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STOCK ASSESSMENT AND STATUS OF THE ORNATE LOBSTER *PANULIRUS ORNATUS* IN REEF AREAS OF TORRES STRAIT FISHED BY PAPUA NEW GUINEA DIVERS

BY

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A PRELIMINARY STOCK ASSESSMENT OF THE TROPICAL (ORNATE) ROCK LOBSTER *PANULIRUS ORNATUS* IN REEFS OF THE TORRES STR. PROTECTED ZONE, PAPUA NEW GUINEA AREA OF JURISDICTION.

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ABSTRACT

The stock of Panulirus ornatus in Papua New Guinea reef areas of the Torres Strait Protected Zone was assessed using (1) a linear model of catch per unit of fishing effort (CPUE) on total effort and (2) a parabola (Schaeffer) model of yield on effort. The status of the fishery was also assessed from observations on trends of CPUE, yield and the mean weight of the stock, from which exploitation rates in the range 0.49-0.61 were obtained, for the years 1987-1994. A first approximation of sustainable yield based on data for 1987-1994 was obtained: 135 t, with wide error margins (70-200 t). Yield has been increasing exponentially since 1973. In 1994 there was the highest annual yield (91.7 t) since records began (1973) suggesting a record stock abundance on the most frequented reefs (which are Wapa, Silver and Kokope Reefs). In 1994, the estimated total allowable catch for the Papua New Guinea Area of Jurisdiction was much lower at 58.5 t. The effectiveness of the TAC management system is questionable in light of the discrepancy of 1994.

INTRODUCTION

Background

The Torres Strait Treaty between Papua New Guinea and Australia established a framework for the management of the marine fisheries of Torres Strait. Current management includes an agreement for catch-sharing which permits 27 PNG dinghies to fish in Australian waters of the Torres Strait. They may be served by 3 mother (freezer) ships. The 1992 catch sharing agreement allows PNG fishermen to fish a 25% share from the Australian Area of Jurisdiction.

The present study was undertaken because the Torres Strait Treaty Catch Sharing Arrangements are up for review in October 1995 and an assessment of the lobster stocks on the PNG side and of the status of the fishery, and also a documentation of the distribution of fishing effort is needed as background information for the review.

Life History and Biology

Panulirus ornatus is found everywhere in Torres Strait, apart from the large area of unsuitable habitat (mostly sand and silt) between the Wapa-Warrior and Orman Reef Complexes (Williams, 1994). They are most abundant in and around these reef complexes. The postlarval or puerulus (swimming) stage settles in holes in the seabed in between reefs sometimes covered by algae or seagrass, or in structure comprised of epifaunal growth. In the reef areas, juveniles live in rocky crevices, holes, or coral outcrops or under rock ledges. Most of the resource is located on rocky bottom in depths of 5-25 metres, in between the reefs (Pitcher, 1993).

Mature females hatch their eggs at the edge of the Coral Sea. The larvae disperse into the open ocean where they transform through several larval stages that take 4-8 months, after which they reach the puerulus (swimming) stage. The puerulus is a miniature, but transparent, lobster about 2 cm long. It swims into shallower water and settles into small holes in the substrate to grow and take on colour (Williams, 1994). Over a year later, the juveniles reach the legal minimum size of 100mm tail length and enter the fishery when they are 18-24 months old (Pitcher, 1993) where they remain until the age of about

32-34 months (Pitcher, 1993). Between August and October, a large proportion of the lobster population migrates out of the Torres Strait to breed. This causes a great drop in catch rates. The migrating lobsters move to the east and northeast through the Great Northeast Channel, and form dense concentrations in the prawn trawl grounds and into the Gulf of Papua. Tagging studies conducted jointly by Australia and PNG have indicated that the lobsters mature on this migration and some go as far as Yule Island in the eastern Gulf of Papua, where the combined stresses of migration and repetitive breeding cause a high proportion of them to die (Williams, 1994). Nearly all female tropical rock lobsters greater than two years old make the migration, along with males of the same age and older. The Torres Strait lobster population immediately after the migration is mainly male and of two years of age or under (Williams, 1994).

Lobster research in the 1970's and 1980's indicated that most P. ornatus lobsters migrated into the Gulf of Papua to breed and then died. Further, it suggested that trawling that was targeting the dense aggregations of the migration had the potential to effectively wipe out the population if allowed to continue for three consecutive years (Williams, 1994). In 1984, to sustain the stocks, Australia and Papua New Guinea agreed to ban trawling of migrating lobsters.

