In 1986, professor Jacobsen gave a lecture on the Symposium 'Troebel Water' at Wageningen University (NL) on the threat to the aquatic environment. The report of the symposium has not been broadly distributed since. For Cryptocoryne it is still very valuable.

DETERIORATION OF THE HABITATS OF THE *CRYPTOCORYNE* SPECIES

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Abstract
Few tropical plants are as well known as the genus *Cryptocoryne* (Araceae). It is aquatic to amphibious, found throughout SE Asia, although each species usually has only a limited area of distribution. *Cryptocoryne* grows in running water and each species is in growth and flowering adapted to just those circumstances under which they grow. The habitats of the more than 50 known species are mostly streams and rivers, 1-20 m wide with not too rapidly flowing water, in the lowland forest. Few other aquatic plants have been able to adapt themselves to such habitats. The lowland rain forests are usually the first ones to be cut in tropical SE Asia: they are the main sites for settlements, for agricultural and horticultural activities, and the rivers are the primary water supply for the people. In areas where the cutting of the forest is not total and so does not result in a total washout of the rivers and where the pollution can be kept at a minimum, the rivers can survive - and in many cases even be re-colonised, so that they may contain a variety of aquatic habitats - at the same time serving as a supply of water.

Tropical forests

The tropical rain forests are the home of more than 2/3 of all known flowering plants equalling about 160,000 species. There are many different kinds of tropical forests, e.g. cloud forests, different kinds of deciduous and evergreen monsoon forests, savanna forests, and lowland rain forests. The more than 50 known species of *Cryptocoryne* are found in the tropical lowland rain forests of Southeast Asia.

A closer description of the tropical rain forests will elucidate the problems regarding the future survival of the species of *Cryptocoryne*. On the other hand you may say that by elucidating the problems regarding the survival of the species of *Cryptocoryne* you are, at the same time, engaged in the future of the tropical rain forests.

As is well known, around two hundred thousand square kilometer of tropical rain forest are logged each year to make room for settlements, roads, agricultural purposes etc., and to provide wood for fuel. Forest cutting is going on all over the world, but the greater the part of the remaining forest areas are found in the tropics (problems concerning the temperate areas are outside the scope of this presentation).

The destruction occurring in the tropics today is so fast and devastating that it is almost incomprehensible. There has, of course, also previously been agriculture in the tropics, e.g. for hundreds of years intensive agricultural practices in India and Central America, but the population today is far greater than ever before. With the present alarming proportions of the forest cutting, there will hardly be any major forest areas left by the turn of the century, except or the most remote and impenetrable lowland rain forest in Africa and South America. The situation is of course very difficult to estimate, but a rather recent survey has been presented by Myers (1980). Southeast Asia comprises about 1/3 of the moist, tropical forest; a great part of it belongs to the biotically richest to be found, but at the same time the most attractive for timber exploitation.

Not all areas have been equally exploited, and many factors render it difficult to obtain and compare exact figures (cf. Myers, 1980). A reasonably good estimate does exist for e.g. Malaysia (Peninsular Malaysia, Sarawak, and Sabah), where the 1977 figures say that on the peninsula less than 30% undisturbed forest remains, most of it montane forest (less than 5O% in Sarawak and Sabah). Future conversion of forest will leave less than 5% of the total area covered with lowland rain forest. Peninsular Malaysia is at present one of the most developed - and well managed - areas in Southeast Asia.

During the last 10-20 years developing schemes have been (and still are) launched at such a high rate that a definite shortage of timber is foreseeable within the next generation (cf. Myers, 1980; and Davidson et al., 1985).

The ecological conditions in the tropical rain forest are among the most complex just as they are among the most delicate. It is both correct and wrong to designate the tropical rain forests as some of the most fertile areas in existence. In many instances the soil itself is not very fertile, and the nutrients are to a great extent tied up in plants as well as in animals. Upon dying they quickly will be decomposed and re-circulated in the food chain and in the nutrient cycle. In many tropical areas the soil, unless carefully managed, cannot support more than a few seasons of cropping, after which the nutrients will be washed out. The trees, the herb vegetation, and the humus-rich topsoil layer can temporarily withhold much precipitation. Some of the water will quickly be accumulated by the plants, the rest will slowly run away. When the vegetation is stripped off large areas, there is no foliage to alleviate the violent tropical rain and no roots to retain the nutrient-rich humus layer. Everything is washed out and because of the enormous masses of water that have to run off, the previously rather minor streams will dig themselves further and further into the underlying substratum. The water that previously sustained life in the tropical forest is carried off (from the areas where it was of use) to lower lying areas, often causing flooding.

