

## On the ecology of a small West-African lagoon

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### Abstract

A small coastal lagoon near Tema, Ghana, has been studied from August to December 1971. Data on temperature, salinity and exchange of water with the sea are given for January to December 1971. The extreme hydrographic conditions in the lagoon cause a reduction of the fauna, as compared with a typical "open" lagoon or with the marine shore.

The structure of the food web in the lagoon is given. The main part of the animal biomass consists of the gastropod *Tympanotonus fuscatus* var. *radula* and the cichlid fish *Tilapia melanotheron* which feed on bottom deposit and associated microorganisms and are well-adapted to the rapid changes of salinity that characterize the lagoon. After the rain period (May-July) there is a steady increase of marine species, represented mostly by juvenile stages.

### Kurzfassung

**Zur Ökologie einer kleinen westafrikanischen Lagune.** Eine kleine Lagune in der Nähe von Tema, Ghana, wurde von August bis Dezember 1971 untersucht. Daten für Temperatur, Salzgehalt und den Wasseraustausch mit dem Meere sind für das ganze Jahr 1971 angegeben. Infolge der extremen hydrographischen Bedingungen in der Lagune ist die Fauna ärmer als in einer typischen „offenen“ Lagune oder vor der Küste.

Die Struktur des Nahrungsnetzes ist angegeben. Der Hauptteil der tierischen Biomasse besteht aus der Schnecke *Tympanotonus fuscatus* var. *radula* und dem Cichliden *Tilapia melanotheron*, die sich beide von Bodensediment und den assoziierten Mikroorganismen ernähren und gut an die raschen Salzgehaltsänderungen angepaßt sind, die die Lagune charakterisieren. Nach der Regenzeit (Mai-Juli) nimmt der Anteil mariner Organismen zu; es sind vor allem Jugendstadien.

### Résumé

**Note sur l'écologie d'une petite lagune d'Afrique Occidentale.** Une petite lagune côtière près de Tema, Ghana, a été le sujet d'une étude d'août à décembre 1971. Les cycles de salinité, de température et d'échange d'eau avec la mer sont donnés pour toute l'année 1971. Les conditions extrêmes dans la lagune sont la cause d'une réduction de la faune, en comparaison avec une lagune «ouverte» typique ou avec la côte marine.

Les éléments des chaînes alimentaires sont indiqués. La plus grande partie de la biomasse animale est représentée par le gastropode *Tympanotonus fuscatus* var. *radula* et par le poisson cichlide *Tilapia melanotheron* qui tous deux se nourrissent de la vase des fonds et des microorganismes associés et sont bien adaptés aux rapides variations de la salinité qui sont caractéristiques pour la lagune étudiée. Après la période des pluies (de mai à juillet) des espèces d'origine marine augmentent dans la lagune; elles sont surtout représentées par des stades juveniles.

### 1. Introduction

Lagoons are dominant features along large stretches of the West-African coast. They are of utmost importance as natural harbours, nursery grounds for marine fishes and shrimps, and often sustain significant fisheries.

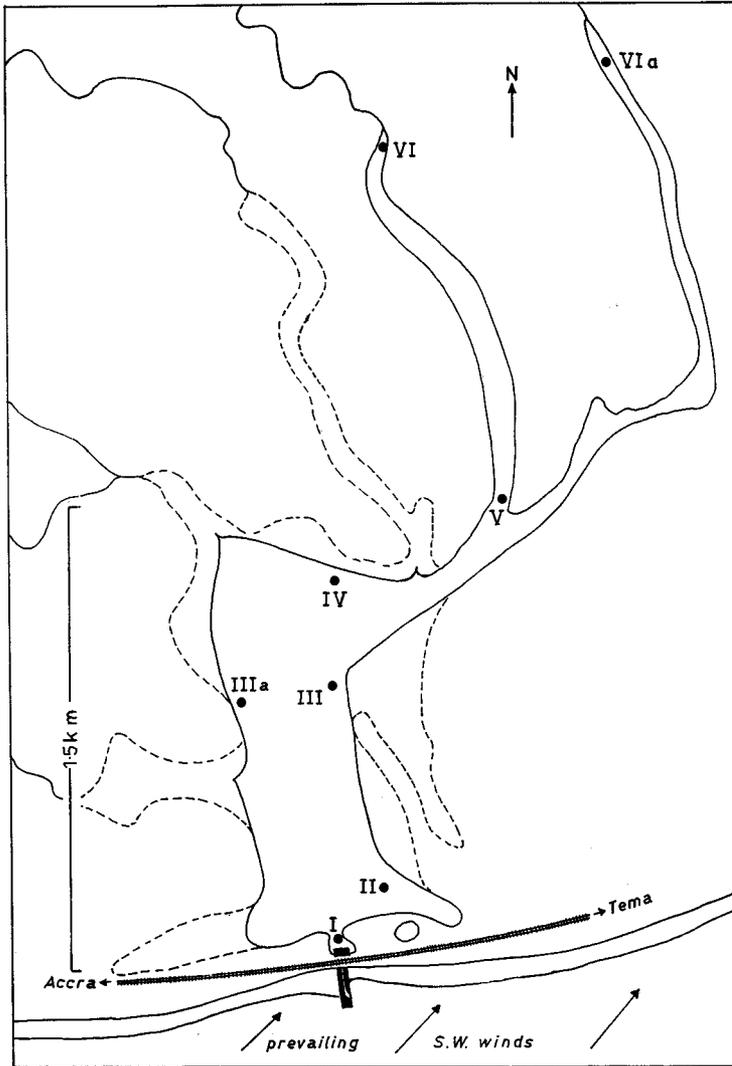


Fig. 1. Sakumo-Lagoon, previous extent and location of the stations. (After: African West Coast, Map Barako Pointo to Great Ningo 3432, 1838-1955)

The formation of lagoons by sand movement along the coast line have been dealt with by WEBB (1958) and DAVIES (1960) and will not be considered here.

Most investigations of West-African lagoon ecology took place in "open" (BOUGHEY 1957) lagoons. The following data on the ecology of Sakumo Lagoon, a "semi-closed" lagoon very similar to a "closed" lagoon have been collected in connection with an investigation of its suitability for aquaculture (PAULY 1973 b).

The investigated Sakumo Lagoon (Fig. 1) is situated behind the Ghanaian Coast on the Greenwich Meridian, about 20 km east of Accra (there is another lagoon of the same name 12 km west of Accra).

