

DOCUMENT NO. 368

ST LUCIA DOCUMENT COLLECTION



Author FORBES A T

Title BENTHIC STUDIES. PART 2: MACRO-BENTHOS

Source 1982 ST LUCIA RESEARCH REVIEW. CH.10. NATAL PARKS BOARD

Keywords BENTHOS*PRAWNS*CRUSTACEAE*MOLLUSCA*

BENTHIC STUDIES : PART II

MACRO-BENTHOS

A.T. FORBES

SUMMARY OF RESEARCH CARRIED OUT

In this review the macro-benthos will include all those invertebrates which are not or only rarely taken in grab samples. Information on this component of the St Lucia fauna has been derived in two ways. The Zoology Department of the University of Cape Town visited St Lucia several times between 1948 and 1965 during their pioneering studies on southern African estuaries. They undertook two major surveys during July 1964 and January 1965, the results of which were published by Day, Millard & Broekhuysen (1954) and Millard & Broekhuysen (1970). Later studies concentrated on particular species or groups. Interest in the penaeid prawns has given rise to several published and unpublished reports such as those by Crass (1957); Joubert & Davies (1966); and Champion (1976). Monitoring of the prawn bait fishery has varied in intensity but catch data are now available for the past 13 years. Wallace (1969) investigated salinity effects on the distribution of the larger bivalves while more recently there have been studies on caridean prawns of the genus Macrobrachium (Forbes & Bickerton, unpublished) during 1975-1979 and the swimming crab Scylla serrata (Hill, 1979).

SUMMARY AND SYNTHESIS OF RESEARCH RESULTS

1 General surveys

The emphasis in much of the early work and still today has been on the effect of salinity, particularly hypersaline conditions, on the species composition in different areas of the lake and later on the effects on particular species.

The general surveys provided essential background information and allowed comparisons of the St Lucia system with other estuarine or coastal lake systems on the Natal coast such as Kosi Bay, Richards Bay and Durban Bay. Kosi Bay and Richards Bay were broadly similar to St Lucia in terms of species and diversity of the larger crustacea, gastropods and bivalves although all three had very much less diverse faunas than Durban Bay. It is worth noting that tidal effects in the St Lucia system are not as noticeable as in the other systems mentioned. Wind affects the lake level but there is no tidal effect and even in the

Narrows tidal rise and fall is negligible a few kilometres up from the mouth. The banks in the Narrows generally slope fairly steeply so that there is a minimum intertidal area and accordingly less development of the intertidal fauna.

The siltation problem at St Lucia arose particularly during the early years of the UCT surveys but their records are probably representative of an environment relatively unmodified by man. No general surveys of the invertebrate fauna have been carried out since 1966 so any subsequent changes are unknown. It is notable that there are no records from St Lucia of some species characteristic of more stable systems such as the burrowing prawns Upogebia africana and Callinassa kraussi.

Salinities during the time of the UCT surveys varied from a maximum of 42-52ppt. during 1948-49 to a low of 5-11ppt. in 1964-65. Despite subsequent benthic studies faunal records from these periods still represent a large proportion of what is known of invertebrate salinity tolerances and salinity effects on invertebrate distribution in the St Lucia system. It should be noted that the salinities recorded in 1948-49, although considered high at the time were only half as high as those recorded during the early 70's.

In their analyses Millard & Broekhuysen (1970) discussed the effects of changing salinities on the faunal composition in different parts of the lake and pointed out that these changes resulted in both loss and replacement of species as well as changes in range. They found that the richest fauna occurred in the lower parts of the system with fewer species in North Lake and fewer still in False Bay. They ascribed this trend to the northern areas being subject to more extreme conditions and also furthest from the sea and hence the last to be colonised by marine forms. Later studies did not contradict this interpretation.

