FINAL REPORT

FISHERY INDEPENDENT STUDY OF THE SPAWNING STOCK OF THE WESTERN ROCK LOBSTER

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NON-TECHNICAL SUMMARY

The fishery for western lobster (*Panulirus cygnus*) has supported an annual catch of about 10 500 tonnes per annum over the last twenty years and is worth between $200-300 million per annum. The fishery has been experiencing increasing exploitation rates over time and estimates in the 1990s were suggesting that the brood stock had declined to between 15-20% of unfished levels. These low levels were considered to pose a serious risk to future recruitment and resulted in a number of management measures being introduced in the 1993/94 season aimed at raising the levels of the brood stock.

In the past, the state of egg production in the stock has been estimated using data obtained from the commercial fishery. Data from this source can introduce possible bias, in that it is possible for fishers to avoid certain areas where there are large numbers of female animals in a breeding state and which under the new management measures are now required to be returned to the sea. Furthermore, the effect of increases in fishing power on commercial fishing effort due to changes in gear technology, can lead to the spawning stock index being over estimated if valid measures of the increases in effectiveness are not available.

The only way of avoiding the potential biases of using commercial data, is by conducting a sampling programme independent from commercial fishing data. Such a pilot programme was undertaken at Fremantle and the Abrolhos Islands in 1991, was expanded to include Dongara and Jurien in 1992 and with the assistance of FRDC funding was continued and expanded to include Lancelin and Kalbarri from 1993 onwards. The results from this survey form the basis of this report.

Commercial lobster fishing boats were chartered to do research fishing in five areas on the coast and a research vessel was assigned to the Abrolhos Islands. Fishing took place at each of these areas over ten days during the last new moon prior to the start of the commercial fishing season in mid-November. Standard commercial pots were set on the same GPS positions each year in areas that had previously been identified as localities which consistently yielded large numbers of spawning animals. All lobsters caught were measured, sexed and in the case of females particular attention was paid to their reproductive state. Environmental parameters (bottom and surface temperature, salinity, swell size) were recorded daily in each area.

Egg production indices (expressed as the mean number of eggs per pot lift) were calculated annually for each area based on the number of mature female animals in the catch. Analysis of the results at all the coastal sites showed significant differences in egg production since the surveys first commenced. Differences in egg production at the offshore Abrolhos Islands

were not significant, but bordered on significant levels. All the survey areas have shown an upward trend in egg production since 1993 when the management changes came into effect.

Other analyses showed that there were substantial inter-annual differences in swell size as well as surface and bottom temperatures varied significantly from year-to-year. These environmental factors did not significantly increase or decrease the egg production indices in any one year, but the analysis did suggest that swell size has an influence on the index.

The independent spawning stock survey has been shown by this study to provide a reliable index for egg production on a regional and whole fishery basis. The improvements in egg production indices over the relatively short time period that the survey has run, is encouraging given the recent management changes aimed at improving the brood stock. The two year FRDC-funded extension to this project (FRDC Project 96/108) will provide increased confidence in the results.

CONTENTS

BACKGROUND

Towards the end of the 1980s and early 1990s, managers became seriously concerned about the state of the western rock lobster breeding stock. Indicators of the size of the brood stock using fishery dependent techniques were suggesting that it had declined to between 15-20% of its historical levels (Brown, Caputi and Barker, 1995). In response to these concerns about the state of the brood stock, a management package was introduced into the fishery in the 1993/94 season with the expressed aim of improving the state of the brood stock (Anon, 1993).

The management package attempted to raise the level of the brood stock by introducing a new minimum size of 77mm carapace length (CL) (the previous minimum size was 76mm) for the first two and a half months of the season, before reverting back to the old minimum size for the balance of the season. The prime objective of this change was to allow immature 'white' lobsters in the 76-77mm CL size range that would under normal circumstances have been available to the fishery at the start of the season, to undertake their offshore migration into the deeper water breeding grounds before entering the fishery in February. Other changes that were introduced as a way of improving the brood stock were an 18% pot reduction, the placement of a restriction on the taking of lobsters displaying setae on the endopodites, and the retaining of large females over 115mm CL in the southern part of the fishery and over 105mm CL in the northern part of the fishery.

These changes to the fishery regulations were drastic, but given the state of the brood stock at the time of their introduction they were considered very necessary. It would have been possible to have monitored the way that the stock responded to these changes using the fishery dependent spawning stock index (Caputi *et al.*, 1995), an index which is based on commercial catch and effort data as well as biological information gained from regular at-sea catch sampling, but such information can be subject to a number of potential biases. There is, for example, the possibility that fishers could change their fishing pattern in a way that might avoid areas where mature female lobsters occur. This would result in underestimating the spawning stock index. Additionally, the effect of increases of fishing power on commercial fishing effort can lead to the spawning stock index being incorrectly estimated (Brown et al., 1995).

The only way of avoiding the potential biases of using commercial data, was by the initiation of a commercial fishery independent sampling programme. Such a pilot programme was undertaken at Fremantle and the Abrolhos Islands in 1991, was expanded to include Dongara and Jurien in 1992 and with the assistance of FRDC funding was continued and expanded to include Lancelin and Kalbarri from 1993 onwards.

NEED

The specific need in the fishery was to develop a fishery independent annual index of egg production for the stock, which would provide the ability to interpret correctly the effects of fishing on the reproductive potential of the western lobster stock. Comparisons of the fishery independent index with other data sources such as puerulus data commercial monitoring, and research log-book based spawning stock indices would provide a means of validating the fishery independent index as a measure of egg production. An independent index of reproductive potential would address the problems (e.g. efficiency increases) associated with commercial catch-rate based indices over the longer term.

OBJECTIVES

1. To fully develop experimental spawning stock survey techniques based upon successful feasibility studies conducted in the 1991/92 and 1992/93 fishing seasons.

2. To test the feasibility of developing annual fishery-independent indices of reproductive potential on both a regional and whole fishery basis.

METHODS

Sampling strategy

Six sites, covering the major portion of the commercial western lobster fishing grounds, were selected as spawning stock survey sites. The sites, Fremantle, Lancelin, Jurien, Dongara, Kalbarri and the Abrolhos Islands (Fig. 1), were believed to be wide enough apart and important enough in their own right, to provide adequate coverage of the commercial lobster grounds.

Each of the areas were visited prior to undertaking the first survey and local knowledgable fishers were consulted as to which parts of the grounds and between what depths that they most frequently encountered mature/breeding female lobsters. Based on this information, survey sites within any one area were designed to incorporate four or five sub-areas with identified high mature-female catch rates and possibly different bottom types. The depths covered by the coastal sampling sites ranged from 16.5-37.5 fathoms, with most depths in the 20-30 fathom range. Spawning lobsters are frequently found in shallow depths at the Abrolhos Islands and consequently sampling covered a greater depth range there (8-30 fathoms) than at the coastal sites.

Because the survey was to rely on chartered commercial vessels to do the catching, it was not possible to run it during the commercial fishing season (November 15-June 31). Periods

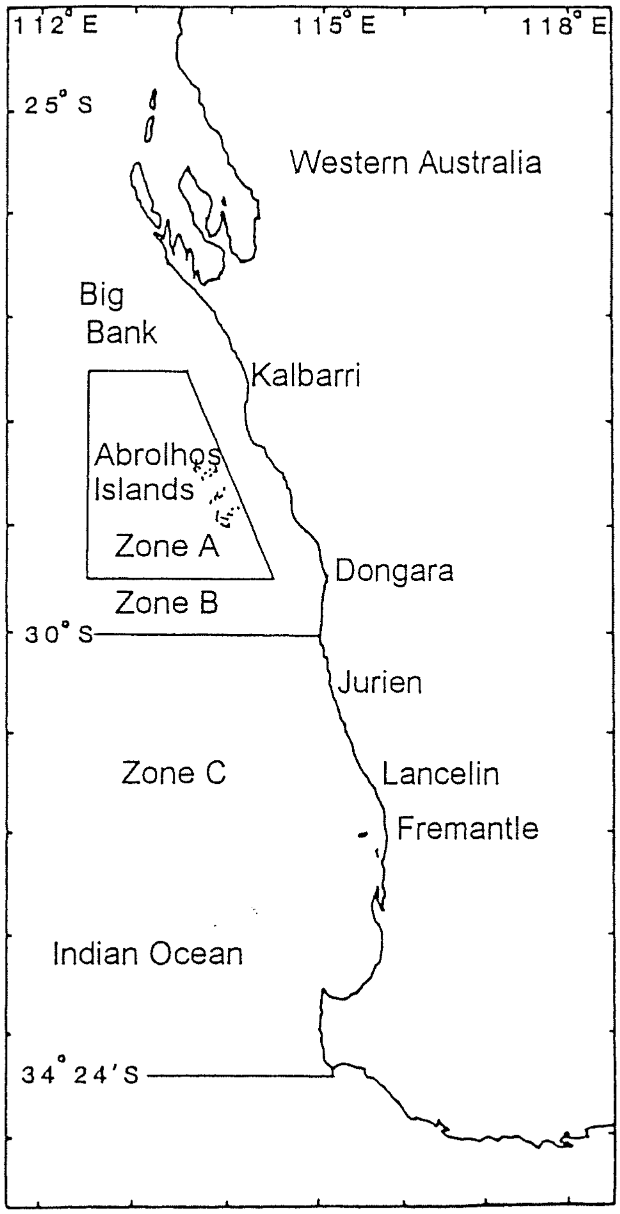

Fig. 1 Map showing the fishery independent spawning stock survey sampling sites

outside of the fishing season are not ideal because of winter storms, but it was felt that a compromise would be to run the survey at the end of winter just prior to the start of the commercial fishing season and at the start of the spawning period which occurs from September-February (Chubb, 1991). Catch rates are best over the dark phase of the moon and therefore it was decided to conduct the annual survey during the last new moon period prior to the start of the western lobster commercial fishing season (i.e. November 15).

