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ABSTRACT

A salinity gradient reversal in the St. Lucia system in 1968, caused reductions in prawn numbers in affected regions. This did not appear to affect commercial prawn yield in the bait fishery. Prawns in the fishery did, however, become progressively smaller. It is suggested that this was a consequence of most of the system becoming inaccessible due to hypersalinity.

Recommendations on future prawn research are made.

INTRODUCTION

The St. Lucia lake system represents the largest estuarine penaeid prawn reservoir in South Africa. This is reflected in the fact that the Natal Parks, Game and Fish Preservation Board (N.P.B.), has operated a commercial bait fishery there since 1952, which has yielded a mean annual harvest since 1967 of 88 834 cartons of prawns (approximately 15,000 kg).

Monitoring of commercial catches in the bait fishery was implemented by the N.P.B. during 1966 and has continued in more or less detail to the present. Although the Oceanographic Research Institute in Durban (O.R.I.), conducted research on the St. Lucia prawns at intervals, between 1964 and 1968 (Joubert & Davies, 1966; Champion, 1970), the bulk of information gathered over the last 8 years is from the bait fishery. This data has not been formally evaluated previously. Attention will therefore be focused on these results, and an attempt made to interpret them against the background of previous research, particularly, environmental changes in the system. Assessment of commercial catch data is confined to Penaeus indicus which comprised 76,8% of the sampled prawn population in the system between 1966 and 1968.

METHODS

(a) Biological Surveys

Twenty seven stations were sampled, based on the programme of Joubert & Davies (1966) (Fig. 1). To simplify interpretation of results, the system was divided into three regions and data was grouped accordingly. The lower reaches or Narrows, south of Mitchell Island, were designated area A, and incorporated stations 1-7. Area B comprised the middle reaches, represented by stations 8-17. The upper reaches, area C, were represented by stations 18-27.

Surveys were conducted monthly in two sustained periods, from January 1966 to February, 1967, and from November, 1967 to January, 1969. Each survey lasted up to one week.

Prawns were sampled, using a 3,7m x 1,1m aluminium frame beam trawl with a 3,7m deep, 12,8mm mesh net. The trawl was towed behind an outboard powered dinghy for 10 minutes at each station. All specimens were identified, sexed and measured. Carapace length, as measured from the orbital notch to the posterior dorsal margin of the carapace, was used to describe specimen size.

Salinity measurements were initially made with an IMC, 4-electrode salinometer, but subsequently, with a callibrated specific gravity hydrometer, accurate to within 2ppm. Hydrometer readings taken by the N.P.B. were used in 1967 and the period after 1968.

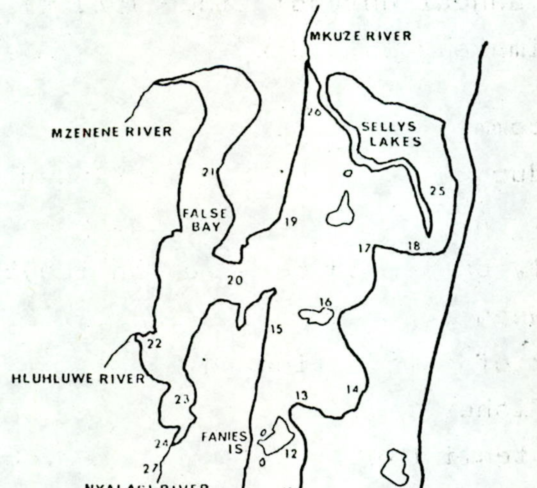

Fig. 1. A map of the St. Lucia lake system showing the prawn sampling stations.

