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Human impacts on coral ecosystems at Mauritius island: Coprostanol in surface sediments

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Key words: Coprostanol, fecal pollution, coastal ecosystems, marine sediments, coral diseases, waste-water, coral reefs, Mauritius

ABSTRACT

Coprostanol, a reliable marker of fecal pollution, has been determined from 57 marine sediment samples in the west, the south-west and the east of Mauritius.
84% of sediments contain more than 0.2 mg per kg of coprostanol, indicating significant fecal pollution. Contamination was detected at all the sites studied, except in 'Tamarin' bay (south-west coast) which is strongly affected by wave action.
'Port-Louis' estuary (capital, west coast), 'Grande Rivière du Sud-Est' estuary, the zone near the hotel Touessrok and the exit of 'Trou d'eau Douce' channel (east coast) are the sites most contaminated by sewage pollution, with coprostanol contents higher than 1.5 mg per kg.
Sewage impact decreases with distance from the coast and depth. Lower coprostanol concentrations are generally measured in the open sea, but at 190 m depth (south-west coast) the coprostanol concentration is always relatively high (0.9 mg per kg).

RESUME

Le coprostanol est un remarquable marqueur de pollution fécale. Nous l'avons dosé sur 57 échantillons de sédiment marins prélevés en surface dans l'ouest, le sud-ouest et l'est de l'île Maurice.
84% des échantillons ont des teneurs en coprostanol supérieures à 0.2 mg par kg. Quasiment tous les sites étudiés sont contaminés, excepté la baie de Tamarin (côte sud-ouest) qui est brassée par de longues vagues.
L'estuaire de Port-Louis (capitale de l'île, côte ouest), celui de la Grande Rivière du sud-est, la région de l'hôtel Touessrok et la sortie du chenal de Trou d'eau Douce (côte est) sont les sites les plus contaminés par les eaux usées, avec des teneurs en coprostanol supérieures à 1.5 mg par kg.
L'impact des eaux usées diminue avec la profondeur et l'éloignement de la côte, mais il persiste toujours 0.9 mg par kg par 190 mètres de profondeur (côte sud-ouest).

Introduction

Mauritius is situated in the austral part of the Indian ocean, forming part of the Mascareignes archipelago 800 km to the east of Madagascar. The area of Mauritius is 1840 km^2 and a coral reef is developed all around the island except in the south (Harmelin-Vivien 1981).

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At the moment, the island has a population of about one million. Industry, agriculture and tourism have been developed during the last 50 years and sewerage systems are inadequate. The waste from factories, farming and urban zones is untreated and goes directly to the sea, the rivers and the lagoons.

A multidisciplinary study of the coastal ecosystems of Mauritius between 1989 and 1991 suggests that several factors cause the current imbalance in reef communities (Müller & Vasseur 1989, Müller et al. 1989, 1990a, b, c, 1991a, b, c; Gendre 1992). Excess nutrients in marine waters (nitrates and phosphates from agriculture and cattle breeding) and intensive fishing, give rise to algal blooms and proliferation of sea-urchins which compete with corals. Coastal development alters lagoonal currents and increases turbidity which is harmful to corals. Corals are stressed under such conditions and become susceptible to disease (Antonius 1981). Some of their diseases are linked to pathogens which might be carried in waste-water. The presence of coprostanol in sediments proves the pollution has an anthropogenic origin. Here, we only show the impact of fecal pollution on coastal sediments around Mauritius.

Coprostanol (5β-cholestan-3β-ol), one of the principal sterols found in both esterified and non-esterified form in the feces of man and other mammals (Brown et al. 1982), is produced by the bacterial reduction of cholesterol in the intestines. Coprostanol has been shown to be a reliable marker of fecal pollution (Murtaugh & Bunch 1967).

Sampling and methods

In this study, coprostanol concentration was determined in surface sediment from 57 sites in the west, the south-west and the east of Mauritius (Fig. 1).

The samples were taken with a grab and were air-dried in a sheltered space.

