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Are the northernmost mangroves of West Africa viable? – a case study in Banc d'Arguin National Park, Mauritania

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Abstract

In the Parc National du Banc d'Arguin (P.N.B.A.) in Mauritania, the mangroves of the West-African coast reach their northernmost distribution and comprise exclusively *Avicennia germinans*. As a biogeographically marginal, monospecific mangal in an area where freshwater availability has decreased over the last decades, concern about the survival of the mangroves has been expressed. As yet, a description was lacking and no data regarding the fitness of *A. germinans* in the P.N.B.A. were available.

The mangrove and associated vegetation nearby Cape Timiris (southern border of the P.N.B.A.) was mapped in January 1998 and described for the adult, young and juvenile vegetation layer, along the lagoon perimeter of about 4 km. Physiognomic aspects of the mangroves were compared with those of a mangrove formation on the tidal island of Eizin further North and with those of the northernmost mangrove system, in Iouik. Four different formations were found (tall trees, wide trees, shrub and sebkha formations) with 'trees' as small as 30 cm flowering profusely. There were no site-related differences in leaf morphological characteristics. Propagules were available in large numbers but germinated successfully only where protected from the main Sahara wind currents and from the sun. Experiments to investigate the effects of predation or aridity (air exposure) on germination showed an absence of predator influences and that drought did affect viability of propagules. Release of propagules at the time of spring tides may favour colonisation of new areas. Future management plans can consider the collection and broadcasting of fresh propagules, as well as favouring free play of hydrodynamics (including flooding, breaching of barriers) in the system.

Except for inappropriate topographical conditions (mangroves growing in terrestrial locations, with little chance for propagule survival), *A. germinans* did not show signs of reduced vitality at its biogeographical limit.

Introduction

Most mangroves are found between the Tropic of Cancer and the Tropic of Capricorn on all continents. Along the West African coast, mangroves reach their northernmost distribution in the Banc d'Arguin National Park, Mauritania, being composed exclusively of *Avicennia germinans* (L.) Stearn 1958 (= *Avicennia nitida* Jacq. 1760, = *Avicennia tomentosa* Jacq. 1760, = *Avicennia africana* Palisot de Beauvois 1805, according to Tomlinson, 1986). Stretched over more than 180 km Mauritanian coastline (around 20° N) and covering 12 000 km^2 (Gowthorpe, 1993), the Parc National du Banc d'Arguin (hereafter called P.N.B.A.) comprises desert, coastal swamps, small islands and shallow coastal waters. The austerity of the Sahara desert and the biodiversity and productivity of the upwelling marine system in a land and seascape of exceptionally contrasting natural value have seen that this site was inscribed as a World Heritage Site in 1989. A wide variety of migratory birds spend the winter in the P.N.B.A. (Ens et al., 1990), and the monk seal and several species of sea turtle and dolphin, the latter of which are reported to assist fishermen in attracting and containing shoals of fish (Kane et al., 1993), can also be found there (among others Wolff et al., 1993a) and in the adjacent Cap Blanc satellite reserve.

World-wide human interference in mangrove areas has caused substantial changes in both physiognomy and species composition. The ecological and derived socio-economical importance of mangrove areas is however established clearly (Cormier-Salem, 1999; Omodei-Zorini & Contini, 2000; Dahdouh-Guebas et al., 2000) and a will to protect and manage the mangrove ecosystems in general (e.g. Charter for Mangroves, Field, 1995), and for the P.N.B.A. in particular (N'Gaïdé & Nicoll, 1994; Campredon & Gawler, 1998) can be discerned clearly. This is not matched by our understanding of factors governing mangrove establishment, dynamics and regeneration, an ignorance that impedes rational management plans. Socio-economically the mangroves are of little importance to the fisher folk villages in the P.N.B.A. Rather, its biogeographical interest must be considered. It is alarming that, according to Mahé (1985) and Gowthorpe (1993), the region of the P.N.B.A. testifies of the past existence (5000–4000 B.P.) of a more extended mangrove ecosystem (e.g. around Cape Timiris and Bay of St. Jean). Together with a poor regeneration of mangroves highlighted in the General Plan for Research in the P.N.B.A. (Greth, 1994), this could indicate that the disappearance of mangroves at this latitude is inevitable.

The aim of the present study is to provide a description of the mangrove vegetation around Cape Timiris as a reference basis, and to compare it with preliminary descriptions for all other mangrove systems currently known within the P.N.B.A. Descriptions of the vegetation, its structure and its current state, and aspects of regeneration were considered. Factors that could interfere with regeneration, such as aridity or predation stress, were experimentally approached.

Description of the sites studied

The more detailed part of the study was done in and around the Lagoon of Cape Timiris or Râs Timirist (19° 23′ N), located a few kilometers North-West of the village of Nouâmghâr (also referred to as Mamghar) (Fig. 1). One part of the lagoon is locally called Al'Ain, Arab for 'eye', because of the eye-shaped form of the lagoon. We will further refer to this section of the lagoon as Al'Ain, and to the small islet in the middle of Al'Ain as 'Iris'.

Along the Bay of Saint Jean sites lodging mangroves were studied, as well as the northernmost mangrove system a few kilometres north of the village of Iouik (also spelled as Iwik) (Fig. 1). Finally, an inventory was made of the vegetation along two transects on the tidal island of Eizin (Fig. 1). This island is located north of the island of Tidra, between the islands of Niroumi and Arel, as indicated by Gowthorpe (1993).

Materials and methods

Field work was carried out between 18 January and 2 February 1998 and included the spring tide of 28/01/98. Results reported here (e.g. salinity, reproductive phenology, predatory stresses) should thus be interpreted within the frame of this time. Some of these biotic and abiotic factors might be different during other times of the year or during other years. However, there is on average little seasonal variation in temperature and precipitation in coastal Mauritania (Walter et al., 1957). Although a mean precipitation of 24 mm is reported, some years are without any (Dia et al., 1997). Some of the observations were purely descriptive, and were intended to form a basis for further research. In order not to interfere with mangrove regeneration, sampling of propagules was kept deliberately small. The term 'propagule' is frequently used to identify the viviparous structures of numerous mangrove tree species, however, according to some, the structure of the diaspore of *Avicennia* does not allow the application of this term.

