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The distribution of the freshwater cichlid *Sarotherodon mossambicus* in estuarine systems

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Synopsis

The distribution of *Sarotherodon mossambicus* in south east African estuaries is reviewed. It occurs commonly in closed estuaries and coastal lakes but is absent from open tidal estuaries. When a closed estuary opens to the sea the species usually retreats to the upper reaches. It is euryhaline and eurythermal and can feed on a wide variety of foods but experiments indicate that *S. mossambicus* avoids areas where current speeds exceed 370 m h^{-1}. It is concluded that the distribution of *S. mossambicus* in estuarine systems is governed by an interplay of the following factors: salinity stability, water currents, suitable breeding sites, presence of marginal vegetation, marine competitors and marine piscivorous fish.

Introduction

Sarotherodon mossambicus (Peters) has a distribution which extends from the middle and lower Zambezi River system to the Pongolo River (Jubb 1967) and thence southwards in estuaries as far as the Bushmans River (33°42′ S, 26°40′ E) in the Cape (Allanson & Noble 1964). *S. mossambicus* is tolerant of a wide range of salinities (0 – 117°/₀₀) (Wallace 1975) and temperatures (12° – 38° C) (Allanson et al. 1971). Furthermore this cichlid can feed on a wide range of food organisms (Crass 1964), occupies widely differing habitats (Bruton & Boltt 1975) and occurs in waters of varying turbidity. Research by the present authors on fishes in the east coast estuaries of southern Africa has shown that *S. mossambicus* is abundant in closed estuaries and coastal lakes, but absent from open estuaries. Closed estuaries have a limited catchment area and because of erratic rainfall and longshore drift of sand, are cut off from the sea for most of the year. A review of the estuarine distribution of *S. mossambicus* is presented in this paper, together with results of experiments designed to test hypotheses concerning factors which may influence this cichlid in estuaries.

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Materials and methods

Distribution

Between July 1970 and July 1978 the fish of the following estuarine systems were studied by the authors: Kosi Estuary (open estuary connected to lake system), Lake St. Lucia (open estuarine lake system), Mhlanga Estuary (closed estuary), Mpenjati Estuary (closed estuary), Mtentu Estuary (large open estuary), Msikaba Estuary (open estuary) and West Kleinemond Estuary (closed estuary). Fish were captured using gill, seine and cast nets. Salinity was measured with a Goldberg optical salinometer and current speeds with an Ott water current meter.

Experiments

A choice chamber experiment was designed to determine the reaction of *S. mossambicus* to strong water currents. Ten *S. mossambicus*, between 5 and 10 cm standard length (SL), were placed in a 500 l tank divided in half by a sheet of perspex. A 15 cm diameter hole in the centre of the perspex sheet allowed fish free access to either chamber. An anticlockwise water current was created by a hosepipe connected to one of the chambers (A) from the domestic water supply. Current speeds were measured in the centre of chamber A and represent the minimum current speed in the chamber. Water temperatures during experiments were 20° – 21° C. Following an acclimation period of 24 h, counts were made every hour, between 0800 – 1800 h, of the number of *S. mossambicus* in each chamber. Each experiment was run for 48 h and a minimum of 15 counts made. A total of 5 experiments were conducted, each with a different water current in chamber A (Table 2). No water current was recorded in chamber B.

Results

Table 1 shows the distribution of *S. mossambicus* in southern African estuarine systems. It is common in

Table 1. Distribution of *Sarotherodon mossambicus* in southern African estuarine systems.