Recent research shows that a significant proportion of the migrating lobsters probably move east or southeast from the Torres Strait to deeper water at the edge of the far northern Great Barrier Reef, at the edge of the Coral Sea. This deep water habitat may even be the main breeding ground for the Torres Strait lobster stock, and it seems likely that lobsters there may not suffer the same high mortality after migration and breeding (Williams, 1994). The fate of the P. rnatus larvae in the northwestern Coral Sea will be studied by an Australian CSIRO cruise, with PNG Fisheries biologists participating, in May-June 1995.

MATERIALS AND METHODS

Catch (weight of tails) was graphed on total effort (man-days). The source was the Fisheries Database at Daru. A quadratic curve (Schaeffer, 1956) was fitted to the data, for weights of tails landed in order to obtain an approximate preliminary estimate of the sustainable yield.

This curve was forced through the origin. Correlation/ regression analysis of catch per unit of fishing effort (CPUE, in kg per man-day) on total effort (in man-days) was also carried out. The equation used for estimation of maximum sustainable yield (MSY) was as follows:

MSY = (the intercept raised to the power 2) divided by (4 x slope).

The residual mean square or variation about the fitted curve (s^2 or R) was generated by the Easyplot for Windows Curve fit programme as a statistical measure of the goodness of fit, along with the maximum deviation.

The residual mean square was calculated by *Easyplot* from s^2 or R = the sum of $(y_{fit} - y)^2/(n-3)$, where n is the number of points, and the sum of $(y_{fit} - y)^2$ is the sum of the squares of the residuals; it is a measure of the variance of the data from the fitted curve (pers. comm. *Easyplot* Tech. Support Officer, Cherwell Scientific, Oxford, 1994).

The trend of change of CPUE and yield was analyzed graphically. The distribution of PNG dinghies by reef in 1990 was also studied, to provide information on the stock.

The status of the fishery was assessed by calculating the exploitation rate (E) using the Allen (1953) equation:

$E = W_c/W$, where W_c = weight-at-first-capture and W = mean weight of the fishery stock. The estimated mean weight at the legal size limit of 100 mm tail length (0.168 kg) was derived from the minimum size limit of 100 mm tail length, which is equivalent to 75 mm carapace length (CL) (Pitcher, 1993). The 75 mm CL was converted to tail weight (median for male + females) using the male and female tail weight/CL relationships determined from DFMR measurements of P. ornatus lobsters at Yule Island, Central Province, PNG, in the 1978/79 Yule Island Lobster Season, by researchers Macfarlane and Paska (MacFarlane and Paska, 1979).

RESULTS

In recent years (1987-1994) landings of crayfish to Daru from the Papua New Guinea reefs have ranged from 47.7 to 91.7 metric tonnes (Table 1).

The most frequently-visited reefs by PNG lobster fishermen were Wapa, Silver and Kokope Reefs (Fig.1; Table 2)). These were by far the most frequently visited reefs in 1990 (30, 28, and 28 % of the total respectively). Wapa use peaked in November, Silver in May and September, and Kokope in March, May and October (Table 2).

Annual Tail Weight Landings from the Torres Strait Lobster Fishery over the period 1973-1994 have increased steadily since 1973, in cycles with a 3-5 year periodicity (Fig. 2). The moderate yield in 1993 (61.5 t) was followed by the highest-ever annual total catch in 1994 (91.7 t).

Analysis of the trend of change of CPUE by calendar year was carried out graphically: a cyclic 5 year fluctuation in CPUE is suggested tentatively from the trend both by tail weight CPUE and tail number CPUE, with peaks in 1989 and 1994 (Figs. 3-4).

From linear regression of CPUE (in terms of tail weight) on effort, an estimate of the MSY was derived (135 t of tails) by elimination of the three points of `random variation' (which may represent years in which the abundance, in terms of CPUE, was controlled chiefly by environmental variables rather than chiefly by harvest). Five points fell in a straight line (Fig. 5). The correlation coefficient for this linear regression line was $r = -0.5402$, $n = 5$, with 3 degrees of freedom ($P = 0.2$, single-tail test for negative correlation). A further stock assessment estimate was made by graphing yield on effort from Table 1 (by quadratic regression forced through the origin). It yielded an MSY estimate of 135 t of tails approximately, by excluding the years 1987, 1989 and 1994, in which the abundance and biomass (CPUE) may have been controlled by an environmental variable such as sea temperature (Fig. 6), as suggested by the cyclic trends of yield (Fig. 2) and CPUE (Figs. 3-4). The error margins of the estimate are +/- 70 t if all the points are included. The estimate is not robust but serves as a first approximation.