During the dry season (Sep/Oct. to March/April), the average surface area of the

lagoon is 1 km<sup>2</sup>, with an estimated average depth of 50 cm. It was formerly a typical "closed" lagoon, later pipes were laid under the sand bar to enable the construction of a road along the coast. These pipes permanently connected the lagoon with the sea, and it now represents a transitory stage between a closed and an open lagoon.

The tides along the West-African Coast are semidiurnal. Mean high water (spring tides) is 5.3 ft (162 cm) and mean low water, 1.1 ft (34 cm) above datum for Accra (Ghana tide Table for 1971).

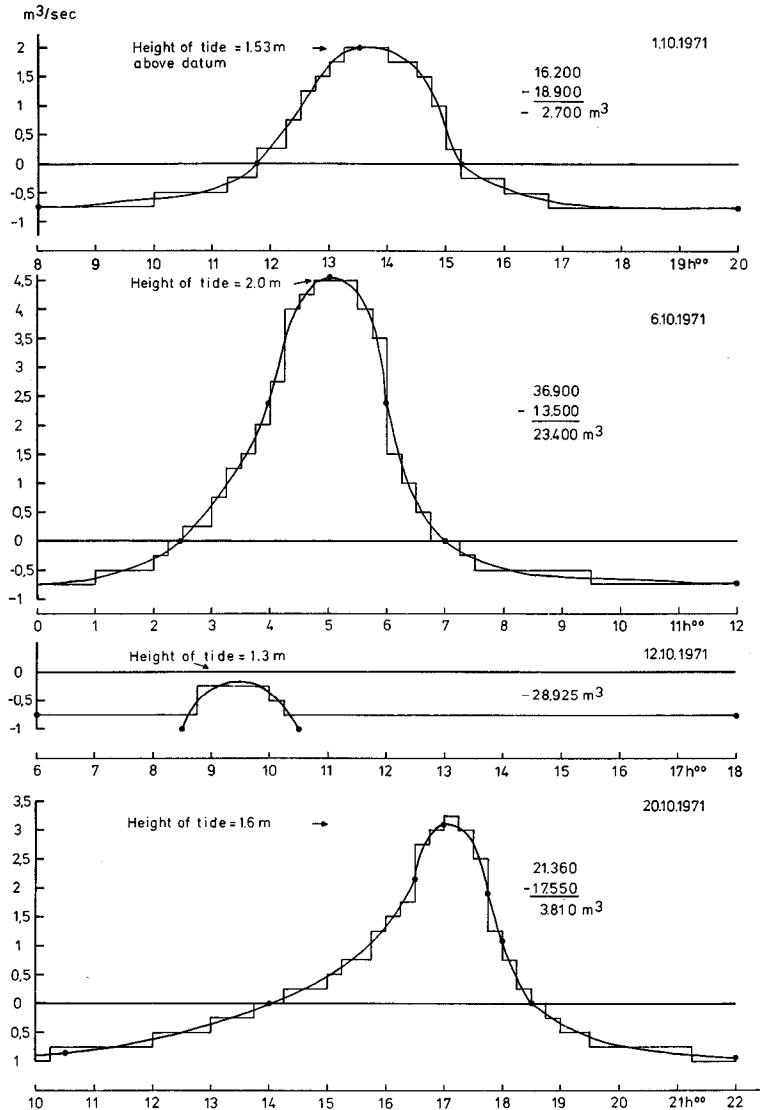


Fig. 2. Inflow and outflow of seawater in m<sup>3</sup> per sec. into and out of Sakumo-Lagoon during 4 different tide periods of approx. 12 h height of tide as indicated by Ghana tide table for 1971

Due to the height of pipe construction and the build up of a sill on the lagoon side of the pipes, only tides of over 1.53 m above datum can reach into the lagoon. At lower tidal levels and after strong rains, water flows out of the lagoon (Fig. 2).

## 2. The abiotic factors

### 2.1. Material and methods

The investigation took place from August to December, 1971. Salinity and temperature data for January to August were obtained from the FAO/UNDP Fishery Research Unit (F.R.U.) in Tema, which is located 2 km from the Sakumo Lagoon and where parts of laboratory work was conducted. The stations in the lagoon were chosen to reflect the salinity gradient from South to North (Fig. 1).

They were to be visited during a 4–5 hours walk, generally every other day.

Salinity was determined with a Hydrometer. The error, as determined by comparison with the conductivity salinometer of the F. R. U., was 1 ‰ from 0 ‰ to 25 ‰ and 2 ‰ from 26 ‰ to 50 ‰. No error was determined for higher salinity measurements. Corrections for temperature were calibrated according to a graph published by DIETRICH and KALLE (1957). Surface temperatures were determined with a thermometer to the nearest tenth of ° C. The data for the air temperature and the rainfall originated from the Tema Weather Station, located about 10 km from the Sakumo Lagoon. The oxygen content of the water was determined at the F.R.U., by the Winkler-Method.

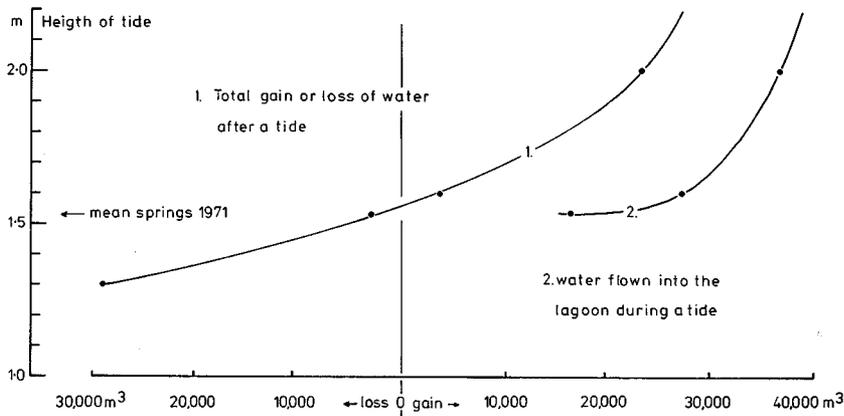


Fig. 3. 1. Gain or loss of sea water of the Sakumo-Lagoon after a tide period of approx. 12 h and 2. absolute quantity of sea-water flown into the lagoon during 12 h tide period. Both in function of tide as given in the tide table

The exchange of water between the lagoon and the sea was measured at station I, by means of a flow-meter held 15 min. in the flowing water and by measuring the width and average depth of the water channel. This procedure was applied repeatedly, at and near the peaks of high tides as indicated by the tide table, and at the time that the flow started out of or into the lagoon. The quantities of water flowing in or out of the lagoon was then calculated by graphical integration of flow rates for tides of various heights (Fig. 2). These quantities of water depended on the height of the tides, as expressed in fig. 3.