They also discussed seasonal differences in the presence or absence of several species and considered that it was at times difficult to distinguish between salinity and seasonal effects. They noted greater activity by intertidal crabs in summer and generally found greater numbers of prawns and shrimps. There were some exceptions in that the brackish water species Caridina nilotica and Palaemon concinnus were present in July 1964 but were not recorded in summer 1964-65.

2 Special studies:

2.1 The penaeid prawns

2.1.1 Introduction

Interest in the penaeid prawns of the St Lucia system extends back to before World War II when small scale private commercial netting was done (Joubert & Davies, 1966). In 1952 the enterprise was taken over by the Natal Parks Board and from 1967 to 1976 yielded an annual harvest of about 15000kg (Champion, 1976). Natal Parks Board bait records show that the catch has been maintained at a similar level up to the present. Despite the value of this catch and the significance of bait prawns to sports anglers at St Lucia the amount of published information both on the biology of the prawns in the system and on the fishery is not large. An early report on the bait fishery (Crass, 1957) was followed by the first attempt at a detailed investigation by Joubert & Davies (1966). This survey concentrated on assessing the species present in the system, their distribution and relative abundance plus aspects such as growth, feeding, reproduction and migration. The results of this study were based on samples collected at 26 stations covering the entire system during June and November 1964 and February and May 1965. The same stations were sampled by Champion (1976) at monthly intervals from January 1966 - February 1967 and again from November 1967 - January 1969. There was a normal salinity gradient during the 1964-65 survey but by January 1969 the gradient had reversed and salinities above 70ppt. were recorded in the northern reaches. Champion (1976) discussed the effects of these high salinities on the penaeid prawns and also attempted to assess the status of the bait fishery using Natal Parks Board bait catches and fishery records.

2.1.2 Synthesis of results

Five species, Penaeus indicus, P. monodon, P. japonicus, P. semisulcatus and Metapenaeus monoceros were recorded by the University of Cape Town in their surveys of 1948-65 (Millard & Broekhuysen, 1970) and also by Joubert & Davies (1966) and Champion (1976). Of the five species P. japonicus and P. semisulcatus were either periodically absent or taken in very small numbers. All catches in both the surveys and the bait fishery were dominated by P. indicus (generally in excess of 70%) with smaller numbers of M. monoceros and P. monodon. This was confirmed by Champion (1976) in his surveys and also in his investigation of the bait fishery.

The life cycle of the penaeid prawns occurring in the St Lucia system is similar to that shown by many littoral penaeids in tropical and sub-tropical areas. Juveniles are recruited to the system where they grow to adulthood before migrating back to sea to breed. Recruitment apparently occurs in spring while emigration occurs in late summer through to winter beginning with P. indicus and followed by

P. monodon and M. monoceros. (Joubert & Davies, 1966).

Residence time in the system is unknown but will presumably be affected by growth rates. Temperature has been shown to affect growth rates in P. aztecus but there were no salinity effects over the range 2-40ppt. (Zein-Aldin & Aldrich, 1965). As P. indicus in St Lucia is near the fringe of its range salinity rates have not been measured but Burdon (unpublished) showed that there were no significant changes in condition as measured by calorie, protein lipid and carbohydrate content over the year.

The penaeids of the St Lucia system are remarkably euryhaline. Champion (1976) recorded all five species at salinities up to 60-65 ppt. but despite this high tolerance the increase in salinities during the 1964-69 surveys eventually reduced the numbers of prawns and excluded them from some of the northern areas. The effects of low salinities are less known although reduced catches were obtained by the bait fishery during 1975 and 1976 when the lake was virtually fresh water. While it is clear that salinity would be an over-riding factor little attention has been paid to other possible factors affecting the distribution of the prawns despite the wide variety of habitats sampled during both surveys. Champion (1976) in fact pooled most of his results and divided the system into only three areas, viz. the Narrows as far as Mitchell Island, Mitchell Island to Hell's Gates and the northern areas of North Lake plus False Bay.