A copy of the Map of West Africa at scale 1:200 000 from the French National Geographic Institute (feuille NF-28-11-VIII) was redrawn, enhanced and corrected for Cape Timiris using a compass and one-meter steps after reconnaissance surveys. The maps from the entire lagoon and from the Iris in particular were digitised and combined with our vegetation data described underneath, in order to produce the first maps on a linear scale exceeding that of the currently available maps by more than 40 times.

Every mangrove tree or colony was described [density, colony diameter, D_{130} (term according to Brokaw & Thompson 2000, but formerly referred to as DBH, the diameter at breast height) tree height, reproductive phenological status] around the 4 km long circumference of Cape Timiris lagoon complex, with particular attention to Al'Ain. The Iris was considered to be representative for Al'Ain because of the

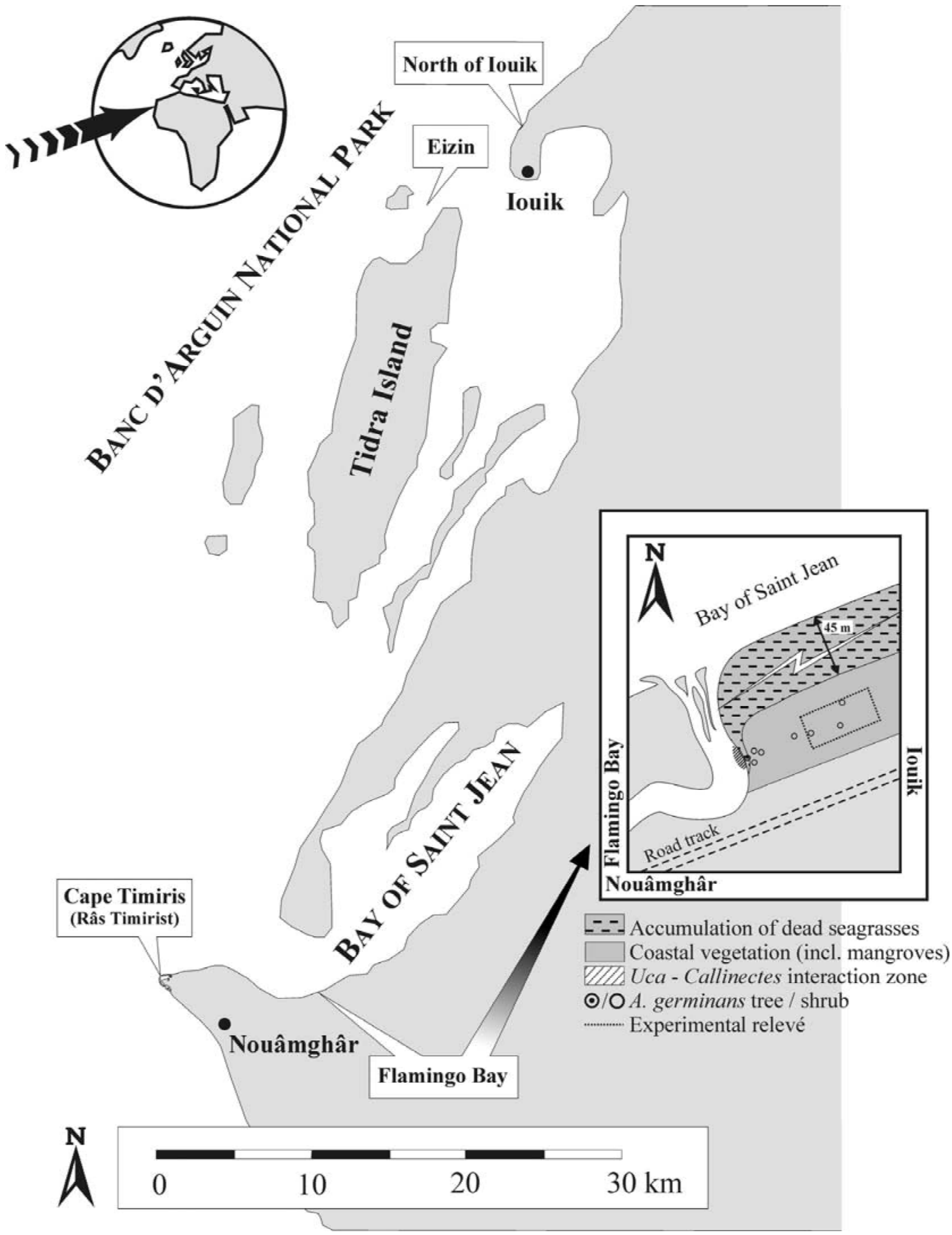

Figure 1. The southern part of Banc d'Arguin National Park (Mauritania, N.-Africa) and the location of our study sites. The connection between Flamingo Bay and the Bay of St. Jean has been given in detail (not on scale).

presence of all different physiognomies for *Avicennia germinans* in a small area of approximately 2500 m^2: relatively large adult trees, shrubs, young plants and saplings (individuals with maximum 3 leaf pairs). Therefore the vegetation of this islet was determined and described in detail. The same was done for a transect of about 200 m, crossing Al'Ain from the Atlantic coast to the Iris, at one-meter intervals.

The few mangroves along the Bay of St. Jean (south-eastern side) were described like the ones around Cape Timiris. The vegetation of the eastern side of the lagoon, which opens to the Bay of St. Jean at its southern bank, was described on a plot of 200 m^2. Since this bay does not have a name on the topographic map, we will refer to it as Flamingo Bay because of the continuous presence of flamingos during our field work there. This area is located at 5 km East Northeast from the Life Base at Nouâmghâr on the road to Iouik.