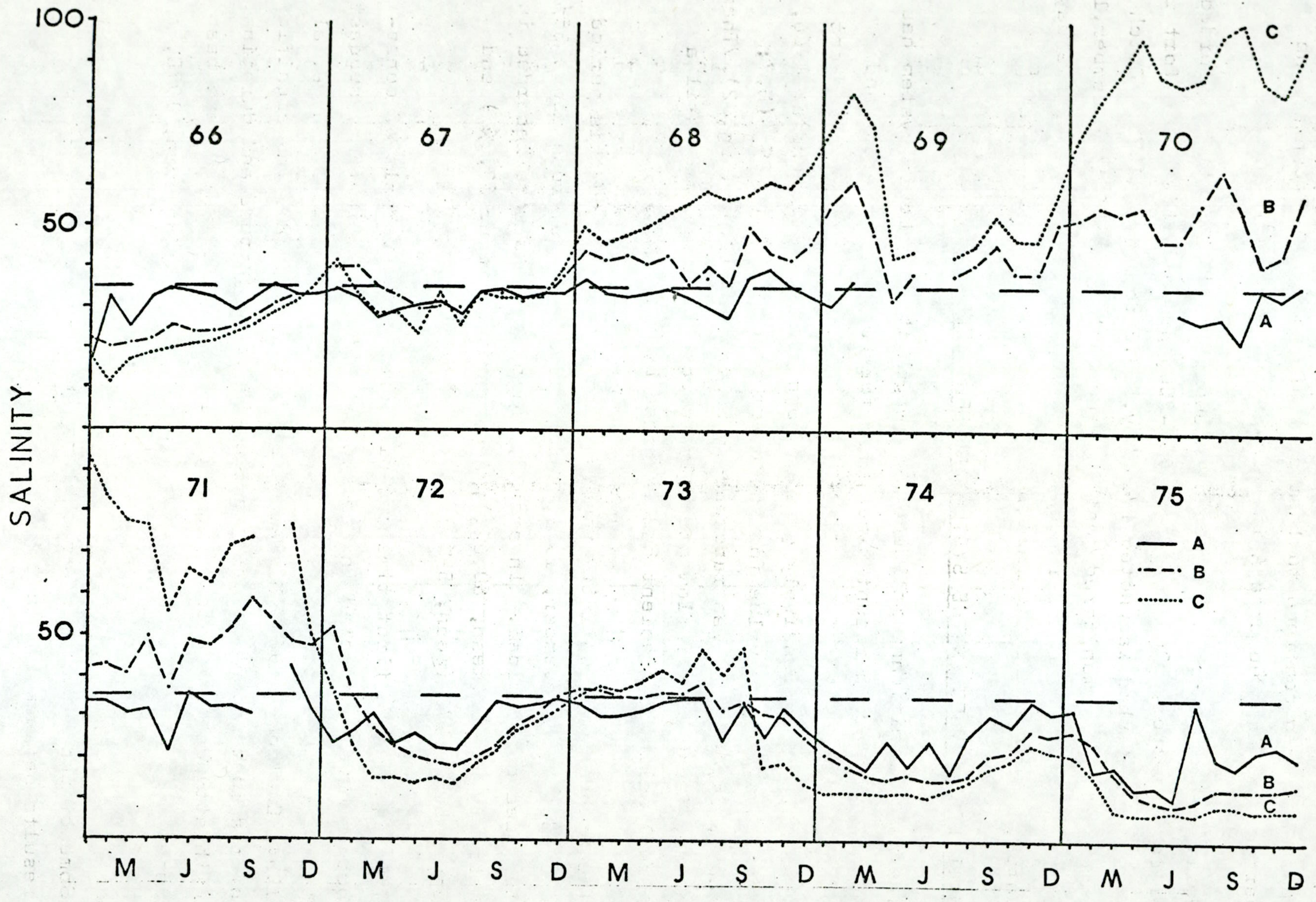

Fig. 2. Mean monthly salinities for the lower (A), middle (B) and upper (C) reaches of the St. Lucia lake system from 1966 to 1975.

(b) Commercial catches

The N.P.B. bait fishery catches were made with 4,9m x 1,1m frame beam trawls supporting 4,9m deep, 25,4mm mesh nets. The fishery has up to now been confined to that part of the system known as the Narrows, designated area A in this study (Fig. 1).

Daily catch rates, in cartons of prawns landed, have been recorded since September, 1966 (carton = 150-200g prawns). Fishing effort in boat hours fished was noted from May, 1970 to March, 1973. Catch composition was monitored monthly from January, 1969 to December, 1971 by analysing 200 to 500 randomly taken specimens from a single day's catch.

SALINITY CHANGES IN THE SYSTEM AND SOME EFFECTS

The most significant influences to which the St. Lucia system has been subjected in recent times, are freshwater starvation and replenishment. Freshwater starvation led to a salinity gradient reversal of progressively greater magnitude from the end of 1966, until a peak mean value for the upper reaches of 100,3‰ (N,7; range, 84,4-109,5) was recorded in September, 1970 (Fig. 2). Thereafter, freshwater inflow steadily reduced the reversal until a normal salinity gradient had returned by May, 1972.

The highest mean salinity recorded for area A during this period was 43,4‰ in November, 1971, though levels seldom rose above 35‰, the area being tidal. In area B, salinity peaks were recorded in February, 1969 (mean, 60,6‰), August, 1970 (mean, 63,8‰) and Spetember, 1971 (mean, 59‰).

This is not the first time salinity gradient reversals of consequence have been noted in the system. Evidence, in fact, suggests that they have for some time been a recurrent feature (Day et al, 1954; Cholnoky, 1968; Millard & Broekhuysen, 1970). The significance of the most recent recurrence lies in its magnitude and duration, with attendant effects on aquatic life, a few of which have been documented (Forrest, 1969; Wallace, 1969, 1975; Heydorn, 1970, Grindley & Heydorn, 1970).

Some of the effects on penaeids may be assessed from survey results between 1966 and 1968.

Changes in prawn abundance were gauged by comparing catch returns

Table 1. Changes in the relative abundance of penaeid prawns in the St. Lucia Lake system between 1966 and 1968.

REGION	YEAR	Penaeus indicus	Metapenaeus monoceros	Penaeus monodon	Penaeus japonicus	Penaeus semisulcatus	TOTAL
LOWER REACHES	1966	4 458	2 281	133	13	18	6 903
	1968	3 758	2 316	15	23	0	6 112
	% change in 1968	- 15,7%	+ 1,5%	- 89,5%	+ 76,9%	- 100%	- 11,5%
MIDDLE REACHES	1966	251	15	3	0	0	269
	1968	102	28	2	0	2	134
	% change in 1968	- 59,4%	+ 86,7%	- 33,3%	-	+ 100%	- 50,2%
UPPER REACHES	1966	8 228	78	37	3	8	8 354
	1968	566	584	41	23	5	1 219
	% change in 1968	- 93,1%	+ 648,7%	+ 10,8%	+ 666,7%	- 37,5%	- 85,4%
WHOLE SYSTEM	1966	12 937	2 374	173	16	26	15 526
	1968	4 426	2 928	58	46	7	7 465
	% change in 1968	- 65,8%	+ 23,3%	- 66,5%	+ 187,5%	- 73,1%	- 51,9%

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Table 3. Penaeid prawn yield at progressively higher salinities in the St. Lucia lake system.