Locality		Description of system	Distribution and abundance of *S. mossambicus*	Source of information.
Morrumbene	(23°43'S,35°23'E)	Open estuary	Present in upper reaches	Day 1974
Poelela	(24°0'S,35°0'E)	Coastal lake	Common	Hill *et al.* 1975
Piti	(26°33'S,32°55'E)	Coastal lake	Common	Bruton pers. comm.
Kosi	(26°54'S,32°52'E)	Open estuary	Absent	Broekhuysen & Taylor 1959
Nhlange	(27°0'S,32°50'E)	Coastal lake	Present	Blaber 1978
Mgobozeleni	(27°33'S,32°40'E)	Coastal lake	Common	Bruton & Appleton 1975
St. Lucia	(28°0'S,32°30'E)	Coastal lake	Present	Day *et al.* 1954
Umlalazi	(28°56'S,31°48'E)	Open estuary	Absent	Hill 1966
Sinkwazi	(29°17'S,31°26'E)	Closed estuary	Common	van der Elst pers. comm.
Mhlanga	(29°43'S,31°5'E)	Closed estuary	Common	This paper
		Open estuary	Common	This paper
Umgeni	(29°50'S,31°3'E)	Open estuary	Absent	This paper
Mpenjati	(30°58'S,30°18'E)	Closed estuary	Present	This paper
Mtentu	(31°14'S,30°3'E)	Open estuary	Absent	This paper
Msikaba	(31°19'S,29°57'E)	Open estuary	Absent	This paper
Kleinemond	(33°33'S,24°7'E)	Closed estuary	Present	This paper
		Open estuary	Absent	This paper

Table 2. Percentage of *Sarotherodon mossambicus* in chamber A (current) and B (calm) at different current speeds (n = number of recordings).

Experiment number	Minimum water speed in chamber A (m h^{-1})	Percentage *S. mossambicus* chamber A	Percentage *S. mossambicus* chamber B	n
1	0	45.1	54.9	19
2	77	58.1	41.9	19
3	258	55.5	44.5	18
4	372	39.3	60.7	18
5	517	36.9	63.1	19

coastal lakes and lagoons but absent from open estuaries. An exception is the Mhlanga Estuary where this species was recorded during the open phase of this normally closed estuary. Figure 1 indicates that *S. mossambicus* move to the lower reaches of the West Kleinemond Estuary during the closed phase but retreat to the upper reaches when the estuary opens. Following an 18 month closure of this estuary *S. mossambicus* comprised 95% of the total fish catch in the lower reaches. Breeding has been recorded in the following estuarine systems: Lake Poelela, Lake Nhlange, Lake St Lucia, Sinkwazi Estuary, Mhlanga Estuary and West Kleinemond Estuary.

In the experiments to determine the reactions of *S. mossambicus* to various current speeds, the fish avoided chamber A when currents exceeded 370 m h^{-1} but the selection for chamber B was not total (Table 2). With a minimum water speed of 517 m h^{-1} in chamber A, almost 37% of the fish frequented this chamber. Unfortunately, it was not possible to increase the current speed above this level. Current speeds recorded in selected estuarine systems are shown in Table 3. The reed channel linking Lake Nhlange and Lake Sifungwe had a higher current

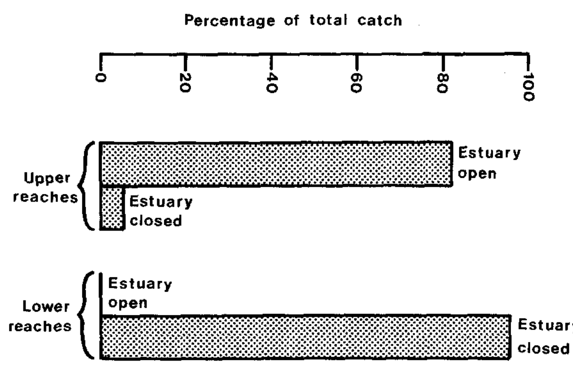

Fig. 1. Changes in the abundance of *Sarotherodon mossambicus* in the upper and lower reaches of the West Kleinemond Estuary related to the open and closed phase (1970–1973).

Table 3. Current speeds recorded in estuarine systems.

Locality	Current speeds (m h^{-1})
Lake Nhlange	250 – 510
Kosi Reed Channel (centre)	1970 – 2200
Kosi Reed Channel (margin)	110
Kosi Estuary	810 – 1300
Lake St. Lucia	20 – 210
Umgeni Lagoon	220
Umgeni Mouth	1270

speed than both the Umgeni and Kosi estuaries. *S. mossambicus* were present in the reed channel but absent from the latter areas. However, *S. mossambicus* in the channel were distributed along the margins where current speeds were reduced by the dense *Phragmites* beds (Table 3).