Each single mangrove tree located in the creek system to the North of Iouik was described like the mangroves around Cape Timiris.

On Eizin, the plant species along two line transects of 400 m were recorded at 1 m intervals. The transects were oriented close to the WNW-ESE direction and the centre of the first transect (−77° N) was crossing the start of the second one (−102° N). Mangrove trees were described like those around Cape Timiris.

In all sites, length and width of 25–197 leaves per population from 11 to 25 different trees per population were measured (different sites were assumed to comprise different populations). A distinction was made between flowering and non-flowering branches, and alternating the left and right leaf of the third leaf pair from the apex was taken for measurement.

On five randomly selected and individually marked branches of a tree, three generations of flowers were followed over a period of 6 days in order to estimate the duration of flowering. The first generation (existing flowers of unknown age) was counted on day 1 or 2, whereas the second and third generation started on day 3 and day 4, respectively.

Three artificial short term plantations, with 10–20 mangrove propagules each, were followed in order to check for propagule predation: underneath adult *Avicennia germinans* trees, in the intertidal zone dominated by the fiddler crab *Uca tangeri* Eydoux and in the infralittoral dominated by the predator *Callinectes marginatus* A. Milne-Edwards. In seven artificial plantations, with 8–33 propagules each, germination of the propagules was followed: in a sand basin (approximately 50 × 50 × 40 cm) dug into the soil, along a land-water transect within transparent PVC bottles from mineral water (1.5 l), and along a land-water transect within small nylon bags (5 × 10 cm, < 1 mm mesh size), all of these experimental settings exposed to the tides. Another plantation was made underneath an adult *Avicennia germinans* tree and one more inside dead coastal seagrass heaps, both of them only susceptible to spring high waters. For the remaining three plantations, propagules were submerged into a humid, saline environment for 5 days after one of the following treatments:

1. Treatment A: collection of fresh and mature propagules found on or underneath an adult individual and exposed to air and sun for 24 h (*n*=16);
2. Treatment B: collection of fresh and mature propagules found on or underneath an adult individual and submerged in a humid, saline (49‰) environment for 24 h (*n*=17);
3. Treatment C: collection of dried/desiccated seeds found on the soil in a zone invaded by desert sand and submerged into a humid, saline environment for 24 h (*n*=15).

Finally, the root systems of 19 saplings were exposed to verify whether the plant originated from a propagule or from the cable root of another mangrove. The choice of the individuals was such that they apparently seemed to follow below ground cable roots, suggesting development from the latter.

Salinity (using an Atago hand refractometer), light intensity (using a Lutron luxmeter) and topography (using water tubes and recording differences in height at regular intervals) were measured and described in every site.

Results

Distribution of mangrove stands

The location, vitality and physiognomy of the mangroves around Cape Timiris is shown in Figures 2 and 3. To visualise the vitality, the mangrove vegetation was subdivided into four classes according to their density and regeneration state:

1. dense mangrove, forming a visual screen (cf. Fig. 3c);
2. intensely regenerating mangrove, which has a relatively high presence (> 0.05 m^{-2}) of small individuals or saplings, defined as a young plant with more than 6 leaves;

