A REVIEW OF THE COMMERCIAL, SHALLOW WATER PENAEID PRAWN RESOURCE OF SOUTH AFRICA:
Status, Fisheries, Aquaculture and Management

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by

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TERMS OF REFERENCE

Marine and Estuarine Research cc was contracted by Ezemvelo KZN Wildlife to put together a review detailing all the available information on the South African shallow water penaeid prawn resource. The work was funded by the Marine Living Resources Fund to aid management of the KZN crustacean fisheries. The mandate given to the consultant was to collate all available information and recommend wherever possible "best practice" actions which would inform management and enhance the conservation of the prawn stocks and ecological functioning of their associated habitats.

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Status, Fisheries and Aquaculture

1 INTRODUCTION

The penaeid prawns, or shrimps as they are referred to outside the Indian and western Pacific Oceans, have a world-wide distribution in tropical and sub-tropical seas within the 20^{o}C isotherms. They are most varied in the Indo-Pacific where there are roughly five times more species than in the Atlantic. The Indo-Pacific region, which stretches from eastern Australia and the Philippines to eastern and southern Africa, supports 125 species of which 124 are endemic. The Indo-Malaysian sub-region which encompasses the area from Sri Lanka and the Bay of Bengal to the Philippines and the northern coast of Papua New Guinea supports 85 species with 25 endemics and is the centre of diversity in the Indo-Pacific region. Diversity and endemism decrease in all directions from this sub-region declining to 16 species and one endemic in the southern African region which stretches from Durban to Swakopmund (Dall, Hill, Rothlisberg & Staples 1990).

The life cycles in all known members of the family Penaeidae involve planktonic larvae with a variety of naupliar, protozoeal, mysis and postlarval stages, followed by juvenile and adult stages (Figure 1). The greatest differences between the species lie in the preferred habitats of postlarvae, juveniles and adults *i.e.* whether they are predominantly estuarine, inshore or offshore, and whether demersal or pelagic. Depending on these preferences, Dall *et al.* (1990) recognized four different types.

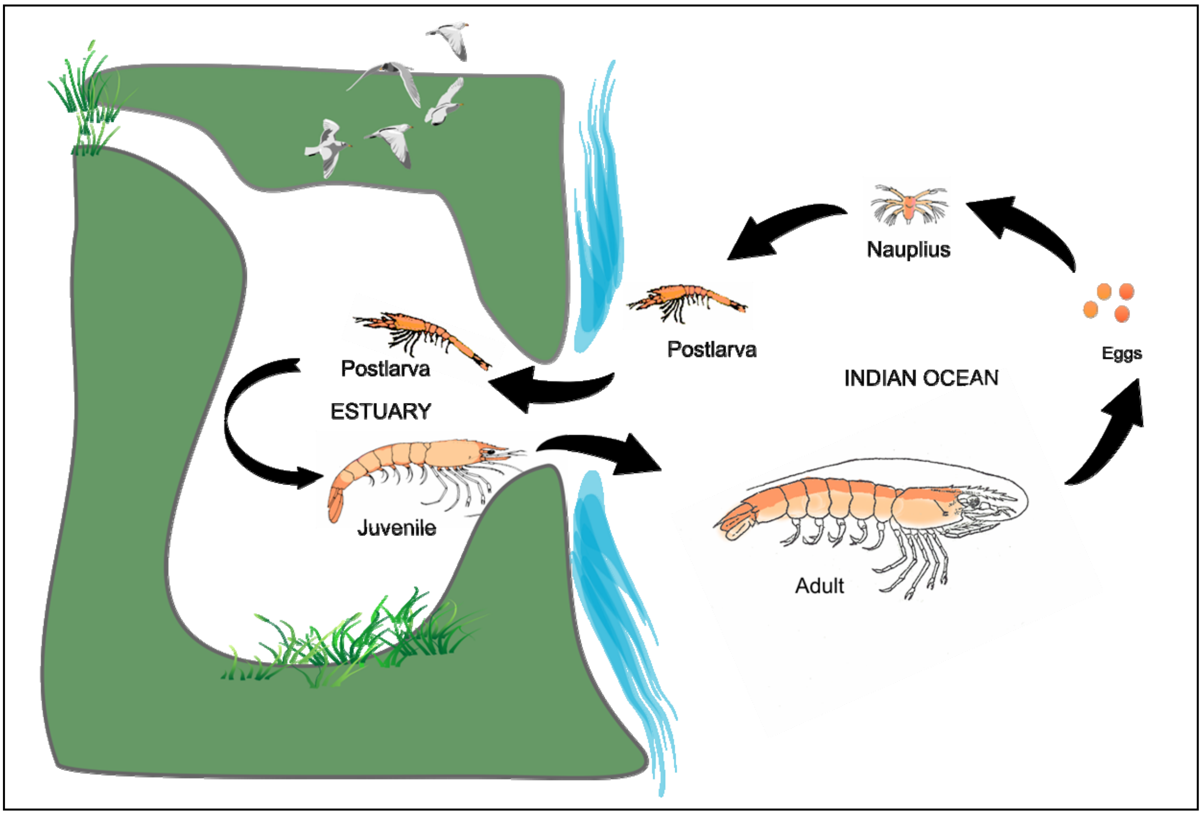

Figure 1: Life cycle of a typical Type 2 shallow water penaeid prawn.

Type 1 species appear to be restricted to smaller members of the genus *Metapenaeus* and may have entirely estuarine life cycles in which the postlarvae move upstream into lower salinities while the juveniles subsequently return towards higher salinities in the lower estuary, mature and breed. No South African examples exist.

The postlarvae of most Type 2 species prefer estuaries or estuarine-like environments. This preference is characteristic of most *Penaeus* and *Metapenaeus* species including all the commercial South African examples. This habitat preference demands a degree of euryhalinity because of the salinity fluctuations typical of estuaries, but this tolerance does vary from species to species. Species specific substratum preferences are typical of these estuarine juvenile stages and heterogeneous estuarine environments incorporating a variety of habitats will support a greater variety of species.

During maturation the juveniles or sub-adults emigrate from the estuaries to the offshore adult breeding grounds. The size or degree of maturity at emigration varies from species to species. Substratum preferences characteristic of the juveniles tend to be maintained in the adult phases.

The larvae of Type 3 species are pelagic while the postlarvae prefer relatively high salinity, usually sheltered, inshore waters. The adults remain in the marine environment. The only South African example of this type is the endemic, cool water, non-commercial *Macropetasma africanus.*

Type 4 species have an entirely offshore life cycle and while some of these species are harvested in South African waters they are not the subject of the present review.

The life span of most coastal penaeids is between one and two years in the tropics but may be longer in cooler, more temperate waters where growth rates would be slower. Laboratory development time from spawning to postlarva is about eight to 24 days, largely depending on temperature, while estimates of field durations are about 14-21 days. Recruitment of the postlarvae to the estuarine nursery grounds from the adult breeding grounds offshore is followed by a period of growth in the estuaries after which the juveniles or subadults return to the marine environment and complete their growth phase. There is no known deviation from this cycle in the South African species.

Virtually wherever they occur, prawns with a Type 2 life cycle are exploited in both the juvenile, estuarine phase and in the offshore, adult breeding phase. As might be imagined, this situation can be a cause for conflict between users of the juvenile and adult resources with each group of fishers claiming that their particular “rights” are being infringed. In recent years a third pressure has developed, although this has not yet occurred in South Africa, in that the immigrating postlarvae are collected for sale to aquaculturists as “seed stock”.

This review will attempt to synthesise available historical and recent information on the shallow water, commercial prawn species of South Africa as regards:

- the species involved, their distribution, life cycles and biology
- immigration and emigration – movement, dispersal and origin of South African populations
- population dynamics
- the South African prawn fishery under the headings:
  - the offshore fishing grounds,
  - the trawl fleet
  - the catch composition, size, variability and trends,
  - the estuarine bait fisheries – history and status
  - status and threats to the major prawn nursery grounds and the offshore habitat - the future of South African prawn stocks
- history, status and future of prawn farming in South Africa
- bycatch
- management

2 METHODOLOGY

Use was made of the published literature, which is listed at the end of the report, unpublished personal field observations and data on catches and the results of tagging programmes carried out in Richards Bay and St Lucia, unpublished catch data obtained from the records of the Chief Directorate: Marine and Coastal Management, minutes of the Prawn Fisheries and Development Association and input from various people who have been involved in different ways with the prawn resource in KwaZulu-Natal and elsewhere in the country. The latter are acknowledged at the end of the review.

3 REVIEW OF AVAILABLE KNOWLEDGE AND INFORMATION

3.1 Prawns in South Africa: the species, their distribution, life cycles and biology

The warm, southward flowing Agulhas Current on the east coast of Africa results in an extension of the tropical and sub-tropical fauna of the western Indian Ocean into the South African region (Macnae 1962). There is a rapid attenuation of this fauna, including the penaeid prawns, towards the southern boundary of KwaZulu-Natal although the seasonal occurrence of prawns in estuaries at least as far south as Port Elizabeth has long been appreciated by local anglers (Hughes 1966).

Recent revisions by Perez Farfante & Kensley (1997) of what were previously sub-genera within the genus *Penaeus* have resulted in the following name changes at the generic level. *P. indicus* is now *Fenneropenaeus indicus*, *P. japonicus* is now *Marsupenaeus japonicus*, *P. canaliculatus* and *P. latisulcatus* are now *Melicertus canaliculatus* and *M. latisulcatus. P. monodon*, *P. semisulcatus* and *Metapenaeus monoceros* remain unchanged.

The seven species recorded in the region are listed in Table 1. Of the total of seven, *M. canaliculatus* the striped prawn and *M. latisulcatus* the western king prawn or brown prawn as it is known in the South African region, although having very wide distributions in the Indian and western Pacific Oceans (Dall *et al.* 1990), are by far the least common and the least known in the region and for the sake of the present review will be disregarded. They do not contribute to the commercial catch.

The southern limits of distribution of all the above species (Table 1) are indicative of their tropical affinities. The records mentioned in the table in some cases (Day, Millard & Harrison 1952, Hughes 1970) reflect collections by the authors concerned but in the others are based partly on museum specimens (Barnard 1950) or literature records. Lack of agreement between the different authors is striking. It would presumably be expected that, over time, recorded southern limits for species such as these with their offshore planktonic larval stages, are more likely to expand but in some cases the same author (Day *et al.* 1952; Day 1968) extended a species range in one case (*M. japonicus)* but reduced it in another (*F. indicus)*. Overall, the number of species recorded increased from five at St Lucia (Joubert & Davies 1966) to seven at Durban (Joubert 1965), dropping again to five in the Swartkops estuary at Port Elizabeth (Hughes 1970). Only two species have been recorded beyond Port Elizabeth, *viz. F. indicus* as far as Knysna, and *M. japonicus* from the Breede River (Day 1968) or "False Bay" (Branch *et al.* 1994).

Table 1: Distribution records of penaeid prawns in South Africa. See Figure 2 for places and rivers mentioned in the table.

Author	*M. canaliculatus* **Olivier**	*F. indicus Milne-Edwards*	*M. japonicus* **Bate**	*M. latisulcatus* **Kishinouye**	*P. monodon* **Fabricius**	*P. semisulcatus* **de Haan**	*M. monoceros* **Fabricius**
Barnard 1950	Port Edward	Swartkops R. Port Elizabeth	Knysna	No record	Swartkops	No record	Cape Henderson, north of East London
Day *et al.* 1952		Knysna	Knysna				
Hughes 1966	Swartkops R.	Swartkops R.	Swartkops R.	Swartkops R.	Swartlops R.	No record	No record
De Freitas 1980	Swartkops R.	Knysna	Knysna	Durban Bay	Swartkops R.	Durban Bay	Durban Bay & off Port St Johns
Day 1968	East London	Keiskama R.	Breede R.	No record	Bashee R.	Durban Bay	Keiskama R.
Branch *et al. 1994*	East London	"Transkei"	False Bay	No record	No comment	Durban Bay	East London

