summer 2013.

Basic aspects of the biology and ecology of the highly amphibious *P. waltoni* are briefly reviewed. Observations of the behaviour of the study population, including activity patterns, feeding, courtship and recruitment of pelagic larvae, are compared with the literature and are found to differ in certain particulars from studies by Clayton and others in Kuwait. The breeding season in the UAE commences by mid-February and may extend through June.

The origin of the UAE study population is speculative. It seems almost equally improbable that it has survived unnoticed for two decades or more, and/or that *P. waltoni* has somehow re-colonised this single small site during a time of massive disruption of UAE coastal environments.

Information newly elicited by the authors suggests that in the early 1970s the UAE may also have been home to a second species of mudskipper, *Boleophthalmus dussumieri*. A lone record of *P. waltoni* from the East Coast of the UAE has also been brought to light.

INDEX

Fig. 1. The mudskipper *Periophthalmus waltoni* Koumans, 1941 at the UAE study site. [Photo by BR]

Introduction: Mudskippers, *Periophthalmus* and *P. waltoni*

Mudskippers are amphibious fish that inhabit mudflats, muddy creeks and lagoons and mangrove forests in the Old World, mostly in the tropics and subtropics; a few species extend to temperate regions of South Korea and southern Japan where they hibernate in winter (Baeck *et al.* 2008). They all belong to the goby family (Gobiidae). The common name "mudskipper" is a descriptive term that is generally applied to the several most amphibious genera of the subfamily Oxudercinae, in particular the genera *Periophthalmus*, *Periophthalmon*, *Boleophthalmus* and *Scartelaos*, which number in total about 30 species (Murdy 1989, 2011, Lee & Graham 2002, Lee *et al.* 2005, Polgar 2010, Ishimatsu & Gonzalez 2011). Mudskippers of one species or another are distributed widely around the Indian Ocean and West Pacific (Polgar 2010). A single species is found on the Atlantic coast of Africa (Murdy 1989, 2011, Polgar 2010).

Mudskippers are of scientific interest because they are the most thoroughly amphibious fish. They have been studied in order to understand their physiological and behavioural adaptations to terrestrial life and to the extreme variations of temperature, salinity and dissolved oxygen levels often found in the tropical and subtropical mudflat environment. Those studies have given initiative and support to theories of the evolutionary origins of air-breathing and colonisation of the land by vertebrates (Shultze 1999, Ishimatsu & Gonzalez 2011, Polgar 2010).

They are of popular interest because of their distinctive, comical appearance and their novelty as a "walking" fish" – sometimes a very active one. Their prominent, closely-spaced bulbous eyes, set atop the head, effectively give them a 360º view of their environment. They breathe air and feed on the damp mud surface when the tide is out, frequently interacting with their conspecifics. Hogarth (1999) says truly, "Anyone who has visited mangroves or tropical mudflats in the Indo-Pacific region will have been captivated by these fish."

Periophthalmus is the largest genus of mudskippers, comprising about 18 species (Murdy 1989 and 2011, Polgar 2010). The name is derived from the Greek *peri* (around), and *ophthalmôn* (eye), and refers to the wide visual field of these species. The genus is distributed throughout the Indo-West Pacific, with one species found on the coast of tropical West Africa. Most species have limited geographic ranges, but the ranges of individual species may overlap (Taylor *et al.* 2005, Polgar 2010). The centre of diversity is in the eastern Indian Ocean (Polgar 2010). All are primarily carnivorous predators and most occupy the upper intertidal zone (Polgar 2010).

Periophthalmus waltoni (Fig. 1) is found in the Arabian Gulf and along the Indian Ocean coast of Iran and Pakistan to extreme NW India (the Gulf of Kutch) (Polgar 2010; see also Encyclopedia of Life, Fishwise). The type locality is Iraq and Pakistan (Polgar 2010, Fishwise). Within the Arabian Gulf *P. waltoni* is locally common on mudflats in northern

Kuwait (Clayton & Wells 1987), Iraq (Mhaisen & Al-Maliki 1997) and along the Iranian coast of the Strait of Hormuz (Askari *et al.* 2010, Kooseg *et al.* 2011). A single site was known at Al-Khor in north-eastern Qatar from at least the mid-1980s until the early 1990s, when the land was reclaimed (Fran Gillespie, *pers. comm.*), and *P. waltoni* was once locally common in the Northern Emirates (see discussion below).

In Kuwait, *P. waltoni* is sympatric with two other species of mudskippers, *Boleophthalmus dussumieri* Valenciennes, 1837 (discussed in much of the earlier literature from Kuwait as *B. boddarti* (Pallas, 1770)) and *Scartelaos tenuis* (Day, 1876), as well as a fourth Oxudercine species, *Apocryptodon madurensis* (Bleeker, 1849) (Clayton & Wells 1987; taxonomic nomenclature updated per Murdy 1989, Froese & Pauly 2012b and 2012c, and Polgar 2010). The four species are recognised to segregate themselves within the mudflats environment on the basis of different 'preferences' of habitat and diet, i.e., they occupy different ecological niches (Clayton & Wells 1987). The carnivorous *P. waltoni* occupies the highest intertidal environments of the four, and is correspondingly the most fully amphibious. *B. dussumieri* is a somewhat larger herbivorous species that grazes microalgae and cyanobacteria. Its habitat range overlaps with that of *P. waltoni* but overall it occupies a slightly lower intertidal range. The omnivorous *S. tenuis* and the much smaller, herbivorous *A. madurensis* occupy a much lower intertidal zone of permanently wet, oozing mud and do not interact with *P. waltoni*.

P. waltoni is included in *Coastal Fishes of Oman* (Randall 1995), along with the mudskippers *Boleophthalmus dussumieri* and *Scartelaos tenuis*. Randall's stated range for all of those fish is given as the Arabian Gulf to Pakistan or NW India, but no provenance is given within Oman by Randall or any other authors. One strong possibility is (or was) the extensive mudflats in Khasab Bay, on the north-west of the Musandam peninsula, opposite current Iranian sites in the Strait of Hormuz, but those mudflats have been largely destroyed in the past decade by dredging and reclamation. Suitable sites for any mudskipper species along the Gulf of Oman coast are few and limited, even more so for the lower intertidal *B. dussumieri* and *S. tenuis* than for *P. waltoni* (see Feulner 2000), but an unpublished Gulf of Oman record from the UAE was brought to our attention prior to publication of this paper and is discussed below, under "An East Coast record, too".

Historical records of Periopthalmus waltoni in the UAE

Mudskippers identified as *Periophthalmus* sp. were known from at least two Arabian Gulf sites in the UAE in the 1970s and had been mentioned to the senior author (GRF) in passing, mostly as a curiosity, by researchers active in that era (Michael Gallagher, *pers. comm.*, Kenneth W. Glennie, *pers. comm.*). In fact, newly elicited information makes it more likely than not that the herbivorous mudskipper *Boleophthalmus dussumieri* was also present in the UAE at that time (John Stewart-Smith, *pers. comm.*; see discussion below).

Historically, the principal UAE mudskipper site, to which all of the foregoing sources referred, was Khor Madfaq, the mouth and estuary of Wadi Lamhah, on the border between Umm al-Qaiwain and Ra's al-Khaimah emirates. Although Wadi Lamhah is normally dry, it drains a very large inland watershed originating in the Hajar Mountains, extending from Manama and Masafi in the north to Shawkah and Fili in the south; before reaching the coast, it crosses *ca.* 30 km of coastal sands. Khor Madfaq has always been relatively accessible in the modern era, being traversed by a bridge on the original coast road.

An April 2012 reminiscence by John Stewart-Smith (*pers. comm.*) gives the flavour of the site in the early 1970s:

> "During my time in the Abu Dhabi Defence Force / UAE Air Force, my children visited from UK during school holidays. One of their most enjoyed outings was to go to the coast between Umm al-Qaiwain and Ras al-Khaimah to see the funny fish that walked on the sand. These were particularly plentiful around a muddy area at Al Hamra(?). Maps were less than detailed in the early 1970s so I cannot be precise about the location."

Subsequent correspondence confirms that the site in question was Khor Madfaq and Stewart-Smith adds that the mudskippers were "widespread and numerous".

A second early mudskipper site was Khor Hulaylah, north of Rams, a broad, shallow lagoon with a sinuous channel, situated inshore of a 9 km barrier island. Attention had been called to Khor Hulaylah in the early 1970s by the work of malacologist Kathleen Smythe and by Michael Gallagher and other naturalists, who remarked on the unique character of the Dhayah salt marshes, which are fed by fresh water springs debouching within the more extensive khor (lagoon). Colin

Richardson (1994) mentioned mudskippers at this site in an entry in a compendium of Middle East wetlands sites (now online) with a primary emphasis on avian fauna. He wrote: "The shallows around the mangrove areas are one of the best places in the UAE to find mudskippers *Periophthalmus* sp." Richardson (*pers. comm.*) has elaborated in correspondence with the authors that he saw mudskippers regularly at both the Dhayah marshes and Khor Hulaylah generally, beginning in the mid-1980s and continuing at the Dhayah marshes into the early 1990s, but always in small numbers (typically one or two fish per visit). A page about the Dhayah marshes in a current UAE general interest website also mentions the presence of mudskippers (*Periophthalmus* sp.) (UAE Interact). The source of that information could not be determined (Peter Vine, *pers. comm.*) but it is likely to be derived from Richardson (1994).

The authors have independently confirmed the former presence of mudskippers at Khor Hulaylah through conversation on site with Mohammed Salem, a middle-aged resident of a nearby village who is a frequent visitor to the khor for bird photography and other activities. He understood our question about the "walking fish" immediately and was able to give a correct indication of its size. He agreed, however, that it has not been seen there in recent times.

Both of the known former mudskipper sites have been substantially altered since the reports cited above. Khor Madfaq was bridged in the 1970s and was re-bridged by a double span in the late 1990s. The beach there today is popular with kite-surfers. At Khor Hulaylah, since the late 1990s the northern end of the khor has been progressively developed as a commercial and industrial free zone, and since 2007 most of the Dhayah marsh area has been covered with landfill for residential development.

The mudskippers themselves, meanwhile, were all but forgotten. They were gone from Khor Madfaq by the early 1980s, if not sooner, and have not been mentioned in any of the now voluminous books and articles on UAE natural history that have been published since the mid-1980s. Richardson's (*pers. comm.*) records from the early 1990s are the last known for Khor Hulaylah; they are preserved in memory in a corner of cyberspace (Richardson 1994, UAE Interact) but there appear to be no fish on the ground. Several visits by the senior author (GRF) to Khor Hulaylah from 1998 to 2007 resulted in records of rare air-breathing intertidal molluscs, but no mudskippers, and a thorough examination by both authors in March 2012 and September 2013 also found no evidence of mudskippers. This is consistent with the experience of local resident Mohammed Salem (*pers. comm.*), cited above.

Another UAE resident, a local government conservation official, immediately applied the Arabic name *buleghlegh* (pronounced BU-legh-LEGH) to *P. waltoni* on seeing it, although he may possibly have been conflating mudskippers with a smaller and more common burrowing, non-amphibious subtidal goby species, since he tried (unsuccessfully) to show us more of them by taking us to the downshore edge of the mangrove forest, in the mid to lower intertidal zone.

Other experienced naturalists who arrived in the UAE as long ago as the early or mid-1990s, and who have worked at one or both of the known historical sites, have proved to be unaware that mudskippers ever existed here, notwithstanding professional interests and field studies encompassing coastal ecology. No mudskipper species have been included in recent lists or accounts of UAE fish species (Beech *et al.* 2005, Froese & Pauly 2012a, ARKive). Efforts were made in the late 2000s to limit the scope of proposed residential development at Khor Hulaylah and at the Dhayah marshes in particular. Surveys were conducted and reports prepared, highlighting the unique aspects of the habitat, flora and fauna (Llewellyn-Smith *et al.* 2007, Llewellyn-Smith 2011), but none of those reports mentioned the former presence of mudskippers.

It was a surprise, therefore, when in February 2012 the authors encountered the population reported here.

Current Field Observations

The story of the fortuitous re-discovery of mudskippers at a site in the Northern Emirates (Fig. 2) was reported in the UAE press in March 2012 (Todorova 2012), but it should be noted that Richardson's sightings in the early 1990s (Richardson 1994 and *pers. comm.*) and the unpublished East Coast record from 1997 (Kevin Budd, *pers. comm.*, Chris Stuart, *pers. comm.*) were not then known to the authors, or to the several other UAE naturalists whom they consulted. The actual interval since mudskipper populations were last known to occur in the UAE is therefore closer to 15-20 years than to the 35 years initially reported.

Fig. 2. The UAE mudskipper site discovered by the authors in February 2012. [All photos are by the senior author (GRF) unless otherwise stated.]

The identification of *Periophthalmus waltoni* could be made confidently on the basis of photographs because of its distinctive appearance and markings, the existence of regional records, and the availability of a number of authoritative print and online photographic references (e.g., Clayton & Wells 1987, Randall 1995, Polgar 2010). In the ensuing weeks the authors attempted to locate additional populations, both nearby and at other broadly similar sites elsewhere along the Arabian Gulf coast of the Northern Emirates, but none were found.

Because of the small size of the known population, its apparently unique status and its proximity to human access (Figs. 3 and 4), the determination was made that the site location should not be publicly disclosed. Those same factors make the population unsuitable for collection of specimens or for study other than by discreet and non-invasive means. Our own field work has relied exclusively on visual inspection, with or without binoculars, and on photography. Care has been taken to disturb the fish as little as possible during the course of our observations. In the text below, certain details have been omitted in order to prevent indirect disclosure of the site location.

For most of the past decade the area of the study site has been under a regime of protection by local authorities, who have kindly facilitated our periodic visits, but major infrastructural development has continued nearby and recreational amenities are now planned on immediately adjacent land. The presence of the mudskipper population and its significance have therefore been highlighted to the concerned local authorities and the maintenance of a buffer zone has been encouraged.

Summary of field visits

The authors monitored the site for almost 20 months, from mid-February 2012 until early October 2013, under diverse conditions of tide, daylight and weather, visiting at irregular intervals of 24 hours to 6 months.

The territorial nature of the fish, their construction of relatively conspicuous main burrows, and the fact that they were active only when the site was emergent, made it relatively easy for us to obtain a count of the population and to associate burrows with individual fish, to which we assigned field names for convenient reference.

- **February 2012:**
  Preliminary investigation consisted of two periods of observation in mid and late February 2012, the first in midday sunshine following a high tide at 0900 hrs which puddled the site, and the second in late afternoon on a falling tide under breezy and overcast conditions. We observed a minimum of 8 or 9 individual fish and estimated that there were at least 14 occupied burrow complexes. Courtship and mating behaviour was observed in late February.

- **June 2012:**
  The authors' circumstances prevented follow-up observation for several months, until June 2012. Then an evening visit was made in early June, less than two hours after a moderate high tide (which had only barely reached the site). 9 individuals were observed but none ventured beyond their burrows after dark. Two consecutive morning visits (commencing at first light) were made in late June, in each case within two to three hours after inundation

by a spring high tide. Only 5 fish were active each day but feeding and an unsuccessful courtship interaction were observed.

- **July 2012:**
  In late July 2012, another early morning visit was made after an exceptionally high overnight spring high tide. A population of 15 fish was confirmed, all but one of which were seen, and two territorial confrontations were observed. The last fish was observed the next day, during an early evening visit following an intermediate afternoon high tide.

Throughout our visits in 2012, the mudskipper population at the study site appeared stable and we were able to recognise specific individuals by their burrow locations.

- **January 2013:**
  Two early morning visits were made in mid-January 2013, after low overnight spring high tides. Both were on relatively cool mornings, one very windy and cloudy with air temperatures steady at about 20.5ºC (69ºF), the other sunny but cooler, with air temperatures in the range of 14º-16ºC (57º-61º F). It was disappointing to find that only 8 burrow complexes appeared to be active, and only 5 fish were actually seen, none of which were active. All but one of the active burrows had been shifted from their positions in July 2012, although it was possible to associate at least half of them with the burrows that they had replaced.

- **March 2013:**
  Another morning visit was made in mid-March 2013, following a low overnight spring high tide. The weather was sunny with estimated air temperatures between 22º-27ºC (72-80ºF). This visit confirmed a count of 8 active burrows. Burrow distribution was similar to January 2013. 6 fish were seen; 2 were cohabiting and exhibited courtship and mating behaviour.

- **August 2013:**
  Two early morning visits were made in mid-August 2013, after overnight spring high tides. Air temperature at dawn (0545 hrs) was 29ºC (85ºF), reaching 37ºC (99ºF) by 0930 hrs. These visits confirmed a continuing adult population of 8 fish but also revealed – to our great surprise – the recent recruitment of juvenile fish, resulting in a significant population increase within the study area (to *ca.* 30+ fish) as well as the presence of additional juvenile fish in a nearby satellite location where no mudskippers had been found before.

Fig. 3. Vehicle tracks encroach on the study area, containing the only population of mudskippers currently known in the UAE. Enhanced official protection has been encouraged but, due to the small size of the population and its proximity to human access, the site location has not been publicly disclosed.

Fig. 4. A mudskipper glumly inspects a tyre track that skirts the edge of its burrow platform.

- **October 2013:**
  A final pre-publication visit was made in early October 2013 to review the status of the juvenile fish. The late afternoon visit followed a spring high tide and confirmed a population and distribution largely unchanged from what was seen in August 2013.

Following our recognition of juvenile recruitment in mid-August 2013, we spent two days in late August and early September visiting other potential mudskipper sites in the Northern Emirates, in an attempt to determine whether newly arrived juveniles could be found more widely. Again, we found no evidence of this.

Summary description of the UAE study population

Basic details of our study population can be summarised as follows:

- **Habitat:**
  Perimangal mud with small to medium mangrove shrubs (*Avicennia marina*) and scattered clumps of low halophytes (*Arthrocnemum macrostachyum*), within 15 metres landward of well-developed mangrove forest; not remote from human activity and readily susceptible to potential observation, disturbance and/or destruction (Figs. 2 through 3).

- **Location within the tidal regime:**
  Upper intertidal, inundated by *ca*. 56% of all high tides.

- **Population size:**
  An estimated 15 individuals, all considered to be adult fish, were present from discovery (in mid-February 2012) through late July 2012. 15 individuals were confidently observed in July 2012 and their burrow systems (sometimes multiple) were accounted for. Possible independent burrow systems would permit an estimate of 16 to 17. Any higher number posits the presence of additional individuals for which no evidence was actually seen. Numbers had fallen by January and March 2013, when only 8 adults were reckoned to be present. By mid-August 2013, juvenile recruits had swelled the population to *ca*. 30 or more individuals.

- **Area of occupation:**
  For most of the period of observation, all of the adult mudskipper burrows except one (which is *ca*. 15 metres from any other) could be roughly circumscribed by an elongated rectangle approximately 30 metres by 12 metres (*ca*. 360 square metres), with its long dimension parallel to the local shoreline. From a mudskipper's perspective, that rectangle is effectively closed to expansion on three sides by either ecological or physical barriers – the

shoreline in the upshore direction, the mangrove forest in the downshore direction, and a man-made physical barrier in one of the longshore directions. The average density of mudskippers within this area is therefore *ca.* one per 26 square metres.

If we include the most isolated adult, the rectangle of occupation would become approximately 45 metres by 12 metres (*ca.* 540 square metres) and the average density would fall to *ca.* one fish per 36 square metres.

All of that expanded rectangle, and somewhat more, was in fact used by the juvenile recruits seen in August and October 2013, adding perhaps an additional 120 square metres to the total area of occupation for *ca.* 30 fish, equivalent to a density of one fish per 22 square metres.

In mid-August through early October 2013, during or following the recruitment period, *ca.* 25 juvenile fish were found in a discrete satellite area some 400 metres away from the study site, as further described under "Juveniles and juvenile recruitment", below.