Coprostanol was extracted from the sediment at the LASUR laboratory of the geological Institute of the University of Neuchâtel. The extraction method is the one recommended by Pierce (1984). It can be summarized as:

- extraction, using methanol-toluene, of about 50 g of dry sediment.
- addition of an internal standard (pregnenolone, which is absent in sediment).
- saponification with equal volumes of water and 0.5 N potassium hydroxide in methanol.
- neutralization with 0.1 M hydrochloric acid.
- extraction using 3 times 50 ml of methylene chloride.
- separation by column chromatography in a glass column containing silica gel over neutral alumina; elution with hexane, methylene chloride and methanol; preservation of the methanol eluate containing stanols and sterols.
- the methanol eluate was evaporated under a stream of nitrogen.
- derivatives of the sterols and stanols were formed using one volume of trimethylchlorosilane, two volumes of hexamethyldisilazane and one volume of pyridine.
- after ten minutes, about one microliter of the solution was injected into a gas chromatograph (Perkin-Elmer 8500).
- the determination of coprostanol is made from the area of peaks on a graph and their comparison to a standard curve.

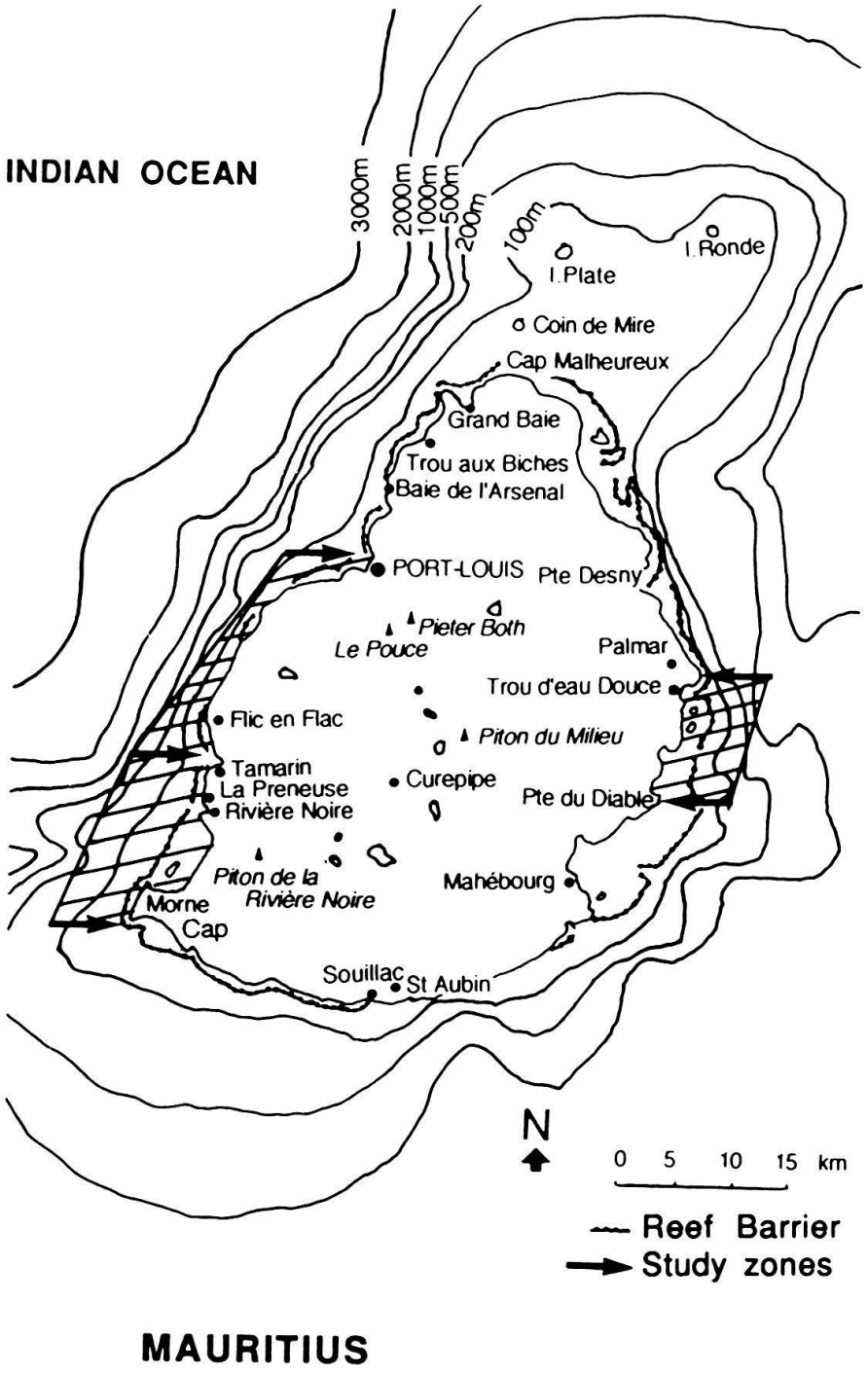

Fig. 1. Sample locations.