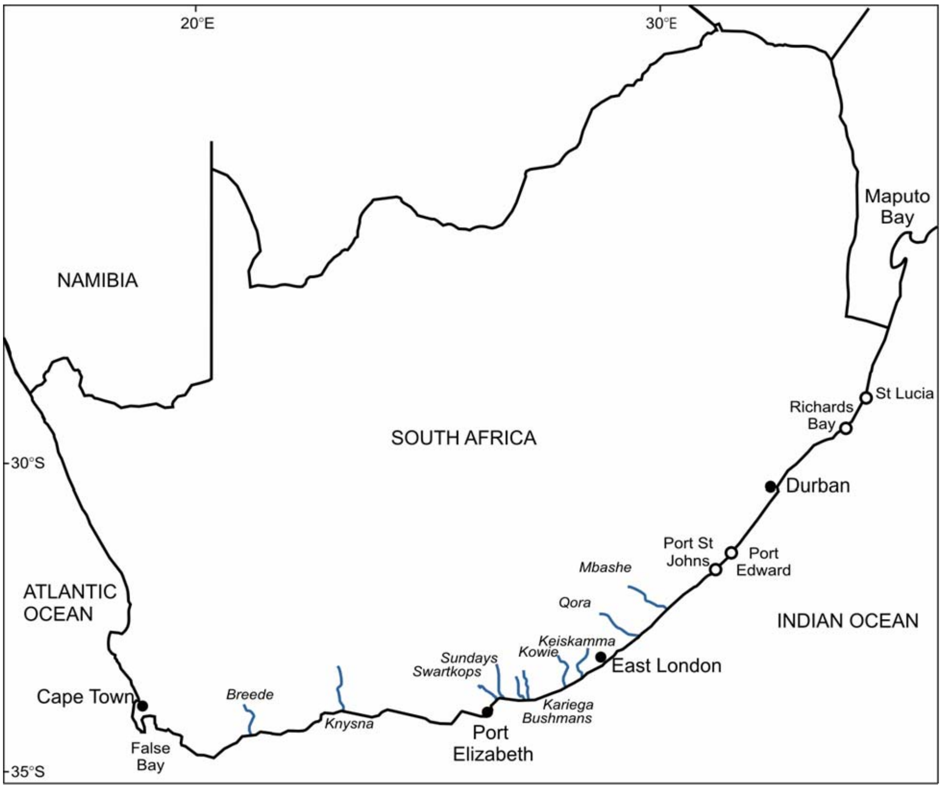

Figure 2: *Map of South Africa showing places and rivers mentioned in the text.*

At the southerly limits of their range the penaeids are known primarily from their estuarine juvenile habitats in rivers such as the Kowie, Kariega, Bushmans, Sundays (personal conversations with local fishermen) and from the Swartkops (Hughes 1970). In all cases the description from the anglers was that the prawns “came into” the estuaries in late summer, particularly March and April and were usually about 12 cm in length (Hughes *loc.cit.)*. Assuming that the species involved was primarily *F. indicus,* which is by far the commonest in South African waters, the appearance in Eastern Cape estuaries corresponds with the end of summer period of emigration characteristic of this species in the estuaries of KwaZulu-Natal where it is more common. The description of the prawns as “coming into” the Eastern Cape estuaries at a size and time when they are typically emigrating from estuarine nursery grounds to marine breeding grounds would represent a complete reversal of the normal migration pattern.

Presumably the late summer-early autumn prawn season in the Eastern Cape represents a period when the animals have reached a more noticeable size and are more obvious because they are actively migrating. The fate of these migrants is unknown but doubtful in terms of their potential for maintaining a local offshore population because of the relatively low local winter marine and estuarine temperatures which would preclude survival of eggs, larvae and juveniles.

A similar situation to the above prevails in the cases of the local shallow water spiny lobster or crayfish *Panulirus homarus* which, despite occurring as far south as the Port Elizabeth area, does not breed south of the Quoha River in the Transkei (Berry 1971). The large portunid crab *Scylla serrata*, variously known as the mangrove, mud or Knysna crab, depending on the locality, also occurs erratically in estuaries of the eastern and southern Cape (Robertson 1996). In all cases it appears that these occurrences, which are generally more erratic in the short lived prawns, are dependent on the transport of planktonic larvae by ocean currents from breeding populations further north. This situation was recognized over 40 years ago by MacNae (1962) although he was then presumably unaware of the prawn population on the Thukela Banks as he took the suggestion much further and proposed that "the penaeid prawns of the Bay of Lourenco Marques (Maputo) and of Natal bays and estuaries are not of local origin but derived from larvae washed in from further north". He did not specify how much further north. This possibility in relation to the prawns will be dealt with at a later stage.

Prawn benthic habitat preferences are typically well defined in the juvenile stages, which occur in estuarine nursery grounds, and also in the adult stages which occur on the offshore but generally shallow breeding habitats. In the southern African situation more information is available regarding the juvenile than the adult preferences. There is no published information specifically on South African juvenile prawn habitat preferences but as the local species also occur in Mozambique, information derived from Maputo Bay, which is a relatively large system with a variety of benthic habitats, is incorporated here. In an early paper Hughes (1966) described the habitat preferences of *P. monodon, P. semisulcatus, F. indicus* and *Metapenaeus monoceros* in Maputo Bay. de Freitas (1986) extended this investigation to include *M. japonicus* and *Metapenaeus stebbingi*; the latter species has not been recorded south of Maputo Bay. de Freitas (*loc.cit.)* questioned Hughes' identification of *P. semisulcatus* and accordingly de Freitas' description of habitat preferences will be incorporated here. de Freitas selected 11 stations in Maputo Bay which were sampled for any prawns present. *P. semisulcatus* was obtained almost exclusively on intertidal flats covered with seagrasses. This accords with records from St Lucia where this species was uncommon and only obtained in *Zostera* beds (personal observations). *M. japonicus* in Maputo Bay was obtained only on intertidal flats in bare, sandy mud to muddy sand where it burrowed during day time or during low tides. This behaviour was mirrored in Durban Bay where push netters for many years collected "ginger shrimp" at night over sandy sediments in shallow water during low tide periods (Joubert 1965). de Freitas *(loc. cit.)* recorded *F. indicus* and *P. monodon* in similar habitat types although *F. indicus* was three times more abundant. Both species were most common in muddy areas within mangrove swamps. A similar situation prevailed in the major KZN nursery areas of St Lucia and Richards Bay where the bait prawn fisheries operated by the then Natal Parks Board in the muddy channels and backwaters of these two areas produced primarily the white prawn *F. indicus* and very much smaller numbers of the tiger prawn *P. monodon* and the speckled prawn *M. monoceros.* de Freitas *(loc.cit.)* described *M. monoceros* as occurring in a "more diverse number of habitats; from areas with submerged macrophytes to the deeper reaches of the mangrove swamps" and most individuals obtained were caught in "a low salinity zone" which was interpreted as demonstrating a greater tolerance of low salinities than the *Penaeus* species. Whether the occurrence of *M. monoceros* in low salinities represents a distinct preference is unknown. Unpublished observations of bait fishery catches and collections in St Lucia and Richards Bay supported the observations and conclusions reached in the Maputo Bay area.

A beam trawl survey of Richards Bay in 1996 -1997 (Weerts, Cilliers & Cyrus 2003) covered five sites including the traditional bait fishery areas in the west of the harbour, as well as three sandy areas in the south and north areas of the harbour. Five penaeid species were obtained, *viz. F. indicus, P. monodon, M. japonicus, M. canaliculatus* and *M. monoceros.* The most consistent of these was *M. japonicus* which occurred in all seasons in all areas but was more abundant at the sandier sites. *F. indicus* and *P. monodon* occurred only at the muddier sites or in areas adjoining mangroves; neither occurred at the two sandy northern sites. *M. monoceros* was present in all seasons and was the most common species in the muddy/mangrove sites. It was also recorded at one of the sandy sites. *M. canaliculatus* was recorded twice in the muddy, mangrove-lined western channel but at a lower density than any of the other species. The distribution patterns accorded with known habitat preferences and the survey also indicated that despite over 20 years of harbour operation suitable prawn habitats still existed in the mid '90's.

3.2 Immigration and emigration – movement, dispersal and origin of South African prawns

Day, Millard & Broekhuysen (1954) as well as Millard & Harrison (1954) all referred to the uncertainty at that time of the nature of the shallow water penaeid prawn life cycles in South Africa. As indicated earlier, the fundamental nature of these life cycles is now well known for most of the commoner species, including the South African examples, although there are clearly still real differences between the species in terms of aspects such as habitat preference, diel behaviour, dietary preferences and growth rates. Despite a quite extensive literature, reviewed most recently by Dall *et al.* (1990), there are still many unknowns or uncertainties as regards aspects such as mechanisms of migration of larvae and postlarvae from marine breeding grounds into estuaries and subsequent emigration to adult habitats, and also the extent of dispersal of planktonic larval stages from the breeding grounds. It is also relevant that the combination of particular habitat requirements and availability of such habitats on the east coast of Africa due to the generally narrow continental shelf, results in prawn habitats, and therefore fisheries, being localised into specific areas in the western Indian Ocean, typically associated with suitable estuarine nursery grounds.

The life cycles of the local penaeid prawns (Figs. 1 & 3) are punctuated by two major events, firstly the transition from a marine planktonic larva to a benthic estuarine juvenile, which obviously represents a major morphological, physiological and behavioural transformation, and secondly the return of the juveniles or sub-adults from the estuarine nursery grounds to the offshore adult breeding grounds.

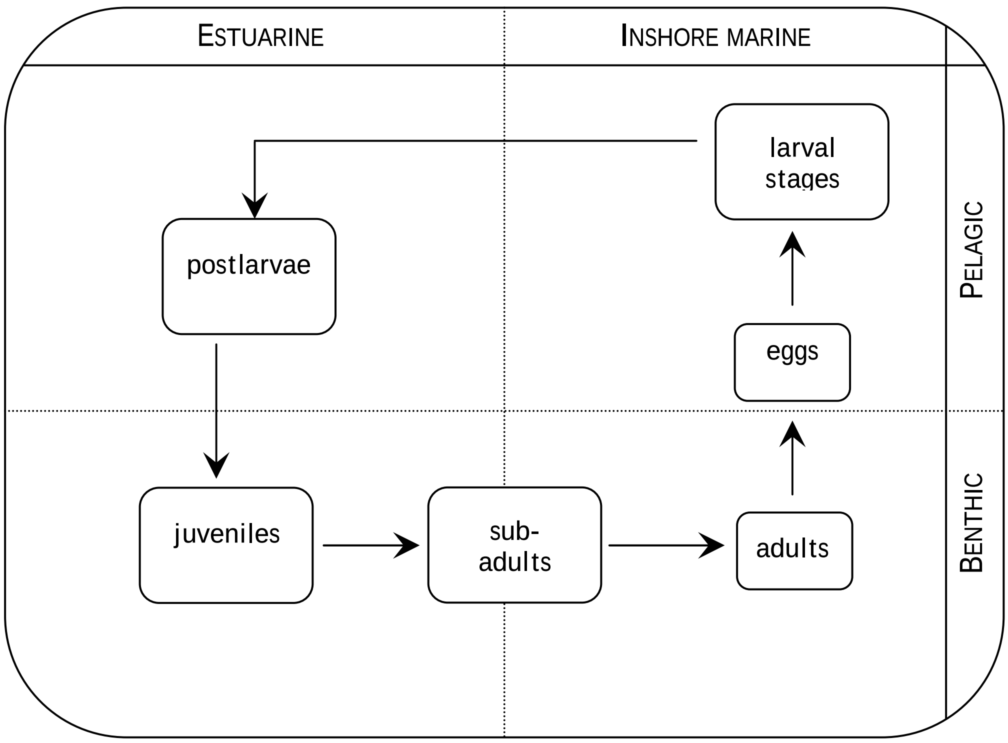

Figure 3: Diagrammatic representation of the penaeid life cycle detailing the habitats and behavioural changes.

The analyses of offshore catch species composition referred to earlier, and the presence of tiger prawns *P. monodon* only in the two largest commercial size classes indicate a minimum threshold size before emigration in this species. The emigration of *P. indicus* is a more protracted process and involves a wider range of size classes beginning well before adult size is reached, as shown by the presence of individuals of this species in the smallest offshore commercial size classes.

The mechanisms involved in migration from breeding grounds to estuarine nurseries in *P. plebejus* in Australia have been discussed by Rothlisberg, Church & Fandry (1995) but not investigated experimentally. Available evidence indicates that larval migration in any of the Type 2 penaeid species does not involve active swimming up some sort of concentration gradient but rather the selective use of currents based on active vertical migration. The details of the integration of this process with the accessing of suitable currents remains to be clarified. Subsequent movement and dispersal in estuaries represents a different process as these occur in a tidal environment where currents flow in opposite directions at regular intervals. This latter phase coincides with the transformation of the planktonic, migratory postlarval stage into the benthic, substratum specific juvenile.

It was apparent from the St Lucia study that there was very little variation in the size of the postlarvae recruiting into that system in any one species. More than 80% of *F. indicus, P. japonicus* and *P. semisulcatus* postlarvae had carapace lengths between 1.5 and 2 mm; more than 90% of *P. monodon* and 75% of *M. monoceros* fell between 2 and 3 mm (Forbes & Benfield 1986). The conclusion arising from this situation was that immigration and dispersal of postlarvae in estuarine environments involves a very specific set of behavioural cues and responses which are associated with a particular period in the development of the prawn. The stages preceding the postlarvae are entirely planktonic while the subsequent juvenile stages are essentially benthic. The post-larvae are intermediate, alternating between planktonic and benthic phases following a largely tidal, diel or lunar rhythm. The literature is replete with references to statements that postlarvae are most abundant in the estuarine water column over flood tide periods particularly at night and often over particular moon phases (Dall *et al.* 1990).

Possible cues to the above behaviour were investigated by Hughes (1969) who suggested that a salinity response was involved. He proposed and experimentally found support for an hypothesis that post-larvae on the bottom responded to increasing salinities associated with flood tides by becoming more active and thereby being transported upstream. During subsequent slack water the post-larvae sank back to the bottom. Falling salinities during ebb tides did not elicit any response but the subsequent flood tide and increasing salinities again resulted in greater activity and further transport upstream. This process would be repeated and would result in net upstream transport and the possibility of the postlarva locating a suitable substratum on which to settle.

