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Distribution, Pore-Water Chemistry, and Stand Characteristics of the Mangroves of the United Arab Emirates

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ABSTRACT

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Mangroves are the dominant coastal vegetation of the United Arab Emirates (UAE), occupying one of the driest mangrove habitats in the world. However, published estimates of mangroves do not represent current conditions for the country as a whole. This study provides an up-to-date estimate of UAE's mangroves, summarizing their habitat characteristics, stand heights, and pore-water conditions. Estimates of mangrove cover are based upon remote sensing, aerial photointerpretation, and field verification. Our results document more mangroves than previously estimated for Abu Dhabi and the nation altogether. Mapped areas were classified into three descriptive density cover classes to facilitate interpretation of the data: low (<10%), moderate (10–75%), and high (>75%). The high-density class reflects prior national estimates for mangrove coverage (roughly 3613 ha), while moderate- and low-density classes contributed an additional 5659 ha and 4344 ha (respectively) to the national total. The largest contiguous mangrove area was 710 ha, while the smallest mapped area was 0.03 ha. Mapped mangrove habitat types included fringe, basin, and overwash, with average heights of 3.36 ± 0.25 m and density of 61.83% ± 5.01%. Stand height and pore-water sulfide concentrations were significantly different between habitat types, while stand density, pore-water salinity, and redox potential were highly variable. In sum, approximately 13,616 ha of mangrove area was mapped, roughly three times more than prior estimates. This is the first study in recent years to document the full areal extent of mangroves and associated stand characteristics across the seven emirates.

ADDITIONAL INDEX WORDS: *Arabian Peninsula,* Avicennia marina, *halophytes*, *coastal resource mapping*, *geographic information system (GIS)*, *management*.

INTRODUCTION

Mangroves are the dominant coastal vegetation of the Arabian Peninsula, occupying one of the driest and least diverse mangrove habitats in the world (Abo El-Nil, 2001; Dodd *et al*., 1999; Kathiresan and Rajendran, 2005). Notably sparse, these communities represent both a geographic and ecological extreme for mangroves (Dodd *et al*., 1999; Duke, Ball, and Ellison, 1998; Polidoro *et al*., 2010). In fact, the mangroves of the United Arab Emirates (UAE) are composed exclusively of the highly salt tolerant gray mangrove (*Avicennia marina* [Forsk.] Vierh.) (Dodd *et al*., 1999; Saenger, 1997), which has been shown to tolerate salinity twice that of seawater (Shalom-Gordon and Dubinsky, 1993). Reports indicate that the Asiatic red mangrove (*Rhizophora mucronata* [Lam.]) has also been planted in limited reintroduction efforts as well (FAO, 2007), but specimens from this species were not noted in the present study. These systems provide a variety of ecological functions and values, from provision of habitat for economically and ecologically valuable fisheries, birds, and marine wildlife, to shoreline protection from storms, erosion, and sedimentation. Together with shellfish and sea grass communities we noted, these mangroves also serve to protect and improve the quality of coastal and nearshore waters and represent an important coastal resource for the country and the region.

Globally, mangrove habitats are in decline (FAO, 2007; Polidoro *et al*., 2010) due to a number of factors, including coastal development and land reclamation, aquaculture, oil spills, and coastal pollution (Ellison and Farnsworth, 1996), as well as increased pressure due to climate change impacts (IPCC, 2007; UNEP/UNESCO, 1992). Despite this fact, the mangroves of the UAE appear to have increased to some extent over the last 30–40 years (Howari *et al*., 2009; Loughland *et al*., 2007) due in part to localized planting activities, alteration of shorelines and water-flow patterns, and increased public awareness and conservation efforts (FAO, 2007; Howari *et al*., 2009). Although mangroves such as *A. marina* have one of the largest biogeographical distributions of any mangrove species (Tomlinson, 1986), populations are more at risk from area declines at these extremes of their distribution where mangrove diversity is lowest (Duke, Ball and Ellison, 1998; Polidoro *et al*., 2010).

