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Analysis of a habitat used by Antillean manatee (Trichechus manatus manatus) in French Guiana

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Preface

This Masterthesis (Diplomarbeit) describes the results of a study on a manatee habitat in French Guiana. The study was initiated by Kwata, a French Guianan NGO for nature conservation. After the implementation of a working group on marine turtles, Kwata wanted to draw more attention to the estuaries and looked for a related flagship species: the manatee. Through Kwata, the contact to PD Dr. Udo Gansloßer from the Friedrich-Alexander University of Erlangen-Nuremberg, Chair of Zoology, was initiated and Mr. Gansloßer gladly agreed to assist in this project.

Due to the changes in the methodology the study is divided into two sections. After the first part of the work, in which the submerged aquatic vegetation was investigated, it was clear that the proposed procedure would not lead to any satisfying results. The methodology was changed and the bank vegetation moved into the centre of interest. Thus, the division of the thesis into two parts, the first study of the aquatic vegetation and the second study of the vegetation of the creek banks, reflects the temporal evolution and changes during the fieldwork.
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Zusammenfassung

Eine Studie zur Beurteilung der Qualität der Sümpfe von Coswine als Habitat für die Seekuh (Trichechus manatus manatus) wurde von Juni bis September in Französisch Guyana durchgeführt.

Die Sümpfe von Coswine sind eines der größten Feuchtgebiete in Französisch Guyana und vollständig unter dem Einfluss der Gezeiten. Das Klima ist tropisch und beeinflusst maßgeblich das Wasserregime. Im Arbeitsgebiet befinden sich drei verschiedene Schutzgebiete. Die Sümpfe sind relativ unberührt, was ein Grund für die in der jüngsten Vergangenheit hohe Anzahl an Seekühbeobachtungen und die vermutete große Population sein könnte.

Da Seekühe aquatische Herbivoren sind, wurde in einem ersten Teil der Studie die Unterwasservegetation untersucht und gleichzeitig einige für die Verbreitung der Seekühe wichtige Wasserparameter aufgenommen, die aus der Fachliteratur bestimmt wurden. Das Arbeitsgebiet wurde in Sektionen eingeteilt, in denen während einer Voruntersuchung die Unterwasservegetation und einige Wasserparameter aufgenommen wurden. Die erzielten Ergebnisse zeigten, dass keine submerse aquatische Vegetation in den Sümpfen von Coswine vorhanden ist. Die Wasserparameter sind den Werten aus anderen Studien in Französisch Guyana und Südamerika ähnlich, wenn klimatische Umstände in Betracht gezogen werden.

Der zweite Teil der Arbeit baut auf dem ersten auf und untersucht die Ufervegetation, da nun vermutet wird, dass diese die einzige für Seekühe erreichbare Nahrungsquelle darstellt. Der methodische Ansatz für die Aufnahme der Wasserqualität wurde nach den Erfahrungen der ersten Studie minimal verändert. Die Vegetation wurde in 100 m langen Transekten entlang des Ufers aufgenommen, die untereinander einen Abstand von 1 500 m aufwiesen.


Für die Seekühe scheinen die Sümpfe von Coswine ein interessantes Habitat darzustellen mit viel Futter in Form von Blättern der Roten Mangrove, mouko-mouko (Montrichardia arborescens) und anderen von Manatis verwertbaren Pflanzen. Die aquatischen Parameter sind in einem Bereich, der in der Literatur als für Manatis passend bezeichnet wird. Die relativ unberührt eingefüttert und Maßnahmen zur ihrem Schutz sollten getroffen und auf eine gesetzliche Grundlage gestellt werden.
Abstract

A study was carried out from June to September to assess habitat quality for manatees (Trichechus manatus manatus) in the Coswine swamps in French Guiana.

The Coswine swamps are one of the largest wetlands in French Guiana and totally under the influence of the tides. The climate is typical for the tropics and has a huge impact on the water regime. In the area, three different protection zones exist. The swamps are quite untouched from humans, perhaps a reason for the high number of manatee sightings in the recent past and the its suspected large population size.

As the manatee is an aquatic herbivore, in a first part the submerged aquatic vegetation was investigated. At the same time, some parameters important for manatee distribution were measured, which had been determined by literature survey. The whole area was divided into sections and in each such section the vegetation and water parameters were recorded during a preliminary study. The results showed, that no submerged aquatic vegetation was present in the Coswine swamps. The aquatic parameters were similar to those obtained in other studies in French Guiana and South America if climatic circumstances are taken in account.

The second part of the study is based on the first one and deals with the bank vegetation, as it is supposed, that this is the only available food resource for manatees in the area. The methodological approach was slightly altered for the assessment of the water quality, considering the recommendations made after the first study. The vegetation was sampled in 100 m long transects at the banks with a distance of 1 500 m between each in the whole study area.

During the study rarely any manatee was spotted, but this more likely was due to the methods applied than an indicator for the non-presence of sireniens. The aquatic parameters varied slightly more than in the first part of the study. Salinity unexpectedly was low and more than ¾ of all samples were taken in fresh water. The vegetation sampling showed an overwhelming importance of Red Mangrove (Rhizophora racemosa) in the whole study area. In contrast to the first impression on the site, the swamps are quite homogenous when regarding only the aquatic parameters. It is therefore difficult to distinguish any zones of changing environmental aspects. Regarding the vegetation the Coswine swamps are also homogenous but to a lesser degree as the plants are more influenced by the soil on which they thrive than by the water quality.

For manatees, the Coswine swamps seems to provide a suitable habitat with plenty of food in the form of overhanging branches and leaves of Red Mangrove, some mouko-mouko (Montrichardia arborescens) and other consumable plants. The aquatic parameter are in a range which is described in literature as manatee-fitting. The quite untouched Coswine swamps provide shelter from wave action, humans and pollution. Therefore they can be judged to be important manatee areas. Corresponding steps for the conservation of this still natural area should be taken and secured by nature protection laws.
1 Introduction

1.1 Context of the study

The Antillean manatee (Trichechus manatus mantatus, Linneaus, 1758), a sub-species of the West Indian manatee, is restricted to the tropic and sub-tropic New World Atlantic (HUSAR 1977). Together with the three other living species of the order Sirenia, it is the only fully herbivore, large aquatic mammal in the world (BERTRAM and BERTRAM RICARDO 1973). All species are classified as endangered by the Red Data Book of the World Conservation Union (HILTON-TAYLOR 2000). In French Guiana, the manatee is totally protected by a decree of 1986 and 1995 (MINISTRE DE L’ENVIRONNEMENT 1986, 1995).

Throughout its range of distribution, the status of the West Indian manatee is more or less well studied. A good overview is given by the CARIBBEAN ENVIRONMENT PROGRAMME (1995) and LEBEVRE et al. (1989). Nevertheless, the manatee population in French Guiana is virtually unknown. A first interview study among fishermen and residents was started in autumn 2000 by KWATA. First results suggest that manatees may be less abundant than thought to be 20 years ago, although they are still present and widespread. Furthermore, the study showed that a small but stable manatee population lives in the estuaries of the River Maroni and the River Oyapock and in the swamps near Sinnamary (DE THOISY et al. 2001). As manatees have been living in the estuary of Maroni since a long time and are often seen, it is safe to assume that the mouth of the River Maroni is a well accepted habitat of manatees.

Even nowadays manatees are still hunted in French Guiana for meat. Additionally, but to a lesser degree, they are also killed out of traditional beliefs. But the decline is first of all caused by increasing human occupation of the coastline, which is in consequence followed by more boat traffic. Incidental catches by fishermen are also reported (DE THOISY et al. 2001). As many recent publications show, the adequate strategy to fight against further decline of a species is not to protect only individuals but to conserve its environment or its habitat, respectively to give the whole population a better chance to survive (LEFEBRE and O’SHEA 1995).

Thus, for an efficient conservation of the species and for its protection against further reduction, the demands of manatees on their habitat must be investigated, because “the loss of suitable habitats constitutes the greatest threat to the survival of manatee populations (...)” (REYNOLDS 1999:267). The few studies on this issue were all conducted in fairly clear water. BENGTSON (1981) and HARTMANN (1979) describe the habitat of the Florida manatee (Trichechus manatus latirostris L.), the other sub-species of the West Indian manatee, which lives around the Florida peninsula (RATHBUN et al. 1990). By assembling manatee habitat requirements and human impact on the coast, PACKARD and WETTERQVIST (1986) try to develop a method to evaluate areas of existing and potential conflicts between man and manatee. They worked with maps of different information which were juxtaposed, a method developed for urban planning. But transmission of the found aspects to the Antillean manatee
must be regarded carefully, because the two subspecies differ at least in behaviour (AXIS ARROYO et al. 1998; REYNOLDS 1999).

AXIS ARROYO et al. (1998) published an interesting article on the variables associated with the use of manatee habitat in Quintanan Roo, Mexico, an area with turbid waters. Except for those articles little has been published yet on the habitats and the habitat use of the Antillean manatee in Central and South America, even though a large part of the world population of Antillean manatees lives in the coastal zone from Mexico to Brazil. As BENGTSON and MAGOR (1979) pointed out for Belize and BEST (1984) for the Amazonian manatee, the turbid waters which predominate those areas make observations very difficult or even not possible. Also the secretive behaviour and the inaccessibility of the habitat (TIMM et al. 1986) are important reasons why this topic has not been studied before.
1.2 Aims and main questions of the study

The aim of the study is the analysis and the description of the important parameters determining manatee habitat use in a typical estuarine environment in the Wider Caribbean Region.

Precisely, the main questions of the study are:

• What are the critical factors and in which amplitude do they occur?
• Are there any remarkable differences regarding the critical factors between distinguishable zones in the study area?
• How can the zones be classified into groups of similar character?
• Can any specific behaviour of manatees be related to these areas?
• Is there a difference between already described habitats and the habitat in the Coswine swamps?

Therefore, the different parameters were measured at stations distributed over the working area in a certain distance. At each station the critical factors of manatee habitat use which were identified during literature study are recorded. Then, in a second step, the stations will be grouped into zones of similar character by means of the vegetation and the aquatic factors. Finally the classified zones are mapped and described.

With such a classification and description of an existing area used by manatees, the author aims to contribute to a better knowledge of manatee habitats as it is demanded by MARSH et al. (1986:180), because “the major threat to sirenians is alteration of their habitat”. POWELL et al. (1981:645) conclude for the population in Puerto Rico, which is similar to that in French Guiana – small and wide spread- that “destruction of their habitats or human-caused mortality (…) could have a deleterious impact on their status”, because demographic factors, environmental variability and genetic variations can easily influence long-term survival (REYNOLDS 1999).

The results of this study may be used to identify potential manatee habitats with the aid of only a few important variables. This should result in a better adaptation of conservation plans to the specific needs of manatees in a certain area. In addition, monitoring can be focused on the main factors and therefore can be less expensive and easier to handle. Moreover, effects of habitat alteration are easier to predict and adequate countermeasures can be taken. All these improvements should enable nature conservation authorities to respond more quickly to any threats of habitat alteration. In consequence, conservation measures will be easier to apply and will be more efficient.
2 The Coswine swamps

Among the three important areas where manatees can be found in French Guiana (cf. chapter 1 Introduction) the Coswine swamps were chosen as the study site. They provide a better access than the estuary of River Oyapock, which is only accessible by aeroplane from Cayenne. Furthermore most of the recent observations have been made in the estuary of the Maroni.

2.1 Location and geographical boundaries of the study area

French Guiana, the largest French over-sea department, is situated on the north-east coast of South America between 2° - 6° latitude North and 51° - 55° longitude East (see Map 1). It belongs to the equatorial zone of the northern hemisphere. The border with Surinam is marked by the Maroni River, the guianan-brazil border by the River Oyapock.

Map 1: Map of South America (extract from DIERCKE WELTATLAS 1988)
The study was carried out in the Coswine swamps (North 5°34’ to 5°41’, East 53°53’ to 54°00’) in the north-west of French Guiana. The area (Map 2) is restricted by the Crique Coswine with its side-rivers in the North and the Crique Vache in the South. In the West, the zone is limited by the Maroni, the largest river in French-Guiana. In the East, it is restricted by the D9, the departmental road linking the town of Mana to the town of St. Laurent du Maroni.

The Coswine swamps are one of the largest wetlands in French Guiana and for a huge part only accessible by boat. Their total area is approximately about 160 km² (study area ca. 150 km²). Situated in the Southeast of the estuary of the Maroni, they are totally under the influence of the tides (CHOUBERT 1961) and communicate with a network of creeks widely branching out formed during the quaternary (TURENNE 1973). The canals are mainly bordered by mangroves and due to the movements of the tide still navigable (BOYÉ 1963) during high and low tide. The Coswine swamps may be characterised as a system of many meanders in a plain flooded for the most part and therefore be described as a transition zone between the sea and the inland.
Map 3: Names of the Criques, 1: 50 000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL, 1990)
2.2 Abiotic factors

2.2.1 Climate

The climate is equatorial and therefore characterised by a wet and a dry season, and a maximal variation of the average temperature of 2° C over the year. The seasonal change is caused by the intertropical zone of convergence (IZC), which results from the meeting of the St. Helene anticyclone and the Azores anticyclone. The Azores anticyclone plays an important role for the duration and the style of the rain season. The St. Helene anticyclone in contrast influences the dry season. The IZC is responsible for the peaks of rainfall in January and May. Precisely the different seasons can be classified into a short wet season lasting from December to February, the short summer in March (in some years hardly remarkable), the long wet season from April to August and the long dry season from September to November.

The Coswine swamps belong to the climate region 1c (cf. Map 4). According to the Atlas of French Guiana (CNRS and ORSTOM 1979). The climate is characterised by:

- sometimes heavy rain, with a very remarkable variation within one year,
- a long and well marked dry season,
- high evaporation, even causing water deficit,
- important winds,
- a light thermal amplitude and,
- the Northeast of the coastal zone being a little bit drier with an average of 2 m of rainfall each year.

Map 4: Climatic regions of French Guiana
All following values are taken from the monthly Meteo France bulletin (METEO FRANCE 1998).

The annual precipitation in the villages surrounding the Coswine swamps is very low. In Awala-Yalimapo it is about 1746 mm, 2656 mm in St. Laurent and 2591 mm in Charvein (average precipitations). September and October (cf. Fig. 1) are the driest months with less than 30 mm of precipitation in Awala-Yalimapo, in contrast to the wet season with precipitation up to 312 mm in May. Charvein already has some more precipitation, with the minima (less than 80 mm) in September and October as well. In contrast, precipitation reaches nearly 400 mm during the wet season in May. In St. Laurent the precipitation is even higher with the minima in September (104 mm) and October (92 mm) as well, and the maximal precipitation in May (383 mm) and June (334 mm). The annual average humidity is about 80.6%, with peaks in May and June (84%) and its minima during the dry season in September and October with 76%. The Atlas of Guiana (CNRS and ORSTOM 1979), however, gives another value for the humidity (86% in average).

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1 Calculations of the averages are made with 1961 as base year for Awala-Yalimapo, 1957 for the precipitation in Charvein, 1978 for the temperature in Charvein and 1949 for St. Laurent, as the records of Meteo France only started in these years.
The air temperature does not vary very much (cf. Fig. 2). The mean temperature is about 26.3°C in Charvein and reaches 27.0°C in St. Laurent. For Awala-Yalimapo, no temperature data is available. The highest values are noted during the dry season in September and October with 27.3°C and 27.4°C in Charvein and 28.9°C and 28.5°C in St. Laurent. The minima are reached during the wet season in the months of January and February with average values of 25.2°C for Charvein, 25.8°C for St. Laurent and 26.0°C for Mana. The annual average soil temperature in St. Laurent, measured in a depth of 0.1 m, is 28.7°C with its maxima in September (29.6°C) and in October (29.5°C) and a minimum of 27.5°C in January.

Evaporation is very high in the region with 900 mm/year in contrast to the rest of Guiana where the average evaporation is between 300 and 400 mm/year (LOINTIER and PROST 1986). Comparisons of the average evaporation values from 1955-1965, measured in a Piche evaporation meter (TURENNE 1973), to the precipitation shows that in August to October, evaporation is higher than the precipitation. In St. Laurent the precipitation is little higher in October than the evaporation (78 mm).

In conclusion, one can say that the study area is situated in one of the driest region of French Guiana, but has still a substantial quantity of precipitation.
2.2.2 Geology

Situated in the coastal low plain of French Guiana, the whole study area is more or less flat with only a few slight elevations not exceeding 9 m. The area can be divided into the actual coastal plain and the old coastal plain. ROSTAIN (1994) describes the actual coastal plain as low and swampy with elevations not exceeding 4 m. Therefore, it is flooded with each high tide. The deposits are those of the series Demerara with fine clayish, loamy-clayish and sandy parts. The old coastal plain, situated between 5 – 15 m, resembles more closely a landscape of savannah and forest island. The deposits are mainly from the series Coswine (also called Coropina), with marine clay at the bottom and sandy loam towards the surface. The basis for these deposits is the Guiana Shield formed during the Pleistocene.

Map 5: Extract from the geological map of Mana – St. Laurent (CHOUBERT 1961). Explications see text.
The evolution of the swamps started in the Enien age when the Coropina-Coswine clays were deposed in the tide canals. The sediments of the Coswine series are subdivided into an totally marine upper part, where mostly sands dominate, and a lower part formed by often bicoloured clays. This latter part progressively acquires an estuarine character towards the South (CHOBERT 1961). At the same time, a network of thalwegs is caused by the preflandrien phase of erosion. That erosion also provoked the inversion of the relief and in consequence the development of the present landscape with its small islands. Afterwards, these canals were invaded by the transgression in ria of Demerara (BOYÈ 1963). The sediments of Demara are composed of mud (illite and kaolinit) and of sand (CHOBERT 1961) and can only be found at the bottom of the creeks. The banks are covered with fine fluvial alluvium which was transported downstream by the creeks. (BOYÈ 1963).

The thalwegs of the water streams are often deep, in particular in the Crique Vache and Crique Coswine (CHOBERT 1961). In fact, it is been reported that the high basin of Crique Coswine is up to 65 m deep (DIJOSEF and DESBOIS, pers. comm.), which corresponds to the explications of CHOBERT (1961), who mentions that the native granite rock in the Crique Coswine is found in a depth of 65 m and in 30 m for the Crique Vache. He writes further that some cliffs of 5 to 6 meters and of 10 to 12 meters (low Crique Margot, Crique du Nouveau Camp or Crique Rouge, etc.) can be seen. These cliffs result from the erosion of the banks which happens mainly on the concave side of the meanders (BOYÈ 1963).

Following the geological map of Mana – St. Laurent (cf. Map 5) three different types of deposits can be found in the study area:

1. Recent and sub-recent deposits: marine deposits: mud and sand (Q4)
2. Deposits of the series of Demerara (young coastal plain) (Q3):
   a. marine deposits: blue clay and sand
   b. river deposits: sandy clay and grey clay
3. Deposits of the series of Coswine (old coastal plain) (Q2):
   a. Marine deposits: red clay and white and sand more or less clay

The recent deposits are mainly found along the Maroni and on the banks of the greater creeks like Crique Vache or Crique Coswine. Where no recent deposits border the banks, the marine deposits of the Demerara series are normally close to the creeks. At very few locations the deposits of the Coswine series are found on the banks, forming mostly high slopes (e.g. village of Coswine, Ancien chantier 1900, etc.).
Map 6: Extract from the pedological map of Mana – St.Laurent, 1:250 000 (explications see text) (ORSTOM 1973)
The pedological map (cf. Map 6) of Mana-St. Laurent (ORSTOM 1973) shows seven different soils occurring in the study area, which TURENNE (1973) describes as follows:

1. **Immature soils** – of non-climatic origins – marine deposits – above marine clayish alluvium:
   (Ac 0-10 cm C 10-50 cm) These soils with an A-horizon not at all or only little differentiated are formed by recent deposits of marine salty clay. They show biological activity only in the first centimetres. Very little organic matter is present. They are often invaded by *Avicennia germinans* or *Rhizophora*. Under the influence of the tide, and - if colonised by vegetation - oxidation and desalination will start.

2. **Hydromorphic soils** – moderately organic – humic to gley – anmoor acide – on fluvio-marine alluvium: (A 1-20 cm B 20-50 cm BC 50-100 cm) The native rock is a grey, not salty clay, covered by a humid lowland forest sometimes changing into a palm swamp and flooded during the rain season and high tides. A very small layer of non-degraded organic matter covers the surface. The saturation is very high and the soil reaction lightly acid.

3. **Hydromorphic soils** – mineral or little organic – gley at the surface or in total – above old Coropina marine clay: The Coropina clay normally is covered by coarse clayish fluvial sands. These soils are often seen on clayish terraces, overgrown by wet lowland forest with a mince litter of leaves. The water sheet is in a depth of 90 cm². The profile shows all aspects of a mature marine clay: red rusty stain and during the dry season well visible polyhedral structure. The percentage of organic matter is high, but it is only found in the upper 5 cm.

4. **Hydromorphic soils** – mineral or little organic – leached gley – above fine clayish Coswine sand: This profile is the most typical for the region of St. Laurent. It has a large percentage of fine sable. The leaching is indeed visible. The hydromorphic horizon can be found at 20 cm³, the gley is individualised at 50 cm. At the surface, the highly desaturated soil is rich in organic matter.

5. **Ferruginous soils** – hydromorphic – above coarse fluvio-marine clayish sand: (A1 1-20 cm, A2 20-60 cm, B1 60-120 cm, C 120-200 cm) The native material is a Coswine sediment. The presence of more coarse elements indicates fluvial mixing. The leaching is well visible. A clayish layer, found at 60 cm, which conditions the hydromorphy begins sometimes to build up a carapace. The soils are limited in their distribution to the fluvio-marine zones in the quaternary plain.

6. **Ferruginous soils** – hydromorphic – above clayish Coswine sand: (A 0-10 cm, A 1 10-60 cm, B 1 60-120 cm, BC 120-200 cm) These rather compact, hardly permeable soils of the Quaternary have now emerged to the surface. They contain up to 30 % of fine sand with a large part of coarse loam. The bleaching is well visible (accumulation at 40-60 cm) and indicates the begin of degradation. The soil reaction is acid (4.7 at the surface). During the wet season the water saturation is rather

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² No profile depth were given by TURENNE

³ No profile depth were given by TURENNE
high and signs of waterlogging appear in the profile, leading to the creation of a secondary pseudo-gley.

7. Podzols and podzolic soils—“mor” enriched with sesquioxides with gley horizon at the bottom—with ironpan—above coarse Coswine sand above Coropina clay: (A₀ 0-10 cm, A₁ 10-20 cm, B₂ 20-60 cm, B₃ 60-100 cm, II C 110-150) These soils are found in the zone of heterogeneous sedimentation which separates the actual marine clay of the native rock from the detritic sands at the border of zone of deposits. The content of organic matter is high at the surface. The clay in the deeper horizons is highly desaturated. The sandy matters are of continental origin.