Bait for the pots was standardised in the first year of the survey. Salmon heads, North Sea herring and cow hide were chosen because of their availability and well known reliability as good bait. Approximately 2kg of bait per pot was used at each setting. All pots were soaked for two weeks prior to the start of the survey. This soaking period took place well away from the survey area and apart from hide that was to be used later in the survey being put into the pots to mature, no other bait was used. Soaking of pots prior to the start of the season is standard commercial fishing practice, the aim being to rid the pots of any 'foreign' odour that might deter lobsters from entering.

At each of the coastal locations 160 standard commercial lobster pots with jarrah batten slats, red-necks and closed escape gaps were fished, except for the Fremantle area where large numbers of cane beehive pots are traditionally used. Because of this tradition of using substantial numbers of cane beehive pots in the Fremantle area, it was decided to use an equal number of beehive and batten pots for the survey in this particular area and to alternate the setting of the two pot types. In all the coastal survey locations pots were set for two day soaking times with 80 pots being pulled and reset each day for the duration of the survey, however because of occasional adverse weather conditions, some soak times were one or three days. Two day pot soaking times were chosen because they provided better catch rates than one day soaking times during lower catchability periods. The location of each pot setting was recorded on GPS navigational equipment and the positions for each location were standardised after the first survey in each area for use as the sampling points in subsequent surveys.

Pots were set singularly, but in lines tracking what was considered by the skipper to be optimal ground. This method of setting pots in lines is a standard fishing practice and assists in the retrieval of the gear by enabling the skipper to be pulling a pot while at the same time having the float of the next pot to be pulled in sight. Since each of the areas in the survey had four or five sub-areas and since 80 pots were being hauled per day, the strategy adopted was to have either 16 or 20 pots to a line. Every day one line of pots would be pulled and reset in each sub-area, in this way spreading many of the day-to-day effects that might have otherwise influenced lobster catchablility, over the whole area.

The offshore Abrolhos Islands locations were fished in a slightly different manner to those on the mainland. All four Islands of the Abrolhos Group were fished by the Fisheries Department's research vessel R.V. *Flinders* using a combination of cane beehive and jarrah batten pots. Because of the high catch rates in this area, it was only feasible to set the pots for 24 hour soak periods and because of the large amount of animals in the catch that were required to be measured and sampled, it was only practical to work 50 pots per day in this location. Another difference in the fishing method was that since the Islands are relatively far apart, it was not possible to haul and set pots at all the Islands on the same day. Accordingly, the Island sub-areas were fished systematically from south to north. This fishing strategy differed from that used on the mainland where it was attempted to spread the daily fishing out in such a way as to set and haul traps in each of the different sub-areas.

For each day of fishing and for each pot, individual rock lobsters were measured (carapace length in mm), sexed and if female assigned a breeding state. Rock lobsters were returned to the water in the vicinity of where they were caught to minimise any mortality due to translocation. Environmental data likely to affect catchability, eg. water temperature (bottom and surface), swell, current, salinity and general weather conditions, were recorded on a daily basis throughout the programme.

The first year of the survey in each area provided the GPS locations for subsequent years. There is a random error in GPS positions of up to 100m standard deviation (pers. comm. E.Skender, Transair Australia), which means that it is theoretically possible for a vessel returning to a GPS position to be as far as 200m from the original GPS position. Because this error precluded the possibility of setting the gear in exactly the same position each year, a sampling strategy had to be devised to cope with the errors that would occur through using GPS positions. The strategy that has been followed when repeating the original GPS sampling points in subsequent years has been to carefully follow echo soundings and traces when steaming up to the sampling position. If the ground on the given GPS position proves, based on the echo trace, to be unsuitable habitat for lobsters, then the boat is required to continue on the same course for a further approximately 100m, before circling back to set the pot on the most suitable piece of ground that was covered over the 100m course that was steamed on either side of the GPS position.

As might be expected, it was found that not all of the sites that were chosen in the first couple of years of the survey produced good catches of lobsters. As a result, it was necessary to make changes to the positions of some of the lines of pots in the subsequent years. Since then though, the positions of the pots with the exception of some very minor changes have been standardised.

Data analysis

Prior to undertaking any detailed analyses, the data were validated by generating plots showing the mid-point of each line of pots, for each year surveyed, for each of the six areas. Lines outside of the sampling areas were identified and their coordinates were checked for possible errors. In some cases, particularly in the first year of the survey, there were occasional lines that had been set well outside of the main sub-areas and which had then been discontinued. These lines were excluded from the analysis.

In the case of the pilot breeding stock survey conducted in the Fremantle area in 1991, the lines were not set in well defined sub-areas. From 1992 onwards the sampling strategy changed and most of the 1991 lines were discontinued. It was therefore considered appropriate to exclude the Fremantle 1991 data from the analysis.

As has been noted, for particular reasons the sampling strategy for the Abrolhos Islands has been designed differently to the coastal sites. There have been a larger range of depths fished at the Islands than at the mainland, the sub-areas have been fished sequentially each day over the survey rather than concurrently and lastly pot soaking times have been one rather than two days in duration. All of these differences have provided strong reasons for excluding the small Abrolhos Island data set from the bigger coastal data set when combining areas for analysis.

Pots with structural damage and open escape gaps, both situations which could have influenced catch rates, were omitted from the analysis. The number of eggs produced per pot in a line in each area for each year, was then calculated by estimating the number of eggs produced by each mature female sampled. This calculation used the size-fecundity relationship, percent double spawning-size relationship, and percent maturity-size relationship (Chubb *et al.* 1989). The total egg production for each line was then logarithmically transformed, to take account of the skewed distribution resulting from the dependence of the index on catch rates, before being used in any of the statistical analyses.

An ANOVA was undertaken on the egg production index in each of the six areas, with main effects year, fishing depth (in 5 fathom depth intervals), sub-area, soak time (in days) and interactions, sub-area - depth, depth - soak time, year - sub-area and year - depth to take into account some of the main effects which might influence the index. The number of samples in the above cells was dependent on all the lines being fished each year, but since some lines were omitted in certain years due to weather conditions and minor changes to the design, this led to the ANOVA design being unbalanced.

This ANOVA was later broadened to test the effect on the egg production index of three key environmental factors, namely swell size, and surface and bottom temperatures. Swell size was scored in each area against a range of given categories and these have been coded numerically for analysis so that no swell=0, low=1, moderate=2 and heavy=3. Since the environmental variables were generally only measured once a day at each sampling area, there were many pot lines for which the data were missing. Missing data have been generated for those lines by assuming that they were similar to the measurements made for other lines in the same area on the same day. In a few instances this information was missing for all lines pulled on the same day and in those cases the missing variables were generated using measurements made for these sea conditions in other areas for the same day, but taking into account the average differences between locations.

DETAILED RESULTS

A plot of the general distribution of the survey areas over the coast is presented in Fig. 2 with the mid-points of lines being indicated by the year that they were sampled. Each of the six sampling areas are shown in more detail in Figs. 3 to 8, with numbers indicating the mid-points of pot sampling lines and with different numbers being used to indicate the various sub-areas in any one sampling locality.

In analysing the data, particular interest lay in the effects that year, fishing depth, sub-area and soak time might have had on the egg production index in the six survey areas and whether any of these factors interacted with each other. ANOVAs run for each of the survey areas showed that in four of the six areas none of the interaction effects were significant. However, sub-area and depth were shown to significantly interact with each other at the Abrolhos Islands ($p<0.05$), as did year and sub-area in the Fremantle area ($p<0.05$). In both the Abrolhos Islands and Fremantle area cases, the interactions explained approximately 8% of the sum of the squares compared to the main effects which explained 57% and 31% respectively. Since there was a lack of any substantial or consistent significant interaction between the main factors, further ANOVA runs were restricted to only the main effects. The results of those runs for the six survey areas are presented in Tables I to VI.

