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.

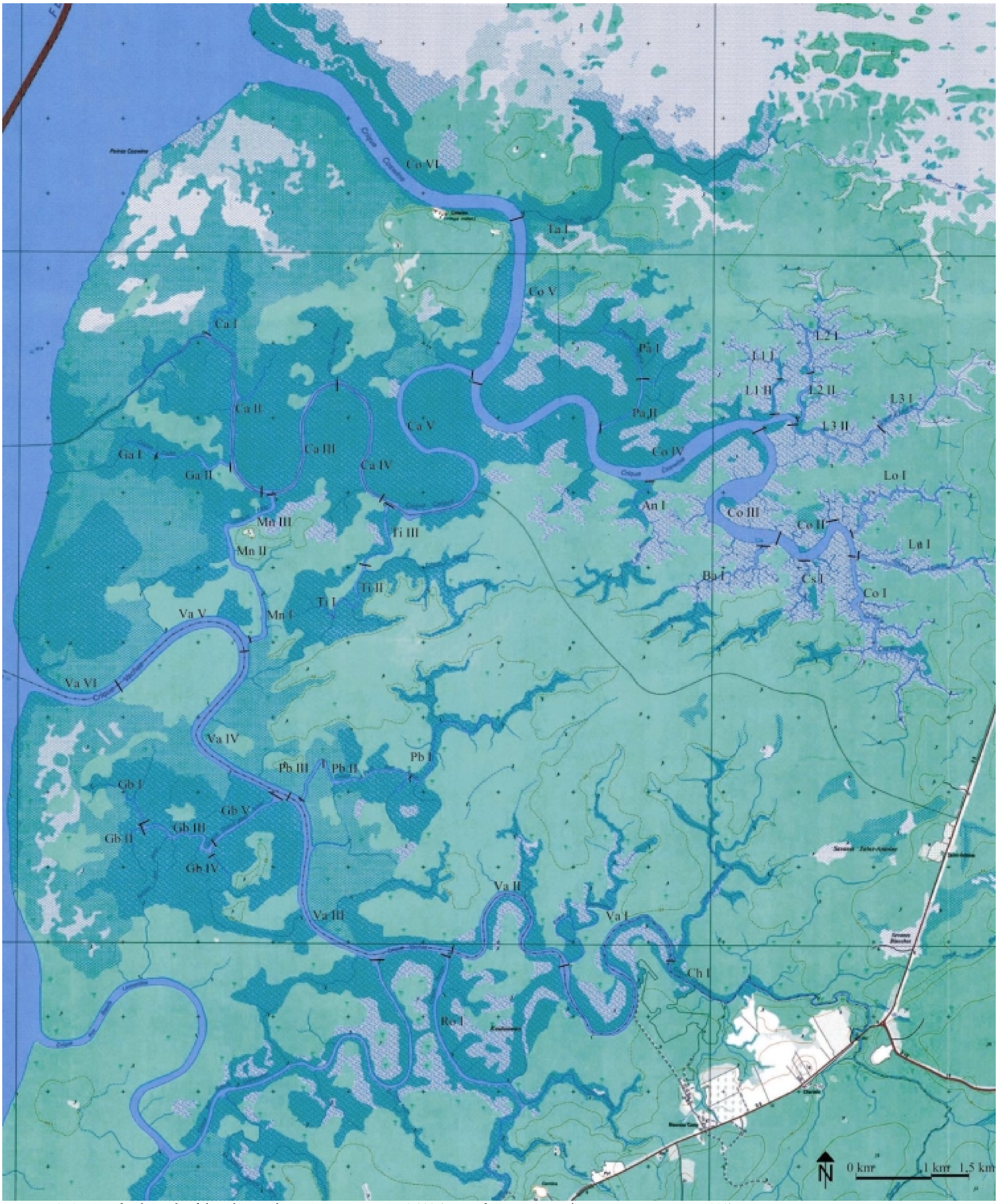
4.1.1 Division into sections

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 exsist. 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.