Recent developments in remote-sensing technology have demonstrated the efficiency of mapping finer-scale mangrove communities with the ability to differentiate between dominant species and stand density (Held *et al*., 2003). Application

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of such technology is particularly well suited to document vegetation change and community response to impacts, as well as to develop sustainable site-specific management strategies for coastal habitats (Dahdouh-Guebas, 2002; Krause, 2004; Loughland *et al*., 2007). Several authors have estimated the mangrove area of the UAE (Embabi, 1993) or portions thereof (Althausen *et al*., 2003; Howari *et al*., 2009; Loughland *et al*., 2007; Saenger *et al*., 2004) using such approaches. These estimates suggest approximately 3000–4000 ha of mangrove area, but these efforts were concentrated in selected areas such as Abu Dhabi Island and Khor Kalba, where significant mangrove areas are known to occur (Al Abdessalaam, 2007; Blasco, Carayon, and Aizpuru, 2001; Saenger *et al*., 2004). The published studies that cite total areal extent of mangrove were largely based upon older imagery (*ca*. 1999–2000) and may not adequately represent diffuse, low-density stands, nor the breadth of mangrove areas across the country as a whole. The discrepancy between prior and current areal extent of mangroves limits land management and conservation initiatives because the data may be incomplete or inaccurate today, in light of significant land alteration throughout the coastline of the UAE over the last 10+ years. Accordingly, we initiated a country-wide mangrove mapping effort to document all mangrove areas, regardless of community density, under present-day conditions. The survey, which was based on various aerial imagery data sets and selective field verification, complements prior studies by improving the resolution of baseline mangrove distribution and quantification, determining the plant density and community zone composition, and identifying further mangrove mapping, research, and conservation needs in the country. Comprehensive mangrove resource mapping will facilitate repeated assessment to monitor short- and long-term trends within these habitats (Moore, Gilmer, and Schill, 2014; Ramirez-Garcia, Lopez-Blanco, and Ocaña, 1998).

METHODS

The UAE is located on the northern coast of the Arabian Peninsula, bordered by Saudi Arabia and Oman (Figure 1). Encompassing 83,600 km^2, it is composed mainly of arid desert and is generally flat, aside from the eastern mountains. Six of its seven emirates are situated on the Arabian Gulf (Abu Dhabi, Dubai, Sharjah, Ajman, Ras Al Khaimah, and Umm Al Quwain), while Fujairah and portions of Sharjah (Khor Kalba) occur on the Sea of Oman. The coastal areas stretch for over 850 km and include several natural plant communities, including algal mats, salt marsh, and mangrove. The latter are dominated by the gray mangrove (*Avicennia marina*) and are the subject of the present study. Published estimates suggest that the UAE has approximately 4000 ha of mangrove, some 2500 ha centered in Abu Dhabi alone (Saenger, 1997), the largest of the seven emirates.

A combination of remote sensing, aerial photointerpretation, and field surveys was used to estimate forested mangrove areal coverage (Grizzle, Moore, and Burt, 2011; Moore, Grizzle, and Ward, 2013). Preliminary coarse-scale (30 m pixel) maps representing mangrove extent were produced from *Landsat* Thematic Mapper (TM) image mosaics. *Landsat* TM data were processed using MultiSpecCarb (v. 6.28.10) and interpreted using ArcGIS software v. 10.1 (ESRI, 2012). However, the resolution was inadequate for locating small, sparse, or isolated mangroves and spanned an inconsistent temporal range from 1998 through 2010 depending on the tile selected. These initial estimates were reassessed using pan-sharpened (1×1) *Ikonos* imagery dated 2000–03. Areas classified as mangroves were resolved from other habitat types by subsequent field verification and modification of stand boundaries as needed. The *Ikonos* imagery had much higher spatial resolution (1–4 m^2), but it was also dated. Resulting maps were compared with available historic maps (Saenger *et al*., 2004) to identify additional areas for consideration. Mangrove boundary estimates were further refined in ArcGIS using the most current collection of Google Earth™ and Bing™ Maps available through the ESRI ArcGIS server (*ca*. 2010–12) and digitized using ArcGIS version 10.1 software and projected to Universal Transverse Mercator zones 39 and 40, WGS84.