Many other plants, dependent on the ecosystem created by the trees, will also disappear when the trees are cut. Of greatest interest to us are of course all the known useful plants found in the tropical forests. But what about all the plants that we have not yet investigated. Only a few percent of the plants of the tropical forests have as yet been investigated, and considering the products that have been discovered during the past hundred years we can see that there must be other fantastic products hidden in the plants not yet investigated.

There are many important food plants in the tropics, and for future improvement of these, regarding both quantitative and qualitative properties, we are dependent on the genetical material found in the primitive forms of the cultivated plants or in some of the wild, related species. Our interest is not limited to only the well known food plants such as rice, yam, taro, coffee, oil palm, banana, and industrial plants such as cotton and rubber, but is extended also to a large array of plants containing chemical substances useful for e.g. medicinal purposes, as well as to various horticultural plants.

Turning to another aspect of the *Cryptocoryne* habitats, we must not forget that in Southeast Asia the streams and rivers are the most important and steady water supply for the people, whether in small villages or in larger towns or cities. It is true that the cutting of some forest does not destroy the water supply as such, but development is usually accompanied by pollution that has frightful consequences for the quality of the water.

Habitats of *Cryptocoryne*

Generally it may be said that the *Cryptocoryne* species grow in running water, i.e. smaller or larger, slowly or quickly running streams and rivers, sometimes also in seasonally inundated forest pools (near the streams). The altitude is generally below 300 m (but 700 m has been recorded) in what would be labelled lowland rain forest; towards the sea it is found until the tidal zone. The position of the plants in the watercourse varies with the species, from those that are high up on the banks and submerged only at high water via those regularly submerged to the almost constantly submerged ones. Even though several species today are found in quite open, sunny localities, this no doubt due mostly to human influence and generally speaking they are still species of the shady rain forest. The soil they grow in varies from peat, mud, sand to coarse gravel between stones and is usually rather specific for each species.

Rather few species of flowering plants occupy the same habitats as *Cryptocoryne*, and the reason for the success of *Cryptocoryne* can no doubt be ascribed to their subterranean rhizomes and runners providing a means of vegetative reproduction even if the leaves are destroyed by e.g. too strong a current or other accidents. Furthermore the different species have differently formed leaves, adjusted to just those circumstances under which they grow.

The following account of *Cryptocoryne* habitats is based mainly on my own experiences from four trips to Southeast Asia of a total duration of three months. Taking into consideration the large area covered it evidently was not possible to perform profound ecological investigations, the main aim of the travels being to collect documented, live material for cytological and taxonomical studies, but of course also to study the habitats of the various species. Trying to locate the *Cryptocoryne* habitats naturally led to a rather good insight in the various types of forest and their variation according to the landscape and land use in general. Of the 54 species and 1 hybrid that are presently recognised, I have seen 28 in their natural habitat (some mentioned by Jacobsen, 1982).

Sri Lanka

Sri Lanka is near the boundary of the distribution area of the genus towards the west. The island has a central highland and therefore several different vegetation zones. It here suffices to mention two areas and vegetation types, viz. the south-western lowland, evergreen rain forest where three species of *Cryptocoryne* occur (*C. thwaitesii*, *C. bogneri*, and *C. alba*), and the central midlands (Kandy area) and central western lowlands with 5 species (*C. walkeri*, *C. beckettii*, *C. undulata*, *C. wendtii*, and *C. parva*) in the semi-deciduous monsoon forests having a seasonal change in precipitation.

Cryptocoryne thwaitesii from the south-western lowland rain forest is, among a few other places, found in the small Kottawa Forest Reserve, growing in deep shade in a small slow running stream, in acid mud and sand (Bastmeijer et al., 1984). This stream has a very small catchment area, the plants are therefore mostly emersed as the water quickly runs off. A cutting of this and other forests like it will quickly destroy the habitats, and it is doubtful whether *C. thwaitesii* can then survive (the same is probably also true for *C. alba* and *C. bogneri*). The south-western rain forests are diminishing very rapidly because of logging and conversion into agricultural land and no doubt they are among those most sensitive to habitat destruction. Fortunately the three mentioned species are unsuitable for aquarium purposes, so a commercial demand is limited.