Estimates of exploitation rates during 1987 to 1994 ranged from 0.49 to 0.61. The mean of E for 1987-1994 was 0.522 +/- SE 0.013. The optimum exploitation rate would be 0.500 (Allen, 1953).

DISCUSSION

The high yield in 1994 (91.7 t) suggests that lobster abundance and population density on the Wapa-Warrior Reef complex was relatively high in 1994, perhaps the highest ever (at least on the PNG side). This infers that postlarval settlement in the Strait in 1991 was relatively high on these reefs. The estimated TAC was lower (58.5 t) than the actual yield (91.7 t), suggesting that the TAC system should be reviewed. It seems that the TAC for Papua New Guinea reefs was set too low for 1994. It should have been double that estimated.

The total stock of Panulirus ornatus in the Torres Strait's Australian Area of Jurisdiction was estimated by the Australian fisheries authorities to be between 11 and 17 million lobsters in 1989 (Williams, 1994) with about 8 million of these being large enough to be taken by the commercial fishery (>100mm tail length). In 1993, there were about 6.4 million lobsters on the Australian side. This represents the pe-migration abundance estimate for 1 and 2 year olds made by Pitcher et al (1994). Thus there is some variability in abundance which is probably related more to environmental variation, eg. sea temperature, and/or the paths and strength of ocean currents in the Coral Sea.

The long-term sustainable yield in Australian waters alone is approximately 600 t (Williams, 1994). The 1990 stock of legal-size lobsters in Australian Area of Jurisdiction (of >100 mm tail length) was about half that of 1989 (Williams 1994) and projections for 1991 were the same as for 1990 (Williams, 1994). It would seem therefore that the postlarval settlement in 1992, resulting from the parent stock in 1991, may have been particularly successful around the Wapa-Warrior Reefs, resulting in the record high stock abundance there in 1994.

Table 3 shows the variation in yield and estimated pre-migration abundance on the Australian side from 1989, including the yield from Australian reefs visited by PNG divers with cross-border licenses. 1989 and 1994 were years of peak catch on the Australian side.

As a consequence of the relatively few data points, the linear and quadratic models provide only an approximation

(135 t) of the long-term MSY of the reef areas frequented by the PNG lobster fishermen on the PNG side. The reef use is also detailed quantitatively and documented in Table 2.

The analyses suggest that the fishery has not yet reached peak production, with the 1994 catch (91.7 t) at a somewhat lower level than the estimated maximum sustainable yield (135 t) (Fig. 6). However the equilibrium catch (Schaeffer, 1954) for 1994 was somewhat lower than the actual weight of tails caught, according to the exploitation rate of 0.61 for 1994, estimated in the present study (Table 1). The fishery seems to have been at an optimum exploitation rate for most of the 1987-1994 period (average $E_{1987/1994}$ = 0.522 +/- SE 0.013).

On the basis of the background knowledge and the further information from the present study, the current management arrangements may need revision. The 1992 arrangements have certainly extended the population available to exploitation by PNG divers and may also have eased some local pressure off the resource in PNG waters, but the total allowable catch should perhaps be estimated at a higher level in future. A thirty-five (35) per cent increase in the PNG TAC is suggested from the analyses of the present study.

The suggestion of cyclic fluctuation in CPUE and yield with a major peak in 1994 (1991-1993 were El Nino years, and the 1st qtr of 1994 was of similar climate) (SPC, 1994) suggests the possibility that there may be an association between the pre-migration abundance of P. ornatus in the Torres Strait and change in sea temperature and ocean/atmosphere climate (brought about by the El Nino Southern Oscillation Events).

Evans and Evans (1995) and Evans et al (1995a) documented associations between spiny lobster (Panulirus argus and P. guttatus) CPUE and yield and annual mean sea temperature at Bermuda. The Lellis and Russell (1990) parabolic physiological model of growth/survival of aquarium-held postlarval P. argus in Florida was demonstrated in the survival and growth of juvenile and subadult lobsters in the Bermuda fishing grounds (Evans and Evans, 1995; Evans et al, 1995a).

CONCLUSIONS AND RECOMMENDATIONS

1. An increase of PNG's TAC in the PNG Area of Jurisdiction of the Torres Strait Protected Zone is recommended: an increase of around 35 per cent is recommended in order to accommodate the discrepancy between yield and TAC.

