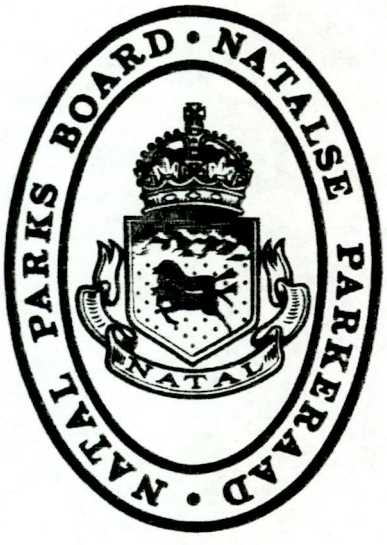

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RECOMMENDATIONS FOR ITS DEVELOPMENT IN SOUTH AFRICA

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INTRODUCTION

Artificial prawn culture potential in Natal and factors affecting its implementation have been briefly discussed in a previous report (Champion, 1971). It was suggested that northern Natal met die climatic requirements for culture development but that the geomorphology of the coastline imposed certain limitations. Only three estuarine systems, Kosi Bay, St Lucia lake and Richards Bay, are large enough for "free ranging" estuarine farm practices (Durban bay excluded for obvious reasons). Each of these systems are however, subjected to different environmental influences, both natural and induced, which would affect attempts at aquaculture. The merits of prawn culture development were therefore considered independantly for each system.

A concession has recently been applied for to establish a prawn farm (free range cultivation) within the Kosi Bay system. This has resulted in a controversy which has been prominently featured by the Natal Press (Natal Mercury 17.3.71; Daily News 19.3.71, etc). It may be of some assistance at this stage, to examine the possibility of penaeid prawn culture in South Africa in greater detail, with particular reference to implementation within the context of local environmental conditions.

ARTIFICIAL PRAWN CULTURE AT THE INTERNATIONAL LEVEL

The artificial production of penaeid prawns for the market is as yet a highly specialised and expensive operation which is far from having been perfected. It is widely recognised that this is a pioneer development, still in its infancy, and even in countries with the most advanced

culture /.....2

culture techniques, many problems still have to be solved. A large number of these problems are basically economic rather than biological and considerable research effort is motivated by the necessity to provide an economically viable technique rather than a biologically successful one. In this connection it is therefore important to realise that the development of prawn culture techniques has been possible largely because of the high prices prawns command. Prawns for human consumption fetch high prices throughout the world and as a commodity fall into the 'luxury food' category. The "produce high class protein to feed the hungry masses" concept cannot be applied to artificial prawn culture at this stage and it is unlikely that this will be realised in the immediate future.

Prawn culture practices may be said to have originated in the Far East where "The culture of shrimps and prawns is an ancient art which is essentially a pastoral practice" (Webber, 1970). In Japan however, "a partially successful effort has been mounted by government subsidized private industry to develop a more sophisticated maricultural technology for the rearing of Penaeus japonicus. This work was led by Fujinaga and his associates (1942)". (Webber, 1970). Today, Japan is generally regarded as having developed the most advanced prawn culture techniques, to the extent that Japanese larviculture technology has been "exported" to countries such as the U.S. (Webber, 1970) and more recently, Korea and Europe (Fujinaga, 1970 pers. comm.).

The achievement of successful techniques for producing postlarvae or small juveniles must not however, be confused with the requirements for artificially rearing juvenile prawns to marketable size, which still presents many problems. Perhaps the most important of these problems is devising economic means of feeding prawns during the adult rearing phase. Webber (1970) summarises the situation in Japan as follows:- "The Japanese spawning and larviculture techniques through to the production of postlarvae or small juveniles, have proven highly successful, and tens of

millions/.....3

millions of postlarvae can be produced at a cost of about 0.1c U.S. each. However, the culture of juvenile-to- market size shrimp is still limited by the inability to feed the rapidly growing shrimp economically, since the reliance on minced clam meat is not likely to be a commercially viable practice. Along the shores of the Inland Sea of Japan, where many shrimp hatcheries are maintained with government subsidies, postlarvae are produced mainly for stocking managed embayments, with the expectation that stocking natural waters will make a significant contribution to the commercial trawler catch. This has not yet been proven to be a sound practice." Further comment on the feeding problem is made by Heydorn (1970) who after returning from a visit to Japan stated "cost of the food is astronomical and only the high price of Kurumu shrimp on the Japanese market makes this venture profitable. 7 Kg. of food are necessary to produce 1 kg. of Kurumu shrimp and the cost of the food without any other overheads is ⅓ of price obtained for the final product on the market" (it should be noted though that food conversion rates vary enormously being dependant on physical, chemical and climatic conditions and also food quality and availability).

It is extremely difficult to assess the profitability of artificial prawn culture practices. Hickling (1970) referring to both fish and prawn farming states "The fact that fish farming is carried out shows that it must pay". Indications however, are that profitability in most instances still hardly exceeds subsistence levels. Longhurst (1969) in a recent F.A.O. sponsored review of the world's crustacean resources, refers to pond production in the western central Pacific area and states "Pond production of larger species of marine prawns is practiced in several places within the region, and fractionally increase the total prawn production of the region." Fujinaga (1969) has, under carefully controlled experimental conditions been able to show a marketable yield of 2.5 kg. of prawns per square metre of pond per annum, but it has not yet been shown that this can be repeated economically on a commercial scale. Commercial prawn pond yield in Japan is

generally/.....4

generally estimated at 200-300 gms/m^2 (Fujinaga, 1968) while in Singapore Tham (1968) gives it at approximately 80 grams/m^2, and in the Philippines Caces-Borjas and Rasalan (1968) give it at approximately 15 gm/m^2. Thus while estimates of prawn pond productivity are available, those of related cost structures are not.

In the U.S., Marifarms Incorporated (a branch of Akima International, Incorporated) have initiated a vast commercial prawn culture undertaking in part of St. Andrew's Bay, Florida, under Japanese technological management. The principle employed here represents a departure from traditional prawn culture practices in that instead of practicing intensive pond culture within preconstructed ponds with a maximum size of 25-30 hectares, a very much more extensive approach is adopted. Farms may incorporate more than 1,000 hectares of natural waters (sheltered bays, estuaries, lagoons, etc.) Webber (1970) terms this practice 'embayment culture' while it has been locally referred to as 'free ranging culture' (Champion, 1971). 'Farms' of this type are enclosed by suitable mesh netting fences which exclude predators and competitors and confine the prawns. Farms may be subdivided into different camps, the concept being analagous in many respects to terrestrial animal husbandry practices. The development of free range or embayment prawn cultivation is interpreted as an attempt to overcome the necessity for artificial feeding and water quality control. By introducing prawns into vast rearing camps, it is hoped to rely on natural biological productivity to meet prawn food requirements. Predators and competitors within the confinement area are eliminated and the production of natural food is stimulated by inorganic and/or organic fertilization. This concept has not yet proved successful. As an experimental exercise, it is expensive in terms of the large area of water required and as a commercial undertaking is limited in the lack of effective control over stock. Furthermore, the ecological repercussions of this type of operation have to be assessed. Only those countries having extensive stretches of undeveloped suitably sheltered waters, where adverse effects could easily be absorbed by the ecosystem are

therefore/.....5

therefore in a position to experiment with such a scheme.

