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Lemna tenera Kurz, a little known species of *Lemnaceae*

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1. INTRODUCTION

Lemna tenera was described first in 1871 by S. KURZ. He collected the species in December 1870 in the Pazwoodoung Valley near Pegu in Burma. HEGELMAIER (1895) completed the description. At this time flowers and fruits were still unknown. DAUBS (1965) did not mention the species in his monography. However, VAN DER PLAS (1971) in his treatment of the *Lemnaceae* for "Flora Malesiana" gives an accurate description with figures and more localities. At one of these samples he saw also flowers and assumed from the morphological characteristics that flowering fronds float on the surface of the water, in contrast to the vegetative ones which are submerged. Up to 1980 the following localities became known apart of the type locality in Burma (LANDOLT 1986).

Malaysia: Beruas (Ridley 1891: L, SING) ; Penang, Prai (Nur 1892: L, SING)
Singapore: Geylang (Ridley 1899: L, SING), Sarengoon (Möller 1897, with a few flowers: L, SING; Ridley 1899: SING), Tanglin (Jan 1893: SING), Telok Kuran (Ridley 1890: L, SING), Thong Hoe (Sinclair 1949: L, SING).

The present author tried to collect living material of *L. tenera* in Singapore (1981), Malaysia (1981, 1984, 1986) and Thailand (1989). But he was unable to detect any occurrence.
In Singapore, the localities are built over. The two localities in Malaysia are

in regions which are now rather densely populated. *Lemnaceae* are not rare in this region, but the species found occur mostly in eutrophic water. Since I did not know the special biotope of *L. tenera* I collected only near the roads. Therefore, the possibility remains that *L. tenera* can still be found in less populated areas. VAN DER PLAS (1971) describes its habitat rather globally as "in ditches and ponds, in rice-lands often together with *L. perpusilla* (= *L. aequinoctialis*), at low altitude, in swamp forest (KURZ), rare".
In 1988 I received a specimen of *L. tenera* for verification from C.R. Dunlop, Palmerstone, N.T., Australia. The species was collected by B. Bailey in the Condorl Waterhole (12°37', 132°52'), Kakadu National Park , N.T., Australia. This discovery was quite amazing since *L. tenera* was thought to be an endemism of Southeastern Asia (Singapore, Malysia and Burma) and the closest occurrence, concluded from herbarium specimens, was in Singapore, c. 3500 km to the Northwest of the new locality.
To look at the biotope of the species and to collect living samples I decided to visit the locality in the Northern Territory. The field trip was performed in August 1990. The route is shown in Fig. 1.

Acknowledgements
I am very grateful to Mr. Ian Cowie, experimental scientist at CSIRO Division of Wildlife and Ecology, Winnelie, N.T., Australia. He kindly gave us all needed information, arranged the accommodations and accompanied us during several days. He drove us to the locality of *L. tenera* at Condorl Waterhole where we found the species. Without his guidance we probably would never have found the site since *L. tenera* did not show up at the edge of the water-hole. We had to walk several hundred meters to get to the locality in a *Melaleuca* swamp. I also thank the authorities of the Australian National Parks and Wildlife Service for granting permission to conduct scientific research in Kakadu National Park and to the Conservation Commission of the Northern Territory for other parks. Rick Hope showed us *Lemnaceae* sites in the surroundings of Wildman Ranger Station. During the trip I was accompanied by Walter Lämmler, Zürich , who assisted in the field. Anita Hegi prepared the scientific accessories, cared for the living cultures and prepared the figures, and Erwin Schäffer and Katharina Rentsch Brassel analysed the water samples. The photographs of the cultivated fronds were taken by René Graf. Hans-Ruedi Binz assisted in statistics and Anny Honegger prepared the manuscript for printing. I am very thankful for all this assistance.

2. FIELD OBSERVATIONS

L. tenera was found in the following places (Fig. 1):

1. Kakadu National Park. Corndorl Waterhole.12°39'/132°52'. *Melaleuca* swamp (*M. leucadendra, M. argentea*), along the edge of the forest. leg. I. Cowie, E. Landolt, W. Lämmler. 6.8.1990. 22/90

2. Kakadu National Park. Condorl Waterhole. The same place as 1, but c. 100 m to the South. 23/90
3. Kakadu National Park. Mudginberri. 12°35'/132°52'. *Melaleuca* swamp. leg. I. Cowie, E. Landolt, W. Lämmler. 6.8.1990. 25/90.
4. Kakadu National Park. Nourlangie Camp. 12°36'/132°34.5'. *Melaleuca* swamp. leg. E. Landolt, W. Lämmler. 9.8.1990. 43/90.
5. Kakadu National Park. Nourlangie Camp. The same place as 4, but c. 70 m apart. 44/90.
6. Daly River area. Nancar Billabong. Northern end. 13°48.5'/130°43.5'. *Melaleuca* swamp. leg. E. Landolt, W. Lämmler. 19.8.1990. 85/90.