Over several weeks in December 2011 and May 2012, all major mangrove areas discerned from preliminary map estimates were visited to confirm vegetated mangrove area boundaries, define habitat classifications, collect stand characteristics data, and measure pore-water chemistry. Habitat classifications generally follow Lugo and Snedaker (1974), further explained by Kathiresan and Rajendran (2005) for the Indian Ocean region, including forested fringe, basin, and overwash mangrove habitat types. Most mangroves were accessed from the water's edge by boat (with assistance from the Ministry of Environment and Water), while some stands were more effectively accessed by walking in from the landward edge. At a minimum, we documented whether historic mangrove locations (derived from review of available maps and imagery) still contained mangroves by viewing stands from a distance with binoculars, as site access was often restricted. In total, site visits were conducted at approximately 45 noncontiguous mangrove areas, spanning each of the seven emirates. These field visits included many previously unmapped, low-density areas that were discovered during our field verification. At each mangrove area, a minimum of 50 GPS waypoints were averaged to ensure accuracy of stand boundaries using a Trimble (2011) Nomad handheld computer with integrated GPS (model 900LC) running ESRI ArcPad version 10.0 software (ESRI, 2012). Resulting waypoints were later uploaded to ArcGIS and used to confirm, correct, or refine remotely mapped mangrove area estimates. Additional data were collected when access to the mangrove was possible. Haphazard plots were used to collect basic physical and biogeochemical data at each site. Each plot location was recorded using GPS, and the data were downloaded to ESRI ArcGIS v. 10.1 daily. Canopy height and plant density coverage were visually estimated. Coverage classes followed a modified Braun Blanquet (1965) scale, subsequently characterized into three density classes per square meter: low ($<10\%$), moderate (10–75%), and high ($>75\%$ m), as illustrated in Figure 2. Soil type was examined in the field and described using standard methods (USDA-NRCS, 2010).

Soil pore water was sampled using the sipper method (Portnoy and Valiela, 1997), which extracts water trapped in pore spaces using a 1-mm-diameter stainless-steel tube fitted with a 60 cm^3 plastic syringe. Pore water was sampled at two

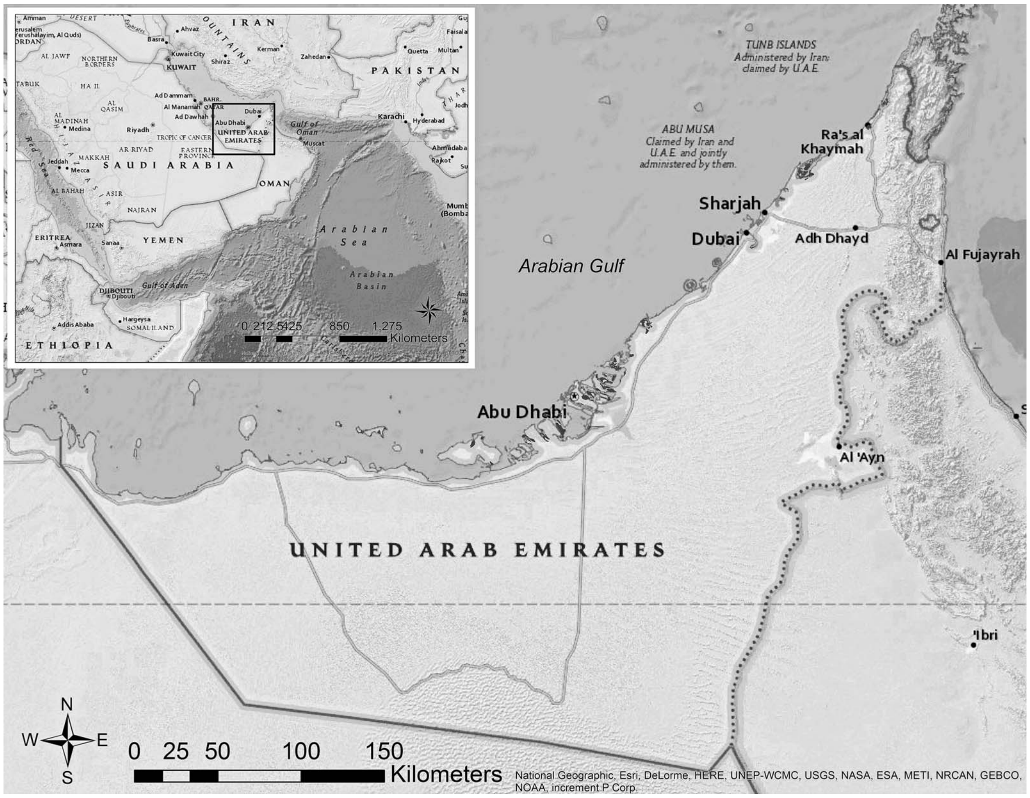

Figure 1. Map of the study area spanning the United Arab Emirates; inset provides study area location within the regional context of the Middle East.