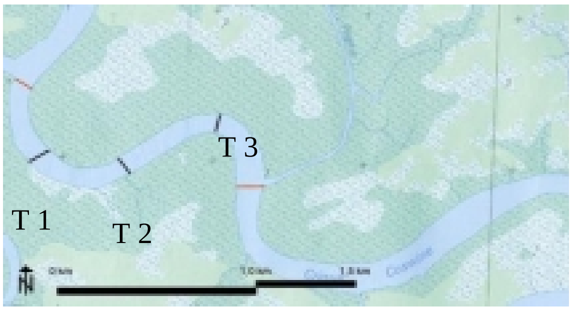


Fig. 14: Example of the emplacement within one section

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).

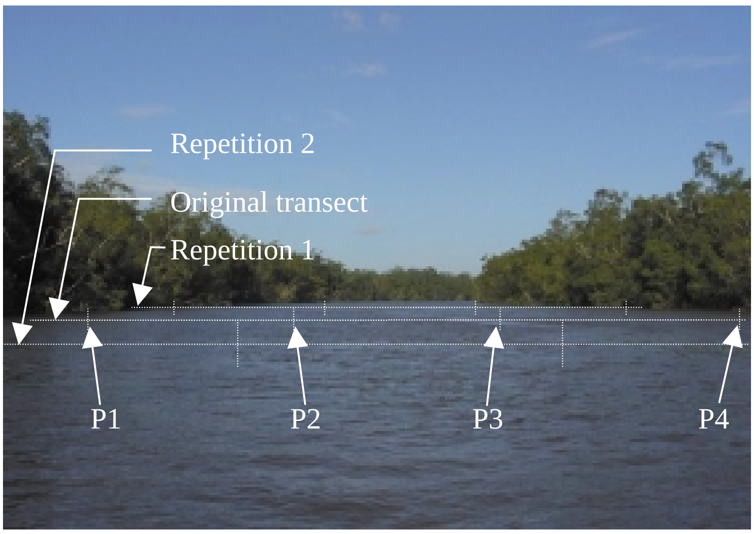


Fig. 15: Station at the Crique Coswine

The aqua-chemical para–meters 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

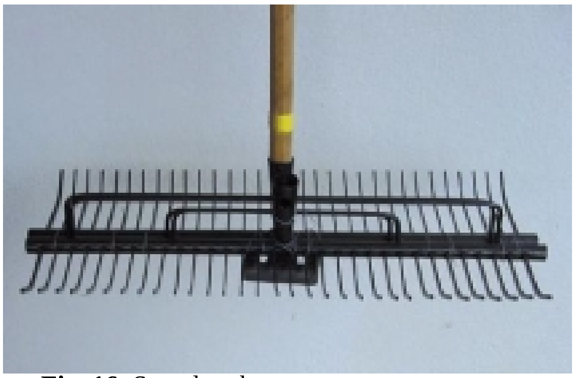


Fig. 16: Sample rake

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).

quantity of plants	description
1	very rare
2	rare
3	diffused
4	frequent
5	lots of

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

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.

Fig. 17: Limit of the high tide

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 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 exsists. 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