2.2.3 Hydrology

LOINTIER and PROST (1986) describe the ion concentration of the river water for the great rivers in French-Guiana as identical. Sodium and chloride represent 70 % of the ions (average 10 $\text{mg/l}$), while the other ions occur in a maximal concentration of 1 $\text{mg/l}$. These values are constant all over the year. LOINTIER (1990) describes the average type of river waters as follows: rate of dissolved matter (> 8 µm) between 8 and 10 $\text{mg/l}$ (only approx. $\frac{1}{10}$ of the suspended matter of the lower Amazon (PAYNE 1986; SIOLI 1984), sum of major ions between 12 and 14 $\text{mg/l}$, dissolved silicate between 10 and 15 $\text{mg/l}$ and pH at 6,5 in contrast to the pH of the sea which normally lies at 8,0 units. The slopes are very low (0,03 mm/km) and therefore the velocity as well. The maximal speed of the ebb current has been recorded by BERTHOIS and HOORELBECK (1968) with 6,5 km/h in March during a period of medium discharge (about 2000 $\text{m}^3/\text{s}$), while the maximum is around 7730 $\text{m}^3/\text{s}$.

Regarding the high evaporation during the dry season and the low precipitation in the region during the whole year, the salinity changes considerably during the different seasons (LINDEMAN 1953). In the dry season, salt water flows upstream with the raising tide up to the inflow of Crique Beuf aux Lamantins, while in the wet season marine waters enter the mouth of Maroni only up to the Crique Coswine (JOUNNEAU and PUJOS 1988). Salty water has a higher density and is transported in a lower depth than fresh water (GERLACH 1994). This explains why in the Coswine swamps, marine fishes and other organisms are found at the so-called site “Lac du bagne” (DIJOSEF, pers. comm.): the more dense salt water rises up the Crique Coswine to the “Lac du bagne” where it comes up in the lake-like opening in the Crique Coswine (cf. Map 2). In general, in French Guiana the estuaries are invaded during the tides with salt water (dry season) or brackish water (wet season) (LOINTIER and PROST 1986). The average salinity in the sea is 36,1 ‰, in the estuaries it does not exceed 35 ‰ (CNRS and ORSTOM 1979). Commonly, water with a salinity under 0,5 ‰ is called fresh water, between 0,5 ‰ and 30 ‰ it is brackish water and above 30 ‰, salt water (GERLACH 1994). The average water temperature is about 27°C and varies between 26°C and 29°C depending on the season (CNRS and ORSTOM 1979).

Two different systems of water importation into the swamps exist: rain and raising tide. The rain has its main influence during the wet season, when precipitation is - in contrast to the dry season - very high. At this time, the influence of the flooding on the swamp is mainly mechanical: raising tide only changes the water level, but does not have a huge impact on the already soaked swamp soils. In contrast, during the dry season the import of brackish water is of greater importance to the soils, as at
that time precipitation is very low. With each raising tide or at least with the spring tide, the soil of the inland swamp is flooded (LOINTIER and PROST 1986).

The Coswine swamps are drained by a system of tributaries which flow into the three largest creeks Crique Coswine, Crique Vache and Crique aux Beauf Lamantins. Canals of changing streams depending on the tide connect the system: the Crique 1900 connects the Crique Canard to the Crique Vache, and the Bistouri Ben Amar connects the Crique aux Beufs Lamantins to the Crique Grand Ben Amar. The three big creeks drain entirely to the Maroni River which flows into the Atlantic Ocean approximately 2 km in the north of the study area. The rivers in French Guiana do not transport many particles and the estuaries are mainly filled with marine silt. Sedimentation of river load is restricted to the inflow of smaller creeks where water velocity is slower because of the faster current of the main river (BERTHOIS and HOORELBECK 1968). The sedimentation of the Maroni River is very low before the inflow of the Crique aux Beufs Lamantins (BERTHOIS and HOORELBECK 1968). Going downstream from this creek, the mud appears only locally at first and shows a wide distribution close to Pointe Coswine. This typical estuarine feature is observed in many estuarine situations and is called “estuarine circulation” (GERLACH 1994): at high tide, the salt water is transported upstream at the bottom, as it is more dense than the fresh water. Because the currents are rather fast, silt particles are taken away and deposited further upstream to the limit of the salt water transport. At low tide, the faster flowing water at the surface transports many particles into the other direction. As a result suspended matter is deposited in the estuary.

The tides are semi-diurnal with unequal duration. Every 12h 25’ a new high tide is recorded. The schedule of the tides is made by the maregraph of the Iles du Salut; to get the exact time of the tide at the Pointe des Hattes (mouth of the Maroni, cf. Map 2) one must add 5 minutes for the high tide and 15 minutes for the low tide (APAVE 2000). During the study time, the maximal difference between low and high tide was 2.83 m (17/18. September), the minimum 0.72 m (25. September), calculated for Les Hattes (LES MAREES DANS LE MONDE 2000).

BOYÉ (1963:18) concludes from the existence of Rhizophora and Montrichardia arborescens in an area totally submitted to the influence of the tides that “nous sommes donc là en milieu proprement estuarien”\(^4\).

\(^4\) Engl. “we are here in a clearly estuarine milieu” (T.S.)
2.3 Vegetation and vegetation units

LINDEMAN and MORI (1989) give a rough overview over the existing vegetation types in the Guianas. Concerning the study area, three types are taken in consideration: a. mangrove, b. marsh forest and c. swamp forest. In contrast to marsh forests which have waterlogged soils during one part of the year and are dry during the rest of the year, swamp forests grow on soils which never dry out completely. Their distribution is restricted to fresh-water areas, whereas the saline swamp forest are treated as mangroves. The marsh and/or the swamp forest are commonly called “várzea” or “igapós”, two terms mainly employed for the vegetation types along the Amazonian Brazil (cf. PIRES and PRANCE 1985).

The classification of the vegetation types for French Guiana by GRANVILLE (1992) which is based on that of LINDEMAN and MORI (1989), is concentrated on one country and therefore more detailed. He notes six different vegetation formations for the actual coastal plain. Out of these, the herbaceous swamps, the swamp forest and the estuarine mangrove occur in the study area.

Map 7: Extract of the vegetation map, 1:250 000 (CNRS and ORSTOM 1979)
According to the topographic map (Map 2) of the INSTITUT GÉOGRAPHIQUE NATIONAL (1990), one can find three different types of vegetation on the borders of the creeks: Low mangrove (cf. Fig. 4), high mangrove (cf. Fig. 5), and dense forest. This classification is very rough, derived from aerial photos and sometimes not justified. The border between the low mangrove and the high mangrove for examples often cannot be seen. Furthermore the inland forest in French Guiana are also called “dense forest”, but both are not similar concerning species distribution. The more precise Atlas of Guiana (Map 7) shows more vegetation units as the topographic map. In total, five different units appearing in the study area are mapped in the Atlas: old or decadent mangrove, herbaceous swamp or swampy savannah, forest frequently flooded or swampy, forest with light xerice tendency above white sands and ancient coastal belt, secondary forest of the plain.

The inventory of CORINE-BIOTOPES has not been finished in French Guiana until now. A preliminary list of vegetation units is under revision at the Herbarium of Guiana in Cayenne (de GRANVILLE, pers. comm.).

In the followings paragraphs, the three dominant vegetation types, mangrove, herbaceous swamp and marsh/swamp forest (sensu GRANVILLE 1992), will be described.

### 2.3.1 Mangrove

Mangroves are found at the coasts and on silty soil in the estuaries of tropical countries. In general, mangroves can be divided in two groups: the Atlantic Mangrove in Africa and America and the Oriental Mangrove in Southeast Asia, Malaysia and in the Pacific. Due to the warm Brazil Current the mangroves extend at the Atlantic coast of America from Florida (27° – 28° N) to Mid-Brazil (28°20’ S) in contrast to the Pacific coast of America where the mangroves are only found up to 3° 48’ S because of the cold Humboldt Current (SCHNELL 1987). On the northern Pacific coast of America, mangrove vegetation is limited to 25°38 N (CHAPMAN 1976b). WEST (1983) considers with Avicennia at St. Augustine, Florida (29°53’ N) and mangrove association with Rhizophora at the Bermuda Islands (32°20’ N) as the northmost distribution of mangrove vegetation association. In accordance with CHAPMAN (1976b), he explains the limited distribution of mangroves at the Pacific coast by the lack of quiet bays and the absence of river deltas with fine sediments. In French Guiana, mangroves cover only 70 km² of the land surface (~ 0.8 %) (LESCURÉ and TOSTAIN 1989). Estuarine mangroves
can be found at the mouths of all big rivers in French Guiana and coastal mangrove nearly all along the shore (Granville 1986).

The distribution of the different species depends on temperature, mud substrate, protection, salt water, tidal range, ocean currents and shallow shores (Hutchings and Saenger 1987). To survive in this environment, the mangrove plants have developed different survival techniques: their seedlings are viviparous (Avicennia and Rhizophora), they have the ability to excrete salt through the leaves (Avicennia) or they have a membrane in the roots (Rhizophora) to separate the salt ions (Chapman 1976a). Further root modifications lead to pneumatophores in Avicennia and to the typical stilt roots in Rhizophora (King et al. 1990) or to buttress roots (Pterocarpus).

The mangroves appear in salt and in brackish water and settle on already existing land; afterwards they accelerate the sedimentation (Berthois and Hoorelbeek 1968; Chapman 1976a; Seibert 1996). In contrast to the coastal mangrove, the estuarine type has a lower salt concentration in the soil and elements of river sedimentation are mixed to marine mud. Moreover, the mangrove of the estuaries is a stable mangrove and not subjected to temporal changes of the mud banks. Therefore the estuarine mangrove is richer in species. The further it is away from the sea, the more intermediate vegetation units between those of the mangrove and those of swamp forests exist (Granville 1986). The productivity of the mangrove is about 2 kg m$^{-2}$ a$^{-1}$ of dry matter (Gerlach 1994).

The vegetation of the estuarine mangrove is often dominated by the Red Mangrove Rhizophora racemosa (cf. Fig. 7), which replaces and substitutes the Black Mangrove Avicennia germinans, the typical species of coastal mangroves. Rhizophora ssp. are sometimes even found at the level of the first rapids, i.e. at the limit of the tides away from any salt water (Lescure and Tostain 1989) or they can even live constantly in fresh (LindeMAN 1953) or in slightly brackish water (West 1983). Pires and Prance (1985) in contrast, sees the distribution of Rhizophora ssp. limited to the salty water areas. Locally, the White Mangrove Languncularia racemosa (cf. Fig. 6) replaces the Red Mangrove and develops mixed stands where the two species meet, but Languncularia racemosa never reaches tree habit in these areas (LindeMAN 1953). Rhizophora mangle is another species of the Red Mangrove which occurs mainly along the coast and saline river banks. Where the R. mangle and R. racemosa meet, a hybrid of the two exists, Rhizophora harrison (LindeMAN and Mori 1989).

According to West (1983), the lower river courses of French Guiana are bordered by a fringe of Rhizophora mangle, while further upstream Languncularia racemosa appears. Besides these, typical mangrove plants like Machaerium lunatum, Montrichardia arborescens, Conocarpus erecta, and the two palm species Mauritia flexuosa and Euterpe oleracea are often present in the mangroves of.

Fig. 6: Languncularia racemosa  
Fig. 7: Rhizophora racemosa
French Guiana (GRANVILLE et al. 1993) (cf. Fig. 8 and Fig. 9). In the transition zone to the swamp forest, the mangrove vegetation is enriched with species possessing more or less “bank character” like Carapa guianensis, Pterocarpus officinalis, Pachira aquatica. Behind this curtain, some swamp formations dominated by Euterpe olerace can be found (SCHNELL 1987). BENOIST (1924/1925) considers Macrolobium bifolium and Muellera to be important species beyond the limit of the mangrove.

PIRES and PRANCE (1985) describes the mangrove appearing in a small strip in Amazonian Brazil along the coast as poor in species and dominated by Rhizophora mangle, Avicennia germinans, Languncularia racemosa and Conocarpus erecta all of which appear in great dominance. Besides these plants, only a few others occur: Pterocarpus officinalis, Hibiscus tiliaceus, Annona palustris, Pithecelobium cochleatum and Spartina brasiliensis.

LINDEMAN (1953) gives an overview of the general appearance of mangroves in Surinam. He characterises the vegetation patterns along the riverbanks as follows: at the river mouth a belt of Rhizophora mangle is found if tidal action is low. Sometimes this fringe is interrupted by Languncularia racemosa or by Machaerium lunatum. Further inland with decreasing salt content, Avicennia germinans replaces Rhizophora and Languncularia. Where the riverwater becomes fresher, Montrichardia arborescens appears. Further upstream, when Rhizophora mangle and Languncularia racemosa are less common, Pachira aquatica and Pterocarpus officinalis border the riverbanks.
2.3.2 Herbaceous swamp

The herbaceous swamp is the most important vegetation unit of the recent coastal plain (GRANVILLE 1992) and occupies about 1500 km² in French-Guiana, mainly on recent marine mud (GRANVILLE et al. 1993). GRANVILLE (1986) and GRANVILLE et al. (1993) classify different types of herbaceous swamp formations into four groups and describe their increasing floristic variety from the mangrove to the interior:

1. Swamps of *Eleocharis mutata*: also called dead mangrove savannah, this formation mainly growing on still salty soil is the predecessor to the fresh water swamps and successor of the mangrove. The soil differs from the soil of the mangrove: due to the intake of rain water in the rainy season, organic matter is accumulated at the surface, the acidity is higher and the salinity lower. The vegetation is characterised by *Eleocharis mutata*, a plant which has a large tolerance of salt and is found from fresh water habitats to water with a salt rate of two times the sea water (LINDEMAN 1953). In addition, other *Cyperaceae*, *Machaerium lunatum*, *Montrichardia arborescens*, *Chrysobalanus icaco* and *Euterpe olearcea* can be found.

2. Swamps of *Typha angustifolia* and *Cyperus articulatus*: this is a transition formation making the conjunction to the following unit of fresh water swamps. The vegetation is very dense, attains a height of 2 m to 2.5 m and is dominated by *Typha angustifolia*. The fern *Acrostichum aureum* and some graminoides (*Cyperus articulatus* and *Leersia hexandra*) are often found as well.

3. Fresh water swamps of *Cyperaceae* and ferns: the most widely distributed formation. It grows on a small organic layer and it is under the influence of changing water levels due to the different seasons. The desalination is quite progressed and salt can only be found in a depth of 1 m. The flora is dominated by *Cyperaceae*, *Onagraceae*, *Convolvulaceae* and *Poaceae*. Two fern species (*Blechnum serrulatum* and *Thelypteris interrupta*) are very abundant and produce the main part of the peat layer. Often, *Montrichardia arborescens* is very abundant.

4. Swamps of *Echinochloa ploystachya*: Also called grass savannah this formation can be found in French Guiana only in the upstream region of the River Kaw. The soil is not salty and sometimes the marine deposits are mixed with alluvials. Patches of *Chrysobalanus icaco* and *Maurita flexuosa* are less widespread than in the other formations and the herbaceous vegetation is dominated by *Leersia hexandra* and *Echinochloa polystachya*.

LINDEMAN (1953) gives a very similar but more detailed description for Surinam.
2.3.3 Swamp forest and marsh forest

This formation occupies approximately 3 000 km² in French Guiana (3.3 % of the total land surface). The different vegetation types can be classified by the period of flooding, the development and the hydromorphic level of the soil. GRANVILLE (1986) and GRANVILLE et al. (1993) distinguish four species of flooded forest:

1. Woody swamp: this formation corresponds to the “igapo” in the Brazilian nomenclature. Woody swamps are flooded permanently by stagnant fresh water and are mainly found in the coastal swamps or in the river meanders. The most common species are *Triplaris surinamensis* or *Inga sp.* LINDEMAN (1953) distinguishes three subspecies: (1) the mixed woody swamp with mainly *Annona glabra* and *Triplaris surinamensis*, (2) the woody swamps of *Erythrina glauca* forming isolated stands of *E. glauca* and (3) the association of *Machaerium lunatum* which reaches a height of 3-4 m and sometimes entirely covers small creeks.

2. Swamp forest: also called “várzea” in Brazil, this floristically rich formation (170 to 210 different vascular plant only in the formations of the coastal plain) thrives on not always flooded, but hydromorphic soils. LINDEMAN (1953) has established a classification for the swamp forest of Surinam in which he describes two groups: (1) the swamp forest of *Triplaris surinamensis* and *Bonafusia tetrastachya* and (2) the swamp forest of *Symphonia globulifera* which prospers on clayish marine deposits of the rivers and streams (cf. Fig. 10). The two formations are dominated by different species. The most important are *Euterpe oleracea*, *Symphonia globulifera*, *Virola surinamensis*, *Pterocarpus officinalis* and *Mauritia flexuosa*.

3. Alluvial forest: this forest temporally flooded during the rain season is characterised by its non-existing undergrowth.

4. Riparian forest: the riparian forest normally grows on terra firme and is flooded only rarely. Being comprised of forest species, undergrowth species, canopy species and light requiring species, it is rich in species. The number of species in this formations in French Guiana is about 1500 to 2300, which is due to the circumstance that the forest canopy descends to the water level (OLDEMAN 1972).
The dominant plants of marsh and swamps forests are the palm species *Mauritia flexuosa* and *Euterpe oleracea*. *Machaerium lunatum* is a shrub which appears regularly in this vegetation type. Along the river banks a thick vegetation of *Montrichardia arborescens* is often found (GRANVILLE 1992). PIRES and (PRANCE 1985) are more categorical and defines the “estuarine várzea” as an area with extraordinary abundance of palms in particular *Astrocaryum murumuru*, *Raphia taedigera*, *Euterpe oleracea*, *Maximiliana regia*, *Oenocarpus distichus*, *Jessinia bataua*, *Mauritia martiana*, *Mauritia flexuosa*, and *Genoma ssp*.

SCHNELL (1987) draws special attention to the woody riparian formation. He mentions that a nearly pure formation of *Pterocarpus officinalis* is found in the Guiana-amazonian region. This formation is bordered by *Montrichardia arborescens* and often *Pachira aquatica* is abundant. In the convex meander *Inga sp.* is found.

### 2.4 Fauna

GRANVILLE *et al.* (1993) note that the fauna of the estuarine mangrove is relatively rich: White-tailed Deer *Odocoileus virginianus*, Mangrove Oyster *Crassostrea rhizophorae*, Mangrove Crab *Ucides cordatus*, and Caiman *Caïman croc̣idilus* can be found. Furthermore, some primates like the Common Squirrel Monkey *Saimiri sciureus* lives in these zones. Further away from the sea, the diversity of the fauna increases, similar to the plant species richness. Thus some nectarivore birds like the Plain-bellied emerald *Amazilia leucogaster* and some fructivore birds, e.g. the Yellow-rumped Cacique *Cacicus cela*, appear. In contrast to that description, TOSTAIN *et al.* (1992) judge that the avifauna of the mangrove is not very rich. But these different assumptions are more a result of different classifications than a substantial disagreement: GRANVILLE *et al.* distinguish coastal and estuarine mangrove, while TOSTAIN, DÜJARDIN *et al.* classify the coastal mangrove in one group and lagoons and subcoastal swamps, including estuarine mangrove, in another.

During the field work the following animals have been observed apart from manatees: Crab-eating Raccoon *Procyon cancrivorus*, Giant Otter *Pteronura brasiliensis*, Jaguar *Panthera onca*, Common Squirrel Monkey *Saimiri sciureus*, Red Howler Monkey *Alouatta seniculis*, Caiman *Caïman croc̣idilus* and Green Iguana *Iguana iguana*.

Birds often seen are the Yellow-rumped Cacique *Cacicus cela*, White-winged Swallow *Tachycineta albiventer*, Greater Ani *Crotophaga major*, Black Vulture *Coragyps atratus*, Muscovy Duck *Cairina moschata*, Sunbittern *Eurypyga helias*, Pied-Water Tyrant *Fluvicola pica*, Willet *Catoptrophorus semipalmatus*, Snowy Egret *Egretta thula*, White Egret *Egretta alba*, Little blue Heron *Egretta caerulea*, Little Kingfisher *Chloroceryle amaericana*. Even the Hoazin *Opistocomus hoazin*, the only ruminant bird in the world, was heard one time.

In general it can be said that the fauna of the estuarine mangrove is quite untouched. Hunting occurs only rarely (GRANVILLE *et al.* 1993). This is valid even more for the Coswine swamps, as they are rather badly accessible except by boat.
2.5 The conservation areas

Situated in the North of the study area, the “Réserve naturelle de l’Amana” (cf. Map 8) was created in 1997. The reservation is dedicated to the conservation of Leatherback turtles *Dermochelys coriacea*, Olive Ridley turtle *Lepidochelys olivacea* and Green turtles *Chelonia mydas*, which nest on the sandy beaches. According to SPOTILA et al. (1996) the Plage des Hattes (cf. Map 2) is considered to be the most important Leatherback turtle laying site of the world.

Since 1992, the Coswine swamps are part of the Ramsar zone “Basse Mana”. The Ramsar perimeter includes 15 000 ha of marine waters and estuaries, and 44 000 ha of terrestrial zones. The area is subject to constant changes of its shoreline by the accumulation of deposits and erosion (DIRECTION REGIONAL DE L’ARCHITECTURE ET DE L’ENVIRONNEMENT 1992). Beginning in the North at the Plage des Hattes, a ZNIEFF II (“Zones d’Intérêt Ecologique, Faunistique et Floristique”: zone of ecological, faunistic and floristic interest) was created in 1992. The ZNIEFF is restricted in the South by the Crique Vache and in the East by the departmental road. A ZNIEFF II is either a large natural ensemble rich and little modified, or one which offers important biological potentials compared to an ZNIEFF I, which is an area limited in surface, characterised by its remarkable biological interest (LÉVY-BRUHL and COQUILLARD 1998).

Map 8: The protection areas, 1: 200 000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL 1990)
Summary

The Coswine Swamps, the study area for this project, are one of the biggest wetlands in French Guiana. They are situated in the Northwest near the Guianan-Surinamese border in one of the driest regions in French Guiana. The climate is characterised by a dry and a wet season, both of which have a major influence on the water regime in the swamps. The swamps are drained by a system of different tributaries flowing into three bigger creeks.

The soils are mainly formed by recent marine deposits without much organic matter. On these soils, different vegetation formations thrive: mangrove, swamp/marsh forest and herbaceous swamps. Chemical water properties of all big rivers in French Guiana are the same and rivers do not transport much suspend matter. The estuaries are filled with marine mud brought in by the flood and varying between 0.7 and 2.8 m in height. The fauna is quite untouched and animal observations are numerous. Therefore, different conservation areas have been installed in the area: the “Réserve naturelle de l’Amana”, the Ramsar zone “Basse Mana” and the ZNIEFF II.
3 The Antillean Manatee (Trichechus manatus manatus)

3.1 Systematic of the Antillean manatee

The Antillean manatee (*Trichechus manatus manatus* Linnaeus, 1758) (Fig. 11) belongs to the Phylum Chordata, the Class Mammalia and the Order Sirenia. This order is divided into two families: Dugongidae and Trichechidae.