Table I: Summary of an ANOVA of log egg production indices for the Abrolhos Island area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	111.5	4	27.9	4.47	0.0016
Sub-area	509.5	3	169.8	27.21	0.0001
Depth	1470.3	5	294.1	47.12	0.0001
Soak-time	37.4	2	18.7	3	0.0513
Pot type	22.0	1	22	3.52	0.0617
Error	1866.1	299	6.24		

Table II: Summary of an ANOVA of log egg production indices for the Dongara area

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	571.6	3	190.5	10.16	0.0001
Sub-area	47.3	4	11.8	0.63	0.6414
Depth	42.3	2	21.1	1.13	0.3270
Soak-time	24.4	2	12.2	0.65	0.5235
Error	2418.7	129	18.7		

Table III: Summary of an ANOVA of egg production indices for the Fremantle area

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	240.4	3	80.1	7.98	0.0001
Sub-area	171.2	4	42.8	4.26	0.0023
Depth	34.4	3	11.5	1.14	0.3322
Soak-time	78.8	2	39.4	3.92	0.0208
Pot type	73.1	1	73.1	7.28	0.0074
Error	2951.7	294	10		

Table IV: Summary of an ANOVA of egg production indices for the Jurien area

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	128.8	3	42.9	3.59	0.0149
Sub-area	733.6	4	183.4	15.33	0.0001
Depth	40.6	2	20.3	1.70	0.1866
Soak-time	58.5	2	29.3	2.45	0.0897
Error	2057.5	172	12.0		

Table V: Summary of an ANOVA of egg production indices for the Kalbarri area

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	130.4	2	65.2	4.2	0.0174
Sub-area	444.1	3	148.0	9.6	0.0001
Depth	47.0	1	47.0	3	0.0844
Soak-time	0	0	0	0	0
Error	1705.1	110	15.5		

Table VI: Summary of an ANOVA of egg production indices for the Lancelin area

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	235.4	2	117.7	10.81	0.0001
Sub-area	185.7	3	61.9	5.69	0.0012
Depth	150.1	3	50.0	4.60	0.0045
Soak-time	0	0	0	0	0
Error	1208	111	10.9		

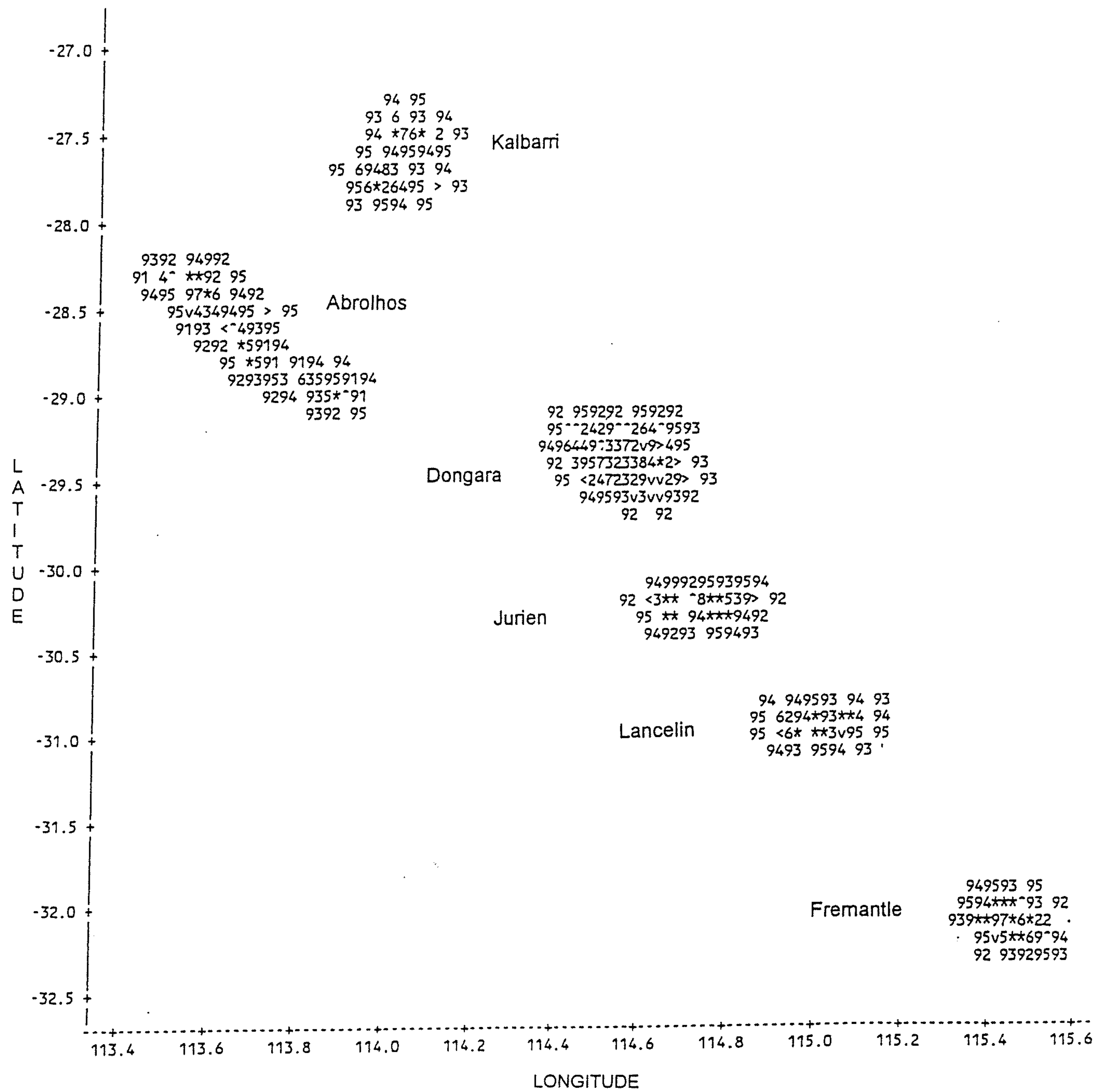

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Fig. 2. Plot of the positions of sampling lines over the coast. The numbering refers to the years that the lines were set. Note: latitude and longitude is expressed as decimals, not minutes.