Results and discussion

According to Pierce (1984), a coprostanol concentration of 0.01 mg per kg of dry sediment is sufficient to indicate contamination by sewage. In this study (Tab. 1, 2, 3), most results (84%) lie above our detection limit (0.2 mg per kg). All studied sites are contaminated by sewage.

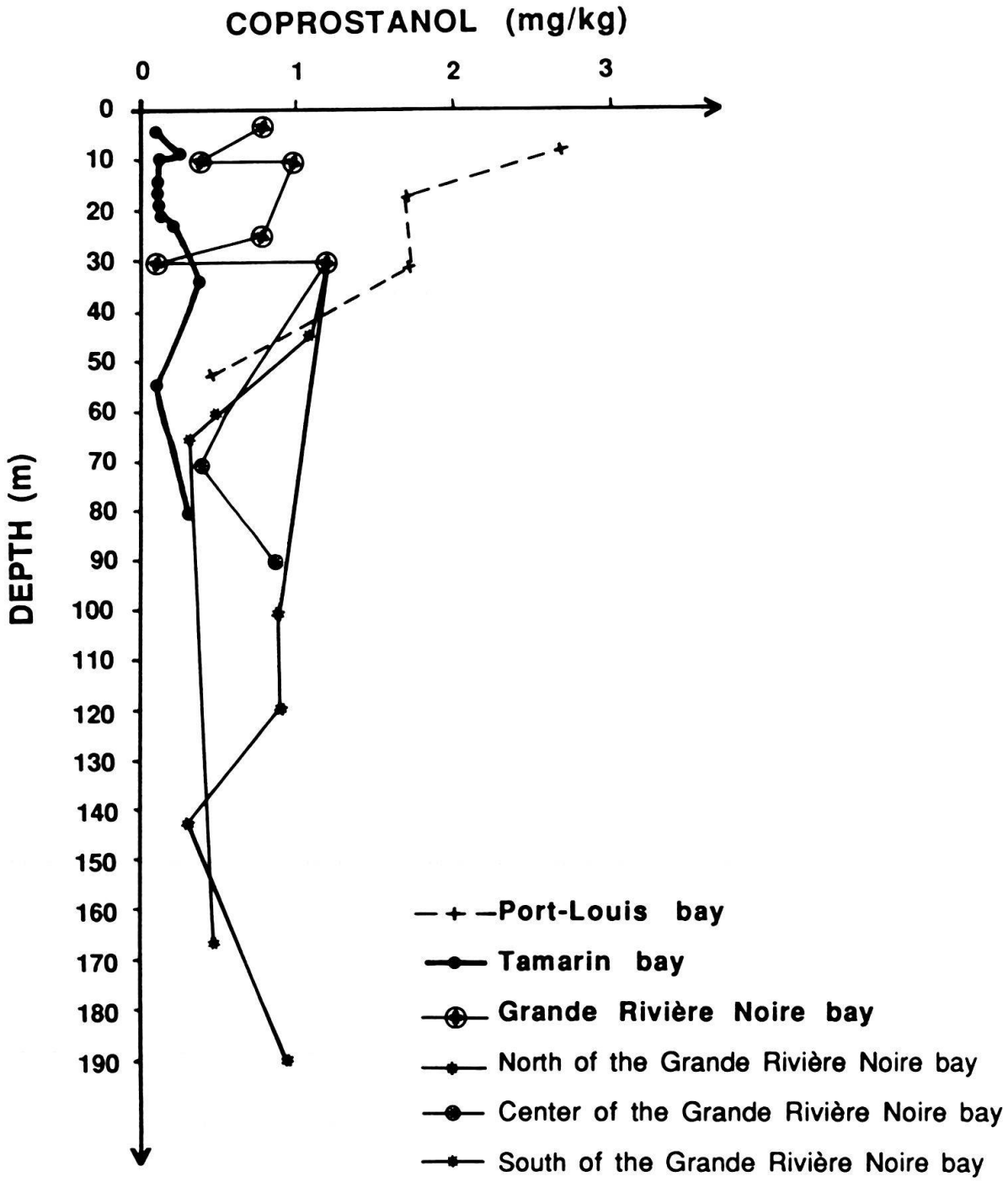

Fig. 2. Coprostanol abundances in surface sediments as a fonction of water depth.