The family Dugongidae consists of only one still living species, the Dugong *Dugong dugong*. It lives in the Indo-Pacific area and is the only completely marine Sirenia species. The extinct Steller’s sea cow (*Hydrodamalis gigas*) in contrast, belonging to the family Dugongidae as well, lived in the Bering Sea. That species demonstrates the vulnerability of sirenians, as it was hunted to extinction in 1768, only 27 years after its discovery (MARMONTEL et al. 1997). The family Trichechidae contains one genus, *Trichechus*, which includes three species: *T. manatus* (West Indian manatee), *T. inunguis* (Amazonian manatee) and *T. senegalensis* (African manatee). *T. manatus* has two subspecies, which can be distinguished by morphological criteria (DOMNING and HAYECK 1986). *T. m. manatus* is found on the Atlantic coast of South and Middle America and *T. m. latirostris* (Florida manatee) around the Florida peninsular to Louisiana. The two subspecies are separated by the cool winters of the Northern Gulf coast and the deep water and strong currents of the Straits of Florida (DOMNING and HAYECK 1986). There are some doubts about the classification of the subspecies (cf. Introduction), but the discussion of this topic is far beyond the aims of this study. Nevertheless, the new results based on DNA analysis from GARCIA RODRIGUEZ et al. (1998) show that three lineages exist which correspond in geography approximately to Florida and the West Indies, Gulf of Mexico to the Caribbean rivers of South America, and the Northeast Atlantic coast of South America.

*T. manatus* mainly lives in rivers, estuaries and bays in the Caribbean and the Gulf of Mexico, while *T. senegalensis* occupies the same zones in West Africa. *T. inunguis* is only found in the freshwater areas of the Amazon and Orinoco, but there is some evidence that Amazonian manatees appear in slightly salty water as well (DOMNING 1981). At the mouth of the Amazon, *T. inunguis* and *T. manatus manatus* meet (DOMNING 1981), but no hybrids are formed (DOMNING and HAYECK 1986).
The evolution of the manatee species shows that the West African and the West Indian manatee share a more common ancestor than they do with Amazonian manatee. Domning (2001) gives a more precise overview of the prehistoric development of manatees.

### 3.2 Biology and Ecology of the Antillean manatee

As the only fully herbivore and aquatic mammals, Sirenians are highly specialised and very well adapted to their environment. In the following paragraphs the most important features are explained.

#### 3.2.1 Biology of the manatee

**Morphology**

An overview over the morphology is provided by HUSAR (1977) from which the following extracts are taken.

Manatees are large, totally herbivorous aquatic mammals with a total length of 2.5 m to 4.5 m and a weight of 200 kg to 600 kg. Their body is streamlined and covered with short hairs. The colour is uniform grey but sometimes obscured by algal growth, barnacles or incrustations. Manatees have one paddle-like tail and two forelimbs with nails on the dorsal surface. The flippers are quite movable and used for feeding and social behaviour.

Manatees have a low metabolic rate of only 20 % to 30 % compared to other animals of the same body size. For this reason manatees, are not able to keep their body temperature up at a certain level (Wells et al. 1999), what can, in consequence, cause in extrem cases the death of an animal.

**Behaviour**

Manatees are described by HARTMANN (1979) from whom the following information is taken, to be secretively, but they are active during night and day. Their daily course is arhythmic and they show no certain behaviour which is repeated several times per day.

Manatees are slow swimming animals with an average speed of only 3 to 7 km/h. As herbivores they do not need speed and acceleration. But when fleeing, they can reach 25 km/h over a short distance. Cruising depth for manatees is usually between 1 – 3 m with a maximal depth of about 8 m, due to the higher water pressure in the depth. Occasionally, they descend down to 20 m. While swimming acceleration is achieved with the paddle-like tail and steering with the two forelimbs. In shallow water manatees move their body back and forwards by strong strikes of the forelimbs (Tschada 1994).

Diving time increases from calves to adult manatees. The average time is about 4 ¼ minutes (Hartmann 1971), but other authors give 2-3 min (Wells et al. 1999). For breathing, manatees raise their snout out of the water and breath through the movable nostrils (Tschada 1994).
Reproduction

Manatees are typical K-selected species: they breed repeatedly during their lifetime, litter size is small, it takes years to reach sexual maturity, and lifespans are long (REYNOLDS 1999).

Concerning reproduction, little is known about the Antillean manatee in contrast to the Florida manatee. BOYD et al. (1999) see female *T. m. latirostis* reaching sexual maturity between the ages of 2.5 and 6 years, approximately at the same time as the males ones, while MARMONTEL et al. (1997) give an age of 3 - 4 years. The gestation takes 12 - 14 months (BOYD et al. 1999). HUSAR (1977) and BELITSKY and BELITSKY (1980) suggest from observation of young manatees during any time of the year that manatees breed throughout the year, but more recent publications show that breeding peaks exist for the Florida and the Amazon manatee (BOYD et al. 1999) and the Antillean manatee (COLMENERO-ROLON 1985). For the two last ones, this is caused by the change of wet and dry season, while for the Florida manatee temperature may be responsible. Normally, only one calf is born, but twin birth has been reported (WELLS et al. 1999). For giving birth manatees select quiet backwaters (HARTMANN 1979). Cows probably breed at least every 2 years (BENGSTSON 1981); MARMONTEL et al. (1997) suggest three years, but more recent publications show, that the calving interval is between 2.5 to 5 years (BOYD et al. 1999). After birth cows and calves form a strong unit during 1-2 years (HARTMANN 1971). The long period of calf dependence is perhaps used to transmit acquired traditions from cow to calf (BENGSTSON 1981).

Manatees are long-lived animals and may live about 60 years (REYNOLDS 1999), but population models work with 39 years as life expectancy (MARMONTEL et al. 1997). In contrast to other large bodied mammals, manatees do not have a stable mid-age population and survivorship curves resemble curves of exploited populations. The reproduction rate $R_0 = 1.09$ of Florida manatees is low and the finite rate of increase $R = 0.005$ close to zero (MARMONTEL et al. 1997). This makes manatees vulnerable to exploitation and it is further difficult for them to recuperate from reductions (MARSH et al. 1986; REYNOLDS 1999).

**Fig. 12:** Female manatee with young (drawing BATEMAN 1987)

Alimentary system

The manatee’s snout is well adapted to the aquatic environment. It is used to discriminate different surfaces (BACHTELER 1997) and for food intake. The lower and upper lip pads are covered with bristles of which the upper lip bristles are used to bring plants to the rear of the mouth (HUSAR 1977). Manatees have horny pads in the forward parts of the mouth and in the backward teeth replaced regularly throughout life from the rear (BERTRAM and BERTRAM RICARDO 1973). The old teeth, worn out by sand and grit ingested during feeding, fall out. This pattern is unique among placental mammals. Chemical receptors in the mouth may help manatees to avoid plants containing alkaloids (BENGSTSON 1981). They chew incessantly emitting little sounds which can be used to record chews per minute (for example used by ETHERIDGE et al. (1985) or BENGSTSON (1981).
Sirenians have a single stomach and do not ruminant. The stomach is small in size, but the intestines are long (BERTRAM and BERTRAM RICARDO 1973). The digestive system is similar to those of other herbivores, with bacterial digestion of cellulose in the hindgut (VAN METER 1989).

Manatees and dugongs possess kidneys which allow them to survive for longer periods in marine environment and even to drink salt water. But access to a fresh water source is “an overwhelming consistent pattern” (LEFEBVRE et al. 1989:591). The influence of fresh water is reviewed by POWELL and RATHBURN (1984) (taken from PROVANCHA and PROVANCHA 1988). ORTIZ et al. (1999) found out that manatees consume small amounts of salt water or must feed in marine areas to avoid hyponatremia.

3.2.2 Feeding ecology

Foraging behaviour

Manatees are known to eat a wide variety of aquatic and semi-aquatic macrophytes (BERTRAM and BERTRAM RICARDO 1964; CAMPELL and IRVINE 1977; THE NATIONAL SCIENCE RESEARCH COUNCIL 1974). They favour submergent vegetation to floating and floating to emergent and show preference for luscious, non-woody and plants which are easy to eat (ALLSOPP 1969). Plants are selected due to their palatability, digestibility and nutritional value (HEINSOHN and BIRCH 1972). By comparing feeding behaviour of manatees in Florida and Puerto Rico, LEFEBVRE et al. (2000) suggest that manatees in Florida eat whatever they find along their travel routes, while manatees in Puerto Rico have developed more specialised feeding strategies, as they are not restricted by thermal regimes. Manatees in Florida are also selective in their choice of feeding sites and regularly return to one place until it is depleted or another area is favoured (HARTMANN 1979).

Manatees use their pectoral flippers to pull food under water to eat it (REYNOLDS et al. 1999; TSCHADA 1994). It has been observed that they “grab” grasses with their forelimbs (TIMM et al. 1986) or “walk” with their flippers on the creek bottom during foraging (HARTMANN 1979). Moreover, they push their body up to 30 cm out of the water to graze on the banks (BERTRAM and BERTRAM RICARDO 1964; HAIGH 1991) or browse on plants hanging over the water if they can reach them (EISENBERG and REDFORD 1999; MOU SUE et al. 1990). The degree of rostral deflection of the skull seems to indicate in which environment a manatee prefers to feed: Sirenians feeding in seagrass areas have higher deflections as animals browsing on floating, bank or overhanging vegetation (DOMNING and HAYECK 1986). This has been proved by a skull found in Panama which showed the smallest rostral deflection ever seen. In this area, manatees live mostly in fresh water or brackish environments than in seagrass dominated areas (MOU SUE et al. 1990). DOMNING (1980) found in experiments with Trichechus manatus and Trichechus inunguis that T. manatus feeds with a weaker preference in the low water column than T. inunguis. DOMNING attributes it to the fact that T. manatus is more a “generalist” than T. inunguis concerning foraging behaviour.

5 Hyponatremia is deficiency of Na⁺ ions. To avoid that the Na⁺ content in the blood falls beyond a certain level, manatees consume small amounts of salt water.
As mentioned above, manatees are restricted to shallow waters where aquatic macrophytes productivity is high (BEST 1981). Feeding normally takes place in shallow water in a depth of 0.4 – 1.6 m in Florida or of 1 – 5 m in Puerto Rico, maybe for energetically purpose (LEFEVBRE et al. 2000). Manatees feed for 6-8 h per day (BEST 1981), but more recent research on Florida manatee suggests 5.1 h per day (BENGSTON 1983). One feeding session normally takes 30 – 90 min, but hungry manatees were observed to graze for more than two hours (HARTMANN 1979). BENGSTON (1983) explained seasonal differences in feeding behaviour with changes in the nutritional needs, temperature or forage quality. As the nutrition quality of plants eaten by the manatees is not very high - aquatic macrophytes are composed of water by 70 % to 95 % (JUNK 1983) - they must consume large quantities of food every day (BEST 1981). Non-breeding captive Amazonian manatees consume 8 – 9 % of their body weight in plants per day, and growing, lactating or pregnant ones 10 – 13 % (BEST 1981). With those values BEST is in accordance with BENGSTON (1981), BENGSTON (1983) (4 – 9 %) and ETHERIDGE et al. (1985), even if ETHERIDGE and co-workers believe that results from captive manatees can not be extrapolated to free-ranging animals. If calculation of food is made in kg, BENGSTON (1983) gives 33,2 kg/day and ETHERIDGE et al. (1985) 33,4 kg/day of wet matter for an “average” manatee. Converted to dry matter by a ration of 1 g wet weight to 0,18 g dry weight (PROVANCHA and HALL 1991) this gives a daily dry plant biomass consumption of 5,9 kg/day.

Feeding plants

For Florida manatees the food mainly consists of the seagrasses Syringodium filiforme, Thalassia testudium, Halodule wrightii, Ruppia maritima and Halophila sp. (POWELL and RATHBURN 1984). Algae normally do not belong to the diet of manatees, but in captivity or in turbid waters with not sufficient vascular plants, they feed on these plants as well (HARTMANN 1979).

Feeding on mangrove occurs regularly, in particular during the dry season, when leaves of mangroves are the main food resource (MIGNUCCI-GIANNONI and BECK 1998; O’SHEA et al. 1988). From Surinam and Brazil it has been reported that manatees feed on mangroves (Avicennia nitida, Rhizophora mangle, Languncularia racemosa) and Monrichardia arborescens (BEST 1981), on Rhabdadenia biflora (DOMNING 1981) and even on the thorny Machaerium lunatum (DUPLAIX and REICHARD, cited after DE TOYRIS et al. (2001). This, however, has been denied by DEKKER (1974). From Puerto Rico it has been reported (SMETHERST and NIETSCHMANN 1999) that manatees feed - among other plants - on Pachira aquatica and in Panama, various Poaceae seem to play an important role in daily diet (MOU SUE et al. 1990).

Incidentally, manatees consume invertebrate periphyton when feeding on submerged plants (HARTMANN 1979). Piscivoriy is reported from Jamaica, where manatees regularly seem to “steal” fish entangled in fishermen’s nets (POWELL 1978 in O’SHEA 1986).
3.2.3 Habitat use

Manatees live in fresh, brackish and salt water and inhabit rivers, estuaries and coastal areas of the tropical and subtropical regions of the New World Atlantic coast (HUSAR 1977). In general, they seem to prefer estuarine and riverine habitats (POWELL and RATHBURN 1984).

Many authors agree that manatees need lush vegetation (e.g., DOMNING 1981; POWELL et al. 1981; REYNOLDS et al. 1995; SMITH 1997; TIMM et al. 1986). Furthermore, areas sheltered from heavy wave action and human water activities, and with fresh water access are important as well (O'SHEA et al. 1988; O'SHEA and SALISBURY 1991; RATHBUN et al. 1983; REYNOLDS 1999). This corresponds to the observations of POWELL et al. (1981) in Puerto Rico, who made over 93% of their sightings in areas with calm seas, extensive seagrass beds and freshwater. BELITSKY and BELITSKY (1980) observed manatees living all the time in sea water around the Dominican Republic, which includes feeding and drinking in salt water and REYNOLDS (1999) suggested that access to fresh water is not a physiological necessity but an apparent preference.

In Surinam, mangrove forests provide habitat for manatees (DUPLAIX and REICHARD in DE THOISY et al. (2001). According to REYNOLDS et al. (1995) an excellent habitat is characterised by lush vegetation, quiet, overgrown small canals and freshwater.

Climatic conditions

Water temperature is the most important factor limiting manatee distribution (SMITH 1993) to the South and North (LEFEBVRE et al. 1989). To the question of the minimum water temperature needed by manatees several opinions exist: ALLSOPP (1961) mentions 21°C, HARTMANN (1971) observed winter aggregations of the Florida manatee beginning at 20°-23°C and BENGTSON (1981) fixed the beginning of winter aggregation at 21°C. LEFEBVRE et al. (1989) and BATEMAN (1987) see the manatees restricted to areas with water temperatures of at least 20°C, while WELLS et al. (1999) favours 19°C as minimal temperature. IRVINE (in O'SHEA et al. (1988) sees the lower limit of thermoneutrality of about 24°C. In the inner tropics, temperature does not affect manatee distribution (COLMENERO 1981 in COLMENERO-ROLON 1985; AXIS ARROYO et al. 1998). The low metabolic rate is one of the reasons why manatees are restricted to the tropics.

Other climatic parameter like cloudiness, sunshine intensity and duration have no influence on the manatee distribution (AXIS ARROYO et al. 1998; HARTMANN 1979).

Movements and temporally aggregation

Manatee populations are mobile and regularly change their residence (SMETHURST and NIETSCHEIMANN 1999). REID et al. (1991) describe a 850 km journey of a manatee and DEUTSCH et al. (1998) followed a manatee by satellite tracking over 2500 km from Florida to Rhode Island, the most northern appearance of the species. The Florida manatees aggregate in large herds at thermal outflows of power plants around Florida peninsula from autumn to spring to avoid cold temperature (BENGTSON 1981; HARTMANN 1979; PACKARD et al. 1989; WELLS et al. 1999 and others). Seasonal movements due to different seasons and food availability are also reported from the Amazonian manatee (BEST 1983; ROSAS 1994) and from South Mexico (COLMENERO-ROLON and ZÁRATE 1990).
The aggregations around power plants in Florida are explained by some authors as resource-based, and as an expression of the cold weather (Wells et al. 1999), while others see this aggregation as social- and resources-based (Provancha and Provancha 1988). The total number of manatees around the out-falls of power plants can reach 400 individuals per day (Wells et al. 1999) which is approximately 1/3 of the whole manatee population in Florida. Within the distribution area of the Florida manatee, fluctuations in number at winter aggregation sites in one specific area may be caused by changes in the composition of the submerged aquatic vegetation and the increased human activity (Provancha and Provancha 1988). Other types of aggregation exist for the West Indian manatee: feeding herds, travelling herds, mating herds and cavorting herds (Bengtson 1981; Hartmann 1979).

River topography and currents

River topography seems to play an important role for manatee distribution as T. manatus needs a minimum depth of 50 cm to swim (Packard 1984). Already at a water depth of less than 1 m manatees balked to swim in creeks with shallow waters except for feeding when adjacent to deeper canals (Hartmann 1971). In Brazil and Honduras, manatees died during the dry season when locked in creeks with shallow water, which they had entered during the wet season to browse on the adjacent vegetation (Rosas 1994). On the other hand, it seems that manatees avoid areas deeper than 8 m (Hartmann 1971; Powell and Rathburn 1984). In conclusion, manatees prefer a water depth from 2 to 5 m, with a minimum depth of 1 m (Haigh 1991). Smethurst and Nietschmann (1999) used a fishfinder to map river topography and, in particular, blowing holes, where manatees congregate to wait for rising tide to swim up shallow rivers or to play.

Fast currents cause a navigation problem for manatees which have never been seen swimming in creeks with currents exceeding 6 km/h. Correspondingly manatees prefer to swim more closely to the slower shore than in the middle of a canal and tend to lay in the eddies at elbows of rivers when resting (Hartmann 1979). Distribution of the Amazonian manatee can be limited by fast turbulent water and rapids (Best 1984).

Predators and concurrence

Manatees hardly have any natural enemies beside man (Husar 1977; Wells et al. 1999). Potential predators may be caimans or parrot-fishes (Bertram and Bertram Ricardo 1964), piranhas (Allsopp 1961), jaguars or sharks (Bertram and Bertram Ricardo 1973; Wells et al. 1999). Normally only young or hurt animals are in danger of being attacked. Only one case of shark attack is proved in literature (Mou Sue et al. 1990). Hence manatees did not develop anti-predator behaviour. Further their secretive habitat seems to be a very effective protection (Wells et al. 1999).

Manatees share their environment with only few other animals. While grazing in seagrass communities, manatees compete with sea urchins, fish, and green turtles (Thayer et al. 1984). In estuaries and river systems, river dolphins (Inia geoffrensis and Sotalia fluviatilis), giant otter (Pteronura brasiliensis), capybara (Hydrochoerus hydrochoeris) and caimans use the same area. Out of these only the capybara is herbivorous. Because of its low consumption of only about 4 kg fresh grass per day (Best 1984) and the small population size in the Coswine swamps (de Thoisy, pers. comm.) it can not be considered a strong competitor to manatees.
Observations of manatees

In clear waters, manatees are easy to observe. Often, the population size and the distribution are assessed by aerial counts (see for example (BELITSKY and BELITSKY 1980; MOU SUE et al. 1990; O'SHEA and SALISBURY 1991; PACKARD et al. 1989; PROVANCHA and PROVANCHA 1988; RATHBUN et al. 1983). In Florida, many animals even are individually identifiable by scar patterns on their back caused by collisions with boats (REID et al. 1991).

Observations of manatees in turbid water by aerial studies are fairly difficult (e.g. BENGTSON and MAGOR 1979; O'SHEA et al. 1988; REYNOLDS et al. 1995). According to POWELL (cited in (POWELL et al. 1981) manatees can only be seen for 15 sec while breathing at the surface, this secretive behaviour does not allow to make long-time observations. The poor visibility prevented further aerial surveys in French Guiana after a first one had been carried out without success (DE THOISY et al. 2001). DEKKER (1974) had the same problem of turbidity in Surinam.

Habitat degradation

Human activity has the main influence on the decline in number of sirenians (LEFEVBRE et al. 1989). Intensive settlement of the coast (PACKARD and WETTERQUIST 1986) or installation of tourist resorts (COLMENERO-ROLON and ZÁRATE 1990) contributes strongly to manatee decline. Furthermore, manatees concentrate in areas where less environmental degradation has taken place and not much boat traffic exists. Residents in Costa Rica quoted that the noise of the outboard engines as well as the gasoline released to the water frightens manatees (SMETHURST and NIETSCHMANN 1999, cf. also DEKKER 1974). This confirms the hypothesis, that manatees seek isolation areas (PROVANCHA and PROVANCHA 1988). In general, habitat alteration by pollution or silting of rivers results in reduced food supply which in consequence forces manatees to find other habitats (Husar 1977).
3.3 Distribution and status in French-Guiana

The distribution and status of the manatee in the Wider Caribbean Region is well studied. The CARIBBEAN ENVIRONMENT PROGRAMME (1995), LEFEBVRE et al. (1989) and CARMEN COLMENERO ROLON (1991) give a good overview. Except for Belize and Quintanan Roo in Mexico, distribution of manatees in the area is patchy which REYNOLDS (1999) relates to the poor availability of suitable habitats and the long history of exploitation.

The first report on the status of manatees in the Guianas by BERTRAM and BERTRAM RICARDO (1964) characterises the environment to be not very promising for the Sirenias in the Northeast region of South America mainly due to the shallow and turbid waters with a brown colour and the almost complete lack of vegetation. Nevertheless, manatees are found along the Guianan coast, and to a lesser degree also in French Guiana, although suitable habitats are rare because of the narrow coastal plain (cf. 2.2.2. Geology). The coastal plain has an average width of 16 km in French Guiana whereas in the other Guyanas, it is 40-50 km wide (BLANCANEAX 1981) (cf. Fig. 13). The coastal plain is important for the distribution of manatees as the waters are shallow and without heavy wave action. Hence, the manatees of the Guyanas travel around from one river to another to find the habitat which provides the best environment (BERTRAM and BERTRAM RICARDO 1964).

As mentioned in the Introduction, the NGO KWATA carried out a first interview survey in 2000. DE THOISY et al. (2001) pointed out that the manatee is still well present in many estuaries and in a large part of the coastal area, but the populations probably are weak in number, because only a few suitable habitats – especially those excluded from any perturbation by man - exists. The DIRECTION REGIONAL DE L’ARCHITECTURE ET DE L’ENVIRONNEMENT (1992) in its resume of the report for the Ramsar secretary mentions that the manatee is common in the estuary of the River Mana and the River Maroni, but the numbers of the population remain unknown.

According to DE THOISY et al. (2001) the actual distribution of the manatee in French Guiana is limited to a few areas: beginning in the Northwest, manatees are often seen in the estuaries of the Maroni and the Mana. Further South, they dwell in the estuary of the creek Malmanoury, near Cayenne at the Point Montravel, close to Brazil in the estuary of the Oyapock and the River Ouanary. Some offshore observations were made around Ilet la Mère, about 10 km from the coast.