	SALINITY CLASSES	35-39,9	40-44,9	45-49,9	50-54,9	55-59,9	60-64,9	65-69,9	70-74,9	75-79,9
	SAMPLING TIME IN MINUTES	480 mins	120 mins	60 mins	40 mins	70 mins	70 mins	30 mins	20 mins	10 mins
Prawn species netted per hour (actual numbers in brackets).	Penaeus indicus	23 080 (2885)	169 (338)	126 (126)	15 (23)	0	255 (298)	0	0	0
	Metapenaeus monoceros	21 928 (2741)	29 (57)	44 (44)	11 (17)	3 (4)	387 (451)	2 (1)	0	0
	Penaeus monodon	672 (84)	2 (4)	12 (12)	9 (13)	0	0	0	0	0
	Penaeus japonicus	192 (24)	2 (3)	5 (5)	0	0	16 (19)	0	0	0
	Penaeus semi-sulcatus	120 (15)	0	0	0	0	1 (1)	0	0	0
	Total	45 992 (5749)	201 (402)	187 (187)	35 (53)	3 (4)	659 (769)	2 (1)	0	0

in 1966 and 1968. Fewer stations were routinely sampled in 1968, a number having become inaccessible due to lower water levels. The comparison was therefore confined to stations sampled in both years (Table 1).

Total sampled prawn abundance decreased by 51,9% (15 526 to 7 465) in 1968 compared with 1966. Since the sample sizes are large, this is considered a highly significant reduction. A breakdown of netting returns from the three defined regions of the system, shows that returns decreased by progressively greater amounts from the lower to the upper reaches. This pattern can be related to salinity changes over the same period.

In the lower reaches, where salinities were relatively stable, and seldom exceeded 35‰, a small sample decrease of 11,5% from 1966 to 1968 was recorded. Dredging operations during 1967 and 1968, however, affected sampling efficiency in this region, invalidating direct comparisons. In the middle and upper reaches of the system, where successively higher salinities were encountered, sampling procedures remained unaffected in 1968, and the catch reductions of 50,2% and 85,4% respectively, were attributed to salinity differences

The relative abundance of prawns netted at salinities above 35‰, and the maximum values at which different species were encountered, are shown in Table 2. Returns, expressed as specimens caught per hour, decreased as salinity increased up to 59,9‰. In the 60 - 64,9‰ salinity range a dramatic, though momentary, reversal of the trend occurred, a high index of abundance being shown (Table 2). Thereafter, catches fell quickly to zero.

The sudden increase in catches at the tail end of a trend of diminishing returns is interesting and requires comment. Of the 7 stations sampled within the 60-64,9‰ salinity range, 4 yielded nothing, while the other 3 yielded 8, 12 and 749 prawns respectively. The latter catch was made at station 24, near the mouth of the Nyalasi river, in October, 1968 (Fig.1). Mean salinities in the upper reaches of the system had been above 55‰ since June, 1968. All other sampling above 55‰ (19 samples combined), yielded only 25 prawns. It was therefore concluded that this catch represented an isolated pocket of prawns contained in the north by ubiquitous high salinities, with no obvious avenue of retreat down a salinity gradient. The Nyalasi river had no fresh water flow and there was no possibility of the prawns obtaining osmotic relief there. The salinity further up the river was in fact higher than at the sampling point.

The highest salinities at which the various species were taken were 65,1‰ for M. monoceros, 63,7‰ for P. indicus and P. monodon and 63,1‰ for P. japonicus and P. semisulcatus. Although sampling above 70‰ was too limited to provide reliable indications of salinity tolerances, these values are amongst the highest at which wild specimens of the species mentioned, have been recorded.

The extreme salinities of 1968, forshadowed worse conditions in 1969, 1970 and 1971 (Fig.2). During 1970, the mean salinity in the upper reaches fell below 80‰ only in January, when the value was 71,8‰. It has been shown that the prawn populations in the middle and upper reaches diminished in 1968. It is therefore suggested that even fewer prawns penetrated these areas in the ensuing 3 years, during which time their contribution to the total prawn biomass of the St. Lucia system was minimal. Commercial catches in the Narrows, must be considered against this background.

COMMERCIAL PRAWN CATCH RETURNS

Commercial prawn catch data may be analysed in basically two ways. Firstly, results may be used to assist in describing the biology of the component species. Secondly, data may be viewed as an aid to management of the resource. Information collected to date, will not allow either theme to be developed very far. A few observations are, however, possible.