2. A first approximation of the MSY from the reefs visited by PNG divers is 135 t, *Prima facie*, safely greater than the size of PNG's 1994 harvest (91.7 t), the highest so far. However, the error margins of the estimate are 70-200 t and therefore caution must be excercised.

3. The estimated 1994 exploitation rate was 0.61, somewhat greater than the optimum level (0.50) and this suggested overfishing in 1994. A more conservative estimate for the potential yield from the PNG reefs would be 100 t approximately.

4. Wapa, Kokope and Silver Reefs were the most frequently visited reefs by PNG divers (30, 28, and 28 per cent of total visits respectively).

5. It is suggested that the abundance of juvenile lobsters on the Wapa, Kokope and Silver Reefs in 1994 was the highest ever, and that this may have been the result of record postlarval settlement on these reefs in 1991.

6. Studies of the association of annual mean sea temperature and pre-migration abundance (yield, CPUE and visual census in 500m x 2m transects) of juvenile P. ornatus in Torres Strait should be carried out.

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Table 1: Catch, Effort, Catch Per Unit of Fishing Effort and Exploitation Rate, Daru-Based Crayfish Fishery 1987-1994.

Year	Tail wt (kg)	No.tails	Effort (man-days)	CPUE (kg/ man-day)	CPUE (number/ man-day)	Mean Tail Wt.(kg)	Exploit. Rate (E)*
1987	47740	139867	15481	3.08	9.03	0.341	0.493
1988	56104	179880	16379	3.43	10.98	0.312	0.538
1989	70264	213962	14143	4.97	15.13	0.328	0.512
1990	59492	184005	17127	3.47	10.74	0.323	0.520
1991	63417	184256	18560	3.42	9.93	0.344	0.488
1992	50597	149606	14143	3.58	10.58	0.338	0.497
1993	61536	192106	17047	3.61	11.27	0.320	0.525
1994	91702	331412	23199	3.95	14.29	0.277	0.606

* Based upon (1) the Allen (1953) equation for exploitation rate (E): $E = W_c/W$, where W_c = weight-at-first-capture and W = mean weight of the fishery stock; and (2) the estimated mean weight at the legal size limit of 100 mm tail length (0.168 kg) derived from the minimum size limit of 100 mm tail length, which is equivalent to 75 mm carapace length (CL) (Pitcher, 1993). The 75 mm CL was converted to tail weight (median for male + females) using the male and female tail weight/CL relationships determined from DFMR measurements of P. ornatus lobsters at Yule Island, Central Province, PNG, in the 1978/79 Yule Island Lobster Season, by researchers Macfarlane and Paska (MacFarlane and Paska, 1979).

Table 2: Numbers of PNG Lobster Dinghies (ex. Daru) on Common Reefs of the Torres Strait, Sorted by Month (1990).

MONTH	SILVER	KOKOPE	WAPA	OTAMABU	GIMINI	OTHERS
January	20	16	18	0	0	0
February	32	63	33	0	0	8
March	56	95	35	0	0	0
April	90	72	97	3	6	14
May	186	109	92	2	10	65
June	7	25	50	29	3	11
July	0	0	75	0	0	5
August	69	64	85	6	6	13
September	147	43	1	6	1	19
October	68	122	114	16	13	52
November	48	62	193	9	1	37
December	26	64	15	11	4	14
TOTAL	749	735	808	82	44	238

Table 3: Torres Strait Tropical Rock Lobster Catch from Australian Waters (mt) 1989 to 1994, and estimated pre-migration abundance (millions of 1+ and 2+ years lobsters) 1989 to 1993 (Source: Pitcher *et al*, 1994).

(Compiled from records of all product caught in Australian waters and taken out of Torres Strait by carrier boats and aircraft and P.N.G. boats fishing in Australian waters under cross-border arrangements).