In contrast to earlier observations, the estuary of the Sinnamary does not shelter any important manatees populations anymore.
3.3.1 Traditional significance of manatee

As in many others areas where manatees or dugongs are widespread, their traditional and spiritual value is very high.

Since a long time, manatees have been played an important role in the history of the indigenous people. The names of the creeks give a good example: beginning in the North with Crique Coswine, which is derived from the Dutch word “koe zwem”, meaning “swimming cow”, thus manatee. A little bit more to the South, Crique Vache (French, “creek cow”) and Crique aux Beuf Lamantin (French, “creek of manatee bull”) follow. Similar evidences are given by ALLSOPP (1961:548) who mentions the town of Manati in Puerto Rico, Lamantin in Martinique and the district Manatee County in Florida. He concludes that “Sirenians were once common in all these places”.

The high traditional significance can also be seen in the existence of different legends around the manatee. One is told by the Galibis Indians (quoted after DE THOISY et al. 2001:17):

“Two sisters are married to a tapir. One day, the sisters went to festivities, and their brothers went to hunt, where they killed the tapir. Back from the festivities, the sisters are invited to eat the bag which they appreciated particularly. As the sisters were told that their brothers gave them their husband to eat, they plunged into the Maroni in mourning and anger: one became manatee, the other dolphin. Since this time, the two sisters are held responsible for sunken and capsized”.

The same legend is reported by O'SHEA et al. (1988) from the Warauno tribe in Venezuela and from Suriname (DUPLAIX and REICHARD in DE THOISY et al. 2001).

The manatee for a long time was (and still is) much appreciated for meat and oil (e.g. DOMNING 1981; HUSAR 1977; O’SHEA et al. 1988; REYNOLDS et al. 1995; THE NATIONAL SCIENCE RESEARCH COUNCIL 1974). Manatees were commercially exploited in Surinam (HUSAR 1977), Brazil and Guyana (BERTRAM and BERTRAM RICARDO 1973) and transported to the West Indies. BERTRAM and BERTRAM RICARDO (1973) even proposed the rational use of manatees for meat production. The ear bone of the manatee is supposed to have medical properties against teeth eruption of children (O’SHEA et al. 1988), or in general for several medical problems (DOMNING 1981). Aphrodisiac and digestive effects are also attributed to these ear bones and for these manatees are still hunted near the estuary of Maroni in French Guiana (DE THOISY et al. 2001). In the shaman tradition, the sternum of the manatee is used as an insignia (O’SHEA et al. 1988) and the rib bones can be used as a substitute for ivory (HUSAR 1977; THE NATIONAL SCIENCE RESEARCH COUNCIL 1974).

In French Guiana, manatees were introduced as weed control agents in the Polder Marianne near the river Mahury, but without success (DE THOISY et al. 2001). In contrast T. manatus is used in Guyana to clear small canals from invading plants since the 1960s (ALLSOPP 1961, 1969).

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6 The region of Coswine was Dutch territory until 1875. Today, many Surinamese refugees settled on the other side of Maroni River after the beginning of the civil war in 1986.
3.3.2 Actual threats

**Hunting** was more or less common in all countries with manatee populations (cf. Domning 1981; Morales-Vela et al. 2000; O’Shea et al. 1988; Reynolds et al. 1995; Rosas 1994). The impact of hunting and poaching is estimated differently: O’Shea et al. (1988) do not think that hunting is the main reason for the decline of manatees in Venezuela. Morales-Vela et al. (2000) speak of poaching as a serious problem for manatees in Belize and Mexico, and The National Science Research Council (1974) and Rathbun et al. (1983) attribute the decline of the manatee population to hunting. For Reeves et al. (1996), still ongoing hunting and trapping of manatees for food is the main reason for the decline of *T. inunguis* in Peru.

In French Guiana, manatees are still hunted in the waters of Oyapock and Maroni either for private consumption or because of religious traditions (De Thoisy et al. 2001).

**Increasing human activity** and **boat traffic**, the main problems for the manatees in Florida (see for example Garrott et al. 1994; Hartmann 1979; Marmontel et al. 1997), is not intense in Crique Coswine and its side rivers, except around the village Coswine. More boat traffic can be found in the Crique Vache, as it is used as an access for clandestine rice transports from Surinam and for Surinamese hunters. For the Swamps of Kaw – well known for the presence of caimans and Scarlet Ibis – the increasing boat traffic caused by eco-tourism, may be a reason for the decline of manatees in that region.

**Incidental killing in fishing nets** happens from time to time in French Guiana. Between 1998 and 2001, five cases have been reported. When entangled in the nets, manatees were either found drowned or were slaughtered and eaten (De Thoisy et al. 2001).

**Pollution** with mercury due to gold mining has a huge impact on the fauna in the Amazonian region (Rosas 1994). No such activities are reported from the Coswine Swamps. Runoffs by agricultural pesticides observed in Costa Rica (Reynolds et al. 1995) and Panama (Mou SUE et al. 1990) do not take place in the Coswine swamps, but rice cultivation may also lead to such pollution. Whether poison on plants effects manatees is not clear. Bengtson (1981) showed that manatees avoid plants sprayed with the herbicide 2-4-D.

**Debris** like plastic bags, unattached fishing nets, or floating ropes where seen several times swimming on the surface or drifting in the current in the Coswine swamps. Manatees can become entangled in the bags, nets or ropes, or may swallow smaller items.
3.4 Selected variables

Out of the total of factors influencing the distribution of manatee, only a few can be considered in this study. In this chapter, the most important and easily investigable parameters are examined.

One of the first studies which called for more research on manatee environments was the report of THE NATIONAL SCIENCE RESEARCH COUNCIL (1974). It proposes to study relations between manatees and their environment. In particular the authors suggested investigations on the chemical, physical and topographical conditions of the water environment, on quality of the water, food plants and populations structure. Concerning the quality of the water, they consider pH, oxygen content, salinity and temperature to be important factors (cf. Tab. 1).

Out of the variables which influence the distribution and the habitat use of manatees, vegetation is among the most important. This opinion is shared by a large numbers of authors (for example AXIS ARROYO et al. 1998; BOYD et al. 1999; ETHERIDGE et al. 1985; PACKARD and WETTERQVIST 1986; ROSAS 1994; WELLS et al. 1999, see chapter 3.2.2 as well). Distribution of T. inunguis is limited by the lack of vegetation in some regions. BEST (1984) and BENGTSON (1981) suggest that manatees leave their winter aggregation sites because food availability is reduced.

HARTMANN (1979) conducted research on different parameters (climate, depth, tides, salinity, currents, storms, sun, turbidity and dense vegetation) in order to find out whether they have any influence on manatee movements. Among these, tides have a huge influence on manatee distribution as they deny the animals access to shallow feeding grounds during low tide. Furthermore salinity is strongly responsible for the manatee’s habitat selection, as the animals seem to prefer rivers and estuaries with a salt concentration less the 25 ‰ and use salt water only for travelling.

Outside the tropics, temperature is an important factor of distribution (see 3.2.3). GARROTT et al. (1994) and PACKARD et al. (1989) investigated wind, turbidity, water and air temperature and their influence on manatee aggregations around power plants in Florida. During two winters, no significant relation between the environmental factors and manatee aggregation were found. One of the first studies on habitat use of manatees in turbid water was carried out by COLMENERO - ROLON (1985) in Mexico. He recorded water depth, turbidity, currents, temperature and vegetation and explained their influence on manatee distribution except for currents. AXIS ARROYO et al. (1998), who recorded temperature, winds, cloudiness, depth, salinity, water temperature, grass and algal abundance and group structure of manatee population, showed that wind intensity and food availability were most influential on the distribution of manatees. As their study was carried out along the coastline of Mexico (the study site for the present project lies in less windy areas in the inland) and as HARTMANN (1971) observed that even heavy storms do not affect manatee distribution, wind intensity was not considered to be an important parameter for the actual study.

In contrast to Florida the Coswine swamps are only to a very small degree under the influence of humans. Therefore conflicts between man and manatee are rare. PACKARD and WETTERQVIST (1986) used town planning methods to map potential and existing conflict areas, human influence and negative impact on manatee conservation efforts in Florida. They defined the components of a manatee habitat system in two different parts: human and manatee system. The human system includes
information on boat traffic, boating facilities and urban areas, the second informs about vegetation, bathymetry/topography, seasonal water temperature, manatee sightings and manatee activities.

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Tab. 1: Parameters investigated in different studies of manatee habitat

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<tr>
<th>Author</th>
<th>Species</th>
<th>Place</th>
<th>Remarks</th>
<th>Water temperature</th>
<th>Vegetation</th>
<th>Water depth</th>
<th>Tides</th>
<th>Currents</th>
<th>Storms/winds</th>
<th>Sun/cloudiness</th>
<th>Turbidity</th>
<th>Population</th>
<th>pH</th>
<th>Oxygen</th>
<th>Salinity</th>
<th>Shelter</th>
<th>Fresh water access</th>
<th>Human influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEILMAN (1979)</td>
<td>T. manatus</td>
<td>Wider Carib. area</td>
<td>Only proposal</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>x</td>
<td>xxx</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
<tr>
<td>LEFEVRE et al. (1989)</td>
<td>T. manatus</td>
<td>Wider Carib. area</td>
<td>Town planning methods</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>+</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
<tr>
<td>PACKARD AND WETTERQVIST (1989)</td>
<td>T. manatus</td>
<td>Florida</td>
<td>T. manatus</td>
<td>+</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
<tr>
<td>COLMENERO - ROLON (1985)</td>
<td>T. m. m.</td>
<td>Mexico</td>
<td>Mexico</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
<tr>
<td>COLMENERO - ARROYO et al. (1998)</td>
<td>T. m. m.</td>
<td>Mexico</td>
<td>Mexico</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
<tr>
<td>THOMPSON et al. (1994)</td>
<td>T. m. m.</td>
<td>Mexico</td>
<td>Mexico</td>
<td>-</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>-</td>
<td>(x)</td>
</tr>
</tbody>
</table>

---

7 A similar study was also made by GARROTT, ACKERMAN et al. (1994)
All parameters, investigated during several studies, are summarised in Tab. 1. After comparing the studies, those parameters were considered for the study in hand, which

1. are important for manatee distribution,
2. are easy to record,
3. can be worked out within two months,
4. can be measured from a canoe and
5. are not too expensive to investigate.

Based on these criteria the following parameters were chosen for the present study (cf. Tab. 1):

1. submerged aquatic vegetation,
2. water depth,
3. salinity of the water,
4. pH of the water,
5. temperature of the water and
6. oxygen content of the water.
3.5 Summary

The Antillean manatee is a subspecies of the West Indian manatee, which inhabits the coast, estuaries and rivers in Middle and South America. The only living fully aquatic and herbivorous mammal, manatees are well adapted to their special environment: the body is streamlined, the forelimbs are used to manipulate nutrition, and teeth are replaced during life-time. Because of their low reproduction rate and the small litter size, manatees populations experience steep declines after habitat destruction or man-made threats.

An important occupation for manatees is feeding, which can take up to 8 hours per day. While grazing, manatees consume 8 – 13 % of their body weight which is around 6 kg/day in dry plant matter for an average manatee. Feeding normally takes place in shallow water and nearly every aquatic plant is eaten, but mangrove vegetation and grasses as well.

For the distribution of manatees, different factors are important besides vegetation. Among these, temperature seems to play a major role, as it restricts manatees to the tropics. Furthermore, tides and river topography can limit the access for manatees to certain regions. Man is as well responsible for the (non-) occurrence of manatees, as nowadays many former manatee habitats are degraded or occupied by man.

Out of all parameter determining manatee distribution, six are selected for the present study: vegetation, water depth, salinity, pH, temperature and oxygen content.

Manatees are widely distributed in the Wider Caribbean Region, but only in patchy populations, caused by unsuitable habitats. In French Guiana, the present populations are weak in number, but at least still existing. The traditional significance of manatees is reflected by the incorporation of the manatee’s local name for labelling creeks, towns or counties and their traditional importance for indigenous people as talisman. Hunting out of traditional believes and for meat stays a important factor for manatee decline in French Guiana, in contrast to boat traffic, which seems to be less important than in Florida.
4 Study of the aquatic vegetation and the related parameters

The aim of the present study was to characterise different sections of the Coswine swamps by their aqua-chemical parameters and the aquatic vegetation.

As the study design was developed without any personal knowledge of the study site or of the applicability of the chosen procedures, a preliminary study (cf. chapter 4.2) was carried out to test the chosen parameters and the sample methods. Its results are presented (cf. chapter 4.2.2 Results of the preliminary study) and discussed (cf. chapter 4.2.3) and implications for further research are mentioned (cf. chapter 4.2.4).

4.1 Material and methods

In the following paragraphs different bank sides often are mentioned. It is important to know that the labelling is made following the water current from the creek’s spring to the mouth of a creek. For tide canals with changing currents and without a spring (e.g. Crique 1900), the labelling is made from South to North.

4.1.1 Division into sections

In order to find out whether there are any remarkable differences regarding the critical factors between distinguishable zones in the study area and in order to classify these zones into groups of similar character (cf. chapter 1.2), it is supposed that zones with different characteristics exist. To test this hypothesis, the study area was divided into sections, in which the aquatic parameters and the submerged aquatic vegetation (SAV) were recorded.

As a basis for the first classification, the physiological map of Awala-Yalimapo (INSTITUT GÉOGRAPHIQUE NATIONAL 1990) was used. The sections were created by the following characteristics:

- homogeneity of the vegetation (changes in the vegetation),
- homogeneity of the water quality (inflow of other creeks),
- if possible, equal distances.

The Map 9 on the following page shows the different sections used for the study.
Map 9: Sections for the study of the submerged aquatic vegetation, 1: 50 000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL 1990)
4.1.2 Recording of aquatic variables and the vegetation

To determine the important parameters of manatee distribution, the following variables were chosen for the present study (see chapter 3.4):

1. water temperature,
2. salinity,
3. oxygen concentration,
4. depth,
5. pH,
6. vegetation.

Within the limits of a section (cf. Fig. 14) (red lines) four subsections with equal length were established. Three line transects perpendicular to the current are situated between those subsections. The line transect 1 (T1) separates subsection 1 from subsection 2, line transect 2 (T2) separates subsection 2 from subsection 3, and so on. As the lengths of the sections vary, it is possible that the distance between the transects changes from section to section. Along a line transect, four plots (cf. Fig. 15) were situated in equal distances, which also may vary in distance from one transect to another. The first and the fourth plot were situated near the bank (P1 and P4), P2 and P3 near the middle of the creek. To get the correct position of a plot, a string was put up from a tree on the left bank to another tree on the right bank. The string was marked every 5 meters. By dividing the total width of a creek by four, the distance between the plots was obtained. At each plot, the position was acquired with the GPS 12 by GRAMIN (precision 15 m).

The aqua-chemical parameters were recorded at each plot at a depth of 0.5 m under the water surface. Salinity was measured in ‰, pH in units, the rate of oxygen in mg/l and temperature in °Celsius. All parameters were recorded with the Universal Pocket MultiLine P4, fabricated by WTW. The pH was measured with a SenTix 97/T electrode (accuracy 0.01 ± 1 digit), the dissolved oxygen with a CellOx 325 probe (accuracy ± 0.5 %), the temperature and the salinity.
with a TetraCon 325® cell (accuracy ± 0.2 with 25° C - 30° C for salinity and 0.1 K ± 1 digit for the temperature). If the water was salty (salinity over 0.0 ‰), the oxygen concentration was measured with a salinity correction factor.

After the assessment of the aquatic variables, the SAV was collected with a rake (cf. Fig. 16) similar to the one used by DEPPE and LATHROP (1992). The double-headed garden rake with 32 tines, each 10 cm long and 0.3 cm thick with a spacing of 1.5 cm, had a 1.35 m long shaft. At the bottom of the rake a diving weight of 500 g was attached with a wire. A 20 m rope was attached to the shaft, allowing to drag the rake on the bottom of the creeks. For collecting the SAV the rake was thrown into the water and dragged on the bottom of the creek. The length of one pull was about 2 m. Afterwards, the rake was immediately turned to an upright position to avoid that any plants were taken away by the current. The rake was pulled out of the water and the plants were deposed in the hull. The quantity of the collected plants was estimated in five steps according to the Kohler scale (KOHLER 1978) (cf. Tab. 2).

The rope attached to the rake was marked every 1 m. This allowed to measure the depth of the creek at the same time. To prevent that the changing water levels were taken in consideration, the difference between the actual water level and the maximal water level, very well distinguishable (cf. Fig. 17) by a clear horizontal line at the bank, was added to the measured depth of the creeks.

When all plots had been investigated once, the transects was moved and sampling repeated to get a larger data base. Each new transect was moved downstream 10 meters from the original transect for the first repetition and upstream 10 meters for the second repetition (cf. Fig. 15). This avoids that the samples of the aquatic vegetation were taken at the same places as in prior studies, which could lead to a lower abundance of species as they might already have been pulled out during the first recording.

Statistical tests were calculated with Excel 2000, SPSS 10, SsS 1.0 and PC-Ord 4. For descriptive statistics, the median and the mode was used. To test the hypothesis whether the water quality samples differ in the median, Friedman-test was used for more than two samples within one section and

<table>
<thead>
<tr>
<th>quantity of plants</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>very rare</td>
</tr>
<tr>
<td>2</td>
<td>rare</td>
</tr>
<tr>
<td>3</td>
<td>diffused</td>
</tr>
<tr>
<td>4</td>
<td>frequent</td>
</tr>
<tr>
<td>5</td>
<td>lots of</td>
</tr>
</tbody>
</table>

Tab. 2: Kohler scale for the estimation of aquatic macrophytes

![Fig. 16: Sample rake](image)

![Fig. 17: Limit of the high tide](image)
depended randomised test when only two samples were taken. If not mentioned otherwise, the tests were calculated on a significance level of $p = 0.05$. In aquatic systems, a problem of independence of the recorded data exists. For sure, the samples which had been taken downstream depend on the samples taken further upstream. But in the Coswine swamps with its system of tide canals with changing currents, it is probably that the upstream samples depend on the downstream samples as well. Therefore, non-parametric, two-tailed, independent tests were chosen for all statistical calculations.

### 4.2 Preliminary study

A preliminary study was carried out in order to check whether the chosen parameters and the applied method were sufficient to obtain any results. Another aim of this first study was to get a better knowledge of the present condition on the study site.

#### 4.2.1 Simplified methods for the preliminary study

To prevent that too much time was lost within this period of the study, some adaptations on the methods were made. In contrast to the main study design, the emplacements of the plots were randomly chosen within one creek. The in-situ measurements of the variables were made in the middle of the creek to avoid influence by falling or raising tide and stagnant waters at the banks. The recording of the aquatic parameters was made from the bow of the hull to eliminate the disturbing effect of the screw. When possible at least two samples were taken in each channel. All measured parameters were noted in a record sheet (cf. Appendix 7.2).

#### 4.2.2 Results of the preliminary study

During one week (from 21.06.2001 to 25.06.2001) 175 values were recorded at 55 plots (Map 10). Due to organisational problems, the Crique Rouge was not investigated.
Map 10: Plots within the section for the aquatic study, 1: 50'000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL 1990)
Aquatic parameters

The range of aquatic parameters measured is shown in Tab. 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum</th>
<th>Quartile I</th>
<th>Median</th>
<th>Quartile III</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>25,3</td>
<td>26,5</td>
<td>27,0</td>
<td>27,7</td>
<td>29,0</td>
</tr>
<tr>
<td>Oxygen (mg/l)</td>
<td>2,4</td>
<td>3,7</td>
<td>4,2</td>
<td>4,7</td>
<td>7,2</td>
</tr>
<tr>
<td>Salinity (‰)</td>
<td>0,0</td>
<td>0,0</td>
<td>0,2</td>
<td>1,5</td>
<td>1,5</td>
</tr>
<tr>
<td>pH</td>
<td>5,1</td>
<td>6,2</td>
<td>6,4</td>
<td>6,7</td>
<td>6,9</td>
</tr>
<tr>
<td>Water depth (m)</td>
<td>0,5</td>
<td>2,5</td>
<td>4,8</td>
<td>9,1</td>
<td>&gt;15,0</td>
</tr>
<tr>
<td>Modus</td>
<td>26,6</td>
<td>3,8</td>
<td>4,0</td>
<td>6,7</td>
<td>3,5</td>
</tr>
</tbody>
</table>

Tab. 3: Range of the aquatic parameters

Water visibility amounted 0,6 meter at the upper stream of Cirque Charvein and less than 0,5 meter in the rest of the study area.

Submerged aquatic vegetation (SAV)

No SAV was collected at all. Even when the search was repeated several times at the same plot, the result stayed the same. Only little objects like decaying leaves and small branches were hoisted. It was not possible to determine clearly whether these objects had been floating or were lifted up from the ground. But it is supposed that most of the branches and leaves were taken from the bottom of the creek, as they mostly were covered with a fine layer of silt.

Thus, no classification of the SAV could be done.

Classification in sections

Except for Crique Loutre 2 (p = 0,009), no significant differences in the median were found between different samples within one creek (Friedman-test for more than two samples, randomised test for 2 samples per creek). The differences in the three samples at Crique Loutre 2 can be explained by the lowest value for oxygen concentration yielded during the whole study for sample 1 (L2 I) which may, together with the low temperature at that station, be responsible for the significant changes showed by the Friedman-test.

When comparing the sections among each other, the same result was yielded (p = 0,374). Nevertheless, some differences within the whole area exists: an area with higher salinity can be found at Crique Coswine, starting in the east of the inflow of Crique Pagais and covering the whole area of the “Lac du Bagne” (cf. Map 3). While in the “Lac du Bagne”-region the median of the salinity is at 0,4 ‰ and water therefore can be described as nearly brackish, it was purely fresh in the others creeks except for one sample at Crique Petit Ben Amar (salinity 0,8 ‰) (cf. Map 10). In contrast, there were only two outliers in the “Lac du Bagne”-region with salinity at 0,00 ‰, one sample at Crique Anglais and another at Crique Loutre 3. Furthermore, there were some differences in the medians of the oxygen content and the pH values. The “Lac du Bagne”-region has a higher pH (6,7 units) and a lower oxygen content (3,6 mg/l) as the other creeks with a pH of 6,3 units and the oxygen content at 4,1 mg/l.
4.2.3 Discussion of the preliminary study

Aquatic parameters

In the present study the aqua-chemical parameters were recorded with a multi-parametric instrument with high accuracy. Nevertheless, there are some facts which may had an influence on the data. The changing tides and in consequence the changing water level where taken into consideration for the water depth, but measurements of the chemical composition of the water was carried out during the whole day. The problems related to this feature are discussed later in this paragraph. At first, the attention is to be drawn to the water temperature, which raises from the morning to the afternoon. due to longer insolation. APAVE (2000) carried out measurements of the water quality at two sites in the north of the study area between the Crique Tapir and the street relaying Awala-Yalimapo and Mana. The temperature values (cf. Fig. 18) increased considerably for both sites from 8 h to 16h from 25,9°C to 28,9°C and 27,9°C, which is a maximal difference of 3,0°C within 8 hours. The total difference measured in the present study is 3,7°C for the whole Coswine swamps during one week with partly sometimes rain for some hours. For further projects it would be better to always record temperature at the same time, but this was not possible during this study as it would imply that only one to two station are sampled each day. As shown above, water temperature varied in an acceptable interval. Furthermore, for manatee distribution the minimal critical temperature is normally fixed at 21°C (cf. chapter 3.2.3). The lowest value recorded during the preliminary study was 25,3°C at about 10:00 am. Regarding the nearly constant air temperature in French Guiana (cf. chapter 2.2.1) it seems very unlikely, that water
temperature falls below 21°C. Thus, water temperature appears not to be a critical survival factor for manatee in French Guiana.