The possibility of an additional mechanism was investigated by Forbes & Benfield (1986) in relation to the St Lucia system where Champion (1976) noted that prawns were still present in the Narrows during periods of hyper-salinity, *i.e.* when salinities in the lake were greater than sea-water. This situation was at odds with the Hughes (1969) model which was predicated on a normal estuarine salinity gradient, *i.e.* one in which salinities declined upstream. Wickham (1967) established the presence of a pressure response in *P. duorarum* juveniles in the U.S.A although this was discarded as a possible mechanism for migration by Penn (1975) in the case of *P. latisulcatus* in Shark Bay in Western Australia because of the depth at which the postlarvae and juveniles occurred and the small local tidal range.

Forbes & Benfield (*loc.cit.)* investigated a possible pressure response in the postlarvae recruiting into the St Lucia system based on the hypothesis that a response by the postlarvae to increasing salinities during a flood tide in a normal estuary could be replaced by an ability to detect increasing hydrostatic pressures on the bottom resulting from depth increases during flood tides. Conversely, hydrostatic pressures would decrease on the bottom during ebb tides. In an experimental laboratory situation where postlarvae of *P. japonicus* were exposed to simulated pressure changes that would occur on the bottom in the St Lucia Narrows, the postlarvae responded by becoming more active under increasing pressures, a response which would have allowed them to be transported up the Narrows in a manner corresponding to the Hughes salinity response model. The pressure changes which generated increased activity were in the order of 1-2 kPa. Whether all species have a salinity or a pressure response or both and how either is selected is unknown.

Emigration of juveniles or sub-adults from the estuarine nursery grounds to the marine environment has been suggested to be triggered by minor flood events which would be a feature of the summer rainfall areas occupied by the penaeid prawns in South Africa. In addition, the major South African species *F. indicus,* is relatively sensitive to salinities < 10 and would not require major floods to be induced to leave the estuarine environment. At the same time it has been noted that, unlike *P. monodon* which only contributes to the offshore TG and TM categories, the smallest size classes in the offshore fishery include *F. indicus* and while estuarine catch records indicate that *F. indicus* seldom exceeds a carapace length of 25 mm in the estuaries under open mouth conditions, emigration begins well before this threshold is reached. The cues for this species are unknown.

Tagging experiments using Australian streamer tags were carried out in successive years (January 1990 and February 1991) in Richards Bay and St Lucia in an experiment sponsored by Natal Ocean Trawling. Five thousand prawns were tagged at Richards Bay and 1 550 at St Lucia.

Fifty four of the Richards Bay tagged animals were recovered from the Thukela Bank by the prawn fleet over a period between 44 and 135 days after release. Co-ordinates of the recovery sites indicated net movements of more than a kilometre per day in some cases. Fifteen of the prawns tagged at St Lucia in 1991 were captured by the prawn fleet on the Thukela Bank during the following season. In each case the recoveries amounted to *ca.* 1% of the tags.

The above operation was mounted in response to a user conflict situation between the then estuarine bait fisheries and the offshore trawl operation and a statement that the Bank prawns originated from Mozambique. While the tagging operation clearly demonstrated, as might have been expected on a geographical and proximity basis, that prawns from Richards Bay and St Lucia were contributing to the Bank catches, it obviously did not entirely resolve the question of input from Mozambique. Maputo Bay has historically supported a prawn fishery (de Freitas 1980) based largely on *F. indicus*. Maputo Bay and St Lucia are about 260 km apart with only the Kosi lakes and the small Mgobezeleni estuary between. Neither of these systems generate much silt due to the sandy nature of their catchments. The local neritic zone, and particularly the benthic habitat, are consequently totally unsuitable environments for the prawn species dominating the catch on the Thukela Bank. It therefore appears highly unlikely that juvenile prawns emigrating from the local Mozambican estuaries into Maputo Bay would be able to negotiate the intervening unfavourable environment and thereby contribute to any significant degree to the Thukela Bank population.

The above argument suggests that prawn stocks on the Thukela Bank are derived largely from KZN nursery grounds, and are dependent on juveniles emigrating particularly from the large systems of St Lucia and Richards Bay. A similar question arises in relation to the origin of postlarvae migrating into the KZN nursery grounds, *i.e.* are they derived from a Thukela Bank breeding population or is there an input from “further north” as suggested by MacNae (1962). Available genetic information on *P. indicus* (Querci 2003) and *P. monodon* (Forbes, Demetriades, Benzie & Ballment 1999) from Mozambique, Madagascar and South Africa does not indicate any distinction between populations from these areas. Penaeid prawns are, however, genetically highly conservative and this lack of any contrast cannot be taken as proof of regular genetic exchange between South African populations and those further north. As already mentioned, the habitat requirements and life cycles of the penaeid prawns result in the presence of isolated stocks in the entire western Indian Ocean region and the degree of exchange between them is unknown. In the absence of conclusive genetic evidence, an attempt was made to resolve the question of local larval sources by using data on postlarval recruitment into KZN estuaries comparing Kosi Bay, St Lucia, Richards Bay and Durban Bay. Forbes & Cyrus (1991) and Forbes, Niedinger & Demetriades (1994) described the contrast in the species composition of immigrating postlarvae between Kosi Bay, which was dominated by *P. japonicus* to the virtual exclusion of any other species, and the three more southerly systems in closer proximity to the Thukela Bank where, in addition to *P. japonicus*, there was recruitment of postlarval *F. indicus*, *P. monodon* and *M. monoceros.* Assuming a "northern source" and a south flowing current it would be expected that postlarval recruitment into estuaries en route southwards would be similar in species composition. The disparity between Kosi Bay and the more southerly systems of St Lucia, Richards Bay and Durban, where a greater variety of recruiting species was noted in all three systems, argues for a southern source of postlarvae and consequently a Thukela Bank – St Lucia/Richards Bay axis with a high degree of separation and independence of this southern stock from that in Mozambique.

3.3 Population dynamics

The dynamics of penaeid prawn populations world wide have long been a subject of study for research scientists and obviously of interest to the industry because of the fluctuations in annual population size and the consequent variations in annual catches which characterize these fast growing, highly fecund organisms. The catch is based on the generation of the year or the 0+ year class in fisheries terms. The biomass which contributes to the catch is therefore generated each year and there is none of the averaging effect seen in longer lived species where the total biomass of the population is based on a succession of generations or year classes.

The life strategy of fast growth and high fecundity and the variability of the habitats occupied, particularly as juveniles, because of their proximity and vulnerability to catchment processes can be seen as factors contributing to variations in annual generation size. Death rates in these fecund species are typically highest in the early stages of development; variations in these mortality or survival rates at these early stages are therefore the factors most likely to affect subsequent population sizes.

It is common cause amongst local trawler operators that a drought adversely affects the catches although they have no readily available explanation. This effect is not unique to South Africa; catches of the banana prawn *P. merguiensis* in the Gulf of Carpentaria in northern Australia have been strongly correlated with rainfall (Staples, Dall & Vance 1981). Initial correlation analysis (Demetriades, Forbes, Mwanyama & Quinn 2000) supported the relation between summer rain and offshore catches the following winter. Subsequent more detailed consideration of the possible interactions between *F. indicus* and catchment runoff included the possible negative effect of very low salinities in the nursery areas which would make them inaccessible and secondly the possibility of the introduction of terrestrially derived nutrients into the generally oligotrophic inshore waters of KZN which would contribute to phytoplankton production and thereby potentially enhance survival of the planktonic larval stages. Timing of the latter events was crucial and the model produced indicated that runoff in late winter-early spring when postlarvae were still recruiting to the estuaries was a critical period. Favourable conditions for larval development in combination with favourable nursery ground conditions for the juveniles would then be reflected in greater offshore catches in the following winter. There is not necessarily a clear correlation between estuarine abundance and subsequent offshore catches (Forbes & Benfield 1986) because of the variability in the sizes at which juvenile *F. indicus* leave the estuary. Reductions in salinity in the nursery grounds would simply act as a trigger for earlier emigration At this stage the relationships described above are still largely qualitative and will initially require, at a minimum, data on nutrient inputs to the Thukela Bank and some measure of phytoplankton production on the Bank to test the hypothesis.

Support for the acceptance of variations in postlarval abundance and estuarine recruitment was provided by sampling done between 1982 and 1992 at Kosi Bay, St Lucia, Richards Bay and Durban Bay (Figs. 2 & 4) (Forbes, Niedinger & Demetriades 1994). Unfortunately because of the nature of the work and the associated logistics it was impossible to sample all areas simultaneously and the possible significance of catchment runoff was not appreciated when the programme was begun. The available data are therefore patchy and cover St Lucia over the periods 1982 -1984 and 1988, Kosi Bay 1988 and early 1989, Richards Bay and Durban Bay mid 1991 – mid 1992. The most consistent species was *M. japonicus* but from the point of view of the fishery and the dominance of *F. indicus,* recruitment of this latter species into St Lucia was up to two orders of magnitude higher in 1988 than at any time over the period 1982-1984. 1982-1984 were drought years while 1988 was still showing the effects of cyclone Domoina four years earlier and coincided with record catches on the Bank.

3.4 The South African prawn fishery

3.4.1 The offshore fishing grounds.

There are few areas off the South African coast suitable for shallow water penaeid prawn trawling due to the very narrow continental shelf, particularly in the sub-tropical areas of northern KwaZulu-Natal

(KZN) which are the only areas warm enough to support a breeding population. The Thukela Bank off northern KwaZulu-Natal accordingly supports the southernmost commercial prawn fishery in the western Indian Ocean.

Much of the Bank has been built up by sediments transported by the Thukela River and deposited in the Natal Bight, which stretches roughly from Durban to Richard Bay and represents a slight indentation in the coastline, sheltered from the main force of the southward flowing Agulhas Current. The physical oceanography of the region is described in detail by Schumann (1988) and is graphically depicted in Figure 4.

The fishing grounds are situated on the Bank within the 50 m contour, and are centred off the Amatigulu (Matikulu) River between three and 20 km offshore. The shelf is at its widest in this area with the break about 50 km offshore (Fig. 4).

The trawlable grounds are limited to an area of about 200 km^2 (Fennessy 1995) due to the presence of low profile beachrock outcrops (Fennessy 1994a) which are avoided by trawlers. The trawl grounds also coincide with a mud depocentre, which is a rare environment along the east coast of South Africa, and which comprises about 10% of the shelf area (Demetriades & Forbes 1993). It arises from sediments brought down by rivers in the area, particularly the Thukela, and has developed because of current patterns and gyres which exist in the Natal bight shoreward of the main force of the Agulhas Current. The mud on the trawl grounds is grey and stiff with a low clay content (Flemming & Hay 1988). The muddy, relatively shallow bottom and the sediments brought down by the rivers result in a constant, relatively high turbidity in the water column particularly in the first few metres above the bottom. The three major species taken in the fishery, *viz. F. indicus, P. monodon* and *M. monoceros*, all occur in this habitat.

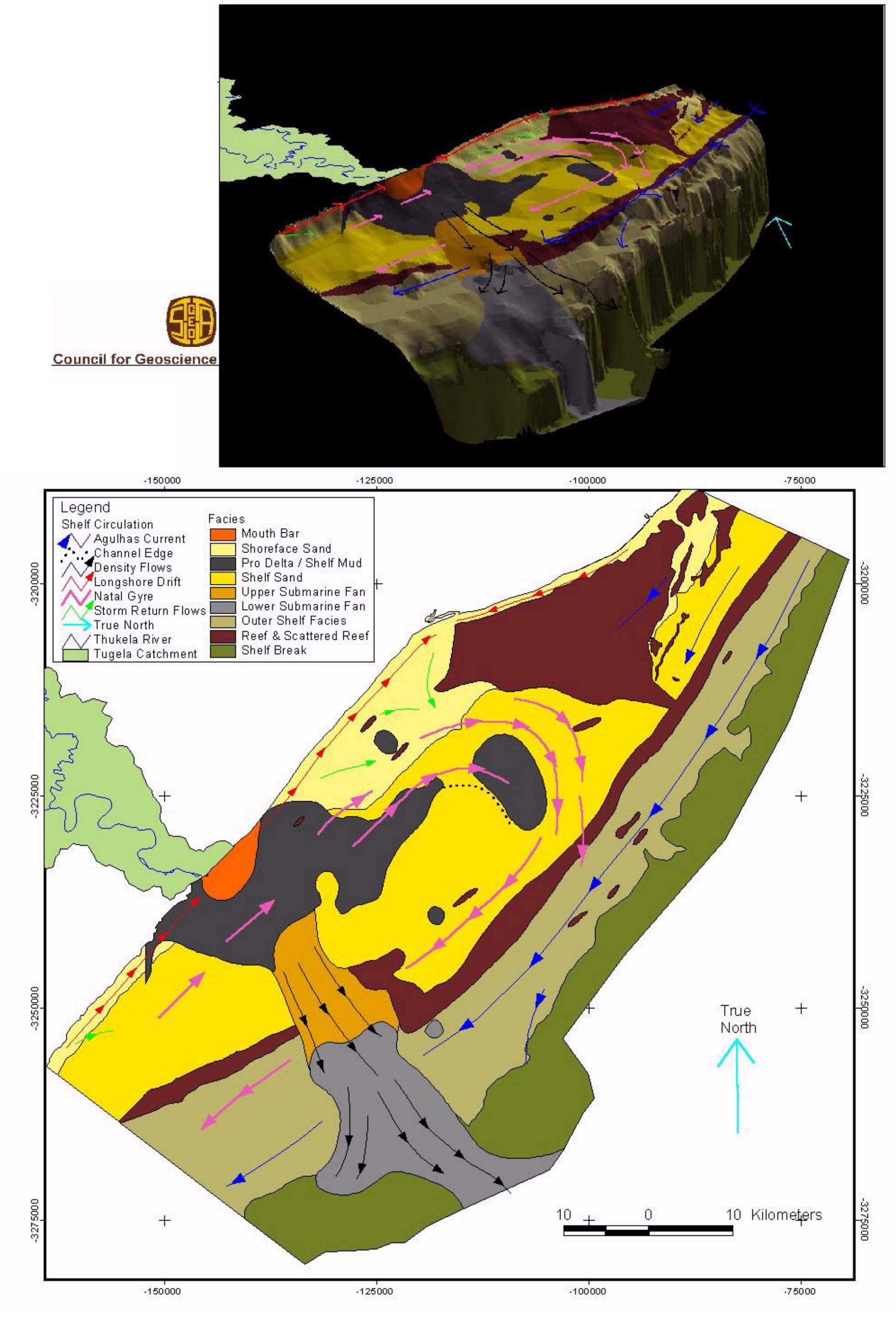

Figure 4: *Sediment map of the Thukela Bank and surrounding areas. Inset picture above provides a perspective view (from Forbes & Demetriades 2000)*