- **Size of the fish:**
  Adult length was estimated very roughly at 11.0 to 17.5 cm (*ca.* 4.5 to 7.0 inches) total length (TL). Our estimate for the largest animals was twice confirmed by indirect measurements. In several references the maximum total length for *P. waltoni* is given as 15 cm, but a recent study records a 20.8 cm individual from southern Iran (Sarafraz *et al.* 2011). Juvenile length was estimated at *ca.* 9.0 to 11.0 cm (*ca.* 3.6 to 4.5 inches) total length (TL). Our estimate for the smallest animals was twice confirmed by indirect measurements.
- **Breeding cycle:**
  Breeding appears to occur in late winter to early spring. Courtship and mating behaviour were observed in at least five individuals, including two pairs, in mid-February 2012 and mid-March 2013 and may continue into June (see "Courtship and mating behaviour", below). The arrival of juveniles was not observed in 2012, despite field visits spanning early June through late July (although with hindsight, one of the fish then present may have been a juvenile). In 2013, however, the recent arrival of a significant number of juveniles was evident in mid-August (see "Juveniles and recruitment of juveniles", below).

Burrows and burrow distribution

Adult mudskippers are territorial and construct burrows from which they exploit and defend a surrounding territory. The following account of burrows at our UAE site is based primarily on observations of a stable adult population of *ca.* 15 fish from February until July 2012, and a residual population of 8 adult fish in January until August 2013. In the final paragraphs we discuss the distinctive features of the burrows constructed by the influx of juvenile mudskippers observed in August and October 2013.

At the study site, the burrows of neighbouring adult fish were at least two metres apart, and generally three to five metres apart, but, with one exception, each burrow was within eight metres of another. The exception was a burrow located approximately 15 metres from any other. This is a much looser concentration than at the site studied by Clayton and Snowden (2000) and could reflect the fact that the UAE site constitutes sub-optimal habitat that cannot support either a large or a dense population of mudskippers.

Most mudskipper burrows were located in areas without significant growth of mangrove pneumatophores (Fig. 5), but two of the more conspicuous burrows and one nondescript one (belonging to one of the smallest fish) were within areas of moderate pneumatophore density (Fig. 6). One main burrow platform enjoyed shade from an erect mangrove sapling and one auxiliary burrow was constructed in the dense shade of a small but spreading mangrove shrub.

A typical *P. waltoni* burrow at the UAE site has multiple nearby entrances which are joined below the surface. Several of the UAE fish were observed to move between entrances, either on the surface or from within the burrow. The main entrance is most often on a broad-rimmed low turret or volcano or a flat-topped platform (Fig. 7), but those may fall into disrepair by erosion or collapse. Sometimes one burrow entrance opens into a small, circular 'pond' which the fish itself constructs (Fig. 8). Some fish also maintain one (or sometimes two) auxiliary burrows, the entrance to which may be smaller and more directionally oriented (Fig. 9), making them difficult to distinguish from certain crab burrows (Fig. 10). One auxiliary burrow at the site was approximately 4 metres from the corresponding main burrow. The literature indicates that crab burrows may sometimes intersect with those of *P. waltoni* (Clayton & Wells 1987); at the UAE site this could possibly be the case for the crabs *Metapograpsus messor* and *Eurycarcinus orientalis*.

Fig. 5. Typical habitat of the majority of mudskippers at the study site. A mudskipper is perched at the near edge of the pale grey burrow platform just below the centre of the photo.

Fig. 6. A mudskipper burrow among pneumatophores of *Avicennia marina*.

Fig. 7. A typical burrow platform and entrance.

Fig. 8. A burrow complex showing platform (behind mangrove shrub at left), 'swimming pool' entrance at left foreground, and additional entrance at right foreground.

Fig. 9. An auxiliary mudskipper burrow resembling a crab burrow, but showing a distinctive thin, smooth exit track (compare with the crab burrow shown in Fig. 10).

Fig. 10. A lavender crab *Eurycarcinus orientalis* in the mouth of its burrow.

The lifetime of individual adult burrows can evidently be several months or more. One burrow (the most isolated one) appeared to remain intact and in use for more than one year. Eroded or damaged burrows may be repaired, remodeled or abandoned; these results were observed over a 16-day interval in June 2012 and even more so over a 28-day interval from late June to late July 2012. During the latter interval, five fish seemed to have moved to newly constructed main burrows, although still within their original territory and without clearly abandoning older burrows; the longest relocation was *ca.* 3+ metres, by a small fish on the periphery. During the same period one fish greatly improved its auxiliary burrow, located at the edge of a puddle within its territory, by building a ringed pond at the entrance (Fig. 11). A few conspicuous burrows seemed to be in the same locations in June and July as when they were observed in February, although no attempt was made in February to record the exact position of individual burrows.

We observed only three instances of active burrow maintenance, each sufficiently minor to be better characterised as housekeeping. Twice, adult mudskippers were seen to emerge and deposit a mouthful of mud and water on a low pile near the entrances to their burrows. One of the same fish also deposited a mangrove leaf it had removed from its burrow.

Male and female mudskippers are identical in appearance (Clayton & Wells 1987) although males can grow to be somewhat larger (Sarafraz *et al.* 2011). The only sure way to distinguish the sexes in the field is by observing breeding behaviour (Clayton & Wells 1987). For this reason we are unable to confidently ascribe differences in burrow architecture, or in the presence or absence of courtship behaviour, to sex differences. Nevertheless it is reasonable to hypothesise that breeding adult males have the greatest incentive to build a substantial burrow platform burrow as a podium for sexual display. Two large individuals which we measured (indirectly) at 17.5 cm (7 inches), above average for *P. waltoni*, both had prominent platforms, whereas two of the most nondescript main burrows belonged to the two smallest-appearing mudskippers (estimated *ca*. 11. cm or *ca*. 4.5 inches) (Fig. 12).

One of the larger adult fish remaining in August 2013, presumably a male, had by that time become the proprietor of three large burrows, each with a platform or turret, arrayed in a triangle with sides of approximately 7.0, 4.5 and 4.0 metres, and we watched the fish travel between as well as

Fig. 11. A ringed pond at the entrance to one burrow, constructed during the course of this study. The builder and proprietor sits on the ring at 5 o'clock.

Fig. 12. The nondescript burrow of a small but active mudskipper, perched at left centre. With hindsight, the authors recognised that this fish was the only juvenile observed in 2012.

Fig. 13: The "finger hole" burrow of a newly-arrived juvenile, on firm substrate at the upshore margin of the study area. The eyes and snout of the fish are visible to the right of centre.

Fig. 14. The small mudskipper at right centre has just exited the tiny burrow directly behind it, towards the bottom left of the photo. This burrow complex, on relatively firm substrate in an upshore location, was maintained and the largest entrance had been modified into a low mound when seen again nearly two months later.

Fig. 15. *P. waltoni* burrows at a satellite location modify the surrounding habitat by disrupting the cyanobacterial cover. This may make the habitat more attractive for colonisation by other mudskippers. A fish is visible at the burrow just below centre.

beyond the three burrows on two mornings. This was the largest territory we recorded. The principal burrow was a durable but dilapidated platform at the extreme corner of the study site that, on all previous visits, we had considered abandoned. The other two burrows were pre-existing and had been the property (we think) of two different fish; we speculate that with the demise of some of the former adult population, the fish we observed was able to expand his territory and adopt the vacant burrows as his own.

The burrows constructed by newly arrived juvenile fish, first seen in August 2013, were generally less conspicuous than typical adult burrows, but they were also variable. Most were slightly asymmetrical low mounds, resembling crab burrows; they were distinguished, if at all, by a more well-defined entrance groove. Some juvenile burrows, mostly on the firmer upshore margin of the study area, appeared to be no more than finger holes and would have passed unrecognised had we not seen the resident fish (Fig. 13). Even these rudimentary burrows, however, sometimes proved to have two entrances.

The simplest burrows may often be temporary or auxiliary ones, and newly-arrived and metamorphosed juveniles may be essentially nomadic, at least on a small scale, until they find the 'right' place to settle more permanently. We observed at least two instances in which we could be confident that juvenile fish had constructed new burrows in the 24 hours between our visits, each in the immediate vicinity of their previous burrows. In August, only one juvenile burrow, in a satellite area previously uninhabited by mudskippers, approximated the 'platform and pool' arrangement of the most elaborate adult burrows. By early October, however, some juveniles had burrows consisting of a relatively well-formed platform or turret. In at least one instance, a very simple burrow seen in August in a firm, upshore location, had been maintained and improved by early October (Fig. 14). The active juvenile occupant was observed in each instance.

More generally, it is our impression that *P. waltoni* does not simply choose its preferred habitat and burrow site, but also actively modifies it. In particular, burrowing disrupts the cyanobacterial cover that is found in adjacent upper intertidal areas without mudskippers, and covers the surface with somewhat finer and less consolidated mud (Fig. 15). Impressionistically, it seemed to us that in January and March 2013, when mudskippers at the study site were fewer in number and less active, the cyanobacterial cover within the area was more extensive and more cohesive. Mudskippers sometimes excavate 'swimming pools' in association with their burrows, but we suspect they may also play a role in maintaining shallow feeding pools within their territories. In this way, the presence of a few pioneer mudskippers may make the habitat more attractive for colonisation by others. That hypothesis is arguably exemplified by the nascent satellite colony of juveniles discovered in August 2013, in an area primarily characterised by moderate cyanobacterial cover (see "Juveniles and recruitment of juveniles", below).

Surface activity in general

Periophthalmus species feed and interact with each other primarily on the surface of their mudflat environment when the tide is out. Because they live in the upper intertidal zone, they and their burrows are emergent for longer than they are inundated. They have gills but they can also breathe air, respiring through the skin and through the linings of the mouth and pharynx (cutaneous respiration), assisted by modifications of the gill chambers (Graham 1997). Air-breathing is considered to be an adaptation to the very low dissolved oxygen levels of the seawater remaining at low tide in burrows in anoxic mud. Many and perhaps all *Periophthalmus* species maintain an air chamber in their burrows (Ishimatsu *et al.* 1998, Polgar 2010), at least when brooding eggs (Takeda *et al.* 2012), and some species will reportedly "drown" if forced to remain submerged for prolonged periods (Hagen Aqualab 2005).

In the course of our field work we observed *P. waltoni* engaged in various behaviours including locomotion, feeding, "comfort behaviour" (rolling and fin waving), threat display, male courtship display and the paired mating ritual, as well as less readily decipherable behaviour. Our observations are summarised and compared under the various headings that follow.

Activity period

Mudskippers generally, including *P. waltoni*, have been considered as diurnal species (Polgar 2010), although Columbini *et al.* (1996) concluded that activity patterns of *Periophthalmus sobrinus* (= *P. argentilineatus* or *P. kalolo*) depended more on environmental factors such as air temperature and relative humidity than on the daily light cycle, and nocturnal activity has also been recorded for the forest-dwelling *P. wailailakae*. A conspecific, *P. minutus* from NW Australia, is expressly reported to retreat to its burrow at night (Takeda *et al.* 2012).

Clayton & Snowden (2000) found that in Kuwait, *P. waltoni* was active by day when the tide was out, independent of the weather and the exact state of the tidal cycle, with three exceptions: (1) there was little or no activity on dry mud above the level reached by the previous high tide; (2) activity was inhibited at surface temperatures below 15ºC (59ºF) (a temperature generally exceeded by day in the UAE, year-round); and (3) activity was inhibited by high wind speeds. Clayton & Snowden point out that these parameters correspond to those limiting the activity of the mudflat crabs on which *P. waltoni* preys in Kuwait. Otherwise, Clayton and Snowden (2000) found that, when active, *P. waltoni* spent more time on the surface than in their burrows, by a ratio of almost 9:1.

Consistent with Clayton and Snowden's findings, our study population was not generally active when the site had not been wet by the previous high tide, or when it had dried out thereafter, or at night. Using local tide tables in conjunction with our field observations, we calculate that, on average, 36 high tides each month, or about 56% of all high tides, are high enough to wet the study site to a greater or lesser extent (Fig. 16). Likewise, on average, about every two months a period of 3 to 4 days may pass when no high tide is high enough to inundate the site.

Independent of physical activity, however, the majority of the mudskippers at the study site seemed disposed to perch out-of-water during most of our observations, either in the mouth of a burrow entrance, atop the entrance platform, or perched on a nearby mound of mud, although they retreated to their burrows periodically, most likely to wet their skin to enhance respiration (Ikebe & Oishi 1996, cited in Clayton & Snowden 2000), or if disturbed. This was true in both warm, sunny midday conditions and cool, breezy late afternoon conditions in February, as well as early evening and early morning conditions in June and July.

The same was generally true at night. Observed after dark in early June 2012 (from 1930 until 2100 hrs), the majority of the population (and 8 of 9 individuals seen that night) could be found repeatedly by flashlight, perched in the mouths of their burrows (Fig. 17) or atop their platforms. They were tolerant of the light but withdrew if approached to within 2-3 metres. None were observed to travel from their burrows. In late July, 10 of the 15 known fish were emergent during the two hours after sunset. Several were active during twilight, but after darkness fell only a single fish, which had become habituated to flash photography, was seen more than 30 cm from its burrow, and 5 of the 10 were no longer seen at all.

Takeda *et al.* (2012) observed seasonal variation in the surface activity of *Periophthalmus minutus* in Darwin Bay. They found that these mudskippers were active by day in February, the austral summer and breeding season, whether or not they had been inundated by the preceding high tide. In August, however, the same mudskippers were active by day only following inundation. Takeda *et al.* (2012) also noted that temperatures above 40ºC (104ºF) suppressed the daytime surface activity of the fish.

In the UAE, we found that although adult mudskippers were active at midday in February, they became sedentary by *ca.* 0930 hrs in June, July and August – this in a summer regime of consistent daytime high temperatures of 40ºC or more (daytime highs during our July visits were reportedly 43ºC (109ºF)). However, our observations do not allow us to disentangle the effect of temperature from that of surface desiccation. All of our daytime visits in summer were in early morning following an overnight high tide; both temperature and desiccation increased rapidly and in parallel during the course of the morning. Consistent with the generalisations of Clayton & Snowden (2000), we would expect that *P. waltoni* is habituated to the high temperatures of the Arabian Gulf summer and that surface wetness is likely to be more important than temperature as a constraint on surface activity.

The juvenile *P. waltoni* observed at the study site in mid-August 2013 appeared to be somewhat more active than adults and also somewhat more tolerant than adult fish of surface desiccation and/or high temperature. A number of juveniles continued to move about and to interact on the mud surface into late morning, after all adult fish had settled into their burrow mouths. The same was true in early October 2013, when surface temperature was somewhat less extreme (35ºC (95ºF) at 1400 hrs). However, this could be less a matter of tolerance than of the newcomers' need to explore their surroundings and establish territories of their own.

Juvenile fish were also seen further upshore, on firmer, drier substrate than any adults. But again, this could have been more a matter of necessity than of choice, reflecting their exclusion from the more desirable territories of other fish, including larger juveniles.

Fig. 16. The study area inundated at high tide. Mudskippers retreat to their burrows when the site is under water, but forage diurnally on the damp mud when the water recedes. On average, the study area is flooded by about 36 high tides each month, or about 56% of all high tides. About every two months a period of 3 to 4 days may pass when no high tide is high enough to wet the site.

Locomotion

Normal locomotion in *P. waltoni*, as in all mudskippers, is by 'crutching' with the modified pectoral fins and resting the forward part of the body on the fused and forward-shifted pelvic fins (cover photo) (Fig. 17A). The tip of the tail is held in a distinctively semi-erect posture (see Fig. 1). Rarely, mudskipper locomotion is captured in a trail of 'footprints' (Fig. 18); more normally, only the central groove is preserved.

The modification of the pectoral fins, which consist of two muscular segments – a proximal basal lobe and a distal, modified ray fin (Fig. 19) – constitutes a kind of retrofitting for amphibious life,

Fig. 17. A mudskipper perched at dusk in the mouth of one of two adjacent burrow entrances, both very simple and crab-like. This burrow was abandoned during the following two weeks.

Fig. 18. Mudskipper 'footprints' at an auxiliary burrow.

Fig. 19. The mudskipper's pectoral fins are modified from true rayed fins. The highly vascularised skin serves as a respiratory organ. [Photo by BR]

since mudskippers and other gobies are descended not from primitive lobe-finned fishes but from highly developed ray-finned fishes, specifically the perch family (Order Perciformes) (Polgar 2010). Modification of the pectoral fins for burrowing may have been a pre-adaptation for their use in locomotion.

The modification of the pelvic fins, on the other hand, is characteristic of the goby family as a whole (see, e.g., Feulner & Cunningham 2000), and in many species forms an organ capable of suction, allowing the fish to cling to hard substrates. Some *Periophthalmus* species are even able to climb the aerial roots of mangroves in this way (Hogarth 1999, see photo at p. 113).

When alarmed, *P. waltoni* can also move rapidly for at least several metres by hopping (and flopping), flexing its muscular body and tail to propel itself forward through the air.

'Comfort' behaviour

Comfort behaviour is a term that has come into use to describe behaviour whose function is to make the animal physically more comfortable. At least three such behaviours have been identified in mudskippers and discussed in the literature, all of which were seen in the UAE population: (i) periodic burrow visits, (ii) rolling, and (iii) pectoral fin waving. To that list we would add two behaviours involving orientation or position: shade-seeking and orientation away from the sun.

P. waltoni burrows are filled with water, except for the air pocket deep within, so the fish get wet when they descend beyond the entrance area. So-called "shuttling" between the burrow and the surface has the effect of promoting evaporative cooling and this behavioural adaptation is important to thermoregulation at high air and water temperatures (Taylor *et al.* 2011). Rolling, whereby a mudskipper rolls briefly to one or both sides in a shallow puddle, similarly promotes evaporative cooling. But *P. waltoni* and other species of *Periophthalmus* are active on tropical mudflats at air temperatures that frequently approach or exceed 38ºC (100ºF) (Taylor *et al.* 2011, Takeda *et al.* 2012), suggesting that temperature *per se* is not the only factor involved. Routine burrow visitation and rolling have been persuasively interpreted as equally or more important to facilitating cutaneous respiration, which requires a wet skin (Clayton & Snowden 2000 and references cited therein). Studies of mudskipper species other than *P. waltoni* have shown, for example, that the frequency of burrow visits and rolling is unchanged over a spectrum of temperatures (Yang Ka Yee 1996, cited in Clayton & Snowden 2000) but increases with increased wind speed (Tytler & Vaughan 1983, cited in Clayton & Snowden 2000), and that rolling behaviour is increased to the side towards which a stream of drying air was directed (Ip *et al.* 1991).

Pectoral fin waving is a more subtle and enigmatic behaviour. Sedentary fish will occasionally 'wave' the rayed portion of one or both pectoral fins, bringing it forward from its normal position (directed backwards and pressed back flat against the body) to a position more or less perpendicular to the body and the ground. The movement is brief but deliberate, consisting of forward stroke, brief pause and backward stroke. The entire sequence occurs in about 2 seconds. It does not seem likely to be a signal of any sort, since it does not depend on the presence of conspecifics in the vicinity, but it is sufficiently brief that it also does not seem very likely to contribute significantly to either thermoregulation or respiration. We did not notice that fin waving was associated with opening of the opercular cavity, as has been implied (Stebbins & Kalk 1961, cited in Clayton & Snowden 2000).

Shade is available within the study site from scattered small to medium sized mangrove seedlings and shrubs. Most mudskippers were observed in the sun, most of the time, typically at the mouths of their burrows. But some adult mudskippers had built main or auxiliary burrows with entrances that were shaded or partly shaded by mangroves and they were sometimes found at these locations, especially in summer. We interpret the choice of shade by fish which had the ready alternative of sunshine as a "comfort" choice – one which would obviously protect against overheating and skin desiccation.

It was our impression that the fish tend to orient themselves facing away from the direction of the sun, when it is not directly overhead. We did not attempt to quantify this phenomenon rigorously, but our observations at 0900 hrs on a morning in late June 2012 are illustrative. Of seven fish then in view, four were facing directly away (180º) from the sun and the other three had orientations of between 90-180º away. We hypothesise that such an orientation is more likely to be for reasons of improved vision than for thermoregulation. It is probably easier for these visually sensitive fish to see clearly, just as it is for humans, when they are not looking directly "into" the sun, or into its reflection off puddles on the mud surface.