The pH in the study area is more neutral in comparison to the records of APAVE (cf. Fig. 19). While in the APAVE study the maximal pH is 5.6, the records made during the study reached a maximum of 6.9. The minimum is more similar: 5.2 for the study of APAVE and 5.1 for the present report. The great variance of the pH in the present study must be related to the larger investigated area. For the APAVE report the samples were only taken at two stations, while in the present study the samples of 62 stations are taken into account. It is clear that with a greater number of records the variance of the pH may become greater, just as the chemical composition of the water body in general reflects the geological strata and the soils formed by it in the drainage area (SIOLI 1975). Furthermore the pH of the sea had been recorded near the mouth of the river Mana around 7 units (LOINTIER and PROST 1986). When now putting in relation the results obtained by APAVE and LOINTIER, it is obvious that in areas, where marine waters occur, the pH is higher, and in contrast, in areas where fresh water is dominate, the pH is more acid. The data recorded during the present study showed a similar result: in the “lac du bagne”-region with its higher salt content, the pH was also more neutral than in the rest of the study area.

Concerning oxygen content, PAYNE (1986) explains extreme changes in the oxygen content at a depth of 2 – 3 m. But all measurements for this study were only surface records (measured in 0.5 meters under the water surface). In general, in tropical lakes with a temperature of the hypolimnion above 20°C, the oxygen is totally consumed beyond the thermocline (SCHWOERBEL 1999). So it is quite clear that the oxygen content and pH are highest at the surface (PAYNE 1986), where the gas exchange with the air is possible (SCHWOERBEL 1999).

**Problem of tide and changing water levels**

As mentioned above, tides and in consequence changing water levels have a huge influence on the water chemistry. With each high tide, salt water or at least brackish water is brought into the swamp through the tide canals (cf. 2.2.3). The changing water level is also responsible for changes in the oxygen concentration. The influence of the tides should be avoided in further research projects by gathering the data only in a short period before and after the high tide. It is suggested that this interval for the Coswine swamps may be one hour prior to and after the maximal water level.

**Statistics**

The Friedman-test only looks for differences in the median of a sample (ENGEL 1997). Neither the variance nor the kurtosis or skewness of a sample is taken into consideration. For the comparison of the different aquatic parameters with their different measuring levels (e.g. temperature 25° - 29°C, salinity 0.0 – 1.5 ‰, etc.) an analysis of the variance would be useful, but no further information or explications are given to test this in the consulted literature (ENGEL 1997; LAMPRECHT 1999; SACHS 1999).

**Aquatic vegetation**

Vegetation sampling with a rake as described in the study is a common method for macrophyte cartography (MEILINGER and SCHNEIDER 2001, i. p.; STELZER and SCHNEIDER 2001, i.p.). But there are some difficulties associated with this method. MARSHALL and LEE (1994), who worked with a similar rake, conclude that plants with stem length less than 8 cm (e.g. Isoetes macrospora, Carex lasiocarpa) and plants with robust stems (Thypa latifolia or Scirpus acutus) were not effectively
Study of the aquatic vegetation

collected. The same information is given by Department of Environment (1987) and Caspers (2000). It is possible that during the study, some rare and small plants were not sampled, because they had either slipped through the rake tines or had been taken away by the current when hoisted. But this point seems to be negligible as the manatees need at least 4 – 9 % of their body weight (Bengtson 1983) for feeding each day and it does not appear reasonable that manatees search for such small plants if food is abundant. To be really sure that there is no submerged vegetation it would be necessary to check the bottom of the creeks either with dredges or with SCUBA-divers, but their effectiveness is reduced in turbid water (Goltermann et al. 1988; Marshall and Lee 1994; Melzer 1976).

It is possible that submerged aquatic vegetation (SAV) occurs between two stations and therefore was not recorded. But this does not seem probable, as the water is very turbid everywhere. Further, the median water depth is about 4,8 m. Melzer (1976) limits the occurrence of SAV in waters with a visibility of less than two meters to 4 – 5 meters in temperate Europe. In the study area, water visibility did not exceed 0,6 meters.

As obviously no submerged vegetation is present, manatees must have another feeding source. O’Shea (1986) observed manatees in Florida foraging on acorns boarding the rivers. The acorns were found in high densities at the bottom of a creek, where manatees passed regularly. While cruising in the different creeks in the Coswine swamps, fruits of Mauritia flexuosa were often seen floating at the water surface. But in contrast to acorns, these fruits do not become soft, when fallen into the water. So it is rather unlikely that manatees feed on these fruits. DiJosef (pers. comm.) reports that several times he has seen manatees feeding on lianas opposite to the village of Coswine. These are mainly Rhabdadenia biflora, lianas also eaten by the manatee in Brazil (Domning 1981). Manatee feeding traces have also been observed on Montrichardia arborescens in the River Mana (Desbois, pers. comm.). The sea grass beds around Iles du Salut, approximately in a distance of 150 km, may serve as another feeding ground, although already far away from the Coswine swamps. As many Green turtles live around these three islands, it is supposed that sea beds are in the near of the Iles du Salut. But no research projects have been carried out on this question (Desbois, pers. comm., Kelle, pers. comm.). Even the existence of these beds is not sure, because mainly young Green turtles, which are more omnivorous than herbivorous and therefore independent of seagrass beds (Lanyon et al. 1989), are seen around the Iles du Salut (Kelle, pers. comm.).

4.2.4 Conclusion

The preliminary study showed that no submerged aquatic vegetation is present in the creek of the Coswine swamps. Therefore, it is supposed that the manatees feed on the reachable bank vegetation, as this behaviour has already been observed and other food resources seem to far away. Thus, in a next step, the bank vegetation should be the focus of investigation. In order to find out, whether zones with high importance for manatee feeding can be determined.

Concerning the aquatic parameters, temperature seems to be negligible for manatee distribution in the Coswine swamps. The importance of the other parameters could not be assessed during the preliminary study.

The sampling time for the aquatic parameters should not exceed two hours. It is supposed that within a period of one hour before and one hour after the high tide the best results should be obtained.
4.3 Summary

Due to unsatisfactory results obtained during that preliminary study, the present study of the submerged aquatic vegetation was carried out only for one week.

The results showed that no submerged aquatic vegetation was present in the creeks of the Coswine swamps. The methods used during the study are those applied in other studies of aquatic macrophytes and therefore can be judged as sufficient. The aquatic parameters were similar to those described in other papers when climatic circumstances are taken into consideration. Changing water levels are a problem when coherent water quality data is to be obtained.

For further research projects, the recommendations given in this study should be taken in account.
5 Study of the bank vegetation and the aquatic parameters

After the preliminary study of the aquatic vegetation had showed that no submerged aquatic vegetation was present, the methodological approach was changed and adapted. The second part of the present study deals with the bank vegetation of the creeks, as this seems to be the only food resource for the manatee.

5.1 Material and methods

All research trips were carried out in a canoe with a 5 HP-outboard motor by the author and a second person between 02nd June and 14th September. If manatees were observed, their position was fixed by the help of a GPS and their activity was noted. Observations were more or less made incidentally when passing by with the canoe. No effort was made to search for manatee sightings during a longer period at one site. The observed manatees are listed in Tab. 6.

5.1.1 Aquatic parameters and vegetation

The aquatic parameters and the vegetation were recorded at so-called “stations” (Fig. 20). One station consists of three parallel transects with a length of 100 m each. The first station is situated as near as possible to the end of a creek where the channel has still a width of 3 m. This minimal distance from the two banks is necessary to turn the canoe. In some cases the end of a creek was not reached, because fallen trees or low water level prevented continuing. With the assistance of a GPS, the coordinates of the start position on the right bank of the creek were assessed and noted in the record sheet (cf. Appendix 7.3). Beginning from that point, a distance of 100 m was measured downstream with a thin nylon rope marked every 10 m. The start plot (0 m), the middle plot (50 m) and the end plot (100 m) of such a transect were marked either with white spray paint on the leaves of a close tree or with red and white ribbons attached to the nearest tree in order to find the position again on return. On each plot (0 m, 50 m, 100 m) on the right, middle and left transect, the aquatic parameters were measured. Thus, one station has three transects, with three plots each. The distance between two stations was fixed at 1500 m. This distance seemed to allow an acquisition of a good database and to cover the whole working area with randomly
distributed samples in the fixed time span of eight weeks. In each creek, at least two stations were established. Hence, a total of nine plots at one station was examined and for statistical purposes the value’s median was calculated (cf. chapter 5.1.2). To avoid the influence of the tide and in consequence the changing in the water composition, the suggestions made in the previous study were taken into account (cf. chapter 4.2.3). But as calculations for the high tide are only available for Le Pointe des Hattes at the mouth of Maroni and not for the small creeks, the measurements were only taken, when the maximum difference between the actual water level and the maximum water level did not exceed 40 cm. The aqua-chemical parameters were measured as described in chapter 4.1.2. The only modification adapted was that the depth measurements were made with a 20 m long rope, at the end of which a weight of approx. 2 kg was attached (cf. GOLTERMAN et al. 1988).

The bank vegetation available for the manatee, was recorded in the following manner: between the water surface and a thought line which lies 50 cm above the clearly visible horizontal limit of the maximal high tide (cf. Fig. 17), the abundance of each species was estimated with a modified Braun-Blanquet scale (cf. Tab. 4). These 50 cm results from the fact that the manatee can put its body out of the water to feed on the bank vegetation (cf. 3.2.2). Thus, the transect for this task was 100 m long, 1 meter wide, beginning at the outer fringe of the vegetation, and between 0,5 m and 3,3 m (0,5 m plus 2,8 m maximal tide) high, depending on the tides. The numeric values of the abundance classes at the same time are the factors used for the calculations of the abundance.

In contrast to the aquatic parameters, the vegetation was recorded during low tide, to avoid missing small species growing at the banks and flooded during high tide. If possible the plant species were determined immediately. If unknown species were found, they were collected and determined by comparing them to reference samples in the Herbier de Cayenne.

For the description of the plant distribution some definitions are introduced at this point.

The **relative presence** $r_P$ describes the percentage in which a species was represented in the samples, divided by the total of all taken samples:

$$r_P = \frac{n_x}{n_t} \times 100,$$

if $n_x$ is the number of samples in which the species appears and $n_t$ the total number of samples. For example, a plant which would be counted at 10 places has a $r_P = 10\%$, if in total 100 samples were taken.

The **relative dominance** $r_{D_{xx}}$ is the percentage of cases, in which a species is represented in a certain abundance class in relation to the total number of samples in the study. It is defined as:

$$r_{D_{xx}} = \frac{n_{x\alpha}}{n_t} \times 100, \text{ with } \sum_{i=1}^{25} r_{D_{i}} = 1 \text{ for each species},$$

<table>
<thead>
<tr>
<th>Braun-Blanquet scale</th>
<th>abundance classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>&lt;&lt; 1 %</td>
</tr>
<tr>
<td>+</td>
<td>&lt; 1 %</td>
</tr>
<tr>
<td>1, 2</td>
<td>1-10 %</td>
</tr>
<tr>
<td>2, 3</td>
<td>11-50 %</td>
</tr>
<tr>
<td>4 and 5</td>
<td>&gt; 50 %</td>
</tr>
</tbody>
</table>

Tab. 4: Estimation scale, modified after Braun-Blanquet


if \( n_{ax} \) is the number of samples in a certain abundance class and \( n_t \) the total number of samples. For example, when 100 samples are taken, a plant which is represented 50 times in the abundance class 75 will have a \( rD_{75} = 50 \% \), while a species which occurs 20 times in the same study in the abundance class 0.5 will have a \( rD_{0.5} = 20 \% \).

The **continual dominance** \( cD_{xx} \) is the percentage of the number of samples, in which a species is represented in a certain abundance class in relation to the total number of samples in which the plant is present.

\[
cD_{xx} = \frac{n_{ax}}{n_p} \times 100, \quad \text{with} \quad \sum_{i=0,1}^{75} cD_i = 1 \text{ for each species},
\]

if \( n_{ax} \) is the number of samples in a certain abundance class and \( n_p \) the number of samples in which the plant is present in all abundance classes. For example, a plant which is represented 48 times in the abundance class 75 (\( n_{75} = 48 \)) and in total in all abundance classes 80 times (\( n_p = 80 \)) would have a \( cD_{75} = 60 \% \), while the \( rD_{75} = 48 \% \), when 100 samples were taken in total.

The **absolute dominance** \( aD \) is defined as the sum of the numbers of samples of all abundance classes \( n_a \) each multiplied with the factor of the abundance class \( f_i \) and divided through the sum of the abundance classes’ factors:

\[
aD = \frac{\sum_{i=0,1}^{75} (f_i n_a)}{\sum_{i=0,1}^{75} f_i},
\]

with the maximum at \( \frac{n_{t_{\text{max}}} \times 75}{0.1+0.5+5+25+75} = \frac{n_{t_{\text{max}}} \times 75}{105.6} \)

and the minimum at \( \frac{n_{t_{\text{min}}} \times 0.1}{0.1+0.5+5+25+75} = \frac{1 \times 0.1}{105.6} = 9.469 e^{-4} \).

Because of their presence in all samples and their dominance in the abundance classes, some plants with similar characteristics can grouped by similar features. Therefore some limits for each group are defined as shown in Tab. 5. For the classification in the dominance groups, for each plant the percentage in each abundance class is calculated at first. Then the highest value for each plant is determined. When a plant has a rate higher than 50 \% in one of the five abundance classes, it will be classified as “high dominance”, if the highest values is between 15 \% and 50 \%, it it will be classified as “middle dominance”, and so on.

<table>
<thead>
<tr>
<th>relative Presence (rP)</th>
<th>relative Dominance (rD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant &gt; 50 %</td>
<td>high &lt; 50 %</td>
</tr>
<tr>
<td>frequent 25 % - 50 %</td>
<td>middle 15 % - 50 %</td>
</tr>
<tr>
<td>rare 2.5 % - 25 %</td>
<td>small 5 % - 15 %</td>
</tr>
<tr>
<td>sporadic &gt; 2.5 %</td>
<td>no &gt; 5 %</td>
</tr>
</tbody>
</table>

**Tab. 5**: Limits for the presence and the dominance of a species
In this way the plants can be classified in different groups, for examples:

- plants constantly present with high dominance,
- plants frequently present with medium dominance,
- plants rarely present with low dominance,
- plants rarely present without dominance and
- plants sporadically present without dominance (cf. chapter 5.2.3).

For the description of the communities, different relative values and indexes are calculated.

The relative number of species \( rSp \) of a group of samples is calculated with the following formula:

\[
rSp = \frac{sp}{SP},
\]

if \( sp \) is the number of species in one group and \( SP \) is the total number of species in the compared groups. When for example three groups with \( sp_1 = 10 \), \( sp_2 = 30 \) and \( sp_3 = 60 \) are compared, the \( rSp_1 = 0.1 \), \( rSp_2 = 0.3 \) and \( rSp_3 = 0.6 \); when only \( sp_1 \) and \( sp_2 \) are regarded, the \( rSp_1 = 0.25 \) and the \( rSp_2 = 0.75 \). The values are identical with the homotony by Tüxen (cited after DIERSCHKE (1994)).

For the samples, the relative number of samples \( rSa \) is calculated with the same formula:

\[
rSa = \frac{sa}{SA}.
\]

Both, \( rSp \) and \( rSa \), are used to calculate the relative number of species per samples \( S/S \) which is defined as:

\[
S/S = \sin \left( rSp \times \pi - \frac{\pi}{2} \right) + \cos \left( rSa \times \pi \right).
\]

\( S/S \) gives a value for the species diversity of different groups with changing samples’ numbers. Therefore it can be used to compare the species richness of different vegetation units. The values for \( S/S \) oscillates between \(-2 \) and \(+2 \). A group of samples with many different occurring species (\( \lim sp \to SP \Rightarrow rSp \to 1 \)) and at the same time not many samples (\( \lim sa \to 0 \Rightarrow rSa \to 0 \)) leads to \( S/S = 1 + 1 = 2 \), while for a group with not many species and a high number of samples the result for \( S/S \) is approaching \(-2 \). When calculated on a base of all samples, the \( rSp \) and the \( rSa \) are 1.000 and the \( S/S \) therefore nil.
Furthermore the index of diversity $H$ is used. It combines the number of species and its abundance values within one sample and gives information on its floristic structure (Dierschke 1994; Dierßen 1990; Lozán and Kausch 1998; Pfadenhauer 1997). The following formula is used for its calculation:

$$H = - \sum p \times \ln p; \quad p = \frac{n_i}{N},$$

if $n_i$ is the abundance value for a plant in a sample and $N$ is the sum of all abundance values in a sample. If only one species occurs in the sample, the index of diversity will be nil, because of $n_i/N = 1$ and $\ln 1 = 0$.

The evenness is the index of diversity’s proportion of the sum of all recorded species (Dierschke 1994; Dierßen 1990; Lozán and Kausch 1998; Pfadenhauer 1997). The formula for its application is:

$$E = \frac{H}{H_{\text{max}}} \times 100,$$

if $H_{\text{max}}$ is the total number of found species. When all species are represented with similar abundance in one sample, the evenness will be maximum (100 %), in contrast to samples where only one species is present ($E = 0 \%$).

### 5.1.2 Statistics

The calculations of the statistical tests were made with the aid of the software Excel 2000, SPSS 10 and PC-Ord 4. For descriptive statistics the median, the 25%- and 75% quartile and the mode were used. The mode will be only mentioned, when it differs from the median.

For the aquatic parameters the median was calculated for each station and for each parameter except for the depth. Here, the median was developed per transect. So, the nine single values (3 transects a 3 plots) at each station form the station median, while all single values together describe the area median. The median’s median is calculated on the base of the station median.

The statistical analysis of the vegetation was carried out in two groups. One included all vegetation samples on the left and the right side of the river, the other only these samples, where the vegetation of both sides were statistically identical. This was tested by two-tailed Kolmogorov-Smirnov-test (K-S-test) (Engel 1997; Lamprecht 1999) with significance level of $p < 0.05$. When the results of the K-S-test were significant, the median for the vegetation would be calculated.

For both groups a cluster analysis was performed with PC-Ord. The linkage method for all cluster analysis was Ward’s method, the distance measure was made with Euclidean distance. Before applying the cluster analysis, the vegetation data was transformed with $x^* = x^{0.3}$. The classification of the vegetation is based on this cluster analysis in eight or four groups. Within one identified group, the sub-classification is done by hand to get a coherent table. This is a numeric procedure and has not the pretensions to be a classification in the sense of Braun-Blanquet leading to definite syntaxa sensu Tüxen.

To test whether one region differs from another, a two-tailed randomised test was be used when only one parameter was compared between regions. The proposed significance level was $p=0.05$ and the two samples were tested on differences in the median. The number of permutations was always 10 000..
5.2 Results

5.2.1 Manatee observations

Four direct observations of manatees were made in total, but only for the last two the exact coordinates were recorded (cf. Tab. 6, Map 11). The first sighting was during the first field trip on June, 16\textsuperscript{th}, the second during the study of the aquatic vegetation on June, 22\textsuperscript{nd}. The third and fourth occurred during the study of the bank vegetation.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>North</th>
<th>West</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.06.01</td>
<td>17:10</td>
<td>5° 38,789'</td>
<td>53° 54,902'</td>
<td>1 manatee, only snoot has been seen</td>
</tr>
<tr>
<td>11.07.01</td>
<td>18:30</td>
<td>5° 40,405'</td>
<td>53° 57,044'</td>
<td>3 manatees swimming upwards to the Maroni. Entire body seen</td>
</tr>
</tbody>
</table>

Tab. 6: Manatees sightings during the study

Indirect observations of browsed vegetation were made two times (cf. Tab. 7, Map 11).

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>North</th>
<th>West</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>03.08.01</td>
<td>07:30</td>
<td>5° 39,186'</td>
<td>53° 56,279'</td>
<td>leaves of \textit{Rhizophora racemosa}</td>
</tr>
<tr>
<td>08.09.01</td>
<td>16:30</td>
<td>5° 34,688'</td>
<td>53° 55,621'</td>
<td>stalks of \textit{Montichardia arborescens} and \textit{Scleria pterota}</td>
</tr>
</tbody>
</table>

Tab. 7: Observations of manatee feeding

In the Crique Coswine one plant of \textit{Rhizophora racemosa} was found with grazed leaves (cf. Fig. 22 and Fig. 21) and in Crique Vache one patch of \textit{Scleria pterota} and \textit{Montichardia arborescens} (cf. Fig. 23 and Fig. 24) were browsed in the same manner as described by DEKKER (1974): the leaves of \textit{Montichardia arborescens} were eaten, but the stalks were left standing.

![cropped leaves](Image)

![Fig. 21: Rhizophora racemosa shrub, circle shows the cropped leaves](Image)
Fig. 23: Stalks of *Montrichardia arborescens* cropped by manatees

Fig. 24: Bank with *Montrichardia arborescens* and *Scleria pterota* cropped by manatees
Map 11: Map of the stations and the manatees sightings, 1:50 000 (extract from INSTITUT GEOGRAPHIQUE NATIONAL, 1990)
5.2.2 Aquatic parameters

During the study of the bank vegetation and the aquatic parameters, 62 station were investigated (cf. Map 11, page before). In the following paragraphs each aquatic parameter is regarded independently, prior to vegetation analysis in another chapter. At the end the aquatic parameters and the vegetation are put together and analysed in a more complete manner.

Water depth

The water depth was at least 1.0 m in the whole study area. It was approximately equal at the left and right bank. The depth varied for the area median from a minimum of 1.0 m to a maximum of 8.3 m at the right bank and from 1.0 m to 8.0 m on the left side. For the middle of the creeks, the measurements are not complete as the currents were sometimes to fast that the rope with the attached weight drifted off. Thus, the depth values were not taken at ten stations (16.1 %). Regarding the stations, the middle of the creeks was generally deeper than the side close to the banks. The maximal depth was over 20 m and the minimal one was at 2.5 m. It is worth mentioning that at six plots the depth in the middle of a creek was equal or inferior to 3.0 m (1,1 %). All three plots of the station Va3 had a depth lower than 3.0 m. In the table (cf. Tab. 8) below, the two sides and the middle are compared.

In contrast to the area median, the range of the station median is smaller. The maximum values are at 5.7 m / 5.6 m and, thus, 31,7 % / 30,0 % lower as the area median.