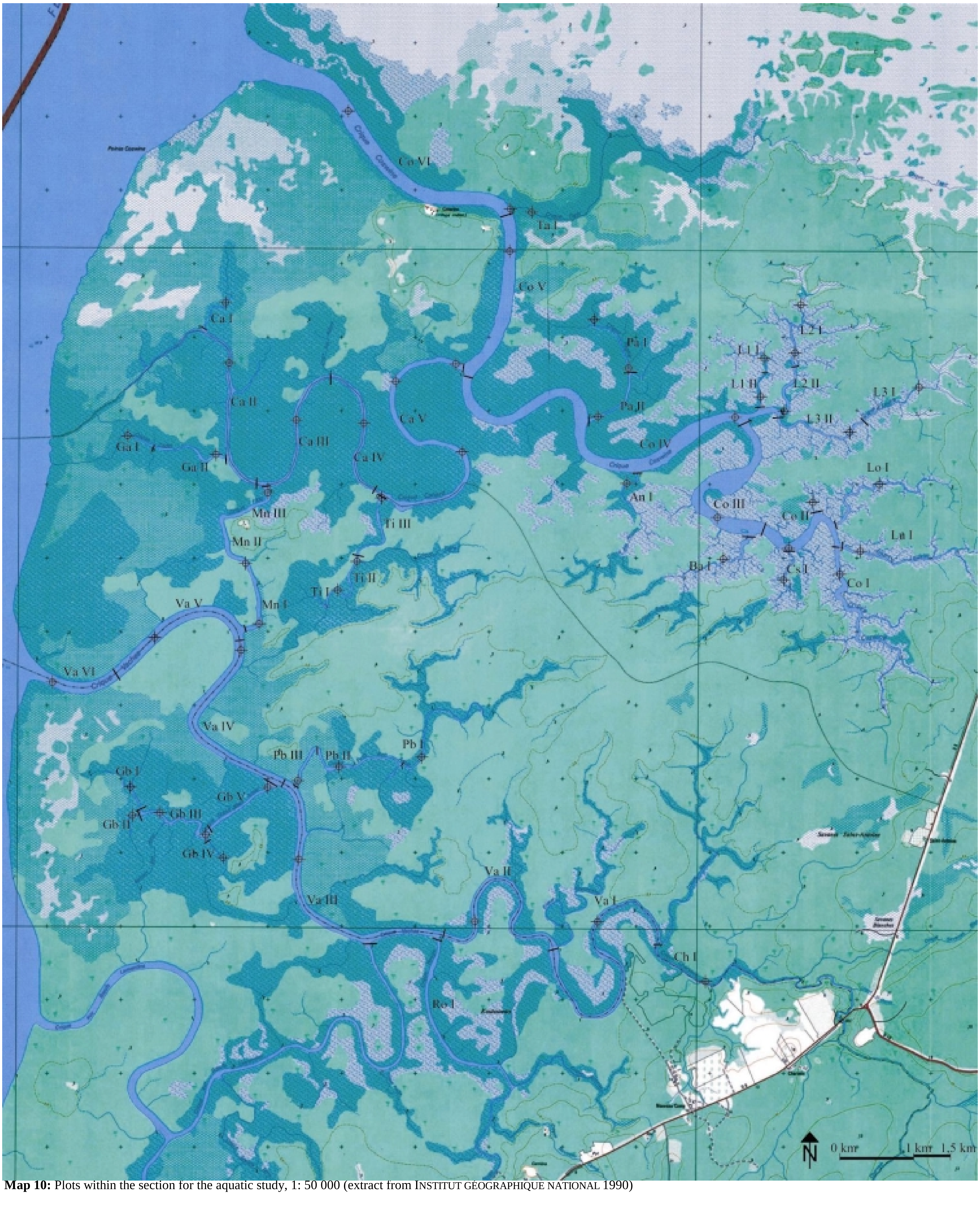
A preliminary study was carried out in order to check whether the chosen parameters and the applied method were sufficient to obtain any results. Another aim of this first study was to get a better knowledge of the present condition on the study site.

4.2.1 Simplified methods for the preliminary study

To prevent that to 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.

	temperature (° C)	oxygen (mg/l)	salinity (‰)	pH	water depth (m)
Minimum	25,3	2,4	0,0	5,1	0,5
Quartile I	26,5	3,7	0,0	6,2	2,5
Median	27,0	4,2	0,0	6,4	4,8
Quartile III	27,7	4,7	0,2	6,7	9,1
Maximum	29,0	7,2	1,5	6,9	>15,0
Modus	26,6	3,8	0,0	6,7	3,5

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 determinate 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 exsists: 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 16 h 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