The Marifarms venture in the U.S. takes in some 2,500 acres (1,012.5 hectares) of St. Andrew's Bay (Ocean Science News, 9.4.70). Experimental operations commenced early in 1968 and the first commercial crop was expected at the end of 1970. Their projected commercial yield was at least 1 million pounds per annum. They in fact stated "In order to get established commercially, Akima must produce from 3 to 5 million pounds per year of edible shrimp tails in its first few years of operation". (Panama City News - Herald, February 23, 1969). Figures on the prawn yield for 1970 are not available but it would appear that the crop was far smaller than anticipated. According to Read (1971, pers.comm.) Marifarms have not made any notable contribution on the open shrimp market and were not registered suppliers in any of the fish houses. It has been estimated that they only produced approximately 25,000 pounds of shrimp (= 10 lb. per acre) which were sold locally.

Predictably, some of the biggest setbacks suffered by Marifarms have been in the open range adult rearing phase of the project. Apart from harvesting difficulties, a major problem has been un unprecedented increase in the confined crab population. The elimination of fish predators and competitors using selective poisons such as rotenone, resulted in an uncontrollable increase in the number of crabs, primarily Calinectes sapidus (Blue crab), to the detriment of prawn stocks under culture. Attempts to satiate the crabs using trash fish as food merely stimulated the population explosion and the crabs became not only competitors for available food, but also predators of the prawns (Read, 1971, pers.comm). The problem of eliminating the crabs without harming the prawns has not yet been solved since 'crab poisons' are invariably equally lethal to prawns.

Maintenance/.....6

Maintenance of the netting barrier and keeping it free of fouling organisms has provided a further source of trouble. Fouling with algae, tunicates, barnacles, polychaetes etc., takes place very rapidly and serious breaks in the netting have apparently occurred twice due to the resistance provided to free water flow. It is reported that up to now, the only way of keeping the net clean has been to spray continuously with a solution of copper sulphate (Read, 1971, pers. comm). Unfortunately however, minute dilutions of copper sulphate (0.2 parts per million) are lethal not only to prawns but also to much of the animal and vegetable matter they feed on.

There is therefore substantial evidence that the commercial production of prawns for the market by artificial means is still at an experimental stage of development throughout the world. Accurate predictions of productivity cannot be given since there are still too many imponderables attached to the process, particularly the large scale rearing of juveniles to adulthood. The recent upsurge of public interest in prawn culture has resulted in increased financial support for research with encouraging results. Apart from the Far East and the U.S., exciting work is being carried out on carideans and penaeids in Conway, Wales, and experimental projects have recently been initiated in Australia. Inability to provide an economic feeding technique however, remains the most important single factor currently limiting the commercial success of the process. While solutions are being sought in the nutrition field, rearing techniques are at the same time being modified in an attempt to minimise the feeding problem. Free range cultivation is regarded as a recent example of this, where it is hoped to improve natural prawn food regeneration within the culture area to an extent where artificial diet supplementation becomes unnecessary. It has been shown that the merits of this approach are still under experimental evaluation.

There can be little doubt that the problems inhibiting commercial prawn culture will soon be solved. It is

unlikely/.....7

unlikely though that any one technique will prove universally successful. A solution to prawn culture problems in one part of the world may provide useful guide-lines for similar undertakings elsewhere, but local environmental conditions and the special requirements of the associated species to be cultivated will also have an important bearing on results. This has been the case with oyster culture, emphasising that techniques should be formulated within the framework of local environmental parameters where operations of this type are envisaged.

PRAWN CULTURE IN SOUTH AFRICA

Possible reasons for the relative paucity of littoral penaeids in subtropical waters of northern Natal have been discussed by Champion (1971). It was suggested that the geomorphology of the coastline was a contributory factor in that suitable inshore nursery areas for juvenile prawns, and the shallow offshore continental shelf zone favoured by adult prawns, were both limited in comparison with major prawn producing countries. Despite these limitations it was felt that the potential existed for successful artificial prawn culture.

Sheltered tidal regions such as estuaries, lagoons, bays, bayous, or similarly protected relatively shallow stretches of coastline generally form the most favourable sites for prawn culture development. In Natal this type of environment is afforded only by estuaries and estuarine systems. Estuaries are however, extremely important and sensitive parts of the marine environment (Grindley, 1970). Their utilization for cultivation must thus be approached with caution.

Grindley (1970) touches on the vital role estuaries play along a coastline and stresses the necessity to not only conserve but also restore them. He discusses their importance in the life cycles of marine organisms, their high productivity compared with the adjacent sea or river,

their/.....8

of the role estuaries play in coastal marine ecology the necessity for not only conserving those estuaries which remain unaffected but also restoring estuaries which are affected is self evident.

It is important at this stage to examine the possible effects of the intrusion of artificial culture activities into the estuarine environment. Basically three groups of estuarine/marine organisms are receiving wide-spread attention for commercial culture possibilities. These are molluscan bivalves such as oysters, mussels and clams, fishes such as mullets, carp, tilapia, milkfish, tunny and crustaceans such as prawns, shrimps, crabs etc. Bivalve culture appears to pose less of a potential threat to ecological balance than either fish or prawn culture, primarily because bivalves are non motile and do not have to be enclosed. Fishes and prawns on the other hand have to be confined because of their motility and in addition predators and competitors have to be removed. If such developments take place in an estuary, the artificial displacement of many species results, and if it happens on a large scale fundamental estuarine function may be infringed to the extent that it can no longer serve as a useful part of the natural ecological environment.

Prawn rearing practices are conveniently divided into three types of operation. Firstly, there is intensive small pond culture in preconstructed pond units which could ultimately give rise to a broiler type rearing technique. Ponds may be up to 30 metres long and their small size allows precise control over many aspects of the culture process. Secondly there is the pond culture practice generally favoured in the far east whereby coastal swamps or similar low lying marginal marine regions may be excavated into tidal ponds up to 30 hectares in area. Water level control and exchange is effected via ingenious siphon systems or sluice gates (Hall, 1962; Fijunaga 1968). Finally, there is free range culture where vast areas of the marine environment such as small bays or parts of an estuary may be fenced off as has been described for the Mariculture project in Florida.