Surface sediments from three bays on the west coast were compared (Fig. 2) to look for variations in coprostanol content with depth. Concentrations decrease with distance from the coast and with water depth. The lowest concentrations are usually found in open ocean sediments, although the coprostanol content is always 0.9 mg per kg at 190 m depth in front of 'La Preneuse' lagoon (west coast).

NAME	DEPTH (m)	COA %	CORT %	COTC %	COPRO mg/kg	% C-copro / COTC
M1	- 1	0.67	2.85	3.53	6.00	0.014
S1	- 1	0.18	0.17	0.35	0.58	0.014
S2	- 1	0.29	0.37	0.66	0.37	0.005
S5	- 1	0.30	0.58	0.88	<0.20	0.001
PN1	- 1	0.12	0.42	0.54	1.20	0.019
BN1	- 1	0.11	0.00	0.11	2.00	0.152
BN2	- 1	0.20	0.00	0.20	1.10	0.046
BN3	- 1	0.18	0.00	0.18	1.20	0.056
R1	-25	0.11	0.09	0.20	0.80	0.034
R3	-10	0.17	0.34	0.51	0.37	0.006
R4	- 6	0.00	0.22	0.22	0.25	0.010
R5	- 3	0.34	1.95	2.29	0.80	0.003
R6	- 1	0.09	0.11	0.20	0.82	0.034
C10	-60	0.14	0.27	0.41	0.53	0.011
C11	-70	0.13	0.25	0.38	0.38	0.008
C13	-90	0.11	0.27	0.38	0.89	0.020
M20	-166	0.12	0.29	0.41	0.47	0.010
M21	-65	0.14	0.34	0.48	0.32	0.006
M23	-45	0.10	0.04	0.14	1.10	0.065
S3	-30	0.12	0.00	0.12	<0.20	0.007
GN3	-10	0.20	1.37	1.57	1.00	0.005
GN5	-30	0.16	0.39	0.55	1.20	0.018
L2	-120	0.11	0.23	0.34	0.89	0.022
L2'	-100	0.12	0.24	0.36	0.90	0.021
L3	-142	0.14	0.44	0.58	0.31	0.004
L4	-190	0.10	0.33	0.43	0.94	0.018
T7	- 4	0.07	0.01	0.08	<0.20	0.011
T8	- 9	0.10	0.03	0.13	0.25	0.016
T9	-10	0.13	0.05	0.18	<0.20	0.005
T10	-15	0.13	0.07	0.20	<0.20	0.004
T11	-16	0.12	0.10	0.22	<0.20	0.004
T14	-19	0.12	0.09	0.21	<0.20	0.004
T15	-23	0.13	0.06	0.19	0.20	0.009
T16	-21	0.13	0.04	0.17	<0.20	0.005
T17	-33	0.15	0.05	0.20	0.38	0.016
T19	-55	0.15	0.08	0.23	<0.20	0.004
T21	-80	0.11	0.11	0.22	0.32	0.012

Tab. 1. The parameters of organic matter measured between the 'Morne Brabant' and 'Flic-en-Flac' in the west coast (Fig. 3): Percentage of Soluble Organic Carbon (COA), percentage of Organic Carbon of the total Rock = Insoluble Organic Carbon (CORT), total Organic Carbon (TOC), Coprostanol content in mg per kg (COPRO), percentage of Carbon of coprostanol in comparison with the total organic carbon (%C-copro/COTC).