Perambulation

This section attempts to give an account of the frequency and extent of movement by individual fish within the study site. *P. waltoni* is a relatively phlegmatic species overall. Movement was extremely limited during our visits in January 2013, in breezy and cool weather, when only a few fish even made an appearance in the mouths of their burrows. Movement was also very limited in March 2013, when only two fish left their burrows, notwithstanding that mating behaviour was observed on that occasion. On our two night visits, as previously indicated, only one fish ventured from its burrow mouth or platform.

Even when the fish were generally most active by day, not all fish were equally active. For example, on our two consecutive morning visits in late June 2012, lasting 3.5 to 4.0 hours each, only five fish each day were seen to travel more than one metre from their burrows, and of those, the same four fish were active on both days. This was evidently not a response to the presence of an observer, since the four fish active on both days were those closest to the main points of observation. Nevertheless, they withdrew towards their burrows if approached too closely.

Of the six most active fish, three spent much of their time away from their burrows. One large fish made repeated extended sorties through a chain of shallow puddles on open ground, travelling and feeding up to *ca.* 5 metres from its well-formed platform burrow. A second, smaller fish, with a nondescript main burrow and an auxiliary burrow *ca.* 4 metres away, was seldom in either burrow but perched on mud lumps within a trapezoidal area of *ca.* 10.5 sq. metres consisting of shallow puddles, crab burrows and a few mangrove sprigs.

The third, another large fish, was the champion in terms of distance and diversity of travel. This fish travelled repeatedly between its main burrow and a small clump of mangroves 2 metres away, where it had an auxiliary burrow. It also travelled *ca.* 8 metres in the same direction, almost reaching another prominent burrow, from which it was chased by the owner, who was coincidentally(?) returning. The first fish also travelled *ca.* 4 metres in a different direction, where it was surprised by an observer in the shade of another small mangrove clump and hopped back towards its burrow. Finally, it travelled 2-3 metres in yet a third direction for a liaison with a neighbouring fish (described under "Other social behaviour", below). The three main directions of travel were approximately 120 degrees from each other.

A fourth fish made occasional sorties from its burrow, each in the same direction, apparently for foraging. On one occasion it stopped and seemed to show awareness of another fish ahead in its path, about 1 metre away, causing it to stop for several minutes before returning toward its burrow.

The same fish later made a 1.5 metre journey to sit briefly in the shade of a small mangrove shrub.

A fifth fish was seen in liaison with a smaller neighbour (the second fish described above) in early morning on our first visit (as described under “Other social behaviour” below), after which it withdrew to a spot near its burrow, *ca.* 4-5 metres distant. On the following morning, it never left its burrow.

The sixth ‘traveller’ was a neighbour of the third fish described above. This fish was normally seen perched in the volcano-like mouth of its burrow or on larger adjacent mud lumps, but it had also travelled *ca.* 2-3 metres away, where it was approached by the third fish mentioned above (as described under “Other social behaviour”, below), beating a hasty retreat in the end.

What might account for the observed differences in individual activity levels? Food and sex are, as always, among the primary hypotheses. On each morning in June, two of the mudskippers that travelled more than one metre engaged briefly in ambiguous but probably amorous physical contact, although we saw no unequivocal male sexual display or courtship behaviour in June 2012 as we had in February 2012 and in March 2013 (see below under “Courtship and mating behaviour” and “Other social behaviour”).

On the other hand, at least three of the ‘travellers’ hunted and fed while they were at large. Were the more sedentary fish already sated and not motivated to hunt? If not, why not? Or was hunting and feeding by the travellers opportunistic and ancillary to travel for other purposes? Three of the fish that travelled farthest visited shallow, flat-bottomed puddles localised within the site, where polychaete worms were successfully hunted (see “Hunting, feeding and diet”, below). Were those puddles, within and marginal to the territories of the concerned fish, the main goal of the excursions?

We have mentioned above, under “Burrows and burrow distribution”, that one of the largest remaining adults in August 2013 had by then succeeded to a territory encompassing three conspicuous burrows, to which the fish circuited on the two mornings we watched, making a round trip of nearly 20 metres.

The newly arrived juveniles seen in August and October 2013 not only greatly outnumbered adult fish at the study site; they also tended to be more active and were somewhat less wary of approach. Possibly that is because, unlike adults, they did not yet have their own territories and needed to explore their surroundings to establish both geographic and social relationships. (See also “Juveniles and juvenile recruitment”, below.)

Hunting, feeding and diet

P. waltoni is an opportunistic carnivore and is known to eat small crabs, barnacles, shrimps, snails, worms (and probably other types of marine invertebrates) and even small fish and flying insects that land on the mud (Clayton & Wells 1987, Clayton & Snowden 2000, Mhaisen & Al-Maliki 1997, Polgar 2010). Although *P. waltoni* forages for food, it is ultimately an ambush hunter that lunges or pounces on its prey. Clayton & Snowden (2000) have described the capture sequence as follows: “Supported on pectoral and pelvic fins, the mudskippers flex their tails to one side forming their bodies into a variably acute “J” shape. By quickly straightening the tail, the fish leap rapidly at their prey.” In Kuwait, where *P. waltoni* has been best studied, small crabs are considered to be their main prey, particularly the Ocypodid species *Tylodiplax indica*, *Nasima dotilleformis* and *Ilyo-plax stevensi* (Clayton & Snowden 2000). Polgar *et al.* (2009) likewise report the presence of numerous Ocypodid crabs within the zone where *P. waltoni* is present near Bandar Khamir, Iran, in the Strait of Hormuz.

At the UAE study site, in contrast, small crabs are effectively absent within the area of the mudskipper habitation. *Macrophthalmus depressus* is present in modest numbers at the downshore periphery, among mangrove pneumatophores. Only a few *Uca annulipes*, the UAE’s most common fiddler crab, were ever observed near the study site. Two were seen on the firm upshore, above the mudskipper range; two others were seen adjacent to the site but separated by a physical barrier; one was seen in the jaws of a large mudskipper. Another small, unidentified Ocypodid was observed about 15 metres alongshore from the site.

Except in winter, the dark purple *Metapograpsus messor* (Fig. 27) is abundant and the somewhat larger, lavender-coloured *Eurycarcinus orientalis* (Fig. 10) is common, each in direct association with *P. waltoni*. Adults of both of those species are probably too large to constitute reasonable prey for *P. waltoni* (Clayton and Wells (1987) estimate that a carapace dimension of about 1 cm is the practical limit) but juvenile crabs are probably at risk. Large and medium sized *M. messor* occasionally ventured

Fig. 20: A large adult mudskipper has captured and will eat a fiddler crab, *Uca annulipes*, a rare species at the study site. [Photo by BR]

into the mouth of mudskipper burrows, although the crabs were invariably wary in the presence of actual mudskippers, always facing the fish, and retreating if approached closely.

We were able to observe eight successful food capture events and one unsuccessful attempt, involving six different fish. In three instances the prey was small flies, which the fish, sitting on mud, pounced on or lunged at, and in one instance caught in mid-air.

In three instances in June 2012, mudskippers were hunting in shallow, flat-bottomed puddles and the prey taken was a long (12cm+), reddish-pink polychaete worm. In each such instance, after a lunge, the fish could be seen with part of the worm trailing from its mouth on the mud alongside its head (and in one case alongside the full body length of the fish). The remainder of the worm was gobbled up in successive gulps. The one unsuccessful capture was a lunge by a fish hunting in a shallow puddle (where it was later successful); the intended prey is likely also to have been the polychaete worm. In five of the six foregoing instances in which we could determine the concerned fish and its burrow, prey was captured (or not) at a distance of approximately 4-5 meters from the main burrow.

The identity of the polychaete worm prey is unknown. The fact that it was evidently soft-bodied suggests that it is most likely a member of the Family Nereididae (Richard J. Hornby, *pers. comm.*) but no species fitting its description, particularly the large size, is known from surface observations of UAE mudflats (*pers. obs.*, R.J. Hornby, *pers. comm.*). The worm is tentatively presumed to be a shallow subsurface dweller that *P. waltoni* can somehow sense.

In the seventh successful instance, a fish perched on the berm of its ringed pond (see Fig. 11) lunged into the surrounding shallow pool and caught a prey item that appeared to require several seconds of mastication; the prey was not seen well but could possibly have been a small crab.

The last instance was arguably the most dramatic, and also "the exception that proves the rule". In August 2013, a large adult caught and ate a fiddler crab *Uca annulipes*. We missed the instant of capture but we were alerted by movement and saw the fish in the mouth of its burrow with the crab in its jaws (Fig. 20). Watching, we were uncertain whether the fish would be successful in ingesting the relatively large crab. The process proved to be slow, but relentless and effective. The crab was repeatedly taken into the oral cavity and then exserted, each time with fewer legs, claws and/or eye stalks than before. Those were undoubtedly severed and crushed by the sharp teeth arrayed in the jaws of *Periophthalmus* spp. and other carnivorous mudskippers (Sponder & Lauder 1981, Murdy 2011).

Since we had never seen any other *Uca annulipes* within the mudskipper site, we tentatively infer that *P. waltoni* predation on *Uca annulipes* is relatively efficient, and that the mudskippers themselves may be responsible for the absence of these fiddler crabs.

Clayton & Snowden (2000) found that *P. waltoni* in Kuwait conducted successive hunting forays in different directions and reasoned that this increased their foraging efficiency because their prey, small crabs, remained in their burrows longer than usual following a hunt in their immediate vicinity. In contrast, in the UAE population, individual mudskippers tended to journey to the

Fig. 21: A territorial confrontation at a mutual border. Only the rear dorsal fins are raised, showing a black band with white borders

same areas repeatedly, whether foraging or otherwise, often favouring shallow puddles. Possibly this reflects the difference in prey species available at the UAE site, being worms and flying insects which would not be sensitive to prior visitation.

Also in contrast to Clayton & Snowden (2000), the UAE mudskippers did not return to their burrows soon after a successful prey capture. In the case of small flies, this might be because those prey do not constitute a "meal", but a fish-length polychaete worm undoubtedly approximates or exceeds the body mass of the small crabs on which Kuwait mudskippers typically feed.

In October 2013, we observed an enigmatic feeding behaviour that we had not noticed previously. Two fish, feeding in adjacent shallow puddles, appeared to be 'snuffling' through the muddy substrate in the manner of a dugong eating sea grass. Possibly this was an attempt to find and uncover food items, or to ingest small food items in a slurry of mud.

Territoriality

P. waltoni is a territorial species (Clayton & Wells 1987), like most if not all *Periophthalmus* species. All of the adult mudskippers that we observed at the study site maintained one or more burrows that were the centre of their activities and that were not trespassed upon by other adult mudskippers. In some cases the burrows or their surrounding areas were actively defended. Clayton & Wells (1987) made the point that, in common with many other species, territorial contests among mudskippers are usually decided in favour of the resident.

We saw four clear instances of intra-specific territoriality. Two, in late July 2012, were classic confrontations at close range, with both fish at or near what we knew to be the margins of their respective territories. In each case the fish alternately turned sideways and then faced each other at centimetre range, sometimes opening their mouths to reveal the bright pink interior (Fig. 21). In one interaction, both fish partially raised their rear dorsal fins and one of the fish repeatedly flashed its forward dorsal fin. In the other, both fish raised their dorsal fins on a few occasions, once for as much as 10 seconds. In no case, however, did the fish make physical contact.

The confrontations were interspersed with intervals when both fish remained motionless for up to *ca.* 30 seconds at a time, and were occasionally interrupted while one fish or the other would roll briefly. In each case the interaction ended after *ca.* 6-7 minutes, when the fish gradually separated and ceased to take note of each other. To the human eye, there was no obvious winner or loser, but it may be significant that in each case it was the fish that was most distant from its main burrow that withdrew first and farthest from the site of the contest.

These encounters lacked the drama of some mudskipper accounts. There was little displaying, no leaping, no vocalising and no ignominious retreat. Possibly this was because in both instances there had been no actual transgression of the territorial boundary, or possibly territorial defence is more relaxed outside the breeding season, or possibly *P. waltoni* is simply a less demonstrative species; however, these do not exhaust the possibilities.

A third instance of territorial defence took place at longer range. In that instance the resident fish was returning towards its prominent burrow. When

Fig. 22: Two small mudskippers basking in close proximity without apparent interaction. The mudskipper on the right is noteworthy because it does not show the vivid black markings typical of juveniles (see also Fig. 25).

it was still in a shallow puddle at a distance of about one metre from the burrow, it evidently spied another mudskipper approaching from nearly the opposite direction, also about one metre from the burrow. The resident became agitated and skipped ahead more quickly, whereupon the interloper turned and retreated at a rapid ‘walk’ in the direction from whence it had come, which was the direction of its own burrow *ca.* 7 metres distant. These fish were sensitive to each other’s presence at a distance of more than 2 metres, despite their low vantage point, the uneven ground between them, and their camouflage colouration.

In a fourth instance, in August 2013, when juvenile fish were also present at the site, an adult emerged from its burrow to clear a mangrove leaf and spied a neighbouring adult that had approached to within *ca.* 0.5 metres. The burrow owner immediately sallied forth and the interloper beat a retreat. The proprietor remained in the confrontation area for only a couple of minutes before returning to its burrow mouth.

The arrival of large numbers of juvenile fish, first observed in mid-August 2013, increased the population density at the study site by a factor of 2 to 3 from what we had previously observed, but the resident adult fish appeared to tolerate this, at least within the limits observed. On one morning in August an observer was surrounded by 5 juvenile fish within a 2 metre radius. Two of them were perched on the margins of an abandoned(?) adult burrow (Fig. 22) and three were within one metre of an adult fish sitting in the mouth of its burrow – a distance that would not have passed without notice among adult fish.

This may indicate that juveniles are recognised as such, and specifically as being sexually immature. It does not explain, however, why juvenile fish would be tolerated if an adult territory is maintained for resource protection purposes. A degree of resource-based exclusion is suggested by the fact that, as previously noted, a number of newly-arrived juveniles (and their burrows) were observed in areas at the margins of the study site, which had not been occupied by the earlier adult population.

In any case, we never saw adult fish actively chase juveniles, although that was perhaps partly because juveniles would typically distance themselves from any adults in motion nearby. We did, however, see larger juveniles actively chase smaller ones, for distances up to *ca.* one metre (see also “Juveniles and juvenile recruitment”, below). We tentatively relate this to their need to establish and maintain territories, and perhaps also social relationships, of their own.

Fig. 23: Threat display towards a crab, E. orientalis, with both dorsal fins fully erect. [Photo by BR]

Threat display

We saw only a single full-blown threat display, which was directed not at another mudskipper but at a medium-sized crab, the lavender crab *Eurycarcinus orientalis*. On our second visit in February 2012, a crab had ascended to the burrow platform of a mudskipper, which at the time was *ca.* 0.4 metres away. The fish returned immediately to the base of the platform and the crab descended to flat ground, where the fish positioned itself between the crab and the burrow and raised both dorsal fins (Fig. 23), the front dorsal fin being sail shaped and the elongated rear dorsal fin being marked with a distinctive black and white stripe. The crab stood its ground for a few seconds before sidling away at a measured pace; the mudskipper lowered its fins but continued to monitor the retreat.

In August 2013 we again saw an adult mudskipper, on open ground near its burrow, briefly flash its dorsal fins at an equivalent sized *E. orientalis* crab, which likewise moved slowly away.

Courtship and mating behaviour

We saw in February 2012 the first of only a few instances of a male courtship display. A large fish perched atop its well-formed platform burrow, to one side of the central entrance hole. It stood high on its pectoral fins, raised its dorsal fins and turned slowly through *ca.* 90 degrees, facing the periphery of the platform. Then it suddenly flipped into the air and landed on the other side of the entrance hole, almost 180 degrees opposite and a fish length or more away. It again erected its fins, but only briefly, before settling down atop the platform. We did not notice any other fish in the vicinity towards whom this display might have been specifically directed, but in the circumstances our attention was focused primarily on the displaying male.

We also saw in February 2012 a single instance of the mating or pre-nuptial ritual, which appeared to conclude successfully. We did not observe the male display or the initiation of contact, but our attention was attracted to two fish, one following the other diligently for about 4 metres across the mud, mostly splashing through very shallow puddles, to a well-formed platform burrow. The lead fish mounted to the flat top of the platform and briefly flared its dorsal fins. The second fish, instead of being intimidated, also mounted the platform and they engaged, face-to-face and open-mouthed in a prolonged mudskipper ‘kiss’, heads elevated and dorsal fins lowered, lasting for perhaps half a minute. Then the first fish turned and popped down the central entrance hole, and the second followed immediately. Egg laying and fertilisation would have followed within the burrow. But for the ending, however, the observed sequence might have been (mis)taken for a territorial or aggressive interaction.

Broadly similar courtship rituals have been described by Brillet (1980, 1984) for *Periophthalmus sobrinus* (= *P. argentilineatus* or *P. kalolo*) and by Lee and Graham (2002) for *P. modestus* (= *P. cantonensis*). The procession of the two fish, led by the male, to the burrow built by the male, has been colourfully christened the "nuptial promenade" (*promenade nuptiale*) by Brillet (1984). In *P. modestus*, Lee and Graham (2002) did not distinguish the nuptial promenade as a phase distinct from the male's continuous effort to display and draw an attentive female towards the breeding burrow, and neither Brillet nor Lee & Graham described mutual physical contact at the breeding burrow.

Our observation permits a tentative summary of the "full" courtship sequence for *P. waltoni* as follows: male display (erection of the dorsal fins, arching and jumping), the nuptial promenade, display at the breeding burrow, mutual contact, descent, cohabitation, egg laying and fertilisation. Because we did not observe the beginning of the sequence, we cannot say whether the sequence may also have included some act or contact to confirm the female's interest prior to the nuptial promenade. It is worth noting specifically that the existence of the nuptial promenade seems to entail that the male's display will often, if not always, take place at a location other than the breeding burrow itself.

A somewhat less romanticised and less rigorously sequential version of courtship and mating was observed in March 2013. On a day when the reduced population of adults as a whole was relatively inactive, one pair was evidently cohabiting. The two fish were first seen together at about 0845 hrs, one at each of the entrances atop two large, closely adjacent burrow platforms in a relatively secluded location (Fig. 24). The fish on the left withdrew underground. The fish on the right platform (slightly darker, believed to be the male and the proprietor of the burrow) then emerged on top of its platform, elongated itself and made two jumps in place, reversing its direction. Then it made 2-3 more jumps, with its dorsal fins flashing, towards the left platform, and went immediately down the hole. Both fish re-emerged in *ca.* 2-3 minutes, one at each entrance, proving the underground connection. Both then descended again, but surfaced within another minute.

Fig. 24: Two adjacent, well-formed platforms, part of a single burrow complex where mating behaviour was observed in mid-March 2013. The proprietor is visible in the near entrance.

Five to ten minutes passed without further action. A fish then emerged on the left and briefly laid out atop its platform, before descending again. The fish on the right emerged onto its platform but immediately took several short leaps towards the left platform and went down. Within a minute, fish had returned to the mouths of both platforms. The time at this point was about 0930 hrs. The fish on the left now laid out on its platform, then hopped towards the fish on the right, making physical contact. Both fish "fell" together down the edge of the platform, but only one (the proprietor and presumed male) returned to the top, where it laid out flat and performed a few low jumps with its dorsal fin flashing. It then went underground, but for less than a minute, returning to lay out on the right hand platform and make two more half-hearted jumps. It descended once more, but reappeared almost immediately at the left hand entrance, where it took up an extended vigil.

The second fish, meanwhile, returned slowly to the vicinity of a neighbouring burrow, probably its own, where earlier a fish (most likely the same one) had been surprised, about 45 minutes before the cohabiting pair was noticed. We tentatively interpret these interactions as a visit by the second fish, presumably a female, to the burrow complex maintained by the first fish, presumably a male, for mating purposes. The observed interactions between the two fish had occupied approximately 1.0-1.5 hours in total. The absence of more structured courtship behaviour could possibly be explained by the fact that the two fish were already acquainted.