The distribution of bottom substrates was established by examination of 28 benthic samples and by direct observation. Only 3 substrate categories have been differentiated: sand; sandy mud (mainly with mollusc shells and shell fragments); mud.

## 2.2. Results

Salinity: Fig. 4 indicates the tremendous changes in the average salinity of the lagoon over one year, and the strong influence of rain on salinity, a feature even more drastically demonstrated in fig. 5, where the salinity at 6 different stations over a period of four months is shown. The emerging pattern is as follows: After the rain season stations with higher numbers (further away from the pipes communicating with the sea) remain fresh longer. However, evaporation is stronger in the shallower water of the North of the lagoon, and the salinity reaches there its highest values ( $> 70 \text{ ‰}$ )

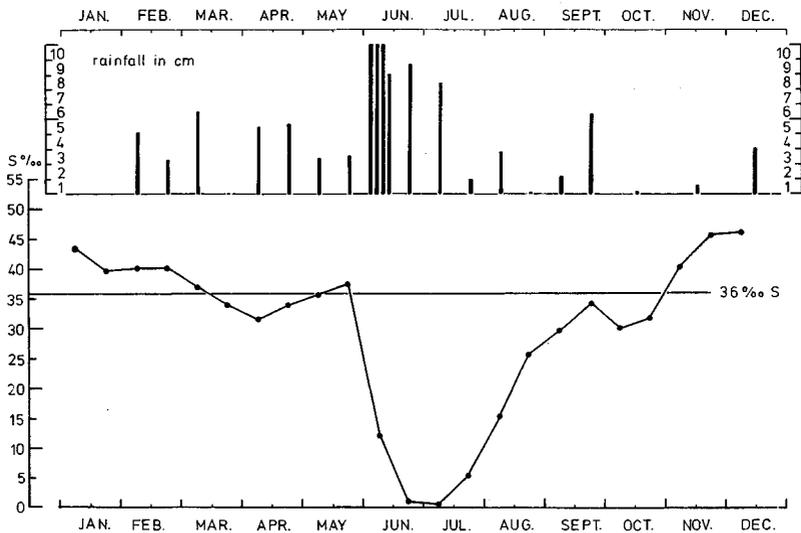


Fig. 4. Average salinity of Sakumo-Lagoon and rainfall in the lagoon area for 1971. (Salinity data Jan. to Aug. F.R.U., Sept. to Dec.: D. Pauly. Rainfall data: Tema Weather Station)

once a first mixing with sea water has taken place. This strong increase of salinity, especially in the North of the lagoon, can be retarded by occasional rains during the light second rainy period in September/October (Fig. 5). During the dry season, however, the North of the lagoon becomes strongly hyperhaline, while the South of lagoon water is partly diluted by inflowing sea-water. Fig. 6 shows evaporation as recorded by a conductivity salinometer measurements during a 20 hour period. The recorded salinity increase corresponds to an increase of about  $10 \text{ ‰}$  per month near station I and of nearly  $40 \text{ ‰}$  per month between stations 3 and 4.

Temperature: The yearly average insolation on the lagoon is  $431.1 \text{ kcal per cm}^2$  per day (USSHER 1969). Fig. 7 shows the influence of the temperature of the air, of the upwellings off the Ghanean Coast (which acts on the lagoon directly by inflow of cooler water and indirectly by lowered air temperature), and by the rain water on the temperature of the lagoon water. The lagoon water temperatures were all corrected to correspond to the condition between 10–12 h, as indicated by the daily temperature

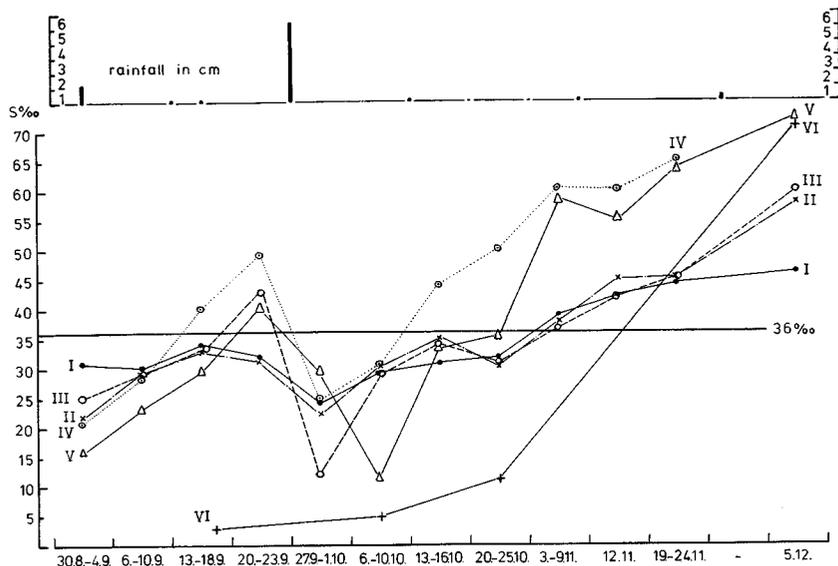


Fig. 5. The influence of rainfalls on the salinity of the lagoon from August to December 1971

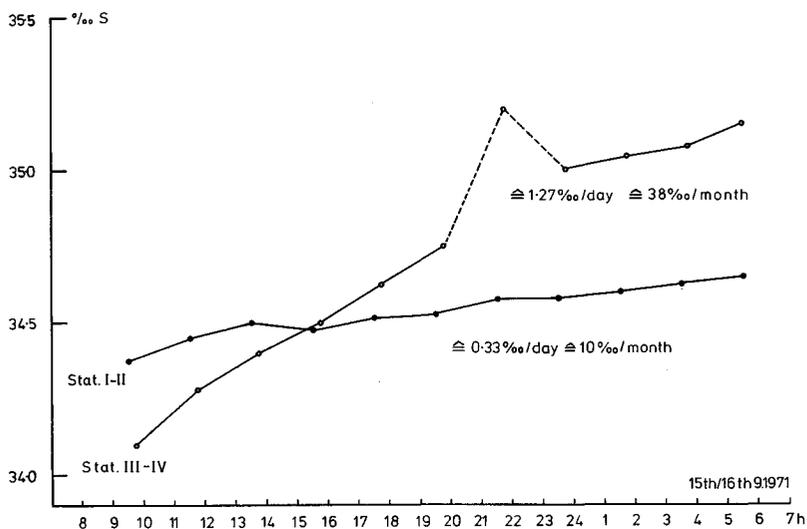


Fig. 6. Evaporation as a cause for salinity increase, as recorded over 20 hours (15th to 16th of Sept. 1971). (Conductivity measurement data: F.R.U.)

cycle in Fig. 7. The lowest temperature recorded during the period of investigation was  $18.0^{\circ}\text{C}$  at station I in an inflowing tide during the upwelling period. The highest temperature was  $34.3^{\circ}\text{C}$  at station 4 at an early afternoon in December.