The /.....10

The essential difference between prawn pond culture and free range culture is that the latter encroaches on the aquatic environment, whereas the former extends it. Arising from this, the controversy may arise as to whether preservation of the marginal land is more important than part of an estuary or vice versa. Obviously hard and fast rules cannot be applied and individual cases should be treated on merit. It may be felt that carefully controlled culture in selected unproductive regions could be complementary to the natural role of an estuary. Even if this contention proved true, it must be remembered that the free range culture system operates on a vast scale and there are very few estuarine systems in South Africa large enough to accommodate the concept, while retaining their integrity as viable natural systems. The free range culture technique should apply only to regions with an abundance of estuaries, sheltered bays and lagoons, where experimentation on such a scale does not unduly threaten the eco-system. It should not be contemplated in South Africa, which has an unsuitable coastline (Champion, 1971). If both the fundamental importance of estuaries and the fact that much of Natal's estuarine endowment is already under stress, is acknowledged, and if, as has widely been claimed, marine areas have the potential for producing far more high grade protein than terrestrial pastures (Ryther and Matthiessen, 1969; Grindley, 1970; Pinchot, 1970; Hickling, 1970), then surely there is a strong case for creating aquaculture facilities in marginal land areas and conserving the remaining estuarine environment until the implications of farming estuaries are better understood.

Apart from the question of proposed prawn culture techniques in South Africa, the species to be cultured must also be considered. The most abundant neritic South African penaeid species is Penaeus indicus. Preliminary confinement studies suggest that it is also the most suitable local species for commercial cultivation (Champion, 1970). Although increasing numbers of penaeid species are being investigated for culture potential,

serious/..... 11

serious work has not previously been undertaken on P. indicus.

Penaeus japonicus, an abundant Japanese species, was the first prawn to be artificially reared from the egg stage (Hudinaga, 1942) and is probably one of the most extensively studied penaeids to date. As has already been emphasised however, the results of research carried out on P. japonicus, or any other species, can only serve as a guide to similar work on P. indicus. Cook (1969) in describing techniques for rearing P.aztecus and P. setiferus states "Although Hudinaga was most explicit in his explanation of the methods used to culture larvae of Penaeus japonicus Bate, I have not been able to rear larvae of penaeids from the United States by following his methods". It cannot be expected that successful methods for one species in a particular region will be equally successful when applied to a different species somewhere else.

This viewpoint is supported by similar findings for artificial oyster culture. Although oyster culture has been successfully undertaken in different parts of the world for many years, ten years of research at Knysna have failed to resolve all the problems relating to this development in South Africa. von Michaelis (1970) in a report on oyster culture to the Fisheries Development Corporation of South Africa Ltd., states "it must be emphasised that hatchery techniques which work well in one region of the U.S.A. may fail in others. Techniques have to be developed for the particular environment and species of oyster. Nevertheless the extensive overseas research may be used as an excellent guide line in developing the industry in South Africa". Later he states "It is essential to approach aquaculture projects in South Africa empirically in the area where they are to be practiced.

The Fisheries Development Corporation hired Mr. van Dort an oyster farmer from Holland, to set up an oyster farm in the Knysna lagoon. His attempts at a bottom

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culture were unsuccessful because the environment in Holland and South Africa were totally different".

Thus while it is believed that the stage is set, at the international scientific level, for significant advances in prawn culture technology, the most urgent requirement in South Africa is for meticulous, well documented research. Experience data resulting from research undertaken elsewhere may be used to advantage in promoting local developments but should not obfuscate the objectivity necessary for local success. Free range prawn culture has not yet proved successful in the U.S. despite expectations to the contrary. It is extremely unlikely that this technique would prove successful in South Africa and in view of the adverse effects which might result, it would be unfortunate if it were attempted.

In South Africa it is particularly important that prawn culture undertakings are developed in harmony with existing eco-systems because of a limited viable habitat which must serve the needs of many organisms. In the words of Pinchot (1970), it is "of the utmost importance that we follow the principles of ecology in our efforts to develop marine farming, by working with nature to establish balanced, stable communities rather than by supporting large single crops artificially, as we do on land, with what are now becoming recognised as disasterous side effects. Perhaps the single most exciting challenge we have in marine farming is this opportunity to make a new start in the production of food, utilizing the ecological knowledge now available".

The time has not yet been reached when entrepreneurs might expect generous short term returns on investments in artificial prawn culture, but there is a very real need for long term investments in the research which will ultimately make this possible.

PRAWN CULTURE IN THE KOSI BAY SYSTEM

The Kosi Estuary system and its interrelationships have been described by Tinley (1958), Broekhuysen and Taylor (1959), Breen and Hill (1969), Hill (1969) and Allanson and van Wyk (1969). The names for the different partsof the system in this report refer to those used in the Trigonometrical Survey Map of the area for reasons explained by Breen and Hill (1969).

Very briefly, the mouth of the system leads from the sea into a broad fairly shallow tidal basin with an essentially sandy bottom. Ku Kongozu is a wide channel linking the tidal basin with Ku Mpungwini, the first lake. Ku Mpungwini is succeeded by Lakes Sifungwe (second lake), Nhlange (third lake) and Amanzimyama (fourth lake). Each of the lakes are connected by interleading channels. According to Hill (1969) Ku Mpungwini has an area of approximately 80 hectares, Lake Sifungwe 280 hectares and Lake Nhlange 3,070 hectares.

In December, 1970, two Japanese scientists, Dr. M. Fujinaga and his son Mr. T. Fujinaga who are acknowledged authorities on artificial prawn culture, spent a week inspecting the Kosi system at the invitation of a South African company interested in promoting such a venture. The Fujinagas were apparently satisfied that the site was suitable for prawn culture and proposals have been put forward to utilise part of the Kosi system for a free range prawn farm. It has been suggested that the farm would be established under Japanese technological supervision, but that they would be phased out once the project was operative. The venture sounds very similar to that embarked on by Marifarms Incorporated in Florida.

According to press reports (Natal Mercury, 17.3.71, Daily News, 29.3.71 etc) it is intended to initiate the project in Ku Mpungwini and incorporate Lake Sifungwe and a small portion of lake Nhlange if the first phase proves successful. It is reported that the entire farm would occupy less than 6% of the total estuary system

(approximately /.....14

(approximately 216 hectares = 534 acres occupied) and suggested that Ku Mpungwini alone "should produce about 200 tons of prawns a year" (Natal Mercury, 17.3.71). This gives an anticipated yield in the region of one ton of marketable prawns per acre (200 tons per 197.6 acres). Net fencing would allow for an unobstructed channel through the farm so that migrations of organisms between the top and bottom of the system would be unaffected. The "nourishment potential of the water" would however, have to be improved by enrichment "with organic fertilizer to the extent of 1 gram per square metre" per annum in the farm area. "On Ku Mpungwini this would amount to about four tons a year", (quoted from Natal Mercury, 17.3.71).