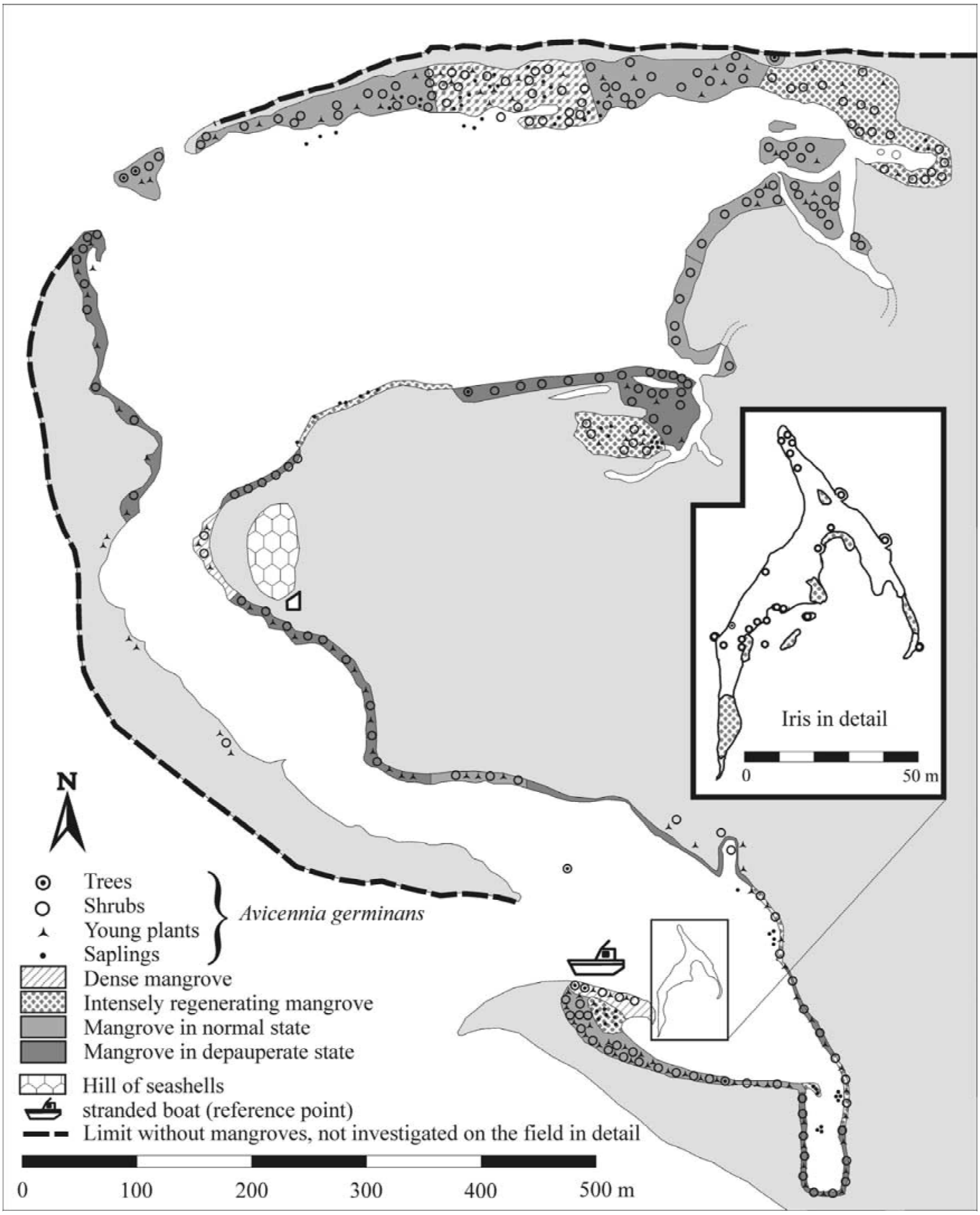

Figure 2. Physiognomy of the mangroves (trees, shrubs, young plants or saplings) and their vitality around Cape Timiris. Except for the trees in general and for all plants on the detailed map of the 'Iris', the mangrove vegetation symbols do not necessarily correspond with actual numbers of individuals, but are rather a relative representation.

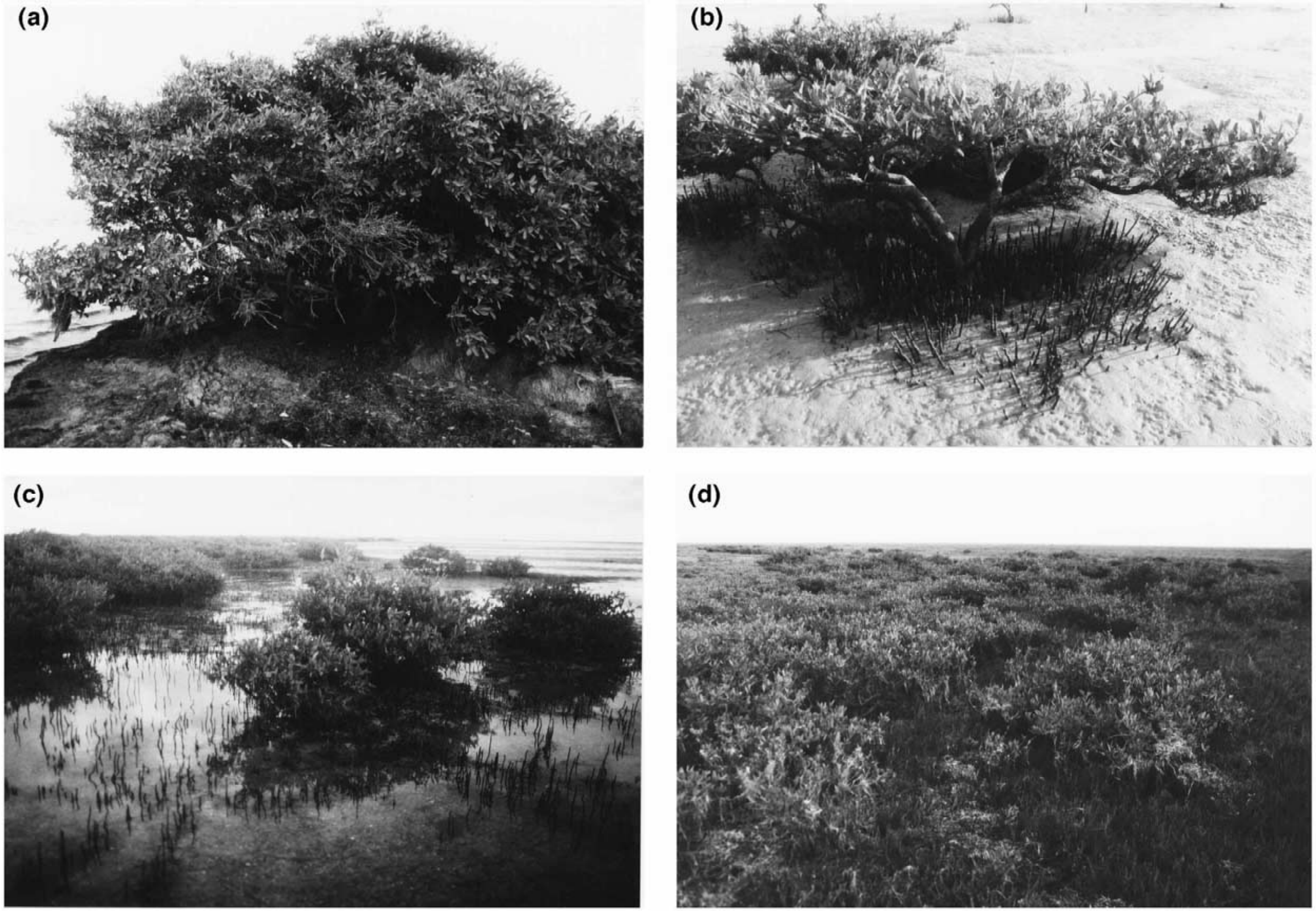

Figure 3. Physiognomies of *Avicennia marina* in Banc d'Arguin National Park. (a) Tall, adult tree with height of 4.8 m (Cape Timiris, Atlantic shore). (b) Wide, adult tree with a height of 1.2 m (Eizin). (c) Dense, shrub formation of 1.4 m height on average (Cape Timiris lagoon). (d) 'Sebkha'-like formation of 0.8 m height on average (Cape Timiris lagoon, photograph taken towards desert). All of these *Avicennia* types were able to flower.