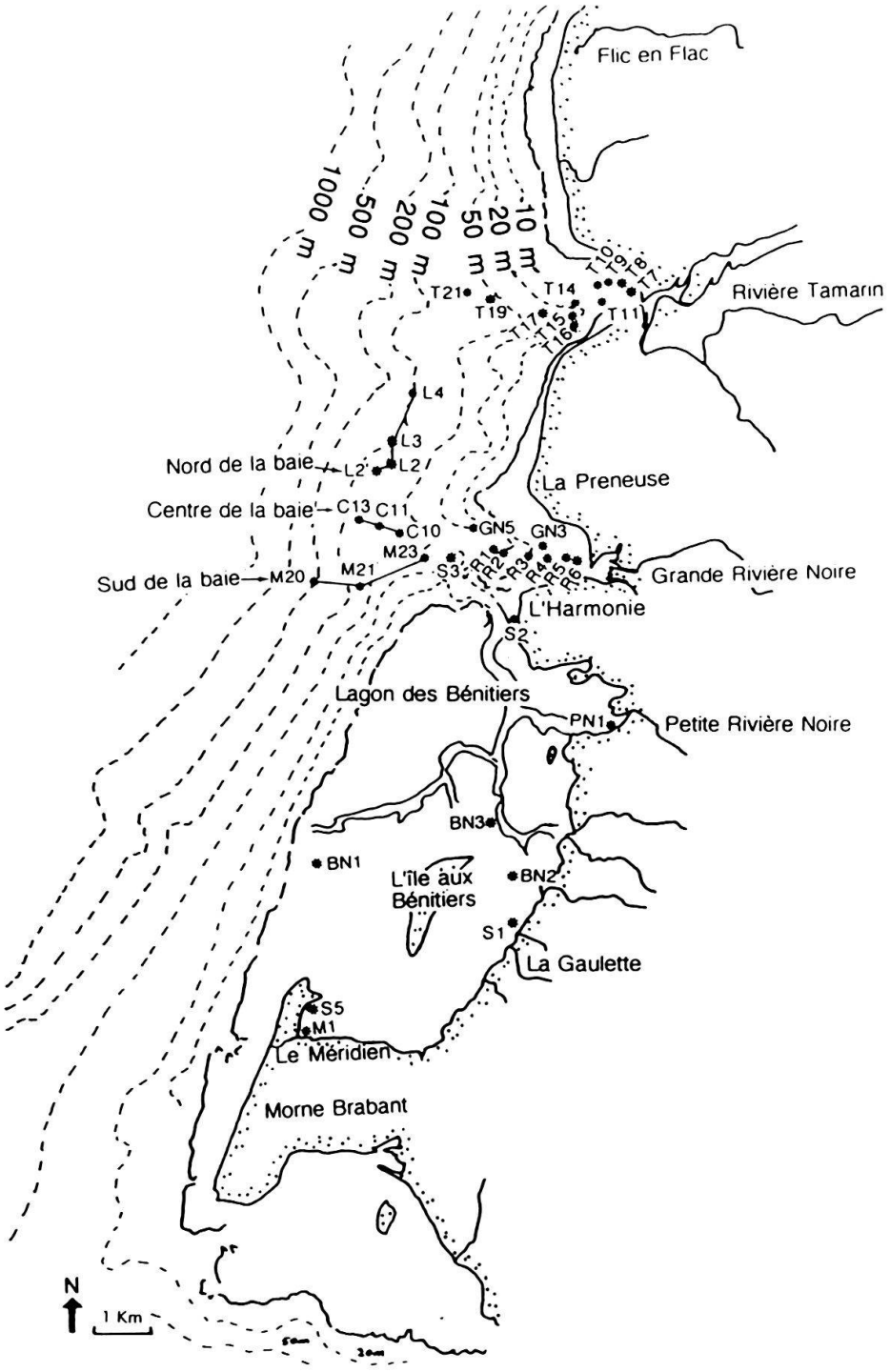

Fig. 3. Sample locations between the 'Morne Brabant' and 'Flic-en-Flac' (west coast).

'Tamarin' bay (Fig. 3, Tab. 1) which is continually mixed by wave action, shows both the lowest coprostanol concentrations (maximum is 0.38 mg per kg) and low TOC (Total Organic Carbon) contents (0.08 to 0.23%) because organic matter is quickly oxidized.

