COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

DIVISION of FISHERIES and OCEANOGRAPHY

Report No. 98

CATCHES OF PUERULUS LARVAE ON COLLECTORS AS A MEASURE OF NATURAL SETTLEMENT OF THE WESTERN ROCK LOBSTER *Panulirus cygnus* George

By B. F. Phillips and N. G. Hall

Reprint No. 1010

Marine Laboratory
Cronulla, Sydney
1978

ISBN 0 643 02199 X

Printed by CSIRO, Melbourne

72.227-600

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Abstract

Data from four sites in Western Australia on catches on collectors of the puerulus stage of the western rock lobster, *Panulirus cygnus* George, were examined to determine the precision of the catches and the relationship between the puerulus catches and the natural settlement.

Variability in the catches of individual collectors at each site was high, but all collectors at each site indicated similar trends in the level of settlement from month to month and from year to year. The settlement pattern on the collectors showed a similar pattern to that expected from the results of larval sampling programs and the circulation pattern of the eastern Indian Ocean.

The data on the relationship between the catches on the collectors and natural settlement were less satisfactory, and it was not possible to detect a definite relationship between the levels of catches of puerulus on the collectors and the resulting juvenile densities at the site examined. This may have been because the relationship was masked by the effects of natural mortality (which is probably density dependent) and by the effect on this mortality of environmental factors.

The catches on the collectors were shown to be useful measures of seasonal patterns and relative strengths of settlement of the puerulus larvae of the western rock lobster.

INTRODUCTION

The western rock lobster is confined to the western coast of Australia, from approximately North West Cape to Cape Naturaliste (Fig. 1). The majority of the commercial catch is taken between 28 and 32° (Sheard 1962). After a planktonic life of 9 - 11 months (Chittleborough and Thomas 1969), the surviving larvae (puerulus stage) settle in shallow coastal areas.

A number of workers have developed collectors to catch the puerulus stage of rock lobsters (Witham *et al.* 1968; Phillips 1972; Anon. 1974; Serfling and Ford 1975). The data on the catches of such collectors have been used to measure seasonal patterns of settlement and relative strengths of settlement from season to season and year to year (Chittleborough and Phillips 1975; Serfling and Ford 1975).

Because of practical difficulties and costs most studies must rely upon small numbers of collectors to yield results. However, there appear to have been no studies of the precision of the collectors in providing repeatable measures of settlement, or of the accuracy of the catches as true indices of natural settlement. In this paper, data from four sites in Western Australia on catches on collectors of the puerulus stage of the western rock lobster *Panulirus cygnus* George were examined for the precision of these data and to assess the level of confidence which can be placed on these catch data as indices of natural settlement.

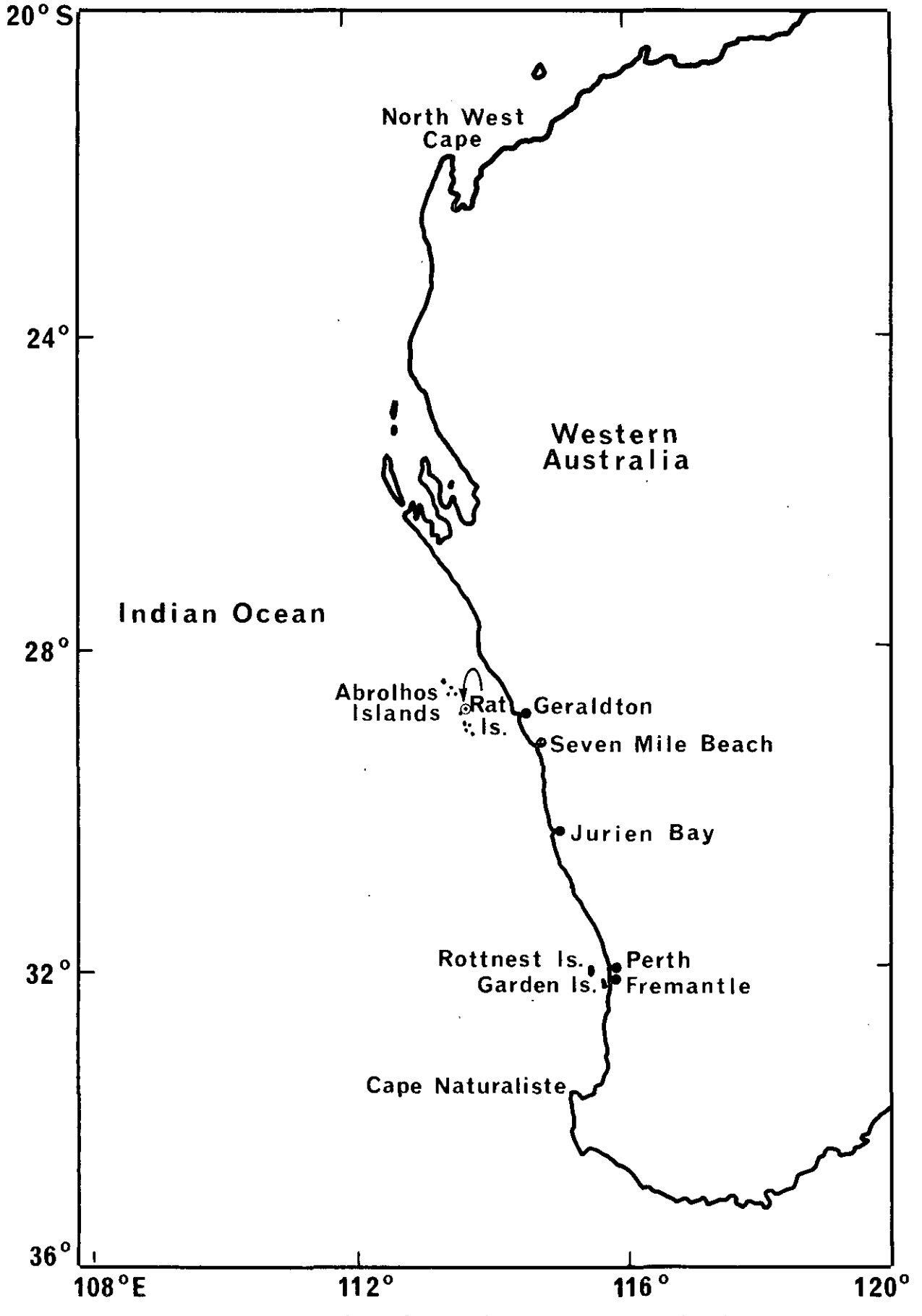

Figure 1 Location of the sites referred to in the text

METHODS

All collectors used in this study were as described by Phillips (1972). The collectors were checked monthly after each new moon period when most larvae settled. All settlement took place at the puerulus stage. The western rock lobsters were removed from the collectors either as puerulus larvae, or after they moulted into very small post-puerulus juveniles.