depths within the rhizosphere (20 cm and 50 cm) at each site to document salinity, redox potential, sulfide concentration, and pH. Pore-water salinity was determined in the field using an Orion 5-Star Plus multimeter with DuraProbe conductivity cell, while redox potential was obtained using the Orion 5-Star fitted with a platinum electrode. Sulfide samples were fixed with 20% zinc acetate and determined colorimetrically in the laboratory (Cline, 1969), while pH values were determined in the field using an Orion 5-Star Plus multimeter fitted with a Ross Sure-Flow temperature-corrected pH triode.

Mangrove stand characteristics and pore-water parameters were analyzed over habitat type using a one-factor analysis of variance (ANOVA). Residuals were examined to ensure homogeneous variance and a normal distribution. If appropriate, transformations were conducted to meet assumptions of parametric statistics. Stand heights, surface salinity, and shallow sulfides were all natural log $(x+1)$ transformed. Stand density did not meet the assumptions of parametric statistics and therefore was tested with a more appropriate test, Kruskal-Wallis. Tukey's means comparison test was applied if the model was significant. Statistical significance for all tests was set at an alpha level of 0.05 to control type I error.

RESULTS

In total, approximately 13,616 ha of mangroves were mapped in the current study (Table 1); details are provided in Moore,

Figure 2. Examples of relative mangrove stand density classes representing low (left), moderate (middle), and high (right) density. (Color for this figure is available in the online version of this paper.)

Table 1. *Summary of mangrove area estimates by emirate. Resulting totals have been grouped into simplistic density classes of low (10%), moderate (10–75%), and high (>75%) density to facilitate interpretation of results.*

Emirate	Area (ha) by Density Class			Total Area (ha)
	High	Moderate	Low	
Abu Dhabi	2481	5291	3062	10,834
Ajman	0	158	0	158
Dubai	38	13	12	63
Fujairah	0	0	0	0
Ras Al Khaimah	250	152	78	480
Sharjah	185	3	16	204
Umm Al Quwain	659	42	1176	1877
	3613	5659	4344	13,616

Grizzle, and Ward (2013). The majority of this total (10,834 ha) is centered in the largest emirate, Abu Dhabi. While accounting for far more mangroves than prior estimates, others have found Abu Dhabi to be the most mangrove-rich of the UAE (Saenger, 1997; Saenger *et al*., 2004). The next mangrove-rich emirate, Umm Al Quwain, had an order of magnitude less (1877 ha), while the remaining mangroves mapped totaled <1000 ha together. Mangroves were documented in six of the seven emirates, excluding Fujairah. When vegetated areas were grouped by density classes (high, moderate, low), Abu Dhabi once again stood out as the most mangrove-rich area for high- and moderate-density stands, while the diffuse and widespread mangroves of Umm Al Quwain contributed the most to the low-density class.

Total land area and the abundance of mangroves per emirate were strongly correlated ($r^2 = 0.97$, $p < 0.001$) as suggested by Figure 3, where the largest emirate contains the greatest mangrove area. To explore whether the abundance of mangroves was related to the presence of suitable coastal habitat rather than total land mass, we compared mangrove areal total as a function of the estimated length of coastline per emirate. Like land area, the length of coastline and total mangrove area were highly correlated ($r^2 = 0.94$, $p < 0.001$) but did not follow the same pattern. Umm Al Quwain had tenfold fewer kilometers of coastline (44 km) than Abu Dhabi (495 km), yet Umm Al Quwain had considerably more mangrove area per linear kilometer of coastline (31.9 ha km^{-1}). This is roughly double that of Abu Dhabi (21.0 ha km^{-1}) and over three times more than the other emirates, which contributed <10 ha km^{-1} each (Figure 3).