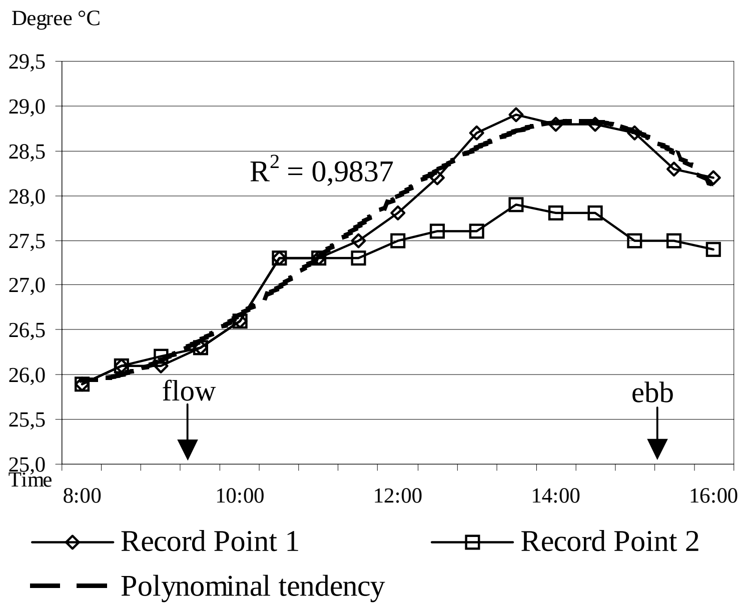


Fig. 18: Water temperature measured by APAVE (05. Nov 1999)

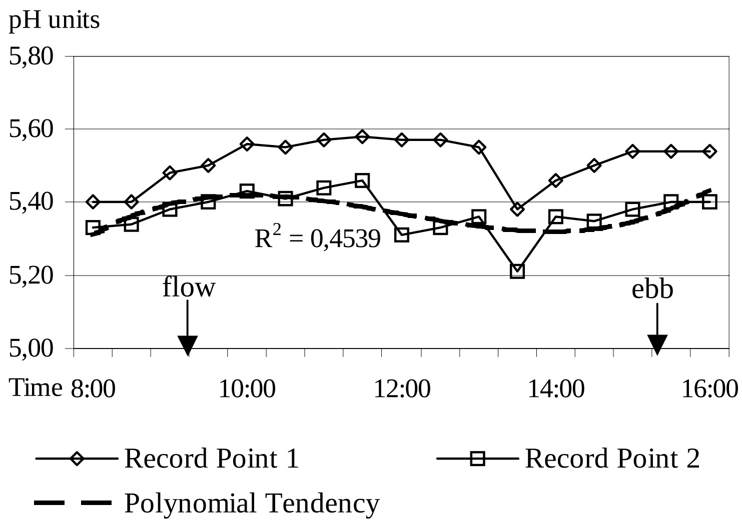


Fig. 19: pH measured by APAVE (05. Nov 1999)

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 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 as 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 (GOLTERMAN *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 theses 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

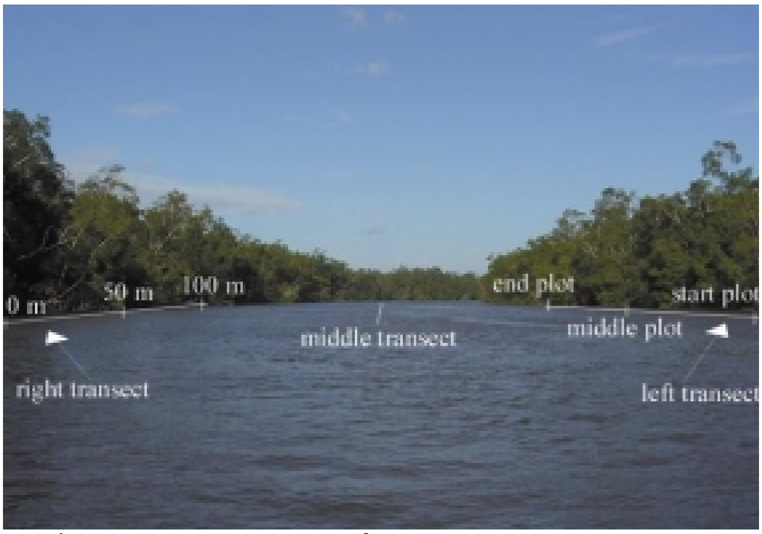


Fig. 20: Station at Crique Vache

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).