Despite studies in Kuwait, the breeding season for *P. waltoni* in the Arabian Gulf has apparently not been described previously (Polgar 2010); for the sympatric *Boleophthalmus dussumieri*, the breeding season in Kuwait is said to extend from April through August, and in Pakistan into September (Polgar 2010). In *P. modestus* of Japan and South Korea, the late spring and summer breeding season has been shown to be somewhat longer at lower latitudes (Ishimatsu *et al.* 2007, Baeck *et al.* 2008, Polgar 2010).

The limited observations reported here for the study site suggest that in the southern Arabian Gulf the breeding season for *P. waltoni* includes the period from mid-February through mid-March, and probably continues through May and perhaps into late June (see "Other social behaviour", below). This is supported by direct evidence of courtship and mating as well as by evidence of the recruitment of seagoing juveniles in late July or early August (see "Juveniles and juvenile recruitment", below). The authors hope that targeted observations in 2014 will elucidate the local breeding and recruitment periods more precisely.

Other social behaviour

We also observed, in late June 2012, what is perhaps best interpreted as an unsuccessful courtship attempt. Two mudskippers, one noticeably smaller than the other, were perhaps a metre apart but were evidently aware of each other when we first noticed them. The larger fish followed the smaller one for another metre or so, into what we later learned was the foraging territory of the smaller fish. When they stopped, both postured at close range (less than a fish length), each one opening its mouth to display the pink interior and then turning sideways and showing its flank to the other, but without any display of fins (Fig. 25).

Finally, the smaller fish approached the larger and held its open mouth obliquely against the side of the larger fish's head – a 'cheek kiss' seemingly identical to the courting behaviour depicted for *Periophthalmus modestus* in Polgar (2010) – for perhaps half a minute. Then, without any further posturing or interaction, the smaller fish moved *ca.* 30 cm away and the larger fish began a slow return, over 10-15 minutes to its own burrow *ca.* 5 metres away. Because of the non-hostile nature of the encounter, the 'following' behaviour and the unilateral close open-mouth contact, we tentatively interpret this interaction to have been an amorous one between a small male and a larger female.

The reasons why this particular encounter was aborted are speculative. The smaller presumed male did not maintain a well-formed burrow and was perhaps not in full breeding condition. He did not display and his approach was demure in comparison to mudskipper courtship descriptions in the literature. Perhaps his small size made a difference, too.

A similar incident was observed in October 2013, involving a small (juvenile) darker fish and a distinctly larger, pale-headed adult. The two fish were seen at the edges of adjacent shallow, flat-bottomed puddles, each with its second dorsal fin up. The smaller fish flashed its first dorsal fin but the two continued feeding. Then the smaller fish advanced to the intervening low ridge of mud. After an interval the larger fish approached and positioned itself obliquely next to the head of the smaller fish, with its mouth open. After a few seconds, the smaller fish lunged unexpectedly at the larger one, which backed off to its puddle and continued its foraging activity. The smaller fish then did the same, and after a few minutes perched on the slopes of its nearby burrow, each fish apparently ignoring the other.

A more dramatic but indecipherable interaction occurred in late June 2012. Two mudskippers who proved to be from neighbouring burrows were observed at a distance, positioned more or less side by side in a trough among mud lumps, at a distance of about 2.5 metres from each of their respective burrows. They remained motionless for perhaps 20-30 seconds. Then, suddenly, one of

Fig. 25. The aftermath of what is interpreted as an aborted courtship (see text under "Other social behaviour"). The smaller (male?) fish is in the foreground.

Fig. 26. Juveniles of *P. waltoni* show vivid black markings on their flanks, gill covers and lower spine.

the fish flared its dorsal fins and turned; there was a splash and the other fish hopped quickly away to a distance of about 0.5 metres, in what turned out to be the direction of its burrow. After a short interval the dominant fish also moved slowly back toward its own burrow. It is possibly significant that the dominant fish was one of the three most active 'travellers', who was observed to explore in three different directions from its burrow.

Juveniles and juvenile recruitment

Mudskipper fry do not develop *in situ*. Instead, after incubation and hatching, mudskippers spend their early lives as pelagic (seagoing) larvae, after which they return to the intertidal zone on a suitable high tide (this process is called "recruitment") and rapidly metamorphose into smaller versions of adults. See "The mudskipper life cycle, including a planktonic larval phase", below.

Juvenile *P. waltoni* were first seen at the study site in August 2013, when they outnumbered adults and increased the local population from 8 to ca. 30+ fish. Juveniles are distinguishable from adults by their smaller size and more vivid black markings on their flanks, gill covers and lower spine (Fig. 26).

Juveniles at the study site were also distinguishable behaviourally from adults, as mentioned in discussion of various points above. Among other things, they tended to occupy more upper intertidal habitats, to build smaller and more nondescript burrows, and to be active on the surface for longer periods.

It should be noted, however, that our description of the smaller fish newly observed in August 2012 as "juvenile" is not meant to preclude the possibility that some of them were sexually mature, or became sexually mature by the time they were observed again in October. The maturation time for *P. waltoni* is unknown but it has been said of the similar-sized *P. barbarus* that it can reach sexual maturity within a year, and at half of maximum adult size (Polgar 2010). In two cases, interactions at the study site that were possibly amorous in nature involved fish of markedly different sizes, although in each case those interactions ended inconclusively (see "Other social behaviour", above).

Modest size differences were noted among juveniles, which were estimated to range from 9 to 11 cm in total length. This can reasonably be interpreted to reflect two different episodes of larval recruitment, most likely on successive spring high tides. On several occasions larger juveniles were observed to chase smaller juveniles, for distances up to *ca.* one metre.

The timing of recruitment can be used in a rough way to reconstruct the breeding period for *P. waltoni* in the UAE. Data is scarce for mudskipper incubation times, which probably vary with temperature, but an estimate of "about one week" is given for *P. modestus* (Ishimatsu *et al.* 2007, Polgar 2010). The only estimate we have found for larval maturation time in mudskippers is 30-50 days for *P. modestus* (Kobayashi *et al.* 1972, Lee & Graham 2002, Ishimatsu *et al.* 2007, Borges *et al*. 2011), a species which is 50-65% smaller than *P. waltoni* (Polgar 2010). The exact timing of recruitment is inevitably influenced by the tidal cycle.

If we assume for *P. waltoni* a minimum larval maturation time equal to or slightly exceeding the high end of the range for *P. modestus*, say 50-60 days, and if we add a week or two for incubation, then the presence of apparently recently arrived *P. waltoni* juveniles in mid-August implies that breeding is likely to have continued until at least mid to late May and possibly into early June. A similar calculation implies that the juvenile progeny of mid-February breeding could return to the upper intertidal zone by latest April or early May.

With hindsight, based on the criteria set out above, one of the 15 fish recognised at the study site in June and July 2012 was probably a recently arrived juvenile (see Fig. 12). If so, it would likely have been the progeny of the earliest mating activity observed, in February 2012. But this begs the question why, in 2012, only a single juvenile was seen through late July, whereas in 2013 at least two dozen juveniles were present by mid-August (and continued to thrive in October). What unknown factor(s) made the July-August 2013 recruitment period so much more successful than earlier recruitment episodes in 2012 and 2013?

The recruitment period that preceded our visits in mid-August 2013 not only increased the population of our study site; it also resulted in the colonisation of a nearby area, about 400 metres distant, similarly positioned above the thick mangrove forest in the uppermost intertidal zone, but on largely open ground covered by a thin layer of cyanobacteria (Fig. 15). In August, some two dozen mudskipper burrows could be readily distinguished over a distance of about 100 metres alongshore, although only three fish were actually seen. Nondescript burrows could have boosted that total by up to 50% or more. A repeat visit to this satellite area in October 2013, less than two hours after inundation, again revealed about two dozen burrows, although not all could be confirmed as active and only two or three fish were seen. Several burrows had relatively well-formed platforms and one had a 'swimming pool'. We hope to be able to continue to monitor the satellite population in the future.

The discovery of a second colony of mudskippers, even one in proximity to our study site, raised the possibility that, at least during the recruitment period, juvenile mudskippers could be found at other locations where permanent colonies did not exist. We therefore spent two days in early September looking for evidence of mudskippers at additional likely sites along the Arabian Gulf coast of the Northern Emirates, but we found none.

Associated species

Other plant and animal species present in the immediate environment include:

- **Plants.** Mangrove trees *Avicennia marina* (Avicenniaceae) have thrived over the past decade in many parts of the khor area in question, except where they have been physically obliterated. A relatively thick forest with trees two to four metres high begins immediately adjacent to the mudskipper site. A few spreading clumps of the mostly supratidal *Arthrocnemum macrostachyum* (Chenopodaceae) are found within the site.
- **Crabs.** *Metapograpsus messor* (Grapsidae), a dark purple diurnal crab, is a generalist species common in many intertidal environments in the UAE. It was abundant within the study site in summer (Fig. 27) but was absent or scarce in mid-winter; none were observed on our initial visit in mid-February 2012, and only a single *M. messor* was recorded on the chilly and breezy late afternoon of our second visit in late February.

The pale violet-coloured *Eurycarcinus orientalis* (Xanthidae) (Fig. 8) is a mudflat specialist. It is common within the study site and its burrows can resemble those of *P. waltoni*. It is the largest crab

Fig. 27. Distribution of the crab *Metapograpsus messor* within the mudskipper area early on a June morning. These crabs are quick to retreat to a burrow or to the cover of mangrove shrubs or saltbushes..

species present at the site, although many smaller than average individuals were seen in July 2012.

Macrophthalmus depressus (Ocypodidae), a small (fiddler-sized) mudflat and mangrove specialist, was occasional in damp, puddled mud on the downshore edge of the mudskipper site, adjacent to the more mature mangrove forest.

Uca annulipes (Ocypodidae), the most common fiddler crab in the UAE, was rare at the study site, with fewer than half a dozen seen, in June 2012 and August 2013, all on firm, sandy mud above the area occupied by mudskippers or separated from it by a physical barrier.

A single, unidentified small crab, probably one of the Ocypodidae *Tylodiplax indica*, *Nasima dotilleformis* or *Ilyoplax* sp., was seen in damp, puddled mud adjacent to the mudskipper site, in association with *M. depressus*. All three of those Ocypodidae are prey species of *P. waltoni* in Kuwait.

Portunus pelagicus (Portunidae), the Blue Swimming Crab, is common in the main channel and smaller individuals are occasional within the mangroves. Some of the latter might possibly venture into the mudskipper area at highest tides.

- **Molluscs.** The small, brown-and-white banded mud creeper *Cerithideopsilla conica* (formerly *Potamides conicus*) (Gastropoda) is common in damp, puddled mud in the intertidal zone just below the mudskipper site. We saw no evidence that *P. waltoni* preys on this mollusc, although it is all but totally absent within the area inhabited by mudskippers. No other surface-dwelling molluscs are present within or immediately adjacent to the study site, nor did we find there the shells of burrowing bivalves.
- **Polychaete worms.** These prey items are apparently present at shallow depth in the substrate (see above under "Hunting, feeding and diet").
- **Insects.** The tiger beetle *Cicindela (Calomera) aulica* (syn. *Lophyridia aulica*) (Carabidae: Cicindelinae) was seen in small numbers in June and July 2012. The same and another tiger beetle, *Salpingophora hanseatica*, were seen in small numbers in August 2013, mostly on firmer ground above the mudskipper habitat. Small flies (Diptera spp.) were also moderately common. At least one resembled a housefly with wings spread in a wide triangle. Another was smaller and elongated, with wings folded directly back over the abdomen, parallel to the body; this is possibly a species of Ephydridae, the larvae of which are known from intertidal samples in the UAE (Richard J. Hornby, *pers. comm.*).
- **Fish.** The Arabian killifish *Aphanius dispar* is present at the site in large numbers when it is inundated by high tides. This is the most common fish in UAE lagoons and can survive stranding in shallow intertidal puddles, at least for single daily tidal cycles.
- **Birds.** Individual Kentish Plovers (*Charadrius alexandrinus*) occasionally fed on the mud surface within the mudskipper site. House Sparrows (*Passer domesticus*) fed on mangrove flowers in June 2012. Individual Little Green Bee-Eaters (*Merops orientalis*) briefly hunted over the site in June 2012, August 2013 and October 2013. Also in August 2013, a short-necked heron, probably a Striated Heron *Butorides striata*, was seen stalking at the edge of the mangrove forest. A few Purple Sunbirds *Cinnyris asiaticus* and White-Eared (formerly White-Cheeked) Bulbuls *Pycnonotus leucogenys leucotis* fed in adjacent mangroves in October 2013. Also in October 2013, a few Indian (formerly Western) Reef Herons *Egretta gularis schistacea* hunted at high tide in the area where a satellite population of juvenile mudskippers was observed, but only while it was inundated.
- **Mammals.** Tracks of red fox (*Vulpes vulpes*) and of a large feral dog (*Canis domesticus*) were found in the immediate vicinity; the dog tracks were headed directly towards the mudskipper site. Despite the current regime of protection, small numbers of humans (*Homo sapiens*) and their vehicles still pass close by on an occasional basis for fishing, hunting and family recreation. Three adult mudskipper burrows on the periphery of the site were constructed over or adjacent to earlier tyre tracks; at least one platform burrow was partially damaged by vehicle traffic during the course of the study.

Predation and predator avoidance

No predation on mudskippers was observed at the study site, nor (with one exception, discussed below) were any potential predators seen in the immediate vicinity, although large waders and gulls feed in good numbers in and along the adjacent arm of the khor (including Western Great Egret *Egretta alba*, Grey Heron *Ardea cinerea*, Purple Heron *Ardea purpurea*, Indian (formerly Western) Reef Heron *Egretta gularis*, Striated Heron *Butorides striata* and 'Yellow-Legged' Gulls *Larus* sp.). The observers' presence undoubtedly discouraged approach by these larger shorebirds known to feed on mudskippers elsewhere (Clayton & Wells 1987), but it is also likely that the very small and localised population of mudskippers, living in marginal and relatively exposed habitat within an otherwise biologically rich area, has simply not attracted the attention of resident avian predators as a resource worth exploiting. Certainly the site would not support specialised predation techniques of the sort described by Clayton & Wells (1987) from the extensive mudflats of Kuwait, where *P. waltoni* is sympatric with *Boleophthalmus dussumieri*:

> "Shore birds are [the mudskippers'] worst enemies, and we have already described the hunting methods of herons [and egrets and other shore birds]. Terns [probably the Gull-Billed Tern *Gelochelidon nilotica* (Richard J. Hornby, *pers. comm.*)] are another menace to the mudskipper which they catch by flying along about three to five metres up, then dive-bombing their prey with their bayonet-like beaks. Sea gulls use a craftier approach, skimming very low, just above the mud walls* and trying to catch the *Boleophthalmus* unawares." [**Authors' note: At high densities* B. dussumieri *builds low mud walls to segregate the polygonal territories of neighbouring fish (Clayton 1987). See discussion below, "Were* two *species of mudskippers present in the UAE in the early 1970s?"*]

The one potential predator we saw at the study site was a short-necked heron, probably a Striated Heron *Butorides striata*, seen stalking on the mud in August 2013 at the edge of the site, beside the mangrove forest, where it retreated when approached. Although the heron was not actually within the area of mudskipper burrows when observed, its presence was perhaps not coincidental, since the study population was swelled by juvenile mudskippers at that time. Indian (formerly Western) Reef Herons *Egretta gularis schistacea* were seen hunting at high tide in the area where a satellite population of juvenile mudskippers was observed, but only while the area was inundated.

Sea snakes, fish and crabs have also been identified as predators of mudskippers elsewhere (Clayton & Wells 1987). The mudskipper's principal defence against marine predators is a retreat to its burrow during high tide, and the main burrow typically has multiple entrances. A number of species of sea snakes are found in UAE waters and many are known to prey on burrowing or hole-dwelling gobies, eels and similar species (Egan 2007), but the upper intertidal habitat of *P. waltoni* makes it less susceptible to regular sea snake predation. The relatively large size of adults may confer additional protection. The two largest burrowing crabs present at the UAE site, *M. messor* and *E. orientalis*, are too small to prey on adult mudskippers but could potentially eat eggs or young (Clayton & Wells 1987). Small numbers of the Blue Swimming Crab *Portunus pelagicus* could possibly reach the site with the highest tides, but it is questionable whether these could effectively prey on mudskippers in their burrows, and in any case the most likely arrivals would be smaller individuals.

P. waltoni is regularly eaten by fishermen in southern Iran (Polgar 2010). It is sufficiently abundant and has been regarded as an important enough part of the local food chain that in both Kuwait and in southern Iran it has been studied as a bioindicator for the accumulation of heavy metals (Bu-Olayan & Thomas 2008, Askari *et al.* 2010, Kooseg *et al.* 2011).

The authors found *P. waltoni* to be well camouflaged when away from its burrow and not in motion. Not only does the body colouration and patterning blend with the damp intertidal mud and its shadows and reflections; the head and prominent dark eyes were found to closely resemble small mud lumps topped with the abundant flotsam of dark, dried mangrove flowers (*Avicennia marina*) (Fig. 28).

In our experience, mudskippers surprised or approached too closely by human observers withdrew into their burrows, or, if encountered on open ground, they would move away, usually towards their burrows if possible. Speed of movement was variable, depending on the degree of surprise, and ranged from a steady "crutching" away to a series of rapid hops covering three metres or more. One juvenile fish that retreated slowly from an approaching observer took shelter not in a burrow but under a small, spreading mangrove shrub, in exactly the same way that many desert lizard species take refuge under scattered vegetation.

Juveniles seemed to be more tolerant of human observers, or at least were more likely to be active when observers were present, even at a close distance, but this may largely reflect the fact that the juveniles we observed in August and October 2013 were more active than adults overall.

Fig. 28. Camouflage? Mud lumps topped by flotsam of dried mangrove flowers resemble a mudskipper head and eyes.

Selected aspects of the biology and ecology of *P. waltoni*

Adaptations to life on the mudflats: physical, physiological and behavioural

Mudskippers are the most thoroughly amphibious fish. They are also well adapted to the rigours of life in tropical and subtropical intertidal mudflats. Their amphibious behaviour itself can in fact be understood as an adaptation to that environment. This recognition has given rise to the hypothesis that the exploitation of the land (and air) by vertebrates was driven in part by the stresses imposed by the muddy intertidal zone (Shultze 1999, Ishimatsu & Gonzalez 2011, Taylor *et al.* 2011).

The ability to "walk" on land and to breathe air through the skin and bucco- pharyngeal mucosa, described above, are only the most obvious of mudskipper adaptations. Other physical adaptations include not only the positioning of the eyes but also the anatomy of the eye, which is better adapted to vision in air than underwater. Mudskippers have good vision both at close range and at a distance, and close vision seems to be especially sensitive to horizontal movement, presumably an advantage in sensing and catching prey (Polgar 2010).

A major physiological adaptation of mudskippers is an increased tolerance to ammonia (NH_3), a natural metabolite which underwater is excreted through the gills, as in most fish, but which cannot be excreted in air. At least some mudskipper species have evolved chemical pathways to detoxify accumulated ammonia (Polgar 2010).

Mudskippers living on exposed tropical mudflats are also tolerant of changes in water temperature and salinity, particularly high temperatures and high salinity, relative to most other fish, and of low dissolved oxygen levels in the seawater that remains in their burrows between inundations (Taylor *et al.* 2005, Polgar 2010). Exposure to the direct rays of the tropical or subtropical sun may cause extreme warming of surface mud and warming and evaporation of shallow surface water, increasing its salinity to as much as twice that of normal seawater (Takeda *et al.* 2012). Underground, the seawater in mudskipper burrows becomes depleted in oxygen through reaction with the substrate of anoxic, organic rich mud as well as from increased temperature and salinity; for upper intertidal species like *P. waltoni*, burrow water may be refreshed by inundation only at extended intervals within the monthly tidal cycle. A complementary behavioural adaptation is the maintenance of an air pocket within the burrow (Ishimatsu *et al.* 1998, Lee *et al.* 2005), although in at least one species, *P. minutus* of northern Australia, this may be only a breeding season or austral summer phenomenon (Takeda *et al.* 2012).