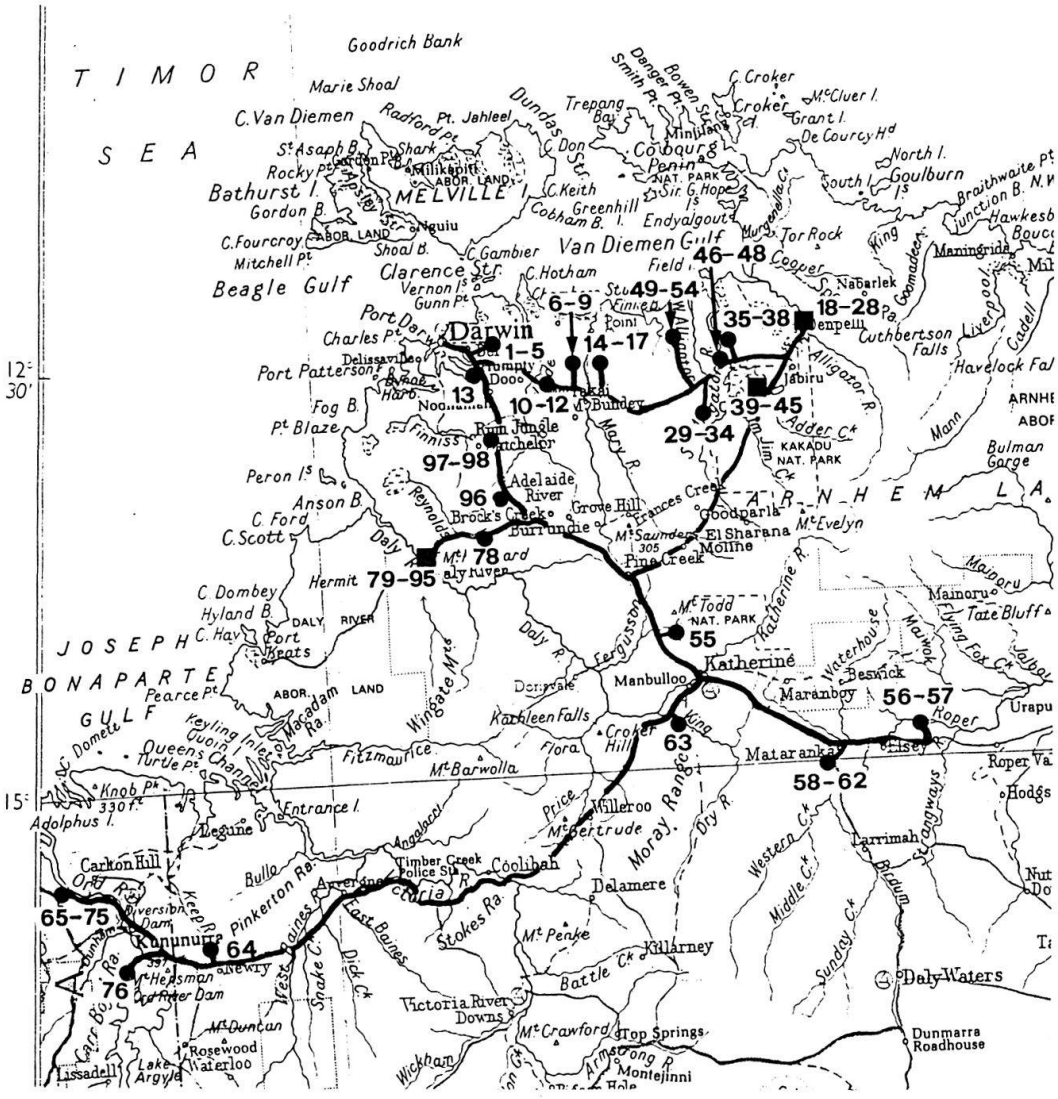

Fig. 1. Route of the field trip through Northern Territory.
● = localities of sampling with collection No.
■ = localities with *Lemna tenera*

Altogether 98 water sites with and without *Lemnaceae* were sampled. Thirty-two out of the 55 waters with *Lemnaceae* contained more than two species of lemnids (Table 1).