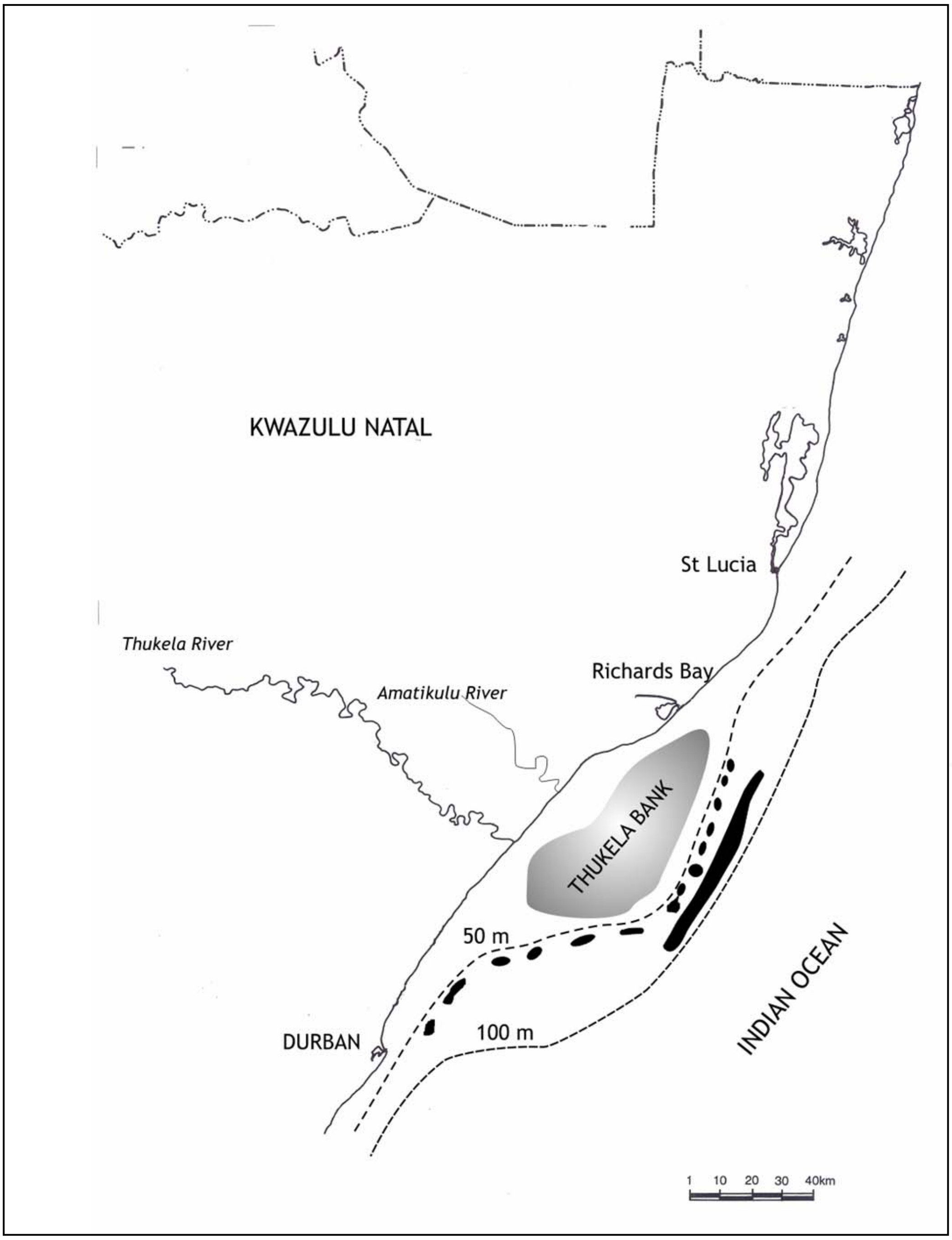

Figure 5 : *Map of the Kwazulu Natal coast showing the trawl grounds (shaded grey), reef (black) and the position of the two main estuarine nursery grounds*

The only other trawling ground is on the St Lucia Banks off the mouth of the St Lucia system (Fig. 5). This is much smaller and much less used than the Thukela Banks and has not been as well described. It appears to present a more sandy environment and *M. japonicus* is taken in this area. Experimental beam trawling off Richards Bay harbour to monitor effects of the local marine outfall is also carried out in a more sandy area than on the Thukela Banks and this has also generated catches of *P. japonicus* (Forbes, unpublished data).

3.4.2 The trawl fleet

The information in this section is derived largely from the review of the South African fishing industry synthesised by Sauer, Hecht, Britz & Mather (2003a & b). KZN prawn trawlers are steel vessels *(see inset photo A & B)* with overall lengths ranging from 25–35 m and main engines generating 300–600 kW. All are equipped with echo sounders, global positioning systems and track plotters, radar, VHF/SSB radios and cell telephones. The trawlers use mainly single otter trawls deployed from the stern with a headline length of 15–48 m and 25–60 m footropes. During the '90's some vessels were converted to boom trawling. The stretched mesh size tapers from 70 mm in the wings to 38 mm in the codend. "Tickler chains" may be used. Trawl speeds are between two and three knots. Drag duration averages about four hours and is carried out on a 24 hour basis. The trawlers carry about 15 crew and remain at sea for three to four weeks. The skipper and a mate alternate six hour watches.

Commercial trawling for crustaceans in both KZN and Mozambique began in the mid 60's. Much of the initial effort was in Mozambique because of more extensive grounds and better catch rates. Permits for crustacean trawling are mentioned in Department of Sea Fisheries reports from 1972 but do not distinguish between vessels operating in KZN and Mozambique. During the 1970's several companies operated out of Durban and fished periodically in KZN waters. Until 1976 Mozambique operated a 12 nautical mile trawling limit which was extended to 200 nm in that year resulting in a decline in the number of KZN based vessels operating there. At this point two vessels began regular trawling on the Thukela Bank. By 1982 there were 20 permitted vessels operating out of Durban, four of which could operate in KZN waters. Anticipating a massive increase in local trawling effort, the Department of Sea Fisheries proposed reducing the total number of trawlers operating in KZN to 10, with only four vessels allowed within 7 nm between Green Point and St Lucia. This was subsequently increased to eight. The Nkomati Accord of 1984 allowed trawlers to return to Mozambique and only four of the inshore permits were used in 1985. In 1987 six permits were used in KZN while in 1989 and 1990 eight inshore permits were issued. In 1991 Sea Fisheries issued five permits only to those vessels active in KZN waters and this number has been retained until the present (2003). Companies holding inshore permits at that stage were Kwa–Zulu Fishing, Spray Fishing, who also used the KwaZulu–Fishing permit, Polana Fishing, Viking Fishing and Sterling Fisheries.

3.4.3 Catch composition, size, variability and trends

As mentioned previously, the diversity within the family Penaeidae decreases westwards and southwards from the Indo-Malaysian centres of diversity and only four species, *viz. F. indicus, P. monodon, M. japonicus* and *M. monoceros* contribute to the South African shallow water prawn resource. Of these *M. japonicus* prefers sandy substrata where it is a day time burrower and generally only accessible to trawl nets at night. Although it has been recorded in the general commercial catches (pers. obs.), particularly on the St Lucia Banks, it very rarely occurs in the Thukela Bank catches. Champion (1970) reported that *P. indicus* made up 73% of the Thukela Bank catches but de Freitas (1980) reduced this figure to 45.5%. Demetriades & Forbes (1993), who sampled landed catches between 1988 and 1990 during February, April, July and September of each year, found that *F. indicus* contributed 73% by mass, followed by *M. monoceros* at 17% and *P. monodon* at 10%.

Demetriades & Forbes (*loc.cit.*) undertook their investigation in order to check on identifications of the prawns made on the trawlers and also to check on the species composition of the catch as the season progressed. The prawns are hand sorted into size categories, packed and blast frozen on the trawlers and catches are typically logged as quantities in these size categories with no accurate indication of the species involved. Any estimate of landed catch quantities of any species therefore required some insight into what species fell into the different categories. This situation came about because the Thukela Bank is a true multi-species fishery with all of the above species, except *M. japonicus,* occurring in the same muddy habitat.

The size categories used by the commercial fishery during the sampling period (1988 - 1990) were (mean mass in g. +/- SD) Tiger Giant TG 200 +/- 9.6, Tiger Medium TM 110 +/- 8.3, King K 68 +/- 14.2, Queen Q 35 +/- 4.3, S 30+/-4.7, SS 18.6+/- 5.6, SSS 11.5 +/- 5.2.

The two largest size categories, TG and TM, consisted entirely of tiger prawns *P. monodon*. The larger category consisted almost entirely of females (>85%) and the smaller mainly of males (>70%) in keeping with the larger size attained by the females in these species. *P. monodon* was virtually absent from any of the smaller categories. The K and Q categories were generally made up by female *F. indicus* (>80%) with low numbers of males in the Q category. This pattern remained fairly constant during the season, although males became more abundant in both K and Q categories towards the end of the season during July and September.

The smaller size categories (S, SS and SSS) showed the greatest change in species composition during the season. The overall pattern during the sampling period was one in which *F. indicus* dominated all three categories in the February samples but was progressively replaced by *M. monoceros* in the smaller categories. By September *P. indicus* was absent from the SSS category and contributed less than 10% to the SS category. The change presumably reflects the cessation of emigration of small *P. indicus* from the estuarine nursery grounds by April/May and the growth of animals on the grounds into the larger size categories.

Catch data over the period 1988 - 2000 are summarized in Figs 6 and 7. Except for 1989 the catch per unit effort (Fig 7) showed relatively little variation. Variations in catch (Fig 6), except for 1989, consequently tended to track effort levels.