Oxygen: The shallowness of the lagoon, the regular inflow of sea surface water, the constant wind, seem to prevent  $\text{O}_2$ -depletion at the lagoon bottom.  $\text{H}_2\text{S}$ -smell was noticed only in August/September in the deep mud at the mouth of the temporary

rivers in the lagoon. Here a high degree of sedimentation takes place during the rain season. For the whole lagoon the  $O_2$  level remains sufficient to support higher animal life over the daily cycle, and during the whole period of the investigation (Fig. 8). The distribution of the sediments is indicated in Fig. 9. It is terrigenous mud as well as marine sand that is filling up the lagoon, as indicated by WEBB (1958).

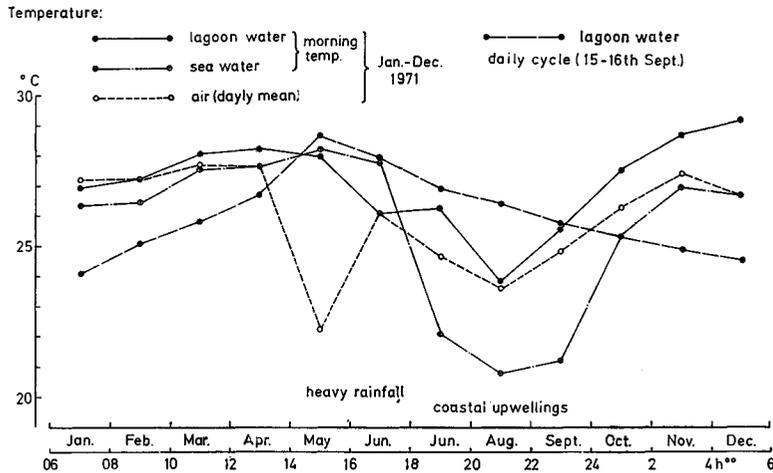


Fig. 7. Morning lagoon water temperature (data: F.R.U. and D. Pauly), morning sea-water (beach) temperature (data: F.R.U.), mean daily air temperature (data: Tema Weather Station) and daily water temperature cycle, the 15th to 16th of Sept. (data: F.R.U.) all 1971

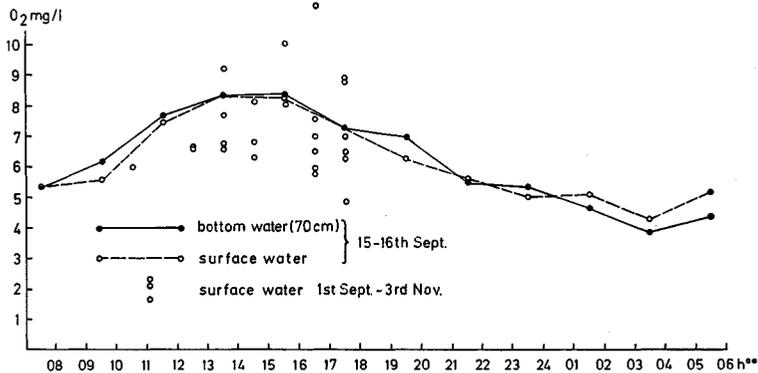


Fig. 8.  $O_2$ -content of lagoon surface water. Daily cycle the 15th to 16th of September (data: F.R.U.) and from August to December, all 1971

**Water exchange:** The method used for the determination of the exchange of water between the lagoon and the sea gives two values for each 12 hour tidal period. One is the measured quantity of water that flowed into the lagoon during one tidal period, the other gives the quantity of water that remained in the lagoon after this period (most of this water flows out later, during the next tide period where the balance is negative). Tab. 1 gives the monthly totals of the water left in the lagoon after the

Table 1

Monthly sum of the sea-water masses in the lagoon left after each tide period approx. 12 h. For comparison: estimated mean quantity of lagoon during the dry season  $\approx 500,000 \text{ m}^3$

Month (1971)	m <sup>3</sup> of sea water	Month (1971)	m <sup>3</sup> of sea water
January	745,000	July	rain
February	702,000	August	rain
March	975,000	September	735,000
April	828,000	October	1,275,000
May	475,000	November	1,114,000
June	rain	December	1,000,000

different tide periods. These water masses are assumed to affect the lagoon more profoundly, by discharging their biotic load and by mixing with the lagoon water.

### 2.3. Discussion

Rapidly changing salinity characterizes the lagoon as poikilohaline. Rainfalls are immediately reflected by marked drops in salinity. It appears that the almost permanent connection with the sea prevents the average salinity from reaching values as high as in typical closed lagoons, such as the Kpeshie Lagoon, where the average salinity reached 72 ‰ in March (POPLE 1962). However, in comparison with open lagoons where the main water body remains mesohaline over most of the year and never becomes hyperhaline (HILL and WEBB 1958) and where the tides “buffer” the

whole lagoon, the “semi-closed” Sakumo Lagoon appears to be an extreme biotope. This fact is reflected clearly by limited macrofaunal diversity.