(a) Fishing effort

The fishery has, up to now, catered exclusively to local bait demand, and is therefore, likely to be sensitive to holiday periods. This raises the possibility that prawn catch peaks are generated by social (i.e. bait demand, freezer replenishment, etc) rather than biological considerations. The only way to clarify the position is to establish the catch per unit effort pattern over at least one biological season This relies on accurate catch, as well as effort, data.

Accurate effort data is only available from May, 1968 to March, 1973. During this period the number of fishing boats and the fishing duration were noted each day, enabling fishing effort to be described in boat hours. For the rest, the nearest approximation to effort available, is the number of days fished (fishing days). While a

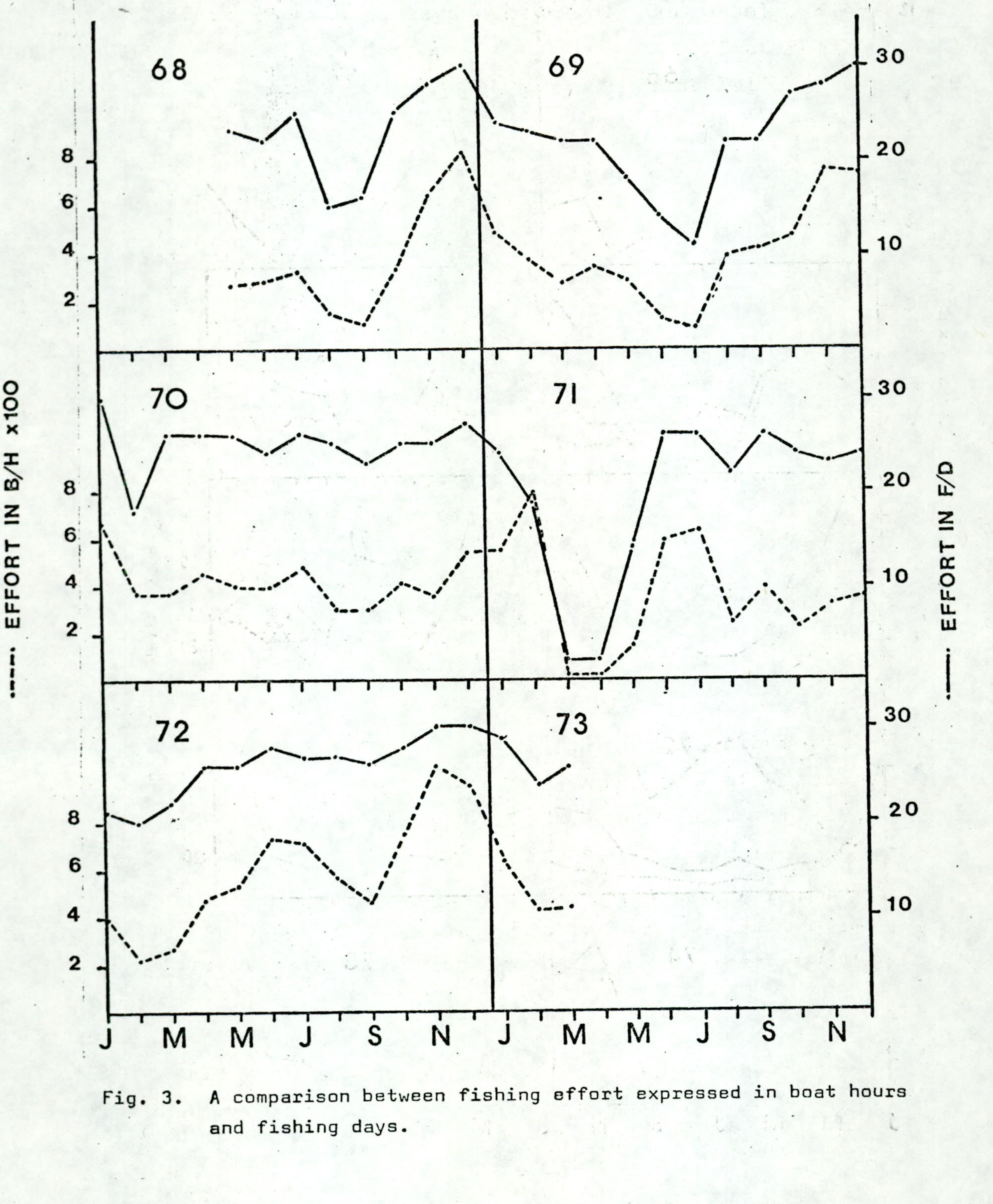

Fig. 3. A comparison between fishing effort expressed in boat hours and fishing days.