Discussion

Hill et al. (1975) postulated that the abundance of cichlids, including *S. mossambicus*, in an estuarine system was related to the degree of isolation of the system from the sea. It was also suggested that reduced competition from the marine component of the estuarine fauna under extreme conditions at Lake St Lucia played a role in the increase of *S. mossambicus* during high (35 – 120°/oo) and low (0 – 25°/oo salinity regimes. However although *S. mossambicus* numbers increase during low salinities, those of potential marine competitors, such as *Mugil cephalus*, do not show a corresponding decrease (van der Elst et al. 1976). The increase in the area of St Lucia colonized by aquatic macrophytes during low salinities (Ward 1976), together with the inundation of marginal terrestrial vegetation because of high lake levels, provide additional shelter for juvenile *S. mossambicus* and hence a higher survival rate could be expected. Therefore, whereas *S. mossambicus* comprised 1.2% of the total catch at St Lucia in 1971 (salinity 80°/oo), it constituted 12.3% of the catch in 1975 (salinity 10°/oo) (van der Elst et al. 1976). Whitfeld & Blaber (1978a) have shown that although the diets of *S. mossambicus*, *Chanos chanos* and Mugilidae at St Lucia overlap, competition is reduced by different feeding mechanisms which result in the available microbenthos being consumed in differing quantities. Therefore, competition among mullet, tilapia and milkfish in an open estuary may not account for the absence of *S. mossambicus* from these areas.

Prior to the isolation of a closed estuary from the sea, the marine component of the estuarine fauna does not depart (Blaber 1973), and the density increase of *S. mossambicus* which followed the formation of a lagoon at the closed West Kleinemond Estuary indicates that food may not be a limiting factor in the colonization of the lower reaches of an open estuary. However a large proportion of the diet of *S. mossambicus* in estuaries consists of particulate organic matter (Whitfield & Blaber 1978a) and conditions during the open phase of an estuary may not be conducive to the deposition of such material.

S. mossambicus is capable of surviving in seawater and has colonized south east coast estuaries via the sea (Harrison 1966) yet this species is absent from open estuaries (Table 1). A possible explanation for this phenomenon could be that, whereas *S. mossambicus* can readily adapt to gradual changes in salinity, they may not be able to tolerate the rapid salinity fluctuations of open estuaries. *S. mossambicus* were present in only the upper reaches of the West Kleinemond Estuary when this system was open, but following closure of the estuary underwent a density increase and after 18 months comprised 95% of the fish fauna of the lower reaches (Fig. 1). A major portion of the *S. mossambicus* present in the lower reaches probably came from the upper reaches because numbers there dropped considerably following closure of the mouth (Fig. 1). Following closure of an estuary, gradual changes in salinity take place due to the changing balance between evaporation and freshwater inflow, and *S. mossambicus* would therefore not be subjected to rapid salinity fluctuations such as occur in a tidal open estuary. The abundance of *S. mossambicus* in estuarine lakes such as Poelela may be due to the relatively stable salinity together with suitable breeding habitats and marginal vegetation.

S. mossambicus apparently avoids strong water currents such as occur in open estuaries (Table 1) and Gaigher (1973) showed that *S. mossambicus* had a preference for pools in both perennial and annual streams of the Limpopo River System and that this species avoids rapids and swiftly flowing water. Pienaar (1968) states that still water, in quiet open pools, is the habitat choice of *S. mossambicus* in the eastern Transvaal lowveld but that they are also found in the larger pools of perennial rivers. Experimental evidence (Table 2) indicates that *S. mossambicus* avoid strong water currents and this is supported by field recordings (Table 3) at the mouth of the Umgeni and Kosi estuaries, where currents in excess of 1000 m h^{-1} were recorded and *S. mossambicus* was absent. However *S. mossambicus* were present in the Kosi reed channel (current speeds 2200 m h^{-1}) but restricted to the vegetated shallows where current speeds were reduced (Table 3). Current speeds in the Umgeni Lagoon are comparable to those at Lake St Lucia (Table 3) but *S. mossambicus* is absent from the former area and present in the latter (Table 1). Therefore current speeds are not the sole factor determining the distribution of *S. mossambicus* in estuaries.