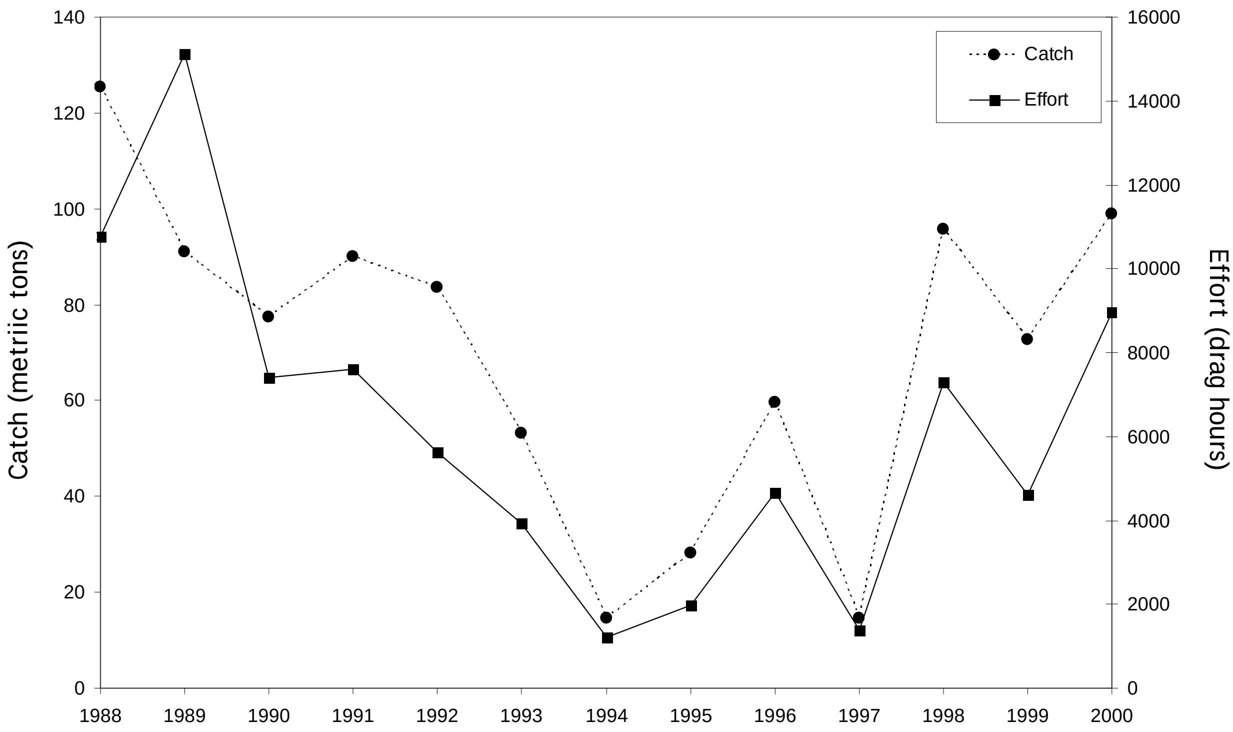

Fig 6: *Catch and effort in the Thukela Bank prawn fishery.*

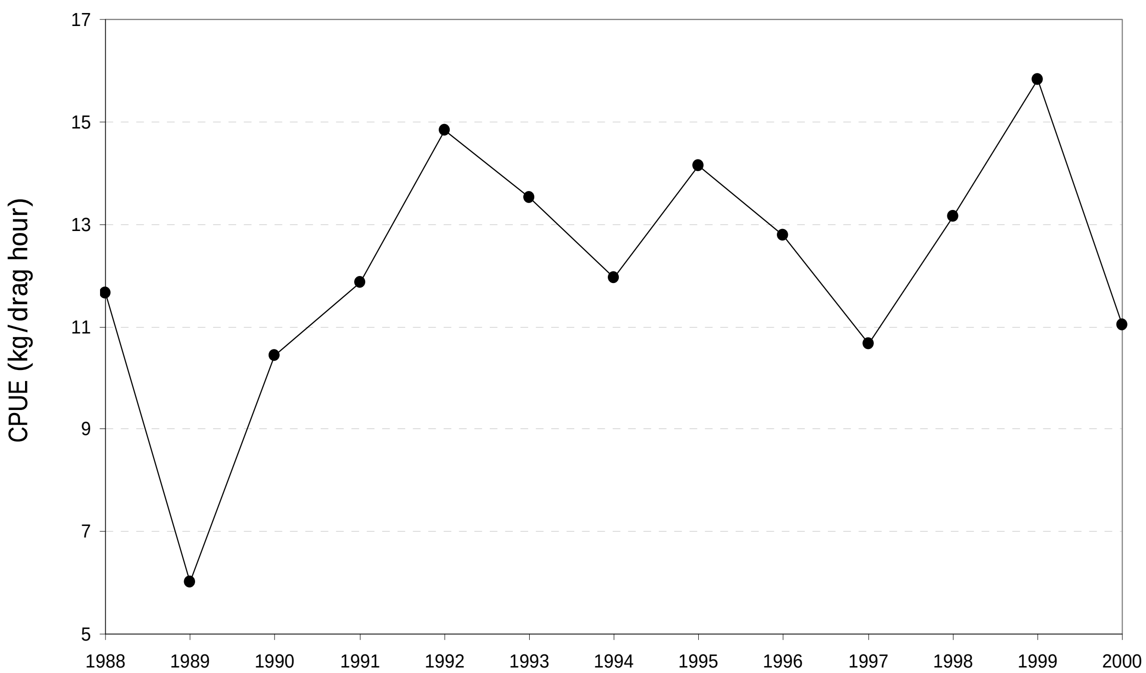

Fig. 7: *Catch per unit effort (CPUE) in the Thukela Bank prawn fishery.*

3.4.4 The estuarine bait fisheries – history and status

Although the distribution of penaeid prawns on the east coast of South Africa extends well beyond the centre of abundance in KwaZulu-Natal estuaries and on the Thukela Bank, and while they are well-known to anglers in Eastern Cape rivers such as the Swartkops, Sundays, Bushmans, Kariega and Kowie, several hundred kilometres to the south, commercial harvesting has historically been limited to the more tropical St Lucia Lake system and to Richards Bay (Fig. 5), both of which are in relatively close proximity to the adult habitat on the Bank. This situation is also in keeping with the relative sizes of the many South African estuaries. St Lucia, with an area of *ca.* 300 to 350 km^2 , depending on water levels, contributes *ca.* 75% of the total estuarine habitat in the country (Begg 1978).

According to Champion (1976) "the St Lucia lake system represents the largest estuarine penaeid prawn reservoir in South Africa". Nothing has happened since that time to contradict this statement, except that cyclical salinity fluctuations in the lake ranging from fresh to hyper-saline and the extreme drought conditions during summer 2003 – 2004, when the mouth closed and the lake virtually dried up (January 2004) for the first time in recorded history, result in the periodic loss of this nursery area. This loss of nursery function will occur both during fresh and hyper-saline periods. Richards Bay is a much smaller system and has been drastically modified by harbour development but, until very recently, still appeared to provide prawn habitats. As described above, five species, *viz. F. indicus, P. monodon, M. japonicus, M. canaliculatus* and *M. monoceros* were recorded in 1996-1997 by Weerts *et al* (2003) in areas which have not yet been lost to harbour development. The channels in the west of the harbour area still support a small commercial bait fishery.

Both the St Lucia and Richards Bay fisheries referred to above were operated by the then Natal Parks Board (NPB) and, despite the vastly different sizes of the two areas, produced remarkably similar annual catches. This will be discussed later. The prawns of St Lucia and Richards Bay respectively are first listed and referred to in terms of species composition, distribution, habitat preference and relative abundance in the pioneering estuarine surveys carried out by Day, Millard & Broekhuysen (1953) and Millard & Harrison (1954). According to Champion (1976) the NPB run commercial bait fishery in St Lucia began in 1952 although Joubert & Davies (1966) refer to private "small scale" commercial exploitation "before World War II". Millard & Harrison (1954) refer to prawns being "netted commercially for sale to anglers as bait" in Richards Bay but without mentioning the operators of the fishery nor when this fishery began.

The reasons for the undertaking of these operations by the NPB are uncertain but presumably represented an attempt to control the harvesting of prawns and to resolve the dilemma of what species are or should be afforded protection in areas such as these two systems, where the "right" to catch fish has long been taken for granted, despite the protection afforded to other organisms such as mammals and birds. The St Lucia lakes fall within one of the oldest proclaimed nature reserves in the country while the original Richards Bay, or at least a part thereof right up to the present, despite harbour development, has also had a degree of conservation status. The Mhlathuze estuary, formerly the southern section of the greater Richards Bay, was initially referred to as the Sanctuary following the separation of this area from the northern area by a berm wall and the development of the northern sector as a harbour. On the above basis it could be argued that the operation of the bait fisheries by the NPB and the exclusion of recreational, and specifically other commercial operators, conferred a level of protection on the stocks as effort could be controlled. There is, however, no record of the manner in which the level of effort was set and, in the absence of any indication to the contrary, it is a reasonable assumption that it was based simply on demand for bait prawns and the ability of the trawl operation to meet this demand.

The prawn catching technique in both systems involved aluminium dinghies powered by single 25 to 30 hp outboard motors with a three man crew. Three such rigs were operated at St Lucia and two in Richards Bay. The nets used were referred to as "gate nets" and consisted of rectangular aluminium frames 4.9 m long by 1.1 m high mounted on skids which prevented them from sinking into the generally muddy areas trawled. The nets were approximately 4 m deep with 25 mm stretch mesh. Photographs of boats and nets taken in the mid 60's (Joubert & Davies 1966) and personal observations in the mid 90's indicated that no change in technique occurred over this period (*see inset photo C*). The nets were towed in shallow water – observations indicated that the nets rarely disappeared below the surface – where the wash from the motor, which the driver frequently swung from side to side, appeared to be a major factor driving the prawns into the nets. There were no tickler chains and the skids would have kept the lower portion of the net frame off the bottom.

Netting times and periods at St Lucia were more consistent than at Richards Bay where the tides were more of a controlling factor over access to the trawl grounds. At St Lucia in the summer prawn season, the boats would leave before first light, *i.e.* about 04h00, typically returning between 11h00 and midday depending on catches. Exceptionally large or small catches would often result in an earlier return either because the holding capacity would have been reached or because catches were small and further effort was considered pointless. During the late 80's in Richards Bay, the prawn boats operated for about five hours a day (Demetriades 1990) although without the regular daily St Lucia type schedule because of the tidal factor mentioned above.

Netting at St Lucia occurred in the Narrows, the 20 km partially tidal channel linking the sea and the lakes. Observations over several years in the 70's and 80's indicated that the boats never operated in the lake and the northern limit was in the area known as Brodie's Crossing at the southern end of the lake. Netting in the Narrows was done as close to the fringing reed beds as the draft of the boat and the reach of the outboard motor permitted. In the Brodie's Crossing area the nets were hauled wherever there was enough water. A possible explanation for this contrast was provided by the work of Owen (1992) who showed that the invertebrate macrobenthos, which would have supported the prawns, was more abundant in the non-dredged fringes of the Narrows and in the undredged Brodie's Crossing areas. Dredging of the Narrows, which included the construction of Potter's Channel immediately south of Makakatana Bay, was undertaken as a management strategy in the 60's to enhance water exchange between the sea and the lake.

The St Lucia Lake trawl grounds were very much bigger than those at Richards Bay which, following the initial phases of harbour development, were localized in the mangrove lined Bizholo and Amanzimnyama channels in the west of the harbour where they covered less than 1 km^2. Netting was typically concentrated over low tide periods when falling water levels forced the prawns out of the mangroves into the channels.

Care of the catch in both areas was rudimentary. *F. indicus,* which dominated the catch, dies rapidly when removed from the water. On the boats the catch was typically held in heavy duty, open, black plastic tubs. At times these were partially filled with ice blocks which would have afforded some protection against the summer temperatures but the more common practice was simply to cover the tub with a hessian sack. Insulated cooler boxes were used in the later years in the Richards Bay fishery but seldom with any arrangement to chill the catch. On return the catch would be rinsed with ordinary tap water. In mid summer at St Lucia and Richards Bay, tap water temperatures would not provide any chilling effect. The prawns would then be packed in cartons holding about 250 g, the cartons stacked in crates and the crates stored in large walk-in freezers. Even at a storage temperature of -20^{0}C, by the time that freezing of the catch was complete, up to seven hours may have elapsed since the time of removal from the water. Such treatment was virtually guaranteed to cause blackening of the gills and softening of the muscle tissue following subsequent thawing, representing a significant quality deterioration. This fact was not lost on the fishermen of St Lucia and queues would build up rapidly at the bait shop following the return of the bait boats in the hope of obtaining fresh prawns.

Early monitoring of the catch was described by Champion (1976) who refers to monitoring of effort in boat hours from May 1970 to March 1973 and of records of catch composition on a monthly basis from January 1969 to December 1971. Subsequent to these efforts, Champion (1976) commented at the 1976 Charter's Creek Workshop that "the monitoring of commercial prawn catches, as practiced (sic.) (by the NPB) at present, is probably motivated more by accounting than biological needs. Prawn catches are, for example, recorded in number of cartons, not mass. Catch compositions are not analysed and recording of the boat hour index of effort has been discontinued. This type of information is needed for even the most basic assessment of the fishery. Not only should appropriate data collection be resumed, but the quality of monitoring should also be improved." It can also be mentioned that, for bait purposes, anglers were more interested in obtaining an adequate number of bait size prawns rather than a few large prawns in their cartons and accordingly any large prawns, particularly the tiger prawn *P. monodon*, would be kept aside during processing of the catch and typically not recorded.

Personal experience at St Lucia during the 80's indicated that this situation had not changed, the prawn fishery was low on the management priority list and responsibility for the bait fishery was often given to the newest recruit to the station who seldom had any fisheries experience. It took several years before persuasion resulted in any relevant monitoring being resumed but there was rarely any attempt to consider the catch data on a long term basis. The result of this combination of events was to some extent predictable and reached a conclusion in the recorded decision below:

"Shrimping has been low for a number of years and staff decided at the meeting to stop the shrimping operation. It was felt that there is not enough information available as to what effect the shrimping operation has had on this resource" (Eastern and Western Shores Management Meeting Minutes 1996). Even with the benefit of hindsight, a statement such as this, emanating from a provincial conservation body which had its own research staff and which operated a commercial fishery in a proclaimed nature reserve for over 40 years, must be seen as a serious indictment.

Monitoring at Richards Bay was equally erratic and highly dependent on the very variable level of interest shown by staff at the station. For reasons unknown to the authors the rights to the Richards Bay fishery were sold to private enterprise in 1996 with the proviso that catch returns be submitted to EKZNW and that the operation be conducted on the same basis as that followed by EKZNW in the past, *i.e.* same number of boats, crew, boat and engine size, and nets. While the basic operating techniques were retained there was little evidence that catch records were maintained in any organized fashion. Permits to trawl require application to the Chief Directorate: Marine and Coastal Management and are issued on an annual basis but regular discussions with the only active licence holder indicated that delays and uncertainty in the issuing of licences were the norm. The national issue of commercial exploitation of any estuarine stocks anywhere in the country is presently unresolved but there appears to be a likelihood that commercial fisheries in these environments will be phased out.