YEAR	1989	1990	1991	1992	1993	1994
CATCH	243	186	166	158	189	216
ABUND.	14.10	9.89	10.54	12.93	6.38	

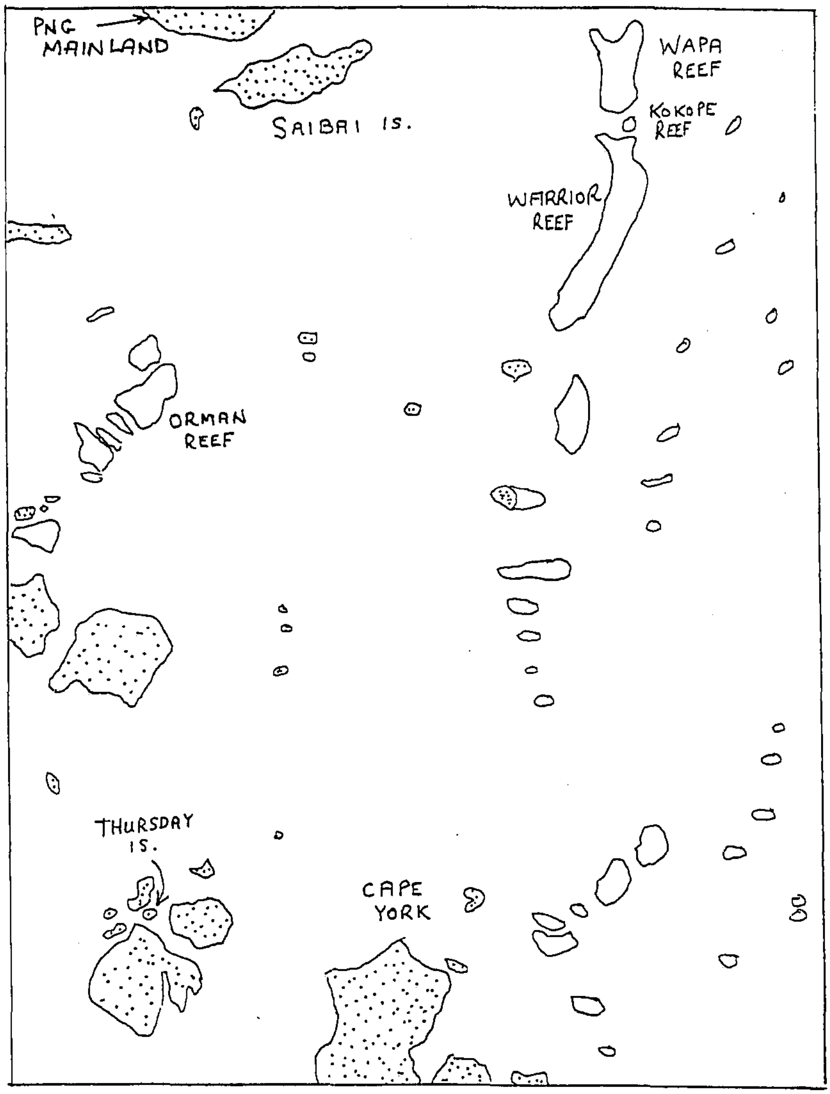

Fig. 1: The Torres Strait Showing the Wapa-Warrior Reef Complex.
Key:

Stippled areas are land, areas closed by lines are reefs.