In spite of the understandable enthusiasm and admirable intention of the South African company promoting the project, and with due respect to the Fujinagas, it is felt that it would be financially disastrous to invest in the prawn culture scheme at Kosi Bay outlined above. In addition there is the very real possibility that undesirable ecological side effects would result. Dr. Fujinaga is held in high esteem internationally for his pioneering work on penaeid prawn culture, but it is unrealistic to assume that anyone could assimilate the scope of potential problems facing such an undertaking in a system as large and diverse as Kosi Bay in one survey lasting a week.

The importance of conserving estuaries in Natal and the need to carefully assess the ecological impact of culture implementation has already been stressed. It should be clear that a natural ecological balance cannot be maintained within a prawn culture area and free range culture in an estuary could well prove inimical to the ecosystem. The fact that the free range culture technique is still under experimental evaluation, and is in certain respects suspect, has also been discussed. Quite apart from these considerations however, there are factors inherent in the Kosi system which detract from the feasibility

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of free range culture there.

It should at this stage be mentioned that Champion (1971) in a previous report on the implications of artificial prawn culture in South Africa, stated that "The Kosi Bay estuary is broad and shallow with clean water and an essentially sandy bottom". He also referred to "an extensive system of tidal traps in the estuary". These statements do not apply to the whole system but only that portion nearest the sea known as the tidal basin and part of Ku Kongozu. The recent disclosures in the press indicate that this region is not directly implicated in the culture proposals.

(i) Depth: The majority of recent publications describe the depth of prawn culture ponds as between 1 and 2 metres (Caces-Borjas, 1968; Tham, 1968; Fujinaga, 1968; Heydorn, 1970). The Marifarms prawn farm in Florida is said to have a depth of 8 to 10 feet (Ocean Science News, 9.4.70). Although neritic penaeidae are trawled from depths greater than 60 metres at sea, it is suggested for various practical reasons, that artificial culture areas should not be much deeper than 5 metres.

Harvesting becomes progressively more difficult as water depth increases, water movement and chemical and physical interactions with the atmosphere are often adversely affected, and the production of many nutritiously valuable algae with their associated epifauna is inhibited in deeper water.

In the Philippines "lab-lab" a jelly like growth of blue green algae with associated plant and animal epiphytes is promoted in shallow water ponds approximately 1 metre deep as an excellent natural food for young fish and prawns (Caces-Borjas, 1968; Hickling, 1970). In deeper water "lumut", essentially filamentous green algae, is similarly promoted in the place of "lab-lab" as food for larger fish and prawns (Caces-Borjas, 1968; Hickling, 1970). Hickling (1970) states that one of the best algal diet supplements in this area is Gracilaria confervoides which flourishes between salinities of 5°/oo and 30°/oo and at

depths/.....16

depths up to 8 feet with optimum growth around 4 feet. Since similar natural foods would probably be necessary at Kosi Bay, water depth becomes important.

Vast areas of Ku Mpungwini, Lake Sifungwe and Lake Nhlange are deeper than 5 metres (Breen and Hill, 1969; Hill, 1969). According to Breen and Hill (1969) the eastern half of Ku Mpungwini is about 8 metres deep, but towards the west it is shallow and sandbanks are exposed at low tide. Hill (1969) gives the maximum depth of Lake Sifungwe as 18 metres (mean 8.1 metres) and of Lake Nhlange as 31 metres (mean 7.2 metres). The areas enclosed by depth contours at 5 metre intervals given by Hill (1969) show that approximately half of the total area of both Lake Sifungwe and Lake Nhlange is deeper than 5 metres and his bathymetric chart of the lakes shows that the increase in depth from 5 metres to 15 metres is rapid in both lakes.

If prawn farming were to be ideally carried out within the 2-5 metres depth range, probably less than 25% of the proposed farm area would fall within this range.

(ii) Dissolved oxygen content: All penaeid prawns used for culture are benthic aerobes. They are unable to survive under anoxic conditions. Confinement studies on P. indicus, P. monodon and Metapenaeus monoceros have shown that mortalities increase when the dissolved oxygen content falls below 3 mg/litre and a content of less than 2 mg/litre is lethal.

Prawns are also essentially bottom dwellers. Although they may be seen swimming in the water column, most feeding takes place on the bottom. When at rest, prawns may be seen sitting on the bottom (P. monodon) and many species spend most of the daylight hours totally (P. japonicus, M. Monoceros) or partially (P. indicus) buried beneath the substratum.

A distinct thermocline has been detected in the deeper half of Ku Mpungwini, the bottom water being warmer and more saline than at the surface. Anaerobic

conditions/.....17

conditions are known to develop on the muddy bottom under these conditions (Grindley, 1971, pers. comm; Broekhuyzen and Taylor, 1959).

The complex physical and chemical character of Lake Sifungwe and Lake Nhlange has been discussed by Allanson and Van Wyk (1969). They show that a thermocline also exists in Lake Sifungwe which is particularly marked at the 9 metre depth contour in winter and not quite so marked, although still present, in summer. Effects associated with the thermocline resulted in completely anoxic conditions being found at 9 metres in July 1967 and at 13 metres in January 1966 (Allanson and van Wyk, 1969). No evidence of a thermocline or of permanent stratification of dissolved oxygen exists in Lake Nhlange (Allanson and van Wyk, 1969).

From the above it is clear that penaeid prawns would be unable to exist in approximately 50% of Ku Mpungwini and slightly less than half of Lake Sifungwe due to anaerobic conditions.

(iii) Salinity: Tham (1968) referring to the pond culture of P. indicus, P. merguiensis, M. ensis, M. burkenroadi and M. brevicornis in Singapore, suggests that the minimum desired salinity level for efficient culture is 15°/oo, the most favourable regime being 24°/oo to 30°/oo. He refers to significant catch reductions after heavy drainage of rainwater into ponds in support of Racek's (1957) contention that a rapid salinity decrease causes mass migrations of prawns of all age groups from the estuarine to the offshore environment. Webber (1970) states "Salinity control must be exercised to ensure that for the Gulf and Caribbean Penaeids, salinities are appropriate for the growing stages and generally may range from as low as 20 ppt during juvenile growth periods on up to full salinity for adults. Generally however, salinity between 28 and 32 ppt appears to give optimum results". Hempel (1970) comments further stating "Basically, American shrimp farming is similar to the Japanese method of pond culture. Optimum salinity increases from 20 to 30°/oo.

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Local penaeid species such as P. indicus, P. monodon and M. monoceros are euryhaline (as are most littoral penaeids) and able to tolerate wide fluctuations in salinity. Specimens of P. indicus have been netted in completely fresh water and in water with a salinity of 63.1°/oo on different occasions. Observations during rearing studies however, suggest that P. indicus suffers osmoregulatory stress after prolonged confinement in salinities below 12°/oo. It is well known that prawns migrate out to sea prior to spawning and do not subsequently return to the estuarine environment. It would not therefore be surprising if larger prawns were found to favour salinity levels closer to sea water.