The earliest recorded monitoring at St Lucia was carried out by Champion (1976) from about 1966 to 1971. He recorded catches in terms of numbers of cartons, the currency of the day, but also attempted to measure effort in terms of both days and hours fished. Unfortunately he recorded catches on a calendar year basis which distorted the picture because the catch is seasonal over summer and annual catch records combined catches from the end of one season with the start of the next.

Use of monthly catch records over the period 1968 to 1975 (Champion 1976) confirmed the pattern of predominantly summer catches. Effort in fishing days did not necessarily track catches and supported his suggestion that the fishery catered significantly to local bait demand. Consequently, levels of effort, and to some extent catch peaks, were generated by social, *i.e.* bait demand, rather than biological considerations. Prime fishing periods, however, *e.g.* during the grunter *Pomadasys commersonnii* run in late winter/early spring, did not necessarily coincide with periods of prawn abundance.

Demetriades (1990) used recorded catch masses from both St Lucia and Richards Bay either directly or by converting carton numbers to catch masses on the basis of average mass of prawns per carton in order to investigate catch trends in the two areas over the period 1973 to 1990. This period covered the wet years in the mid 70's, the drought of the early 80's and cyclone Domoina in January 1984 but not the pre-harbour period at Richards Bay. "Annual" catches were calculated using a seasonal year from June to May which was taken as more representative of successive generations than data accumulated over a calendar year. Catch per unit effort (CPUE) was calculated as kilograms per boat day. Monthly samples from St Lucia and Richards Bay collected during 1984 – 1987 and weekly samples from 1987 to 1988 were used to determine species composition in the catch.

Three species *viz.,* in order of abundance, *F. indicus, M. monoceros* and *P. monodon*, contributed to both fisheries during the above period (Table 2). A description of the contribution by mass as opposed to numerical abundance decreased the significance of the relatively smaller *M. monoceros* and increased the significance of the relative larger *P. monodon.* The total seasonal catches varied between *ca.* 5-25 metric tonnes at Richards Bay and 10-30 at St Lucia with most values for both areas falling between 10 and 20 tonnes (Figure 8).

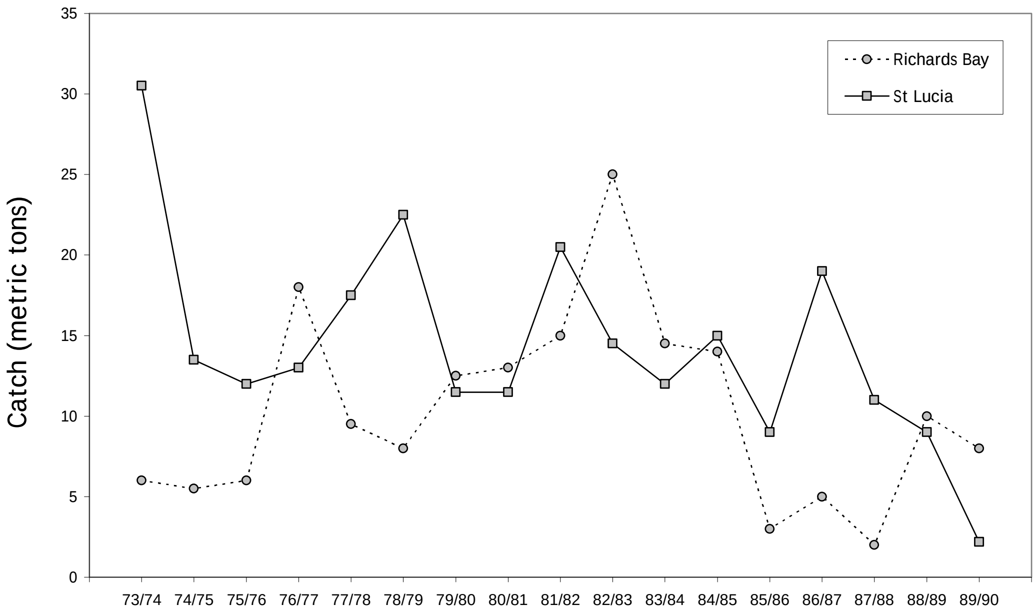

Figure 8: Catches in the two estuarine bait fisheries

Total fishing effort in boat days at Richards Bay was lower because only two boats were used instead of three, but far more consistent than at St Lucia (Fig 9). This contrast was reversed when CPUE values were compared (Fig 10). Catch rates were remarkably consistent at St Lucia at an seasonal average of *ca.* 25 kg. boat^{-1} day^{-1} while catch rates at Richards Bay were far more variable, although even after harbour construction had started, catch rates in the mid 70's and early 80's were three to four times the St Lucia rates. Although the same species were involved in both areas, trends in catch rates in the two areas did not co-vary.

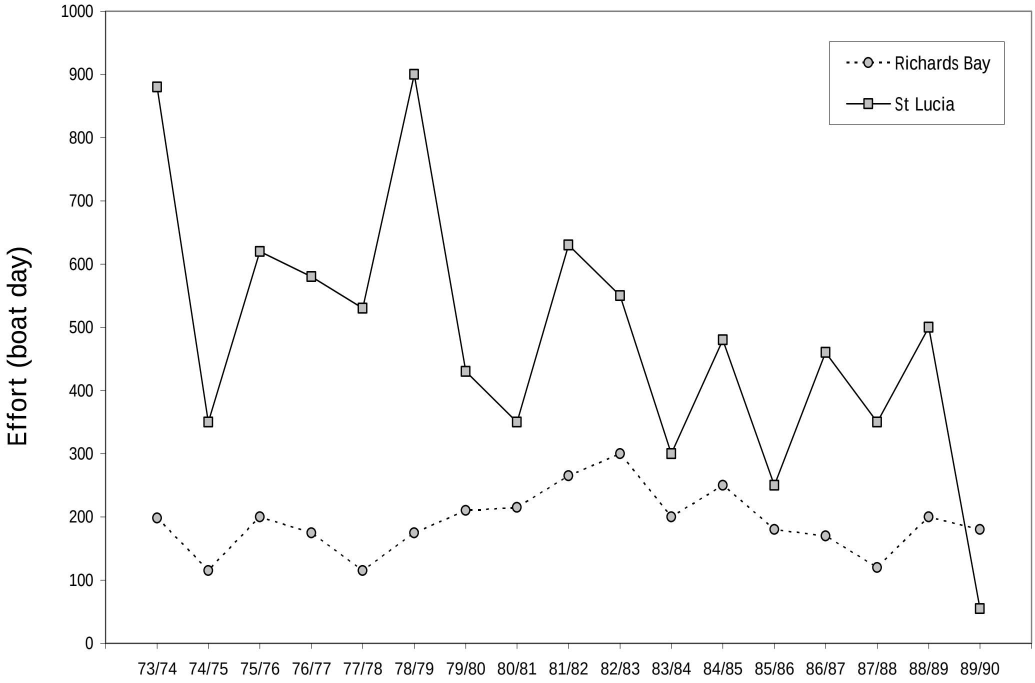

***Figure 9**: Fishing effort in the two estuarine bait fisheries*

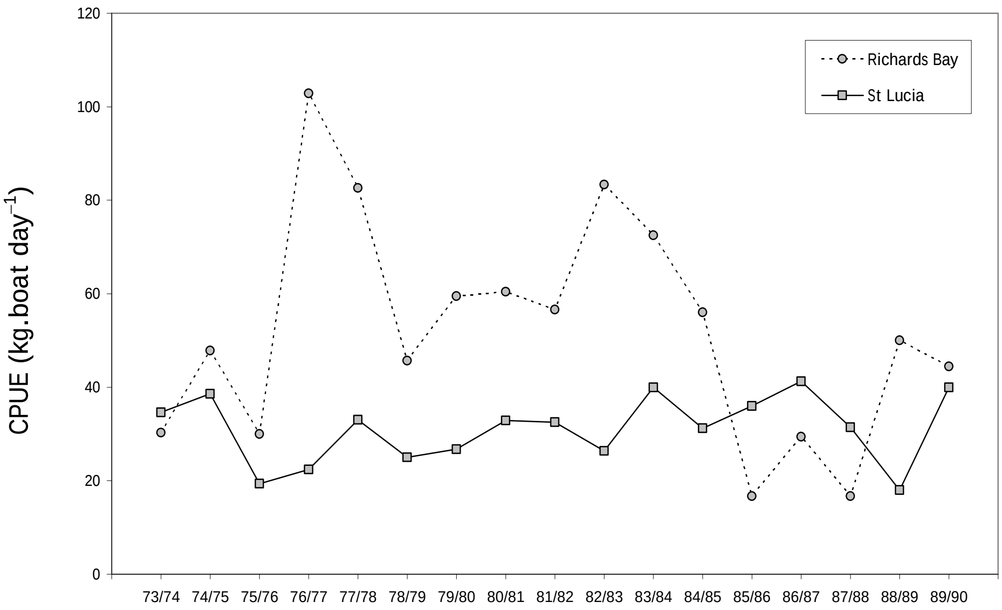

***Figure 10:** Catch per unit effort in the two estuarine bait fisheries*

Table 2: Percentage species composition in the estuarine bait fisheries. Samples of approximately 1 kg were collected monthly from 1984 – 1986 and weekly during 1987 – 1988 (n = 24 246)

Species	St Lucia		Richards Bay	
	Abundance	**Mass**	**Abundance**	**Mass**
P. indicus	75	82	86	85
M. monoceros	19	9	10	5.8
P. monodon	3	8.6	3.7	9
other species	0.7	0.4	0.3	0.2

3.5 Status and threats to the major nursery grounds and the offshore habitat – the future of South African prawn stocks

On a size basis and from previous arguments it is clear that St Lucia and Richards Bay are by far the major providers of prawn nursery grounds in KZN. St Lucia is now part of a world heritage site, the Greater St Lucia Wetland Park, and the bait fishery has been closed down suggesting that the role and significance of this system as a prawn nursery should be enhanced. It has been pointed out however, that *F. indicus*, the most common species cannot handle salinities much below 10^{0}/00 and consequently during wet years the available habitat at St Lucia will be reduced. Equally during drought years, areas of the lake where salinities exceed 60^{o}/oo will be inaccessible to the prawns (Forbes & Cyrus 1992, 1993) while the extreme drought conditions of 2003-2004 resulted in a total loss of habitat over large areas of St Lucia due to a combination of mouth closure and the drying up of some 75% of the lake.

The nursery role of St Lucia is not threatened at present by direct human impact due to its heritage site status, but the significance of catchment developments, particularly the effects of forestry and agriculture on runoff, and the consequent effects on the frequency and duration of hypersalinity periods present a still unquantified problem. This is being tackled through a Department of Water Affairs and Forestry (DWAF) initiative to consider the river flow reserve required for the functioning of the St Lucia ecosystem and to manage abstraction accordingly.

Richards Bay presents a very much more dismal picture as it can be anticipated that harbour developments in coming years will result in progressive loss of the present prawn habitat in the mangrove lined channels to the west of the harbour. This will certainly impact on the Thukela Bank fishery, particularly during periods when St Lucia becomes inaccessible for either of the reasons described above. The Mhlathuze estuary, the southern section of the original Richards Bay, presents a relatively unknown quantity as it supports a prawn population, as shown by the activities of poachers, but, as much of the area drains over spring tide periods, the carrying capacity of the system is uncertain.

The possibility of negative impacts of catchment developments not only on the estuarine nursery grounds but also on the offshore environment is very real. The coastal waters of KwaZulu-Natal, in common with much of the east coast of Africa, are typically oligotrophic. Nutrients are arguably derived from terrestrial run-off rather than the rare and localized upwelling events while the Thukela Bank itself is derived largely from sediments transported by the Thukela River. The potential impact of dams on the Thukela River on the Bank has been considered (Forbes & Demetriades 2000) in terms particularly relating to changes in sediment input. Dams tend to have a winnowing effect in that coarser sediments are trapped while finer material, particularly in high flow conditions, remains in suspension.

Possible changes in sediment distribution patterns on the Banks were envisaged as a likely consequence. An extension of muddier sediments would be expected, based on known substratum preferences, to improve the habitat for the major commercial species but the potential reduction in nutrient inputs due to reduced flow could have an adverse effect.

3.6 History, status and future of prawn farming in South Africa

Prawn /shrimp culture is now an accepted, although often controversial activity in many tropical and sub-tropical countries around the world. Attempts to farm prawns in South Africa date back to the early 70's. Initially diatom culture for larval feeding and larval rearing techniques were tested at the Port Elizabeth Museum Complex, but were later centralized at the Amatikulu Prawn Research Unit in KZN, funded by the Fisheries Development Corporation (FDC) at a site originally occupied by a private project at the Amatigulu estuary. A team of researchers was based at the farm with the aim of developing techniques suited to the local environment. The aspects investigated included algal production methods for larval feeding, techniques for larval culture, juvenile and adult dietary and growing out requirements, and techniques for bringing prawns to sexual maturity under laboratory conditions. Several theses were produced for higher degrees during this period and formed the basis of a number of scientific publications.