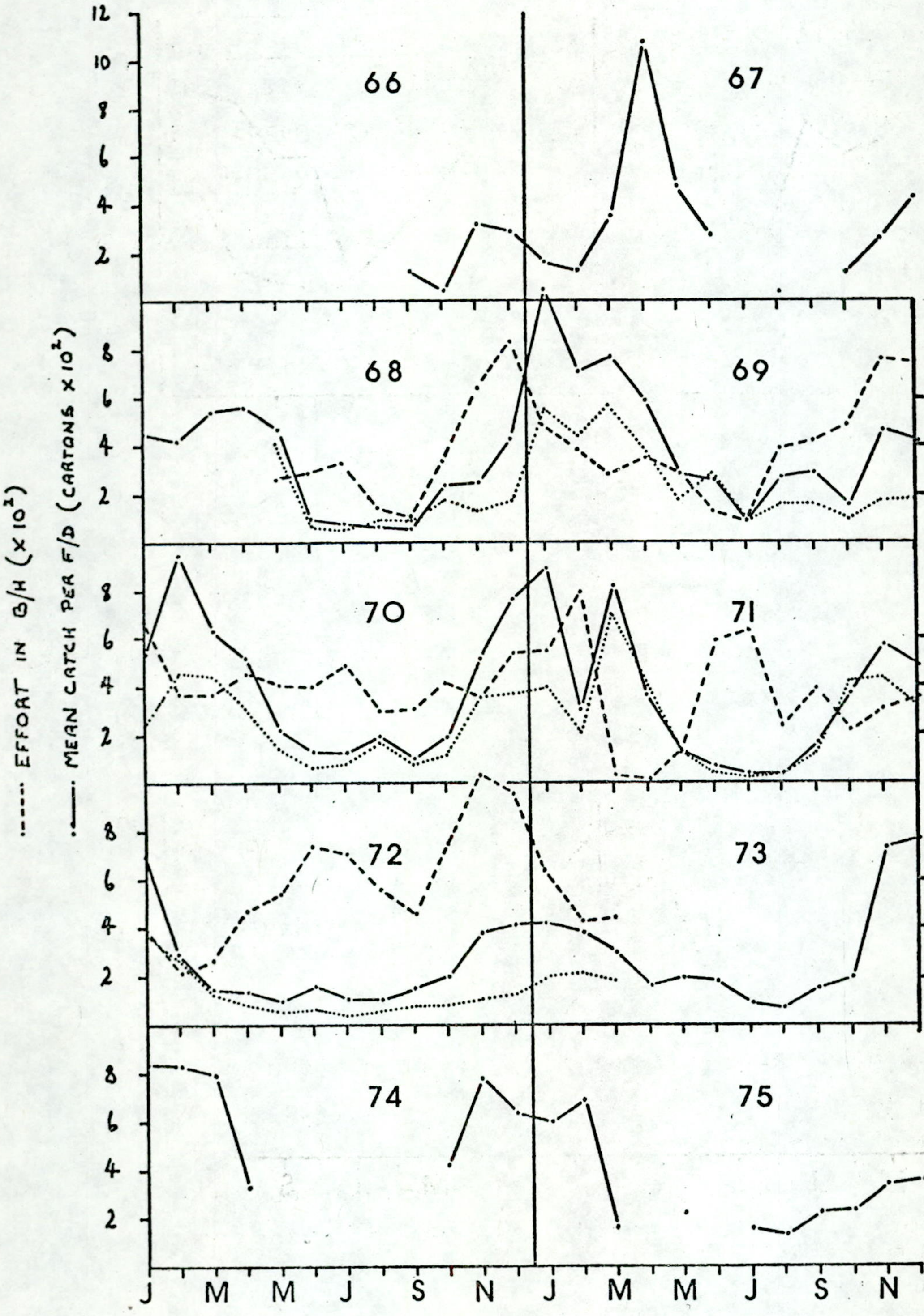

Fig. 4. Monthly commercial prawn catch rates expressed in cartons per fishing day (F/D) and cartons per boat hour (B/H). Monthly effort in boat hours is also shown.

comparison of these two measures shows a good general agreement, numerous minor discrepancies are evident (Fig.3). From December, 1970 to February, 1971, for example, effort in boat hours increased, while effort in fishing days decreased. Conversely, fishing day values, from July to October, 1972, do not reflect the boat hour fall in effort. Calculation of the estimated correlation coefficient, r, however, showed very strong correlation between the measures. The r value was 1.164 with 56 degrees of freedom. This is significant at the 0.1% probability level.

The bait fishery currently operates up to 3 fishing boats simultaneously (F. Joubert, pers.comm.). This number has apparently remained constant since before 1966. The fishing day estimate of effort, can therefore be accepted with a measure of confidence in this study. At the same time, it is obvious that the fishing day unit of effort is relatively insensitive. Increases in the fishing fleet would distort its value. The boat hour index of effort would therefore be a far better long term estimate of this variable.

(b) Monthly catches

The seasonal catch pattern was established by noting the average monthly catch per unit effort (Fig.4). Both catch per fishing day and catch per boat hour were logged. Agreement was good. Catch peaks occur during the summer months, from November to April. Low returns are obtained in the winter. Measures of effort clearly show that the catch cycle is biologically generated. Effort in 1970, for example, remained fairly high throughout the year, but distinctive catch peaks occurred at the beginning and end of the year, with low returns in between (Figs. 3,4). Similarly, in 1971, minimal effort in March, resulted in high catches, but greatly increased fishing effort in June and July made no impression on the low returns. This pattern is apparent throughout the monitoring period and the peaks, in fact, tie in well with offshore data, suggesting a seaward migration to the spawning grounds at the times they appear (Champion, 1970).

Monthly size composition analyses of P. indicus research and commercial samples, unfortunately, did not reveal any trends. Sample sizes were probably too small.