Amphibious behaviour helps mudskippers to alleviate the rigours of their mudflats environment. In particular, air-breathing frees them from the threat of oxygen-depleted waters and amphibious locomotion allows them to take advantage of evaporative cooling, even at relatively high temperatures.

To assess the adaptive contribution of amphibious behaviour, Taylor *et al.* (2005) compared the physiological and behavioural responses of a mudskipper (*Periophthalmus kalolo*, an air-breathing, amphibious goby) and two non-amphibious burrowing gobies (*Bathygobius* spp.) found sympatrically on mudflats in Sulawesi, Indonesia. Taylor *et al.* considered that their site experienced some of the most demanding daily temperature fluctuations seen in an aquatic habitat, but there is no reason to think that upper intertidal conditions in the Arabian Gulf are much less rigorous. They found by experiment that in both the mudskippers and the non-air breathing gobies, the increase in metabolic rate as water temperature rose was much lower than expected, thereby reducing increased oxygen demand. Nevertheless, both non-air breathing gobies, who could not leave their intertidal burrows, had significantly higher physiological tolerances than the mudskippers for elevated water temperature and low dissolved oxygen. Consistent with this finding, when temperature and O_2 parameters were manipulated experimentally, mudskippers would react by exiting their burrows, if possible, when their tolerance limits were reached.

The mudskipper life cycle, including a planktonic larval phase

The life cycles of most individual mudskipper species have not been studied in detail but it is possible to generalise from studies to date of some of the better known species. Adult male mudskippers construct a breeding burrow containing an egg chamber with an air pocket maintained by air gulping (Kobayashi *et al.* 1972, Lee & Graham 2002, Ishimatsu *et al.* 2007, Ishimatsu & Gonzalez 2011, Takeda *et al.* 2012). The air pocket is important to development of the eggs due to the low dissolved oxygen content of burrow water in the anoxic mud, which can be less than one-tenth that of air-equilibrated seawater (Ishimatsu *et al.* 2007, Ishimatsu & Gonzalez 2011). In at least some species the eggs actually develop within or near the air pocket, embedded in the mud walls (Lee & Graham 2002, Ishimatsu *et al.* 2007, Ishimatsu & Gonzalez 2011). After mating, the male guards the eggs (as in many non-air breathing goby species), usually alone but sometimes in co-operation with a female (Lee & Graham 2002, Polgar 2010).

Eggs numbers are very high, probably thousands per brood in most cases. Studies for three northerly species from Japan and South Korea report an average of more than 5,000 eggs per burrow for *Periophthalmus modestus* (Ishimatsu *et al.* 2007), 5,000-20,000 eggs per fish for *Boleophthalmus pectinirostris* (Kim *et al.* 2011) and *ca.* 1,300-18,300 eggs per fish for *Scartelaos gigas* (Kim *et al.* 2011).

Ishimatsu *et al.* (2007) showed that in *P. modestus*, when the eggs are ready to hatch, the guardian male causes them to be inundated on a nocturnal flood tide by actively gulping and removing air from the breeding chamber. This triggers hatching and the newly released larvae, which are planktonic (only millimetres long and with a yolk sac that will last them for a few days), disperse to find their way seaward on the ebb tide (Ishimatsu *et al.* 2007, Kim *et al.* 2011). In *P. modestus*, the planktonic larval stage lasts for 30-50 days, after which the larvae re-enter the intertidal zone, become benthic and rapidly metamorphose into miniature adult mudskippers (Kobayashi *et al.* 1972, Lee & Graham 2002, Ishimatsu *et al.* 2007, Borges et al. 2011).

P. waltoni has been estimated to reach maximum size in about 1.5 years for males and 0.9 years for females; its lifespan has been estimated at 4+ years (Sarafraz *et al.* 2011). This is roughly consistent with estimates for the similar-sized *P. barbarus* from West Africa, which reaches maturity in less than one year and at about half maximum size (Polgar 2010); *P. barbarus* has an estimated lifespan of 6 years (Polgar 2010).

The existence of a planktonic larval phase in mudskippers parallels the life cycle of many intertidal molluscs, including two of the most common gastropods on the mudflats of the UAE, the Potamidids *Cerithideopsilla cingulata* (formerly *Cerithidea cingulata*) and *C. conica* (formerly *Potamides conicus*). Planktonic larval dispersal preserves the genetic homogeneity of such species throughout their ranges, despite their often highly localised occurrence as adults (David G. Reid, *pers. comm.*). The existence of a planktonic larval phase is of particular significance in considering the origin of the UAE study population.

Re-Discovery of *P. waltoni* in the UAE: Why here? Why now?

The origin of the newly discovered UAE population of *P. waltoni* is speculative. It seems almost equally improbable that it has survived unnoticed for two decades or more, and/or that it has somehow re-colonised this single small site during a time of massive 'development' and disruption of UAE coastal environments.

The senior author (GRF) has explored many areas of the khor in question in the course of at least 15 prior visits from 1998 through 2010. He has devoted special attention to intertidal molluscs (including the recognition of two air-breathing upper intertidal species new to the UAE) but has also observed there a dozen or more fish species, cuttlefish, spoonworms (Phylum Echiura), an agama lizard and a tiger beetle new to the UAE, all in the intertidal or shallow subtidal zones. On two or three occasions from 2006 to 2010 he passed within easy view of the mudskipper site, in one case having stopped to look for small, air-breathing molluscs under adjacent saltbushes. But it is impossible to say whether mudskippers were then absent or were overlooked.

The population encountered in 2012 consisted of adult fish, some of them evidently males of essentially maximum size, so it is reckoned to have been a minimum of at least 1.5 years old (Sarafraz *et al.* 2011) when discovered, therefore having existed since at least mid-2010. On the other hand, if the lifespan of individual *P. waltoni* is a maximum of 4+ years (Sarafraz *et al.* 2011), then the fish observed in early and mid-2012 must have arrived during or after the second half of 2007.

The distribution of *P. waltoni* within the Arabian Gulf is patchy, so its requirements are evidently not indiscriminate, but it is not immediately clear what exactly those requirements might be. The principal one appears to be a 'suitable' mud substrate in the uppermost intertidal zone. But what is suitable? Presumably it needs a substrate having the 'right' consistency for burrowing (muddy, but a certain fraction of sand is tolerated), the presence of sufficient animal prey of some sort (crabs are evidently not essential, at least not year-round), and the absence of 'excessive' levels of negative influences such as pollution, predation and habitat disturbance.

Mangrove trees or shrubs are not a requirement for *P. waltoni*. Mangroves are absent altogether in the northern Arabian Gulf (Kuwait and Iraq) and were absent at the historical UAE site of Khor Madfaq. The *P. waltoni* populations in the Strait of Hormuz are also not closely associated with mangroves (Polgar 2010).

One UAE popular account gives the impression that freshwater input may be a requirement, noting the (former) occurrence of mudskippers at Khor Hulaylah in Ra's al-Khaimah, where freshwater springs fed by aquifers flowing from the mountains of the Musandam peninsula have created the only brackish water salt marsh environment in the UAE (UAE Interact). In fact, both historical mudskipper sites in the UAE are associated with freshwater input, since the other, Khor Madfaq, constitutes the UAE's principal modern estuary, draining a very large inland area. Similarly, in the northern Arabian Gulf, the mudskipper populations in Iraq, at Khor Al-Zubair (Mhaisen & Al-Maliki 1997), and at Kuwait Bay are associated with the influence of freshwater outflow from the Shatt al-Arab (Swift & Bower 2003) and its surrounding marshes (Zajonz *et al.* 2002), the modern terminus of the Tigris and Euphrates river systems. However, the Iranian populations in the Strait of Hormuz do not generally receive significant freshwater input (although the population sampled for leeches by Polgar *et al.* (2009) near Bandar Khamir "received freshwater input from the small town nearby") and the UAE study site is not known or suspected to receive freshwater input, at least not to any greater extent than other khors in Dubai and the Northern Emirates.

Nevertheless, the distribution of the known and historical populations prompts the hypothesis that offshore seawater salinity may play a determining role and that *P. waltoni* may be indisposed to areas of extreme hypersalinity. All of the known mudskipper sites (Kuwait and Iraq in the northern Arabian Gulf, the Northern Emirates and the Strait of Hormuz) are situated in areas where surface water mapping shows that the characteristic hypersalinity of the Arabian Gulf is mitigated, either by input from the Shatt al-Arab, which favours the Kuwaiti coast (Swift & Bower 2003), or by input from the Indian Ocean via the Strait of Hormuz, where incoming ocean water of normal salinity favours the Iranian shore (Swift & Bower 2003, George & John 2005). In these areas, the salinity of surface water (0-3 metres) in the open Gulf does not normally exceed 39 psu (Swift & Bower 2003, Fig. 9). In comparison, surface water salinity in the north-eastern Gulf exceeds 39 psu for about half the year, sometimes reaching 40-41 psu, and surface water in the south-western Gulf ranges from 40-41.5 psu for most of the year, and is never lower than 38.5 psu (Swift & Bower 2003, Fig. 9). Steeper nearshore physiographical gradients along the Iranian coast immediately north-west of the Strait of Hormuz (Swift & Bower 2003) probably inhibit the development of mudflats there, where salinity might remain suitable for much of the year.

If, in fact, offshore surface water hypersalinity is a determinant of mudskipper distribution within the Arabian Gulf, its influence must be exerted at the pelagic larval stage, since adult *P. waltoni* are limited to the upper intertidal zone, where they are necessarily tolerant of increased salinity created by the interaction of local climatic conditions and the tidal cycle.

Consideration of the origin of the UAE population is rendered more complicated by the history of the khor in question. As early as the mid-1990s the khor area as a whole had already experienced dredging and filling in anticipation of actual and prospective development. In 1998 it was noted that many specimens of the intertidal mud creeper *Cerithideopsilla cingulata* (formerly *Cerithidea cingulata*) showed unusual and somewhat discontinuous growth (abnormally narrow shells with a disproportionately large final whorl) indicative of stressful conditions (Robert Moolenbeek, *pers. comm.*), stressful intervals and/or possibly pollutants. During the 2000s, the remaining natural areas of the khor continued to suffer disruption due to infrastructure projects, including additional dredging in the lower channel and construction of an electric power and desalination plant beside one embayment of the intertidal zone. Most recently, at some point between August 2008 and May 2010, a corner of the seaward mangrove forest was obliterated for improved road access, a square kilometre of peripheral saltbushes and cyanobacterial mats was filled, and major dredging, wharfage and other infrastructure works were begun in the channel immediately below the mangrove forest. All of these development activities have been associated with smaller scale rearrangement of the original landscape in the vicinity of the mudskipper study site, including improved off-road access, construction of several small earthen boat ramps, and finally extensive perimangal bulldozing (for reasons not immediately apparent).

The latest phase of development, occurring after mid-2008 and continuing to the present, has been paralleled by changes in the prevailing mollusc and other invertebrate fauna of the khor. It is possible that those faunal changes and the presence of mudskippers are related, and that both are related to changes in the physical, chemical and/or hydrological parameters of the site. One possible hydrological change might be an increased flow rate of sea water into and out of the upper channel, possibly facilitating access by certain planktonic larvae (molluscs, mudskippers and others) that were previously excluded. The same kinds of changes could possibly have acted indirectly as well, by selectively excluding species that might have preyed on mudskipper larvae or young.

Changes in patterns of sedimentation and/or substrate change may also have resulted and could be determinative. From general observation, the authors are inclined to think that sedimentation at the *P. waltoni* site is influenced by adjacent earthworks, which seem to have created a 'pocket' where somewhat finer or slower settling sediment collects, and from which drainage is slightly impeded. Those works may also have involved removal of some of the original sediment cover and/or disruption of its original thin but cohesive veneer of algae/cyanobacteria. Did these changes create (or re-create) a differentiated local habitat conducive to colonisation by incoming mudskipper larvae, that had not existed in previous years? If so, then mudskipper colonisation can be dated from 2005 or later, when the works in question were completed. It is possible, however, that some of the observed changes to the local substrate were engineered by the mudskippers themselves.

On balance, the authors are inclined to favour the hypothesis of recent re-colonisation by *P. waltoni* due to serendipitous local contingencies, rather than to posit its persistence, unnoticed, for several decades. That hypothesis presumes that re-colonisation was facilitated, inadvertently, by alteration of physical parameters in such a way as to promote larval recruitment and/or the favourable modification of habitat on a local scale. A larger former population ought to have been noticed (even now, the site is within easy view of off-road vehicles, fishermen and picnickers), whereas the current population seems much too small to have persisted for so long. This view entails the paradox that broader environmental destruction in the surrounding area may actually be responsible for the return of the small population of mudskippers that now exists. There is, however, no proof of either alternative at the moment.

Whatever the truth, the re-discovery of *P. waltoni* is a reminder that there is no substitute for careful field observation. And that injunction is a fitting segue to our final topics . . .

Were *two* species of mudskippers present in the UAE in the early 1970s?

John Stewart-Smith, a former UAE resident, aircraft pilot and amateur naturalist, was a co-founder and first Chairman of the Emirates Natural History Group (ENHG) when it was formed in Abu Dhabi in 1977, and he has been honoured as a life member of the ENHG. He read the initial press report of the re-discovery of mudskippers in the UAE and wrote to give a brief account of his own acquaintance with the mudskippers present in the early 1970s. Some of his observations have already been quoted above. He was kind enough to correspond further in response to questions about various details. His description of the site and of the behaviour he witnessed added a provocative detail not seen in our UAE study population: territorial walls. He wrote:

> "The mudskippers were in an area that was also populated by small crabs that waved one large claw about when approached. We noticed that each mudskipper seemed to build a 'reserved' area outside its burrow by pushing the wet sand into small walls that enclosed an irregular piece of sand that it treated as its property. The 'owners' reacted fiercely to any mudskipper approaching their boundary, sometimes jumping into the air and grunting."

P. waltoni is not associated in the literature with any reports of territorial walls, but at Sulaibikhat Bay in Kuwait a second mudskipper, *Boleophthalmus dussumieri* Valenciénnes, 1837 (Fig. 29) (discussed in much of the earlier literature from Kuwait as *B. boddarti*), is present at high densities and is notorious for building mud-walled polygonal territories (Fig. 30) and for its exuberant territorial and mating displays (Clayton 1987, Clayton & Wells 1987, Clayton & Vaughan 1986, Clayton & Vaughan 1988, Clayton & Wright 1989). In Kuwait *B. dussumieri* is present sympatrically with *P. waltoni* although it occupies a tidal range

Fig. 29. *Boleophthalmus dussumieri*, a herbivorous mudskipper sympatric with *Periophthalmus waltoni* in Kuwait, Iran and Pakistan. This photo is from a sequence of an aggressive encounter. [Photo by Clayton & Vaughan (1988), from Polgar (2010)]

that is slightly lower overall. *B. dussumieri* was present within and adjacent to the *P. waltoni* study site of Clayton & Snowden (2000).

B. dussumieri is similar in appearance to *P. waltoni*, and although it differs in colouration and can grow somewhat larger (to *ca.* 25 cm), it would be easy for a novice or casual observer to overlook those distinctions (especially as colour may vary with breeding status) or to fail to ascribe taxonomic significance to them in the context of what appeared to be a single population. We presented the above information to Stewart-Smith, referring him to additional resources, and asked whether he thought it was possible that *B. dussumieri* was also present on the UAE mudflats that he visited in the early 1970s. His reply was judicious but clearly affirmative:

"After careful perusal of http://www.mudskipper.it/ [Polgar (2010)] I now believe that both *Boleophthalmus dussumieri* and *Periophthalmus waltoni* were present in the same general area. Some of the mudskippers definitely had built retaining walls that held a layer of water outside their burrows, indicating *B. dussumeri*, although I do not remember any 'grazing' feeding action by them. Some of them engaged in an aggressive 'defensive' reaction to any other fish approaching their boundary walls. The size difference between these species doesn't help me to a firm decision, but my memory leads me to think that some were the smaller *P. waltoni*. The size and location of their erectile dorsal fin supports this thought. I did notice that there were two different patterns of dorsal fin but assumed these were sexual variations, i.e., larger males and smaller females. It is so easy to get it wrong when one assumes something without any evidence!"

The description of the retaining walls, layers of water and demonstrative territorial defence are all highly consistent with previous descriptions of *B. dussumieri* at Sulaibikhat Bay in Kuwait (Clayton 1987, Clayton & Wells 1987, Clayton & Vaughan 1986, Clayton & Vaughan 1988, Clayton & Wright 1989), although Stewart-Smith did not recall the characteristic side-to-side head movement of *B. dussumieri* when grazing on the surface film of diatoms, cyanobacteria and filamentous algae

Fig. 30. *Boleophthalmus dussumieri* builds mud walls between adjacent territories where it is present at high densities, as in this photo from Bandar Khamir, Hormozgan, Iran. Researchers are collecting mudskippers by stick-beating, a traditional technique. [Photo by G. Polgar, from Polgar (2010)]

within its territory (Polgar 2010). In the authors' opinion, however, the single most persuasive detail is his recognition of "two different patterns of dorsal fin" (which he attributed at the time to sexual dimorphism), whereas both *P. waltoni* and *B. dussumieri* are monomorphic.

Taken as a whole, Stewart-Smith's information strongly suggests that a second and distinctive species of mudskipper, *Boleophthalmus dussumieri*, was present in the UAE into the modern era, but has been 'lost' before it was ever 'found'.

An East Coast record, too

The original newspaper report of our study population (Todorova 2012) elicited, about six months later, a record from the East Coast of the UAE, so far the only one known. Kevin Budd of the Breeding Centre for Endangered Arabian Wildlife, in Sharjah, related in conversation that in 1997, when he was still newly arrived in the country, he observed several mudskippers at Khor Kalba, the largest mangrove forest on the Gulf of Oman, in the narrow fringe of mudflats on the eastern edge of the mangroves, just inland of the main beachfront ridge. He was confident in distinguishing the animals he saw, presumably *P. waltoni*, from the smaller and non-amphibious, burrowing intertidal goby species (taxon/taxa unknown) that can also be found in and around UAE mangroves. However, being new to the UAE and being primarily engaged in work with terrestrial mammals, he did not appreciate at the time that this was an exceptional record.

And it does genuinely appear to have been exceptional. Prior to 1997, Khor Kalba had been the subject of at least two conservation surveys and reports (Hornby 1996, Stuart & Stuart 1996) and from mid-1998 through 2006 it was extensively explored on various occasions by Feulner and others in connection with research on *Terebralia palustris* (Feulner 2000) and other intertidal molluscs (Feulner & Hornby 2006), as well as intertidal crabs. None of those investigations recorded mudskippers, nor were mudskippers suspected.

Budd's East Coast visit in 1997 was in company with Chris and Tilde Stuart, South Africa-based consultants who at the time were engaged in follow-up field work at Khor Kalba. They have recalled and promptly confirmed seeing mudskippers there (Chris Stuart, *pers. comm.*).

Our own study suggests that, during the recruitment season, juvenile fish can potentially be found in habitats where permanent colonies did not previously exist, and where it is questionable whether they will become established (see "Juveniles and juvenile recruitment", above). That is potentially significant because Budd's Khor Kalba visit was, by his estimate, during the period August to October, which we now know includes or closely follows the recruitment period on the UAE's Arabian Gulf coast.

The Stuarts believe they may have filmed the mudskippers seen at Khor Kalba and they have volunteered, once they return from extended international travel, to make those films (if any) available. Reasonable images should permit a determination whether the fish shown are adults or juveniles, and therefore give a better indication whether a potentially breeding population has previously existed at Khor Kalba. In the meantime, staff of the Sharjah Environment and Protected Areas Authority, which has authority over Khor Kalba, are also keeping a lookout for mudskippers there.

Epilogue

This paper is intended to make a record of the presence and behaviour of *Perioptthalmus waltoni* in the UAE and to try to put our observations in the larger context of knowledge about this species. The known UAE population is too small and vulnerable to support extensive follow-up study. There can be no better justification for our account than to quote, once again, John Stewart-Smith, writing in 2012 of his experience four decades earlier:

> *"I wish I had taken more careful note of these fish, never thinking that they would become rare."*

Acknowledgements

It is a pleasure for the authors to acknowledge the ready cooperation of John Stewart-Smith, Colin Richardson, Kevin Budd and Chris and Tilde Stuart in providing information about prior records of mudskippers in the UAE. Dr. Richard Hornby commented on an early draft of this paper and provided helpful information about a number of UAE intertidal invertebrate taxa. Particular thanks are extended to the concerned local authorities who facilitated our research within a protected area; regrettably, they cannot presently be identified more specifically without risk to the study population.