<table>
<thead>
<tr>
<th></th>
<th>station median per bank</th>
<th>area median per bank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>right transect</td>
<td>middle transect</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.2 m</td>
<td>3.0 m</td>
</tr>
<tr>
<td>Quartile I</td>
<td>2.0 m</td>
<td>5.0 m</td>
</tr>
<tr>
<td>Median</td>
<td>2.4 m</td>
<td>7.0 m</td>
</tr>
<tr>
<td>Quartile III</td>
<td>3.0 m</td>
<td>10.7 m</td>
</tr>
<tr>
<td>Maximum</td>
<td>5.7 m</td>
<td>&gt; 20.0 m</td>
</tr>
</tbody>
</table>

Tab. 8: Depth at the three transects

So, the creeks in the Coswine swamps have a depth between 2.5 m and more than 20 m in the middle of the creek.
Temperature

Regarding the individual measurements, temperature oscillated between 24.5°C and 30.3°C. The modus at 28.7°C was higher than the median (28.5°C). The minimum of the station median was at 26.2°C and the maximum at 30.1°C. If one would like to do a classification despite of the small values’ range, it could be made in the following manner: the region of the mouths of Crique Coswine and Crique Canard can be grouped together with Crique Vache and its tributaries (without Crique Charvein) and Crique 1900 to a warmer part as the rest of the study area which is formed by the "lac du bagne" region, Crique Charvein and the source of Crique Canard with its tributaries (cf. Fig. 25 and Map 12). The randomised test gave a highly significant result (p<0.001) for the difference in temperature of the two areas.

Fig. 25: Temperature range of the station median of all samples and two groups of samples (in brackets the number of samples)
Salinity

Salinity ranged from 0,0‰ to 1,9‰ for the whole study area. Regarding the single values, 86,9% of the samples can be described as fresh water and only 13,1% of the single values were in brackish water (higher or equal to 0,5‰, cf. chapter 2.2.3). When the station medians are taken into consideration, only eight samples of the 62 stations (13,9%) were in a brackish milieu. The farthest inland record of brackish water was in the Crique Grand Ben Amar (salinity of 0,7‰) approximately 15 km from the sea. The points, where brackish water was recorded, are randomly distributed in the whole working area with a spot in the Criques Loutre 1 and Loutre 2 (cf. Map 12). The randomised test gave a highly significant result (p<0,001) for the difference of the two areas.

Fig. 26: salt content of all station medians and of two regions with number of outliers (in brackets the number of samples)
pH values

The pH was ranging from 5.4 units to 6.9 units for the area median. As the values differed not significantly, the classification is – as already mention for the temperature – not very coherent. Yet two areas may be distinguishable: the region of the wider “lac du bagne”, including Crique Anglais and transect Co6 with low pH values, and the rest of the study area with more neutral water (cf. Map 13 and Fig. 27). Even when the difference is not evident, the randomised test will give a highly significant result (p<0.0001) for the two areas.

Fig. 27: pH of all station medians and of two regions with number of outliers (in brackets the number of samples)
Oxygen content

During the study, a temporary dysfunction of the oxygen probe occurred. At 44 stations out of the 62 investigated ones (71.0%), the oxygen content was not taken at one or more plots. Therefore, the oxygen content is not taken into account for the explanatory classification of the habitat types further below. The single values of the oxygen content ranged from 1.3 mg/l to 6.6 mg/l, but the low values must be regarded with care, as the accuracy of the oxygen probe deteriorated slowly and the beginning of the quality loss could not be determined exactly. The probe’s loss of accuracy was only recognised when it showed values of less than 1 mg/l at a station, where the oxygen content was expected to be higher. Values which were obviously wrong were excluded.

Low values of the oxygen content were found in particular in the upper streams (region of “lac du bagne”, Crique Charvein, mouth of Crique Grand/Petit Ben Amar, and mouth of Crique 1900/Crique Gadet/Crique Canard, cf. Map 13 and Fig. 28). All three areas differ highly significantly from each other (p<0.001).

Fig. 28: Oxygen content of the station median for all complete samples and the regions (in brackets the number of samples)

Conclusion

The recorded aqua-chemical parameters showed a small range which makes it difficult to clearly distinguish different areas with changing water composition. In particular, this is true for the temperature and the pH. The salinity in some areas was slightly higher (brackish) than in the rest of the study area, nevertheless more than ¾ of the samples were situated in fresh water. Only the oxygen content has a widespread range, but there was the problem with the dysfunction of the probe. The water depth in the whole study area was nearly equal for the right and left bankside and in the middle reaches values of at least 2.5 m deep.
Map 12: Map of temperature and salinity, 1:50 000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL 1990)
5.2.3 Presence and abundance of the plant species

At 62 stations, the vegetation of the right and left bank was recorded during the study. Therefore, a total of 124 vegetation transects was investigated. In the following paragraphs the vegetation is regarded first on a population level and afterwards on a plant communities level.

In total, 77 terrestrial plant species were recorded. A complete list with these plants can be found in the Appendix 7.1. Once, a tuff (diameter about one meter) of floating *Eichhornia crassipes* was seen. As it was right at the transect Va6R, it was noted in the record sheet, but in the following analysis only the terrestrial plants appear. Tab. 9 shows the 15 most common plants of the bank vegetation with their absolute and relative presence and their absolute dominance, but only 19,5 % of the 77 species found in the study area are represented. 31 plants occured only one time (40,3 %) and 31 plants (40,3 %) were found only two to nine times in the study area. The percentage of the “relative presence above the abundance’s sum” is calculated with the sum of the absolute presence of all species (∑ absolute presence of all species = 696), while the “relative presence of the 15 most present species” uses the absolute presence of the in the table represented species.

The maximum of the absolute dominance (aD) is for the present study with 124 samples and with abundance classes from 0,1 to 75 at 88,068, the minimum is close to zero (9,469 e−4).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Absolut presence</th>
<th>Relative presence</th>
<th>Relative presence within the 15 most present species</th>
<th>Relative presence above abundance's sum</th>
<th>Absolute dominance (aD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Rhizophora racemosa</em></td>
<td>116</td>
<td>93,5%</td>
<td>21,7%</td>
<td>16,7%</td>
<td>54,26</td>
</tr>
<tr>
<td><em>Zygia cataractae</em></td>
<td>54</td>
<td>43,5%</td>
<td>10,1%</td>
<td>7,8%</td>
<td>7,98</td>
</tr>
<tr>
<td><em>Machaerium lunatum</em></td>
<td>51</td>
<td>41,1%</td>
<td>9,6%</td>
<td>7,3%</td>
<td>7,13</td>
</tr>
<tr>
<td><em>Pachira aquatica</em></td>
<td>44</td>
<td>35,5%</td>
<td>8,2%</td>
<td>6,3%</td>
<td>3,63</td>
</tr>
<tr>
<td><em>Montrichardia arborescens</em></td>
<td>41</td>
<td>33,1%</td>
<td>7,7%</td>
<td>5,9%</td>
<td>0,63</td>
</tr>
<tr>
<td><em>Acrostichum aureum</em></td>
<td>39</td>
<td>31,5%</td>
<td>7,3%</td>
<td>5,6%</td>
<td>1,11</td>
</tr>
<tr>
<td><em>Dalbergia monetaria</em></td>
<td>39</td>
<td>31,5%</td>
<td>7,3%</td>
<td>5,6%</td>
<td>3,02</td>
</tr>
<tr>
<td><em>Rhabdadenia biflora</em></td>
<td>39</td>
<td>31,5%</td>
<td>7,3%</td>
<td>5,6%</td>
<td>0,59</td>
</tr>
<tr>
<td><em>Laguncularia racemosa</em></td>
<td>24</td>
<td>19,4%</td>
<td>4,5%</td>
<td>3,4%</td>
<td>1,63</td>
</tr>
<tr>
<td><em>Clytostoma binatum</em></td>
<td>17</td>
<td>13,7%</td>
<td>3,2%</td>
<td>2,4%</td>
<td>0,32</td>
</tr>
<tr>
<td><em>Crinum erubescens</em></td>
<td>16</td>
<td>12,9%</td>
<td>3,0%</td>
<td>2,3%</td>
<td>0,46</td>
</tr>
<tr>
<td><em>Hippocratea volubilis</em></td>
<td>16</td>
<td>12,9%</td>
<td>3,0%</td>
<td>2,3%</td>
<td>0,47</td>
</tr>
<tr>
<td><em>Pterocarpus officinalis</em></td>
<td>14</td>
<td>11,3%</td>
<td>2,6%</td>
<td>2,0%</td>
<td>0,74</td>
</tr>
<tr>
<td><em>Rhizophora mangle</em></td>
<td>14</td>
<td>11,3%</td>
<td>2,6%</td>
<td>2,0%</td>
<td>1,96</td>
</tr>
<tr>
<td><em>Pavonia paludicola</em></td>
<td>10</td>
<td>8,1%</td>
<td>1,9%</td>
<td>1,4%</td>
<td>0,06</td>
</tr>
<tr>
<td><strong>total</strong></td>
<td><strong>534</strong></td>
<td><strong>431%</strong></td>
<td><strong>100%</strong></td>
<td><strong>77%</strong></td>
<td><strong>84,01</strong></td>
</tr>
</tbody>
</table>

*Tab. 9: Absolute and relative presence of the 15 most common plants*
In chapter 5.1.1 the classification according to abundance and dominance is explained. The groups presented in the study are the following:

1. plants constantly present with high dominance (cf. Fig. 29),
2. plants frequently present with medium dominance (cf. Fig. 30),
3. plants rarely present with low dominance (cf. Fig. 31),
4. plants rarely present without dominance and (cf. Fig. 32),
5. plants sporadically present without dominance (cf. Fig. 33).

The chosen species are typical representatives of the sampled vegetation.

Group 1:

*Rhizophora racemosa* was the most common plant and appeared 116 times in the whole area (93.5 %). All others plants were less abundant and were only represented at less than half of all stations. The analysis of the absolute dominance showed the same result, as *R. racemosa* has a dominance value far higher than all other plants ($aD = 54.26$).

When present, *R. racemosa* had at least an abundance of class 5 ($cD_5 = 13.8 \%$), but normally it was very dominant ($cD_{25} = 54.3 \%$). 29.8 % of the samples were grouped in the abundance class 25.

![Fig. 29: Plant constantly present, with high dominance](image)
Group 2:

_Zygia cataractae_, _Machaerium lunatum_ and _Pachira aquatica_ belong to the frequently occurring plants. Their relative presence \( r_P \) was between 35.5% and 43.5% and therefore they were placed into the group of “frequently” present plants. Their dominance was medium, as they did not reach the 50% limit for the relative dominance \( r_D \), but all plants were represented at least in one abundance class with more than 5%. Concerning the absolute dominance \( a_D \), these three plants followed _R. racemosa_ in the ranking of \( a_D \). _Z. cataractae_ and _M. lunatum_ are the two only species represented in all abundance classes, with a peak at \( c_D = 42.6 \% \) for _Z. cataractae_ and \( c_D = 49.0 \% \) for _M. lunatum_. _P. aquatic_ reached the maximum value of all plants with a \( r_D = 21.0 \% \).

![Bar graph showing relative dominance](image1)

**Fig. 30:** Plants frequently present with medium dominance

Group 3:

The next group is composed of plants with rare presence and low dominance. _Hippocratea volubilis_, _Crinum erubescens_ and _Pterocarpus officinalis_ belong to this group. They were characterised by an \( r_P \) between 2.5% and 25% and a dominance of 5% to 25%. The three represented species showed this later mentioned dominance in the abundance group 0.5. Their absolute dominance was by far lower than in the previous group (between 7.981 and 0.588 / median 3.021; here: 1.634 – 0.063 / median 0.467).

![Bar graph showing relative dominance](image2)

**Fig. 31:** Plants rarely present with low dominance
Group 4:

Plants with rare presence and without dominance are represented in the second largest section with 21 species. In this group *Mauritia flexuosa*, a palm tree, which is characteristic for the banks of small temporary creeks in savannahs (Granville 1986) and *Crenea maritima*, a small herbaceous plant restricted to tidal flats (Tomlinson 1986) had a low $r_P$. Both only occurred in the abundance classes 0,1 and 0.5. In contrast, *Rhizophora mangle* was only recorded with abundance values exceeding class 0,1. Nevertheless, it is also put into this group, as its $r_P = 11.3\%$ and the $D_{\text{max}} = 4.8\%$ was between the fixed limits for the groups. Because of the accumulated occurrence in the upper abundance classes *R. mangle* has an $a_D = 1.955$, the fifth highest values for all plants.

Group 5:

The last and largest group by species number is formed by 42 plants never becoming dominant and with only sporadic presence. The chosen examples all had a $c_{E_{\text{ss}}} = 100\%$, as they were only found one time in the study area. Their $a_D$ was very low ($A. \text{wachenheimi} 0.005, M. \text{maripa} 0.047, P. \text{albiflora} 0.001$). The median for the whole group was at 0.008.
5.2.4 Vegetation classification of all samples

After the analysis of vegetation on a plant species level, the following paragraphs discuss vegetation on a community level. For a first approach, all samples were taken into account, while later only the combined samples were regarded. In both cases, the results of the cluster analysis were accumulated to eight or four groups described below. When percentages or average values are given, the median is used for all samples. Their distribution in the study area can be seen on the Maps 13 and 14.

As already mentioned in chapter 5.1.1, the classification presented here has not the pretension to be a syntaxonomic classification in the strict sense of Tüxen and Braun-Blanquet.

The 124 samples can be divided in two groups (A and B) by the presence/absence of *Rhizophora racemosa*. In 19 cases *R. racemosa* was not dominant (group A), while in group B the species was constantly present and had as least an abundance of 5.

![Hierarchical diagram of the vegetation units](image)

**Fig. 34:** Hierarchical diagram of the vegetation units

**Group A – Dalbergia monetaria mangrove, species rich**

In this group with 19 samples, *Rhizophora racemosa* was not present (7 times) or in abundance class 5 (11 times). In one sample (Va1R), *R. racemosa* had an abundance of 25. At the same time, the number of species per samples was high with a median of 9.0 plants for each transect. The $S/S$ reached with 1,410 the highest value of all investigated groups. The evenness was high as well (E = 43 %) and the index of diversity at 1,877. Except for the sample Va1R, *R. racemosa* was not the dominant species. The cluster analysis divided the group A into two units: unit 1 with a dominance of *Zygia cataractae* and *Pachira aquatica* and unit 2 with mainly *Machaerium lunatum* and *Dalbergia monetaria*. Besides these dominate plants especially *Monrichardia arborescens* often appeared in this group.
**Unit 1 – *Zygia cataractae and Pachira aquatica* mangrove**

This formation, composed of eleven samples, is characterised by the dominance of *Zygia cataractae* which reached the abundance class 75 in one sample. Only in one transect, *Z. cataractae* had an abundance lower than 5, in this single case *Rhizophora mangle* was abundant with class 25. *Pachira aquatica* is the second most important species and constantly present with at least an abundance of 5. The species number per transect was high (10 species) just as the number of occurring plants in all samples (43, what means 55.8 % of all species). The indices of diversity and evenness (45 % and 1,490) had high values and the $\text{S/S}$ (1,144) reached the highest values of all eight units. This unit of *Zygia cataractae* and *Pachira aquatica* can therefore be described as the species richest formation in the Coswine swamps. Besides the already mentioned plants, some other species were well represented: *Dalbergia monetaria* once even reached the abundance class 25 and did not occur in only three samples. Further *Pterocarpus officinalis* was present in 63.6 % of all samples. *Euterpe oleracea* is worth mentioning as a species sometimes present (27.3 %), but only in abundance classes 5 and 25. *Virola surinamensis* was a little more frequent, but its abundance was lower (0.1 – 5). *Montrichardia arborescens* showed the same abundance, but was only in 72.7 % cases present.

**Unit 2 – *Machaerium lunatum and Dalbergia monetaria* mangrove**

A relative small group of only eight samples was formed by the dominate *Machaerium lunatum* and *Dalbergia monetaria*. These two species were accompanied by the liana *Rhabdadenia biflora* which was present in seven of the eight transects in low abundance (0,1 – 5) and *Clytostoma binatum* (4 times, abundance 0,5 - 5). *Desmonchus polycanthus*, a thorny palm species, is a further plant which was often found (50 %) in middle abundance (5 and 25). Species number (7,5), index of diversity (1,770) and evenness (41 %) were lower than in the previous unit. In contrast, the $\text{S/S}$ of 0.456 indicates that this unit had a lesser species diversity than the previous one. An exception is the sample Ca7L, where 17 species were represented. With *Languncularie racemosa* another typical mangrove plant occurred. It was found in 50 % of all samples in abundance between 0,5 and 25. When the plant was present, *Rhizophora racemosa* normally was not found. Again *Montrichardia arborescens* was well present (50 %), but in low abundance (0,5 – 5).
Group B – *Rhizophora racemosa* mangrove, species poor

In this group, widely dominated by the Red Mangrove which in only 5.7% of the samples had an abundance lower than 25, six units were obtained by the cluster analysis. These can be regrouped into two subgroups by the quantity of the appearing species. In total, 105 samples were regarded and 61 species occurred in this group. Therefore, the $S/S$ was 0.092, one of the lowest values of the whole study. In contrast to group A, evenness (17%) and diversity ($H = 0.551$) were much lower.

Subgroup I - *Rhizophora racemosa* mangrove, species poor

For the first subgroup, species richness (3 different plants in each transect), index of diversity ($0.551$) and evenness (13%) were low. Furthermore, the $S/S$ had the lowest value (-0.482) obtained for all groups, as the number of species was low as well (34). The small values for evenness in connection with the low number of species indicated that these formations were more or less “monocultures” of *R. racemosa*. In fact, in only four of the 74 samples (5.4%) dominance of the species was not clearly visible, as the abundance class 75 was not present and at the same time, two plants with abundance class 25 occurred.

Unit 3 –*Rhizophora racemosa* mangrove

*R. racemosa* widely dominated in this unit with 42 samples. In total, only 23 species were found. In only five transects, *R. racemosa* had an abundance lower than 25 (9.5%). In eleven samples only *R. racemosa* occurred. (24.4%). A sub-unit with *Acrostichum aureum* can be distinguished in 21 cases (46.6%). In general, the abundance of *A. aureum* was low (0.1 – 5), except for two samples where class 25 was reached. Therefore the index of diversity was very low ($H = 0.328$) and the distribution very uneven (8%). With $-0.106$ the $S/S$ had the lowest value for all units. This is also the case for the diversity index and the evenness. Other plants, which occasionally occurred, are *Zygia cataractae* (abundance 0.1 – 5) and *Kyllinga brevifolia* (16.7% of the 42 samples, abundance 0.1 – 0.5), *Crenea maritima* (0.1 – 0.5) and *Pachira aquatica* (0.1 – 0.5 / 14.3%) and *Rhabdadenia biflora* (0.1 – 5 / 11.9%).

Unit 4 –*Machaerium lunatum* mangrove

Evenness and the diversity index were slightly higher in the second formation ($E = 17\%$, $H = 0.744$), even when the median number of species (3) was not any bigger. The $S/S$ was also higher (0.125). *Machaerium lunatum* joined *R. racemosa* as a species with high abundance (5 – 75). In seven out of the total of 15 samples (46.7%), *Zygia cataractae* formed a sub-unit with an abundance between 5 and 25. Two other plants occurred in a small part of the samples (18.8%) and in low abundance (0.1 – 0.5): *Rhabdadenia biflora* and *Montrichardia arborescens*.

Unit 5 –*Rhizophora mangle* mangrove

A relatively small sample size was yielded for the third unit, as only 8 transects form this group. *R. mangle* constantly reached an abundance class of 5 or higher, but *R. racemosa* was still present as well (abundance 25 – 75) except for one sample (Va1L), where *R. mangle* was dominant with an abundance of 75 and *R. racemosa* did not occurred. *Machaerium lunatum* may be used to describe a sub-unit, but the sample size was too small to test that assumption. It was present in 50% of the samples in medium dominance (0.5 – 25). *Zygia cataractae* was also well present (37.5%) but only in low abundance
(0.1 – 5). Concerning evenness, diversity and the S/S, the R. mangle mangrove is comparable to the previous one (E = 20 %, H = 0.885, S/S = 0.138).

Unit 6 – *Languncularia racemosa* mangrove

The last unit of the first subgroup is characterised by the appearance of *L. racemosa*, accompanied by *Rhabdadenia biflora*. In this alliance the level of 1 was exceeded for the diversity index (1,064) for the first time. Evenness reached to 24 % and the median of occurring species in the transects was 4. Therefore this unit can be described as a linking unit to the following subgroup. S/S (0,161) was the highest for all units low in species. *Machaerium lunatum* once again may be used to determine a sub-unit, but like in unit 3, the number of samples was low (8). *M. lunatum* was present in half of them with little dominance only (5 – 15). Except for one sample, *R. racemosa* was dominant with an abundance of 75. Only in the sample Mn1R *R. racemosa* had a lower abundance. There *L. racemosa* and *M. lunatum* were strong competitors (abundance of 25).

Subgroup II – *Pachira aquatica* mangrove, species rich

In contrast to the subgroup with low species richness, the second alliance had a higher species richness (8 different plants in each transect), a higher diversity index (1,801) and a higher evenness (41 %) as well. As the sample size was lower (31) and the number of found species higher (49), S/S was higher compared to the first subgroup augmented (1,123).

Unit 7 – *Pachira aquatica* mangrove

This is the formation with the highest diversity (2,141), the most even distribution (49 %) and the highest S/S (0,941) for the classification of all samples. The species number (ten) was as high as in the *Zygia cataractae/Pachira aquatica* mangrove. In total, eleven samples were investigated. In this formation, some other plants were present once in high abundance (class 25): *Crinum erubescens* (in total in 36,4 % transects present) and *Allamanda carthartica* (18,2 % of all transects). *Pachira aquatica* and *Dalbergia monetaria* were found in all samples with an abundances between 5 – 75. These species were accompanied by *Hippocratea volubilis*, a liana, was present in 63,7 % of all cases with an abundance between 0,5 and 25. Further some Arecaceae like *Desmonchus orthocantus* (18,2 % / abundance 0,5), *Desmonchus polycantus* (27,3 % / 0,1 - 0,5), *Euterpe oleracea* (27,3 % / 0,5 - 5) and *Mauritia flexuosa* (18,2 % / 0,5 - 5) were present.

Unit 8 – *Zygia cataractae* mangrove

21 transects were combined to this group. Diversity (1,655) and evenness (38 %) were high. An average sample normally had 7 different species (S/S = 0,652) of which *Rhizophora racemosa* and *Zygia cataractae* were the most important and found in all samples with abundances between 5 - 75. *Pachira aquatica* was present in 61,9 % of the samples and forms a sub-association with an abundance of mainly 5. In contrast to the previous unit, no palm species, neither *Crinum erubescens* nor *Allamanda carthartica* was found in this mangrove formation, but *Montrichardia arborescens* (60,0 % / 0,5 - 25) and *Dalbergia monetaria* (70,0 % / 0,1 - 5) were present frequently. Further important species were *Machaerium lunatum* (45,0 % / 0,1 - 25) and *Rhabdadenia biflora* (35,0 % / 0,5 - 5).
Map 14: Vegetation map for all samples, 1:50 000 (extract from INSTITUT GÉOGRAPHIQUE NATIONAL 1990)
5.2.5 Vegetation classification of the combined samples

When regarding the combined samples, the number of transects will be reduced to \( N = 42 \). These samples can be classified into four units by means of a cluster analysis. In contrast to the formerly described classification of all samples, the evenness of all combined samples is higher (\( E_{\text{comb}} = 37 \% \), \( E_{\text{all}} = 22 \% \)) and so is the index of diversity (\( H_{\text{comb}} = 1,432 \), \( H_{\text{all}} = 0,960 \)).