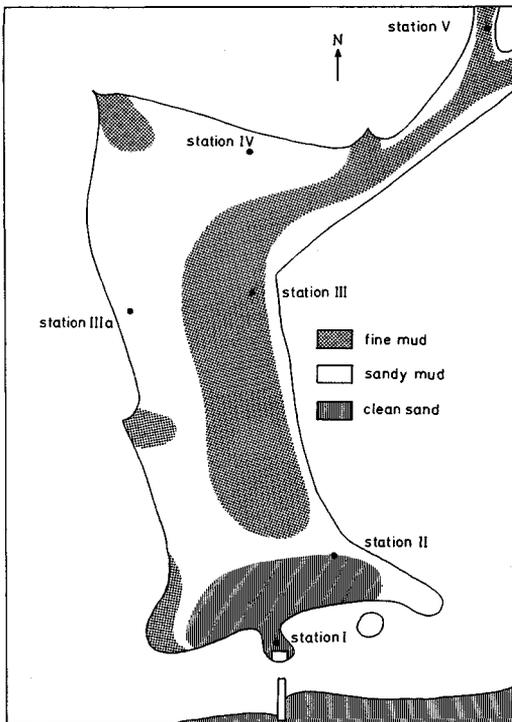


Fig. 9. Bottom substrates as indicated by bottom grab samples and direct observations

### 3. The Macrofauna of the Lagoon

Sakumo Lagoon is not surrounded by dense mangroves that would affect its fauna. Its mangrove trees (*Avicennia nitida*) grow on land far from the shoreline, their roots remain in water only during the flood of the rainy period, with the exception of a few mangrove trees growing in the water of the "arm" of the lagoon (the remnants of temporary rivers). The rest of the vegetation has a distribution corresponding to that described by BOUGHEY (1957) for closed lagoons.

#### 3.1. Material and methods

Phytoplankton: 30 samples were taken with Utermöhl-bottles held under water. The shallowness of the water prevented the use of more classical methods. The samples were preserved in Lugol-solution, and were later treated using the „seston-method“, as described by LENZ (1971). The O<sub>2</sub>-data used for the calculation of the primary productivity were obtained from the F. R. U.

Zooplankton: Samples could not be taken inside the lagoon, as boats were not permitted. Samples taken by holding a net in tidal water flowing into the lagoon only reflected the standing crop occurring along the Ghanean coast, and will therefore not be considered here.

Benthos: 28 samples were taken with a 4 kg Ekman-sampler, which covered an area of 0.0625 m<sup>2</sup>, and which was handled with outstretched arm. Its biting depth was about 25 cm in fine mud and 10 cm in sand. The samples were immediately sieved through 500  $\mu$  netting and preserved in buffered 4 % formaldehyde. They were later washed out, presorted and sorted according to PAULY (1973 a). Since the Ekman-sampler was not capable of catching fast moving animals, a light trawl was built out of wood and mosquito-netting, which was pulled with a long rope and effectively caught shrimps, other crustaceans, and juvenile fishes.

The distribution of the gastropod *Tympanotonus fuscatus* was determined by means of a square, 1 m<sup>2</sup> wooden frame that was repeatedly thrown over the shallow areas of the lagoon with subsequent collection of all animals within the frame.

Fishes: The fishes were all obtained from fishermen fishing either for themselves or for the autor. Their gear consisted of castnets, beach seines and gillnets. The fishes were always taken alive and immediately preserved in 4 % buffered formaldehyde.

Comparisons of numbers of various fish spp. are based on 2 quantitative fisheries organized in September and November 1971. The stomach contents of all collected fishes have been examined. For most spp., the low number of individuals does not allow for quantitative analysis. The main food of each species will be listed, however, to indicate its position in the food web. The intestinal ratio (length of outstretched gut/standard length of fish) was determined for each species.

The various animals found in the lagoon are listed. Also mentioned are the various distribution patterns that emerged, as well as other data that seem relevant.

#### 3.2. Results

The organic matter in the seston over the period of investigation is plotted in Fig. 10. It represented an average of 9 % of the total seston. The Secchi disk-depth varied between 20 and 50 cm. Primary production is indicated in Tab. 2. These values might also indicate the magnitude of the average productivity over the whole cycle of a

Table 2

Primary production in Sakumo-Lagoon. Bottom: depth = 70 cm. The productivity per m<sup>2</sup> is the mean of the surface and bottom values, related to the lagoon average depth of 50 cm

Date (1971)		mg C/l/day	mg C/m <sup>2</sup> /day
the 15 th to 16 th of Sept.	Surface	1.42	385
	Bottom	0.12	
the 11th to 12 th of Oct.	Surface	1.00	320
	Bottom	0.24	

Table 3

## Distribution of the polychaetes in Sakumo-Lagoon

(See also Fig. 11)

Species	South-East	South-West	Central	North	Total	mean per m <sup>2</sup>
<i>Syllis hyalina</i>	1	4	—	2	7	4
<i>Notoneastus lineatus</i>	18	29	9	27	84	48
<i>Nephtys pyrifanis</i>	7	8	21	2	38	22

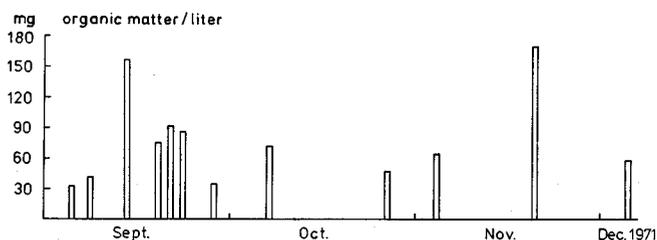


Fig. 10. Organic matter in the seston (mean: 9% of total seston). Plotted are the means for station I to V (n = 40)

year, since the primary productivity in tropical lagoons does not seem to fluctuate in the way that characterizes temperate and boreal waters (QUASIM 1970).

**Polychaetes:** Only 3 species were found. Their distribution is indicated in Tab. 3 (Fig. 11). No marked distribution pattern inside the lagoon could be established, but it should be noticed that the low number of species contrasts markedly with the 71 spp. of coastal and sublitoral polychaetes listed by BASSINDALE (1961) for the Ghanaian Coast.

**Oligochaetes:** The epitok parts of undetermined oligochaetes were found in two samples.

**Gastropods:** *Tympanotonus fuscatus* represents by far the largest fraction of the molluscs biomass in the lagoon. It occurs mainly as *T. fuscatus* var. *radula* (89%, n = 1.400). The shells of the other form, characterized by protuberances, were always empty. 50% of the shells of *T. fuscatus* var. *radula* were empty in the southern part of the lagoon, 20% in the northern part. The average distribution was 5 live *T. fuscatus* var. *radula* per m<sup>2</sup> in the southern part, and 210 m<sup>2</sup> in the northern part. Here this

gastropod covers large patches of the bottom, and provide substrate for filamentous green algae. Reproduction takes place after the rainy period, at the end of August, when their pearshaped egg-masses were seen attached to the sand by filaments.

*Thais spec.*

1 ind., washed into the lagoon

*Glycimeris spec.*

1 juv. ind., probably washed in

*Semifusus morio*

large, empty, half destroyed shells along the shore, north of the lagoon.

*Hydrobia ulvae*

1 juv. ind.