RESULTS

Collector catches as a measurement of settlement at a site

Observations were carried out at Rat Island, Abrolhos Island, Seven Mile Beach, Jurien Bay and at Garden Island in Western Australia (see Fig. 1).

These sites were chosen to give a range of data from the centre (Seven Mile Beach and Rat Island) to the periphery of the population (Garden Island), and a site approximately midway between these points (Jurien Bay) (Chittleborough 1970).

Phillips (1972) found no significant difference in the catches of collectors set out in pairs at Seven Mile Beach. This result was confirmed by the catches of a set of eight collectors approximately 2 m apart (Fig. 2). The catches made by these collectors over a period of six months during 1971 are given in Table 1.

Table 1. Catches of puerulus on the collectors at Seven Mile Beach in Western Australia

Collector	Aug. 1971	Sept. 1971	Oct. 1971	Nov. 1971	Dec. 1971	Jan. 1972	Total
A	1	9	12	4	6	7	39
B	6	19	12	13	7	7	64
C	7	18	9	3	2	7	46
D	6	16	8	5	2	5	42
E	8	6	11	9	1	8	43
F	5	7	9	8	3	5	37
G	4	6	9	4	5	5	33
H	6	15	9	6	4	8	48
Total	43	96	79	52	30	52	352

The homogeneity of catches of the collectors was tested using the log likelihood ratio test (Sokal and Rohlf 1969, pp. 559-607; Plackett 1974, pp. 12, 58), with a nominal level of significance throughout this paper of $P = 0.05$. The catches of the collectors in the same month agreed closely and the effects of interaction between collectors and months were not found to be significant ($P > 0.10$). As expected, there were significant differences in the catches of the individual collectors from month to month ($P < 0.001$).

It was not possible to detect a significant difference at the 0.05 level between the catches of any of the collectors in the array ($0.10 > P > 0.05$) and it was concluded that the exact positioning of a collector within the area tested (16 m^2) did not significantly affect its catch.

Data were examined from two sites to determine the effect on catch of collector positioning. The catches of six collectors along approximately 1 km of coast at Seven Mile Beach (Fig. 2) from September 1968 to May 1976, and of 10 collectors along approximately 9.6 km of coast at Garden Island (Fig. 3) from August 1975 to February 1976 were examined. The data from Seven Mile Beach (Table 2) showed that all the collectors indicated similar trends in the level of settlement from month to month and from year to year;

Table 2. Catches of puerulus stage of western rock lobster on collectors over *lunar months* at Seven Mile Beach, Western Australia

	Collectors						
Date	1	2	3	4	5	6	Total
September 1968	18	38	62	34	29	17	198
October	18	20	18	10	52	13	131
November	6	13	20	8	12	6	65
December	13	9	15	5	9	2	53
January 1969	9	6	7	1	7	3	33
February	2	3	2	1	1	2	11
March	4	1	1	0	1	0	7
April	2	0	0	0	0	0	2
May	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0
September	0	2	1	1	0	0	4
October	1	0	7	4	1	2	15
November	9	6	3	6	4	3	30
December	1	2	4	6	2	1	16
January 1970	0	1	4	1	1	2	9
February	0	0	1	1	4	0	6
March	3	3	2	1	0	0	9
April	0	0	1	0	1	0	2
May	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0
July	1	0	0	1	0	0	2
August	0	0	0	0	0	0	0
September	7	6	6	2	4	4	29
October	7	9	7	10	7	3	43
November	2	8	9	8	4	2	33
December	4	8	10	5	6	1	34
January 1971	6	8	2	4	6	3	29
February	2	4	1	0	3	4	14
March	3	0	3	0	1	1	8
April	2	2	1	4	0	6	15
April	0	2	1	0	0	0	3
May	1	1	1	1	2	2	8
June	3	3	5	4	0	1	16
July	4	1	2	8	1	2	18
August	12	10	10	8	2	1	43
September	17	4	12	10	7	7	57
October	16	15	16	13	14	5	69
November	20	15	19	18	25	7	114
December	4	3	4	1	5	1	18

Table 2 (contd). Catches of puerulus stage of western rock lobster on collectors over lunar months at Seven Mile Beach, Western Australia

Date	Collectors 1	2	3	4	5	6	Total
January 1972	10	5	2	4	9	3	30
February	2	1	1	0	1	1	6
March	2	1	1	1	0	0	5
April	1	1	3	0	0	1	6
May	0	0	0	1	0	0	1
June	0	0	0	0	0	0	0
July	6	4	1	3	6	1	21
August	0	0	0	0	0	0	0
September	6	7	4	4	12	3	36
October	3	4	4	1	1	2	15
November	8	5	16	3	7	3	42
December	4	4	7	3	3	4	25
January 1973	6	2	6	2	6	0	22
February	3	6	7	7	2	1	26
March	2	3	1	2	1	1	10
April	0	1	1	0	0	0	2
May	0	1	1	0	0	0	2
June	0	0	0	0	0	1	1
July	1	0	1	0	0	1	3
August	2	3	1	0	2	2	10
September	16	20	23	36	11	18	124
October	13	14	21	18	13	14	93
November	9	7	14	18	11	15	75
December	14	6	5	8	4	4	41
January 1974	15	18	18	14	9	11	85
February	8	6	7	5	5	5	36
March	5	4	4	3	2	2	20
April	1	1	1	1	0	1	5
May	0	0	1	0	3	1	5
June	0	0	1	2	0	0	3
July	0	0	0	0	0	0	0
August	5	5	5	5	4	8	32
September	32	19	30	10	28	14	133
October	84	64	66	46	59	23	342
November	42	47	57	25	67	16	254
December	11	12	12	10	15	3	63
January 1975	17	7	7	5	3	4	43
February	11	10	10	6	5	6	48
March	5	5	6	4	3	2	25
April	3	3	3	2	3	1	15
May	1	0	0	0	0	0	1
June	0	0	1	0	2	0	3
July	0	1	0	0	0	0	1
August	8	2	2	2	4	0	18
September	5	4	6	6	0	1	22
October	13	16	22	9	11	6	77
November	20	21	20	22	25	16	124
December	11	13	15	13	16	11	79
January 1976	21	32	41	12	32	12	150
January	13	9	15	9	6	6	58
February	3	3	6	3	2	2	19
March	4	6	5	5	4	5	29
March	1	2	1	0	0	0	4
April	0	0	0	0	1	0	1
May	0	0	0	1	1	0	2