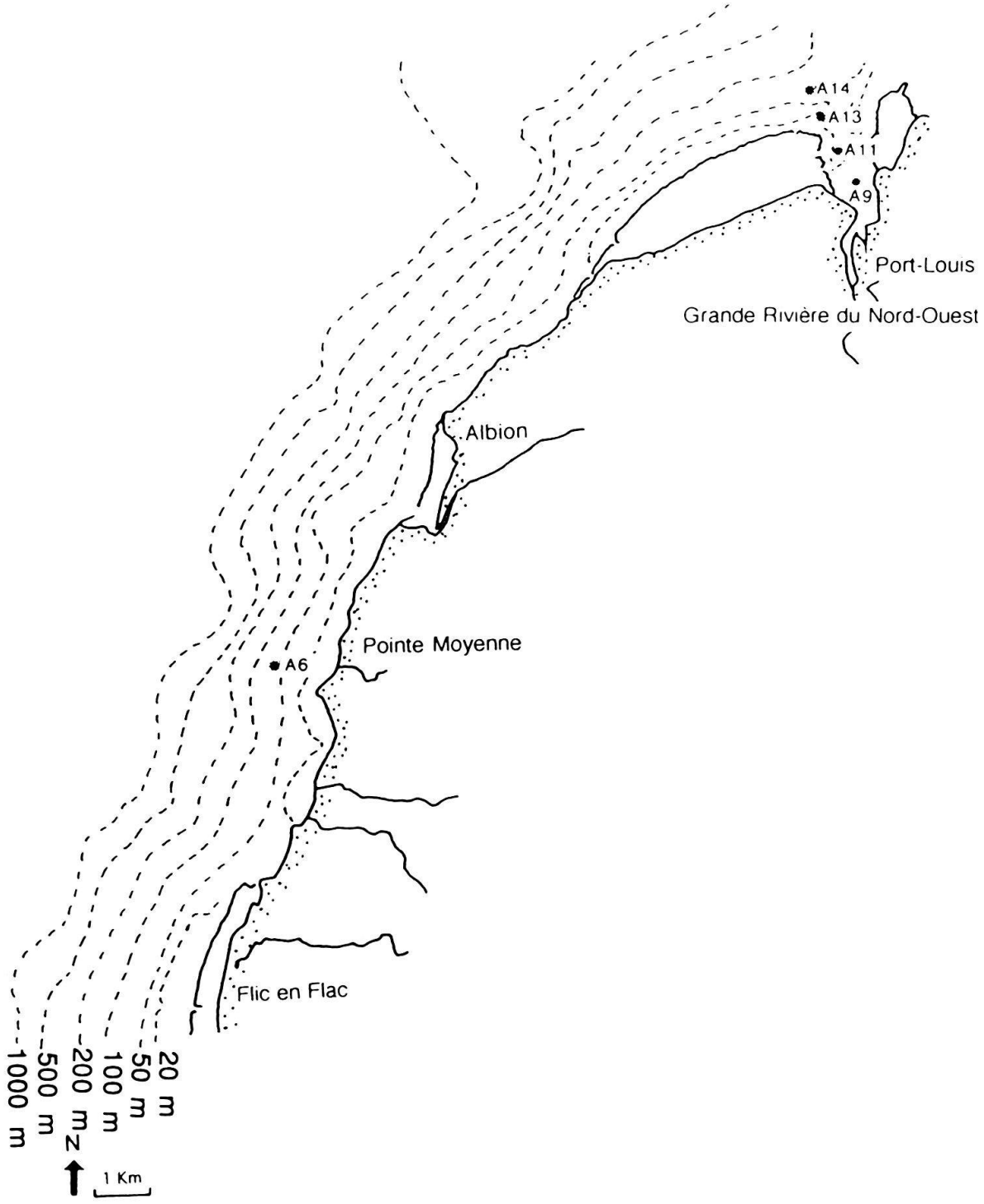

Fig. 4. Sample locations between 'Flic-en-Flac' and Port-Louis (west coast).

Concentration measured near the sewer of 'Pointe Moyenne' (Fig. 4, Tab. 2) is only of 0.6 mg per kg, but the carbon of coprostanol represents 0.031% of TOC. At this site coprostanol content is high relative to the quantity of organic matter and the comparison with total organic carbon gives a better indication of the sewage pollution.

Coprostanol concentrations higher than 1.5 mg per kg are characteristic of the most contaminated zones in Mauritius (estuaries and some lagoonal zones).

The north of 'Black River' bay (Fig. 3, Tab. 1) shows higher coprostanol concentrations than the south. At 30 m depth, the coprostanol content is 1.2 mg per kg in the north and less than 0.2 mg per kg in the south. TOC is higher in the north of the bay (0.34%) than in the south (0.12%). This can be explained by the local currents and river supply. Silicate, detrital material, organic matter and mud are carried to the north of the bay rather than to the south. Resuspended sediments from the 'Bénitiers' lagoon (calcite, aragonite and magnesium calcite) are accumulated in the southern part of the bay.