Two groups can clearly be distinguished (cf. Fig. 35) and already separated on a very high level in the dendrogram. First, the \textit{Dalbergia monetaria} mangrove with \textit{D. monetaria} as constantly present plant. Here, the median of \textit{R. racemosa} was lower (15) and the minimum (0) as well. The maximum was also at 75, but the \textit{R. racemosa} was only dominate in eight cases (38,1 \%). Secondly, the \textit{Rhizophora racemosa} dominated mangrove, where \textit{R. racemosa} had a median occurrence of 75 with the minimum at 4 and the maximum at 75. Except for two samples, \textit{R. racemosa} was the plant with the highest abundance index.

\begin{center}
\begin{tikzpicture}[level distance=1.5cm, level 1 distance=3cm, level distance=2cm, level 2 distance=2.5cm, level 3 distance=2cm, every node/.style={anchor=west}, grow=right]


\node {Vegetation of the Coswine swamps}
  child {node {Dalbergia monetaria mangrove, species rich}
    child {node {Zygia cataractae}}
    child {node {Pachira aquatica}}
    child {node {Rhabdadenia biflora}}
    child {node {Lanuguncularia racemosa}}
    child {node {Macheterium lunatum}}
    child {node {Acrostichum aureum}}
  }
  child {node {Rhizophora racemosa mangrove, species poor}
    child {node {Macheterium lunatum}}
    child {node {Acrostichum aureum}}
  }
\end{tikzpicture}
\end{center}

\textbf{Fig. 35: Hierarchical diagram of the combined samples}

\textbf{Group A* – Dalbergia monetaria mangrove, species rich}

In most cases, \textit{Rhizophora racemosa} was still present, but to a smaller degree than in the next group. One species occurred in all samples: the liana \textit{Dalbergia monetaria}. Its abundance was not very high, the minimum at 0,25, the median at 2,50 and the maximum at 12,50. In total, this group is much richer on species (39 different plant were found) than the \textit{Rhizophora racemosa} dominated stands. When calculating the median of species per combined sample, nine plants were found in average. The index of diversity \( H = 1,969 \) and the evenness \( E = 51 \% \) are higher in comparison to the next group for the same sample size (\( N = 21 \)), which leads to a higher \( S/S \) as well (1,468).

\textbf{Unit 1* – Zygia cataractae and Rhabdadenia biflora mangrove}

15 combined samples were examined to describe this association, in which \textit{Z. cataractae} was always present in abundance classes between 2,50 and 37,50. \textit{R. biflora} had lower abundance classes (0,25 to 12,50) and was not found in 13,3 \% of the combined samples. In contrast to the species poor units, the diversity (\( H = 1,909 \)) and \( S/S \) (0,894) were much higher, because nine different plants were found per combined samples in average and a total of 30 species. Even when \textit{Rhizophora racemosa} was still well present and often in the highest abundance class, evenness was high (\( E = 50 \% \)). Sometimes \textit{Macheterium}
lunatum (2,50 – 37,50) was found in high abundance classes and could be used to distinguish two sub-units. Further, Pachira aquatica (60,0 %, 0,25 – 15,00), Languncularia racemosa (40,0 %, 0,25 – 12,50) and Montrichardia arborescens (73,3 %, 0,11 – 2,50) were plants which regularly occurred.

**Unit 2** – **Pachira aquatic and Languncularia racemosa mangrove**
The second unit is the species richest of all groups. At only six combined samples, 28 different species were found with an average of 12 plants per combined transect. The diversity therefore was very high (H = 2,379) just as S/S (1,236). Dominating plants were hardly recognisable and evenness was high with E = 62 %. The plants often found, were Machaerium lunatum (66,7 %), Zygia cataractae (66,7 %), Pachira aquatic (83,3 %), Languncularia racemosa (83,3 %), Montrichardia arborescens (50,0 %), Rhizophora mangle (66,7 %), Pterocarpus officinalis (50,0 %), Virola surinamensis (50,0 %) and Clytostoma binatum (50,0 %).

**Group B** – **Rhizophora racemosa mangrove, species poor,**
This group with 21 samples is characterised by a low species richness – only four different plants were found on average and 22 different species in total. Therefore diversity index was low (H = 0,480) and S/S was next to nil (-0,068). In 52,4 % of all samples, R. racemosa had a large dominance and reached the abundance class 75 what explains the low evenness E = 12 %.

**Unit 3** – **Acrostichum aureum mangrove**
In this unit, A. aureum was present in all samples with combined abundance values between 0,25 and 12,75. Except for two samples (22,2 %) A. aureum was the second dominating plant after R. racemosa. The evenness therefore was very low (9 %). As only nine plants were found in the nine samples, diversity (H = 0,353) and S/S (-0,035) were less as well. Crinum erubescens (six times present, 0,31 – 2,75), Pachira aquatica (5 x, 0,25 – 0,57) and Kyllinga brevifolia (4 x, 0,31 – 0,57) also occurred often. As the abundance values for these plants were very low, no sub-units could be distinguish.

**Unit 4** – **Machaerium lunatum mangrove**
A second unit was formed by M. lunatum in high abundance (between 2,5 and 37,5). In two cases, M. lunatum was even more dominant than R. racemosa (16,7 %). In total, 17 species were found in the 12 combined samples which resulted in an S/S of 0,225 and a diversity of H = 0,708. Evenness was higher than in the previous unit 3* (E = 18 %). With the occurrence of Zygia cataractae (58,3 %, 0,57 – 5) a sub-unit can be defined, in which Acrostichum aureum (41,7 %, 0,25 – 2,75) and Rhabdadenia biflora (33,3 %, 0,25 – 0,50) were also frequently present.

The mapping of the four vegetation units clearly shows an accumulated appearance of the Acrostichum formations in the upper course of Crique Coswine and its tributaries, beginning eastward from Crique Balata. Nowhere else was this formation found (cf. Map 15). It can clearly be associated with the low mangrove. More to the West, the second species poor association (Machaerium stands) begins. Out of the twelve samples only one is not part of the Crique Coswine and tributaries system (Ti1). The most divers Pachira aquatica/Languncularia racemosa stands are
concentrated in the Criques Petit and Grand Ben Amar with two outliners in Crique 1900 and the source of Crique Gadet. The last unit is mainly found in the Crique Canard.

Conclusion

The classification by abundance and presence of species shows the overwhelming dominance of *Rhizophora racemosa*. This outstanding importance is underlined by the syntaxonomic classification which separated the *R. racemosa* dominated samples from all others. Only about $\frac{1}{5}$ of the species found in the Coswine swamps are relevant for the description of the different vegetation units. The rest appears only rarely or sporadically and in small or without any dominance. For the syntaxonomic classification, these plants have the character of accompanying species.

In both, the classification of all samples and of the combined samples, the presence/absence of *R. racemosa* is in relation with the species paucity/richness. In species rich units the liana *Dalbergia monetaria* forms the contrary unit to *R. racemosa*. 
Map 15: Vegetation map of the combined samples, 1:50 000 (extract from INSTITUT GEOGRAPHIQUE NATIONAL 1990)
5.2.6 Characterisation of the Coswine swamps as a manatee habitat

As the previous chapters showed, the Coswine swamps are on the one hand characterised by a rather homogenous aquatic milieu without any submerged aquatic vegetation and on the other hand by a vegetation dominated by *Rhizophora racemosa*. Manatees demand both: water quality in a manatee fitting range and enough food resources to support a viable population.

The Coswine swamps show similar values of the aquatic parameters in the study area. A differentiation into smaller zones is not useful, as the parameters range is small for each variable and an effect of egalisation would appear when the parameters are regarded together.

Concerning the vegetation, the study area is characterised mainly by the presence of *Rhizophora racemosa*. Except for *Machaerium lunatum*, a thorny shrub, and *Crinum erubescens*, a Liliaceae which produces alkaloids, no plants seem to be avoided by manatees. The units without *M. lunatum* are the *R. racemosa* mangroves of all and the combined samples. *C. erubescens* is in these units present but only to a small degree.

These formations appear most often in the “lac du bagne” region (cf. Map 14 and Map 15). This zone can therefore described as “more favourable” in an area which generally is well fit to shelter a manatee population. Furthermore, the “lac du bagne” region is very seldomly used for hunting by indigenous people and therefore virtually unvisited by humans (DIJOSEF, pers. comm.).
5.3 Discussion

5.3.1 Manatee observations

The poor observation results were in first place caused by the study design which dealt mainly with recordings of biotic and abiotic factors. Therefore, most of the time was spent with sampling vegetation and water quality and less time was dedicated to quiet and long-time observation efforts. Further, the noisy kind of moving with an out-board motor, is not helpful for sightings of manatees (cf. BERTRAM and BERTRAM RICARDO 1973; SMETHURST and NIETSCHEMMANN 1999), even if DIJSEF (pers. comm.) recommended several times that the manatees’ attention could be attracted by loud screaming.

As already mentioned in the introduction, the water turbidity also plays an important role for manatee observations and sightings are “far more a matter of chance than plan” (BERTRAM and BERTRAM RICARDO 1973:303). The clarity of the water is very limited and so it is strongly possible, that not all manatees present in the area were seen, a problem that influenced sightings in Brazil (BOROBIA and LODI 1992), Venezuela (O’SHEA et al. 1988) and Mexico as well (COLMENERO-ROLON 1985).

Browsed vegetation a good indicator for the presence of manatees (TlMM et al. 1986), but it could be only found twice. The cropped plants can easily be recognised by the typical feeding manner of manatees.

Except for the sighting of the one group (cf. 5.2.1), manatees were always spotted at the edge of the creeks near the bank. HARTMANN (1979) suggests that this behaviour – to be seen in Florida as well – may be caused by the currents, which are more slow at the shore than in the middle of a creek. Moreover, it is likely that manatees prefer to swim at the border while searching for food, which can be found only on the banks.

During the study faecal, excrements were also searched for, as described by BEST (1983), but nothing was found. This could be the result of the high velocity at the water surface due to the changing tides. Often, little wave action disturbed the surface and the occurrence of much floating organic matter in particular, when rising tide nearly “stops” the currents, hindered the observations of faecal excrements. REEVES et al. (1996) reports the same problems from Peru.

5.3.2 Sampling methods

Recording of the aquatic factors

As already shown in chapter 4.2.3, the measurement of the aquatic parameters provided some difficulty; for example the stronger heating and in consequence a higher water temperature in the afternoon than in the morning. This problem has been already discussed in a previous chapter (cf. Fig. 18). The median values for the stations varies between 26,2° C and 30,1° C in this study and thus is above the minimal temperature fixed for the survival of manatees. This corresponds to the opinion of
BOROBIA and LODI (1992) who do not judge temperature as a limiting factor in their study made at Barra de Mamanguape (Brazil). At least during the time they made their records, water temperature was between 24° C – 26° C. Thus, temperature seems to be negligible for a manatee habitat classification.

Surprisingly, salinity in all creeks was very low. After literature study (cf. BOYÉ 1963; CHOUBERT 1961; JOUNNEAU and PUJOS 1988; LOINTIER and PROST 1986) and from the ecological aspect of the encountered vegetation (mainly Red Mangrove), it was expected that the area was totally and to a high degree invaded by at least brackish water. This difference between the expected and the real result can be based on two reasons: first, the records had been taken at early low tide or after heavy rain. This could result in the fact, that the fresh water flushes out the salt or brackish water and in consequence only freshwater or low salinity values are recorded. But sampling of the aquatic parameters started only when the tide was rising. Therefore, salty water invasion into the creeks should have been observed. As this was not the case, the second reason may be responsible for the mainly fresh water in the area: the records of the parameters were made at the end of the rain season and only the last weeks were in the dry season. During the rainy season no brackish water invades the inland waters (BERTHOIS and HOORELBECK 1968; BLANCANEAUX 1981; LOINTIER 1990; LOINTIER and PROST 1986). Also, the ion concentration is highest in dry season (PAYNE 1986). But when regarding the samples in a temporal order, no risen occurrence could be found. Two stations with brackish water were recorded on the 13th of July, two on the 24th of July, three on the 11th of August and one on the 13th of September. Thus, the Coswine swamps are either not invaded by salt water in the expected quantity or the records were placed at a time of the day when no sea water invaded the creeks, which regarding the number of samples, would be surprising, but possible. A study by BERTHOIS and HOORELBECK (1968) supports the first assumption, as the maximum of salinity was 28 ‰ for a station near La Pointe des Hattes, but even there salinity was next to nil during low tide. At the mouth of Crique Coswine, salinity has its maximum at 2 ‰ and at the mouth of Crique Beuf aux Lamantins salinity is not exceeding 0,2 ‰. Similar result were obtained by JOUNNEAU and PUJOS (1988) (cf. Fig. 36).

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**Fig. 36:** Salinity in the Maroni in May and November 1984 (after JOUNNEAU and PUJOS 1988)
The depth measurements were very simple, but it was not aimed to get exact profiles of the creeks’ bottom. The deepness was most important for acquiring information whether manatees can be locked in shallow creeks during low tide or during the dry season, when the water level is in general lower than in the wet season. At this point, it is important to remember that the difference between the maximal flood and the minimal ebb is 2.7 m. Manatees may get locked any time of the year by falling tide in channels with depth of less than 3.2 m when accounting for a minimal height of 0.5 m for a manatee. But this seems to be to negligible. In the middle of the creeks the minimal median value was 3.0 m and had been reached only once. The lowest measured value for the whole study area was 2.5 m and was taken at the same station. The three other stations where shallow points were found, were all situated in the upper courses of small creeks already beyond or near the limits where manatees may go as the waters become more shallow there.

**Recording of the vegetation**

For the estimation of the abundance/dominance of a vegetation sample, the Braun-Blanquet scale is quite widely accepted (see for example DIERSCHKE (1994)). For the study, this scale was modified and some units aggregated in higher level groups, in particular the Braun-Blanquet classes 4 and 5. The purpose for this accumulation was that the scale was easier to apply and no transformation was necessary for further calculations. After having done nearly half of the field work, it appeared that the chosen scale was too rough for high abundance (e.g. in the class 25 and 75), a problem which is also mentioned by DIERSCHKE (1994) in connection with the Hult-Sernander-scale, a pure dominance scale, which is similar to the classes 25 and 75 to the scale applied here. In these groups it would have been better to subdivide the two classes in three smaller ones. This may look like the proposition in. Tab. 10. And here, the disadvantages of the previous scale are eliminated. In the upper classes, a differentiation between samples with “total” dominance (over 75 %) and less abundant species can be made. At the same time, this scale allows to name less abundant species in a sufficient way. For vegetation samples in the Coswine swamps, the difference between the classes r and + is not highly important, as there are only few small plants especially grasses. Lianas normally cover a large surface and are therefore, despite their small habit, often occur in abundance classes exceeding 0.1. At the time when these problems became clearly visible, nearly half of all stations had been investigated. So, it was to late to rebegin the sampling with a better adapted scale.

The big variations between the flood and the ebb could have led to miss some small submerged plants thriving on the edges of a creek, as they could have been flooded and not been seen during high tide. The organisation of the study was determined by the fact that the sampling of the aquatic parameters was only possible during high tide (see above). Thus, the vegetation was mainly recorded during low tide and normally all plants should have been seen. Moreover, the huge quantities of food which are consumed daily by a single manatee lead to the assumption, that small and rare species do not play an important role for the characterisation of the manatee’s habitat.

The meandering course of most of the creeks caused some problems. It rarely happened that a transect was straight and not curved. Especially in the smaller tributaries, where meanders are more
numerous, the transect can be slightly shorter or longer at one bank than one the opposite bank. Sometimes “holes” in the clear gallery line of the mangrove’s limit towards the creek appeared. In these cases, the vegetation was sampled in a straight line and the presence of a hole was noted on the sheet. When a transect was strongly curved, the distance was also measured on the left bank. But for the definition, which stations were “heavily” curved and where it was not necessary to do a second distance measurement, no criteria were imposed.

5.3.3 Classification and interpretation of the aquatic parameters

The classification of the aquatic parameters must be regarded with caution. Surely the division into areas with a similar ranges for one parameter could be pushed further on, but it is doubtful whether such a forced classification is useful and necessary for a more exact description of the manatee habitat. The differences for one parameter were small and could only represent daily changes and not determining values for a certain area. To get more exact data to provide a better understanding of the values, a year-around lasting study with numerous fixed record stations distributed in the whole study area would be an advantage.

In comparison, some key values of Sinnamary river, the third largest river in French Guiana, are given: the temperature was recorded during a study made by MERIGOUX and PONTON (1999) from March 1995 to October 1996 in average with 24.7°C for the downstream region, and the pH with 4.6 for the same area. The mean oxygen content was given with 5.2 mg/l. In the present study, the temperature was higher, but MERIGOUX’S work does not take into account the influence of the tides, as the estuary was not investigated. Secondly, the study covers the two wet seasons. The oxygen content is higher than in study in hand because the Sinnamary river is faster flowing and rapids are numerous, while the water in the Coswine swamps is slowly flowing and no rapids are encountered. As sea water regularly dilutes the creeks in the Coswine swamps the pH is raising and higher than in Sinnamary. For the Maroni, a study was undertaken in March 1963 by BERTHOIS and HOORELBECK (1968) who worked mainly on the sedimentation, but salinity was also recorded. The results were already mentioned in chapter 5.3.2 Sampling methods.

5.3.4 The vegetation and its interpretation

Dominance of species

The absolute dominance $aD$ combines the species’ presence and its abundance in one formula and gives a good impression of the species’ importance. On the first sight the formula seems to be very complex and the necessity of the denominator is not clear, as the tendency would also appear clearly when the number of species is only multiplied by the abundance class. The advantage of the $aD$ in the chosen form is that the result for this study is between 0.001 and ca. 100. Without the denominator, the range of the $aD$ would be larger, namely from 0.1 to 9300.

Further, the absolute dominance allows to make some statements on the dominance and abundance of a species. A nearly omni-present plant like Rhizophora racemosa, which was moreover only present in high abundance, has a very high $aD$. The $aD$ gives a mathematical test for the
assumption that this species is very dominant in the whole study area. The smaller *Rhabdadenia biflora* will have an $aD$ of 0.59, even when it is present 39 times, and thereby as often as *Dalbergia monetaria*, but this species reaches an $aD$ of 3.02, because of its raised appearance in high abundance classes.

**Mean number of species versus median of species and index of diversity/evenness versus S/S**

In plant sociological literature (Dierschke 1994; Dierben 1990) the mean number of species in a sample is a common term. In statistical literature (Engel 1997; Lamprecht 1999; Lozán and Kausch 1998; Sachs 1999) it is stressed that the calculation of the mean number of a sample will only be allowed, when normal distribution is guaranteed. If not, the median or the mode, which is even more correct when the distribution is very uneven, but is seldomly applied in biological studies (Lamprecht 1999), should be used. Especially for small samples, the median is recommended as the appropriate tool for characterisation of such a group (Lozán and Kausch 1998). Therefore, in the present study the median is used – against the common practice – for the description of the average number of species per transect or vegetation unit.

Index of diversity and evenness are also widely used methods to describe and compare vegetation units (cf. chapter 5.1.1). Nevertheless, it seemed to be useful to introduce a further formula to describe more precisely the relation between the number of species per transect and the number of samples. The diversity index only considers the abundance of a species. As it is derived from the diversity index, the same is true for the evenness. In contrast, the $S/S$ is based on two parameters: the relative number of species and the relative number of samples. Standardised by the functions sine and cosine, it oscillates between the limits $-2$ and 2. This allows diversity comparison between vegetation units with different numbers of samples. Together with the index of diversity and the evenness, the $S/S$ is a well applicable tool and helps to characterise vegetation units from a diversity’s point of view.

Low evenness values indicate that some plants are dominant. This can be shown when regarding the difference between the *Rhizophora racemosa* unit and *Zygia/Pachira* stands: for the first one, evenness, diversity and $S/S$ is very low, for the second one, these values are high. When regarding the floristic composition of the samples individually it can be seen that in the *R. racemosa* unit, the Red Mangrove is always widely dominant, while in the other unit, the highest abundance class is at least represented twice per transect except for three of the eleven samples (27.3%). On the other hand, high evenness values stand for a rather equal distribution of the found species in dependence of all found plants. The highest values for the evenness are found in the *Pachira/Languncularia* unit.

**The vegetation units and its assignation to existing syntaxonomical classification systems**

Lindeman (1953) describes the swamps and mangroves in Suriname, but he does not give any syntaxonomical indications. In three chapters he explains the mangrove, herbaceous swamps and swamp forest.

According to Lindeman, *Rhizophora* plays a major role in the estuarine mangrove, but when water is fresher, *Montricharida arborescens* appears and forms dense stands. This observation was not made in the Coswine swamps. In the *Zygia/Pachira* unit, *M. arborescens* reaches its maximal dominance, but *R. racemosa* is either absent or in most cases present in abundance class 5.

In the chapter “swamp forest” Lindeman reports of a *Machaerium* scrub, which thrives well even in polyhaline to fresh water on the edges of creeks.

A formation named “*Symphonia globulifera* type”, is mentioned as accompanying creeks and inland waters, where *Pachira aquatica* is very common. Together with *Tabebuia*, *Pterocarpus* and
Virola the association may spread out into real swamps, but the author did not give any supporting data. But he added some more plants which occur in this swampy formation: Euterpe oleracea, Mauritia flexuosa, Maximiliana maripa and Tabebuia. Surprisingly, Zygia cataractea, very common in the study in hand, is not mentioned in his work. SCHNELL (1987) mentions a bank association of creeks with Pterocarpus officinalis, Montricharida arborescens and Pachira aquatica, and with Inga on the concave side of meanders. LESCURE and TOSTAIN (1989) mention back mangrove, where Symphonia globulifera and Virola surinamensis occur and a transition zone to swamps, when Pterocarpus officinalis and Montricharida arborescens are found in heaped stands.

Compared to units yielded in this study, some similarities appear. The species rich units are characterised by many plants, which LINDEMAN put into the section of swamp forest plants. In the Zygia/Pachira unit, Pterocarpus officinalis is found in high abundance next to Pachira aquatica. Furthermore, Euterpe oleracea and Virola surinamensis are present. It can be assumed that the Zygia/Pachira is an association of the swamps. PIRES and PRANCE (1985) in contrast lists Pterocarpus officinalis as a mangrove species.

The three associations made by CHAPMAN mentioned above could be represented in the present study by the units Rhizophora racemosa, Rhizophora mangle and Langucularia racemosa. The other units are transitory units from the mangrove to the swamps.