the correlation between the catches of any pair of collectors was very highly significant ($P < 0.001$). The levels of settlement at Garden Island (Table 3) were much lower and therefore more difficult to interpret but did not detract from this conclusion. Overall levels of settlement on the collectors at Garden Island were consistently low by comparison with the settlement on the collectors at Seven Mile Beach for the same time period.

Table 3. Catches of puerulus on collectors at Garden Island

	1975					1976		
Collector No.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Total
1	0	0	1	0	1	0	0	2
2	0	0	2	0	1	1	1	5
3	0	0	1	1	0	2	1	5
4	0	0	1	0	1	3	0	5
5	0	0	0	0	1	4	0	5
6	0	0	1	0	2	6	1	10
7	0	0	3	0	3	2	0	8
8	0	0	0	0	5	4	0	9
9	0	0	9	3	4	4	0	20
10	0	0	2	2	2	4	1	11
Total	0	0	20	6	20	30	4	80

Analysis of the homogeneity of catches of the collectors at Seven Mile Beach by applying the log likelihood ratio test to all non-zero samples suggested that there might be systematic differences between the collectors; collector 6, for example, produced consistently smaller catches but it was impossible, because of significant interaction between collectors and months ($P < 0.05$), to test whether, for the data being analysed, the catches on the individual collectors differed significantly.

The variability between widely spaced collectors at a site was greater than between closely spaced collectors at the same site. Despite this fact, the overall variability between the catches of the collectors at a site was less than the variability between sites. Because of the variation in the catches of the collectors, collectors need to be distributed along the coast at a site to obtain a representative measure of settlement at that site.

Month to month comparisons within sites

The catches of the individual collectors at Rat Island, Seven Mile Beach, Jurien Bay and Garden Island from August 1975 to February 1976 are given in Table 4. Examination of these data, and the data for Seven Mile Beach in Table 2 showed that peak periods of settlement occurred between September and January but that the peak month of settlement was not necessarily in the same month at each site, nor in the same month at a site from year to year. Almost no settlement occurred during the period from approximately May to August each year.

Table 4. Catches of puerulus on collectors at Rat Island, Seven Mile Beach, Jurien Bay, Garden Island in Western Australia

MONTH	RAT ISLAND Collector				SEVEN MILE BEACH Collector						JURIEN BAY Collector					GARDEN ISLAND Collector					
	1	2	3	4	1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5	6
Aug 1975	2	1	0	0	8	2	2	2	4	0	0	2	1	3	0	0	0	0	0	0	0
Sept 1975	1	1	5	5	5	4	6	6	0	1	2	0	0	1	0	0	0	0	0	0	0
Oct 1975	3	8	1	0	13	16	22	9	11	6	4	6	7	9	1	1	2	1	1	9	2
Nov 1975	1	7	15	23	20	21	20	22	25	16	22	11	6	6	8	0	0	1	0	3	2
Dec 1975	5	6	4	13	11	13	15	13	16	11	24	30	19	28	31	1	1	0	2	4	2
Jan 1976	24	23	37	46	21	32	41	12	32	12	34	20	10	19	16	0	1	2	6	4	4
Feb 1976	27	22	20	26	13	9	15	9	6	6	4	14	10	12	10	0	1	1	1	0	1

Phillips, Rimmer and Reid (1978) sampled the late stage phyllosoma larvae and puerulus of *P. cygnus* offshore in the plankton in 1975 and showed that the highest densities of larvae were present in the plankton off the coast of W.A. between July and December, the same trend as in the collector data. The maximum number of puerulus settling on the collectors at Seven Mile Beach in September coincided with the highest density of late stage phyllosoma larvae in the plankton off the edge of the continental shelf in that area.

Comparisons between sites

The mean catch per collector and the 95% confidence limits of the mean (calculated from the method presented by Land, 1972) have been plotted (Fig. 4) for the 1974/75 settlement at Jurien Bay and Seven Mile Beach and (Fig. 5) for the 1975/76 settlement at Rat Island, Seven Mile Beach, Jurien Bay and Garden Island. For clarity, confidence limits in the Rat Island data are not shown but were wider than the limits on the data for the other sites. In these cases visual comparison is sufficient to show the differences between the monthly catches of the collectors at the different sites. However, a statistical comparison of the seasonal data may be made by treating the different months within the season as separate strata (Cochran 1963, pp. 87-95) and determining the mean catch per collector per month over the entire season.

Using this approach, the mean catch per collector per month between August 1974 and March 1975 at Jurien Bay was found to be 25.9 (SE = 2.8, effective df = 11) and at Seven Mile Beach was 19.6 (SE = 1.5, effective df = 13). These values were compared using an approximation to the t-test (Sokal and Rohlf 1969, pp. 374-375), and were not found to be significantly different ($P > 0.05$).

Between August 1975 and February 1976, the mean catch per collector per month at Garden Island was found to be 1.26 (SE = 0.25, effective df = 13), at Jurien Bay it was 10.57 (SE = 0.84, effective df = 13), at Seven Mile Beach it was 12.57 (SE = 0.85, effective df = 11), while at Rat Island it was 11.64 (SE = 1.15, effective df = 8). The values were obviously different between Garden Island and Jurien Bay, Seven Mile Beach and Rat Island, while the values for Jurien Bay, Seven Mile Beach and Rat Island were found not to be significantly different ($P > 0.05$).

As already discussed, the peak month of settlement was not necessarily identical at each site. The peak month of settlement at the more northern site Seven Mile Beach often occurred earlier than at Jurien Bay (see Fig. 4).