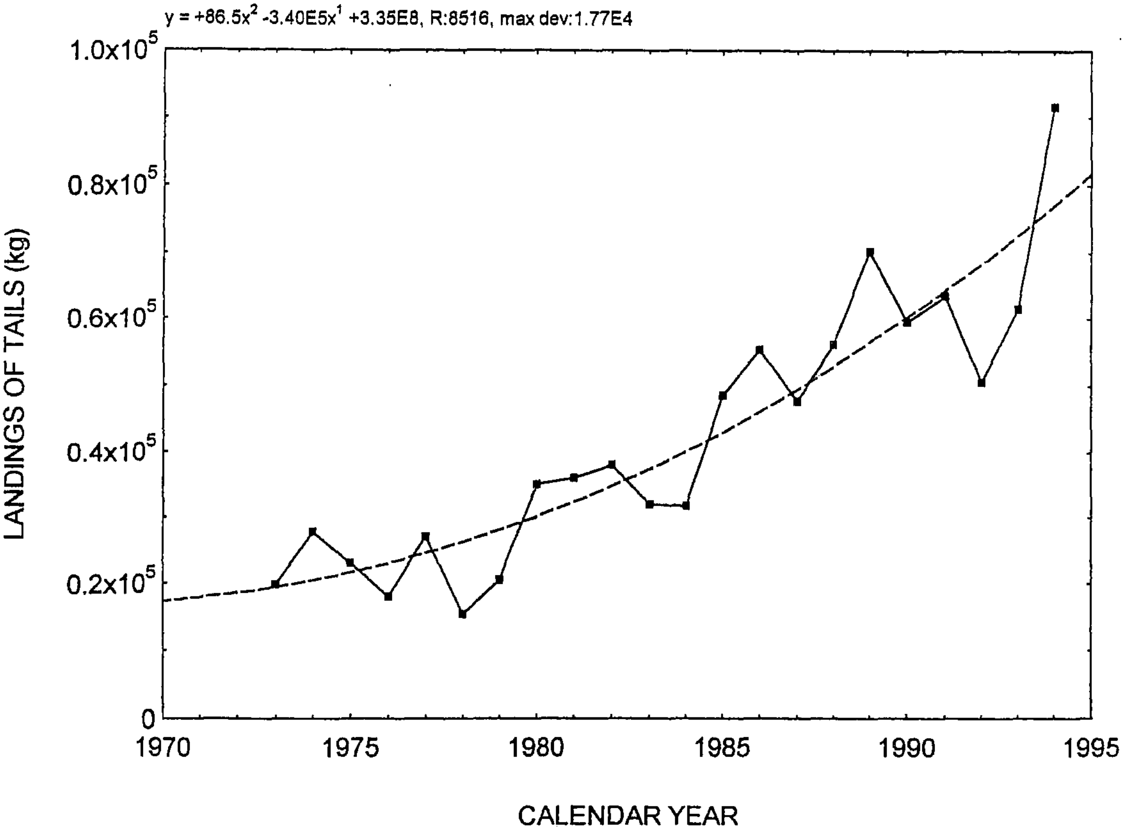

Fig. 2: Annual Tail Weight Landings (kg) from the Daru Crayfish Fishery 1973-1994.

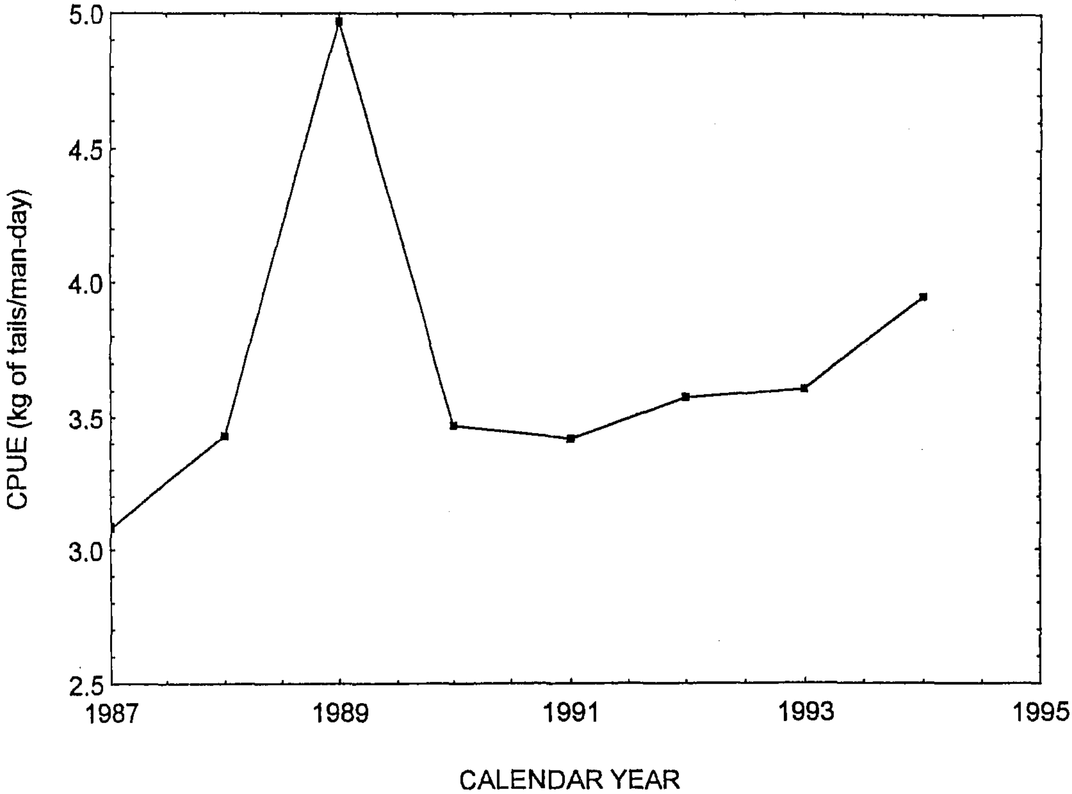

Fig. 3: Trend in the CPUE (by Tail-Weight) of Daru Crayfish, 1987-1994.