Investigation of non-salinity factors affecting distribution in the Lake is complicated by seasonal variations in numbers associated with the recruitment/emigration cycle. The significance of the lake to the St Lucia prawn populations has long been uncertain. It is well known that the Narrows have higher prawn densities than the lake but as there are no population estimates the overall significance remains unknown. It is clear that not all regions of the lake are equally favoured. Some indication of the use of different areas of the lake was obtained by Joubert & Davies (1966). As in the Narrows P. indicus was the dominant species. Despite great seasonal variation in abundance there was a fairly distinct pattern of distribution. Prawn numbers on the eastern shores between Mitchell Island and Lane Island were negligible. Highest densities were obtained on the western shores or, as in False Bay the vicinity of river mouths. These preferred areas were typically more turbid and muddy than the eastern shores where the substrate was sandier and the water clearer (Forbes, unpublished observations; Blaber, pers. comm.). A preference by P. indicus for muddy waters was noted by Hughes (1966) in Mocambique who explained it as a predator avoidance strategy

by a species which unlike many other south-east African penaeids does not dig into the substrate during the day. Burrowing behaviour is particularly well developed in M. monoceros and P. semisulcatus and to a lesser degree in P. monodon (Hughes, 1966) and all are nocturnally active. This could account for the relatively small numbers obtained in diurnal sampling. Taylor (unpublished) obtained an indication of increased activity in the early hours of the morning in M. monoceros during occupation of a 24 hour station between Esengeni and the Mpate River in the Narrows in February 1979. This requires confirmation.

The restriction of P. indicus to muddy substrates is noteworthy in relation to its diet (Joubert & Davies, 1966), Bolt's (1975) benthic studies and Blaber's (1976) observations on food resource partitioning by mullet in the St Lucia system. Penaeid prawns like mullet are benthic feeders. P. indicus in St Lucia concentrates on crustaceans, plant material and small molluscs (Joubert & Davies, 1966). Bolt (1975) has shown that the grab sampled benthos in the lake (as defined for this review) is similar on most substrates but the biomass is relatively much less on muddy than on sandy substrates. No benthic production figures exist, but it appears that P. indicus is localised in areas of least food. Blaber (1976) in describing mullet feeding behaviour in the lake showed that the different species utilised particular substrates down to a minimum mean size of about 150 μ . Known areas of finer particles where P. indicus appeared more common, occurred on the western shores of South Lake and in False Bay. There are no details on substrate types throughout the system but it appears that provided salinities are favourable the choice of habitat is a compromise between the possible disadvantage of a relatively low food supply and the advantages of shelter due to the generally turbid conditions and the lack of competition from benthic feeding mullet.

The situation in the Narrows appears different to the lake. This area typically has a much higher prawn density and is used almost exclusively by the bait fishery. This high carrying capacity was particularly apparent during the high salinity years 1970-1971 when most of the lake would have been inaccessible to the prawns. During this period catches taken by the bait fishery showed some decline in CPUE (Champion, 1976) but no indication of a collapse. There was however a decline in the mean size of P. indicus from 1968 to 1971. Champion (1976) considered the possibility that this could have been due to local over-population and stunting in the Narrows area but as the sampling programme was terminated in 1971 he was unable to demonstrate a reversal in the trend following restoration of a normal salinity gradient.

There is still no real explanation for the high population densities of prawns in the Narrows but it will clearly be related at least partially to food supply. Information on the smaller benthic organisms and organic content of the substrate in the Narrows is minimal but it is notable that Bolt's data (1975 and unpublished report) suggested that there were some differences in the species composition and density between the Narrows and the lake and apparently a much higher biomass than on similar muddy substrates in the lake. There would be a continuous input of organic material from the fringing macrophytes which would help in the maintenance of both the grab sampled-benthos and the penaeids. Decomposing vegetation, particularly Phragmites sp. was common in beam trawls.