These results show a decline from north to south in the mean catch per collector per month, with similar levels of settlement occurring at Jurien Bay and Seven Mile Beach. This pattern, both in timing and difference in levels of settlement from north to south, is consistent with the densities of larvae in the plankton and the water circulation of the eastern Indian Ocean. The water circulation is under the control of a large clockwise gyre which causes a water flow towards the coast of Western Australia in the vicinity of 29°-31°S (between Seven Mile Beach and Jurien Bay). The water then flows southward predominantly parallel to the coast. The easterly current flow and a recurrent eddy in the area give rise to relatively high densities of phyllosoma larvae in the plankton near 29°-31°S. Further south there are relatively fewer phyllosoma larvae in the plankton, and fewer puerulus settling (Phillips, Rimmer and Reid 1978).

The consistency of the settlement pattern at sites in the 29°-31°S area is of interest. Analysis of the mean number of puerulus settling on collectors each season between 1969/70 and 1976/77 at Rat Island, Seven

Mile Beach and Jurien Bay (Table 5), showed that settlement at these three sites was significantly correlated ($P < 0.05$) and the data for Seven Mile Beach and Jurien Bay were highly correlated ($P < 0.01$), indicating similar levels of settlement over these years. The data for Garden Island is given for comparison.

Table 5. Mean number of puerulus settling per collector

Season of Settlement	Rat Island	Seven Mile Beach	Jurien Bay	Garden Island
	A			
1969/70	—	15.0	3.7	—
1970/71	27.6	35.3	20.3	0.3
1971/72	32.8	67.2	36.3	1.0
1972/73	68.8	33.7	41.6	0.3
1973/74	75.0	83.2	117.0	4.3
1974/75	130.8	159.8	209.8	2.0
1975/76	104.5	97.3	79.4	4.0
1976/77	106.8	100.8	64.8	2.4

A - not measured.

Relationship between puerulus catches and natural settlement

No information is available as to whether there is a constant relationship temporarily or spatially between the catch per collector and the density of puerulus in the water. However, visual observations of free swimming puerulus suggest that the catches of the collectors relate to the numbers of puerulus in the water adjacent to the collectors. Phillips and Olsen (1975) recorded sighting 335 puerulus between 1700 and 2400 hours on five nights (15, 16, 18, 19 September and 17 October 1974) at Seven Mile Beach. The catches of three collectors adjacent to the observations were a total of 127 puerulus over these nights. During similar observations on two nights (26 and 27 October 1973) no animals were observed and only one puerulus was caught on the same three collectors over these two nights.

The mean catch per collector between September and April each year from 1968-1976 at Seven Mile Beach, together with 95% confidence levels, has been plotted as Figure 6. The differences in the levels of annual settlement indicated by these data are assumed to be natural variations in the annual levels of settlement. This conclusion has been partly confirmed by Chittleborough and Phillips (1975) who examined the relative Jurien Bay and Seven Mile Beach and stated that in general there was a good consistency between the indices of year-class strength at settlement obtained from the collectors and those derived from measurements of density of juveniles aged two or three years in the same locality. However, because the natural mortality varies with the overall density of juveniles due to the restricted holding capacity of the nursery reefs, the survival of the juveniles through to approximately five years of age (when they become recruits to the fishery) could only be clearly determined from relatively weak years of larval settlement. Relatively strong years of larval settlement do not necessarily produce a high level of recruitment to the fishery, but will in general result in at least an average level. These data were used by Chittleborough and Phillips to make successful predictions in 1971 of a low catch level in the fishery in 1973/74, followed by a recovery in the subsequent season.

A plot of all the data now available on the total annual settlement of puerulus at Seven Mile Beach (as measured by the catches on the collectors) against the densities of two year old juveniles arising two years later at the same site (Chittleborough and Phillips 1977) from these settling larvae is presented in Figure 7. Despite the success of the predictions, it was not possible to determine a mathematical relationship between these indices, however, this may be partly due to the density dependent mortality and also to the effect of environmental factors on the mortality of the juveniles. However, even if a relationship had been demonstrated for Seven Mile Beach, there are a number of untested assumptions in applying this relationship to other sites, including the assumption of similar environmental conditions and similar areas available for settlement at each site. Changes in these factors could result in changes in the level of natural settlement, perhaps reflected in the catch per collector, but with the relationship varying from site to site.

The question of whether the catches of the collectors are truly representative of the natural settlement occurring in an area is thus truly partly answered. This situation is found in most fish sampling programs, density being assumed to be directly proportional to catch per unit of effort. However, the collector is not directly comparable to conventional fishing equipment. The collector (relying on encounter by returning puerulus rather than attraction to a bait) is perhaps nearest in action go a gill net, but Phillips and Olsen (1975) found that the puerulus larvae of *P. cygnus* were clearly capable of detecting hanks of the artificial seaweed of which the collector is formed and were not simply swept into the collector. It should also be noted that the collector, rather than measuring the density of settled puerulus, measures the rate of settlement. The catches of the collectors alone are insufficient to resolve this problem and until an independent method of sampling the puerulus is determined the question remains unsolved.

DISCUSSION

Analysis of the data on the catches of the puerulus of *P. cygnus* on the collectors at Seven Mile Beach, Jurien Bay, and Garden Island has shown that an acceptable precision was achieved by the collectors, even though they were in small numbers. Variability between the catches of individual collectors at each site was found to be high. However, all collectors at a site indicated similar trends in the level of settlement from month to month and from year to year. The variations between months in the catches on the collectors at Seven Mile Beach appeared from visual observations (Phillips, unpublished data) to be related to the direction of the prevailing weather. The individual collectors 1, 2, 3, and 4 at the southern end of the area recorded higher daily catches during periods of strong southerly winds, while those at the other end of the area (5 and 6) recorded higher catches with north west winds.

It is of significance that in each case examined the collector data show a similar pattern to that expected from the results of larval sampling and the water circulation pattern in the eastern Indian Ocean. Comparisons of the catches of areas with low densities of settlement, such as Garden Island, with areas of higher settlement, such as Seven Mile Beach, are always difficult. The confidence limits on these data reflect the fact that in areas of low density of settlement the catches of small numbers of collectors are unlikely to adequately reflect the changes in annual settlement, although they may be adequate to reflect changes in annual settlement in areas of high density. In practice many workers would only compare the

total catch on the collectors from year to year, or perhaps the peak periods of settlement at a site or between sites. Provided the catches of the individual collectors are consistent and of a reasonable magnitude this can be successfully accomplished with a small number of collectors distributed along the coast of a sampling site.