The Kandy area and areas towards the north and north-west (also towards the south) have a quite different vegetation composed of more or less deciduous forest and a more neutral soil. The species of the *C. beckettii* group are found in more sunny situations (although mainly so through human influence), but they can tolerate it. Due to forest cutting etc. many rivers are rather dirty, and only few plants are seen submerged; mostly they grow somewhat up on the riverbanks, and these species seem to be more hardy and to be able to stand a greater extent of habitat disturbance - at least they can survive on the riverbanks, if the riverbed is washed out. In more quietly running streams (and springs) they can form large, luxuriant, submerged stands.
When I visited the Kandy area in March 1975, there were 4 species and 1 hybrid of *Cryptocoryne* growing by the rapids at Halloluwa: *C. parva* growing closest to the water where the course was rapid, *C. walkeri* a little further up, but also rather exposed, while *C. beckettii* and *C. undulata* were found even further up on the banks. The hybrid *C.* x *willisii* was found in several locations, both low and high, in the shade and in the sun. More recent reports from Halloluwa seem to indicate that the plants are not as abundant any more - the most likely cause seems to be commercial collecting. The species of the *C. beckettii* group rank among our best aquarium plants: they are hardy and multiply rapidly. The localities in Sri Lanka for these species will no doubt decline, some may even disappear, because of more intensive agriculture, collecting for commercial purposes may put a heavy toll on them, too. However, because they apparently can tolerate some habitat destruction and to some extent keep step with the changing environments, there seems to be no immediate danger of their extinction.

Thailand
The two species *Cryptocoryne albida* and the very variable *C. crispatula* characterised by the strap-shaped leaves and the spirally twisted limb of the spathe are found in Thailand and surrounding countries (see Jacobsen, 1980a).
C. albida is found on the western side of the Malay peninsula, south of Ranong, where it grows in small rivers and streams with rapidly flowing water. These watercourses come from the mountains close by, carrying only a limited amount of water, but even so the current can sometimes be strong. At the base of the foothills, often close to the sea, the landscape becomes rather flat and *C. albida* may be found in sand, gravel and among stones in the smaller or larger streams. It seems to thrive best when the water is low, in contrast to the aquatic *Crinum thaianum* that grows in the same streams, but withers when the water is low. The streams and the landscape are somewhat disturbed, but *C. albida* seems to thrive on the sand and gravel banks, even if the water become violent. The deeply buried rhizomes and runners ensure survival if the streams are not too violently affected or polluted.
Cryptocoryne crispatula is mostly found in central/northern Thailand. Here the localities are at higher altitudes, up to 700 m, and the forests are of the semi-deciduous monsoon type. The rivers have moderately to fast running water and their bottom is mostly gravel or stones. The many different leaf-forms found in this species hail from different kinds of habitats, within these from different situations.
At Mueak Lek, Sar Buri District, the river runs slowly through calcareous soil: the calcium content is so high that turbulence in the water makes the calcium carbonate precipitate. It thereby self-reinforces further calcium carbonate precipitation leading to the formation of magnificent travertine dam across the river, creating small waterfalls and pools where large, submersed growths of *C. crispatula* ("*balansae*"-form) are found. Here the chemical properties of the water actually created

the habitat that appears rather stable, even though the surrounding areas are agricultural land. Further north, in the Phu Khien Wildlife Sanctuary, Chaiyaphum District, the area is mountainous, and it is evident that the water rushes down the streams and rivers with tremendous force. Here, on the banks of the river Huae Mae Chem, there are large stands of a mostly emersed, smooth, narrow, green-leaved form of *C. crispatula*. It grows among tree roots and in sheltered places between big rocks. In a small tributary to the main river plants with rather broad, copper-brown, bullate leaves are found growing submersed in slow running water. The leaf-form have proven constant in cultivation.
In the wildlife sanctuary the plants could evidently survive the strong currents, but outside the sanctuary where the forest cutting has been vast the run-off was immense: the riverbeds were completely washed out, devoid of any vegetation, and even large stones were moved about.