The integration of the vegetation samples carried out into a syntaxonomic system is not altogether without problems (cf. PFADENHAUER 1997). For a correct analysis of the vegetation units not enough samples were taken and comparison with other neighbouring habitats was not made. In the estuaries of all big rivers in French Guiana, estuarine mangrove formations can be found and on first sight, they seem to be comparable to the ones in the Coswine swamps (p.obs.). For the neighbouring countries (Suriname and Brazil) this is also valid. Further, an accepted classification made by CHAPMAN (1976b) already exists. The for the present study interesting formations, mentioned in CHAPMAN (1976b), are:

**Rhizophoreta**

Rhizophorion occidentalis
1. Rhizophoretum mangale
2. Rhizophoretum racemosae

**Combretalia**

Languncularion
3. Languncularietum racemosae

Unfortunately, CHAPMAN did not publish in his paper any further information about the species composition in one group, neither about the differential species nor the accompanist.

As the classification made in the present study is afflicted by problems because the above mentioned criteria are not fulfilled and tables with the characteristic species were not found in literature, the vegetation units in the present study were only put in different groups. This is a numerical method and the approach has not the pretension to be a syntaxonomical classification in the Tüxen and Braun-Balquet sense. Thus, syntaxonomical names were not attributed to them, but the units were labelled by the characterising species of a group. If one group can be distinguished from another by its high species diversity, it got the name of the two most important plants.

The vegetation units were obtained by a cluster analysis, but then aggregated by hand to higher level groups. This is at first a purely mathematical approach and no ecological information is incorporated in the systematic. Only afterwards, ecological knowledge was used to create the groups
and the sub-groups. In contrast to a “hand-made” classification, each species has the same importance if it is analysed by clustering. Some finesses and particularities are not taken into consideration (DIERSCHKE 1994). This can be avoided or lowered, when the cluster analysis is used as a first approach and the result obtained is regarded afterwards with ecological understanding. The classification made by the cluster analysis (Fig. 37) differs from the classification (cf. Fig. 34) shown in chapter 5.2.4: it put all species rich units into one group and the species poor ones into another. The hierarchical structure is like shown in the figure below. The different levels of the diagram are obtained by the aggregation of the first yielded eight units to higher level groups, a common method in cluster analysis.

Common points between the two classifications are the same number of units and that in both cases the species rich group can be characterised by *Dalbergia monetaria*, while the species poor one can be call *Rhizophora racemosa* group.

![Fig. 37: Hierarchical diagram of the vegetation of the Coswine swamps after cluster analysis](image)

The combined samples approach (see chapter 5.2.5) gave a more coherent picture concerning the occurrence in the field. When mapping all samples, no features will be clearly visible, while the combined samples – in particular the *Acrostichum aureum* unit – are well accumulated and grouped in one area. One reason for this reaction is surly that only four classes exist. Another is that the samples are more well-balanced than the others due to the median values formed by the left and right bank samples. The combined samples have less units, but like the mathematical and the ecological classification of all samples, the two groups are once again characterised by the same species.

**Vegetation and the manatee habitat**

The nearly pure *Rhizophora racemosa* mangrove seems to provide best food resources for manatees. *R. racemosa* is reported to be eaten (BEST 1981) and species with thorny or other for manatee dangerous habit are not present or in only very small abundance (0,1/0,5).
5.3.5 The Coswine swamps as a manatee habitat

A cluster analysis of the total study area with all parameters did not bring any satisfying results. On the one hand this is based on the big heterogeneity of the data, with different ranges for all parameters. LOZÁN and KAUSCH (1998) request for a cluster analysis to omit all extreme values that could falsify the results. On the other hand, parameters with a small range are to be put aside, as they can not be called “variables” when they do not vary in a specific range (LOZÁN and KAUSCH 1998). A standardisation or transformation finally only tests the standardised or transformed values and no longer the in reality recorded ones (ENGEL, pers. comm.). Finally, no classification of the Coswine swamps with all parameters was made, as the result of the test did not bring good results.

It is clear that vegetation is not an indicator of manatee presence, as manatees are mobile and swim from one habitat to another. But if consumable vegetation is available, manatee may travel to these zones and live there if other factors are preferable as well. But the range of distribution is limited by natural frontiers, as a recent study of mitochondria showed (GARCIA RODRIGUEZ et al. 1998). The lineages of one group is limited to the Guianan shield. Moreover the wide plasticity of manatees in food questions allows the species to consume a wide variety of plants (BOYD et al. 1999; CAMPELL and IRVINE 1977; O'SHEA 1986), even algae (LEWIS et al. 1984) or mast (O'SHEA 1986).

The high velocity of the Maroni (max. 6,2 km/h just before the ebb) seems to affect manatee distribution only temporally and for a short period.

5.3.6 Comparison with already described habitats

Most descriptions of manatee habitats are more anecdotal than exact and precise. So it is rather difficult to find good reports from existing and studied areas. In Belize, manatees live in extensive mangroves and creeks opening into the sea (Charnock-Wilson in CARIBBEAN ENVIRONMENT PROGRAMME 1995), similar to the habitats in Colombia (CARIBBEAN ENVIRONMENT PROGRAMME 1995), comparable to the situation in the Coswine swamps.

It seems that the only food resource for manatees in the Coswine swamps are the mangrove leaves. From Eastern Venezuela, O'SHEA et al. (1988) report a similar habitat during the dry season, where manatees browse mainly on mangrove leaves, as there are virtually no aquatic plants available for manatees in this period.

Further, no seasonal behaviour, as it is known from populations in Mexico (COLMENERO-ROLON and ZÁRATE 1990) or Brazil (BOROBIA and LODI 1992), is reported for manatees in French Guiana (de Theoisy, pers. comm.). In Panama, manatees live in fresh or brackish water like in the Coswine swamps, but not in salt water (MOU SUE et al. 1990).

TIMM et al. (1986) reports from Ecuador that the water temperature in creeks where Trichechus inunguis lives, ranges from 25,0°C to 30,7°C and pH from 5,5 to 6,0, which can be described as similar to the Coswine swamps (here, the median temperature is between 26,2 °C and 30,1 °C and the pH ranking from 5,6 to 6,8).

In Mexico, MORALES-VELA et al. (2000) describes the manatee habitat at Chetumal Bay with a water depth of one to seven meters (mean 3m), salinity ranging from 8 ‰ to 18 ‰ and a temperature from 24,5 °C to 31,0 °C. Similar values are given by AXIS ARROYO et al. (1998) for the whole state of Quintana Roo. Thus the temperature is even lower than the median temperature in the Coswine swamps, while the salinity is higher than in the present study site (0,0 ‰ to 1,3 ‰). The depth of the
creeks in Coswine are also similar to those in Mexico, as the median is only 0.5 m deeper for the banks.

The highest value for the lowest minimal temperature for manatees in Florida is given by IRVINE (see chapter 3.2.3) with 24°C. During the present study which took place at the end of the long rain season, the measured minimal temperature was at 24.5°C. It is therefore not likely that the water temperature falls even under 24°C, as the minimal temperature is reached at the maximum of the wet season mid-June.

5.4 Prospects of conservation and further research programs

The study showed that the water quality in the Coswine swamps is in a manatee fitting range and food in the form of bank vegetation is abundant. Therefore, the Coswine swamps are a zone which is favourable for the conservation and the protection of the species. Manatees can find quiet areas there nearly without human impact and sheltered for heavy surf from the sea. Thus, it is recommended to keep the Coswine swamps in their actual state and to enlarge the protection area situated in the North to the Coswine swamps. This approach would imply at the same time a reinforcement of the conservation for the quite untouched fauna and flora in the area. The involvement and the participation of the local people in particular the inhabitants of the village of Coswine must be guaranteed, because if protection is installed by the local authorities only, perimeters would not be accepted.

For the successful conservation of manatees in French Guiana, some efforts should be made mainly in the field of education programs, as it is done in Puerto Rico (REYNOLDS et al. 1995). This may lead to a sensibilisation of the local populations, which often have lost the traditional relationship to manatees or do not have any information on the species (DE THOISY et al. 2001). It is therefore planned by KWATA to edit a leaflet with short information on the species’ importance, traditional interest and actual threats. In connection with eco-tourism, which should become more important in the next years (DESBOIS, pers. comm.), knowledge on manatees may become more widespread, but on the other hand, more eco-tourism also means increasing boat traffic and more disturbance of the up to now nearly untouched Coswine swamps. Together with a probable increase of tourism in the region, the sale of little emblems with manatee or other things in connection with sirenians, can be a source of income for local people and at the same time, the existence of manatee would become more known. In Florida one of the main marine mammal attractions are manatees (TWISS and REEVES 1999). According to local people, sightings are frequent in the region of Coswine even despite the turbid water.

Habitat alteration due to construction of dams or implantation of industry like it is reported from Venezuela (O’SHEA et al. 1988) will be not probable in the next years or even not at all in the Coswine swamps, even though a harbour project at the end of Crique Coswine is in public discussion (DESBOIS, pers. comm.).

For a better understanding of the species, radio tracking could be one tool to assess daily travel routes and the main residences of manatees. Some difficulties for that approach are the high costs and the protection of the species, but the procedure is frequent and recommendations are given by many authors (for instance DEUTSCH et al. (1998). The entire protection of the species, which forbids to
catch the animals, may be a further reason not to work with this method. Year-round measurements of the aquatic parameters were already mentioned as important to get more exact data on the water composition. Further it may be interesting to work on the rostral deflection of the manatees snout, which can give an idea of the consumed vegetation: it can be hypothesised that rostral deflection is – similar to manatees in Panama which live more in fresh water or brackish environment than in seagrass dominated areas (MOU SUE et al. 1990) – about 30° or less degrees.

5.5 Summary

The study of the bank vegetation and the aquatic parameters showed a large dominance of *Rhizophora racemosa* in the study area. As this plant supplies good food resources for manatees, the habitat seems to be well qualified for a huge manatee population from a nutritional point of view. The other determined specific parameters are also in a manatee fitting range. Salinity was low in comparison with other habitats low. Furthermore, the Coswine swamps are in a large part quite untouched from humans and as the secretive behaviour of manatees makes them to a hardly visible animal, the future for manatees in the Coswine swamps should not be too bad. But too much optimism seems to be inappropriate. The increasing boat traffic and the beginning of the eco-tourism in the area in connection with the Great Leatherback laying sites increases the fear that observations of manatees could be forced. But on the other hand, sensibilisation of the local people seems to be important to prevent manatees for being slaughtered only for small ear bones.
6 References

6.1 Maps


6.2 Literature


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# Appendix

## 7.1 List of found plants

<table>
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<tr>
<th>Family</th>
<th>Name</th>
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<tbody>
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<td>FLACOURTACEAE</td>
<td>Casearia N.J. Jacquin sp.1</td>
</tr>
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<td>Cuervea kappleriana (Miquel) A.C. Smith</td>
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<tr>
<td>HIPPOCRATEACEAE</td>
<td>Hippocratea volubilis Linnaeus</td>
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<td>HUMIRIACEAE</td>
<td>Sacoglotis cydonioides Cuatrecasas</td>
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<td>LECYTHIDACEAE</td>
<td>Couratari calycina Sandwith</td>
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<tr>
<td>LECYTHIDACEAE</td>
<td>Couratari multiforma (J.E. Smith) Eyma</td>
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<td>LILIACEAE</td>
<td>Crinum erubescens Solander in W. Aiton</td>
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<tr>
<td>LORANTHACEAE</td>
<td>Phthirusa stelis (Linnaeus) Kuijt</td>
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<tr>
<td>LYTHRACEAE</td>
<td>Crenea maritima J.B. Aublet</td>
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<tr>
<td>MALPHIGIACEAE</td>
<td>Bunchiosia decussiflora W.R. Anderson</td>
</tr>
<tr>
<td>MALPHIGIACEAE</td>
<td>Heteropterys multiflora (A.P. De Candolle) B.P.G. Hochreutiner</td>
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<td>MALPHIGIACEAE</td>
<td>Stigmaphyllon bannisterioides (Linnaeus) C. Anderson</td>
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<tr>
<td>MALVACEAE</td>
<td>Pavonia paludicola Nicolson</td>
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<tr>
<td>MELASTOMATAEAE</td>
<td>Miconia sp. Ruiz et Pavon</td>
</tr>
<tr>
<td>MELASTOMATAEAE</td>
<td>Nepsera aquatica (J.B. Aublet) Naudin</td>
</tr>
<tr>
<td>MELASTOMATAEAE</td>
<td>Species 1</td>
</tr>
<tr>
<td>MIMOSACEAE</td>
<td>Entada polystachya (Linnaeus) A.P. De Candolle</td>
</tr>
<tr>
<td>MIMOSACEAE</td>
<td>Inga cayennensis Sagot ex Bentham</td>
</tr>
<tr>
<td>MIMOSACEAE</td>
<td>Inga sp. 1 P. Miller</td>
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<tr>
<td>MIMOSACEAE</td>
<td>Zygia cataractus (Kunth) L. Rico</td>
</tr>
<tr>
<td>MUSACEAE</td>
<td>Ravelana guianensis</td>
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<tr>
<td>MYRISTICACEAE</td>
<td>Virola surinamensis (Rolander) Warburg</td>
</tr>
<tr>
<td>MYRTACEAE</td>
<td>Eugenia cf. latifolia J.B. Aublet</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Alexa wachenheimi R. Benoist</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Dalbergia cf. amazonica (L.A.T. Radlkofer) Ducke</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Dalbergia monetaria Linnaeus f.</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Dioclea huberi Ducke</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Lonchocarpus chrysophyllus Kleinhoonte</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Machaerium inundatum (Martius ex Bentham) Ducke</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Machaerium leiophyllum (A.P. De Candolle) Bentham</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Machaerium lunatum (Linnaeus f.) Ducke</td>
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<tr>
<td>PAPILIONACEAE</td>
<td>Muellera frutescens (J.B. Aublet) Standley</td>
</tr>
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<td>PAPILIONACEAE</td>
<td>Pterocarpus officinalis N.J. Jacquin</td>
</tr>
<tr>
<td>PAPILIONACEAE</td>
<td>Vataireopsis surinamensis Lima</td>
</tr>
<tr>
<td>PAPILIONACEAE</td>
<td>Species 1</td>
</tr>
<tr>
<td>PASSIFLORACEAE</td>
<td>Passiflora crenata Feuillet et Cremers</td>
</tr>
<tr>
<td>POLYGONACEAE</td>
<td>Species 1</td>
</tr>
<tr>
<td>RHIZOPHORACEAE</td>
<td>Rhizophora mangle Linnaeus</td>
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<tr>
<td>RHIZOPHORACEAE</td>
<td>Rhizophora racemosa G.F.W. Meyer</td>
</tr>
<tr>
<td>SMILICACEAE</td>
<td>Smilax sp. 1 Linnaeus</td>
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<tr>
<td>VERBENACEAE</td>
<td>Avicennia germinans (Linnaeus) Stearn</td>
</tr>
<tr>
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<td>Species 1</td>
</tr>
<tr>
<td>LIGNEOUS</td>
<td>Species 2</td>
</tr>
<tr>
<td>LIGNEOUS</td>
<td>Species 3</td>
</tr>
<tr>
<td>LIGNEOUS</td>
<td>Species 4</td>
</tr>
<tr>
<td>LIGNEOUS</td>
<td>Species 5</td>
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# 7.2 Record sheet for the preliminary study

## Preliminary investigation

<table>
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<th>date:</th>
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<tbody>
<tr>
<td>section:</td>
<td>time:</td>
</tr>
<tr>
<td>total number of sections:</td>
<td></td>
</tr>
</tbody>
</table>

## Plot

### Coordinates

**N**

**W**

## Aqua-chemical parameters

- **temperatur:** °C
- **oxygen:** mg/l
- **saltinity**
- **pH:**
- **water visibility:** m

## Depth

- **water depth measured:** m
- **reference water depth:** m
- **max. water depth:** m

## Largeur

**meter:** m

## Bank vegetation

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
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</tbody>
</table>

## Water vegetation

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
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### 7.3 Record sheet for the study of the bank vegetation

**Record sheet**

<table>
<thead>
<tr>
<th>Code:</th>
<th>Date:</th>
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</thead>
<tbody>
<tr>
<td><strong>Crique:</strong></td>
<td><strong>transect:</strong></td>
</tr>
<tr>
<td><strong>bank side:</strong></td>
<td><strong>coordinates:</strong></td>
</tr>
<tr>
<td><strong>tide:</strong></td>
<td><strong>largeur:</strong></td>
</tr>
</tbody>
</table>

**Aqua-chemical parameters**

<table>
<thead>
<tr>
<th>Code:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>time:</strong></td>
<td><strong>water depth:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>temperatur:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>oxygen:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>saltinity:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>pH:</strong></td>
</tr>
<tr>
<td></td>
<td><strong>water visibility:</strong></td>
</tr>
</tbody>
</table>

**Sketch**

**Vegetation sample**

<table>
<thead>
<tr>
<th>Famil</th>
<th>Species</th>
<th>&lt;0.5m</th>
<th>total</th>
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</thead>
<tbody>
<tr>
<td>Olea</td>
<td>Nephrolepis bissserata</td>
<td>Lymph</td>
<td>Chaetocarpus schomburgkianus</td>
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<tr>
<td>Pteric</td>
<td>Acrostichum aureum</td>
<td>Hippo</td>
<td>Hippocreatea volubilis</td>
</tr>
<tr>
<td>Anno</td>
<td>Rollinia esucca</td>
<td>Hum</td>
<td>Sacoglotis cydonioides</td>
</tr>
<tr>
<td>Apoc</td>
<td>Allamanda cathartica</td>
<td>Liliaco</td>
<td>Crinum erubescens</td>
</tr>
<tr>
<td>Apoc</td>
<td>Rhabdadenia bifiola</td>
<td>Lythri</td>
<td>Crenea maritima</td>
</tr>
<tr>
<td>Arace</td>
<td>Montrichardia arborescens</td>
<td>Malph</td>
<td>Stigmaphyllon bannisterioides</td>
</tr>
<tr>
<td>Arecc</td>
<td>Desmoncus orthacanthos</td>
<td>Malva</td>
<td>Pavonia paludicola</td>
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<tr>
<td>Arecc</td>
<td>Desmoncus polyacanthos</td>
<td>Melai</td>
<td>Miconia sp.</td>
</tr>
<tr>
<td>Arecc</td>
<td>Euterpe oleracea</td>
<td>Mimo</td>
<td>Entada polystachya</td>
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<tr>
<td>Arecc</td>
<td>Mauritia flexuosa</td>
<td>Mimo</td>
<td>Inga cayennensis</td>
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<tr>
<td>Bigno</td>
<td>Cylostoma binaum</td>
<td>Mimo</td>
<td>Inga sp.</td>
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<tr>
<td>Bigno</td>
<td>Pleonotoma albilflora</td>
<td>Mimo</td>
<td>Zygia cataractae</td>
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<tr>
<td>Bigno</td>
<td>Tabebuia fluviallis</td>
<td>Myris</td>
<td>Virola surinamensis</td>
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<tr>
<td>Bomt</td>
<td>Pachira aquatica</td>
<td>Papili</td>
<td>Dalbergia monetaria</td>
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<td>Borac</td>
<td>Tournefortia sp.</td>
<td>Papili</td>
<td>Lonchocarpus chrysophyllum</td>
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<td>Caes</td>
<td>Peltogyne venosa</td>
<td>Papili</td>
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<td>Maytenus cf. myrsinoides</td>
<td>Papili</td>
<td>Muelleria frutescens</td>
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<td>Chrys</td>
<td>Parinari campestris</td>
<td>Papili</td>
<td>Pterocarpus officinalis</td>
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<tr>
<td>Clusia</td>
<td>Carapa richardia</td>
<td>Rhizo</td>
<td>Rhizophora mangle</td>
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<td>Clusia</td>
<td>Clusia sp.1</td>
<td>Rhizo</td>
<td>Rhizophora racemosa</td>
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<td>Clusia</td>
<td>Clusia sp.2</td>
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<td>Smilax sp.</td>
</tr>
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<td>Clusia</td>
<td>Symphonia globulifera</td>
<td>Verbe</td>
<td>Avicennia germinans</td>
</tr>
<tr>
<td>Comit</td>
<td>Combretum cf. laxum</td>
<td>1-5 Ex 0.1; &gt;5 Ex. 0.5; 1-10% 5; 10-50% 25; &gt;50% 75</td>
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<tr>
<td>Comit</td>
<td>Laguncularia racemosa</td>
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<tr>
<td>Cype</td>
<td>Eleocharis interstincta</td>
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<tr>
<td>Cype</td>
<td>Kyllinga brevifolia</td>
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</tr>
<tr>
<td>Dillan</td>
<td>Davilla kunthii</td>
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Abstract

A study was carried out from June to September to assess habitat quality for manatees (*Trichechus manatus manatus*) in the Coswine swamps in French Guiana.

The Coswine swamps are one of the largest wetlands in French Guiana and totally under the influence of the tides. The climate is typical for the tropics and has a huge impact on the water regime. In the area, three different protection zones exist. The swamps are quite untouched from humans, perhaps a reason for the high number of manatee sightings in the recent past and the its suspected large population size.

As the manatee is an aquatic herbivore, in a first part the submerged aquatic vegetation was investigated. At the same time, some parameters important for manatee distribution were measured, which had been determined by literature survey. The whole area was divided into sections and in each such section the vegetation and water parameters were recorded during a preliminary study. The results showed, that no submerged aquatic vegetation was present in the Coswine swamps. The aquatic parameters were similar to those obtained in other studies in French Guiana and South America if climatic circumstances are taken in account.

The second part of the study is based on the first one and deals with the bank vegetation, as it is supposed, that this is the only available food resource for manatees in the area. The methodological approach was slightly altered for the assessment of the water quality, considering the recommendations made after the first study. The vegetation was sampled in 100 m long transects at the banks with a distance of 1 500 m between each in the whole study area.

During the study rarely any manatee was spotted, but this more likely was due to the methods applied than an indicator for the non-presence of sirenians. The aquatic parameters varied slightly more than in the first part of the study. Salinity unexpectedly was low and more than ¾ of all samples were taken in fresh water. The vegetation sampling showed an overwhelming importance of Red Mangrove (*Rhizophora racemosa*) in the whole study area. In contrast to the first impression on the site, the swamps are quite homogenous when regarding only the aquatic parameters. It is therefore difficult to distinguish any zones of changing environmental aspects. Regarding the vegetation the Coswine swamps are also homogenous but to a lesser degree as the plants are more influenced by the soil on which they thrive than by the water quality.

For manatees, the Coswine swamps seems to provide a suitable habitat with plenty of food in the form of overhanging branches and leaves of Red Mangrove, some mouko-mouko (*Montrichardia arborescens*) and other consumable plants. The aquatic parameter are in a range which is described in literature as manatee-fitting. The quite untouched Coswine swamps provide shelter from wave action, humans and pollution. Therefore they can be judged to be important manatee areas. Corresponding steps for the conservation of this still natural area should be taken and secured by nature protection laws.