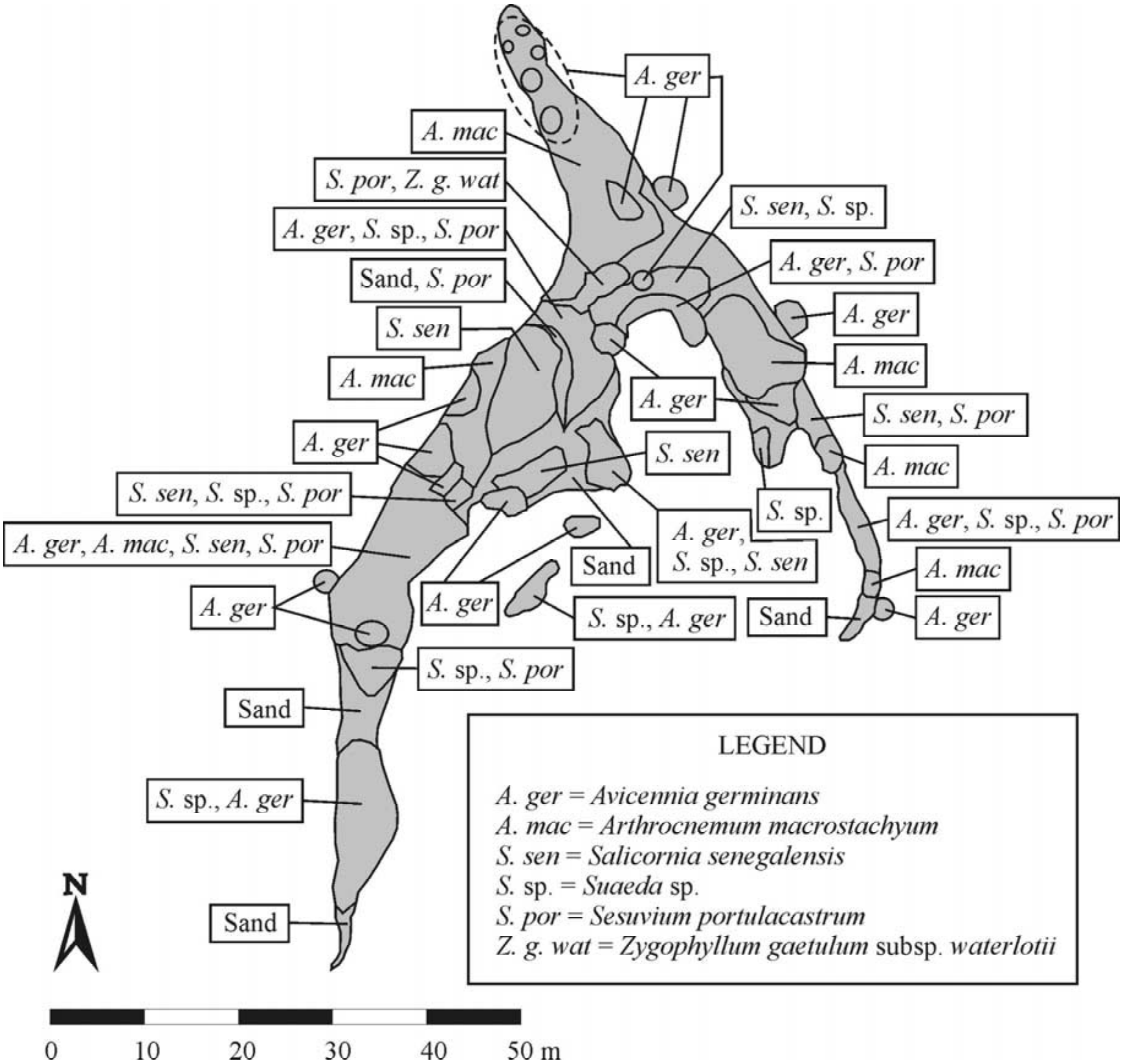

Figure 4. Vegetation assemblages (both mangrove and non-mangrove) on the 'Iris' in Al'Ain (Cape Timiris).

3. mangrove in a depauperate state with desiccated or malformed leaves or propagules;
4. mangrove in an apparently 'normal state', which includes mangroves that do not fall into one of the former categories.

The mangroves located on the Iris are shown in detail in the box in Figure 2, and in Figure 4 the different assemblages of vegetation, including *Avicennia germinans*, *Arthrocnemum macrostachyum* (Moric.) Moris & Delp., *Salicornia senegalensis* A. Chev., *Suaeda* sp., *Sesuvium portulacastrum* (L.) L. and *Zygophyllum gaetulum* Emberger & Maire subsp. *waterlotii* (Maire) Dobignard, Jacquemoud & Jordan (nomenclature according to Lebrun, 1998). Salinities measured within Al'Ain around 26 January 1998 are mapped in Figure 5.

Stand characteristics

The vegetation of the transect crossing Al'Ain from the Atlantic coast to the Iris corresponds with that observed on the Iris (Fig. 3), except for *Z. gaetulum* subsp. *waterlotii* which was absent along the transect.

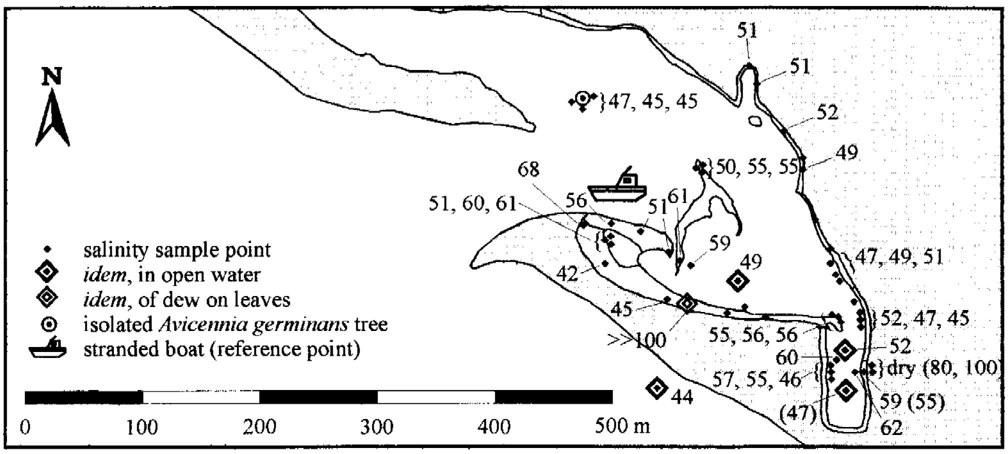

Figure 5. Salinity map (in ‰) from the southern section of Al'Ain (Cape Timiris) around January 26, 1998.