As already discussed, no mathematical relationship was determined between the total settlement at Seven Mile Beach as measured by the catches on the collectors and the subsequent density of three year old juveniles at this site. The inability to demonstrate such a relationship, taking into consideration the level of precision of the data, suggests that further studies to establish the accuracy of the collectors as an index of the natural settlement occurring in an area are desirable. Before full confidence can be placed in the use of puerulus catch data to predict future catch levels in the fishery it will be necessary to establish a relationship between the catches of the collectors and the resultant juvenile densities. This may be achieved with a longer time series of data and additional information on the factors affecting mortality of the juveniles on the nursery reefs. However, in the absence of this confirmation, the catches of the collectors continue to be useful indices of seasonal patterns and relative strengths of settlement.

ACKNOWLEDGMENTS

During the preparation of this paper a number of colleagues have made helpful suggestions. The authors wish to especially acknowledge the following: N. Caputi, A. Grassia, G. Kirkwood, G. Morgan, D. Reid, and D. Williams.

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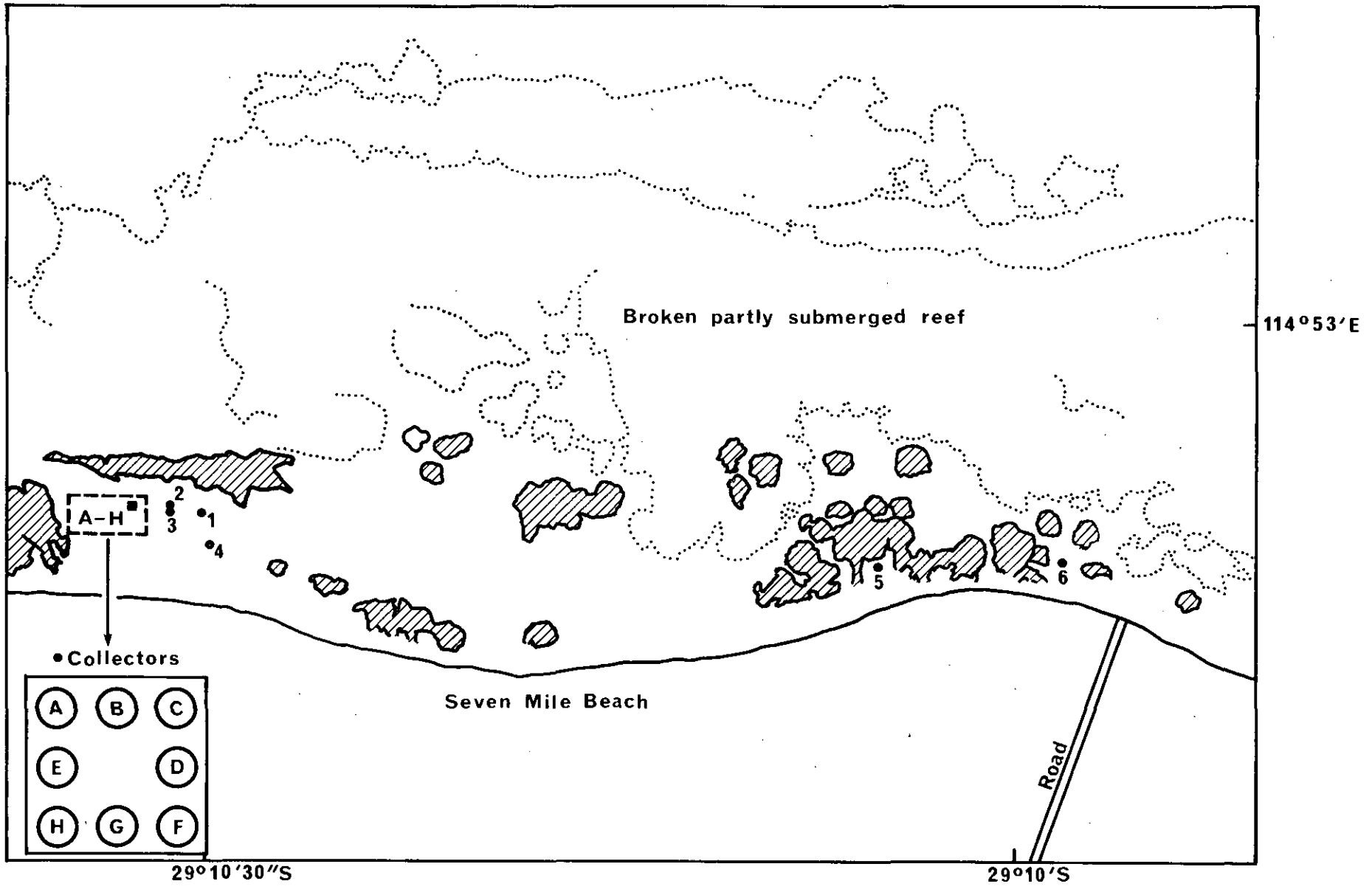