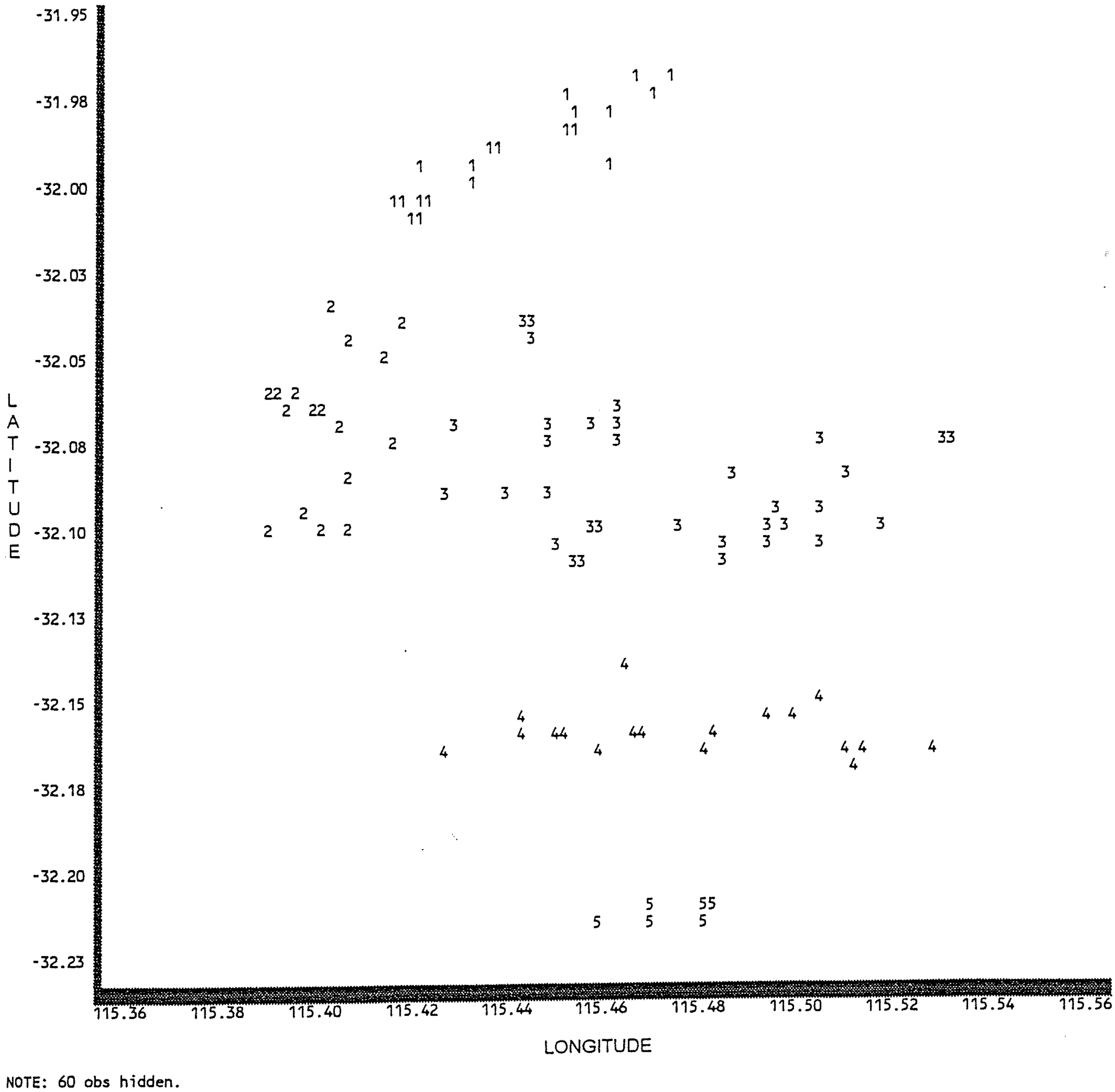

Fig. 3 Plot showing the positions of sampling lines in the Fremantle area. Numbers refer to the various sub-areas.

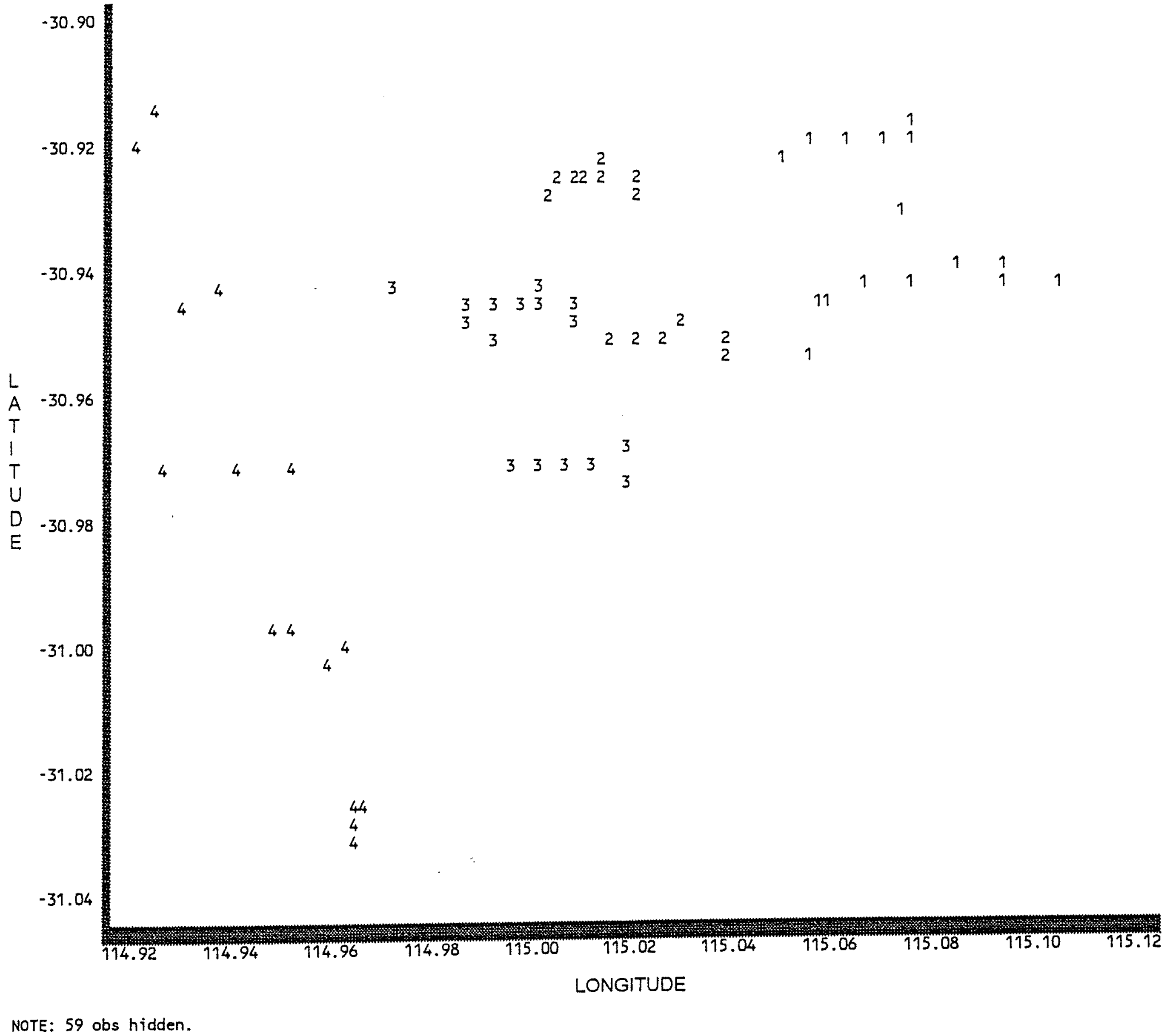

Fig. 4. Plot showing the positions of sampling lines in the Lancelin area. Numbers refer to the various sub-areas.

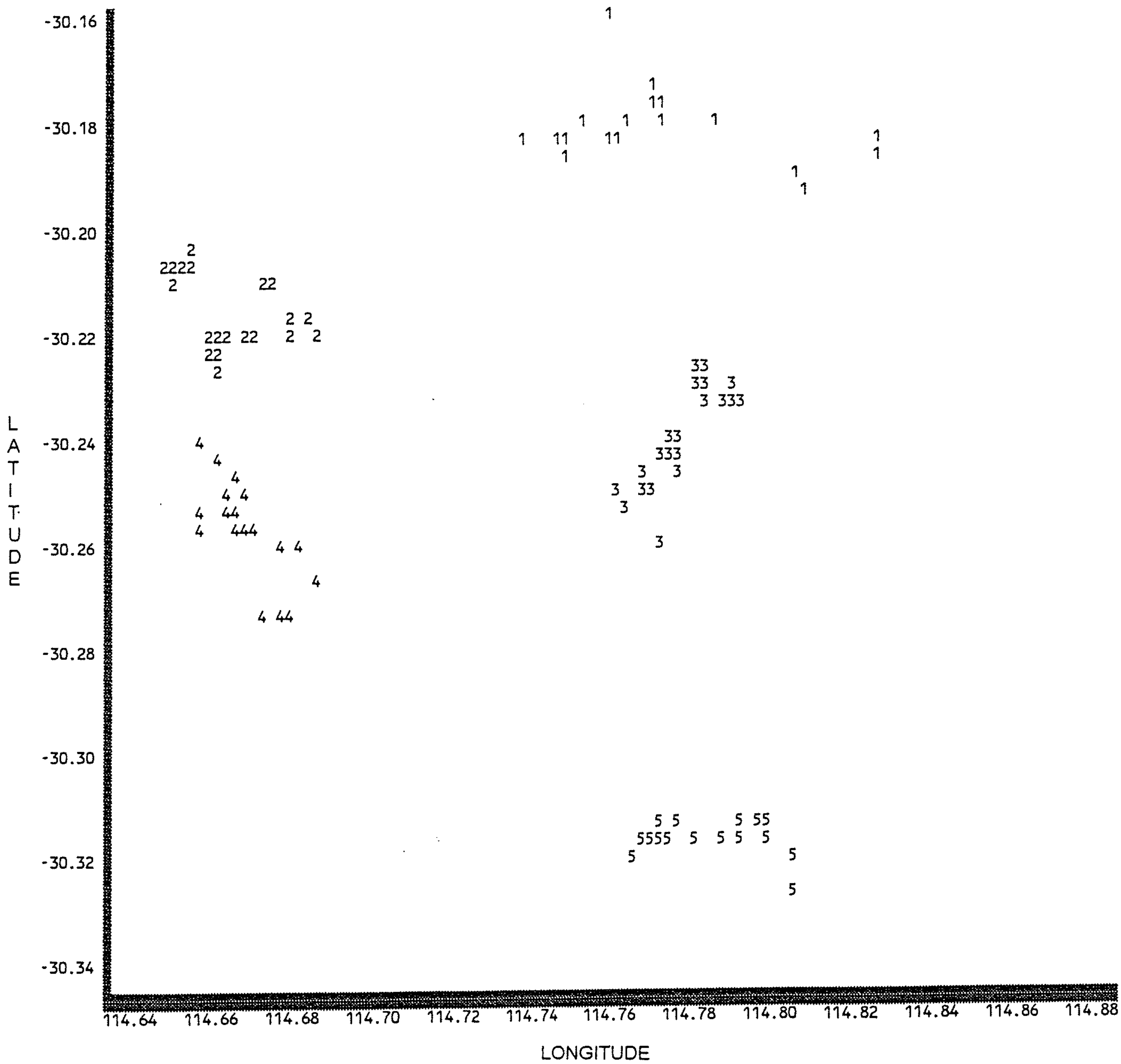

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Fig. 5 Plot showing the positions of sampling lines in the Jurien area. Numbers refer to the various sub-areas.