The junction between a marine creeklet (with the predator *Callinectes marginatus* at 3–4 specimens m^{-2}) and the mangrove-seagrass intertidal zone with the prey crab species *Uca tangeri* (>50 specimens m^{-2}) at the connection between Flamingo Bay and the Bay of St. Jean, makes this a site with strong interactions between predator and prey, and among predators. The present densities observed for *C. marginatus* – about the same densities were observed in Al'Ain – are 3–10 times higher than previous records of 1 specimen per 1–10 m^2 (Wolff et al., 1993b).

In and around our experimental relevé, the soil consists of a peaty substrate, originating from accumulations of dead *Zostera noltii* Hornem. and *Cymodocea nodosa* (Ucria) Aschers. (amongst others) seagrasses accumulations, on a sandy soil layer, which is brought to the surface by *U. tangeri*. In and around our experimental relevé, this crab seems to play an important role in mixing organic and inorganic material in the soil by its burrowing activities. The total cover of the vegetation in our plot of 200 m^2 was 70%, of which 65% was located in the herb layer, dominated by *Sesuvium portulacastrum* (about 60%) and some *Suaeda* sp. individuals (about 5%). The remaining 5% was in the shrub layer (1 m and above), where one *Arthrocnemum macrostachyum* and one *Avicennia germinans* individual were present.

In Iouik, at the northernmost biogeographical limit, the mean height (±S.D.) of the 11 *A. germinans* trees or colonies present, was 1.32±0.60 m, and the flowering and fruiting percentages were 72.7% and 36.4%, respectively. The same parameters for the 41 trees along the two 400 m transects on Eizin were 1.16±0.26 m, 97.6% and 65.9%, respectively. Apart from *Avicennia germinans* only two plant species were present along these transects: cf. *Spartina maritima* (Curt.) Fern. and *Zostera noltii*. The transects are shown in figure 6 (a and b). Elsewhere on Eizin also *Sporobolus virginicus* (L.) Kunth was observed.

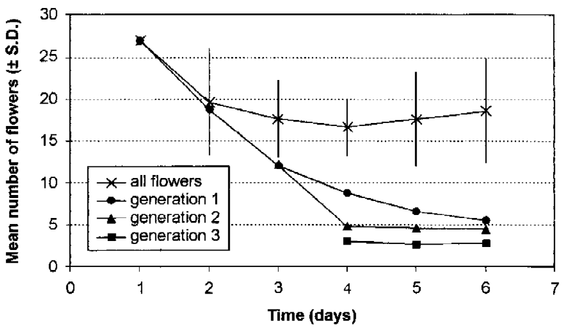

Figure 6. Evolution of the mean number of flowers on 5 branches (± standard deviation for the total number of flowers) of *Avicennia germinans* as a function of the time (in days).

Flowering and leaf characteristics

The record on *Avicennia germinans*' flowering period is shown in Figure 6. Figure 7 shows the association between leaf width and length for all leaf samples. There was no difference between leaves originating from flowering branches and leaves originating from non-flowering branches, or between leaves from different sites (confronting linear regressions between sites gave the following ANCOVA results: F (intercept) = 0.939; d.f. = 3 & 357; n.s.; and F (slope) = 1.365; d.f. = 3 & 360; n.s.). The data in Figure 7 do not show a distinction based on shape either. Leaf shapes of *A. germinans* mangroves could be typified

Table 1. Results of experiments on the predation of *A. germinans* propagules in Al'Ain (Cape Timiris). The numbers given are cumulative (since beginning of experiment)

Date	Intact propagules			Lost
	pericarp closed	pericarp split	rooting	propagules
(a) Predation site located on *Uca tangeri* mudflat				
21/01/98 (initial)	10	0	0	0
22/01/98	10	0	0	0
23/01/98	10	0	0	0
24/01/98	10	0	0	0
25/01/98	10	0	0	0
26/01/98	5	5	0	0
(b) Predation site located under adult *Avicennia germinans*				
21/01/98 (initial)	10	0	0	0
22/01/98	10	0	0	0
23/01/98	8	0	0	2
24/01/98	8	0	0	2
25/01/98	8	0	0	2
26/01/98	8	0	0	2
(c) Predation site located in dead seagrass accumulations				
20/01/98 (initial)	8	0	0	0
21/01/98	8	0	0	0
22/01/98	8	0	0	0
23/01/98	7	0	1	0
24/01/98	7	0	1	0
25/01/98	6	0	1	1
26/01/98	4	2	1	1

approximately within a range from a short elliptical shape (about 2.5 times longer than wide) to a lancet shape (more than 4 times longer than wide), but these types did not associate with particular sites.

Results from visual observations have been included directly into the discussion section.

Predation and germination experiments

The results of the predation experiments on the *Uca tangeri* mudflat, under adult *A. germinans* trees and in dead seagrass accumulations are shown in Table 1. Of the 20 propagules in the *Callinectes marginatus* area, 7 propagules or labels were lost during the spring high tide. Of the remaining propagules, one had rotten, two had split and nine had germinated by the following day. The results of the germination experiments in the basin and along the transects are given in Table 2. The results of germination experiments with *A. germinans* propagules with pericarp closed, which were submerged after various treatments are: 12 (75%), 2 (12%) and 15 (100%) with no change, and 4 (25%), 15 (88%) and 0 (0%) with a split pericarp, for treatment A, B and C, respectively, indicating highly significant differences between dry seeds or seeds exposed to air and sun and fresh seeds ($\chi^2 = 28.321$; d.f. = 2; $p < 0.001$). Exposure of the root system of 19 saplings with a distance to the nearest adult tree ranging from 0.5 to 9.5 m revealed that 17 were originating from propagules (showing no possible connection to any cable root), whereas no conclusive result could be obtained on the remaining two.