Three basic mangrove habitat types are present in the UAE: basin, fringe, and overwash. Basin type habitats occur in the interior of larger mangrove stands and often remain flooded for extended periods. Basin habitats were observed in all but Ajman, and they were characterized by intermediate stand height (3 ± 0.48 m) and moderate to high percent cover (67.92% ± 9.06%). The height of mangroves in basin habitats was not significantly different from fringe habitats, but it was different from overwash habitats (*F* ratio 3.238, $p = 0.047$). Fringe habitats were present in all emirates. These common habitats were characterized as the coastal edge of the mangrove where relatively tall, mature trees form a continuous linear band of forest that is flooded on daily high tides. Fringe habitats also included shrub and immature trees forming the same linear band and were differentiated from overwash habitats by their

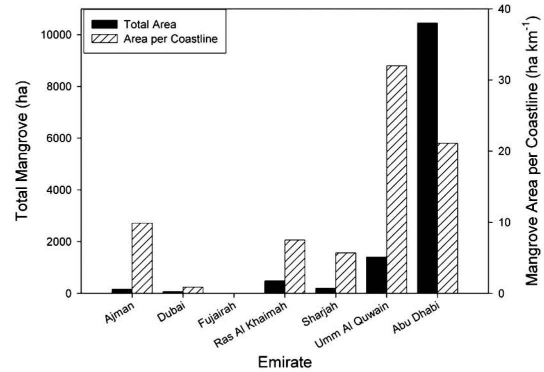

Figure 3. Comparison of total mangrove area by emirate (left axis) *vs*. ratio of mangrove area and length of shoreline (right axis).

slightly more elevated position in the tidal regime. Overall, fringe habitats possessed the tallest plants (3.64 ± 0.3 m) and were generally taller than basin mangroves. Although not significant, fringe mangrove was generally less dense (63.21% ± 6.1%) than basin, likely due to our combining of dense tree-dominated with less dense shrub-dominated fringe habitats. Nonetheless, fringe habitats were significantly taller than overwash habitats (Table 2). Finally, overwash habitats were observed primarily in Abu Dhabi, but they were also noted in Sharjah (Khor Kalba), Umm Al Quwain, and Ras Al Khaimah. Overwash habitats were the shortest and least dense habitats, with a mean height of 1.5 ± 0.5 m and a percent cover of 28.75% ± 15.99%. These habitats are the most exposed and regularly flooded, with stands often composed of particularly few trees. Some stands appeared as new colonizers, while others may have been relics of larger stands damaged by coastal storms or other impacts.

Pore-water chemistry revealed several interesting relationships by habitat type, differing somewhat from the patterns observed for stand height and percent cover. Average surface-water salinity (41.4 ± 1.3 ppt) was lower than shallow and deep pore-water salinity (46.1 ± 1.1 ppt; 47.5 ± 1.1 ppt), presumably reflecting accumulation of salt in the rhizosphere. When pore-water salinity was sorted by habitat type, the substrate in overwash habitats was slightly more saline (52 ± 2 ppt) than basin (45.43 ± 1.96 ppt) or fringe habitats (45.64 ± 1.43 ppt), but the differences were not significant. The extreme conditions, and potential salt stress that may be inferred from the salinity values noted, may contribute to the short stature of plants persisting in overwash habitats.

Despite mangrove's high tolerance of sulfide and anoxia, accumulation of sulfides in sediment affects growth, stature, and survivorship of mangroves (McKee, 1993; McKee, Mendelssohn, and Hester, 1988; Nickerson and Thibodeau, 1985). Basin mangroves had the highest pore-water sulfide concentrations (0.84 ± 0.29 μM and 0.85 ± 0.25 μM), significantly higher than overwash and fringe habitats for both shallow ($F = 7.027$, $p = 0.005$) and deep ($F = 4.021$, $p = 0.035$) sampling depths (Table 2). We noted that basin habitats are often flooded for extended periods due to the relative elevation and locations within the interior of larger mangrove stands, and thus they

Table 2. *Comparison of stand characteristics and pore-water chemistry by mangrove habitat type.*

Habitat Type	*n*	Canopy Height (m)	Percent Cover	Salinity (ppt)			Redox Potential (mV)		Sulfides (μM)	
				Surface	10 cm	50 cm	10 cm	50 cm	10 cm	50 cm
Basin	12	3.00	67.92	43.25	45.43	47.30	−266.43	−287.33	0.84	0.85
s.e.		*0.48*	*9.05*	*1.49*	*1.96*	*1.94*	*70.95*	*61.01*	*0.30*	*0.25*
Fringe	43	3.64	63.21	39.79	45.64	47.92	−136.43	−188.71	0.19	0.31
s.e.		*0.30*	*6.10*	*1.94*	*1.43*	*1.42*	*41.73*	*47.32*	*0.04*	*0.09*
Overwash	4	1.50	28.75	46.00	52.00	44.75	−149.00	−221.50	0.11	0.10
s.e.		*0.50*	*15.99*	*0.10*	*2.00*	*6.15*	*154.00*	*83.50*	*0.09*	*0.07*