Table 2 shows that *Lemnaceae* grow only in waters which are not too poor in nutrients. Especially phosphorus and nitrogen content and conductivity are clearly different in waters with and without *Lemnaceae*. *Azolla* grows in water with low conductivity, low potassium, calcium and magnesium and especially with low nitrogen and phosphorus content. The waters with *Lemna tenera* are similar to those with *Azolla* except for more nitrogen and phosphorus. The phosphorus content is the lowest one for all *Lemnaceae* sites, the nitrogen content is comparable with the other *Lemnaceae* waters. Waters with *W. angusta* have the highest value for all measured factors except Fe, Mn and N which are similar to other *Lemnaceae* waters. We can conclude that waters with *L. tenera* are compared with waters of other *Lemnaceae* extraordinary low in K, Ca, Mg and P.

Interestingly, the habitat of the visited localities with *Lemna tenera* in the Northern Territory always consisted of a *Melaleuca* swamp which, in the middle of August, was still covered by a 20-70 cm deep water layer (Fig. 2). The fronds occurred only at shaded places. They grew submerged (Fig. 3) except at Nourlangie Camp where most fronds floated on the surface of the water. We did not observe any flowers.

Outside of Australia the genus, *Melaleuca*, is distributed with one species (*M. leucadendra*) throughout the whole area of *Lemna tenera*. It is possible, but not at all sure that *Melaleuca* is typical for the *L. tenera* sites. *M. leucadendra* produces cajuput oil containing cineol and some antiseptic derivatives of phloracetophenon (HEGNAUER 1969, 1990). This and the shade might keep competing species from invading the site. It is not known if *L. tenera* of Southeast Asia also grows only in *Melaleuca* swamps. The type collection from Pegu, Burma cites forest swamps as the habitat. From Malaysia and Singapore there is only one sample (Prai) with a habitat indication ("rice fields"). If this indication is true, it must most probably be a secondary habitat, the species coming from a nearby forest swamp. FINLAYSON et al. (1989) mention as habitat: billabong, seasonally inundated plain and permanent swamp. From our experience in Australia, the habitat of *L. tenera* is restricted to forest swamps. It might be that the waters can be permanent. At Nourlangie Camp we saw some places with *Lemna tenera* drying out. *L. tenera* was floating on the surface of the water but not flowering or fruiting.

Table 1. Relevés of *Lemnaceae* communities in the Northern Territory.

No. of relevés	22	24	25	27	43	44	85	45	2	40	90	89	88	92	83	36	93	30	17	9	8	26	19	53	51	11	12	14	15	37	61	82	80	81
Azolla pinnata	2	2	2	+	2	2	2	1	1	4		4	4	1	2	2	3		3	3	3	+			3	3		3	3	1				
Spirodela polyrrhiza	+	1					1		1		2	2	1	1	2	2	2	3	3	1						3	3	2	3	2		3	2	3
Lemna aequinoctialis	1	2		2	4	3		+		+	2		+			1	1	2	2	2	1	2	2	2	4					1			
Lemna tenera	2	2	3	1	3	2	4	+																1	2	3	2	1	2	4	4	2	1	2
Wolffia angusta																																		
Utricularia cf. *aurea*	2	1				3		2		3		2	2								1													
Salvinia molesta			4	4							2	2	2	1								4	4			+								
Hydrilla verticillata											2			1	3	2		4	3	3			3		2	3	3			1		3	2	2
Ceratophyllum demersum											2			1																	3			1
Utricularia cf. *gibba*									1										1															
Ceratopteris thalictroides																												+	+					
Pistia stratioides																																		

Table 2. Characteristics of the water samples collected in Northern Australia.
a = mean of all 55 samples with *Lemnaceae*, b = mean of 43 samples without *Lemnaceae*, c = mean of the eight samples with *Lemna tenera*, d = mean of the 17 samples with *Wolffia angusta* (six of which contained only *Wolffia*), e = mean of 28 samples with *Spirodela polyrrhiza*, f = mean of 31 samples with *Lemna aequinoctialis*, g = mean of 41 samples with *Azolla*, h = mean of 15 samples without *Lemnaceae*, but with *Azolla*.
To calculate mean and standard deviation all values except pH were transformed to ln(1+x). Na, K, Ca, Mg, Fe in mg/l, Mn, P(total) and N(total) in µg/l. In brackets the standard deviation (exponentiated from the logarithmic value).