Discussion

Compared with *Avicennia marina* (Forsk.) Vierh. growing in the United Arab Emirates at about 25° N (ElAmry, 1998), *Avicennia germinans* apparently does well at the Banc d'Arguin National Park, at least in Al'Ain and Iouik, the northernmost population. From the point of view of general appearance, the Eizin population appears to perform less well in that it is rather stunted and crooked. Hardly any dead wood and no sign of exploitation or grazing was observed in any of the sites. Although the mangrove is generally small in size and even displays a dwarf growth, there seems to be regeneration in the middle of stands, judging from propagule production or the density of juveniles. Saplings were found in depressions protected from wind and waves, and inundated at (spring) high tides, except in the daily flooded Eizin island. Some young plants less than 40 cm tall were already flowering luxuriously, yet without ever bearing fruits, unlike taller trees observed at the same time.

Flowering in Avicennia germinans

Although single flowers of *A. germinans* can flower for at least 5 days, we could not discern a clear phenology. There is no indication for a maximum flowering period and potential for propagule production, some flowers desiccate quickly, others remain for longer periods. Considering the number of flowers per inflorescence and the individual flowering time, the inflorescences indicate flowering for at least several weeks. A majority of the flowers did not appear to form propagules. Similarly, for *Avicennia marina* it has been reported that one third of the flower primordia survive to become open flowers, but only 3% survive to produce viable fruits (Clarke, 1995). At the P.N.B.A., the

Table 2. Results of germination experiments on *A. germinans* in a basin and along the transects in Al'Ain (Cape Timiris). Spring tide was on 28/01/1998

(a) Propagules contained in a 50 × 50 × 40 cm sand basin

Date	Intact propagules			Lost
	closed	open	germinating	propagules
22/01/98	18	0	0	0
22/01/1998 after 2h	16	2	0	0
22/01/1998 after 4h	14	4	0	0
23/01/1998 AM	7	11	0	0
23/01/1998 PM	7	11	0	0
24/01/98	7	11	0	0
25/01/98	6	12	0	0
26/01/98	3	11	0	4

(b) Propagules contained in transparent PVC bottles along transect

Date	Number of open propagules of an initial 3										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
22/01/98	0	0	0	0	0	0	0	0	0	0	0
23/01/98	0	0	2	1	2	2	2	2	3	3	L
24/01/98	0	0	2	1	2	2	2	3	3	3	L
25/01/98	0	0	1	L	3	2	2	3	3	3	L
26/01/98	1	L	L	L	L	L	L	L	L	L	L

B1 = landside; B11 = seaside of intertidal zone; L = all propagules lost.

(c) Propagules contained in nylon bags along transect

Date	Number of open propagules of an initial 3										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
22/01/98	0	0	0	0	0	0	0	0	0	0	0
23/01/98	0	0	0	0	0	1	1	1	2	1	2
24/01/98	0	0	0	3	1	1	3	1	3	2	2
25/01/98	0	0	1	3	3	3	3	2	3	3	3
26/01/98	0	0	3	3	3	3	3	3	3	3	3

B1 = landside; B11 = seaside of intertidal zone.

flowers were visited (but not necessarily pollinated) by ants, flies, butterflies and wasps (the latter observed only in Iouik) in decreasing order of frequency of casual observations. A long flowering period is not necessarily correlated to a long fertility period.

Propagule production in A. germinans

Propagule production is irregular: certain individuals produce no propagules, while nearby others produce many. Inflorescences might seem desiccated after the flowering period. Whereas *Avicennia germinans* has been reported to reach a reproductive stage when plants are 2–3 m tall elsewhere (Lescure, 1980), in the P.N.B.A. shrubs of 1–1.5 m can be as fertile as trees. However, no propagules were observed on plants of less than 1 m, even though these were often flowering profusely. Where observed, propagules seemed to grow protected from the main Sahara wind currents, which have been reported to blow up to 8 m sec^{-1} in the P.N.B.A. (Monod, 1977). It is possible that for the whole mangrove of the P.N.B.A. propagule production is rather restricted (i.e. intense flowering and propagule density not correlated). It is common that plant species at their biogeographical limit display a decreased fertility, preceded by a geographically decreasing flowering, as for instance in *Avicennia marina* (Duke, 1990). The latter was not observed, but decreased fertility could be a problem for *Avicennia germinans* in the P.N.B.A.

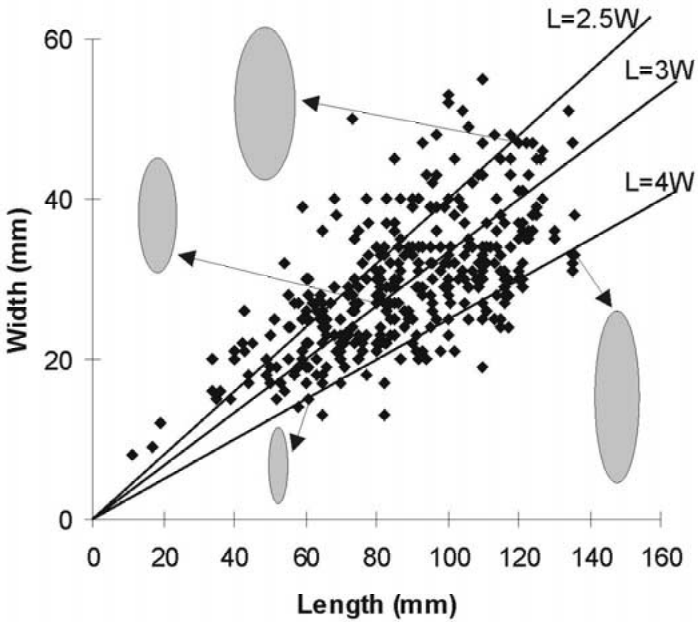

Figure 7. Association between the length and width of 364 *Avicennia germinans* leaves sampled around Cape Timiris, in Flamingo Bay, in Iouik and on Eizin. The three lines indicate three length/width (L/W) ratios and shaded areas show some typical leaf shapes.