The results of a survey of the Kosi Bay Estuary system in July, 1949 by Broekhuyzen and Taylor (1969) showed a salinity gradient ranging from 3.3°/oo in the top part (Lake Nhlange) to 33°/oo near the mouth. Readings showed a salinity layering effect in Ku Mpungwini with surface recordings of 7.4 - 8.1°/oo and a bottom reading of 18.3°/oo. Salinities of 6.6 - 7.5°/oo were recorded in Lake Sifungwe (Broekhuyzen and Taylor, 1959).

Further determinations of salinity in Lake Sifungwe and Lake Nhlange were made by Allanson and van Wyk (1959) during the period July 1965 to July 1967. Salinity layering is shown to be associated with the thermocline in Lake Sifungwe. In January 1966 salinities ranged from 4.8°/oo at the surface to 13.8°/oo at 16 metres. In January 1967 the salinity was 11.6°/oo at the surface and 13.2°/oo at 13metres while in July 1967 surface salinity was 4.2°/oo and that at 16 metres 13.8°/oo. In Lake Nhlange, where no thermocline existed, salinities were relatively uniform throughout the water column and read 4.9°/oo in July, 1965, 4.2 - 4.3°/oo in January, 1966, 3.8 - 3.9°/oo in January, 1967 and 3.0°/oo in July, 1967 (Allanson and van Wyk, 1969).

In January, 1970 a survey of the plankton and productivity of the Kosi Bay system was carried out by the Port Elizabeth Museum. Salinities were measured and it

was/.....19

was found that the tidal basin had a surface salinity of 21°/oo, Ku Mpungwini 13°/oo and Lake Sifungwe 7°/oo (Wooldridge, 1971, pers. comm.).

The above results are summarised in TABLE I.

TABLE I. Salinity readings in the Kosi Bay system from July 1949 to January, 1970.

Area		Jul'49	Jul'65	Jan'66	Jan'67	Jul'67	Jan'70
Tidal Basin		33					21
Mpungwini	Surface	7.4-8.1					13
	Sub-Surface	18.3					
Sifungwe	Surface	6.6-7.5		4.8	11.6	4.2	7
	Sub-Surface			13.8 (16m)	13.2 (13m)	13.8 (16m)	
Nhlange		3.3	4.9	4.2-4.3	3.8-3.9	3.0	

In terms of prawn culture it thus becomes evident that salinity has an important bearing on implementation proposals at Kosi Bay. A typical estuarine salinity gradient exists in the Kosi Bay system with water becoming progressively less saline as distance from the sea increases. If, as has been suggested, penaeid prawns favour fairly high salinities (above 20°/oo) conditions become progressively less favourable for artificial culture the further one moves up the system. It may be mentioned at this point that Marifarms, who operate their prawn farm in a marine bay with very little fresh water inflow, emphasised that low salinity estuaries were not favourable prawn culture sites (Panama City News - Herald, 23.2.1969)

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In Ku Mpungwini, where it is proposed to initiate local prawn farming operations, salinities higher than 15°/oo have only been recorded on the bottom where anaerobic conditions prevail (TABLE I). In Lake Sifungwe the highest salinities recorded (13.8°/oo) have again been in the anoxic zone while surface salinities have varied between 4.2°/oo and 11.6°/oo. Salinity readings from Lake Nhlange have been remarkably uniform both vertically and temporally, ranging from 3.0°/oo to 4.9°/oo.

On the basis of salinity, Lake Nhlange may therefore be regarded as totally unsuitable for commercial prawn culture. In Lake Sifungwe and Ku Mpungwini, operations may be possible but difficulties are anticipated.

(iv) Floods: Although the Kosi Bay system is large enough to absorb most of the physically damaging effects of sudden floods, the work of Breen and Hill (1969) indicates that flooding with a resultant raising of the general water level and lowering of salinities does occur. They concluded that a mass mortality of mangroves in 1965 was due to flooding of the estuary following upon closure of the mouth for 5 months. This need not be regarded as a persistent hazard to prawn farming in the system, but should be recognised as an irregular feature which might intermittently jeopardise short term culture efforts.

(v) Water enrichment by fertilizing: It has been implied that the Kosi Bay system is unproductive in comparison with other South African estuaries (Natal Mercury, 17.3.1971). For this reason, it is proposed to "enrich" the water by applying an estimated gram of organic fertilizer per square metre of farm, thereby making the area more suitable for prawn rearing. It is not clear what form of food promotion is anticipated. Hickling (1970) discusses organic fertilisation which results in an enrichment of phytoplankton and benthic diatoms. He emphasises the importance of providing foods for early stage crustaceans, the simplest form

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being the production of mixed cultures of phytcplankton in well-fertilized seawater kept in sunlight. "Green water" is widely used in Japan for cultivating zooplankton which act as food for shrimps (Hempel, 1970).

The work of Allanson and van Wyk (1969) suggests that considerable movement and mixing of the upper water layers takes place in the Kosi Bay system. Their results for example, indicate very efficient circulation in the upper less saline layers of Lake Sinfungwe. Broekhuyzen and Taylor (1959) show that tidal effects are evident in Ku Mpungwini. If the promotion of a phytoplankton-zooplankton-macro-organism enrichment process is therefore contemplated, the whole Kosi Bay system will probably have to be fertilized, as water displacement will not allow limited enrichment of specified areas.

Water "enrichment" by fertilisation is however, likely to have undesirable side effects unless very carefully controlled. Webber (1970) relates some of these side effects during experimental prawn culture when he states "The bacteriological organic decay of unused feed, and the residue of phytoplankton blooms, is probably the most serious deterrent resulting in mass mortalities due to oxygen depletion. Reduced photosynthetic activity in the ponds during extended periods of cloudy weather, resulting in reduced dissolved oxygen, must be compensated for by mechanical aeration, or water exchange". Rates of feeding of over 40 pounds per acre per day also become a serious problem without supplemental aeration (Webber, 1970). Hempel (1970) states "The major causes of mortality are periods of O_2-deficiency due to overfeeding the ponds without application of aeration", referring to prawn culture in America.

The Kosi Bay system characteristically has exceptionally clear water and most of the shallower areas have a sandy bottom. Artificial enrichment of the water to provide natural prawn foods would be necessary

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for any prawn culture undertaking in the system. Whether or not controlled enrichment can be successfully carried out, there is little doubt that the ecology of the whole system would be profoundly affected, very likely to its detriment.

In view of the situation which exists at Kosi Bay it is unlikely that free range prawn culture could be successfully undertaken. The only advantage the area offers is that temperatures seldom drop below 18°C, even in winter (Broekhuyzen and Taylor, 1959; Allanson and van Wyk, 1969) so that winter growth rates would not be inhibited to the same extent as further south where colder temperatures may prevail. The combined disadvantages of an unfavourable bathymetry and salinity regime, anaerobic conditions over large parts of the proposed farming range, the uncertainties associated with fertilisation, and the unhappy experiences of Marifarms Inc. in trying to implement the free range techniques, by far outweigh any advantage favourable temperatures may offer.