2.1.3 The bait fishery

Fishing technique and effort has remained virtually constant since before 1966. The fishing fleet consists of a maximum of three boats using beam trawls (Champion, 1976). Fishing effort is largely tailored to demand and the major variation in effort is the number of days fished. Champion (1976) obtained accurate effort data for the period May 1968 to March 1973 but prior and subsequent to this period fishing days have been the only measure of effort. There are no long term records of the number of boats involved in each day's fishing nor on the actual time spent netting. Champion (1976) attempted to establish a relation between "fishing days" and "boat hours". It is uncertain whether "boat hours" refers to actual fishing time. He did obtain a reasonable correlation between the two parameters. Measures of effort are nevertheless crude and consequently relatively insensitive. The data do however, extend over a period of 13 years and it could be expected that gross trends would be apparent. Data for 1967-1981 are summarised in Figure 1. There appears to have been a decline in total catch over this period with a few notable peaks and troughs. The decline in total catch from 1970 to 1972 followed a period of hyper-salinity (Champion, 1976). The low catch of 1975-1976 was during a period of virtually fresh water conditions. Peaks in 1973-1974 coincided with peaks in bird breeding (Berruti, pers. comm.), and presumably reflect generally favourable conditions in the system. Effort during the 13 year period measured in fishing days has remained fairly constant. CPUE, expressed as cartons per fishing day has remained remarkably constant during the 13 year period. At present rates of exploitation and allowing for the crudity of the data the results of these more recent data support Champion's (1976) conclusion that "commercial harvesting falls within the biological tolerance of the prawn population".

Concern has been expressed at times for the general impact

of netting on the system. This would presumably act in one of the following ways: i) removal of a source of food from other species preying on the prawns; ii) habitat modification or destruction by netting; iii) destruction of other species caught during the netting process.

Whitfield & Blaber (1978) have shown that none of the fish in the St Lucia system are dependent upon the penaeid prawns for food. The major species preying on penaeids are Argyrosomus hololepidotus and Elops machnata. In these species penaeids have been found to make up 6 to 16% of the diet by mass respectively. Other species of fish such as Platycephalus indicus and also various wading birds are known to take penaeids but the significance in their diets is doubtful. It thus appears unlikely that the bait fishery is competing with other predators in the system.

Netting operations are carried out almost entirely in the Narrows which is an area consisting mainly of soft mud. Tidal and wind induced currents are sufficient to maintain large amounts of this material in suspension so that there is continual sediment transport. Additional disturbance is unlikely to be significant.

Mortalities will undoubtedly occur in fish taken inadvertently in the prawn nets. The extent and impact of this destruction are unknown.

2.2 Macrobrachium spp.

2.2.1 Introduction

Macrobrachium equidens was recorded in the St Lucia system during the UCT surveys of 1948-1965 and described as "present to abundant throughout" (Millard & Broekhuysen, 1970). During 1975-1976 increasing numbers of M. equidens appeared in the prawn bait fishery catches. In April-June 1976 this species apparently made up more than 30% of the total bait catch and by January-March 1977 some samples in the Narrows contained only M. equidens (Joubert, unpublished reports). With the increasing importance of M. equidens in the bait fishery and declining catches of penaeids a sampling programme was initiated by Forbes & Bickerton (unpublished). This was designed to investigate the distribution of M. equidens in the system and to estimate population abundance in different areas using mark-recapture techniques.

2.2.2 Synthesis of results

The taxonomy of the genus is complex and inadequately known. M. equidens is the largest species in the system but a new record, M. scabriculum, was obtained as well as a probable third smaller species. M. scabriculum was typically associated with submerged vegetation and often in areas of localised low salinities such as at the mouths of streams. The small species was typical of the lower Narrows area.

The sampling programme covered the area from Honeymoon Bend to the southern part of North Lake. The full range of habitat types available in this area was sampled. The prawns were found to be restricted to shallow water areas along the margins. Abundance was greater in the Narrows despite seasonal fluctuations. There appeared to be movement in and out of the lake as numbers were higher in summer than in winter. Numbers obtained at the northern stations were always low. No attempt was made to sample the entire lake.