Some zones appear very contaminated like the 'Méridien' hotel zone in the south of 'Bénitiers' lagoon (Fig. 3, Tab. 1). The coprostanol concentration is 6 mg per kg but the carbon of the coprostanol represents only 0.014% of total organic carbon. This site is very rich in organic matter and is a typical example of accumulation of autochthonous organic matter in a lagoon. It is an anoxic site and in this case the coprostanol can be derived from autochthonous cholesterol (plankton, algae and plants) by bacterial reduction in sediment (Pittet 1990). A stag breeding farm is situated on the north slope of the 'Morne Brabant' and an important cattle farm is situated on the south slope where the feces of animals are directly discharged into the lagoon and stay at the water surface and on the beach (Ruch, observation April-July 1990).

Another stag farm is situated near the 'Petite Rivière Noire' estuary where 1.2 mg per kg of coprostanol were measured (Fig. 3, Tab. 1). Here, water flows through pastures and arrives at the east of the 'Bénitiers' lagoon.

The principal source of coprostanol in the 'Bénitiers' lagoon is from animal rearing, so it is difficult to evaluate the impacts of the hotel 'Méridien' and the local population.

'Port-Louis' (Fig. 4, Tab. 2) is the most urbanized site of the island and purification systems are still insufficient. Waste-water is often discharged into rivers, which explains 3 mg per kg of coprostanol near the mouth. For comparison, 1.6 mg per kg were measured in surface sediment from lake Neuchâtel (Pittet 1990) and 5,800 mg per kg were measured in New York Bay (Hatcher & McGillivary 1979).

NAME	DEPTH (m)	COA %	CORT %	COTC %	COPRO mg/kg	% C-copro / COTC
A6	-50	0.09	0.08	0.17	0.63	0.031
A9	-8	0.20	1.60	1.80	2.70	0.012
A11	-17	0.57	2.48	3.05	1.70	0.005
A13	-31	0.11	0.63	0.74	0.44	0.005
A14	-53	0.17	0.95	1.12	1.75	0.013

Tab. 2. The parameters of organic matter measured between 'Flic-en-Flac' and 'Port-Louis' in the west coast (Fig. 4): Percentage of Soluble Organic Carbon (COA), percentage of Organic Carbon of the total Rock = Insoluble Organic Carbon (CORT), total Organic Carbon (TOC), Coprostanol content in mg per kg (COPRO), percentage of Carbon of coprostanol in comparison with the total organic carbon (%C-copro/COTC).

NAME	DEPTH (m)	COA %	CORT %	COTC %	COPRO mg/kg	% C-copro / COTC
ED1	- 5	0.21	0.19	0.40	0.52	0.011
ED2	- 10	0.25	0.23	0.48	0.70	0.012
ED3	- 10	0.27	0.23	0.50	0.76	0.013
ED4	- 12	0.16	0.12	0.28	0.80	0.024
ED5	- 12	0.35	0.55	0.90	0.60	0.006
ED6	- 5	0.16	0.00	0.16	0.58	0.030
ED7	- 9	0.10	0.00	0.10	2.34	0.195
ED8	- 12	0.18	0.19	0.37	0.48	0.011
ED9	- 2	0.13	0.00	0.13	0.46	0.029
IC1	- 1	0.18	0.00	0.18	2.40	0.111
IC2	- 5	0.18	0.07	0.25	0.40	0.013
IC3	- 3	0.13	0.00	0.13	0.50	0.032
GS3	- 25	0.20	0.20	0.40	1.70	0.036
GS8	- 11	0.17	0.19	0.36	2.10	0.048
GS12	- 2	0.43	0.92	1.35	3.00	0.019

Tab. 3. The parameters of organic matter measured between the 'pointe du Diable' et 'Palmar' in the east coast (Fig. 5): Percentage of Soluble Organic Carbon (COA), percentage of Organic Carbon of the total Rock = Insoluble Organic Carbon (CORT), total Organic Carbon (TOC), Coprostanol content in mg per kg (COPRO), percentage of Carbon of coprostanol in comparison with the total organic carbon (%C-copro/COTC).