	pH	cond.	Na	K	Ca	Mg	Fe	Mn	P	N
a	7.6(0.4)	147.7(2.4)	12.4(3.2)	3.0(2.4)	6.7(2.6)	5.6(2.6)	3.5(1.6)	6.0(2.6)	26.2(2.7)	250(32)
b	7.9(0.3)	119.7(3.2)	10.4(4.6)	1.9(2.4)	5.2(3.5)	4.8(3.7)	3.3(1.6)	3.2(1.9)	9.7(1.7)	52(32)
c	7.3(0.2)	66.9(1.5)	5.7(2.2)	0.9(1.5)	1.8(1.3)	1.8(1.2)	3.9(1.4)	5.6(1.8)	19.6(1.7)	229(18)
d	7.7(0.3)	223.7(1.7)	20.0(2.3)	4.7(2.4)	11.0(2.0)	8.8(2.2)	3.3(1.6)	5.3(2.7)	33.9(2.8)	206(40)
e	7.6(0.3)	163.7(2.4)	12.7(3.3)	4.2(2.4)	8.0(2.6)	6.7(2.6)	2.8(1.6)	5.6(2.3)	28.7(2.7)	226(29)
f	7.4(0.3)	103.3(2.3)	8.8(3.2)	1.8(2.1)	4.2(2.2)	3.5(2.1)	4.1(1.6)	6.3(2.7)	25.0(2.6)	264(34)
g	7.6(0.3)	86.4(1.8)	6.2(2.0)	1.5(2.0)	3.2(2.1)	2.9(2.1)	3.7(1.5)	4.5(2.0)	15.1(2.6)	133(32)
h	7.7(0.3)	66.7(1.4)	4.7(1.4)	0.9(1.6)	2.0(1.7)	1.8(1.5)	4.2(1.4)	1.5(2.8)	8.5(1.7)	67(35)