References

Al-Behbehani, B.E. and Ebrahim, H.M.A. 2010. Environmental Studies on the Mudskippers in the Intertidal Zone of Kuwait Bay. *Nature and Science* 8(5): 79-89 [Online]. Available at: <http://www.sciencepub.net/nature>. [*Authors' note: This paper, published online, is valuable principally for its extensive citation and reiteration of the content of earlier literature relating to* P. waltoni *and* B. dussumieri.]

Askari, S.A.A., Velayatzadeh, M. and Mohammadi, M. 2010. Mercury Concentration in Mudskipper (*Periophthalmus waltoni*) and Flat Fish (*Cynoglossus arel*) in Bandar-e-Emam and Bandar Abbas. **Journal of Fisheries** (Summer 2010) 4(2(14)): 51-56.

ARKive. Jewels of the UAE: Fish: Available at: <http://www.arkive.org/uae/en/fish/latin/>. [Accessed 28/12/12]

Baeck, G.W., Takita, T., and Yoon, Y.H. 2008. Lifestyle of Korean mudskipper *Periophthalmus magnuspinnatus* with reference to a congeneric species *Periophthalmus modestus*. **Ichthyoliogical Research 55**: 43-52. [Cited in Ishimatsu & Gonzalez 2011.]

Beech, M.J., Al Abdessalaam, T.Z., and Hoolihan, J.P. 2005. Marine Fish. In P. Hellyer and S. Aspinall (eds.), *The Emirates – A Natural History*. Trident Press. pp. 261-282 and species checklist pp. 361-364. Available at: <http://viewer.zmags.co.uk/showmag.php?mid=srthf&preview=1&_x=1#/page0/>

Borges, R., Faria, C., Gil, F. and Gonçalves, E.J. 2011. Early Development of Gobies. In R.A. Patzner, J.L. Van Tassell, M. Kova i and B. Kapoor (eds.), *The Biology of Gobies*. Science Publisher: Enfield. pp. 403-462.

Brillet, C. 1980. Comportement sexuel du poisson amphibie *Periophthalmus sobrinus* Eggert: ses rapports avec le comportement agonistique. *Revue d'Ecologie,* **Terre et la Vie 34 (3)**: 427-468. [Cited in Polgar (2010)]

Brillet, C. 1984. Étude comparative de la parade nuptiale chez deux espèces de Poissons amphibies sympatriques (Pisces, Periophthalmidae). **C. R. Hebd. Séances Acad. Sc. Serie D, Paris, 198 (12)**: 347-350. [Cited in Polgar (2010)]

Bu-Olayan, A.H. and Thomas, B.V. 2010. Trace Metals Toxicity and Bioaccumulation in Mudskipper *Periophthalmus waltoni* Koumans 1941 (Gobiidae: Perciformes). **Turk. Jour. Fisheries and Aquatic Sciences 8**: 215-218.

Clayton D.A. 1987. Why mudskippers build walls. **Behaviour 102**: 185-195.

Clayton D.A., 1993. Mudskippers. *Oceanogr. Mar. Bull. Annu. Rev.* A.D. Ansell, R.N. Gibson and M. Barnes (eds.), UCL Press, 31: 507–577.

Clayton, D.A. and Snowden, R. 2000. Surface activity in the mudskipper *Periophthalmus waltoni* Koumans 1941 in relation to prey activity and environmental factors. **Tropical Zoology 13**: 239-249

Clayton, D.A. and Vaughan, T.C. 1986. Territorial acquisition in the mudskipper *Boleophthalmus boddarti* (Pisces: Gobiidae) on the mudflats of Kuwait. **Journ. Zool. (A) 209**: 501–519.

Clayton, D.A. and Vaughan, T.C. 1988. Ethogram of *Boleophthalmus boddarti* (Pallas), a mudskipper found on the mudflats of Kuwait. **Journal of the University of Kuwait (Sciences) 15(1)**: 115–138.

Clayton, D.A. and Wells, K. 1987. *Discovering Kuwait's Wildlife*. Fahad Al-Marzouk, Kuwait. 253 pp.

Clayton, D.A. and Wright, J.M. 1989. Mud-walled territories and feeding behaviour of *Boleophthalmus boddarti* (Pisces, Gobiidae), on the mud flats of Kuwait. **Journal Ethol. 7(2)**: 91–95.

Colombini I, Berti R., Nocita A. and Chelazzi I., 1996. Foraging Strategy of the Mudskipper *Periophthalmus sobrinus* Eggert in a Kenyan mangrove. *J. Experimental Marine Biology and Ecology*, 197 (2): 219–235. [Cited in Al-Behbehani & Ibrahim (2010).]

Egan, D. 2007. *Snakes of Arabia*. Motivate Publishing, Dubai. 208 pp.

Encyclopedia of Life. *Periophthalmus waltoni* Walton's Mudskipper. Available at: <http://eol.org/pages/1157620>. [Accessed 20/02/12]

Feulner, G.R. 2000. The Large Mangrove Mud Creeper *Terebralia palustris* (Linnaeus 1767) in Non-Mangrove Environments in Southeastern Arabia. **Tribulus 10.2**: 15-26. Available at: <http://www.enhg.org/Portals/1/trib/V10N2/TribulusV10N2.pdf>.

Feulner, G.R. and Cunningham, P.L. 2000. The freshwater goby *Awaous aeneofuscus* in the Wadi Hatta watershed (U.A.E./Oman). **Tribulus 10.1**: 12-15. Available at: <http://www.enhg.org/Portals/1/trib/V10N1/TribulusV10N1.pdf>.

Feulner, G.R. and Hornby, R.J. 2006. Intertidal Molluscs in UAE Lagoons. **Tribulus 16.2**: 17-23. Available at: <http://www.enhg.org/Portals/1/trib/V16N2/TribulusV16N2.pdf>.

Froese, R., and Pauly, D. (eds.) 2012a. *FishBase*: All fishes of United Arab Emirates: n = 189 (Incomplete). World Wide Web electronic publication. Available at: <http://www.fishbase.org/Country/CountryChecklist.php>. [Accessed 28/07/12]

Froese, R., and Pauly, D. (eds.) 2012b. *FishBase*: Species in *Apocryptodon* – Fish Identification. World Wide Web electronic publication. Available at: <http://fishbase.sinica.edu.tw/identification/SpeciesList.php?genus=Apocryptodon>. [Accessed 09/08/12]

Froese, R., and Pauly, D. (eds.) 2012c. *FishBase*: References used for *Apocryptodon madurensis*. World Wide Web electronic publication. Available at: <http://fishbase.sinica.edu.tw/References/SummaryRefList.php?id=7328&genusname=Apocryptodon&speciesname=madurensis&lang=russian>. [Accessed 09/08/12]

Fishwise. *Periophthalmus waltoni* – Koumans 1941. Available at: <http://www.fishwise.co.za/>. [Accessed 20/02/12]

George, D. and John, D. 2005. The Marine Environment. In P. Hellyer and S. Aspinall (eds.) *The Emirates – A Natural History*. Trident Press. pp. 111-121. Available at: <http://viewer.zmags.co.uk/showmag.php?mid=srthf&preview=1&_x=1#/page0/>

Graham J.B. (ed.) 1997. *Air–breathing Fishes. Evolution, Diversity and Adaptation*. Academic Press, San Diego California. 299 pp.

Hagen Aqualab. 2005. *Mudskipper Standard Operating Procedures*. April 1, 2003 – Revised December 2005. Available at: <http://www.uoguelph.ca/~aqualab/forms/mudskipperSOP2004.pdf>. [Accessed 20/02/12]

Hogarth, P.J. 1999. *The Biology of Mangroves*. Oxford University Press. 228 pp.

Hornby, R.J. 1996. *Khor Kalba Proposed National Park – a Provisional Management Plan*. Unpublished report to the Arabian Leopard Trust. November 1996.

Ip, Y.K., Chew, S.F. and Ping, C.T. 1991. Evaporation and the turning behaviour of the mudskipper *Boleophthalmus boddarti*. **Zoological Science, Tokyo 8(3)**: 621-624. [Cited in Clayton & Snowden (2000).]

Ishimatsu A., Hishida Y., Takita T., Kanda T., Oikawa S., Takeda T. and Khoo K.H. 1998. Mudskippers Store Air in Their Burrows. **Nature, 391**: 237-238. [Cited in Polgar (2010)]

Ishimatsu, A. and Gonzalez, T.T. 2011. Mudskippers: Front-Runners in the Modern Invasion of Land. In R.A. Patzner, J.L. Van Tassell, M. Kova i and B. Kapoor (eds.), *The Biology of Gobies*. Science Publisher: Enfield. pp. 609-638.

Ishimatsu A., Yoshida Y., Itoki N., Takeda T., Lee H.J. and Graham J.B. 2007. Mudskippers brood their eggs in air but submerge them for hatching. **J. Experimental Biology 210**: 3946-3954.

Kim, J.K., Baek, H.-J., Kim, J.-W., Chang, D.-S., and Kim, J.I. 2011. Sexual Maturity and Early Life History of the Mudskipper *Scartelaos gigas* (Pisces, Gobiidae): Implications for Conservation. **Fisheries and Aquatic Sciences 14(4)**: 403-410. Available at: <http://dx.doi.org/10.5657/FAS.2011.0403>.

Kobayashi T., Dotsu Y. and Miura N. 1972. Egg development and rearing experiments of the larvae of the mud skipper, *Periophthalmus cantonensis* (in Japanese with English summary). *Bulletin of the Faculty of Fisheries, Nagasaki University* 33: 49-62. [Cited in Ishimatsu *et al.* (2007) and Polgar (2010)]

Kooseg, N., Rahmani, A., Kamrani, E., Taherizadeh, M. and Alinia, M. 2011. Investigation and Measurement of heavy Metals, Lead and Cadmium, in Muscle of *Periophthalmus waltoni* in Persian Gulf (Khamir Port, Dargahan Island and Golshahr). **Jour. Life Science and Biomedicine 1(1)**: 13-17.
Available at: <http://jlsb.science-line.com/>.

Lee, H.J. and Graham, J.B. 2002. Their Game is Mud. **Natural History Magazine 9/02**: 42-47. Available at:
<http://naturalhistorymag.com/htmlsite/0902/0902_feature.html>.

Lee, H.J., Martinez, C.A., Hertzberg, K.J., Hamilton, A.L., and Graham, J.B. 2005. Burrow air phase maintenance and respiration by the mudskipper *Scartelaos histophorus* (Gobiidae: Oxudercinae). **Jour. Experimental Biol. 208**: 169-177. Available at:
<http://jeb.biologists.org/content/208/1/169.full.pdf>.

Llewellyn-Smith, R. 1999. Khor Kalba Nature Reserve: A Review. Unpublished report by the Arabian Leopard Trust to the Sharjah Department of Environment and Protected Areas. November 1999. 14 pp.

Llewellyn-Smith, R. 2011. Fresh water input to Khor Hulaylah – an unusual feature of Ra's al-Khaimah's wetlands. **Tribulus 19**: 154-157.

Llewellyn-Smith, R., Khuluti, I., Tayseer, Y. and Khalifa, M. 2007. Proposal for a Hulayla Nature Reserve, Ra's al Khaimah. Unpublished report by the Wildlife & Protected Areas Division of the Environmental Protection & Development Agency, Ra's al Khaimah. 43 pp.

Mhaisen, F.T., and Al-Maliki, N.S. 1997. Parasites, diseases and food of the dark-blotched mudskipper *Periophthalmus waltoni* (Perciformes:Gobiidae) in the Khor Al-Zubair estuary (Iraq). **Oceanographic Literature Review (July 1997) 44(7)**: 738

Murdy, E.O. 1989. A taxonomic revision and cladistic analysis of the oxudercine gobies (Gobiidae: Oxudercinae). **Records of the Australian Museum 11**: 1-93.

Murdy, E.O. 2011. Systematics of Oxudercinae. In R.A. Patzner, J.L. Van Tassell, M. Kova i and B. Kapoor (*eds.*), *The Biology of Gobies*. Science Publisher: Enfield. pp. 99-106.

Polgar, G. (ed.) 2010. *The Mudskipper*. World Wide Web electronic publication:
<http://www.mudskipper.it>. [Accessed June-July 2012].

Polgar, G., Burreson, E.M., Stefani, F., and Kamrani, E. 2009. Leeches on Mudskippers: Host-Parasite Interaction at the Water's Edge. *J. Parasitol.* 95(4):1021-1025. Available at:
<http://www.journalofparasitology.org/doi/abs/10.1645/GE-1718.1>.

Randall, J.E. 1995. *Coastal Fishes of Oman*. Crawford House, Bathurst, Australia. 439 pp.

Richardson, C. 1994. United Arab Emirates: Dhayah, Rams, Ghalilah and Hulayla Island (15). In *A Directory of Wetlands of he Middle East*. Available at:
<http://www.wetlands.org/RSIS/WKBASE/MiddleEastDir/UAE.htm>.

Sarafraz, J., Abdoli, A., Hassanzadeh, B., Kamrani, E. and Akbarian M.A. 2011. Determination of the age and growth of the mudskipper *Periophthalmus waltoni* Koumans, 1955 (Actinopterygii: Perciformes) on the mudflats of Qeshm Island and Bandar Abbas, Iran. *Progress in Biological Sciences*.
Abstract available at:
<http://journals.ut.ac.ir/page/download-9c5Sj2qHxAk.artdl>. [Accessed 20/02/12].

Schultze H.-P. 1999. The Fossil Record of the Intertidal Zone. In M.H. Horn, K.L.M. Martin & M.A. Chotkowski (*eds.*), *Intertidal Fishes: Life in Two Worlds*. Academic Press, San Diego California, 399 pp: 373-392.

Sponder, D.L., and Lauder, G.V. 1981. Terrestrial feeding in the Mudskipper *Periophthalmus* (Pisces: Teleostei): A radiographic analysis. **J. Zool. Lond. 193**: 517-530.

Stebbins, R.C. and Kalk, M. 1961. Observations on the Natural History of the Mudskipper, *Periophthalmus sobrinus*. **Copeia 1**: 18-27. [Cited in Clayton & Snowden (2000)]

Stuart, C. and Stuart, T. 1996. Proposal for the creation of Khor Kalba Wetland National Park. Unpublished report to the Arabian Leopard Trust. 13 pp.

Swift, S.A. and Bower, A.S. 2003. Formation and Circulation of Dense Water in the Persian/Arabian Gulf. **J. Geophys. Res. 108**, no. C1, 3004, doi:10.1029/2002JC001360.

Takeda, T., Hayashi, M, Toba, A., Soyano, K., and Ishimatsu, A. 2012. Ecology of the Australian mudskipper *Periophthalmus minutus*, an amphibious fish inhabiting a mudflat in the highest intertidal zone. **Australian Jour. Zool. 59(5)**: 312-320. Available at: <http://dx.doi.org/10.1071/ZO11059>.

Taylor, J.R., Cook, M.M., Kirkpatrick, A.L., Galleher, S.N., Eme, J., and Bennett, W.A. 2005. Thermal Tactics of Air-Breathing and Non-Air-Breathing Gobiids Inhabiting Mangrove Tidepools on Pulau Hoga, Indonesia. **Copeia 2005(4)**: 885-892.

Todorova, V. 2012. Return of the fish that skipped. *The National*. 16 March 2012, p. 5. Available at: <www.thenational.ae>.

Tytler, P., and Vaughan, T. 1983. Thermal Ecology of the Mudskippers *Periophthalmus koelreuteri* (Pallas) and *Boleophthalmus boddarti* (Pallas), of Kuwait Bay. *Journal of Fish Biology* 23(3): 327–337. [Cited in Clayton & Snowden (2000)]

UAE Interact. Natural UAE: Dhayah marshes. Available at: <http://www.uaeinteract.com/nature/natu_ems/en46.asp>. [Accessed 26/02/12 and 28/07/12]

Yang, K.Y.J. 1996. *The feeding ecology of the mudskipper* Boleophthalmus pectinirostris *(Pisces: Periophthalmidae) at the Mai Po marshes nature reserve, Hong Kong*. Thesis for the degree of Master of Philosophy. Faculty of Science, Hong Kong University. 193 pp. [Cited in Clayton & Snowden (2000).]

Zajonz, U., Beech, M. and Gill, A.C. 2002. Fishes of Sabkha-Related Habitats. In H.-J. Barth and B. Boer (eds.), *Sabkha Ecosystems – Vol I: The Arabian Peninsula and Adjacent Countries*. Kluwer Academic Publishers. pp.283-298.

Gary R. Feulner
Dubai, U.A.E.
email: grfeulner@gmail.com

Binish Roobas
Trivandrum, Kerala, India
email: johanruphus@hotmail.com

Report of a short-term reconnaissance study of sand dune temperature profiles

by Stephen Lokier

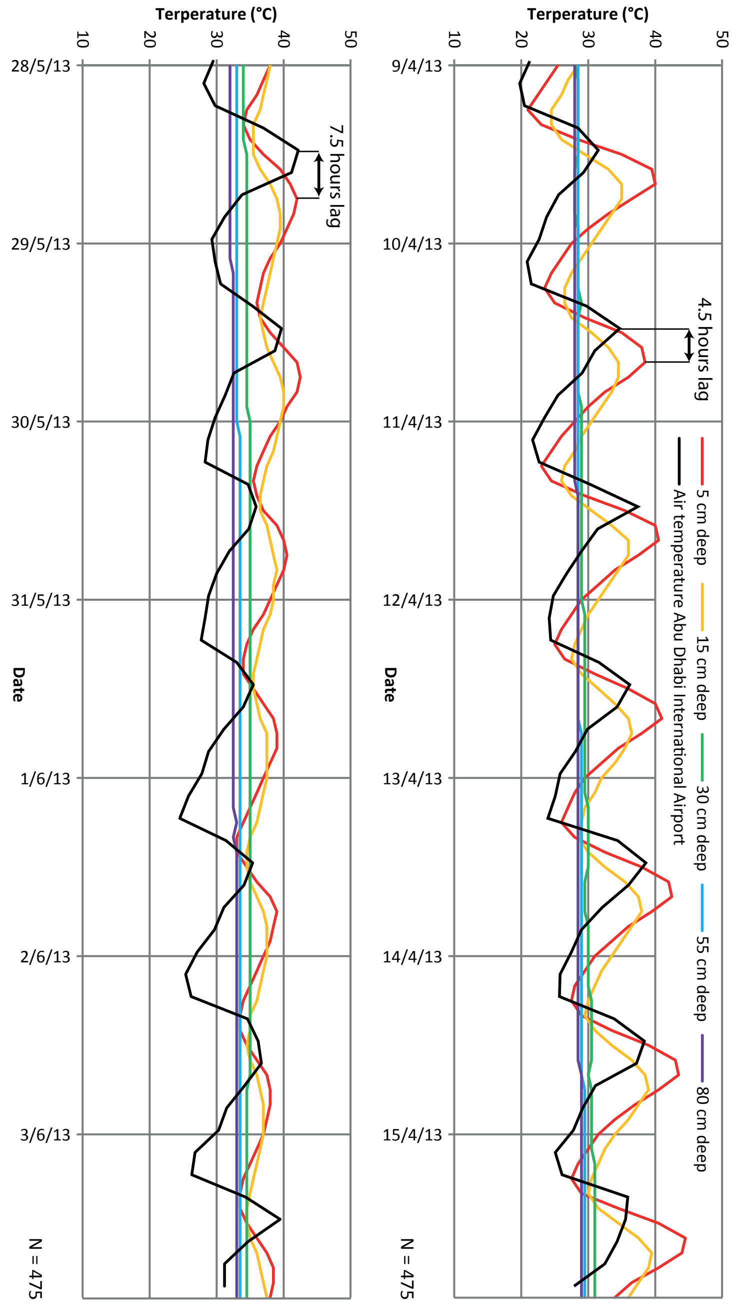


Fig. 1. Graph showing temperature profiles for the five buried loggers compared to air temperature and precipitation measurements made at

Introduction

With an area of six million square kilometres, the Rub al-Khali is the largest sand sea in the world (Besler, 2008). Yet, there is still a surprising paucity of basic environmental and physiographic data from this large and complex sedimentary system. This brief report documents a short-term pilot study that was undertaken to ascertain the validity of recording a temperature profile of the shallow sub-surface from active sand dunes in Abu Dhabi, United Arab Emirates.