Peninsular Malaysia
As mentioned above, Peninsular Malaysia is - or rather was covered with evergreen rain forest and almost all lowland areas are or will shortly become agricultural land. There is a large, central mountain area where there are no *Cryptocoryne* except in the foothills, and some midland areas with *C. affinis*.
Cryptocoryne affinis is found in the northern and central parts on more calcareous soil, in streams and rivers that are not flowing too slowly. It rarely grows on the riverbanks but is confined to the riverbed itself and its sandbanks where the current is strong. When the water is low, it is quite easy to walk around on the sandbanks. The most luxuriant plants grow submerged, even at low water, in the small streamlets between the sandbanks. It is characteristic that the numerous stout runners form a woven mat keeping the plants together, thereby forming the basis for a further depositing of sand so that the sandbanks will steadily grow; *C. affinis* may thus be able to cope with the changing conditions, even if large parts of the forest is cut.
Cryptocoryne elliptica today has its only known locality in the Gunong Bongsu Forest Reserve (in the state of Kedah). It grows on muddy bottom in a small valley in the forest. The locality has recently been described by Bogner & Jacobsen (1986) and thus will not be treated here, except to mention that this habitat is probably just as (if not more) sensitive to forest cutting as the rain forest localities in south-west Sri Lanka where e.g. *Cryptocoryne thwaitesii* grows.
Cryptocoryne minima comes from the rain forest of the western and north-western parts of the peninsula. It grows in small streams, but the most luxuriant plants are found in small, seasonal pools in the forest, deep in the mud (composed of decaying leaves); the plants are 20-25 cm tall, with purple, cordate, bullate leaves; submerged plants are smaller, with smooth, purple or (in the sun) green leaves. When the forest is cut, *C. minima* will no doubt disappear from the forest pools, but there is a chance that it may survive in smaller streams and even recolonise streams in rubber plantations, as I have seen north of Tapah and Schulze has seen south of Kulim (de Wit, 1983).
Cryptocoryne cordata is found from the Phucket area in southern Thailand along the east coast of the peninsula into the southern Malaysian states. It seems that most southern populations have more or less cordate leaves and probably a chromosome number of 2n = 34, while the variation found in e.g. leaves and in chromosome numbers, 2n = 68, 85, 102, probably comes from the northern part of the distribution area. In the southern localities *C. cordata* generally grows in slow running streams in the forest, the plants being rooted deep in the mud. The leaves are purplish but become green in the sun. It seems as if the habitats of the Malaysian populations are very sensitive to forest cutting.

Other species of *Cryptocoryne* from the peninsula grow in similar localities, viz. *C. schulzei*, *C. nurii*, *C. griffithii*, and *C. purpurea*.

A locality differing from the rest in several respects is the Tasek Bera in the southern part of the state of Pahang. Recently a comprehensive study of this swamp has been published (Furtado & Mori, 1982), containing many ecological properties such as e.g. plant production, growth rate, population density, blackwater properties and chemical properties like cations, anions, oxygen et*C.* It is not possible to go into any detail here, but it is a huge freshwater swamp with many channels through which the water runs. The channels are 6-8 m wide and 1-2 m deep at low water. In the parts of the swamp having a tree cover, the bottom of the channels is Covered with 30-50 cm tall specimens of *Cryptocoryne purpurea* (previously reported as *C. griffithii*). This locality probably holds the largest population of *Cryptocoryne* in Peninsular Malaysia. The water and the soil in the Tasek Bera is very acid, and it is difficult to envisage what will happen when the areas surrounding the swamp all have been taken into cultivation.

Sarawak Malaysia

In Sarawak the habitats of *Cryptocoryne* are in many ways similar to those on the peninsula, but other species are found here. As shown in Jacobsen (1985), 11 *Cryptocoryne* species are found on the route between Kuching and Sarikei (a distance of 150-250 km).

Cryptocoryne bullosa and *C. keei* are found in rather quickly running rivers where the plants are rooted deep in the sand on banks in the river. In places where the water flows faster the plants are larger and found in much denser patches. The growth habit is rather similar to that of *C. affinis* from the Malay peninsula; the habitat is also somewhat similar except that the water is acid.

Cryptocoryne striolata can also be found in quite quickly running rivers and streams, but usually it thrives better in more slowly running streams, The streams are usually shaded and the bottom is sand, but sometimes sandy/muddy. *Cryptocoryne auriculata* has two known localities and in both cases *C. striolata* grows in the same stream, usually submerged, while *C. auriculata* grows in the upper parts of the riverbed or on the banks, usually submerged only during and shortly after rains.

Cryptocoryne species growing in more slowly running forest streams are *C. zonata*, *C. grabowskii*, and *C. longicauda* (the two latter are also found in tidal influenced places, as will be mentioned below). These localities are quite comparable to the localities on the Malay peninsula with e.g. *C. cordata* and *C. minima*.

The inner tidal zone is a type of habitat very common is Sarawak, i.e. altogether 6 species are found here: *C. ciliata* common on mudflats or in ditches in smaller or larger rivers, mostly in rather open situations (in the whole of Asia). The two species *C. lingua* and *C. ferruginea* are found in the inner parts of the freshwater tidal zone. These tidal species are able to flower during the periods of the month when the oscillation of the tidal amplitudes is at a minimum and the plants growing high up on the riverbanks become emerged for several days (Jacobsen, 1980b).