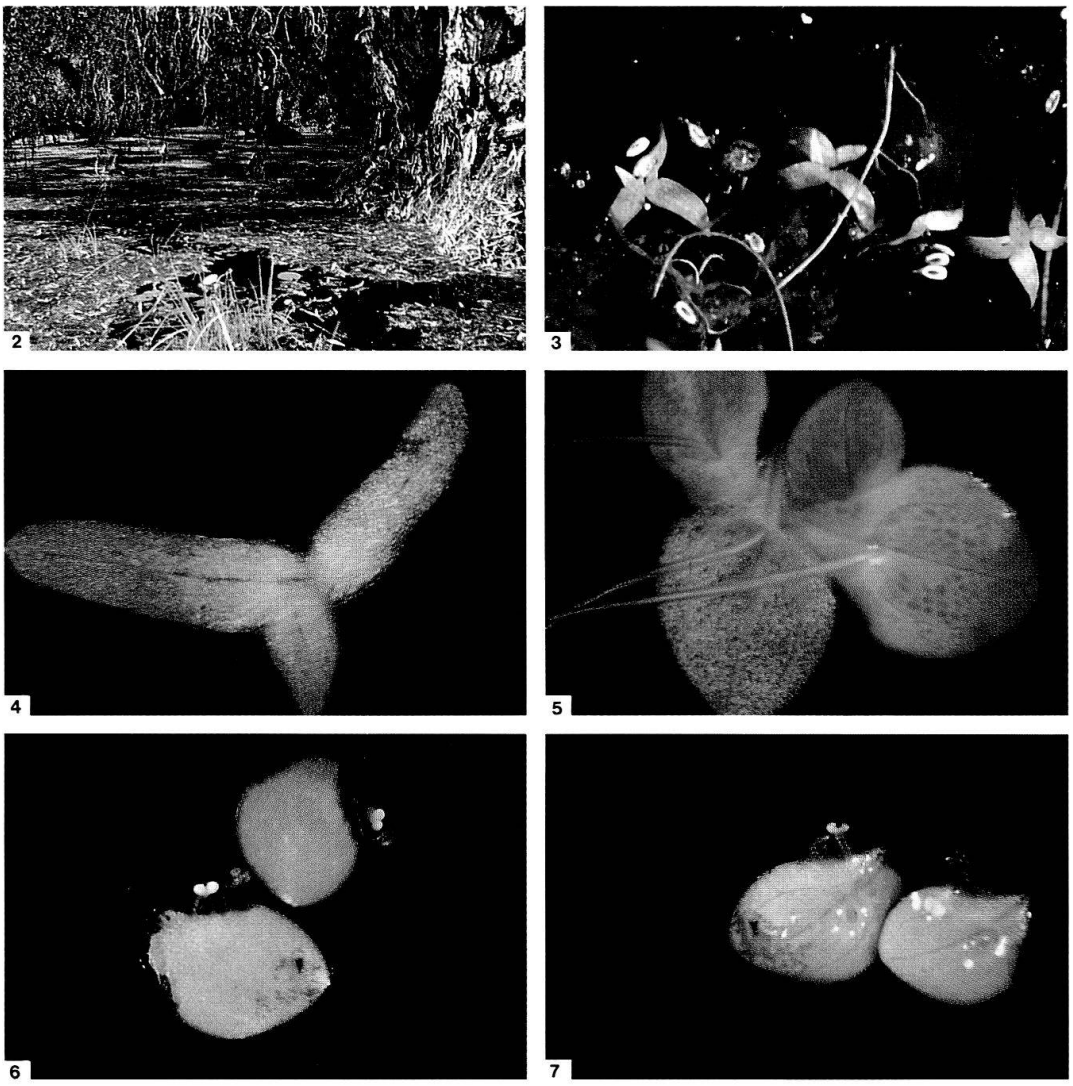

Fig. 2. Condorl Hole (Kakadu National Park) with the *Lemna tenera* site (under *Melaleuca* trees)
Fig. 3. *Lemna tenera* fronds floating below the surface of the water at the natural site (Condorl Hole) (nat. size)
Fig. 4. *Lemna tenera* frond groups, cultivated in a baker with tap water, placed in a shadowy place in the laboratory in Zürich and floating below the surface of the water (6x) (No. 9020)
Fig. 5. *Lemna tenera* frond group (from below) cultivated aseptically in Hutner solution and 1 % sucrose ; fronds floating on the surface of the water (6x) (No. 9024)
Figs. 6 and 7. Flowering fronds of *Lemna tenera* from above and below (6x) (No. 9024)

3. GROWTH IN ASEPTIC CULTURE

In Zürich, three aseptic strains of *L. tenera* were grown in Hutner solution (1/5) with addition of 1% sugar, of 1% sugar and 0. 01 g/l EDDHA and of 1% sugar and 0.005 g/l EDDHA at 25°C and 15000 Lux white fluorescent light (+ incandescent).
Some of the original samples kept in tap water in a room at low light intensities stayed submerged (Fig. 4). But all the aseptic cultures grown on nutrient solution changed their form and floated on the surface (Fig. 5). Though we tried different light intensities in Hutner solution (with and without sugar) we were unable to produce the submerged form. However, it seems that in solutions with low nutrient content the new built fronds become narrower and longer and grow submerged. This is in contrast to *L. trisulca* which grows submerged under most conditions. Only in the rare cases of flowering does it reach the surface. Similar to *L. tenera*, *L. valdiviana* and *Wolffiella neotropica* which often grow submerged in nature float constantly on the water surface when kept under aseptic conditions in culture. Also these two species have differing frond shape on and below the water surface.
Under controlled condition the growth rate was quite high, similar to other *Lemna* species (about doubling in 30 hours at nearly optimal conditions, but only 12 hours daily light). After three weeks of growth some fronds of one *L. tenera* strain began to flower in the cultures with 0.01 g/l EDDHA (Figs. 6 and 7). The flowers are very similar to flowers of other *Lemna* species (e.g. *L. valdiviana*, *L. aequinoctialis*). No fruits developed.

4. DISCUSSION

Lemna tenera is the only known species of *Lemnaceae* which is restricted to forest swamps. All the other species so far investigated (a few very rare and localized ones have not been checked yet) can be found in most waters which suit their nutrient demand, do not dry out and are not too rough or too fast moving. The special habitat is the reason why *L. tenera* is so rarely found. Most botanist collect water plants in open waters like ditches, ponds and lakes, but rarely in shady forest places which are often difficult to penetrate by boat or on foot. Therefore it is possible that *L. tenera* can still be found in a few places outside of Australia (New Guinea, Indonesia, Malaysia, Thailand, Philippines). Also in Australia there are probably more localities of *L. tenera* to be detected, not only in Northern Territory but also in northern

Queensland and in Dampierland and the lowlands north of Kimberley Plateau (W.A.). FITZGERALD (1918) indicates *Lemna trisulca* from Ord River, Dunham River and Parry Creek. It is very unlikely that *L. trisulca* grows in tropical regions at lower altitudes. Therefore it is a possibility that the W.A. records belong to *L. tenera*. Unfortunately I could not find any herbarium specimen from these localities.

SUMMARY

The habitat of *Lemna tenera* in North Australia is described. The species grows in forest swamps under *Melaleuca* trees. The waters with *L. tenera* are on the lower limit of the nutrient content of the *Lemnaceae* waters (especially low in K, Ca, Mg and P). Normally the fronds grow submerged. Under flowering conditions and in cultures with good nutrient supply and high light intensity they float on the surface of the water.

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