Water currents also influence the availability of suitable breeding sites. According to Jubb (1967) *S. mossambicus* build nests in calm areas where water depths are between 1 and 2 m, and a sandy bottom is present. Although most open southern African estuaries have sandy substrates, strong tidal water movement and hence substrate movement, would hamper nesting activities. Furthermore Bruton & Boltt (1975) have shown that *S. mossambicus* nest predominantly in sheltered littoral areas where macrophytes are present. The absence of suitable marginal vegetation in open estuaries and the exposure of littoral areas at low tide prevent nest establishment by *S. mossambicus.* Closure of an estuary however often results in inundation of marginal vegetation, stable water levels and absence of water currents, thus providing favourable nesting conditions.

Another possible reason for the absence of *S. mossambicus* from open estuaries may be the higher densities of marine piscivorous fishes in this zone. Donnelly (1969) has shown that *S. mossambicus* in Rhodesian highveld dams form shoals of all size groups at a variety of water depths but that *S. mossambicus* in Lake Kariba react differently because of the presence of the predatory tigerfish *Hydrocynus vittatus.* The young *S. mossambicus* in the latter situation do not venture far from the vegetated littoral zone until a length of 18 cm is attained, by which time they are too large to be consumed by *H. vittatus.* Since the presence of active predatory species within a fish population can alter the behaviour of the prey species, *S. mossambicus* may avoid the lower reaches of open estuaries because of large, highly mobile predators in these areas (Blaber 1978). The evidence from Lake St Lucia does not support this view because piscivorous fishes despite their abundance within the system, do not feed on *S. mossambicus* to any significant extent (Whitfield & Blaber 1978b). In contrast predation pressure exerted by piscivorous birds at Lake St Lucia on *S. mossambicus* is high (Whitfield & Blaber 1978c, 1979a, b) but *S. mosambicus* do not react by migrating or even colonizing St Lucia Estuary where there are low numbers of piscivorous birds.

Mhlanga is the only estuary where *S. mossambicus* have been recorded in the lower reaches during the open phase (Table 1). This may be attributed to two factors; firstly the shallowness of the upper reaches (<1 m depth) during the open phase and secondly the reduction in water surface area over the whole estuary. The combined effect of these changes in the physical environment may necessitate a redistribution of this species with a proportion of the population utilizing the lower reaches.

It would appear that the distribution of *S. mossambicus* in estuarine systems is governed by a variety of factors (Table 4) and each may play a role in determining the behaviour and distribution of the species in estuaries. The importance of individual factors is

Table 4. An assessment of the influences of six factors (+ favourable, – unfavourable) on the abundance of *Sarotherodon mossambicus* in 11 estuarine systems.

Estuarine system	Salinity stability	Slow water currents	Suitable breeding sites	Marginal vegetation	Absence of marine competitors	Absence of marine piscivorous fishes	Abundance rating
Poelela	+	+	+	+	+	+	Common
Kosi	–	–	–	–	–	–	Absent
Nhlange	+	+	+	+	–	–	Present
Mgobozeleni	+	+	+	+	–	+	Common
St. Lucia	+	+	+	+	–	–	Present
Mhlanga	+	+	+	+	–	+	Common
Umgeni	–	–	–	–	–	–	Absent
Mpenjati	+	+	+	+	–	–	Present
Mtentu	–	–	–	–	–	–	Absent
Msikaba	–	–	–	–	–	–	Absent
Kleinemond	+	+	+	+	–	–	Present

difficult to assess because they cannot be viewed in isolation. However *S. mossambicus* are common where five or more of the factors are favourable, present where four factors are favourable and absent where less than four factors are favourable (Table 4).

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