These initial investigations were aimed at the common local species *F. indicus*, despite the general emphasis in other Indo-Pacific countries on the giant tiger prawn *P. monodon* which also occurs, although less commonly, in KZN waters. During this period the giant caridean fresh water prawn *Macrobrachium rosenbergii,* endemic to south-east Asia and northern Australia, was imported from an aquaculture operation in Mauritius. This species requires brackish water for successful larval development but larval development is shorter and less complex than it is in the penaeids and this was seen as an advantage over the penaeids.

An attempt was then made to commercialise this research effort and begin farming these species. This effort did not succeed at the time due to technical difficulties such as the algal culture method selected and the algal species chosen for commercial production. The commercial venture then added freshwater fish farming for the aquarium market to the menu following policy changes and the cessation of funding from the FDC.

These developments preceded a report in the Natal Mercury in August 1981 under the heading "Prawn farm to open soon" *(See Appendix A for full article)*. The project was financed by the KwaZulu Development Corporation and was intended to produce "prawn, tilapia and hobby fish" on "one of the largest . . . fish farms in the world, covering about 30 ha". The intention was initially to import post-larval prawns from Taiwan and subsequently to become independent by developing a breeding stock. One of the researchers subsequently set up a successful *Macrobrachium rosenbergi* farming operation near Kariba village in Zimbabwe. The KZN operation as then planned never became technically and financially viable although the freshwater aquarium fish operation survived to the present.

During 1989 renewed attempts were made to develop the prawn culture operations at the Amatikulu farm. An algal production method for larval feeding was established, followed by spawning and larval rearing trials with *P. monodon*. Once a successful method had been established, funding was secured from the Industrial Development Corporation (IDC) for a pilot plant venture consisting of 6 ha of prawn ponds at Amatikulu.

In a parallel development during the 80's a separate scheme involving 50 half hectare ponds was developed at the village of Mtunzini on old sugar cane fields on the south bank of the Mlalazi river north of the Amatigulu *(see inset phot D)*. After several more years during which there was a succession of entrepreneurs and imported specialists but no real success, the operation was taken over in 1998 by the Amatigulu group, who by this time had slowly diversified their successful freshwater fish operation, increased the number of prawn ponds at Amatigulu and successfully begun to culture the common local prawn *F. indicus.*

Both farms had initially targeted *P. monodon* but after two years the Amatikulu farm switched to *F. indicus*. The Mtunzini farm did the same a few years later. Attempts at growing *P. monodon* foundered due to the low quality and inconsistent availability of broodstock from the local wild population in conjunction with the relatively short length of the local growing season and the sustained high temperatures required by this species.

Production of prawns during the 90's steadily increased and by the end of the decade the production from the combined farms was beginning to match the trawled catches taken on the Thukela Bank at about 60-80 tonnes *per annum.* Tragedy struck in 2002 when the director of the operation, Mr. Fanie Myburgh, was killed in a motor accident.

Prawn farms require access to a reliable seawater supply and frequently also an adequate freshwater supply. The Amatigulu farm was constructed on the north bank of the estuary immediately inland of the then position of the mouth. The intake works were accordingly situated close to the mouth where there was a strong tidal exchange. During the 1987 floods the river burst through the coastal dune cordon at the point where it turned northward capturing the Nyoni river mouth in the process. As there are no rocky outcrops which could stabilise the positions of the two mouths, they tend to wander and one or both or neither, depending on rainfall and the resulting river flow in conjunction with longshore sand movement, may be open. The proximity of the intake works to a good sea water source is therefore highly variable.

The Mtunzini operation initially relied on an intake from the Mlalazi in the tidal section of the river but several kilometres from the mouth. Wet summers frequently resulted in the salinity in the river approaching the lower tolerance limits of the prawns, particularly *F.indicus.* The Mtunzini problem was addressed by installing a well point on the main beach below the low water spring tide mark and piping the water from there to the farm. An unexpected problem arose during unusually wet years in that seepage of ground water from the coastal dunes was often virtually fresh. Although field observations at St Lucia indicated that the abundance of *F. indicus* declined at salinities below 10 the farming operation at Mtunzini showed that 4 was well tolerated. Low salinity effects are, however, compounded by low temperatures and salinity declines in the farm ponds were countered by adopting a low to zero water exchange policy.

The outflow from both farms is to the respective local estuary without any particular attempts being made to process it in any way although the Amatikulu site has a crude buffer system whereby the water flows into a large sump and has produced an artificial wetland which has reportedly become popular with bird watchers. The outflow into the estuary is at no great distance from the intake works, while the Mtunzini farm drains into the mangroves of the nature reserve, some distance downstream of the former intake. At the Mtunzini site, this resulted in the situation whereby, depending on the tides, discharged water could be drawn back into the ponds from whence it came. Due to the short duration of such events there was apparently no discernible impact on the farming operation.

An Honours degree research project (Pillay 2000) on the effluent water and the benthic fauna in the drainage channels and the receiving areas in the two estuaries was carried out in 2000. In both cases there were well defined channels through which effluent water flowed to the estuaries. In addition there was recognizable flow through the mangroves situated below the Mtunzini farm. Water samples from the channels and the estuaries as well as benthic faunal samples were taken in the areas outside the fenced areas of the farms. In both cases there were frequently raised ammonia levels in the water leaving the farms although these rapidly dropped to background levels. Phytoplankton levels in discharge water at Mtunzini were high enough at times to produce a distinct green colour. No effects on the macrobenthic fauna were however detected in either estuary beyond the effluent channels.

3.7 Bycatch

The issue of the impacts of bottom trawling on benthic communities and the bycatch taken by trawl netting has been a controversial topic world wide for many years. The South African prawn trawling operations are no exception and these were the subject of several papers by Fennessy (1994a, 1994b, 1995) and Fennessy, Villacastin & Field (1994). It should however be noted that these studies did not include any investigation of the effects of trawling on the benthic communities and the studies were focussed on the bycatch.

Bycatch was described by Fennessy (1994a) as being a consequence of the indiscriminate nature of the typical otter trawl used in trawling which resulted in the catching of demersal organisms associated with prawns or with the habitat occupied by the prawns. By-catch would therefore be described as “any organism caught incidentally to the target species”. Some of this bycatch may be retained so that bycatch would then include such species as well as discards which are not used in any way and are returned to the sea.

Fennessy (1994a) classified his trawl samples as either shallow (20-33 m) or deep (33-45 m) and estimated the by-catch:prawn ratios as respectively 4.6 +/- 1.25:1 and 17.13 +/-3.29:1 with a total annual bycatch, based on data covering the period 1989-1992, of 400 tonnes. Prawn abundance and trawling operations are seasonal and higher bycatch ratios can be expected during periods when the prawn catches are smaller. In comparison with the above figures, by-catch:prawn catch ratios ranging from 6:1 to 14.7:1 were quoted by Fennessy (*loc.cit.*) from Kuwait, the Australian Torres Strait and the Gulf of Mexico, which are all much larger fisheries with total annual bycatch quantities of 21 000 t, 4 800t and 500,000 t respectively.

The acceptability of high bycatch:prawn ratios is controversial, particularly when the bycatch involves large or threatened marine species such as rays and turtles. This type of bycatch appears, however, to be extremely unusual in the South African situation. The major problem arising on the Thukela Banks was in relation to a user conflict situation in the area where there was the perception that prawn trawlers were catching juvenile linefish. Linefish were defined in the Thukela Bank situation Fennessy (*loc.cit.)* as all fish species caught by means of a fishing line by other sectors of the South African fishery.

During the 1989-1992 study period teleost fish belonging to 108 species constituted 74% of the bycatch biomass. Only two linefish species, *viz.* the squaretail kob *Argyrosomus thorpei* and the snapper kob *Otolithes ruber*, appeared in the bycatch. In terms of linefish catches, *O. ruber* constituted <0.2% of the commercial skiboat catch and 3% of the recreational skiboat catch. *A. thorpei* contributed 1.5% of the bycatch by number and 22% by mass of the commercial skiboat catch during the period 1986-1991. Further consideration of the sizes of the individuals and the seasonality of the bycatch indicated that most were between 110 and 150 mm long, much smaller than those taken by linefishers, and were most abundant during January and February. Fennessy (*loc.cit.)* found that these juvenile fish were feeding on the prawn trawling grounds during this stage of their lives before moving to low reef areas where the diet changed to include more teleosts and the nature of the habitat precluded trawler operations. A recommendation arising out of this study was to minimise trawling on the Thukela Banks during January and February, a pre-season period when prawn catches are typically low. This policy has now been adopted although it does not seem to have resolved the user conflict which has re-surfaced in various forms during recent years.

Shark fisheries around the world have come under increasing scrutiny in recent years because of declining stocks. It is therefore significant that apart from the teleost bycatch, Fennessy (1994b) also investigated the elasmobranch bycatch taken by the prawn trawl fishery and compared the associated mortalities with those resulting from catches taken by recreational anglers and in the gill net operations run by the Natal Sharks Board.

Monitoring of the bycatch between May 1989 and June 1992 produced a list of 26 elasmobranch species belonging to 10 families. The most common was the scalloped hammerhead shark *Sphyrna lewini* which contributed 21% of the catch. As a group, the five species of dasyatid rays made up 32.8% of the total. Fennessy (*loc.cit.*) suggested, on the basis of the sizes of the individuals of virtually all individuals caught, that the Thukela Bank was acting as a nursery ground.

Mortalities amongst the elasmobranch species taken was highly variable, peaking at 97.6% in the scalloped hammerhead *S.lewini*. Mortalities in other families such as the Dasyatidae, Carcharinidae, Scyliorhinidae, Rhinobatidae and Myliobatidae where more than 10 individuals were caught ranged from *ca.* 27-35%.

The estimated total elasmobranch bycatch during the sampling period was 44 600 of which about 43%, or 19 000 were killed in the process and discarded. During the same period the Natal Sharks Board destroyed an estimated 5 900 elasmobranchs. Figures obtained from the National Marine Linefish System for KZN angling competitions indicated a catch of 37 566 elasmobranchs. Estimates of the proportion released range up to 90% but as Fennessy (*loc.cit.*)

emphasises, these are estimates and in addition there is little definite information on catches taken by recreational skiboat and shore anglers. Equally there are few data to indicate population trends in KZN elasmobranchs although the catch trends in Natal Sharks Board catches of large sharks in shark nets, apart from migratory or pelagic species, are classic indicators of collapsed fisheries and hence the virtual disappearance of large sharks from inshore, shallow waters. The possible significance of the trawl operations in KZN elasmobranch population dynamics and the ecological implications of the removal of these predators are unknown.

Fennessy (1995) also described the nature of the non-commercial crustacean bycatch in the prawn fishery, estimating that during his study period, 20% by mass of the bycatch consisted of crustaceans. This converted to an annual estimate of 80 tonnes comprising 39 species from 17 families. Numerically the crustacean bycatch was dominated by the small portunid crab *Portunus hastatoides* (*62.1%*) followed by the penaeid *Parapenaeopsis acclivirostris* (*13.6%)*, the crab P*ortunus sanguinolenta* (11.4%) and the squillid *Squilla nepa* (5.4%), these four species contributing 92.5% in total. Fennessy (*loc.cit.*) did not quantify mortalities but commented that "most of the crustacean bycatch was still alive when returned to the water, despite the loss of appendages during trawling and sorting of the catch". As with the teleost and elasmobranch bycatch, the eological significance of the transfer, albeit temporary, of benthic organisms to surface waters is unknown.

While bycatch has been a long standing issue in offshore fisheries, the use of nets in estuarine prawn nursery grounds, which also act as nursery grounds for a variety of marine fish species (Whitfield 1998), is potentially equally controversial. Although the bait prawn fishery in the St Lucia system has not operated since 1996, this fishery was an integral part of the recreational angling infrastructure of St Lucia village for over 40 years, and concern over the bycatch resulted in an investigation in the early 90's which was reported on by Mann (1995) and for the sake of completion is included here. A comparative study done by Grljevic (1996) at Richards Bay where the prawn fishery was also a part of the recreational fishery infrastructure is also incorporated.

Samples at St Lucia were collected intermittently between 1990 and 1992 and once or twice a month between August 1992 and September 1993. A total of 40 species from 21 families (Table) was recorded, dominated by the slimy *Leiognathus equula* (23.5%), followed by the longspine glassy *Ambassis productus* (9.8%), the Natal stumpnose *Rhabdosargus sarba* (8%), the longjaw glassnose *Thryssa vitrirostris* (7.8%), the Natal moony *Monodactylus argenteus* (7.8%), the perch *Acanthopagrus berda* (6.4%) and the longarm mullet *Valamugil cunnesius* (6.3%). All other species contributed less than 5%.

Samples at Richards Bay were collected during 1996. A total of 42 species representing 26 families was recorded, dominated by the perch *Acanthopagrus berda* (28%), the glassnose *Thryssa vitrirostris* (17%), unidentified mullet *Liza* spp. (12%), the groovy mullet *Liza dumerilii* (8%) and the slimy *Leiognathus equula* (6%). All other species contributed less than 5%.