Braun-Blanquet scale		**abundance classes**
r	<< 1 %	0,1
+	< 1 %	0,5
1, 2	1-10 %	5
2, 3	11 - 50 %	25
4 and 5	> 50 %	75

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

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 *rP*** describes the percentage in which a species was represented in the samples, divided by the total of all taken samples:

$$rP = \frac{n_s}{n_t} \times 100,$$

if n_s 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 rP = 10 %, if in total 100 samples were taken.

The **relative dominance rD_{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:

$$rD_{xx} = \frac{n_{a_{xx}}}{n_t} \times 100, \text{ with } \sum_{i=0}^{75} rD_i = 1 \text{ for each species,}$$

if $n_{a_{xx}}$ 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.

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

if $n_{a_{xx}}$ 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 ($n_{a_{75}}$ = 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:

$$aD = \frac{\sum_{i=0,1}^{75} (f_i n_{a_i})}{\sum_{i=0,1} f_i},$$

with the maximum at $\dfrac{n_{t\max} \times 75}{0{,}1+0{,}5+5+25+75} = \dfrac{n_{t\max} \times 75}{105{,}6}$

and the minimum at $\dfrac{n_{t\min} \times 0{,}1}{0{,}1+0{,}5+5+25+75} = \dfrac{1 \times 0{,}1}{105{,}6} = 9{,}4\overline{69}e^{-4}$.

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.

relative Presence (rP)		relative Dominance (rD)	
constant	> 50 %	high	< 50 %
frequent	25 % - 50 %	middle	15 % - 50 %
rare	2,5 % - 25 %	small	5 % - 15 %
sporadic	> 2,5 %	no	> 5 %

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 homotonity 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 ($\lim sp \rightarrow SP \Rightarrow rSp \rightarrow 1$) and at the same time not many samples ($\lim sa \rightarrow 0 \Rightarrow rSa \rightarrow 0$) 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 $\overline{H}$ 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; LOZÀN and KAUSCH 1998; PFADENHAUER 1997). The following formula is used for its calculation:

$$\overline{H} = - \sum p_i \times \ln p_i ; \qquad p_i = \frac{n_i}{N} ,$$

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; LOZÀN and KAUSCH 1998; PFADENHAUER 1997). The formula for its application is:

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

if H_{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 co-ordinates were recorded (cf. Tab. 6, Map 11). The first sighting was during the first field trip on June, 16th , the second during the study of the aquatic vegetation on June, 22nd. The third and fourth occurred during the study of the bank vegetation.

Date	Time	North	West	Observation
22.06.01	17:10	5° 38,789'	53° 54,902'	1 manatee, only snooth has been seen
11.07.01	18:30	5° 40,405'	53° 57,044'	3 mantees swimming upwards to the Maroni. Entire body seen

Tab. 6: Manatees sightings during the study

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

Date	Time	North	West	Remarks
03.08.01	07:30	5° 39,186'	53° 56,279'	leaves of *Rhizophora racemosa*
08.09.01	16:30	5° 34,688'	53° 55,621'	stalks of *Montichardia arborescens* and *Scleria pterota*

Tab. 7: Observations of manatee feeding

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

cropped leaves

Fig. 21: *Rhizophora racemosa* shrub, circle shows the cropped leaves

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 GÉOGRAPHIQUE 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.

	station median per bank			area median per bank		
	right transect	middle transect	left transect	right transect	middle transect	left transect
Minimum	1,2 m	3,0 m	1,0 m	1,0 m	2,5 m	1,0 m
Quartile I	2,0 m	5,0 m	2,1 m	2,0 m	5,0 m	2,0 m
Median	2,4 m	7,0 m	2,6 m	2,4 m	6,6 m	2,5 m
Quartile III	3,0 m	10,7 m	3,0 m	3,2 m	9,9 m	3,4 m
Maximum	5,7 m	> 20,0 m	5,6 m	8,3 m	> 20,0 m	8,0 m

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.