The changing seasonal abundance in the lake can be related to a combination of salinity and temperature. Very low salinities prevailed in the lake during winter 1976 and 1977. It has been shown experimentally that M. equidens becomes inactive at a combination of lake winter temperatures and very low salinities. (Forbes, unpublished). M. equidens was present in the lake in low numbers over winter in 1978 when salinities had risen to 5-14ppt.

Associations with particular habitat types were not always apparent because of seasonal fluctuations but the prawns appeared to avoid areas of clear water as on the eastern shores and also areas of greater wave action. Favoured areas typically were muddy and hence turbid. There was a degree of association with vegetation whether submerged or emergent but this was not rigid. The major areas of abundance were in the Narrows and to a lesser extent along parts of the western lake shores as far as Fannies Island. Abundance in the Narrows ranged from 1000 - 2000 per 200 m in winter to 3000 - 6000 per 200 m in summer.

The conditions which led to the build-up of the Macrobrachium spp. populations are still uncertain but probably relate to the low salinity regime during this period and the effects of these salinities on other associated species. During the build-up there was a drop in the CPUE of penaeid prawns which slowly recovered after 1976 coinciding with the decline of the Macrobrachium spp. The areas favoured by the Macrobrachium spp. apart from M. scabriculum, were those supporting the penaeid fishery. As P. indicus tends to avoid areas of low salinities (De

Freitas, pers. comm.) it appears that in the absence of this species, the Macrobrachium spp. were able to colonise a largely vacant habitat because of their greater tolerance to low salinities. Restoration of higher salinities improved conditions but also eventually allowed the build-up of P. indicus and the exclusion of M. equidens.

2.3 Scylla serrata (Forsk.)

2.3.1 Introduction

This is an extremely wide-spread species in the Indo-Pacific. Like many of the penaeids it uses estuaries or shallow muddy inshore areas as nursery grounds and is accordingly eurhaline. Juveniles will tolerate 2ppt. but not fresh water. In high salinity conditions it will still feed at 56ppt. but becomes sluggish at 60ppt. and has an upper limit of about 65ppt. (Hill, 1979). Juveniles move into south-east African estuaries in late winter-early spring (Hill, 1979). The males remain in the estuarine environment but the females emigrate to sea in February-March.

2.3.2 Synthesis of Results

S. serrata was listed by Millard & Broekhuysen (1970) as occurring on mud banks in the St Lucia system but was generally present throughout at salinities of 8,6 - 37,6ppt. Its known euryhalinity would suit it to the St Lucia system but it will still be excluded from parts of the lake at times.

The only specific study of S. serrata in the St Lucia system was done by Hill (1979) in January 1977. A normal salinity gradient existed during the period of the survey with minimum salinities of 2-4ppt. in False Bay and 4-6ppt. in North Lake. He did not consider these salinities to be limiting. For the purposes of the survey he divided the system into four regions : i) the Narrows from the road bridge north to Potter's Channel; ii) South Lake north to Fanie's Island; iii) north of Fanie's Island to Bird Island excluding the north and north-eastern areas, and iv) False Bay excluding the extreme north and south areas. He trapped at 36 sites and used a relationship between CPUE and population size established in the eastern Cape to estimate the total lake population. He estimated a minimum total population of 179000 made up of 51000 in the Narrows, 92000 in the South Lake and 36000 in North Lake. It is not known

whether this represents an average annual population. The population density was highest in the Narrows while in the Lake the crabs were commonest on the muddy bottom of the western shores although they were absent from False Bay. Hill (1979) considered the population density to be low even in the Narrows where the density was less than half that of the Kleinemonde estuary in the Eastern Cape.