The 'Grande Rivière du Sud-Est' (Fig. 5, Tab. 3) drains a wooded region with light urbanization and cattle farming. Terrestrial supplies represent 57% and sediments are rich in organic matter (TOC = 1.35%). Coprostanol content is 3 mg per kg near the mouth and farther seawards at between four and six kilometers distance from the estuary, coprostanol contents are still 2.1 to 1.7 mg per kg.

In eastern lagoons (Fig. 5, Tab. 3), 2.4 mg per kg were measured in sediment in front of the Touessrok hotel which is characteristic of the impact of a hotel. The coprostanol concentration of 2.3 mg per kg measured in the mouth of 'Trou d'eau Douce' channel can be explained by the effects of local currents. The mouth of this channel is the confluence site for the waters from the Touessrok hotel and waters from 'Trou d'eau Douce' bay which is surrounded by houses.

Conclusion

We point out that all the sites studied in Mauritius', except Tamarin bay, are contaminated by sewage.

At the west coast, at 190 m depth, the coprostanol content is still 0.9 mg per kg.

Coprostanol concentrations higher than 1.5 mg per kg of dry sediment are measured in surface sediments from 'Port-Louis' estuary (west coast), 'Grande Rivière du Sud-Est'

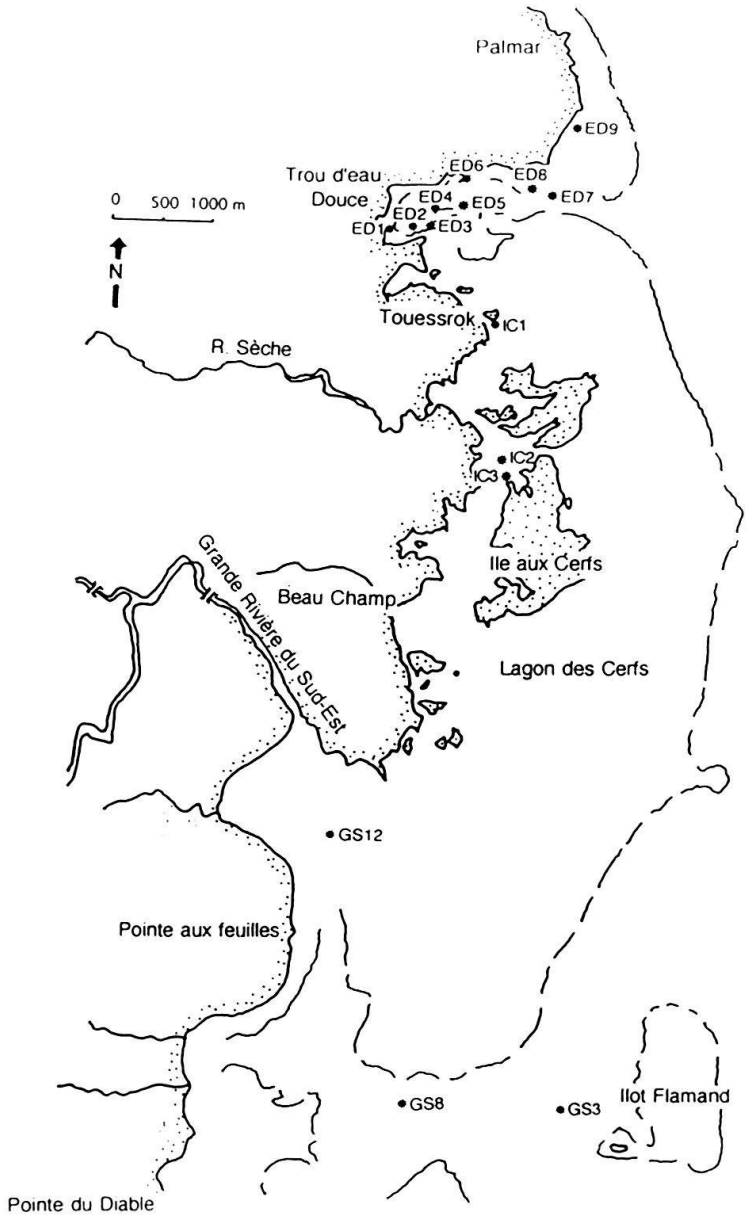

Fig. 5. Sample locations between 'la pointe du Diable' and 'Palmar' (east coast).

estuary, near the Touessrok hotel and in 'Trou d'eau Douce' channel (east coast). These are the zones most contaminated by sewage pollution.

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