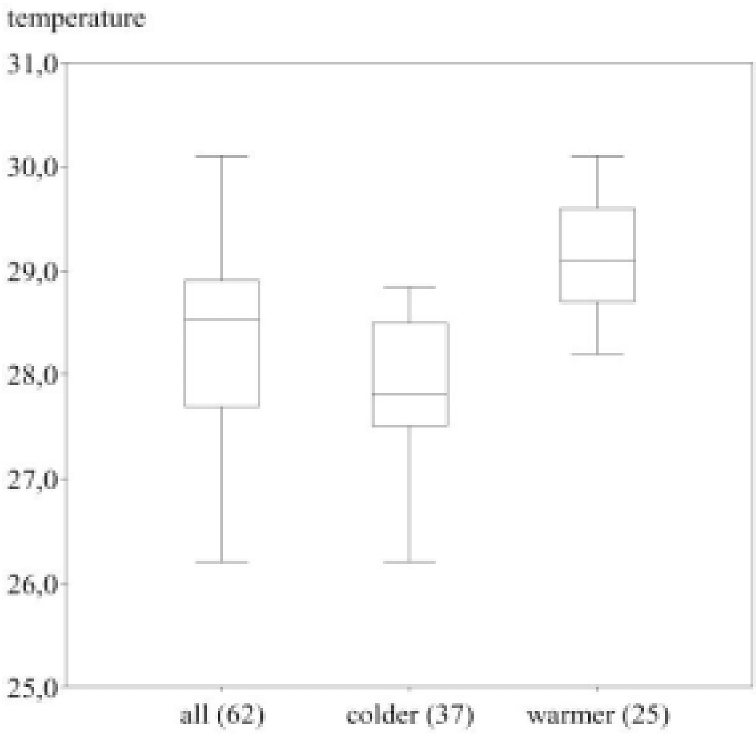


Fig. 25: Temperature range of the station median of all samples and two groups of samples (in brackets the number of samples)

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.

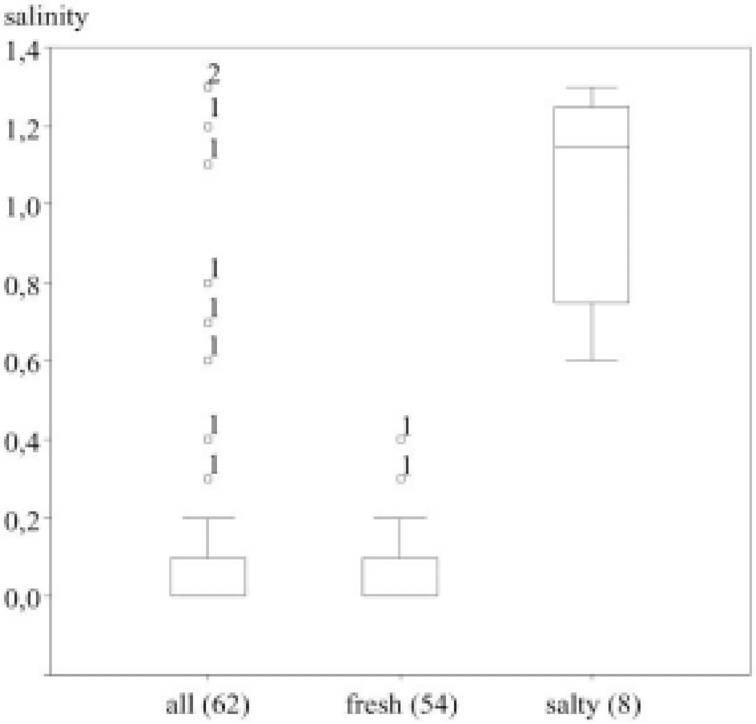


Fig. 26: salt content of all station medians and of two regions with number of outliners (in brackets the number of samples)

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.