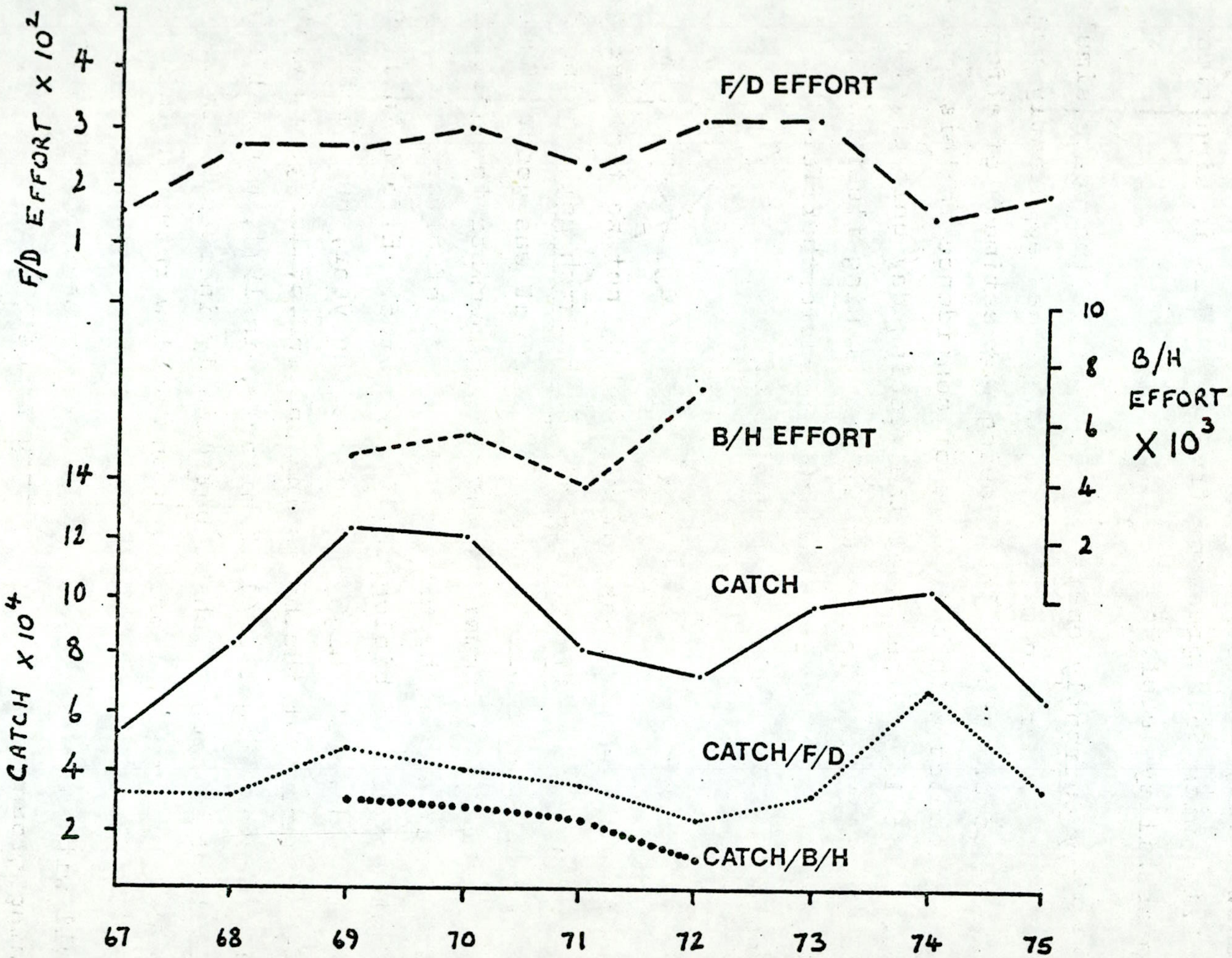

Fig. 5. Annual commercial prawn landings, effort and catch rates in the St. Lucia bait fishery.

Table 3. Specimen size (carapace length) characteristics of annual *P. indicus* samples netted in 1966 and from 1968 to 1971.

Year	Sample Size n	Mean x	Variance s^2	Deviation s	Standard Error	95% Confidence Interval.
1966	10417	14.22	22.81	4.77	±.047	14.13-14.31
1968	3760	20.93	25.16	5.01	±.082	20.77 - 21.09
1969	3592	20.75	10.06	3.17	±.053	20.65 - 20.85
1970	3663	19.79	11.44	3.38	±.056	19.69 - 19.89
1971	3190	18.06	8.37	2.89	±.051	17.96 - 18.16

Table 4. Analysis of variance for specimen size in annual *P. indicus* samples for 1966 and 1968 to 1971.

Source	Sum of squares	Degrees of freedom	Mean square	Variance ratio F
Annual size differences	214 074.0	4	53 518.5	3 010.04
Sampling deviations	437 601.1	24 618	17.78	

(c) Annual catches

The annual prawn catch since 1967, has fluctuated between 52 300 and 122 790 cartons, with a mean of 88 834 cartons (Fig.5). Effort in boat hours, from 1969 to 1972, averaged 5174 hours per annum, with a range of 3764,5 to 7078,5. Catch per unit effort showed no clear trends (Fig.5).