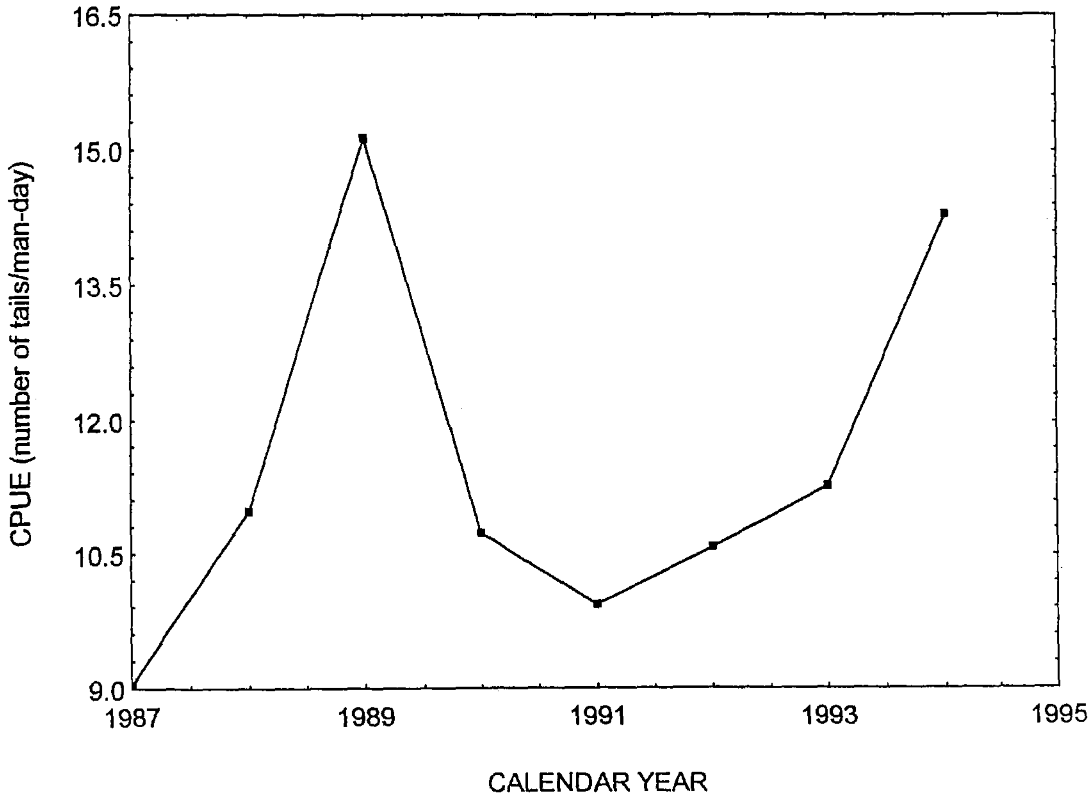

Fig. 4: Trend in the CPUE (by Number) of Daru Crayfish, 1987-1994.