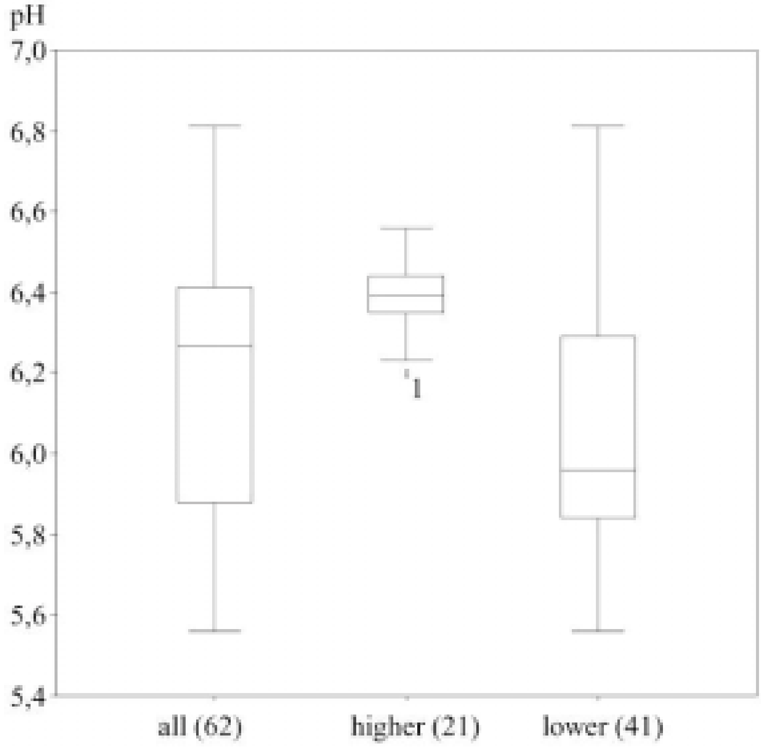


Fig. 27: pH of all station medians and of two regions with number of outliners (in brackets the number of samples)

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.