An interesting aspect of the annual yield, was the extent to which it was affected by high salinities in the north. From 1968 to 1971 severe reductions in the prawn population beyond the Narrows, have been suggested. For much of that time, virtually the entire St. Lucia prawn population was probably confined to the Narrows. Commercial catches were hardly affected. A progressive decline in catch per unit effort, which may have been associated with salinity, did take place from 1969 to 1972 (467 to 237 prawn cartons per fishin: day) though no dramatic effects were noted (Fig.5). The Narrows appears to have a remarkably high prawn carrying capacity. Furthermore, it would seem that commercial harvesting falls within the biological tolerance of the prawn population. The fishery appears to be stable at present catch rates.

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The specimen size compositions of 1966 and 1968 research samples, and 1969 to 1971 commercial catch samples, were analysed. Successive commercial samples (1969 to 1971) showed a progressive reduction in modal and mean size (Fig.6; Table 3). The two research samples (1966, 1968), possessed widely disparate values, but the 1968 research sample showed similar size characteristics to the 1969 commercial sample.

The specimen size range in 1966 and 1968 was similar (Fig.6). The higher proportion of small prawns netted in 1966, however, reflected changed specimen availability, due to dredging in the Narrows which affected netting efficiency.

An analysis of variance on the 5 samples, led to a rejection of the Null Hypothesis (Table 4). The F value, corresponding to 4 and ∞ degrees of freedom, respectively, was 3010,04 ($P < .001$).

Single tailed tests for significant differences in mean specimen size, between sequential pairs of samples, were then carried out. The normal distribution test, involving estimation of the ratio d, given by

$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where n is the sample size, $\bar{x}$ the mean and s^2 the variance, was calculated (Table 5). Probability was greater than 99,9% that the mean specimen size in 1968 was larger than in 1966, as expected.

Table 5. Significance of the differences between paired P.indicus sample means, as given by d (d=3.291 when P=0.001 and 1.960 when P= 0.05).

Sample pairings	1966 & 1968	1968 & 1969	1969 & 1970	1970 & 1971
Resultant d value	74.943	1.848	12.473	22.820

Mean specimen size in the 1968 and 1969 samples, was not different at the 5% level and the Null Hypothesis was accepted. The 1968 sample was obtained with a smaller mesh sampling net (12,8mm) than in 1969 (25,4mm). One might have expected a significantly lower mean in 1968 due to more small specimens in the catch. Whether the small specimen influence was masked by influx of an exceptional number of large specimens, possibly withdrawing from rising