S. serrata in the St Lucia system appears to follow the penaeid prawns (Joubert & Davies, 1966) and the Macrobrachium spp. (Forbes & Bickerton, unpub.) in both distribution and areas of population concentration. The diet of all three appears broadly similar. Hill (1979) reported that during the study period fragments of Lamya capensis (= Brachidontes virgiliae) were found in 48% of crabs examined, remains of Hymenosoma orbiculare and Tylodiplax blephariskios in 16% and further unidentifiable crustacean remains in 12%. Assiminea bifasciata was found in 4% which fits in with the preference of the crabs for muddy areas and the Narrows where this snail was relatively uncommon (Boltt, 1975 and unpublished).

2.4 Mollusca

2.4.1 Introduction

Under this heading are included several species of typically burrowing bivalves. While a variety of estuarine species exist in South Africa a limited number of systems appear to provide suitable environments and accordingly information is limited.

2.4.2 Synthesis of Results

Data on the larger species of the St Lucia system are largely restricted to the species records, distributional data and salinity ranges given by Millard & Broekhuysen (1970). The only investigation of the effects of hyper-saline conditions was done by Wallace (1969). He sampled areas near Charter's Creek, Fanie's Island, between Lane Island and Hell's Gates, between Bird Island and the Nibela peninsula and off Lister's Point in False Bay using a cone dredge. Sampling was done between January and March 1969 when there was a reversed salinity gradient. During this period salinities increased from 40 to 50 ppt. in the Charter's Creek area and from 80 to 90ppt. in False Bay and North Lake. He obtained living specimens of the bivalves Solen cylindraceus, Eumarcia kockii and Theora lata as well as the gastropod Nassarius kraussiana in South Lake but except for a few juvenile S. cylindraceus near Lane Island

no specimens were obtained in North Lake nor False Bay. The upper salinity limits appeared to be as follows: S. cylindraceus adults 64ppt., juveniles 70ppt.; E. kochii, between 55-64ppt.; T. lata between 65-70ppt. and N. kraussiana about 65ppt. There is no information on breeding, growth, biomass, feeding nor details on parameters apart from salinity affecting the distribution of any of these species. They have been implicated as food sources for grunter Pomadasys commersonni but no details are available (Blaber, pers. comm.)

3 Discussion and possible lines of research

All investigations with the possible exception of the studies on the caridean prawn genus Macrobrachium have suffered from the problem of lack of continuity. The majority of benthic studies in the St Lucia system have attempted to provide short term answers to questions which have frequently related to the periodic development of hyper-saline conditions. Many of the common invertebrate inhabitants of the system are able to tolerate salinities up to 60ppt. but there is no information on their response to very low salinities which would be as stressful as hyper-salinities. As salinity cycles in the lake from hyper-saline to fresh water conditions may take 10 years this emphasises the importance of long term monitoring.

Long term responses to salinity fluctuations would be most marked in species resident in the system such as the bivalves and Macrobrachium spp. The bivalves are very poorly known. Apparently favourable conditions during the years 1975-1979 allowed a very marked build-up of Macrobrachium spp. followed by a decline to their more normal background numbers.

Of the non-resident species, fluctuations in abundance of Scylla serrata have not been recorded. The penaeids are better known because of the bait fishery data. The populations of these species in the system are dependent on marine breeding stocks. The extent of annual fluctuations in the magnitude of this recruitment are unknown. There is no proof that the marine breeding stock is dependent on emigration from St Lucia so that even if conditions are unfavourable during one year this need not impair recruitment and hence population size in the following year. CPUE data from the prawn fishery indicate relatively small population fluctuations. Monitoring of recruitment would however have predictive value and would be an important management tool. A measure of the importance of the lake to the penaeid prawns would also be of significance to the fishery.

Research to date suggests that because of its normally low

numbers the Macrobrachium spp. are not a significant long term component of the St Lucia food web. The importance of the bivalves has been suggested but as little is known of their abundance, distribution and predators only speculation is presently possible. They are clearly a prime research target.