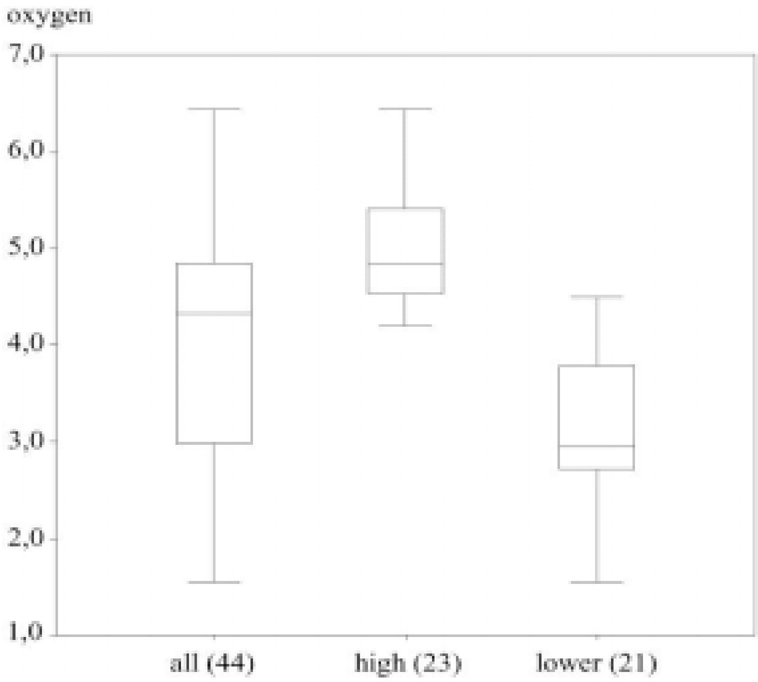
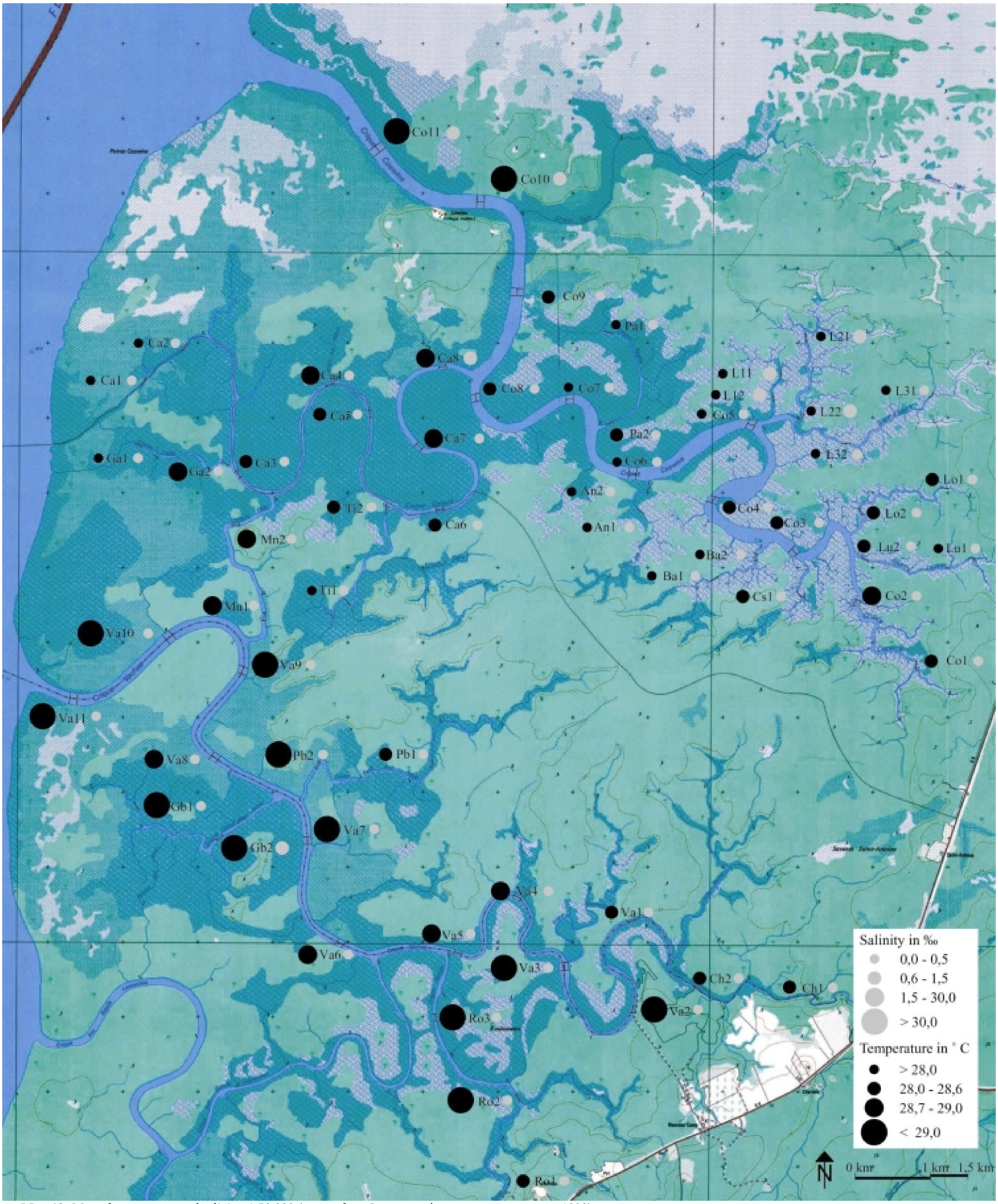


Fig. 28: Oxygen content of the station median for all complete samples and the regions (in brackets the number of samples)

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 ($p<0,001$).

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)