Predation of A. germinans *propagules*

Recently, much evidence of the possible impact of brachyuran fauna on mangrove regeneration (among others McKee, 1993; McGuinness, 1997; Dahdouh-Guebas et al., 1998; Dahdouh-Guebas, 2001) has been published. However, in the P.N.B.A. no predation was observed in the intertidal zone occupied by *Uca tangeri*, which implies also the absence of predation by birds or fish in this area. The experimental problem encountered due to water dynamics (waves, tides) in the infralittoral zone occupied by *Callinectes marginatus* and the consequent loss of propagules and labels did not affect the interpretability of the results. Indeed, the propagules that were recovered (65%), did not show any sign of predation, which would imply the absence of predation by fish or other crustaceans as well. The artificial plantations under the adult *A. germinans* tree and in dead seagrass accumulations also remained intact, leading to the overall conclusion that in the P.N.B.A. predation at the early stage is not a factor in the establishment of its mangroves.

Germination of A. germinans *propagules*

A problem for mangrove regeneration in the P.N.B.A. is the dropping of propagules in environments that limit their development, often dry desert sand. In addition, an air and sun exposure of 24 h, which is compared to a natural situation a 'mild' treatment, is enough to kill the propagules. This short-term die-off has been observed for *Avicennia marina* also (Osborne & Berjak, 1997). On the accumulations of dead seagrasses (*Cymodocea nodosa* and *Zostera noltii*) or under parental trees, naturally germinated propagules were observed. At the western side of the island of Tidra for the second consecutive year a small *Avicennia* population of young individuals (0.5–1 m height and flowering) was reported on dead seagrass accumulations (Tom Van Spanje & Otto Overdijk, pers. comm., 1998). Many young plants were also observed in sebkhas[1], located behind the mangrove amongst the terrestrial vegetation and only flooded via small creeks at spring tides. It is during such spring tides that propagules are transported into these sebkhas and develop further.

Submerged in water with a salinity between 40 and 50‰, both naturally fallen and artificially gathered propagules develop (splitting and shedding of the pericarp, rooting of the radicle and opening of the cotyledons) within a few hours. This ability is conserved for at least a week when the propagule is kept in humid,

[1] *Sebkha*, a common wetland type in arid or semi-arid regions, is a North-African vernacular name for a natural, shallow, salty depression.

saline and shaded conditions. This development is the reaction of a living propagule and not a mechanical one due to water absorption, since propagules that were collected in sand or which were exposed to the sun did not behave in the same way.

Growth of A. germinans

Often fresh, green shoots are observed on the plants. Apart from these, other leaves are frequently covered with a layer of red dust. A majority of the leaves have salt crystals on their adaxial surface (which is typical for *Avicennia*, Tomlinson, 1986), which redissolved in the morning dew, causing very high NaCl concentrations ($>120‰$). The leaves of *A. germinans* did not show traces of herbivory by camels, goats, gazelles, insects, gastropods or any other animals (though most mangroves are easily accessible by land), neither did they show signs of disease. Grasshoppers and dragon-flies were observed in the foliage of the mangroves. Occasional deformations of the mangrove leaves seemed to have been caused by mechanical injuries (wind) or by desiccating atmospheric condition in the early stage of leaf development. Pore or open water salinity is not a differential factor for the vitality of the mangrove. One could expect a relationship between salinity and mangrove vitality, height, flowering, leaf area and so forth, but such a relationship was not apparent, even though interstitial and water salinity varies between 40 and 80‰, with peaks up to 100‰. A relationship between salinity and tree height for instance was absent ($r = 0.19$; d.f. = 7; n.s.), yet for other *Avicennia* species a clear relationship between these variables has been observed (Dahdouh-Guebas et al., subm., pers. comm.). The most probable relationship is that between salinity and seedling growth, as reported for *Avicennia alba* Blume (Dourado & Fong, 1983).

Leaf dimensions varied widely although there was no evidence from this study that larger leaves were likely to desiccate or that long, narrow leaves were more fragile. The leaf dimensions were not related to soil salinity (possible drought stress).

Randomly amplified polymorphic DNA (RAPD) analysis of 30 leaf samples of different *A. germinans* individuals for each of the populations visited, done in the Genetic Diversity unit of the laboratory of General Botany and Nature Management at the Free University of Brussels, preliminarily suggests that, based on genetic characteristics, the *A. germinans* population from Eizin slightly differentiates from the mainland populations at Iouik, Bay of St. Jean and Cape Timiris (Pushpa Abeysinghe & Ludwig Triest, pers. comm., 1999).

Although Mauritanian mangroves may be under biogeographical retreat, there is, on the basis of our 1998 survey, no indication of an immediate threat to their survival. However, to maintain the mangroves, the management of the P.N.B.A. may consider a number of recommendations. First, the dynamics of small creeks and of the coastal dunes should be preserved and interference of motorable tracks with the system, as actually happens, should be avoided. Second, one could also consider the artificial dispersion of propagules, broadcasting them in the lagoon water, particularly those from the desertified zone in the southern extreme of Al'Ain, where no propagules apparently have any chance of survival. Depending on the degree of interference desired, a regeneration plot may be considered. However, for a region of high biogeographical importance for *Avicennia germinans* such as the P.N.B.A., the genetic diversity pattern, and the northernmost occurrence and vitality of this species throughout the entire Atlantic biogeographical region or smaller geographic scales (cf. Duke et al., 1998) must be further investigated.

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