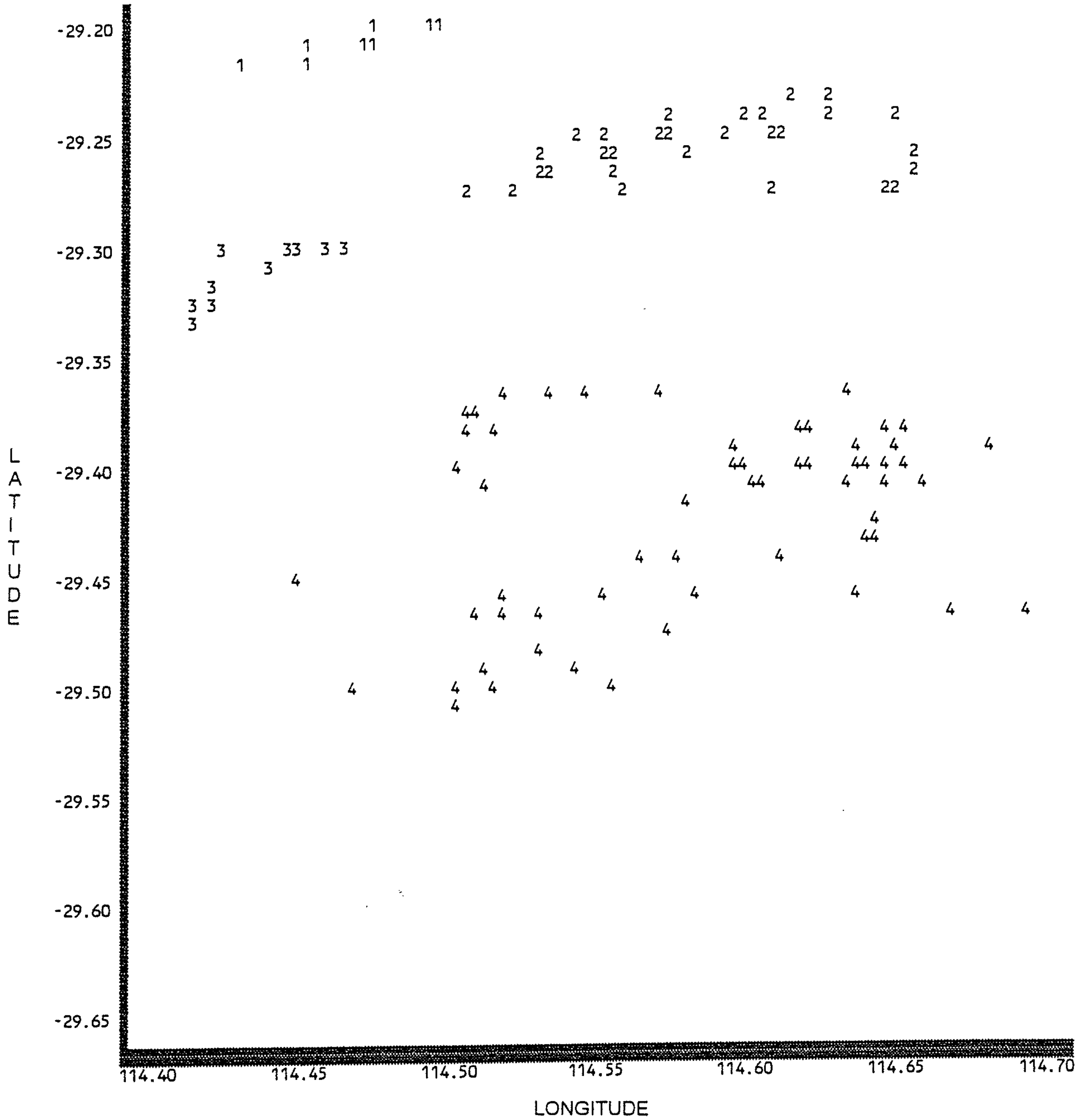

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Fig. 6 Plot showing the positions of sampling lines in the Dongara area. Numbers refer to the various sub-areas.

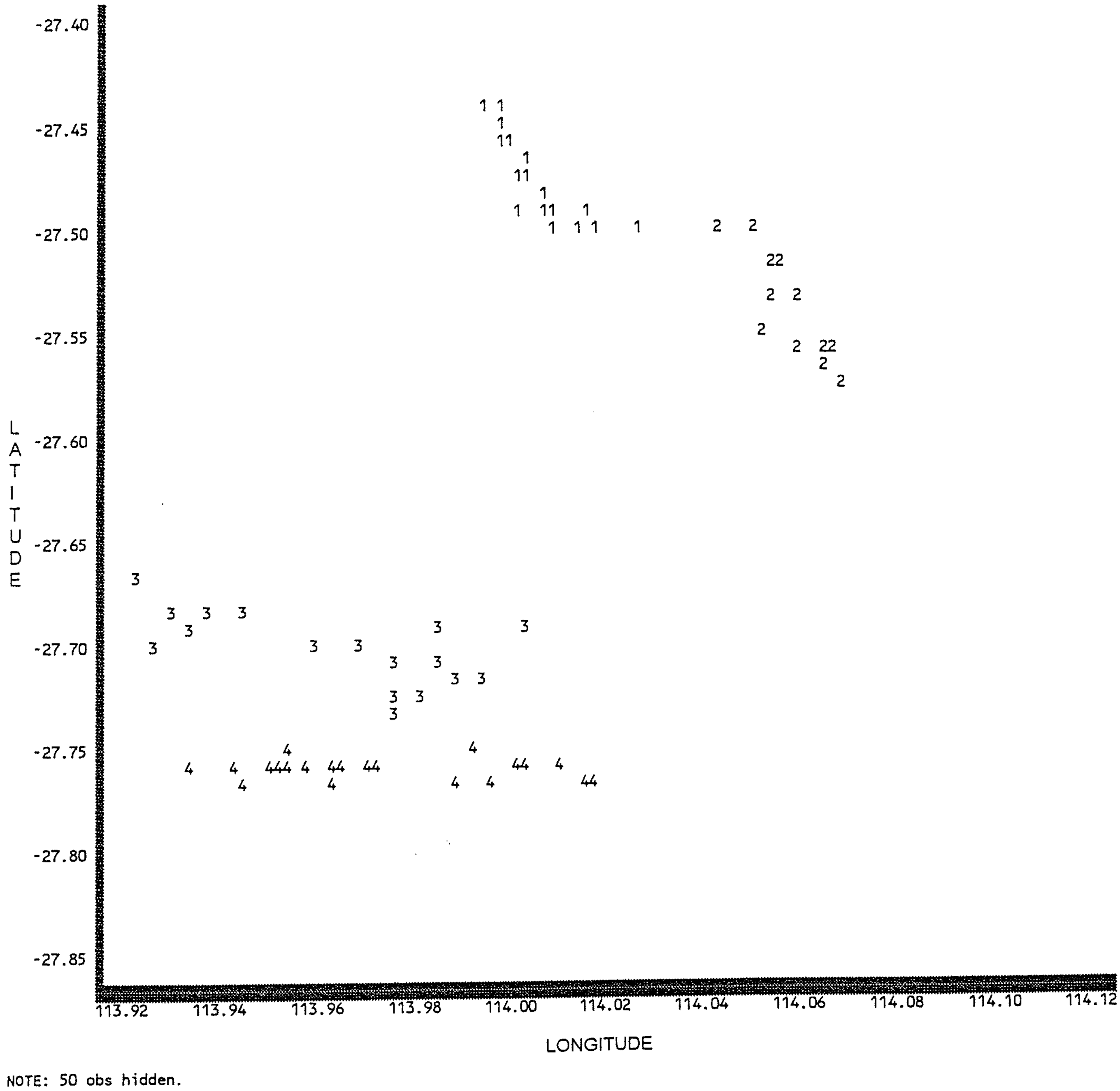

Fig. 7 Plot showing the positions of sampling lines in the Kalbarri area. Numbers refer to the various sub-areas.