The tidal influenced zone has a much larger extension in the lowland swamp forests than immediately recognisable. The incoming tide can push back or stem up the water many kilometers upstream, so that the water in the streams simply stops flowing. The *Cryptocoryne grabowskii* locality at Matang (west of Kuching) in the lowland swamp forest is no doubt influenced by the tide, as the runoff at regular intervals is hindered. *C. longicauda* is also found in small streams in the inner parts of the tidal zone; the tidal influence was first recognised at Serian and Kpg. Stutong (Sarawak), but the localities found at Gunong Pulai (Peninsular Malaysia) and west of Djambi (Sumatra) also seem to be influenced by the tidal zone.

Sumatra

Our knowledge of the *Cryptocoryne* localities in Sumatra is rather limited, the observations made by J. Bogner and myself in 1985 have not yet been published. During the past few years our knowledge of the by now 9 known species has increased very much actually the majority of them have been described as new species within the last 25 years, viz. *C. pontederiifolia* (1863), *C. longicauda* (1879, first documented for Sumatra in 1985), *C. scurrilis* (1962), *C.* sp. near *diderici* (1970), *C.* sp. near *jacobsenii* (1976), *C. gasseri* (1979), *C. villosa* (1980). *C. amicorum* (1982), and *C. moehlmannii* (1983). The geophysical characteristics of Sumatra are that there is a mountain-chain running the length of the whole island. On the south-west coast the mountains are very close to the sea leaving the rivers only a short run, while the north-east coast has a rather broad area of lowland forest towards the sea.

On the south-west coast *C. pontederiifolia* (near Padang) and *C. moehlmannii* (near Sasok) are found in tidal influenced areas comparable to the habitat of e.g. *C. ferruginea* in Sarawak, i.e. the inner tidal zone (Jacobsen, 1980b). The lowland rain forests on the north-east coast have been the place of large-scale forest cutting during recent years and the cutting is continued at a high speed. In just this kind of forest most of the *Cryptocoryne* species are found, in situations basically not so different from the habitats in e.g. southern Peninsular Malaysia; slow running streams in deep shade, acid soil conditions, the bottom mostly muddy when the water runs slowly, more sandy when the water is quicker. The populations that I saw here were in small patches of leftover forest, obviously influenced by the cutting of the surrounding forest and by the agricultural practises, thus e.g. *C. villosa* (near Abai Siat) grew in an old rubber plantation (50 years?) which had turned into a kind of secondary forest.

The future of the *Cryptocoryne* habitats

As mentioned above, *Cryptocoryne villosa* had on Sumatra been able to re-colonise a rubber plantation - a phenomenon also encountered in Sarawak (*C. striolata*, *C. longicauda*) and in Peninsular Malaysia (*C. griffithii*).

For this re-colonisation to take place it is necessary to re-establish a suitable habitat - and to have some plants that can move in and re-colonise. It is true that a rubber plantation is no substitute for a rain forest, but in the case of *Cryptocoryne* it renders re-colonisation possible, at least in some cases. After a fast forest cutting the streams, especially the larger ones, are washed out and dig themselves deep into the ground. In such cases it can be very difficult to re-establish a stable habitat - even if the forest has been only partially cut. The fast running and muddy water, often combined with an abundance of sunshine and the use of agricultural fertilisers, prevents a re-colonisation.

Cryptocoryne habitats will no doubt diminish as will good aquatic habitats - habitats of plants and animals, serving also as a water supply for the human population, The tendencies noticeable today are alarming. Evidently we cannot promote a nature conservation of all tropical rain forests - just as we cannot preserve all plants in gene banks and botanical gardens. What we can do is to promote a wide array of solutions. Clever use of the landscape may create many possibilities for agriculture and forestry, at the same time leaving reasonably sized areas of nature in peace. Many categories of nature reserves are possible, viz. some of great scientific interest, others of value as plant and animal refugia, others still valuable as recreative areas. The latter may not be the least important as they present the possibility for people to experience and use the nature, thereby giving them an understanding of why it is so important to conserve nature. Members of aquarium societies have the primary insight of the expert in what is happening in nature today. They are also obliged to pass on this knowledge and insight to others.

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Postscript (September 1997)

Since the publication of the present article in 1986 a number of articles and books have been published on *Cryptocoryne*. A selection:

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