Only a single S. serrata survey has been done and there is no indication whether the population estimates were typical or not. This would require further investigation. The role of S. serrata in the food web is problematic. Fish predation on large crabs is unlikely and their significance to other possible predators such as water mongoose and crocodile is uncertain. Except for the resident males they possibly represent a net removal of energy from the system.

The significance of the penaeids in the food web has similarly been questioned. It appears that they are preyed on by very few fish and then to a limited extent. This requires confirmation but has implications for the bait fishery which amongst other constraints has been limited by considerations of the possible impact on associated species. It has been suggested in this review and elsewhere that the penaeid stocks are not at present in danger of over-exploitation. Future development of this valuable fishery will depend on a number of factors. At present levels of exploitation no management appears necessary. Bait demand has however been increasing and rationing is presently imposed. Importation of bait requirements would raise prices well above the present very cheap rates and could lead to pressure to extend the existing fishery. If this occurs improved monitoring of the fishery would be imperative.

Many of the present difficulties and gaps in understanding of the St Lucia system arise from a lack of integration of the studies that have been done and tremendous emphasis that has been placed on salinity effects and hyper-saline conditions in particular. While salinity will obviously be an over-riding factor at times, other influences such as substrate type, substrate organic content, detrital input, turbidity, feeding behaviour and interactions among all benthos associated species should be considered.

REFERENCES

- BLABER, S.J.M. (1976). The food and feeding ecology of Mugilidae in the St Lucia lake system. *Journal of the Linnean Society (Biology)* 8: 267-277.
- BOLTT, R.E. (1974). Benthic studies in St Lucia: Progress report 1973/74. Unpublished report submitted to Natal

Parks Board.

- BOLTT, R.E. (1975). The benthos of some southern African lakes. Part V: The recovery of the benthic fauna of St Lucia lake following a period of excessively high salinity. Transactions of the Royal Society of South Africa. 41(3): 295-323.
- CHAMPION, H.F.O. (1976). Recent prawn research at St Lucia with notes on the bait fishery. St Lucia Scientific Advisory Council Workshop Meeting, Charter's Creek.
- CRASS, R.S. (1957). St Lucia Lake: Bait netting. Unpublished report submitted to the Natal Parks Board.
- DAY, J.H., MILLARD, N.A.H. & BROEKHUYSEN, G.J. (1954). The ecology of South African estuaries. Part 4. The St Lucia system. Transactions of the Royal Society of South Africa. 34: 129-156.
- HILL, B.J. (1979). Biology of the crab Scylla serrata (Forsk.) in the St Lucia system. Transactions of the Royal Society of South Africa. 44 (1): 55-62.
- HUGHES, D.A. (1966). Investigations of the "nursery areas" and habitat preferences of juvenile penaeid prawns in the Mozambique. Journal of Applied Ecology. 3: 349-354.
- JOUBERT, L.S. & DAVIES, D.H. (1966). The penaeid prawns of the St Lucia Lake system. Investigational Report No. 13. Oceanographic Research Institute, Durban.
- MILLARD, N.A.H. & BROEKHUYSEN, G.J. (1970). The ecology of South African estuaries. Part X. St Lucia: A second report. Zoologica Africana. 5(2): 277-307.
- WALLACE, J.H. (1969). Some effects of recent high salinities on the fish and molluscan shellfish life in St Lucia Lake. Unpublished report of the Oceanographic Research Institute Durban. 5 pp.
- WHITFIELD, A.K. & BLABER, S.J.M. (1978). Food and feeding ecology of piscivorous fishes at Lake St Lucia, Zululand. Journal of Fish Biology. 13: 675-691.
- ZEIN-ALDIN, Z.P. & ALDRICH, D.V. (1965). Growth and survival of post-larval Penaeus aztecus under controlled conditions of temperature and salinity. Biological Bulletin. 129(2) 199-216.