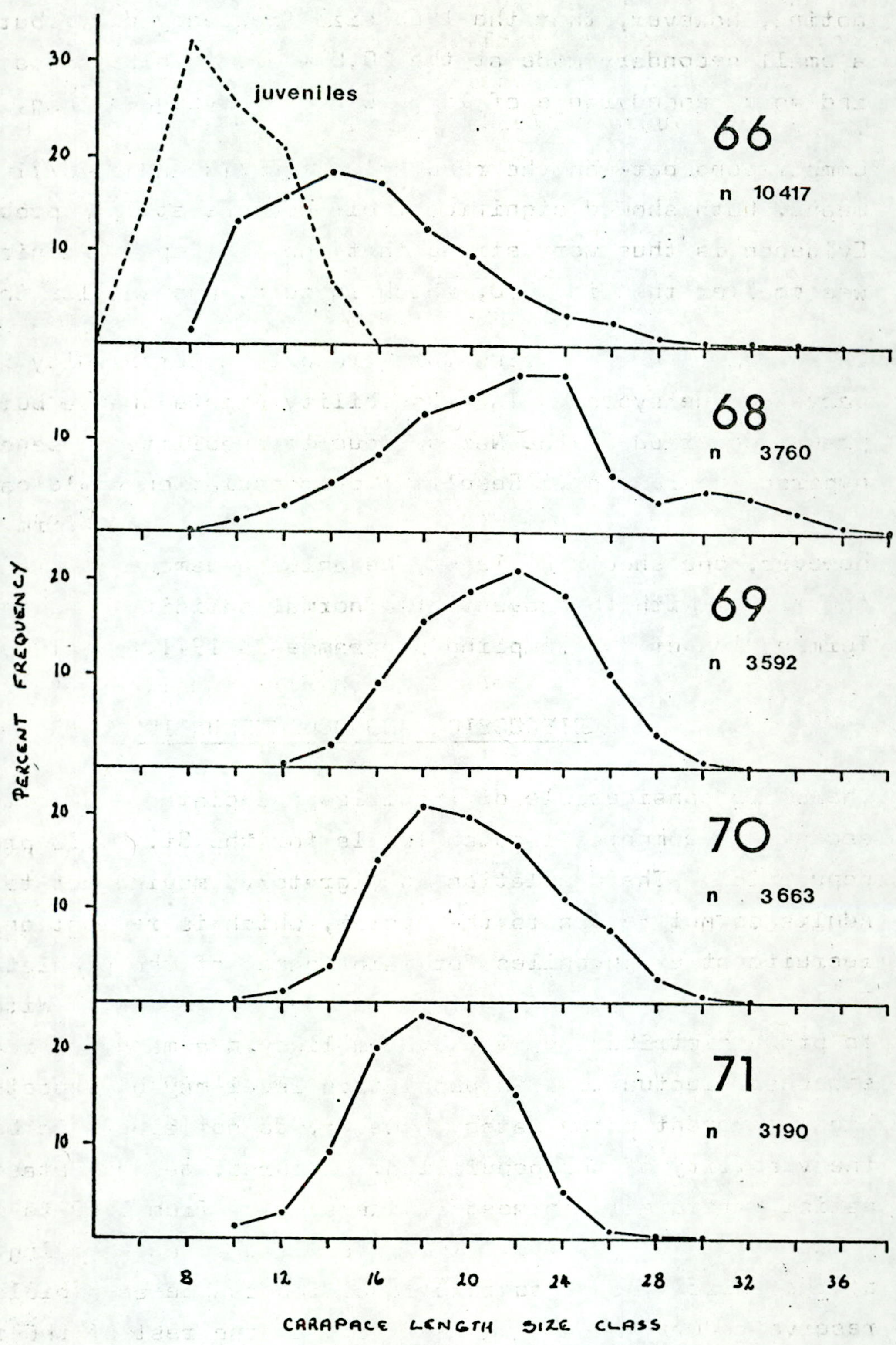

Fig. 6. Penaeus indicus size frequency distributions from annual samples for 1966 and 1968 to 1971. The 1966 sample contained juveniles, too small to sex.

salinities in the north, is a matter for speculation. It is worth noting, however, that the 1968 size frequency distribution shows a small secondary mode at the 30,0 - 31,9mm size class interval, and an extended range of large sized individuals (Fig. 7).

Comparisons between the respective 1969/70 and 1970/71 sample means, both showed significant differences at 0,1% probability. Evidence is thus very strong that the mean specimen size in 1971 was smaller than in 1970, which in turn, was smaller than in 1969.

It is tempting to ascribe this trend to hypersalinity in other parts of the system. The possibility exists that a buildup of prawns occurred in the Narrows due to inability to penetrate the hypersaline regions. Resultant overpopulation could cause stunting or a reduced residence time in the system. To confirm such a view, however, one should at least, be able to demonstrate a reversal of the trend, with the advent of a normal salinity gradient. Termination of the sampling programme in 1971, precluded this.

DISCUSSION AND RECOMMENDATIONS

There are considerable difficulties associated with determining acceptable commercial catch levels for the St. Lucia prawn population. The population is migratory, moving out to sea to breed. Adults do not return to the system, which is reliant on the recruitment of juveniles for maintenance of the population level. The origin of recruits to the system is not known. With respect to prawn distribution, the system lies in a marginal region, where seasonal fluctuations in population level may be expected to be high. Current catch rates, however, do not appear to be affecting the viability of the population. Returns, during catastrophic salinity reversals in most of the system, from 1969 to 1971, were particularly impressive. The remarkable prawn carrying capacity of the Narrows, and its functional importance as a biological reservoir during salinity reversals in the rest of the system, was demonstrated. Maintenance of an open mouth, allowing tidal exchange is crucial in this respect.

The monitoring of commercial prawn catches, as practiced 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.

The prawn mass in cartons varies, according to the size, and therefore, number of specimens contained. Prawn mass would thus be a more accurate reflection of catch than number of cartons. The boat hour estimate of fishing effort should be reintroduced and improved, by recording actual fishing time, rather than times of departures and return. The fishing day measure is insensitive to reductions or increases in the fleet. An increase in the number of fishing boats is likely, as pressure on the resource builds up. The fishing day effort estimate would, under these circumstances, not only provide an underestimate of this variable, but also invalidate comparisons with past catches. Finally, monthly specimen analyses on representative samples of the catch should be carried out. Sample size should not be less than 1000 prawns, to allow interpretation of monthly growth and size composition trends. A reversal of the reduction in prawn size trend, noted for 1969, 1970 and 1971, would tend to support the suggestion that this was a salinity effect. A continuation of the trend might indicate overfishing.

The above proposals do not require the launching of a new research programme. They could probably be accommodated within the existing N.P.B. establishment framework and should, in any event, be regarded as an integral part of the commercial fishing operation. With regard to new research direction, adequate data has been accumulated on prawn migrations, movements within the system and reproductive biology. Very little is however, known of their ecological role.

Feeding studies represent a major area of research. Prawn abundance in the system, suggests they are ecologically important. At one end of the scale, they are benthic feeders, detritus constituting an important dietary component. At the other, they are widely preyed upon, particularly by fishes, and may therefore, be important link organisms between different trophic levels in the food web. With the main biological thrust in South Africa currently tending towards bioenergetics and the understanding of systems, prawns in the St. Lucia system would seem to be an important study choice in any multidisciplinary approach.

At a different level, very little is known of postlarval to juvenile recruitment to, the system. Past research concentrated on the more adult forms. Recruitment studies would clarify the most important invasion periods, possibly indicate recruitment origins, and provide one measure of the prawn contribution to the local energy cycle. An important base line, with prediction possibilities, would also be provided to the fishery.

Finally, mark-recovery studies are important in any commercial fishery. This may, however, be beyond the scope of research currently envisaged.

ACKNOWLEDGEMENTS

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