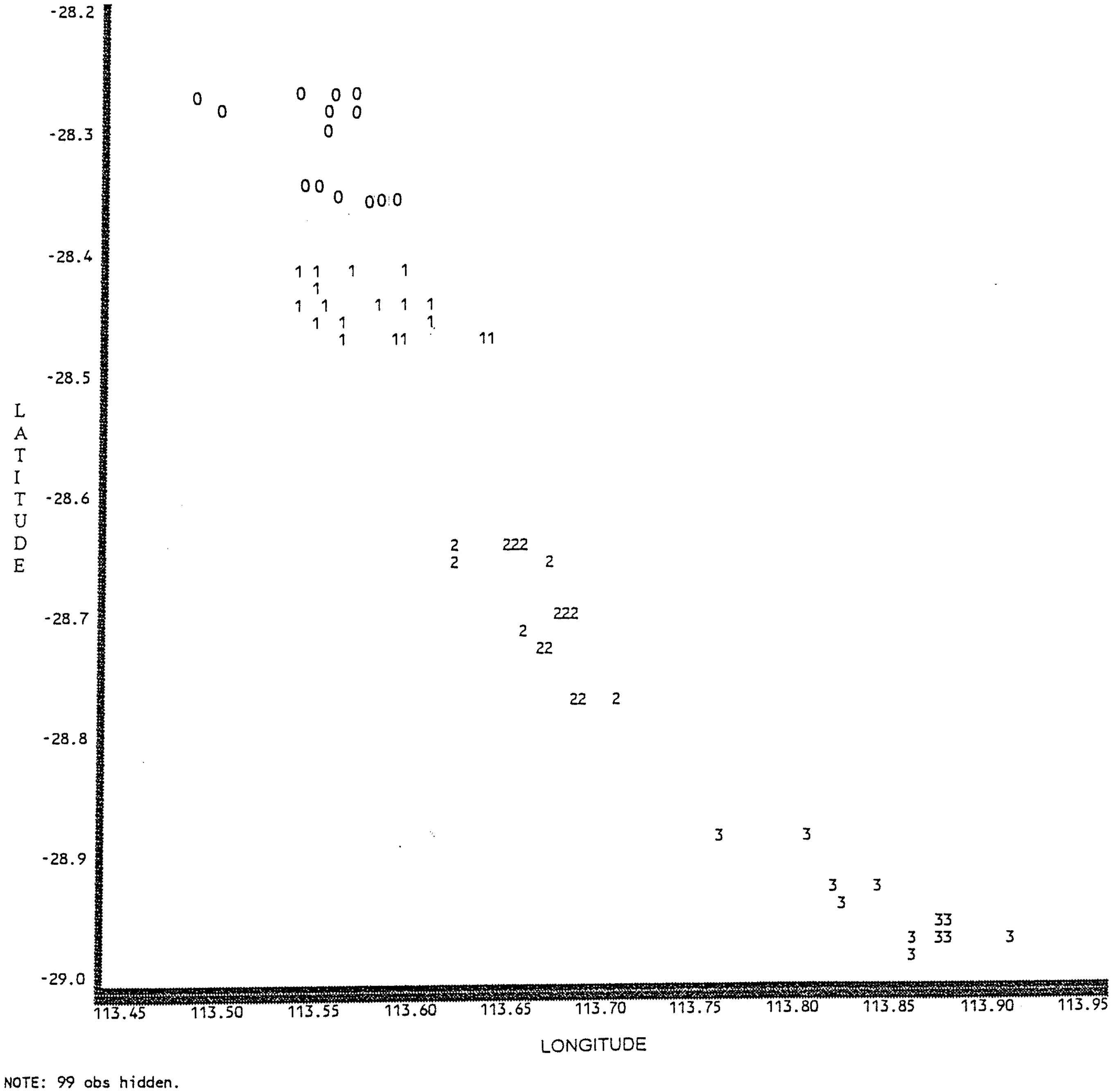

Fig. 8 Plot showing the positions of sampling lines at the Abrolhos Islands. Numbers refer to the various sub areas.

Given the objectives of the study, the most important outcome of the analysis is that five of the six areas have shown significant differences in the egg production index over the three to five year period that the survey has been conducted, with the Abrolhos Islands at the 0.07 significance level (Table I). These differences in egg production index have all been positive (Figs. 9-15), indicating that there has been an increase in egg production in all areas since the 1993 survey.

In addition to establishing regional fishery-independent indices of reproductive potential, this study also undertook to establish egg production indices on a whole fishery basis (see objectives). While the production of such an overall annual index is considered useful in summarising the inter-annual changes in egg production, it has been felt that the inclusion of the Abrolhos Islands in the analysis could complicate the interpretation of the result; Abrolhos Island animals exhibit distinctive biological characteristics (smaller size at maturity) compared to the coastal populations and additionally, different sampling strategies (different pot soak times, sequentially fished sub-areas, greater depth range surveyed) were employed at the offshore Islands compared to the coastal areas. Accordingly, egg production indices for all coastal areas combined (i.e. excluding the offshore islands) are presented in Fig. 16.

Sub-area was shown to be a significant factor affecting the egg production index in most of the areas (Tables I-VI). This result was not unexpected because, as noted earlier, sub-areas were deliberately chosen to provide a better overall index of egg production over the areas being surveyed.

With the exception of the Abrolhos Islands and to a lesser extent Lancelin, depth was shown to not be a particularly significant factor influencing the egg production index (Tables II to V). The reason for this is that the sampling strategy for the coastal survey areas has followed a fairly narrow range of depths (generally 20-30 fathoms), corresponding with the limited depth range of between 20-40 fathoms over which the main breeding grounds for the western lobsters have been shown to lie (Chubb *et al.* ,1987). Additionally, sub-areas take into account some differences in depth which may occur within an area.

The spawning grounds at the Abrolhos Islands are less well defined than on the coast and berried lobsters are found at all depths in this area (Chubb *et al.* 1987). As a result, sampling in that area has been designed to cover a much wider range of depths and as a consequence differences in catch rates (and therefore egg production index) were more significant between depths (Table I).

Pot soaking time was a significant factor in the Fremantle area, with three day pulls producing more than two day pulls and those in turn producing more than one day pulls (Tables I-VI). Most other areas which had variable pot soaking times produced a similar