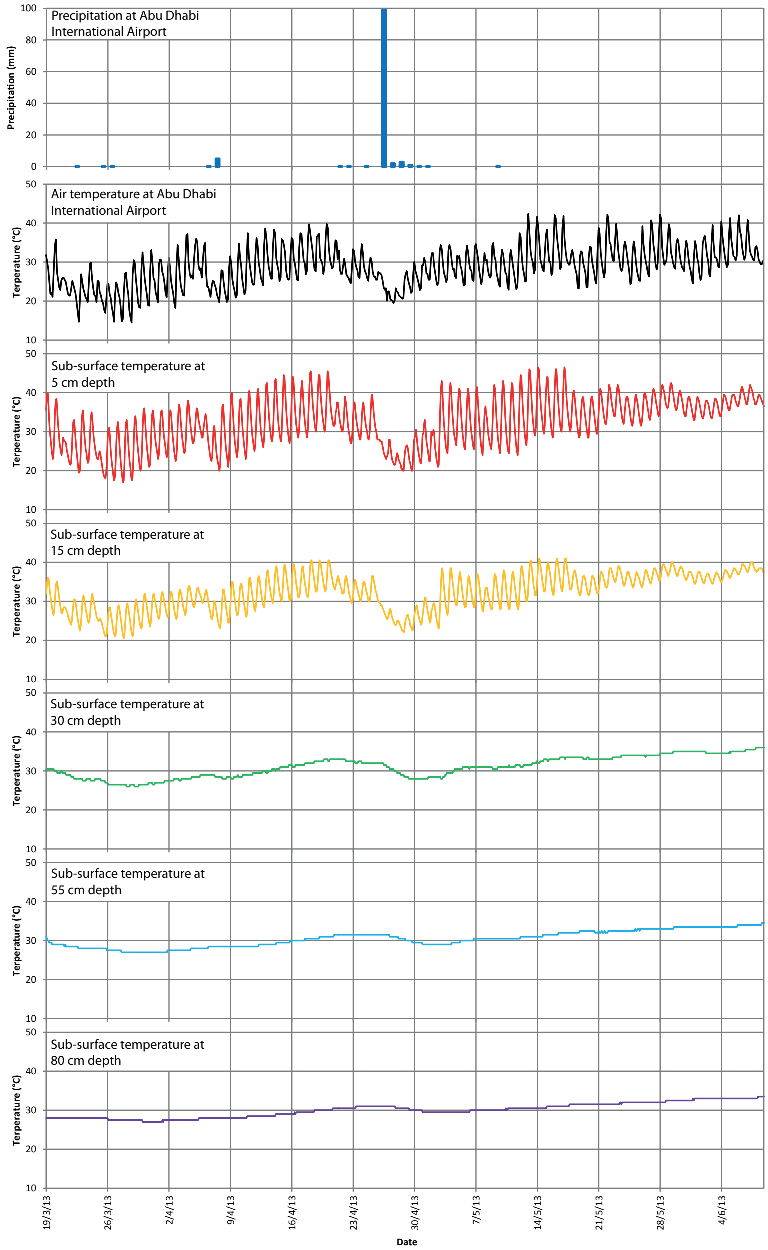


Fig. 2. Detailed temperature profiles for a one week period in early May and early June showing a clear reduction in diurnal ranges over the period of the pilot study. Also note the increase in the lag between maximum recorded air temperatures and temperatures from depth.

Methodology

The general location of the study area was selected on the basis of ease of access and low anthropogenic impact. The site of the monitoring station was further refined utilising historical satellite imagery and repeat visits to document dune migration and risk of deflation. A shallow depression between sinuous transverse dunes was selected at 23° 50.720'N 54° 24.281'E. Temperature was recorded using iButton thermochron DS1920 data loggers calibrated to an accuracy of ± 0.5 °C and programmed to record temperature at intervals of 2 hours. Five data loggers were secured to a nylon line and buried at depths between 5 and 80 cm in the sub-surface. Measurements were recorded between 19th March and 9th June 2013 (82 days, 983 measurements at each depth). At the end of the study period, the data loggers were retrieved and the temperatures uploaded for analysis. In order to provide a control to the dataset, the results were compared with air temperature and precipitation data recorded from Abu Dhabi International Airport over the same period.

Results and discussion

The results of the temperature profiling exercise are presented in Figures 1 and 2. Although this was a short-term pilot study, there are a number of observations worthy of mention. The maximum air temperature recorded at Abu Dhabi International Airport was 42.4 °C whilst the maximum shallow-sub surface (5 cm) temperature was 46.5 °C. This differential in temperature is due to the incidence of solar radiation on the rough sand surface and the thermal conductance, and short-term storage, of heat within the sediment. As may be expected, there is an observed buffering in diurnal temperature range with increasing depth. At 5 cm diurnal temperature ranges average 12 °C (with a maximum of 22 °C), this declined to a range of 7 °C at 15 cm, and <1 °C below 30 cm. This is due to the relatively low thermal conductivity of dry sand (0.15 - 0.25 W/(m.K)) resulting in the accumulation of heat through the day and the retention of much of this heat at night. A sustained overall increase in average sub-surface temperatures during the duration of the study mirrors the increase in air temperatures with the onset of summer. This is accompanied by suppression of the diurnal temperature range that is inferred to result from the thermal capacity of sand at depth increasingly providing a buffer to overnight cooling.

There is a noticeable lag in the time between peak daily air temperatures and peak sediment temperatures. The length of this lag evolved over the period of the study, from 4.5 hours in early April to 7.5 hours in early June (*Figure 2*). Without a complete annual record, it is difficult to ascertain a reason for this observation. A depression in air and sediment temperatures during late April is correlated with a period of rainfall. During this time increased cloud cover reduced incident radiation, thus suppressing the heating of surface and near-surface sand and reducing the diurnal variance. An increase in sediment moisture content would have resulted in an elevation in thermal conductivity thereby intensifying the loss of heat from depth.

This pilot study has highlighted the requirement for a more sustained study of the sub-surface thermal environment of desert sands. It is intended that a long-term study will be initiated during the winter of 2013 with data loggers recording temperature profiles over a period of at least one year.

References:

Besler, H., 2008. Chapter Nine: The History of the Great Sand Sea Compared to that of Other Active Ergs, in: Helga Besler, A.B.O.B.A.H., Loon, A.J.V. (*eds.*), **Developments in Sedimentology.** Elsevier, pp. 195-210.

Stephen Lokier
The Petroleum Institute
P.O. Box 2533
Abu Dhabi, UAE.
email: slokier@pi.ac.ae

A Contribution to the Knowledge of the Distribution and Choice of Habitat of the Ghost Gecko, *Hemidactylus lemurinus* ARNOLD, 1980, in Dhofar

by Wolfgang Grossman, Bernd-Michael Zwanzig & Thomas Kowalski

Fig. 1: Natural habitat of *Hemidactylus lemurinus* at Marneef Cave near Mugsayl, Dhofar, Sultanate of Oman. The arrows point to the exact spots of discovery.

Fig. 2: Habitat of *Hemidactylus lemurinus* in a side-wadi of Wadi Ayun, Dhofar. The arrows point o the exact spots of discovery.

Distribution

Only a few localities are yet known for the ghost gecko, *Hemidactylus lemurinus*. At the time of its original description, Arnold (1980) thought it might be endemic to the Sultanate of Oman and even the Dhofar region. Its type locality is (Wadi) Ayun (also spelt Ayoun or Ayoon). The subsequent records by Schätti & Desvoignes (1999) from near Sayhut and the lower Wadi Hajr on the coast of Yemen were the first from this country and obviously meant the loss of its status as an endemite of Oman. Gardner (1999) provided the second record from Dhofar, i.e., from the "mountains west of Mugsayl", but did not collect vouchers. Details of this find are as follows: "the location was at, or within a few metres of, 16°52'07" N, 53°44'20" E, at 50 m a.s.l., a pale limestone rock overhang or shallow cave in a wadi. The sighting was at night and of a single adult *H. lemurinus*, which was not collected. The site is about 3 km west of the Marneef Cave. Date was 29 March 1989." (A.S. Gardner *pers. comm.*).

Van der Kooij (2000) did not refer to the records from Yemen, but mentioned Gardner's find from near Mugsayl (Wadi Jabal al-Qamar). In their revision of the genus *Hemidactylus* from the Sultanate of Oman, Carranza & Arnold (2012) mentioned the find from near Mugsayl ("recorded from near Mughsayl in Western Dhofar, South Oman [A.S. Gardner, *pers. comm.*]), but then omitted the locality from the distribution map, because "no specimens are available and its presence could not be confirmed in any of our trips".

We here confirm the second-known locality of *H. lemurinus* from Dhofar as we were able to observe several specimens of this species near Mugsayl, too. The exact coordinates of our finds are 17°52'33" N, 53°45'58" E, 26 m a.s.l., and 17°52'32" N, 53°46'00" E, 21 m a.s.l., respectively. This area is a tourist hotspot, commonly known as "Marneef Cave". One of its main attractions is the presence of "blow holes", which are pipe-like holes in the rock that are connected to the sea and produce impressive, loudly hissing, perfectly vertical fountains when the tide comes in.

All our visits to the site during daylight hours, of course, did not yield any finds of ghost geckos, but the results of our nightly excursions can be summarised as follows:

On 15th October 2011, we found two *Hemidactylus alkiyumii* and one male *Ptyodactylus hasselquistii* sensu lato* between 22:55 and 23:30.

On 26th February 2012, we encountered three males and one female of *H. lemurinus*, one *H. homoeolepis*, one female *H. alkiyumii* carrying a well-advanced egg, one female *P. hasselquistii* s. lat. carrying two eggs, and one *Duttaphrynus dhufarensis* during the time from 22:55 through 23:30.

Fig. 3: A male *Hemidactylus lemurinus* in its natural habitat in a side-wadi of Wadi Ayun

On 10th August 2012, we only found one specimen each of *H. homoeolepis* and *P. hasselquistii* s. lat. between 22:40 and 23:10.

On 21st November 2012, we found three male *H. lemurinus*, one *P. hasselquistii* s. lat., as well as two subadult *H. homoeolepis* at this site between 21:00 and about 22:00.

On 25th June 2013, we observed one female and one juvenile *H. lemurinus* and one *P. hasselquistii* s. lat. between 22:40 and 23:10.

More than half of our nocturnal visits yielded records of *H. lemurinus* at the site known as "Marneef Cave".

Another previously unknown, and therefore the third, locality of *H. lemurinus* in Dhofar is a side-wadi of the Wadi Ayun (17°13' 16" N, 53°54' 32" E, 729 m a.s.l.), where we likewise discovered ghost geckos only at night. On 17th October 2011, we observed one male and three female *H. lemurinus*, eight *H. homoeolepis*, six *H. festivus*, and three *P. hasselquistii* s. lat. between 18:00 and 19:30, followed by two male *H. lemurinus*, five *H. homoeolepis*, four *H. festivus,* and two *P. hasselquistii* s. lat. at the same site on 20th October 2011 between 20:05 and 22:10. A random search on 13th August 2012 between 20:00 and 21:00 then yielded one juvenile *H. lemurinus*, eight *H. homoeolepis*, four *H. festivus*, one *P. hasselquistii* s. lat., and two *Echis khosatzkii*.

Natural habitat

As far as the natural habitat at the type locality of *H. lemurinus* is concerned, Arnold (1980) noted, "it seems to be largely restricted to big (up to 3 m diameter), pale, water-smoothed boulders that occur in extensive patches in the wadi." Gardner (1999) did not provide any details on the habitat, and according to Van der Kooij (2000), *H. lemurinus* is "only found on very large white … very water-smoothed … marble boulders in the wadi bottom" in Wadi Ayun. Carranza & Arnold (2012: fig. 31 D) published photographs of the "type locality of the species in Wadi Ayoun" and white boulders that are the "typical habitat of *H. lemurinus*" (fig. 31 E: "detail of the big smooth white boulders at Wadi Ayoun, where *H. lemurinus* is found at night running with great agility, side by side with *Ptyodactylus hasselquistii*").

These statements made us focus our search for *H. lemurinus* on the nearly white, water-worn and rounded boulders in the riverbed, some of which are scattered on the margins in the side-wadi of Wadi Ayun. We failed to find ghost geckos there during all our visits. Instead, we discovered them on the marginal cliffs of the wadi where they sat on ochre-coloured rock that varied in hue from distinctly darker to lighter shades in places. These rock cliffs were worn smooth, and, being pitted with a multitude of crevices, holes and cavities, they provided the geckos with ample opportunities for sheltering and evading predators.

In Mugsayl, the resident *H. lemurinus* live at the so-called "Marneef Cave", a rock cliff reminiscent of a cave. Originally light in colour, its proximity to the spray from the sea and presumably also exposure to the summer monsoon have stained the rock surface blackish brown and have worn it smooth. As with the habitat previously described, numerous openings in the rock provide access to subterranean levels where the geckos find day shelters and oviposition spots.

One male and two females were discovered perched on a boulder a short distance from the actual "cave" (Fig. 1), in the company of *P. hasselquistii* s. lat. and *H. alkiyumii*. A subadult female ghost gecko was also spotted sitting on a rubbish bin that had been set up near the boulder for the convenience of visiting tourists. The juvenile was found climbing on the dark rocks that litter the ground here.

Fig. 4: A male *Hemidactylus lemurinus* in its natural habitat near Mugsayl

Discussion

H. lemurinus had until now been described from Dhofar only from white to whitish rock (Arnold 1980, Van der Kooij 2000, Carranza & Arnold 2012). Information on the Yemeni habitats is very scant, with Schätti & Desvoignes (l.c.) merely mentioning *H. lemurinus* having been found on “big smooth boulders” in Wadi Hajr, with no details provided on the locality near Sayhut.

Our records from the two Omani localities demonstrate that *H. lemurinus* is more flexible than previously presumed with regard to its habitat choice. According to our observations, it quite obviously has a predilection for rock faces with a smooth surface, whereas a nearly white colour of the rock does not appear to be a precondition. Quite the contrary is true in that the colour and pattern of *H. lemurinus* is particularly well adapted to an ochre-coloured environment (fig. 4) and will not even stand out clearly against the very dark coloured rock at Mugsayl (fig. 3). The presence of holes, crevices and cavities in the rock appears to be more important than its colour. Noteworthy is the find of a ghost gecko on a rubbish container whose contents offer potential gecko prey (flying insects, beetles) in increased abundance. Prey like that will be difficult to obtain otherwise on the coast where strong winds are common. Our find therefore suggests that ghost geckos are able to identify such “feeding hotspots” and exploit them for themselves.

Only the type locality and our record from a side-wadi of Wadi Ayun are situated farther inland. All other localities known so far are situated close to, or on, the coast. A distance of roughly 650 km lies between the type locality and the southernmost record from Yemen. The large distance between these two points and the realisation that coloured rock constitutes a suitable habitat substrate indicate that our knowledge of the distribution and ecology of *Hemidactylus lemurinus* is in critical need of completion through further investigation.

* Nazarov *et al.* (2013) recently described *Ptyodactylus dhofarensis* from the Dhofar region of Oman, with the type locality being Wadi Ayun, 17°14’ N 53°53’ E, 678 m a.s.l.. As far as the distribution of this taxon is concerned, they note: “species known only from the type territory. Probably inhabits also bordering areas of Yemen.” We did not examine the specimens of *Ptyodactylus* observed more closely, but presume they represented this new taxon and therefore refer to them herein as *P. hasselquistii* s. lat..

Acknowledgements

We are gratefully indebted to Mirko Bartsarts (Kleinmachnow) for making some literature available to us, and to Andrew S. Gardner (Australia) for kindly contributing as yet unpublished details of his observations. Translation of the original German manuscript by www.herprint.com.

References

Arnold, E.N. (1980): The scientific results of the Oman flora and fauna survey 1977 (Dhofar). The reptiles and amphibians of Dhofar, Southern Arabia. — *Journal of Oman Studies,* Special Report, Muscat, (No. 2) **1980**: 273–332.

Carranza, S. & Arnold, E.N. (2012): A review of the geckos of the genus *Hemidactylus* (Squamata: Gekkonidae) from Oman based on morphology, mitochondrial and nuclear data, with descriptions of eight new species. — **Zootaxa***,* Auckland, **3378**: 1–95.

Gardner, A.S. (1999): The reptiles and amphibians of Oman: Herpetological history and current status. In: Fisher, M., Ghazanfar, S.A. & A. Spalton (*eds.*): *The natural history of Oman. A festschrift for Michael Gallagher*. — Backhuys Publishers, Leiden: 65-88.

Nazarov, R., Melnikov, D. & Melnikova, E. (2013): Three new Species of *Ptyodactylus* (Reptilia; Squamata; Phyllodactylidae) from the Middle East. — **Russian Journal of Herpetology, 20**, **(2)**: 147–162.

Schätti, B. & Desvoignes, A. (1999): *The herpetofauna of southern Yemen and the Sokotra Archipelago.* — Gilbert-E. Huguet, Museum d'histoire naturelle, Genève, 1–179.

Van der Kooij, J. (2000): The herpetofauna of the Sultanate of Oman: Part 2: The geckoes. — **Podarcis**, Leiden, **1** (4): 105–120.

Wolfgang Grossmann
Wulfila-Ufer 33,
12105 Berlin, Germany,
e-mail: wg-gekko@t-online.de

Bernd-Michael Zwanzig
Kurzestr. 5,
15859 Storkow, Germany,
e-mail: berndzwanzig@yahoo.de

Thomas Kowalski
Holzweg 63,
25337 Elmshorn, Germany,
e-mail: geckowalski@googlemail.com

Purple Swamphen as a new breeding bird in Abu Dhabi Emirate, and its status in the United Arab Emirates

by Oscar Campbell

The Purple Swamphen *Porphyrio porphyrio* is a large and spectacular (although often reclusive) gallinule with a very wide world range. It occurs patchily from Portugal around the Mediterranean Sea environs to Turkey and the Arabian Gulf and from Iran through the Indian sub-continent to the Philippines, Australia and New Zealand, as well as across much of sub-Saharan Africa as far south as Cape Town (Cramp, 1980).

Doubtless due to the lack of suitable habitat in this arid region, the Purple Swamphen is a very localised, but quite widespread, breeder in Arabia. Moreover, it has expanded in distribution and numbers markedly since the early 1990s. Jennings (2010) maps records from six countries, with breeding confirmed from four of these. In each, breeding has been confirmed relatively recently, beginning with Kuwait (1996), the UAE (2004) and Qatar and Saudi Arabia (both 2007). In the latter country, regular visits since 2006 to Sabkhat al Fasl, a large man-made wetland with extensive beds of *Phragmites australis* reeds, in the Eastern Province indicate a steadily increasing population with 66 birds counted in one visit in August 2009 (Roberts & Babbington, 2012). Birds have also been observed at two other sites in the Eastern Province, with strong circumstantial evidence of breeding from one of these. In light of this, Jennings' (2010) surmise of an Arabian population of approximately 20 pairs is likely now to be an underestimate. In Kuwait, breeding has continued at Jahra Pools Reserve, and was confirmed in both 2012 and 2013 (M. Pope *in litt*). In many cases, birds have been present at sites for several years prior to confirmation of breeding. These recent records may merely reflect increased observer effort but could equally be due to natural spread as the species finds and occupies newly-created wetlands, which, in Arabia, often follow agricultural and urban development.