typically accumulate higher sulfides due to dense peat and clay soils and the lack of regular tidal flushing. However, the concentrations noted here are not particularly high compared to mangroves elsewhere, which can have values of 5 μM or higher (Moore, 1997). While differences between habitats were not significant for redox potential, basin habitats did possess the most negative redox values (–287.33 ± 61.01 mV) (Table 2). In contrast, overwash habitats had the lowest sulfide concentrations (virtually zero at a mean value of 0.1 ± 0.08). These results are likely due to the exposed nature of these habitats, the sandy substrate in which they occur, and their regular daily flushing with oxygen-rich ocean water.

DISCUSSION

The national total of mangroves estimated by this study far exceeds all prior published estimates of mangrove areal extent, totaling three times more mangrove across the seven emirates than that reported in the published literature (Saenger, 1997; Saenger *et al*., 2004). There are several factors that likely contribute to the vast discrepancy between the prior published totals and the estimate generated in the present study. First, closer examination of the results shows that a large proportion of mapped mangrove exists as large dense forests (high-density classification), which are found in Abu Dhabi, Umm Al Quwain, and Sharjah equaling approximately 3615 ha, comparable to prior estimates in the published literature (~4000 ha). These dense and often larger stands are easily observed and readily mapped, while smaller, diffuse, and scattered stands are more difficult to find, map, and document. As illustrated in Table 1, if we consider only the high-density stands mapped in Abu Dhabi (estimated at 2481 ha), this is almost identical to totals presented by others (~2500 ha) (Saenger, 1997; Saenger *et al*., 2004). Many of the sparse stands we documented may have been overlooked or nonexistent when prior studies were undertaken 10 or more years ago. Prior estimates were largely derived from *Landsat* data (Multimission Modular Spacecraft [MMS], TM, and Enhanced Thematic Mapper [ETM]), which do not have the spatial resolution needed to document small, isolated stands. The roughly 30 m^2 pixel size of imagery interpolation would inherently omit diffuse stands or patches that did not represent a majority of the cover types in an individual pixel. Additionally, prior estimates used data from much older sources and commonly used remote-sensing approaches only. FAO (2007) cites data from a historic field survey (FAO, 1978) and from Saenger *et al*. (2004), which used aerial imagery from 1999; Althausen *et al*. (2003) used *Landsat* TM (1989) and ETM (1999) data; Loughland *et al*. (2007) used a series of aerial photos, *Landsat* MMS (1992) and TM (1984, 1985, 1988, 1996, 1998, 2000, 2002, 2003); and, finally, Howari *et al*. (2009) similarly used TM (1994) and ETM (2000), while their *Ikonos-2* data were from 2003.

It is possible that the nationwide increases in coverage we mapped are simply a continuation of that upward trend over the roughly 10+ years since many prior estimates were made, given that several authors have documented that mangrove cover has been increasing in selected emirates over time across a study period from roughly 1978 to 2003. The most dramatic increases we noted were in Abu Dhabi, where significant restoration plantings have been undertaken since the 1990s (Ministry of Environment and Water, 2010). Increases in mangrove coverage in Abu Dhabi may also be attributed to increased stormwater and irrigation runoff from impervious surfaces linked to urban development along coastal areas of Abu Dhabi. The resulting decreased salinity in lagoons and near-coastal waters may promote mangrove seedling recruitment as physiological stress is reduced (Loughland and Saenger, 2001). Howari *et al*. (2009) noted evidence that geographic extent of mangrove was increasing over the range of imagery they used from 1994 to 2003, perhaps helping to explain the much higher total mangrove area documented in the present study. Similarly, the success of the mangrove plantings at Ras Al Khor by the municipality of Dubai reflects a significant increase from no prior documented mangrove areas (FAO, 1978) to the 63 ha mapped by the present effort (Table 1). It may be worthwhile for future studies to examine potential genetic differences between areas of mangrove increase versus areas of decline, linking findings to dominant environmental conditions that influence seedling recruitment, growth, and resiliency. This may be of particular value in areas where large-scale mangrove plantings have occurred or where planting stock was derived from other geographies.