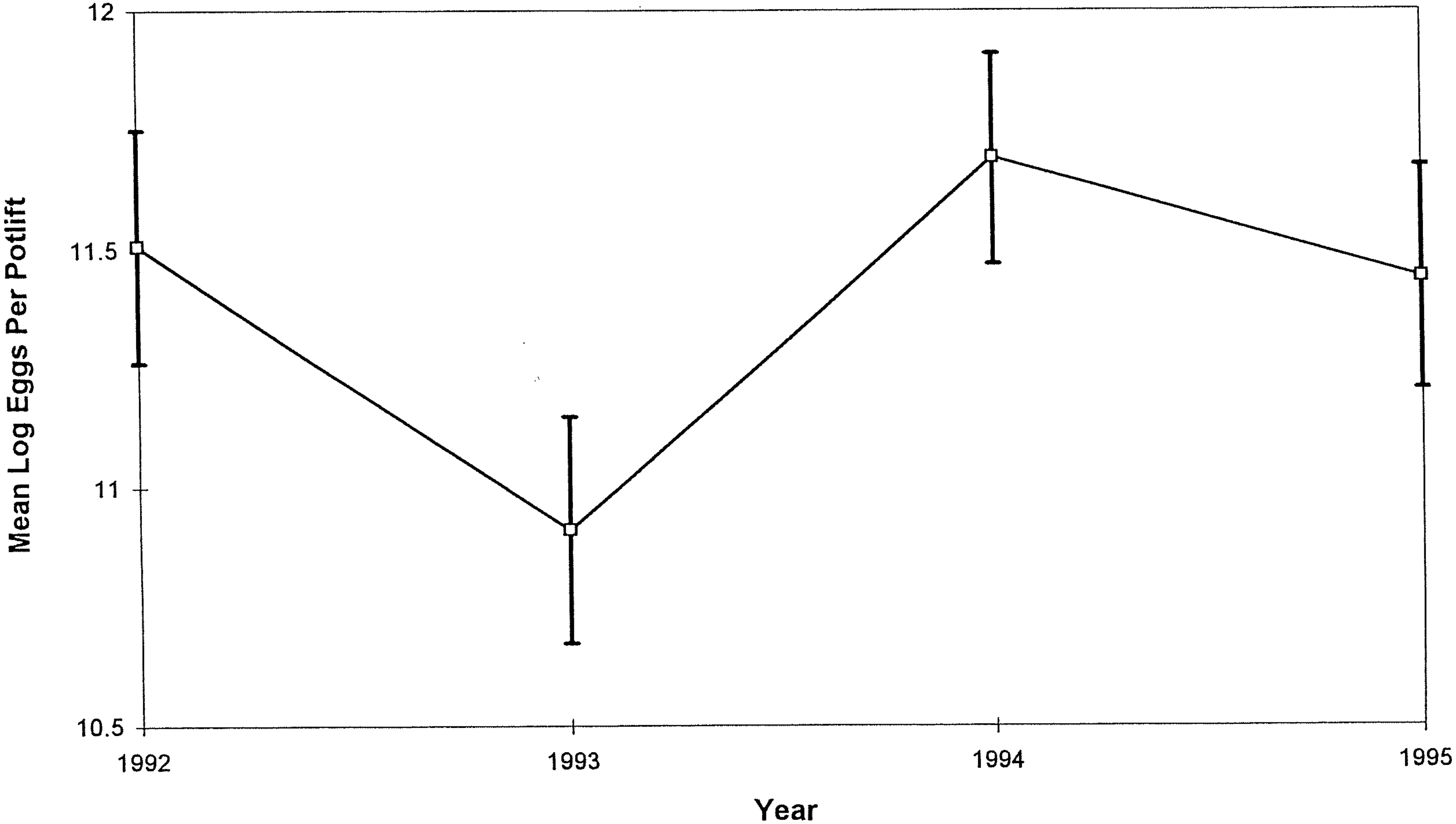

Fig. 9 Year-to-year variation in the egg production index (±1 standard error of the mean), as measured by the spawning stock survey for the Fremantle area.

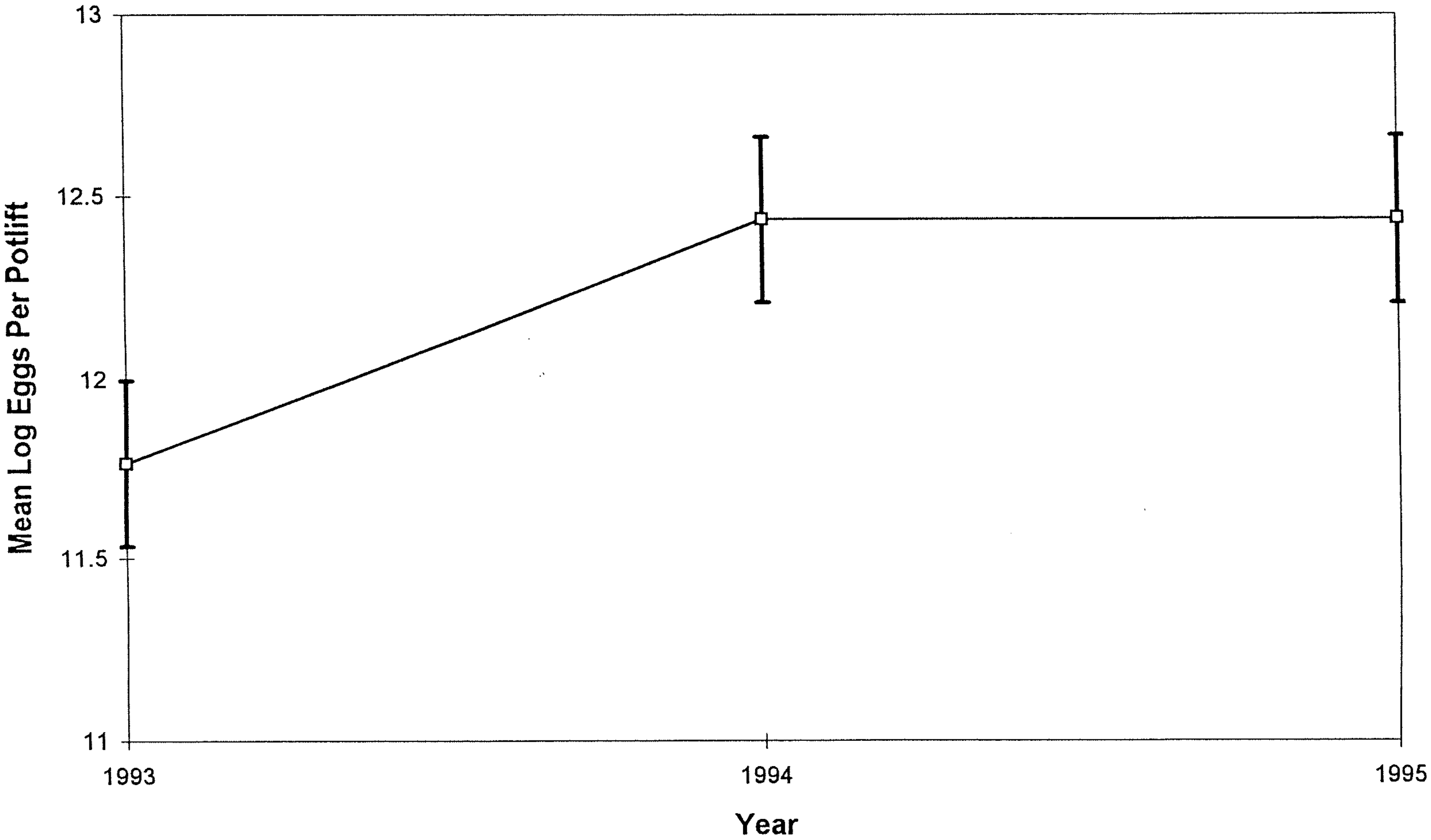

Fig. 10 Year-to-year variation in the egg production index (±1 standard error of the mean), as measured by the spawning stock survey for the Lancelin area.

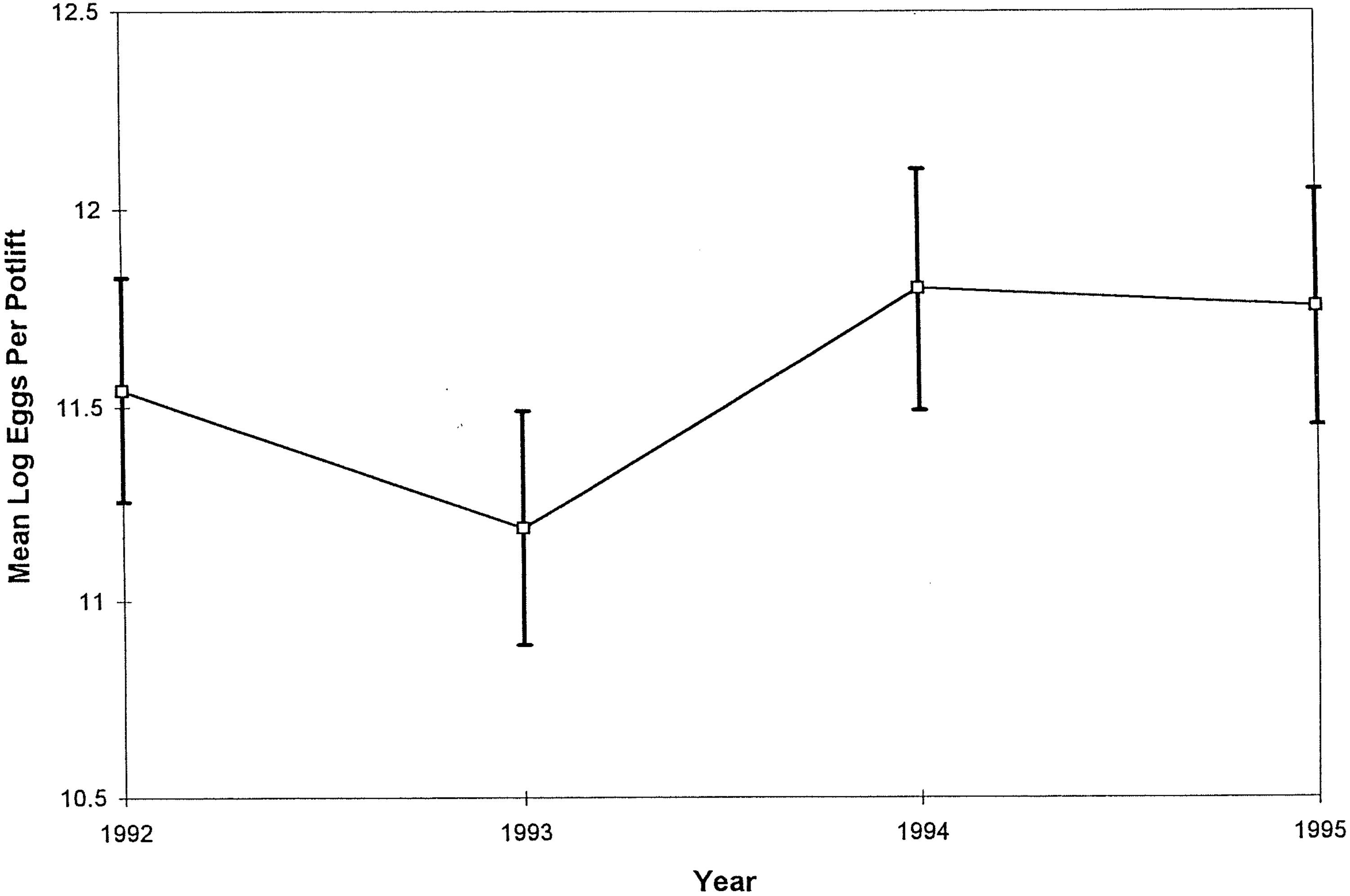

Fig. 11 Year-to-year variation in the egg production index (±1 standard error of the mean), as measured by the spawning stock survey for the Jurien area.