Figure 2 Positioning of collectors at Seven Mile Beach in Western Australia

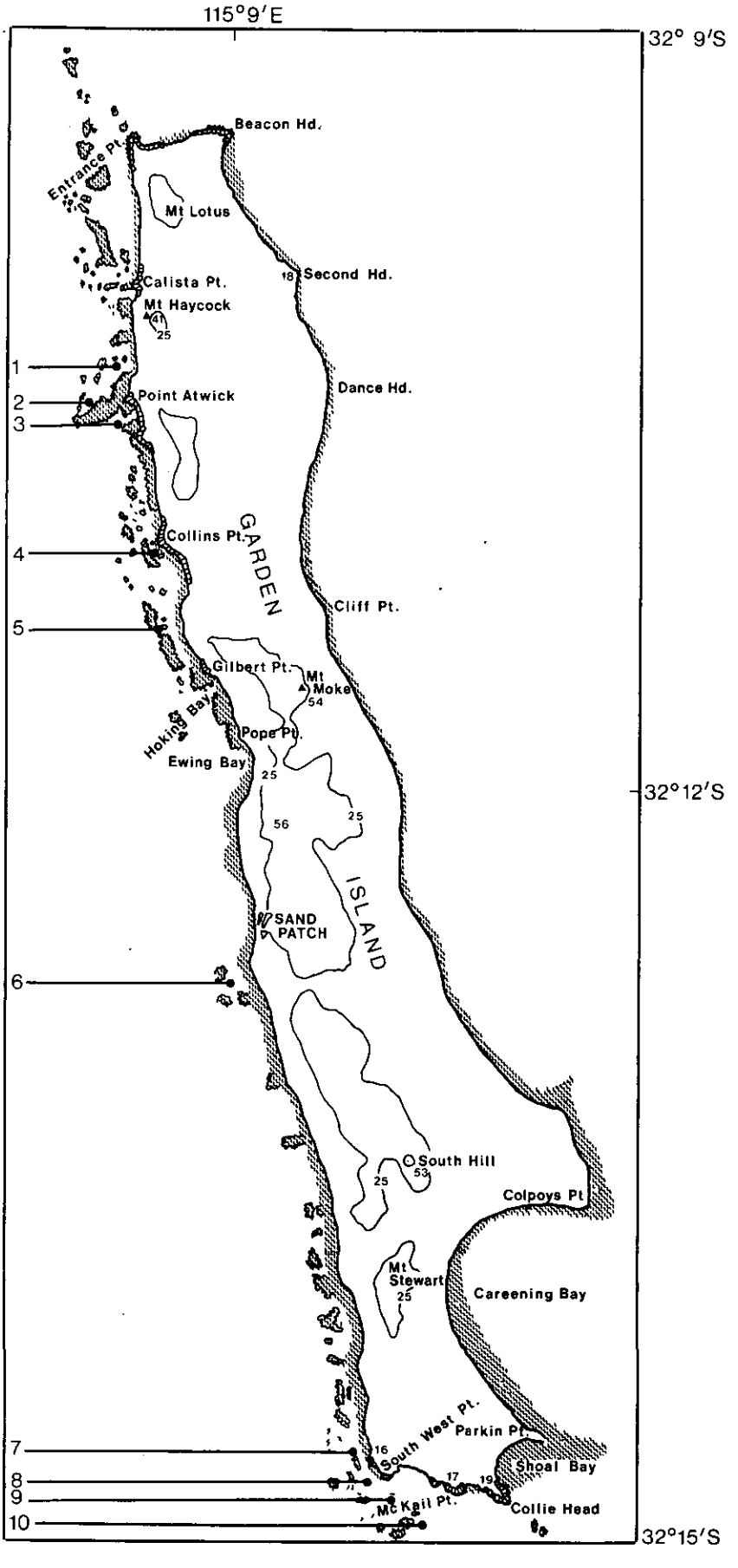

Figure 3 Positioning of collectors at Garden Island in Western Australia

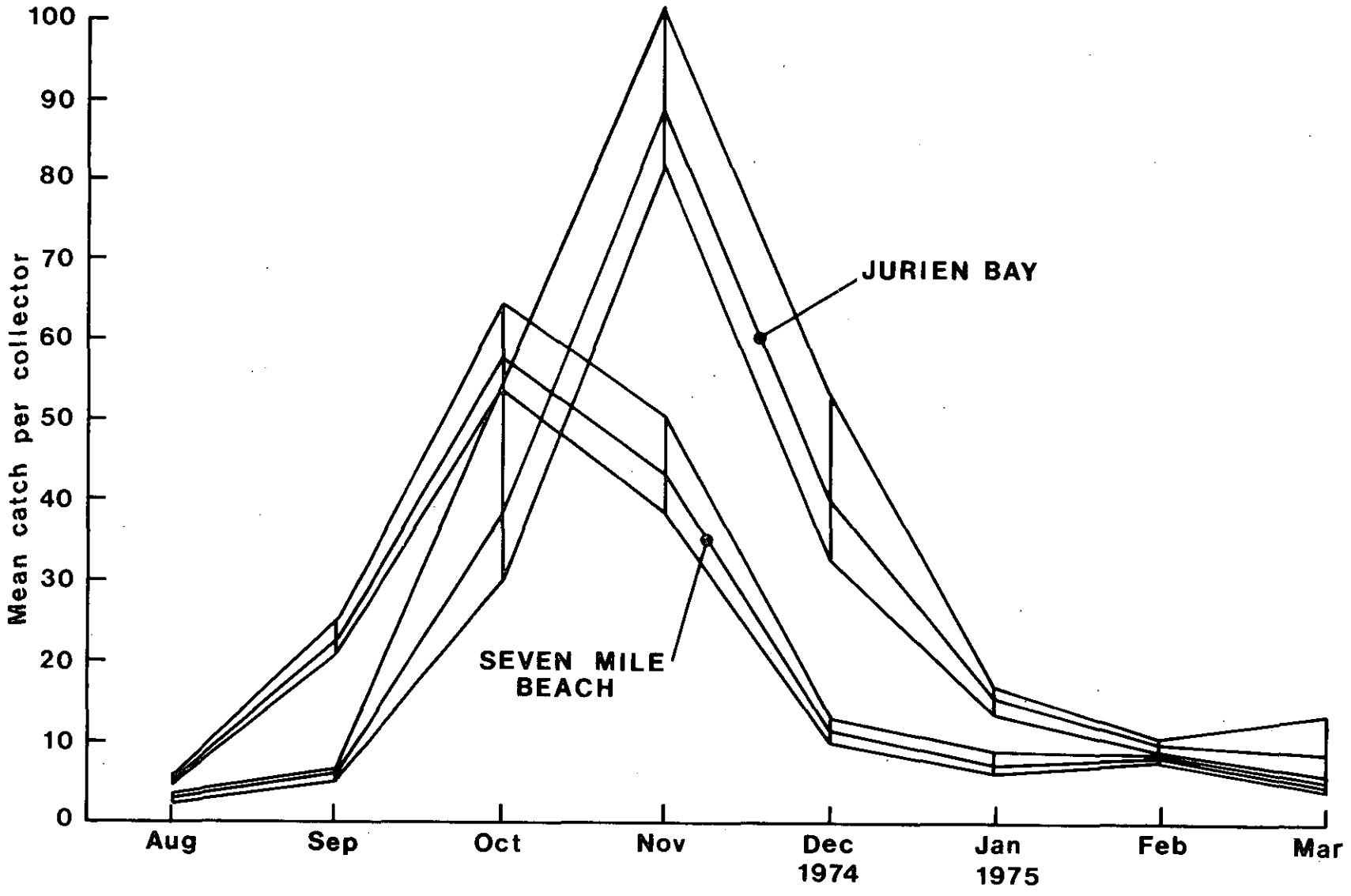

Figure 4 Mean catch per collector and 95% confidence limits for the mean for Jurien Bay and Seven Mile Beach in 1974/75