Opisthobranchia *Aplysia dactilomela* 2 ind. washed in

#### BIVALVES

*Arca senilis*

only empty shells in enormous quantities, especially on the western shore.

*Tagelus angulatus*

only a few empty shells.

*Ostrea tulipa*

The most common substrate for this oyster seems to be roots of mangrove trees. Here it can reach a diameter of over 10 cm and is present in enormous quantities (PILLAY 1965). In Sakumo-Lagoon, they grow on the shell of *Typanotonus fuscatus*. Many *T. fuscatus* shells inhabited by the hermit crab *Clibanarius africanus* had as many as 4 young oysters growing on them. Under these conditions the oyster reach a size over 3-4 cm diameter. Along the shoreline half-destroyed *Ostrea tulipa* shells of up to 25 cm in length suggest earlier better conditions for this oyster.

#### CRUSTACEAN

##### Copepods

*Paeonodes lagunaris* van Banning, 1974, parasitic to *Tilapia melanotheron*. Characteristics of this infestation have been published elsewhere (PAULY 1974; VAN BANNING 1974).

##### Balanids

Remnants of *Balanus spec.* were found attached to the concrete structure of the sluice.

##### Mysids

*Siriella spec.* occurs in large numbers in the southern part of the lagoon (50-100/m<sup>2</sup>); also found in several fish stomachs.

##### Amphipods

*Brandidirella megua*, a typical brackish-water organism which occurs in small numbers over the whole lagoon.

##### Isopods

*Lingia exotica* 1 ind.; probably washed in.

##### Decapods

*Penaeus duorarum* occurs as juvenile in the lagoon in large quantities and is intensively fished. Its migrations, distribution patterns were the object of a study by the F.R.U. in 1971. It established that the post larvae are washed into the lagoon after the rainy period, presumably using the chemosensory mechanism described by HUGHES (1969), spend up to 10 months in their juvenile feeding ground, and leave the lagoon at the onset of the rainy period, as described also by HOESTLANDT (1969) for lagoons in Dahomey.

*Penaeus ketathurus*

same as above, but represents only about 10 % of the shrimp catch.

*Clibanarius africanus*

a pagurid, which only occurs in the southern part of the lagoon. It lives in the shells of *T. fuscatus*. The entire *C. africanus* population could be observed to concentrate in clusters of 30–40 individuals near the outlet when water was flowing out of the lagoon. When the tide was flowing in *C. africanus* was distributed more evenly around station I with a noticeable concentration near the sill where the inflowing water loses much of its velocity. It is assumed that this distribution corresponds to their habit of feeding on dead or dying washed-in animals such as cephalopods or jelly-fishes. A density of up to 5 ind./m<sup>2</sup> was estimated for the southern part of the lagoon.

*Callinectes latimanus*

this portunid crab is common enough to be the object of a subsistence trap fishery in 1971. It was subject of a study by the F.R.U.

The following semiterrestrial crabs were found along the shore:

*Uca tangeri*, Ocypodidae, common

*Cardiosoma armatum*, Gecarcinidae, very common

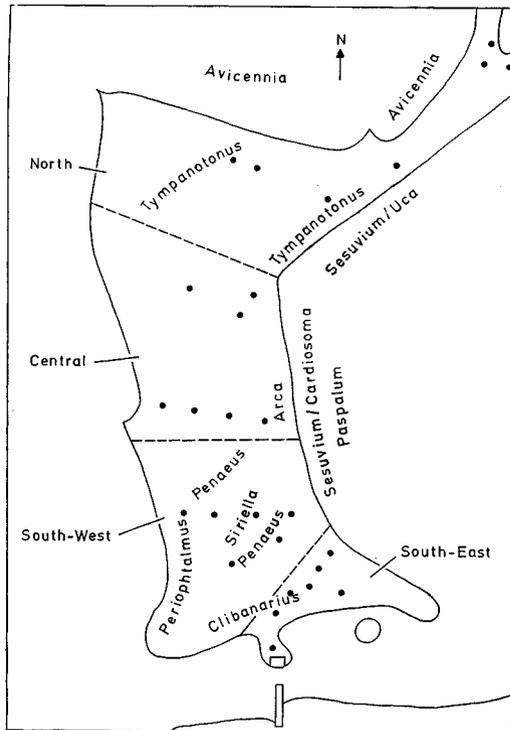
*Gionopsis cruentata*, Grapsidae, only station I, not common.

## PISCES

The occurrence of the various fish species, as reflected in the catches of the fishermen suggest the existence of four groups of species whose importance varies in the course of the year:

1. Fresh water fishes, which swim into the lagoon through the temporary rivers during the rainy season: Only *Clarias senegalensis* was found in an isolated pool near station I which in September still contained fresh water.
2. *Tilapia melanotheron*, the mud-skipper *Periophthalmus papilio*, the bonga *Ethmalosa fimbriata*, the tenpounder *Elops senegalensis*, the gobiid *Oxychthyrictis*

Fig. 11. Distribution of large benthic animals in the lagoon, and main features of the vegetation around the lagoon, with associated crabs. Dots represent places where benthos grab samples were taken (see also Tab. 3)



*occidentalis* and the burro *Pomadasy jubelini*, which spend all or most of their life cycles in the lagoon.

3. *Mugil* spp., *Gerres melanopteros* and *Citharichtys stampflii*, whose juvenile forms are washed into the lagoon just after the rainy season. They probably leave the

lagoon at the onset of the next rainy season. These migrations correspond to those of the shrimps *P. duorarum* and *P. ketathurus*.

4. The species *Lutjanus goreensis*, *Lutjanus agennes*, *Caranx hippo* and *Trachinotus goreensis* are caught in very small numbers, near station I during or shortly after high tide. The occurrence of these fishes inside the lagoon is limited to short incursions.

*Myrophis plumbeus* (Echelidae) and *Caecula cephalopeltis* (Ophichthidae) which are not caught by the nets used by fishermen, can not be allocated to any of the previous groups. They were caught while leaving the lagoon. Their stomachs were empty and they had small yellow eggs in their abdominal cavities.