In select cases, the current study reported fewer mangroves in some areas than reported by other authors. In Sharjah for example, our estimate documented 204 ha of vegetated mangrove areas in the Khor Kalba Protected Area based on aerial mapping and field verification. However, these findings are not in agreement with the recent Ramsar designation of the protected area, which indicates the mangrove is over 800 ha (The Annotated Ramsar List: United Arab Emirates, 2013), nor other authors who indicate just less than 1000 ha are present at this site (Howari *et al*., 2009). The discrepancy between estimates may lie in the approach used to classify "mangrove." Our approach included only those areas with existing mangrove plants and categorically excluded extensive unvegetated areas occurring outside of forested mangrove. In fact, the coastal wetland area of Khor Kalba encompasses approximately 800 ha, comprising mangrove, unvegetated mud flats, lagoon, and tidal creeks. However, the area characterized distinctly as mangrove is a much smaller subset of the larger wetland system (~200 ha) under present-day conditions.

Based on a review of existing literature, it was not surprising to find that Abu Dhabi contained the most total area of mangrove, regardless of stand density. Furthermore, it represents approximately 86% of the total land area of the UAE and contains the longest extent of suitable coastal habitat (estimated at 495 km, excluding the offshore islands). We did not note mangroves in Fujairah, despite historic reference to some 500 ha noted by FAO (2005). It is possible this discrepancy resulted from an accidental inclusion of the mangroves of Sharjah's discontinuous territory along the Sea of Oman, which is surrounded by Fujairah (Figure 1).

Variation between current and prior estimates may stem from differences in mapping approaches, minimum size requirement for inclusion, and the potential for including salt marsh and other halophyte communities along with mangrove. For example, we often found pneumatophores from gray mangrove extending considerable distance into mud flats and sands beyond the drip edge of the canopy during field verification. When able, we mapped these aerial roots as part of the mangrove area coverage estimate, but these structures would be impossible to see in aerial imagery at even the finest scale. The results presented here, while comprehensive in geographic scope, acknowledge that new mangroves areas may be developing throughout UAE as land-use changes alter tidal regimes, coastal energy, and flow patterns as well as through ongoing coastal restoration actions. In like manner, it is equally possible that other areas are being impacted or lost. As this study shows, it is important to regularly update and refine coastal resource mapping when being considered over such a large and discontinuous geographic area.

CONCLUSIONS

Despite considerable land development and ecological change throughout the country and the region over the last 10–20 years (Althausen *et al*., 2003; Beech and Hogarth, 2002; Howari *et al*., 2009; Kathiresan and Rajendran, 2005; Loughland *et al*., 2007), the areal extent of mangrove appears to have increased overall as compared to all prior published studies. Whether these apparent increases are a localized observation or part of a potential regional or global trend remains to be seen. The latter seems unlikely, as our findings are in contrast to other authors who have demonstrated global mangrove loss over a period from 1980 to 2005 (FAO, 2007). However, the significant increase in newly estimated areas may stem from differences in image/data quality available today, mapping approaches, the geographic extent of the study, or actual increases of mangrove forest since previous estimates were completed. In any case, this study has documented that viable mangrove communities exist in six of the seven emirates, however disparate their size and ecological complexity. In fact, this study noted that while Abu Dhabi has the most total mangrove acreage, several of the smaller emirates have surprisingly high mangrove area relative to their available habitat (*i.e*. length of shoreline). The high ratio of mangrove area to shoreline in Umm Al Quwain, for example, underscores its ecological significance and its potential for consideration as a protected area, as has been done elsewhere in the country. The results of this research are based upon the most up-to-date aerial images and provide a basis for additional mapping and evaluation of both current conditions and a reexamination of historic mangrove estimates in key areas as well.

Documentation of the countrywide extent of mangrove resources builds upon prior mapping efforts and provides a valuable foundation upon which to base current and future conservation, restoration, and management strategies for the country. The changes documented suggest such survey and mapping updates may be valuable in other countries, particularly where land use and development are accelerating at a rapid pace. While valuable, maps alone only document the results of ecological change (*i.e*. forest gain or loss), but they provide little information on causes, contributing factors, or opportunities for adaptive management. The mangrove areal estimates and associated stand characteristics data presented here are valuable in tracking the trajectory of mangrove change in the UAE and provide a current baseline to inform ongoing resource management into the future for the country as a whole.

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