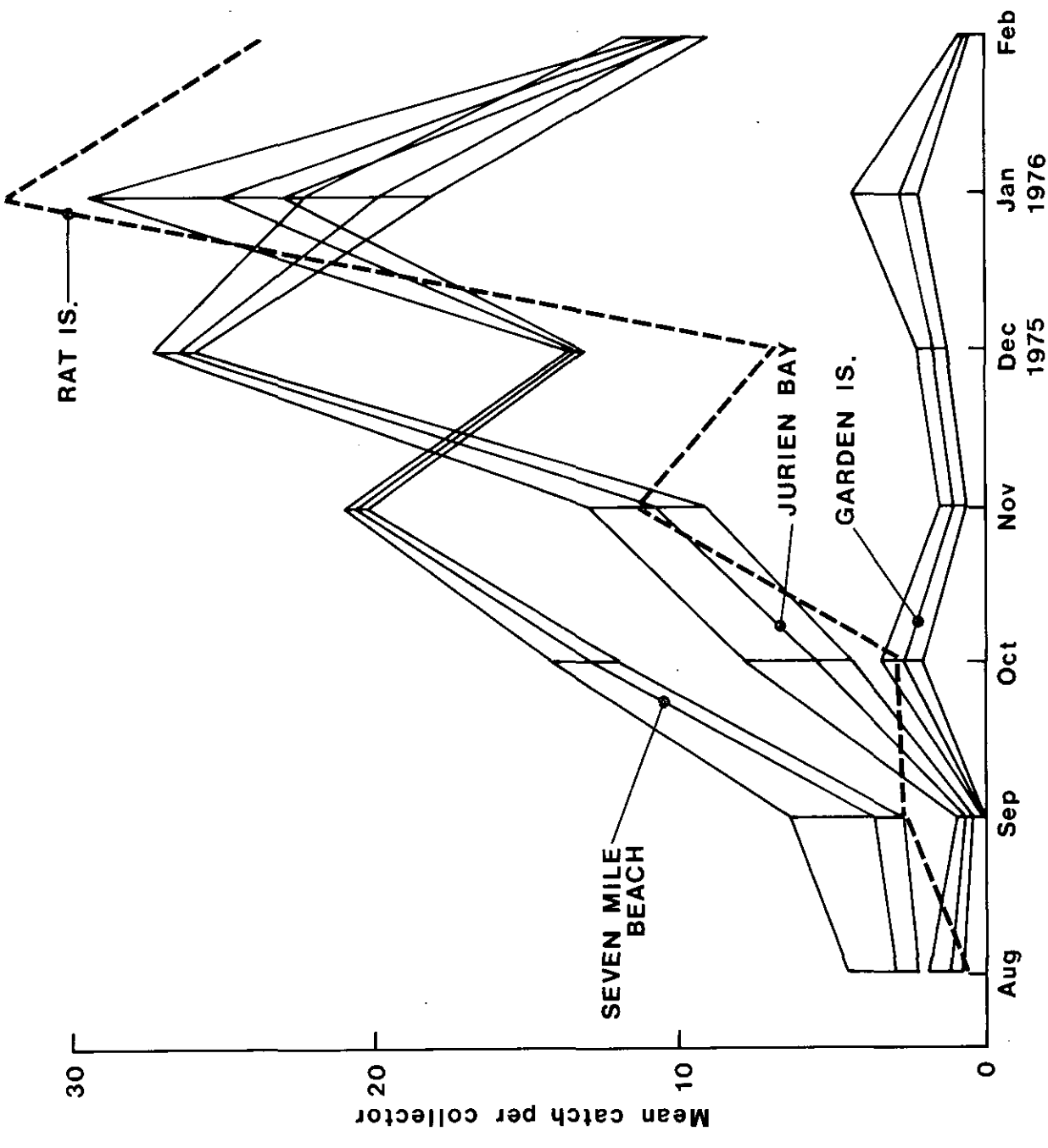

Figure 5 Mean catch per collector and 95% confidence limits for the mean for Garden Beach in 1975/76 and the mean catch per collector for Rat Island in 1975/76 Island, Jurien Bay and Seven Mile