The status of Purple Swamphen in the UAE

To date, there are 227 records of Purple Swamphen from the UAE Bird Database from 1984 to May 2013 (T. Pedersen *in litt*). The vast majority of these (91%) are from Al Warsan Lakes, Dubai where the species has been present, presumably continuously, since March 2001, with breeding confirmed in 2004, 2005, 2007 and 2009. Up to eight individuals have been recorded simultaneously but, reflecting the species' shy and retiring nature, most records number three or fewer individuals. Away from Al Warsan, there are records from Ramtha, Sharjah (1992-1996), Zabeel Ponds, Dubai (October and December 1995) and Ruwais, Abu Dhabi (Sept 1995 and January 1996). Some of these sites no longer exist, having been destroyed by development.

Records from Al Wathba Wetland Reserve, April 2011 to June 2013

The Ruwais records were the only reports of apparently wild Purple Swamphens in the Emirate of Abu Dhabi until April 2011, when one was observed by the present author at Al Wathba Wetland Reserve, a site managed by the Environment Agency – Abu Dhabi, EAD, and situated 40km south-east of Abu Dhabi city. The 500 hectare reserve comprises a saline lake, partially eutrophicated by the discharge of tertiary (treated) sewage water from the adjacent Mafraq Water Treatment Plant. In areas adjacent to the treatment plant, muddy freshwater lagoons have formed and are at various stages of succession. Intensive observations at this location, a recently-declared Ramsar Site (Ramsar Convention on Wetlands, 2013) from September 2006 had failed to locate the species until, on 27th April 2011, an adult was observed just before dusk, feeding along the edge of a *Phragmites australis* reedbed on a small, freshwater pool adjacent to the main lake. Documentary photographs were obtained, despite the distance and rather poor lighting conditions. Despite frequent subsequent visits, there were no further records until January 2013, when an individual was recorded on the same pool. All observations of the species from this site in 2013 have been from this same area and are summarised in the table below; all (except where otherwise indicated) were made by the author, and at dusk, typically 1800 – 1900 hrs.

In addition to the above dates, 13 other visits were made to the site between January and June 2013 inclusive when the species was not recorded. Most of these 'blank' visits were made in the early part of the season, i.e. January to March and, the

31st January	One adult seen very briefly in flight
9th March	One adult observed during the morning (Steve Parr *in litt.*) and two adults observed at dusk, in exactly the same spot. They fed on the reedbed edge for over 10 minutes.
18th April	One adult feeding openly on the reedbed edge.
25th April	One adult feeding openly on the reedbed edge, with a tiny chick just discernible alongside.
4th May	One adult on reedbed edge, followed by a medium-sized chick.
12th May	One adult feeding quite openly in the same spot and again accompanied by one chick, now estimated as being approximately 50% full size. The chick was seen to be fed by the adult and was also attempted to feed itself, in a manner typical of the species, holding thick reed stems in its feet and trying to shred them with its bill.
26th May	One adult visible on the reedbed edge for several minutes.
3rd June	As above
26th June	As above

species was recorded as outlined above on all but one of the visits between 18th April until 26th June. These observations confirm the species as having bred successfully at Al Wathba Wetland Reserve in 2013 and represent the first breeding record of Purple Gallinule in the Emirate of Abu Dhabi. Although there is no evidence of successful fledging, the lack of observations of the chick(s) subsequent to 12th May might merely reflect the secretive and retiring nature of the species, and the fact that much of the habitat favoured by Purple Swamphen at the site is not amenable to observation. Birds were not observed when visits resumed to the site in late August 2013.

Subspecies and possible origin of Purple Swamphens occurring in the UAE

Cramp (1980) states there are approximately 20 subspecies of Purple Swamphen described, of which four occur in the Western Palearctic region. These 20 subspecies can be arranged into six subspecies-groups. Of these, the so-called *poliocephalus* group of three subspecies (sometimes called 'Grey-headed Swamphen') comprising *P. p. caspius*, *P. p. seistanicus* and *P. p. poliocephalus* (collectively inhabiting the Caspian Sea region through the Indian subcontinent east to west Thailand and north Sumatra) is reasonably distinctive, due mainly to an often obvious silver-grey tinge on the head (and, on some individuals, the sides of the neck and the upper breast). This effect is variable and strongest in males. Birds from Al Wathba clearly fit into this group, as do the few individuals photographed at Al Warsan, Dubai (see http://www.uaebirding.com/photos-birds.html for images of the species obtained from both sites). Published images from Saudi Arabia (Roberts & Babbington 2012) and Kuwait (M. Pope *in litt*) also depict birds belonging to this group. Exactly which subspecies is involved in Arabian records is much harder to determine but, on geographical grounds, is presumably either *caspius* (inhabiting the shores of the Caspian Sea, north-west Iran, north-west Syria, and central south Turkey) or, perhaps more likely, *seistanicus* (ranging from central and south-east Iraq, southern Iran, Pakistan, and north-west India). These two subspecies differ in biometrics, but this would presumably be impossible to assess in the field. The species as a whole is generally regarded as resident, but *caspius* is migratory, at least in the Caspian Sea area, where freezing waters force birds south every winter (Cramp, 1980).

It is tempting to suggest a natural origin for the recent spread of Purple Swamphen in Arabia, for example due to birds arriving for the winter after short-distance migration or hard weather movements, oversummering and eventually breeding in newly created wetlands. Identification of the birds involved as being from the *poliocephalus* subspecies-group supports this contention, as do well-known examples of other wetland species (such as Common Moorhen, *G. chloropus,* White-tailed Lapwing *Vanellus leucurus* and Black-winged Stilt *Himantopus himantopus* which have all either colonised Arabia and / or greatly expanded their range and breeding populations in recent decades (Jennings 2010; Aspinall 2010) in response to the availability of new anthropogenic wetlands. In a similar manner, Eurasian Coot *Fulica atra* has colonised Al Wathba in recent years and now breeds there annually (*pers obs.*)

However, another possible explanation, particularly relevant in the UAE, but presumably also elsewhere in Arabia, is the spectre of escape from captivity of birds that have been imported into the region. Some such escapees are easily identifiable as such, being of the 'wrong' subspecies, for example *P. p. madagascariensis*, the sub-Saharan subspecies of Purple Swamphen, has been recorded in the UAE at Al Warsan Lakes (where an adult was seen with a chick in 2006 and 2009) and at Mushrif National Park, Dubai (Pedersen & Aspinall 2010). It has also been recently (2011) recorded in Muscat, Oman and apparently accounts for all swamphens present in Qatar (Jennings, 2012). However, birds corresponding to *P. p. poliocephalus* subspecies-group have also been observed in captivity in the UAE, for example at Mushrif National Park (where at least 20 were noted in 2004; Pedersen & Aspinall, 2010) but also as recently as December 2009 (T. Pedersen *in litt*).

Even more interestingly, with relation to the current note, a consignment of 20 birds, all of this subspecies-group, arrived at Ajban Farm, Emirate of Abu Dhabi on 8th May 2013 (A. de la Torre *pers. comm.*) They had been purchased from Sharjah animal souk; five were kept on the farm and 15 were subsequently passed onto a palace in the Ajban area. Inquiries made at the souk indicated that the going price for these birds was approximately 500 UAE dirhams for two and that birds are easily obtainable. The dealers stated their origin was Karachi, Pakistan, although they also claimed that the original source of the birds was elsewhere, possibly Kuwait or Oman. Given the low and very low numbers of swamphens in those respective countries, this assertion seems questionable. These are the only swamphens to have been brought to Ajban since May 2012, but the situation before then is unknown. Ajban lies a mere 50km due north of Al Wathba and there is a very real chance that any birds that escape from there may well find their way to the latter site, or, indeed, to other suitable sites elsewhere in the UAE.

Acknowledgments

I am very grateful to Salim Javed, Khaldoun Alomari and Mostafa of the Environment Agency – Abu Dhabi, EAD, for facilitating my access to Al Wathba Wetland Reserve for a number of years. Observers that joined me in the field in 2013 included Steve James, Mark Smiles, Abraham Arias de la Torre, Helen Berg and members of the Emirates Natural History Group (Abu Dhabi), whilst Steve Parr provided additional records as detailed above. Mike Pope provided useful comments on recent status in Kuwait. Abraham Arias de la Torre also provided much useful background information on the arrival of birds at Ajban in May 2013 and on their availability at Sharjah animal souk. Finally, I am grateful to UAE Bird Recorder Tommy Pedersen for compiling and providing the database records outlined above and to Mike Jennings for assistance with references.

References

Aspinall, S. (2010) *Breeding birds of the United Arab Emirates*. Environment Agency – Abu Dhabi, Abu Dhabi.

Cramp, S. (*ed.*) (1980) *Handbook of the Birds of Europe, the Middle East and North Africa: The Birds of the Western Palaearctic, Volume 2: Hawks to Bustards*. Oxford University Press, London.

Jennings, M. (2010) The Atlas of Breeding Birds of Arabia. **Fauna of Arabia 25**: 285-288, 304-306, 313-314

Jennings, M. (2012) Editorial comment. ***Phoenix 28***: 4

Pedersen, T. & Aspinall, S. (2010) *Checklist of the Birds of the United Arab Emirates*. OSME, UK.

Ramsar Convention on Wetlands. (2013) www.ramsar.org/cda/en/ramsar-news-archives-2013-usa-wathba/main/ramsar/1-26-45-590%5E26158_4000_0__ Accessed 13 July 2013

Roberts, P. & Babbington, J. (2012) Status and range expansion of Purple Swamphen in Eastern Saudi Arabia. **Phoenix 28**: 4

Oscar Campbell
c/o British School Al Khubairat, PO Box 4001, Abu Dhabi, UAE
email: ojcampbell25@yahoo.com

***Birds of Kuwait* – A Comprehensive Visual Guide. Edited by Mike Pope and Stamatis Zogaris. Kuwait Foreign Petroleum Exploration Company, Kuwait / Biodiversity East, Nicosia. 2012. Hardback, 413 pages, colour photographs throughout.**
ISBN 978-9963-2811-0-7

When this book hits one's desk with a fairly substantial thump, it is hard to resist an exclamatory 'wow'. It represents, first and foremost, a stunning showcase of the birds of the State of Kuwait which, although a small country with a rather limited range of habitats, has a fascinating and varied avifauna. This is mainly due to Kuwait's prime position on a migration super-highway but the country also has some very interesting breeding birds and a wide range of winter visitors, all of which attract a steady stream of keen birdwatchers, including, for a short but most memorable weekend in early May 2011, myself.

The book begins with a short but readable introduction to the avifauna of Kuwait, concentrating on its position on the edge of three biogeographical realms, the migration route on which the country lies, seasonal highlights throughout the year and key breeding species, discussed briefly by habitat. Prime birding locations are presented with concise, clear summaries and there are also brief sections on taxonomy and identification, and observing and photographing birds. These will mainly be of interest to the beginner birdwatcher. Bird conservation from a Kuwaiti perspective also features in this introductory section and, from the point of view of most (northern) European countries and here in the UAE, the shocking and outrageous destruction of birds in Kuwait due to indiscriminate and uncontrolled shooting is also covered in no uncertain terms. This really does represent a crime against all of us (never mind the birds themselves) as the vast majority of birds shot in this manner are merely passing through Kuwait to breed or winter elsewhere. Surely the most important legacy that this book may have is its encouragement to lawmakers that such killing is unacceptable from an international (and ethical) viewpoint, and its encouragement to the local populace that birds are far more wonderful and interesting than an pathetically taken and soon-forgotten 'trophy'.

The main part of the book, of course, comprises a systematic section with photographic documentation of every species to have occurred in the country up to June 2012. Many are given a full page, with typically one large, striking image occupying one-half to two thirds of the page, plus several thumbnails showing the species in different postures or from other angles. Rarer species are generally given a half-page, featuring one or two images. Kuwait has a number of outstanding bird photographers and this work showcases their efforts superbly. For species where suitable images were not available from Kuwait, the editors have managed to procure appropriate pictures from other photographers, mainly from elsewhere in Arabia (including work from no fewer than five UAE-based photographers) but also, where necessary, across Europe. It is hard to imagine how a higher overall standard across 1400 images could have been achieved and, whilst the vast majority are superb portraits with the pre-requisite soft background, a number show genuinely interesting or unusual behaviour. For example, check out the Wood Sandpiper that has just caught an unfortunate toad, or the spread on nesting larks in the introduction. For the experienced birder, these images are an excellent reference collection, although, given the number of photographs involved, it is perhaps inevitable that one or two errors and mislabels have crept in. For the beginner, they are an inspiring and jaw-dropping introduction to the wonderful and colourful diversity of species that routinely occur in Kuwait. An Arabic name, basic dimensions and a short text, typically 30-40 words and mainly outlining status, accompanies each species entry; IUCN species designations are also provided. It would have been useful to have expanded the text slightly, perhaps to give some brief details on food or breeding habits from a local perspective; that could easily have been achieved within the space provided.

The one thing this book is not is portable and, given its splendid, glossy production, most owners are unlikely to even consider keeping a copy to hand in a dusty car. To this end, help is at hand, as the next stage of the project is now underway. This includes an associated web portal, an e-book version, and app for use on iOS and Android devices, all of which should be ready by the end of 2013. The book is already available as a downloadable pdf from http://www.bio-e.org/. Of course, even more valuable would be an Arabic versions of any or all of the above, aimed specifically at the local population, with, for example, copies distributed to all schools. KUFPEC, Biodiversity East, the Kuwait Ornithological Rarities Committee and, especially, the editors deserve congratulations for doing the avifauna of Kuwait such a great service. Hopefully we will be reaping the benefits of their effort for years to come.

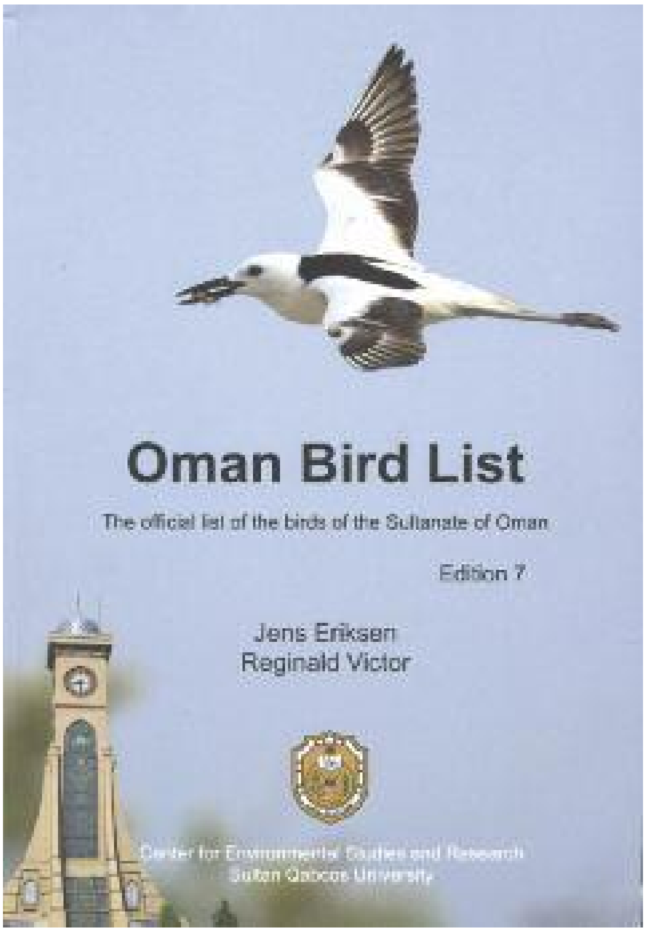
Oscar Campbell

***Oscar Campbell** is Chairman of the Emirates Bird Records Committee.*

***Oman Bird List* - The official list of the birds of the Sultanate of Oman, Edition 7. Jens Eriksen and Reginald Victor. Published by the Centre for Environmental Studies and Research, Sultan Qaboos University, 2013. Softback, 288 pp, colour photographs throughout.**
ISBN: 978-99969-0-218-5

Back in 1980, when ***The Birds of Oman*** was published, with text by Michael Gallagher and illustrations by Martin Woodcock, there were 372 species on the Oman Bird List, then maintained by Effie Warr, a stalwart of what became the Ornithological Society of the Middle East (with the Caucasus and Central Asia now added). She had started the list back in 1971, and also started compiling a list for the UAE at the same time, this later being handed over to the founding chairman of the Emirates Bird Records Committee, Colin Richardson. She handed over the Oman List to Michael Gallagher in 1981, with a card index of around 5,000 cards.

Since then, the database of Oman bird records has grown to over 455,000 records, as on 1st September 2013. Successive editions of the OBL, initially duplicated, have seen the number of species on the list grow to 463 I(OBL5, 2000), 482 (OBL6, 2003) and now to 513 at 15th September 2013, for this latest edition of the list, along with an extinct sub-species (Syrian ostrich) and 30 species which have established feral breeding populations which are considered to have originated from escapes or releases. By comparison, there are 460 species on the UAE list.



This new edition has been produced by Jens Eriksen, well-known to anyone interested in the birds of the region and a much-awarded bird photographer, and Reginald Victor, professor at the Department of Biology at Sultan Qaboos University, which has funded its publication.

Since 1989, much of the work of entering records on the database has been undertaken by one of the authors of the latest list, Jens Eriksen, in collaboration with his wife, Hanne, with other Recorders, such as Dave Sergeant, also entering many thousands of records. In consequence, the Omani national bird database is probably the largest in Arabia, and provides the raw data on which this Edition 7 of the List is based.

It's much more than a simple list. It includes, for example, the number of records for each migrant species, including migrant breeders. It also includes a breeding bird atlas for the 142 species known to breed, or to have bred, in Oman, this having been prepared in close collaboration with Mike Jennings, co-ordinator of the Atlas of the Breeding Birds of Arabia, ABBA project. Histograms showing monthly distribution, taken from the database, are given for all migrant species, For many species, magnificent photographs, all taken in Oman by Jens and Hanne Eriksen, are included, although some cases, generally for the rarer species, the pictures aren't up to the normal stunning Eriksen standard. Around 135 species lack photographs.

Another useful feature is a list of species considered by IUCN to be Extinct, Critically Endangered, Endangered, Vulnerable and Near Threatened at a global level. This provides a useful reminder for UAE birders that some species seen here regularly are of international conservation concern, like Sociable Lapwing (Critically Endangered), Egyptian Vulture (Endangered – i.e. 'high risk of extinction in the wild'), Socotra Cormorant, Great Knot and Collared Kingfisher (all Vulnerable) and Pallid Harrier, Sooty Falcon, Eurasian Curlew and European Roller (all Near Threatened).

Since the book is, emphatically, a checklist, and not a bird guide, not all species are illustrated and a policy has been adopted of using only photographs taken by the Eriksens, and in Oman. For species seen only once or twice, a long time ago, like Great Spotted Cuckoo, one record in 1979, Great Frigatebird, seen once, in 1982, or Mute Swan, with two records from 1984 and 1985, or even Slender-billed Curlew, 5 records, the last in 1999, it's understandable that no Eriksen picture is available. It would have been nice, though, to see some of the other species that Jens and Hanne have photographed, whether in Oman or in the UAE, with proper acknowledgement, if appropriate, of the extra-limital location. As it is, however, one is left to wonder whether pictures of these species for example, Gadwall (619 Oman records), House Martin (335 records), Little Crake (219 records), Wood Warbler (208 records), Great Reed Warbler (201 records) and Alpine Swift (103 records), are sitting in the Eriksen archive, or whether they are on the target list for this winter !

That aside, this is a real tour-de-force, of use to anyone with an interest in the birds of Oman and, more widely, south-eastern Arabia. UAE birders will derive particular interest with regards to species that are relatively regular, if uncommon or rare in the UAE, but extremely rare in Oman, like European Robin (only 5 Omani records), or may see an opportunity to contribute an important rarity sighting to the Oman List. Thus Eastern Cattle Egret has only been recorded 6 times in Oman, always in the south, and never in the Musandam area. A bird, possibly the same one, has been recorded at Wamm Farms in Dibba, just inside UAE territory, for each of the last five years. Does it never fly across the adjacent UAE-Oman border fence when it's flushed?

A 'must-buy' for UAE birders: I look forward to seeing copies on sale at meetings of the UAE's natural history groups, and elsewhere.

Peter Hellyer