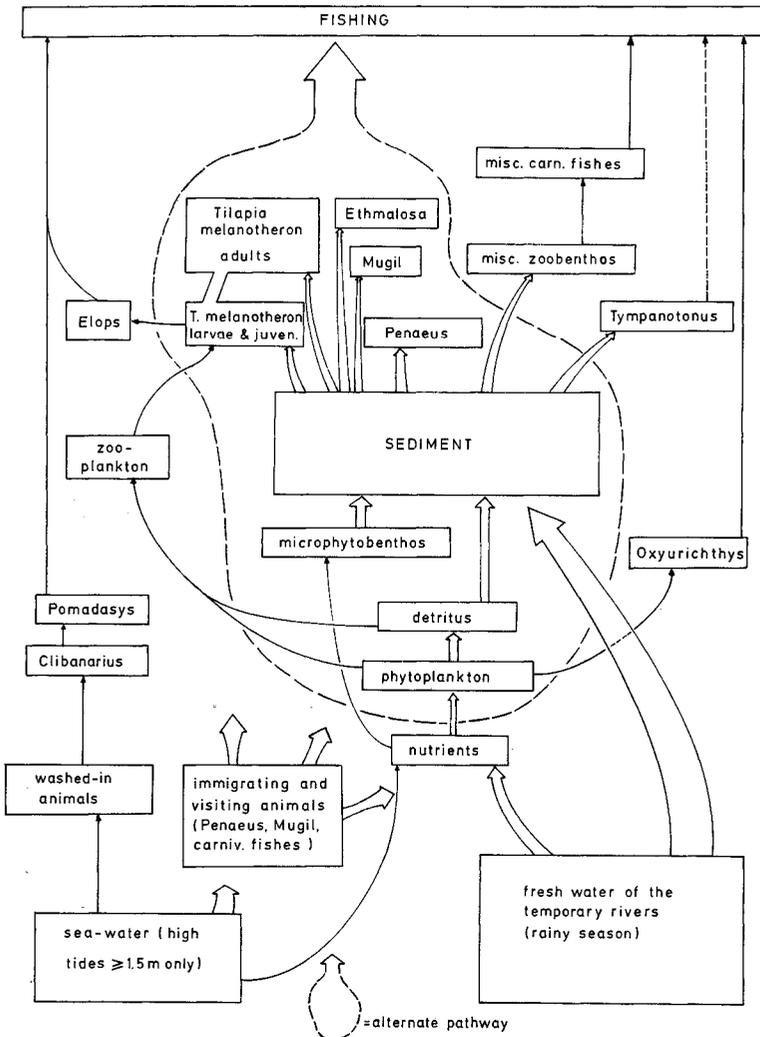


Fig. 12. The main features of the food web in Sakumo Lagoon. Note "alternate pathway" and the marginal position of zooplankton. Misc = miscellaneous; carn = carnivorous; juven = juveniles

Table 4

Fishes in Sakumo-Lagoon, summary of data as calculated from the catch of 2 quantitative fisheries (15th–16th of Sept. and 10th of November 1971) of 7 seine-net hauls each, spp. with a "Ø" were not represented in the catch

Family	Genus	Species	% of fish biomass	mean weight (g)	mean st. length (cm)	Intestinal ratio	main food item in decreasing order of importance (remarks)	number of fishes examined
Cichlidae	Tilapia	<i>melanotheron</i> (adults)	93.00	20	8.0	7.1	bottom substrate (mud)	1,600
Cichlidae	Tilapia	<i>melanotheron</i> (juveniles)	Ø	—	3.0	—	bottom substrate, phytoplankton, zooplankton	20
Cichlidae	Tilapia	<i>melanotheron</i> (larvae)	Ø	—	> 2.0	—	zooplankton, phytoplankton, pennate diatoms	20
Clupeidae	Ethmalosa	<i>fimbriata</i>	2.27	20.8	10.2	1.37	bottom substrate (as <i>T. melanotheron</i> )	50
Elopidae	Elops	<i>senegalensis</i>	1.44	52.2	17.0	0.55	Penaeus, Siriella, fish scales, small <i>T. melanotheron</i>	20
Gobiidae	Oxyurichtys	<i>occidentalis</i>	1.10	41.0	15.0	1.78	phytoplankton	20
Mugilidae	Mugil	spp.	0.85	11.9	8.1	3.0	pennate diatoms, bottom substrate	50
Pomadasydae	Pomadasy	<i>jubelini</i>	0.53	21.9	9.7	0.78	polychaetes, Clibanarius, Siriella	14
Lutjanidae	Lutjanus	<i>agennes</i>	0.27	64.4	11.8	0.50	Penaeus, unidentified fish remains	5
Lutjanidae	Lutjanus	<i>goreensis</i>	0.13	48.0	11.0	0.68	Penaeus, unidentified fish remains	2
Soleidae	Synaptura	<i>punctissima</i>	0.13	73.0	16.5	0.5	polychaetes	1
Bothidae	Citharichys	<i>stampflii</i>	0.11	7.4	7.9	0.56	Siriella, fish remains	50
Gerridae	Gerres	<i>melanopterus</i>	0.09	4.5	6.2	0.63	polychaetes, Penaeus, other small crustaceans	50
Carangidae	Trachinotus	<i>goreensis</i>	0.05	11.9	8.8	0.57	—	2
Carangidae	Caranx	<i>hippo</i>	Ø	18.6	9.4	0.49	—	3
Periophtalmidae	Periophtalmus	<i>papilio</i>	0.05	10.9	8.1	0.46	Callinectes juv.	2
Echelidae	Myrophis	<i>plumbeus</i>	Ø	39.7	37.5	0.44	—	10
Ophichtidae	Caecula	<i>cephalopeltis</i>	Ø	11.5	35.2	0.5	—	2
Clariidae	Clarias	<i>senegalensis</i>	Ø	147.8	21.0	0.82	— (fresh-water fish)	2

The main food items of the various fish species (Tab. 4) correspond in large extent to that of the same species in Lagos Lagoon (FAGADE and OLANIYAN 1973), but with a marked reduction in the variety of food items in Sakumo Lagoon. It is worth noting that *Ethmalosa fimbriata*, normally a plankton-feeder (BAINBRIDGE 1963; FAGADE and OLANIYAN 1972) resorts to substrate-feeding, in Sakumo Lagoon. Also, the stomach contents of *E. fimbriata* suggested a type of feeding behaviour similar to that of *Tilapia melanotheron*, namely without concentration and filtration of the ingested substrate (FAGADE 1971; PAULY, in prep.). This differs from the feeding behaviour of *Mugil spec.* which filter and concentrate the finer fraction of the bottom substrate on which they feed. They ingest only diatoms, small organic particles and sand grains (see also ODUM 1970).

### 3.3. Discussion

The food web of the major parts of biomass in Sakumo Lagoon as given in Fig. 12 contains only those organisms whose trophic position was either clearly determined or known by literature. Emphasis was given to the so-called "alternative pathway" (QUASIM 1970), a food web based on bottom mud enriched with micro-phytobenthos and deposited seston which is consumed directly by fishes and shrimps.