PRAWN CULTURE IN THE ST LUCIA LAKE SYSTEM

In addition to reasons which have already been given why free range prawn culture should not be implemented in any South African estuary, the following considerations should be taken into account.

Nature reserve status has already been conferred on the St. Lucia lake system. This implies conserving the entire area as a natural integrated ecological unit. The fact that penaeid prawns are abundant should not be regarded as a motivation for initiating extensive prawn culture operations within the system.

The St Lucia lake system is a magnificent wildlife area supporting an extensive bird fauna as well as large hippopotamus and crocodile populations. As a tourist attraction it has tremendous potential and probably has

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far greater foreign revenue earning capacity than any prawn farm would have.

The crocodile and hippopotamus are two species which might be regarded as threatened in South Africa due to a limited number of reserves with a suitable water habitat. St Lucia represents perhaps their largest remaining refuge. Free range prawn culture is not compatable with the conservation of these animals.

Vast amounts of money have been spent in attempting to preserve St Lucia as a viable system. Expensive dredging has taken place at the mouth and a groyne has been built in an attempt to consolidate the mouth and keep it permanently open. A deep channel has been dredged up the entire length of the Narrows to ensure efficient water exchange between the lake and the sea and easy access for marine organisms. The mouth of the Umfolozi river has been diverted to prevent silt deposition in St Lucia estuary. All this money and effort has been expended to preserve St Lucia as a nature reserve and sport fisherman's paradise. The requirements of the area as a nature reserve should therefore take precedence over other considerations.

Despite the conservation efforts of the past, the St Lucia system is currently plagued by a lack of fresh water. This has resulted in hypersaline conditions which have risen to lethal levels in the northern regions. A solution to the problem is being sought and various proposals have been put forward. It is essential that the situation be restored if the expense and effort in the past is to be justified. Success must however, be achieved for the right reason, which is to accommodate an ecologically integrated plant and animal community, not to make a prawn farming operation possible, if any value is to be placed on our concept of nature reserves and their fundamental function.

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In a previous report (Champion, 1971), it was suggested that prawn culture might be considered in areas wuch as Makakatana Bay and Brodies Crossing. In retrospect, this is no longer deemed feasible. These regions are too shallow for prawn culture, support a most prolific and varied avifauna, and also harbour crocodiles. Prawn culture undertakings which might be considered at St Lucia should take place outside the estuary and be confined to built-up areas.

MacNae (1970) suggested prawn pond culture in association with hybrid Tilapia culture might be considered in the area between St Lucia estuary mouth and the Umfolozi river mouth. The land is not used at present, is close to St Lucia township, and MacNae pointed out that ponds constructed here would have access to either fresh or sea water for salinity control. The proposal merits serious consideration as the site is ideal for experimental feasibility work.

PRAWN CULTURE IN RICHARDS BAY

Large scale prawn culture in Richards Bay cannot be contemplated until the effects of the planned harbour development are known. Since the ecology of Richards Bay will however, be drastically affected by the harbour, the area not incorporated in the harbour forms the most suitable site for experimental evaluation of the free range culture technique if the foregoing assessment is considered unreliable.

DISCUSSION AND CONCLUSION

Artificial prawn culture in South Africa, particularly the effects of free range culture, has been discussed in some detail. While research into artificial prawn propagation and rearing techniques deserves support, implementation of free range culture in South African estuaries is not advocated.

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Morphogenic factors along the Natal coast do not favour the free range approach to artificial prawn culture. Natal has a limited estuarine endowment which is already overstressed and in urgent need of both restoration and protection. The free range culture technique as practiced in the U.S. has not yet proved successful despite three years of intensive effort and the advantages of Japanese technological supervision. Finally, bio-physical conditions in the Kosi Bay system make proposals to establish a free range prawn farm there unrealistic. The combination of low salinities and anaerobic conditions over large areas of the bottom, are alone sufficient to preclude success. Additional problems to contend with are the unfavourable bathymetry, difficulties associated with artificial fertilisation, and irregular flooding.

Commercial prawn culture developments in South Africa should be oriented towards culture outside the estuarine environment and should be based on the results of local research. Experimental rearing may either be carried out in large excavated pans, forming virtual controlled extensions of the estuarine environment, or smaller tanks which may be constructed in any undeveloped area with access to sea water. Small tank culture is favoured because of the greater versatility in regard to siting and increased operational control, an important aspect of experimental assessment. Any activities which are initiated within an estuary should be strictly controlled and confined to carefully defined areas.

Consideration of large scale commercial undertakings is at this stage, premature. The interest displayed by private enterprise however, emphasises the necessity for research, not only to solve outstanding problems but also to establish the parameters within which culture developments can successfully take place in the best national interest. Research priorities are firstly, that economic production of commercial quantities of local penaeid post larvae (P. indicus

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and P. monodon) via spawning inducement and larval rearing should be perfected. Secondly, conditions for optimum growth of postlarvae to a marketable size must be determined. This involves interalia, establishing water quality requirements and solving the feeding problem. Thirdly, an analysis of artificial prawn production cost structures is required. The answers to these questions will allow logical discussion and implementation of procedures most likely to succeed.

A small group supported by the Fisheries Development Corporation of South Africa has already been established to undertake this work. Participation in the programme by private enterprise would be encouraged. This could either be by augmenting the established team and increasing the scope of their activities, or by establishing an independant research group to work on defined aspects of the programme. A co-ordinating body would be desirable to prevent duplication of effort and the Fisheries Development Corporation might well be the most suitable organisation to fulfil such a function.

Either St Lucia or Richards Bay are regarded as the most suitable sites for experimental work on prawn culture. Juvenile prawns are readily available in both systems throughout the year. This is important until techniques have been developed to produce juveniles artificially. The other important consideration is the availability of electric power. St Lucia obviously has long term advantages in view of the harbour develop- at Richards Bay.

SUMMARY

1. Artificial prawn culture is still at an experimental stage of development throughout the world. There is an urgent need for research in this area in South Africa as a prelude to commercial development.

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2. While most of the problems relating to the artificial production of juvenile prawns in commercial quantities have been solved, those of economically rearing prawns to a marketable size have not.

3. As far as can be determined from operations in the U.S., free range prawn farming has not yet proved to be a successful culture method.

4. Artificial prawn culture in South Africa should be approached empirically.

5. Free range prawn culture is not advocated in South Africa because of the geomorphology of the coastline, the possibility of undesirable side effects on an already limited estuarine habitat, and the fact that this technique has not yet proved successful in the U.S.