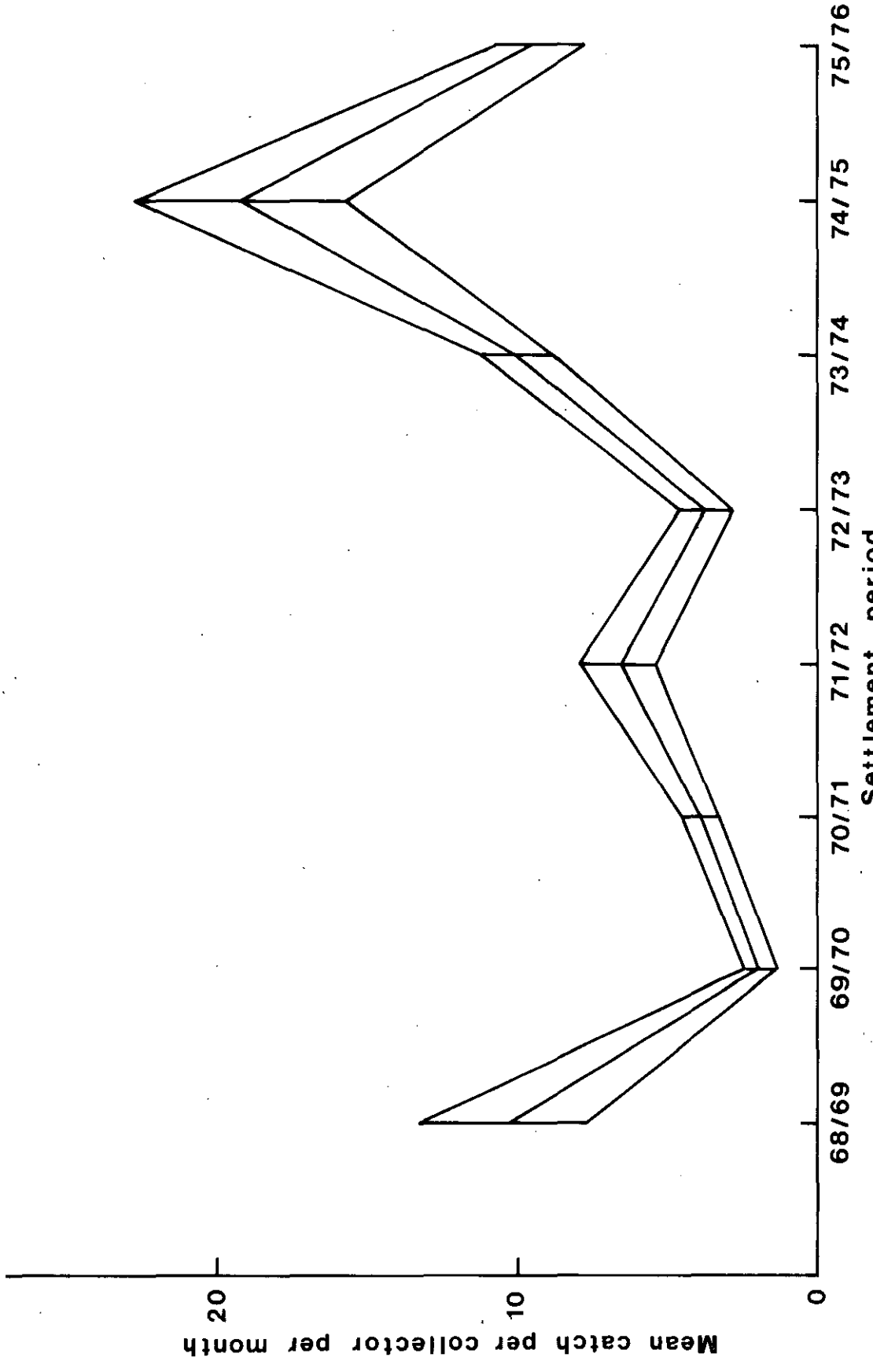

Figure 6 Mean catch per collector per month and 95% confidence limits for the mean for data from September to April in successive settlement periods at Seven Mile Beach

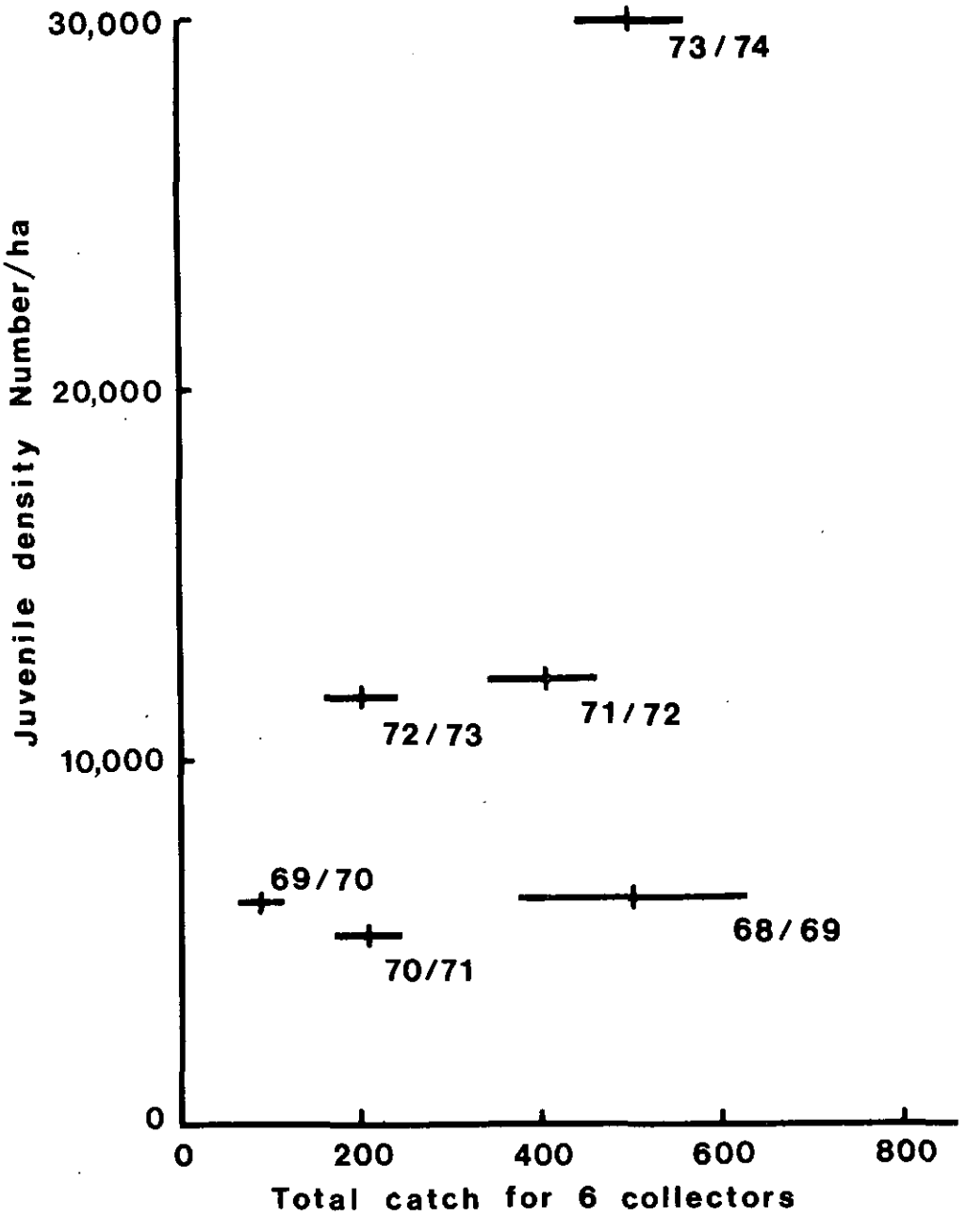

Figure 7 Juvenile density for two year old lobsters in January each year at Seven Mile Beach related to the total settlement of puerulus on six collectors (and the 95% confidence limits for the total) one year previously. The year of puerulus settlement associated with each data point is shown on the figure