The lagoon ecosystem is characterized by an energy storage in form of organic sediment that is the food of those animals which represent most of the biomass (*Tympanotonus*, *T. melanotheron*). These organisms are well-adapted to the changes of salinity that characterize West-African lagoons.

The extreme conditions in the lagoon are the cause for a severe reduction of the macrofauna, as compared with an open lagoon and with the coastal fauna of the area (FAGADE et al. 1972, 1973; BASSINDALE 1961).

The rapid increase of the salinity after the rainy season is followed by a rapid disappearance of purely fresh water animals, then by a steady increase of marine animals which are represented mostly by juvenile stages.

A marked change in the lagoon ecosystem probably occurred a few years ago. It is assumed that the construction of sluices with pipes communicating with the sea have been the cause for this change, by increasing the influence of the marine element and by attenuating or even totally suppressing some of the specific traits of a typical closed lagoon such as changing water levels, stagnant water over most of the year, and a mostly isolated aquatic fauna.

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### Summary

The investigated lagoon, located near Tema, Ghana, belonged to the "closed" type, but now communicates with the sea through pipes cutting the sand bar. It has a surface area of 1 km<sup>2</sup> and an average estimated depth of 50 cm, both during the dry season.

The salinity of the lagoon varies greatly in the course of the year reaching 50–60‰ in the dry season and falling to 0‰ during the rainy season. The morning temperature stays between 25 and 30°C, except during the period of coastal upwelling when a marked drop down to

20° C occurs. The oxygen content of the water is always sufficient to support higher animal life.

The exchange of water with the sea is driven by tidal rhythms, which are of the semi-diurnal type, with an averal tidal range of 128 cm (1971). When there are no strong rains, sea water flushes the lagoon one to three times a month.

Data for seston and primary productivity suggest a moderate, but constant primary production of about 350 mgC/m<sup>2</sup>/day.

Only three polychaete species were found in 28 benthos grab samples, the zoobenthos consists mainly of the gastropod *Tympanotonus fuscatus* var. *radula* and juveniles of the Penaeid shrimps *Penaeus duorarum* and *P. ketathurus*. The latter are intensively fished, the former are occasionally collected. The distribution and movements of the pagurid crab *Clibanarius africanus* is related to their habit of feeding on washed-in animals. The rest of the invertebrates are listed and commented upon.

16 fish species and one genus (*Mugil*) were identified. The fish fauna is dominated by the cichlid *Tilapia melanotheron*, a brackish-water fish which contributed to 93 % of the catch of two quantitative fisheries. With the exception of *Clarias*, an isolated relict of the rainy season, all other fishes were marine coastal species, represented mostly by juvenile stages. The food of the fishes is given for most species. It mostly correspond for the main items to literature data on the same species in Lagos Lagoon.

The lagoon ecosystem is characterized by an energy storage in form of fine mud, detritus and associated microorganisms that is brought in during the rainy season by the temporary rivers and that is constantly enriched by sedimenting seston. The energy fixed in this bottom substrate is utilized directly by *Tilapia melanotheron* and other substrate-feeders. This shortened food chain is an "alternate pathway" differing from those food chains in temperate waters where the fishes mostly are at least secondary consumers.

### Zusammenfassung

Die untersuchte Lagune liegt in der Nähe von Tema, Ghana; sie gehörte zum „geschlossenen“ Typ, ist aber jetzt mit dem Meer über zwei Röhren verbunden, die unter die Sandbank gelegt worden sind. Sie bedeckt eine Fläche von 1 km<sup>2</sup> und hat eine durchschnittliche geschätzte Tiefe von 50 cm, beide Angaben beziehen sich auf die Trockenzeit.

Der Salzgehalt in der Lagune schwankt im Jahresverlauf erheblich, erreicht 50–60 ‰ in der Trockenzeit und 0 ‰ in der Regenzeit. Die Morgentemperatur des Wassers bleibt zwischen 25° C und 30° C, außer während der Periode küstennahen Auftriebs, wo das Lagunenwasser auf 20° C abkühlt. Der Sauerstoffgehalt des Wassers erreicht keine niedrigen Werte.

Der Wasseraustausch mit dem Meer wird durch die Tiden bewirkt, sie haben eine Periode von etwa 12 Stunden und einen mittleren Tidenhub von 128 cm (1971). Außer nach starken Regenfällen wird das Lagunenwasser durch die Tiden 1- bis 3mal im Monat ausgetauscht.

Die Werte für das Seston und die Primärproduktion legen eine mäßige aber konstante Primärproduktion von etwa 350 mg C/m<sup>2</sup>/Tag nahe.

Nur 3 Polychaetenarten wurden in 28 Benthosgreiferproben gefunden. Das Zoobenthos besteht hauptsächlich aus der Schnecke *Tympanotonus* var. *radula* und juvenilen penaeiden Krebsen, *Penaeus duorarum* und *P. ketathurus*, die intensiv befischt werden, während die Schnecken nur gelegentlich gesammelt werden. Die Verteilung und die Bewegungen des Einsiedlerkrebses *Clibanarius africanus* richten sich nach seiner Gewohnheit, eingespülte Tiere zu fressen.

16 Fischarten und eine Gattung (*Mugil*) wurden bestimmt. Die Fischfauna ist beherrscht von dem Cichliden *Tilapia melanotheron*, einem Brackwasserbewohner, der zu 93 % in den Fängen zweier quantitativer Fischereien vertreten war. Mit Ausnahme von *Clarias*, der in einem isolierten Tümpel aus der Regenzeit gefunden wurde, waren alle anderen Fische marine Küstenbewohner in meist juvenilen Stadien. Die Nahrung der meisten Fische ist angegeben. Die Hauptnahrung entsprach den Literaturangaben für dieselben Arten in der Lagos-Lagune.

Das Ökosystem der Lagune ist durch einen Energiespeicher in Form von Bodenschlamm, Detritus und assoziierten Mikroorganismen charakterisiert. Dieser Schlamm wird von temporären Flüssen während der Regenzeit abgelagert und durch sedimentierendes Seston angereichert. Die hier gebundene Energie wird von *Tilapia melanotheron* und anderen Substratfressern verwertet. Diese verkürzte Nahrungskette ist ein „alternate pathway“ und unterscheidet sich erheblich von Nahrungsketten in temperierten Gewässern, wo die Fische zumindest Sekundärkonsumenten sind.

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