6. Proposed free range prawn culture in the Kosi Bay system is impractical due to unfavourable dissolved oxygen, salinity and water depth conditions. In addition flooding occurs and artificial fertilisation could promote the development of anaerobic conditions in previously unaffected areas.

7. Prawn culture in the St Lucia lake system is unfeasible because the area is a declared nature reserve harbouring such animals as hippopotami and crocodiles which are incompatable with culture requirements. St Lucia is also suffering from severe hypersalinity.

8. Short term experimental culture could be considered in Richards Bay since its ecology is to be drasaffected by the establishment of a harbour.

9. It is recommended that as a general principle, prawn culture developments in South Africa should take place outside the estuarine environment and that research efforts on prawn culture should be co-ordinated as far as possible.

REFERENCES.

1. ALLANSON, B.R. and J. D. VAN WYK. 1969. An introduction to the physics and chemistry of some lakes in northern Zululand. Trans. roy. Soc. S. Afr. 38 (3), 217-240

2. BREEN, C.M. and B. J. HILL. 1969. A mass mortality of mangroves in the Kosi estuary. Trans. roy. Soc. S. Afr. 38 (3), 285-303.

3. BROEKHUYSEN, G.J. and H. TAYLOR. 1959. The ecology of South African estuaries. Part VIII : Kosi Bay estuary system. Ann. S. Afr. Mus. 44, 279-296.

4. CACES BORJAS, P. and S. B. RASALAN. 1968. A review of the culture of sugpo, Penaeus monodon Fabricius, in the Philippines. F.A.O. Fish. Rep. No. 57, 2, 111-123

5. CHAMPION, H.F.B. 1971. The implications and application of penaied prawn culture in South Africa: A report to the Natal Parks Board. Unpublished report, Port Elizabeth Museum, 6 pp.

6. CHAMPION, H.F.B. 1970. Preliminary results of an assessment of the feasibility of a commercial prawn fattening venture on the Amatikula estuary. Unpublished report, Port Elizabeth Museum, 30 pp.

7. COOK, HARRY L. 1969. A method of rearing penaeid larvae for experimental studies. F.A.O. Fish. Rep. No. 57, 3, 709-715

8. DAY, J.H., N. A.H. MILLARD and G. J. BROEKHUYSEN. 1954. The ecology of South African estuaries. Part IV. The St. Lucia system. Trans. roy, Soc. S. Afr. 34, 129-156.

9. DAVIES, G.A.T. 1970. Port and industrial development at Richards Bay. Unpublished memorandum, TRP.R.3143., from the Natal Town and Regional Planning Commission, 5 pp, one appendix (A).

10. FUJINAGA, M. 1968. Kuruma shrimp (Penaeus japonicus) cultivation in Japan. F.A.O. Fish. Rep. No. 57, 3, 811-832.

11. GRINDLEY, J.R. 1970. The role of fresh-water in the conservation of South African estuaries. Republic of South Africa Water Year 1970 Convention: Water for the future, 5 pp.

of some Indo-West Pacific Penaeidae (Crustacea, Decapoda). Fish. Publ. Colonial Off., London, (17), 229 pp.

13. HEMENS, J. et al. 1970. Marine disposal of effluents: Detailed survey of Richards Bay. Progress Report No. 1. S. Afr. Counc. Sci. ind. Res., N.I.W.R. Reference W.5/31/1A, Project 6201/9728, 29 pp.

14. HEMPEL, G. 1970. Fish-farming including farming of other organisms of economic importance. Convenor's report of an informal session held on September 11, during the international Helgoland symposium 1969. Helgolander wissen schaftliche Meeresuntersuchungen, 21 (4), 445-465.

15. HEYDORN, A.E.F. 1970. Report on study trip to agricultural centres and marine farms in Japan, September/October, 1970. Unpublished report, Oceanographic Research Institute, Durban, 6 pp.

16. HICKLING, C.F. 1970. Estuarine fish farming. Adv. mar. Biol. 8, 119-213.

17. HILL, B.J. 1969. The bathymetry and possible origin of Lakes Sibayi, Mhlange and Sifungwe in Zululand (Natal) Trans. roy. Soc. S. Afr. 38 (3), 205-216.

18. KUDINAGA, M. 1942. Reproduction, development and rearing of Penaeus japonicas Bate. Jap. J. Zool., 10 (2) 305-393.

19. LONGHURST, ALLAN R. 1969. Area Reviews on Living Resources of the World's Ocean. Crustacean Resources. F.A.O. Fish. Circ. No. 109.13, 69 pp.

20. MACNAE, W. 1970. The biology of the upper shore in tropical and sub-tropical regions and its economic potential. Oceanography in South Africa, Durban 1970. Symposium paper H4, 3 pp.

21. VON MICHAELIS, HANS. 1970. Oyster hatcheries in North America and Europe. A preliminary investigation. Unpublished report, Fisheries Development Corporation of South Africa, 98 pp.

22. MILLARD, N.A.H. and A.D. HARRISON. 1954. The ecology of South African estuaries. Part V. Richards Bay. Trans. roy. Soc. S. Afr. 34, 157-179.

23. MILLARD, N.A.H. and G.J. BROEKHUYSEN. 1970. The ecology of South African estuaries. Part X. St. Lucia: A second report. Zool. Afr. 5 (2) 277-307.

(8), 15-21.

25. RACEK, A.A. 1957. Penaeid prawn fisheries of Australia with special reference to New South Wales. Res. Bull. State Fish. N.S.W., (3), 1-19.

26. RYTHER, J. H. and G. L. MATTHIESSEN, 1969. Aquaculture its status and potential. Oceanus 14 (4), 2-15.

27. THAM, A.K. 1968. Prawn culture in Singapore. F.A.O. Fish Rep. No. 57, 2, 85-93.

28. TINLEY, K. L. 1958. A preliminary report on the ecology of the Kosi lake system. Unpublished report, Natal Parks, Fish and Game Preservation Board. 90 pp.

29. WEBBER, H.H. 1970. The development of a maricultural technology of the Penaeid shrimps of the Gulf and Caribbean Region. Helgolander wiss. Meeresunters. 20, 455-463.

APPENDIX I

COMMENTS ON PRESS REPORTS

NATAL PROJECT TO BEAT FISHERY CRISIS : HOW PRAWN FARM WILL OPERATE

Natal Mercury, Wednesday, March 17, 1971

1. The implication that prawn culture represents a way of averting the so called "fishery crisis" is premature. As has been pointed out, artificial prawn culture is still at an early stage of development, and it will be a long time before a significant contribution to the world food markets might be expected from this source.

2. Japanese fish farms do not produce anywhere near "80,000 tons of prawns a year". Longhurst (1969) gives the total Japanese prawn catch in 1965 as approximately 66,600 tons which includes prawns trawled from the Bering Sea, the Gulf of Alaska, the Guianas, Australia, the Yellow Sea, the East China Sea, the Kovan Bight and the Japanese Inland Sea. His long term prediction for Japanese prawn productivity from the Western Central Pacific region is 60 000 tons per annum. Longhurst (1969) gives the productivity of Japanese prawn ponds as 300 tons per annum whereas Ivanov (1964) gives a figure of 2 000 tons.