A combined total of 59 species was recorded from the two systems of which only 21 were shared suggesting different conditions in the two estuaries which are only about 50 km apart. Only three species contributed more than 5% in both areas. The representativeness of the St Lucia data is, however to some degree challengeable as the sampling was done during a drought period which resulted in mouth closure between December 1992 and October 1993. This would have prevented any recruitment of juvenile fish into the estuary during this period and it is therefore likely that there would have been fewer juvenile fish in the estuary and accordingly fewer fish in the bycatch. Mann (*loc.cit.*) refers to investigations of the bycatch during 1969-1971 which supported his conclusion that the localisation of the bait fishery in the Narrows, the availability of large areas of similar habitat elsewhere in the system, the rapid return of discarded fish to the water and the low ratio of fish to prawn in the catch argue that the bait fishery had little effect on fish populations in the lake. The lack of adequate data and the closure of the fishery in 1996 means that the real impact of the bait fishery will never be known. Data from Richards Bay covered a shorter period but Grljevic (1996) came to a similar conclusion as Mann (1995), *viz.* that the fish bycatch in the prawning areas was unlikely to have significantly impacted on the overall Bay or lake populations.

Table 3 : Percentage contribution by the different fish species recorded in the baitfishery bycatch in Richards Bay (R.B.) (Grljevic 1996) during 1996 and at St Lucia (St L.) (Mann 1995) between Aug 1992 and September 1993. n= 847 at St Lucia and 1 453 at Richards Bay.

Family	Species	Common name	%R.B	% St L
Ambassidae	*Ambassis natalensis*	Longspine glassy		
	Ambassis productus	Slender glassy	1	9
Belonidae	*Strongylura leiura*	Yellowfin needlefish		<1
Bothidae	*Pseudorhombus arsius*	Largetooth flounder	<1	
Carangidae	*Caranx sem*	Blacktip kingfish	2	<1
	Caranx spp.	Kingfish	<1	<1
	Scomberoides tol	Needlescaled queenfish		<1
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia		<1
Clupeidae	*Hilsa kelee*	Kelee shad	3	5
Dasyatidae*	*Himantura uarnak*	Honeycomb stingray	<1	
Drepanidae	*Drepane longimanus*	Concertina fish	3	
Elopidae	*Elops machnata*	Springer	<1	<1
Engraulidae	*Stolephorus punctifer*	Buccaneer anchovy	<1	
	Thryssa setirostris	Longjaw glassnose	<1	<1
	Thryssa vitrirostris	Glassnose	17	8
Gerreidae	*Gerres filamentosus*	Threadfin pursemouth		<1
	Gerres methueni	Evenfin pursemouth		1
Haemulidae	*Pomadasys commersonnii*	Spotted grunter	3	<1
	Pomadasys kaakan	Javelin grunter	3	2
Leiognathidae	*Leiognathus equula*	Slimy	6	23
	Gazza minuta	Toothed soapy	<1	
	Secutor insidiator	Slender soapy	<1	<1
	Secutor ruconius	Pugnose soapy		<1
Lutjanidae	*Lutjanus argentimaculatus*	River snapper	<1	<1
	Lutjanus fulviflamma	Spotsnapper	<1	
	Lutjanus russelli	Russell'snapper		<1
	Lutjanus sp.		<1	
Megalopidae	*Megalops cyprinoids*	Oxeye tarpon	<1	
Menidae	*Mene maculate*	Moonfish	<1	
Monodactylidae	*Monodactylus argenteus*	Natal moony	<1	8

Table 3 (cont.): Percentage contribution by the different fish species recorded in the baitfishery bycatch in Richards Bay (R.B.) (Grljevic 1996) during 1996 and at St Lucia (St L.) (Mann 1995) between Aug 1992 and September 1993. n= 847 at St Lucia and 1 453 at Richards Bay.

Mugilidae	*Liza alata*	Diamond mullet		<1
	Liza dumerilii.	Groovy mullet	8	<1
	Liza macrolepis	Large scale mullet		2
	Liza spp.		12	
	Mugil cephalus	Flathead mullet	3	
	Valamugil buchanani	Bluetail mullet	<1	
	Valamugil cunnesius	Longarm mullet		6
	Valamugil robustus	Robust mullet		<1
	Mugilid spp.			<1
Mullidae	*Upeneus vittatus*	Yellowbanded goatfish	<1	
Muraenidae	*Thyrsoidea macrura*	Slender giant moray	<1	<1
Platycephalidae	*Platycephalus indicus*	Bartail flathead	<1	
Pomatomidae	*Pomatomus saltatrix*	Elf	2	<1
Sciaenidae	*Argyrosomus hololepidotus*	Kob	<1	
	Johnius dussumieri	Nondi		<1
Serranidae	*Epinephelus andersoni*	Catface rockcod		<1
	Epinephelus malabaricus	Malabar rockcod		<1
Sillaginidae	*Sillago sihama*	Silver sillago	1	4
Soleidae	*Solea bleekeri*	Blackhand sole		3
Sparidae	*Acanthopagrus berda*	Perch	28	6
	Diplodus sargus	Blacktail		<1
	Rhabdosargus holubi	Cape stumpnose	<1	3
	Rhabdosargus sarba	Natal stumpnose	3	8
Sphyraenidae	*Sphyraena jello*	Pickhandle barracuda	<1	
Teraponidae	*Terapon jarbua*	Thornfish	1	<1
Tetraodontidae	*Amblyrhynchotes honckenii*	Evileyed puffer	<1	
	Arothron immaculatus	Blackedged blaasop	<1	
	Pellona ditchela	Indian pellona		<1
	Pterois miles	Firefish		<1
Total species			42	40

3.8 Management

Management considerations relating to the South African prawn resource incorporate several aspects including trawler operations in terms of open and closed areas, closed seasons, catch monitoring, bycatch control, exploitation of juveniles in estuaries, protection of estuarine nursery environments and the development and control of prawn farming operations.

The prawn “fishery profile” of the offshore fishery has been described by Sauer, Hecht, Britz & Mather (2003a & b) in terms of catch monitoring, levies and management. Catch monitoring has always presented problems arising largely from non-submission or inadequate access to landing sheets. Catch data presented in the present report, which were based on direct access to drag and landing sheets, cover a slightly longer period than that covered in the above report but the values and trends are very similar. Main control of the fishery lies in the limitation on the number of vessels operating on the Banks which has been restricted for many years. General input from trawler operators indicates that the small size of the fishery, frequently unfavourable weather conditions and the tremendous variation in catches renders it a relatively marginal operation. It thus appears unlikely that there will be many new permit seekers and there is no indication that at present levels of effort the resource is over-exploited. Bycatch has been quite intensively researched and reduction techniques have been investigated but there is no published information. A significant gap lies in the fact that there is no information on the impacts of trawling on the actual benthic environment. It is obviously impossible at this stage to do any pre-trawling studies.

At this point the conservation of the Thukela Bank stocks would seem to be particularly dependent on protection of nursery areas of which the two largest and most significant are either at high risk or only intermittently available. The Thukela Bank prawn population survived the five year loss of the St Lucia nursery grounds because of mouth closure in the 50's, arguably because of the availability of Richards Bay, which is much closer to the Thukela Banks, as a nursery ground and also because Richards Bay at that stage was still in a virtually pristine condition. The western channels of Richards Bay harbour have long maintained a remarkable prawn productivity and carrying capacity and their disappearance would certainly precipitate a decline in the overall size of the stock. The Mhlathuze estuary is still in a state of flux due to changes in the tidal regime associated with the construction of the new mouth and the proliferation of white mangroves *Avicennia marina* on the tidal flats. Other estuaries in the general area include the Mlalazi, Amatigulu, the Thukela and the Zinkwazi. The Thukela has been classified as a river mouth (Whitfield 2000), *i.e.* a system dominated by freshwater inflow. It is accordingly generally unsuitable as a habitat for *F. indicus* due to the sensitivity of this species to low salinities. The other systems all support prawn populations but the sizes of these estuaries render them, under most circumstances, unimportant relative to Richards Bay and St Lucia. Their significance should however be seen as increasing in view of the above comments about harbour development at Richards Bay and the effects of floods and droughts at St Lucia. The protection of these smaller estuaries as functioning ecological entities consequently becomes more of a priority.

An increasing problem in recent years is presented by the proliferation of poaching activities particularly in the Mhlathuzi estuary and both St Lucia lake and the tributary rivers. User conflict arose in the past between estuarine fishers and the offshore trawlers, a situation not unusual in various parts of the world where prawns occur. While the bait fishery in St Lucia has been terminated and it is probable that the Richards Bay fishery will also cease to exist, ultimately because of loss of suitable prawn habitat, the poaching operations stand to replace the legal and known fisheries with an uncontrolled situation and an unknown offtake. This obviously complicates any management policy or strategy.

Prawn farming developed during a period when environmental legislation was less far reaching than it is at present and it is a moot point whether approval would have been obtained in the present climate, although it is fair comment that the areas under prawn ponds represent an extremely small proportion of the KZN coastal environment. The development of the two KZN farms has not involved habitat destruction in any way akin to that found in the mangroves of countries like Thailand and Ecuador, and in fact the Mtunzini farm was developed on what had been caneland so no natural habitat was affected. At the same time the waste water from both farms is discharged into the nearest estuary and while no impacts were detected in the brief study carried out in 2000, the question of the legality of the present system remains. The possibility of further development of prawn farms in South Africa is also an open question. A very recent report in the Natal Mercury (24 February 2005) described a proposed R800 million "super-intensive" farm which would involve substantial extensions to the existing farm at Mtunzini on the KZN north coast including new developments on the northern bank of the Mlalazi River *(See Appendix A for full article).*

The latitude of the present farms already presents climatic problems in terms of the length of the growing season. New developments are more likely to be successful north of the present farms, assuming of course that suitable coastal areas are available. The economic viability of farms situated away from the coast is very doubtful. Developments south of the present farms would have to deal with progressively less favourable geomorphological and climatic conditions. The major flat coastal areas are situated on flood plains where developments would encounter both legal obstacles as well as the obvious risks associated with such an environment. Cultivation of the presently used species at these higher latitudes would require artificial heating or greenhouse facilities of some sort which represent major capital investment. Greenhouse type techniques are under consideration in the Mtunzini development described above. There are other species of prawns, *e.g.* the indigenous *M. japonicus* or the east Asian *P. chinensis* which grow at lower temperatures but the advisability of introducing an exotic species would have to be considered extremely carefully. It should also be borne in mind that it took nearly 20 years before techniques and knowledge were developed to the point that the indigenous *F. indicus* could be successfully and, more importantly, profitably cultivated. This latter factor is, however, critically dependent on international price fluctuations.

A significant step in the management of the prawn resource and the co-operation of the various organizations or individuals linked by a common interest in prawns was taken by the formation of the Prawn Interest Group working out of the then Biology Department of the University of Natal Durban in 1996. This was the basis of the Prawn Fisheries and Development Association which was gazetted in 1998. This represented a major development as it brought together for the first time representatives of the fishing industry, both estuarine and offshore, conservation and law enforcement bodies, prawn farmers and Marine and Coastal Management. This provided a valuable forum for the exchange of views on a variety of aspects of the management of this resource, including trawling, farming, export/import, duties, uncontrolled imports, poaching and viral diseases on farms.

4 CONCLUSIONS & RECOMMENDATIONS

In conclusion, the following are the major points relating to the conservation of the shallow water South African prawn stocks:

- Protection of nursery grounds, particularly the Mhlathuze estuary, as much of the southern and western mangrove channels and areas of Richards Bay harbour as possible, and the St Lucia lake system is vital. In the latter case, floods and droughts are part of the natural perturbations to which the system is subjected and which periodically force salinities beyond tolerance levels, but consideration should also be given to the determination of the ecological reserve for the system such that minimum freshwater inputs are maintained within known natural limits.

- Available evidence indicates that the Thukela River, while not providing significant nursery grounds in the lower reaches, does exert an extremely important influence on processes on the Thukela Bank and any attempts to modify this system

- through, *e.g.* significant water abstraction or dam construction, should be extremely carefully considered.

- There does not seem to be any reason to reduce the present levels of offshore fishing effort although suggestions for any increase should be carefully considered. It should also be reiterated that there is no information on the impact of trawling on the benthic communities as opposed to bycatch.

- Every attempt should be made to either prevent poaching of juveniles in estuaries, particularly in the major nursery grounds, or to manage or at least quantify these activities in some way such that an assessment can be made of the catch relative to the discontinued bait prawn fisheries. Despite strongly expressed differences of opinion regarding the impact of the estuarine fisheries on the offshore catch in the past, the two operations ran in parallel for many years. Unless the poaching operations generate much larger catches than the former bait fisheries, it is presumably possible that the two operations could again follow the same course. The ramifications of such an approach would obviously require careful consideration.

- It should be borne in mind that available evidence indicates that the South African shallow water stocks, particularly the major commercial species, are not part of the larger Mozambique stocks and therefore exploitation based on the surmise that KZN stocks can be replenished from "further north" is a risky assumption.
- From an economic and health point of view, if the profitability of the local fisheries and the quality of the product available to the local consumer are to be maintained, it is imperative that adequate control of overland imports, especially from Mozambique, be exerted.

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All photographs used in this document were taken by N.T. Demetriades with the exception of the inset photos A & B which were provided by J. Walsh.

Members of the Prawn Fisheries and Development Associattion

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