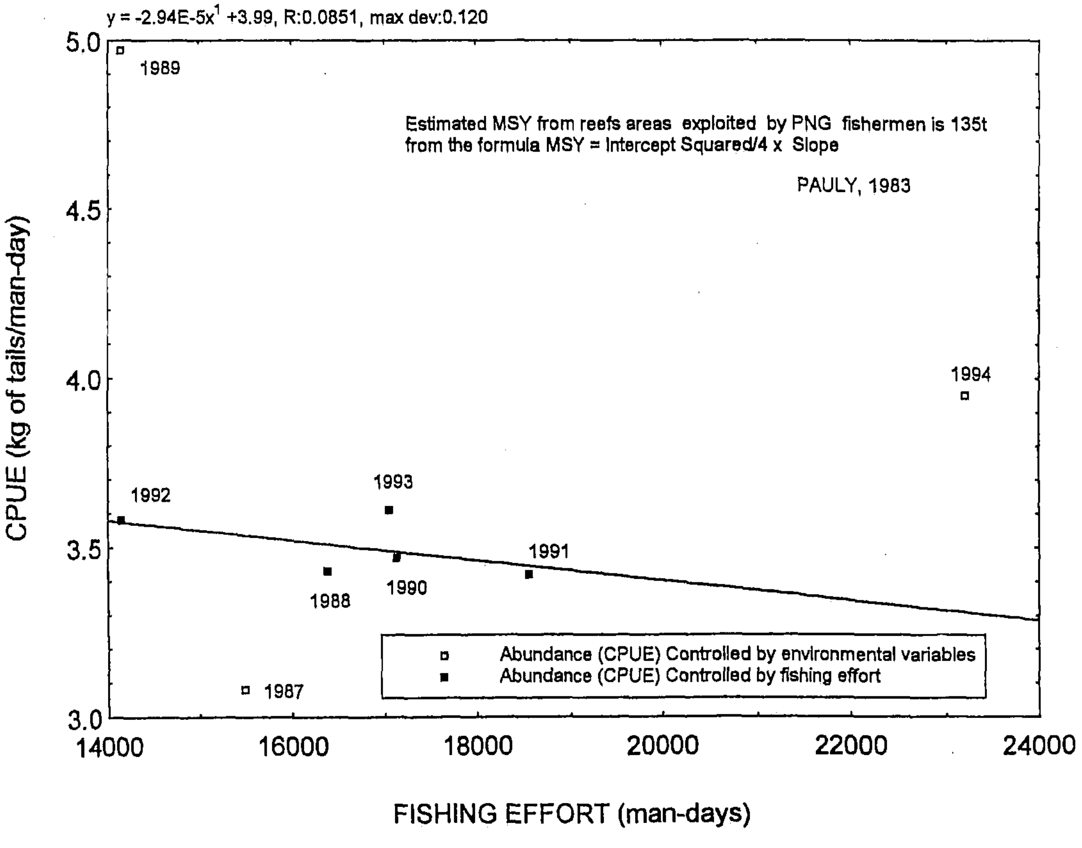

Fig. 5: Crayfish Fishery, Daru: CPUE (by Tail-Weight) on Effort 1987-1994.

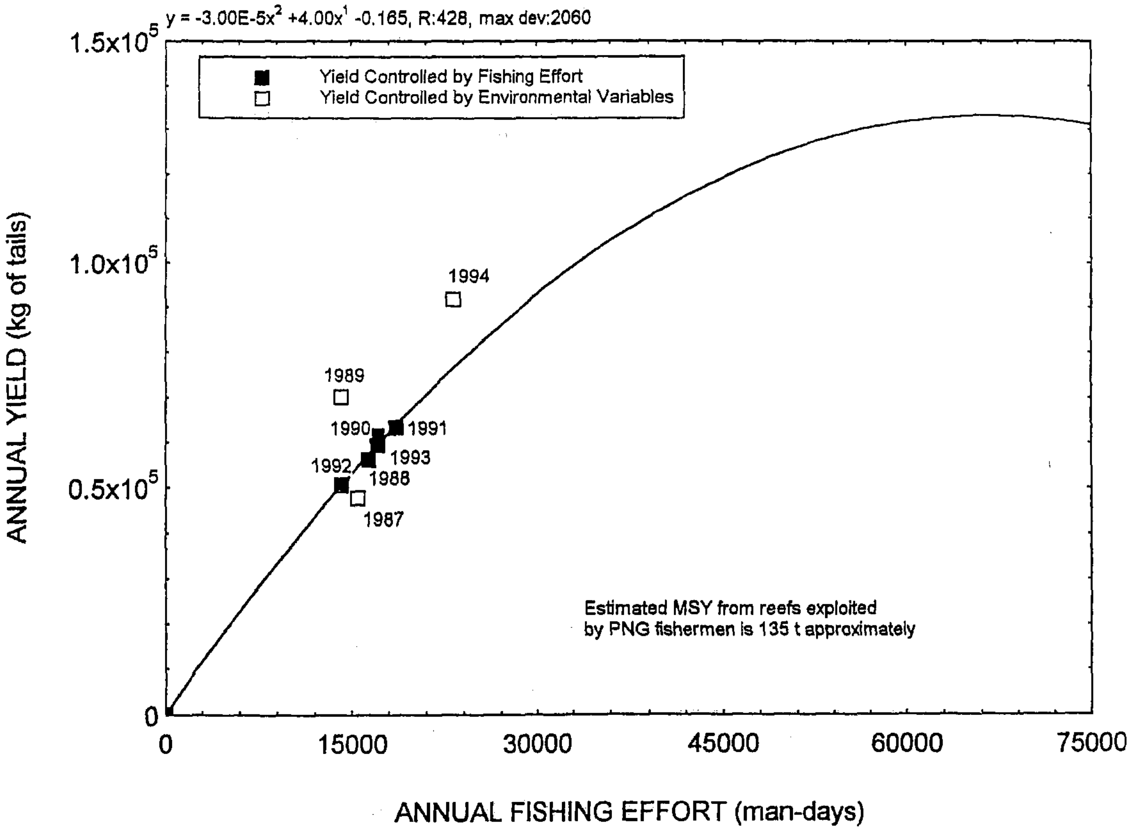

Fig. 6: Yield (by Tail-Weight) on Effort for the Crayfish Fishery, Daru, 1987-1994.