3. South Africa "does not feature in the world fish cultivation stakes" essentially because of her geomorphology as has already been explained. Up until very recently marine culture practices have been a function of the availability of natural resources and favourable sites rather than technological expertise although the latter may be said to have arisen as a result of the former.

4. It is unrealistic to make extravagant claims such as "South Africa could produce her total requirements of prawns within three years". No-one embarking on a pioneer venture still under experimental development can make such predictions with any

certainty.

5. While it is acknowledged that there is still much to learn about the South African penaeidae, the statement "a considerable amount of incorrect information has been bandied about as fact" does not seem justified. The author of the article in fact displays surprising ignorance on many aspects of the biology of local penaeid prawns.

6. Free range prawn culture within an estuarine system affects the whole system. Effects are not confined to the culture range. It has already been pointed out that artificial fertilising, to be effective, would have to involve virtually the whole Kosi Bay system. The effects of rotenone poisoning and copper sulphate spraying would also be felt beyond the fenced area.

7. The number of species in an area does not necessarily reflect productivity.

8. While certain species of prawn bury themselves completely during daylight (P. japonicus), others bury themselves only partially and intermittently (P. indicus), and some not at all (P. monodon).

9. Productivity predictions for free range prawn farming should be interpreted with caution in view of the experiences of Marifarms Inc. in Florida. Since less than half of Ku_Mpungwini is suitable for prawn culture, an estimate of 200 tons for the area seems over optimistic.

10. It has not been proved that "under entirely natural conditions, the adult prawn favours the low salinity water of the lakes, and moves to the higher salinity of the sea to spawn." On the contrary a reversed salinity gradient in the St. Lucia lake system has had no significant effect on penaeid prawn abundance in the Narrows suggesting that salinity does not play an important part in attracting juvenile prawns to an estuary. The work of Racek (1957), Tham (1968), Webber (1970) and Hempel (1970) indicates that hyposaline conditions are in fact detrimental to many adult prawn species.

11. South African offshore neritic penaeid prawn spawning grounds are not fished commercially. It will not therefore be necessary to restock them. Apart from this Webber (1970) states that it has not yet been proved that the artificial stocking of natural waters with juvenile prawns has any material effect on natural stocks.

12. Although the opinion of Dr. Fujinaga and his son is respected, they cannot be expected to speak authoratatively on the merits of free range culture in Kosi Bay after a superficial survey lasting one week.

13. It is unlikely that four tons of organic fertiliser per year would be sufficient for prawn culture purposes in Kosi Bay because of the high exchange rate of the water.

14. Statements such as "If 256 sq. km. of St. Lucia's 361 sq. km. could be used for the cultivation of prawns alone, it would be worth at rates now being obtained overseas, between R150 million and R200 million in foreign exchange" are quite meaningless for reasons perviously stated.

15. Prawn culture in Ku_Mpungwini "is being regarded initially as a prototype" which is virtually the same as regarding it as a feasibility study. If the technique still has to be evaluated under South African conditions using local species, productivity claims are not justified.

16. The Kosi Bay prawn culture scheme is being promoted by a public company which is officially quoted on the Johannesburg stock exchange. While developments may not pose a burden to the taxpaying public, public monies invested in the company will be used.

17. The statement "By allowing the promotors to buy the use of Dr. Fujinaga's patents, South Africa will be saved 20 years of costly research" is so naive it barely merits comment. There is no way of avoiding the local research necessary to develop techniques which will operate successfully under South African conditions.

II. KOSI BAY PRAWNERY: ANSWERS TO CRITICS : INDUSTRY IS DEEPLY CONCERNED WITH OUR FISHERIES.

The Daily News, Monday, March 19, 1971.

1. The statement that sea farming "must be done naturally, in Nature's way, if success is to be achieved without either ecological change or detriment" is ambiguous and contradictory. Farming implies commercial management which is not a natural process. Ecological change is inevitable where successful farming is practiced.

2. The detrimental effects which can result from over-fertilising water have been discussed. Unawareness of this signifies ignorance of basic biological reactions associated with the prawn culture proposals.

3. The reasons why South Africa is not prominent in the prawn culture field have been given.

4. Prawn culture practiced in an estuarine system to the detriment of that system may be regarded as "pollution" in the wider context of the term.

5. The Kosi Bay system is unsuitable for prawn culture for many reasons other than a lack of nutrients despite "Dr. Fujinaga's much respected opinion." A few of these have been listed and discussed.

6. Penaeid prawns do not occur in Kosi Bay in any quantity. The system is known for its paucity of penaeids despite being closer to the centre of radiation of this group than either St. Lucia or Richard's Bay.

7. It is indeed suggested that salinity and other conditions excluding temperature, are unsuitable for prawn life in Kosi Bay as discussed , despite the conclusion of the survey apparently carried out by the South African company.

8. It is logical and widely acknowledged in publications that predators and competitors must be eliminated from prawn culture areas. This cannot be avoided if it is hoped to succeed. Not a single overseas prawn farm is known of where this is not practiced.

9. The selective elimination of fish in prawn culture areas is achieved by application of such poisons as "Rotenone" and the saponines extracted from tea-seed-cake mash. These poisons are well known and used virtually universally on prawn farms.

10. Birds have not been previously reported as a serious threat to prawn culture operations.

11. The statement that prawn predators "around the other farms in the world" have "not been found to be of any significance" is incorrect. If this were the case, it would not be necessary to eliminate fish predators and competitors using selective poisons. The difficulties Marifamrs Inc. are experienceing with crabs in their Florida farm provide a good example of problems which can be encountered.

12. The statement that a prawn predator problem "is in any case risk for the project not reason for fears of the ecology" is illogical. If predators pose a threat to the success of an operation, either the predators must be removed, or the project runs the risk of failure. If the predators are removed, it is impossible not to affect the ecology.

13. Free range prawn culture will certainly threaten many estuarine organisms. While the area may not be denuded of wild life, artificially imposed selection factors are clearly aimed at promoting certain species, and this will inevitably be at the expense of others.

14. The conclusion that "We in South Africa can ill-afford to lose markets or waste assets, particularly when the use of such assets by sea farming is fast proving to be the best antipollution method of food production from the seas around the world" is, in this

case, based on the premise that certain South African estuaries are eminently suitable for free range prawn culture. In the preceding report, it has been argued that not only are South African estuaries physically unsuitable for free range prawn farming, but there are also many other important considerations which should be taken into account. Research into artificial prawn culture possibilities in South Africa should be encouraged. Culture proposals which are motivated by predictions based on, as yet, inadequate research conducted elsewhere, should however, be analysed with the greatest care.