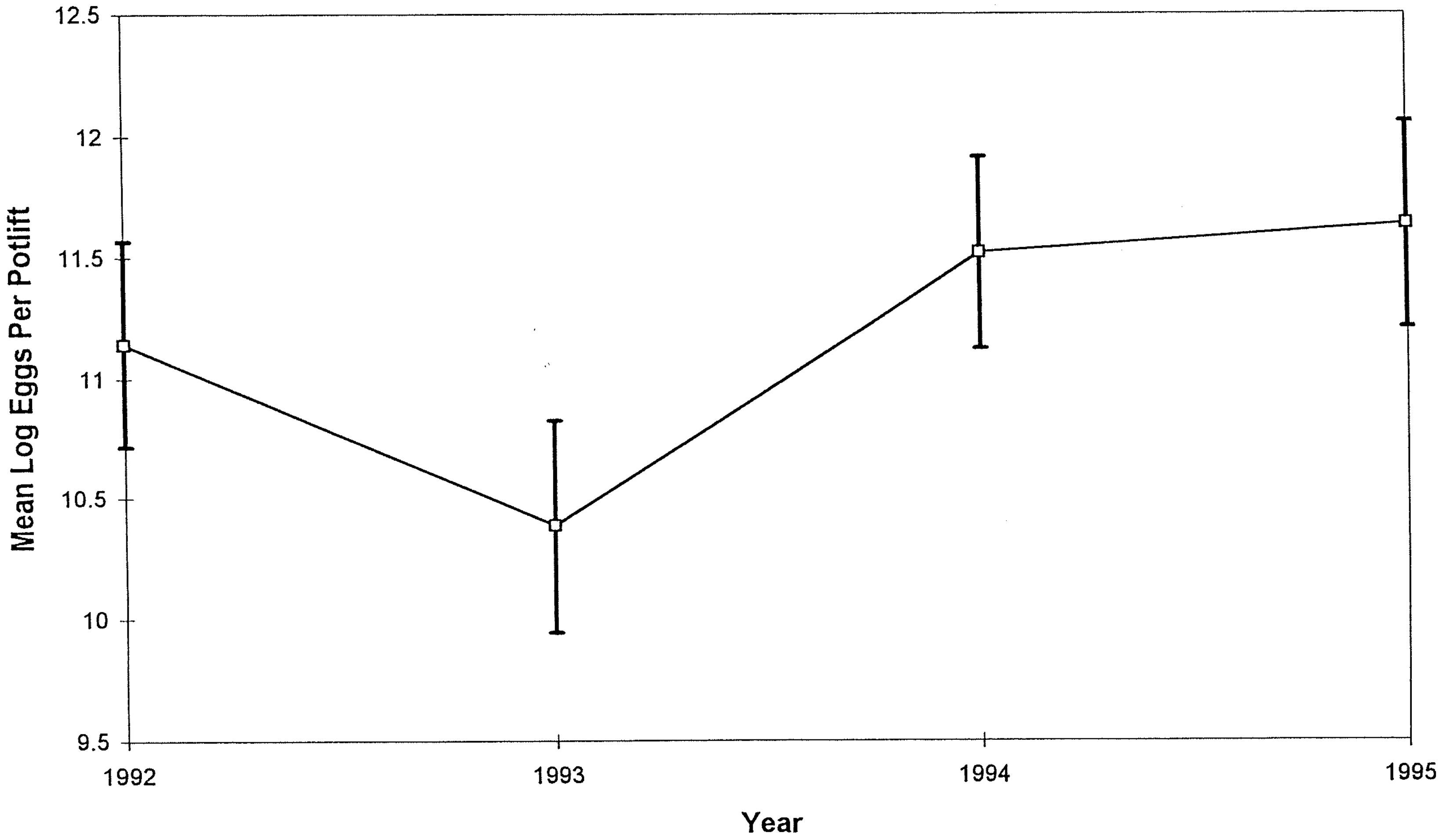

Fig. 12 Year-to-year variation in the egg production index (±1 standard error of the mean) as measured by the spawning stock survey for the Dongara area.

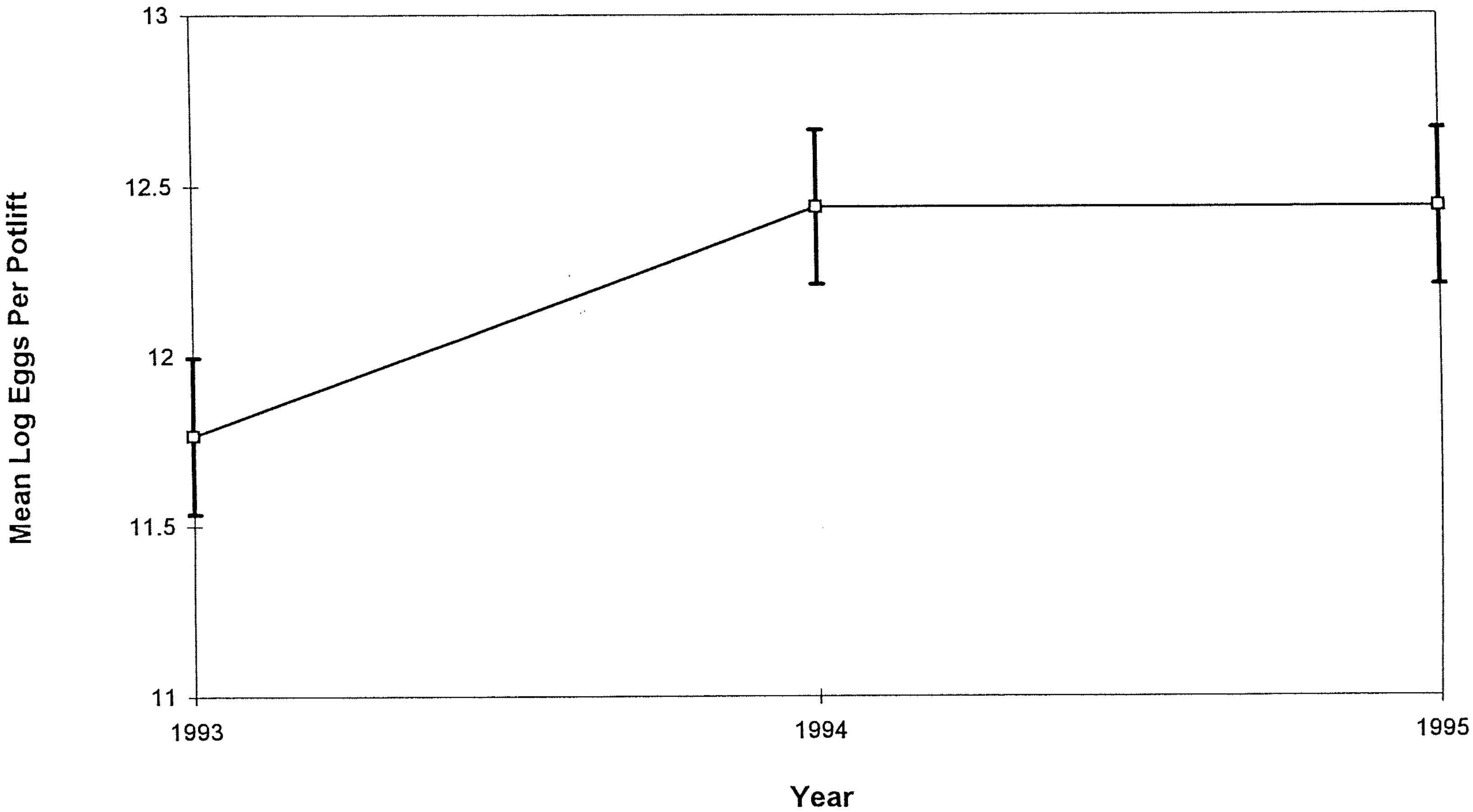

Fig. 13 Year-to-year variation in the egg production index (±1 standard error of the mean), as measured by the spawning stock survey for the Kalbarri area.

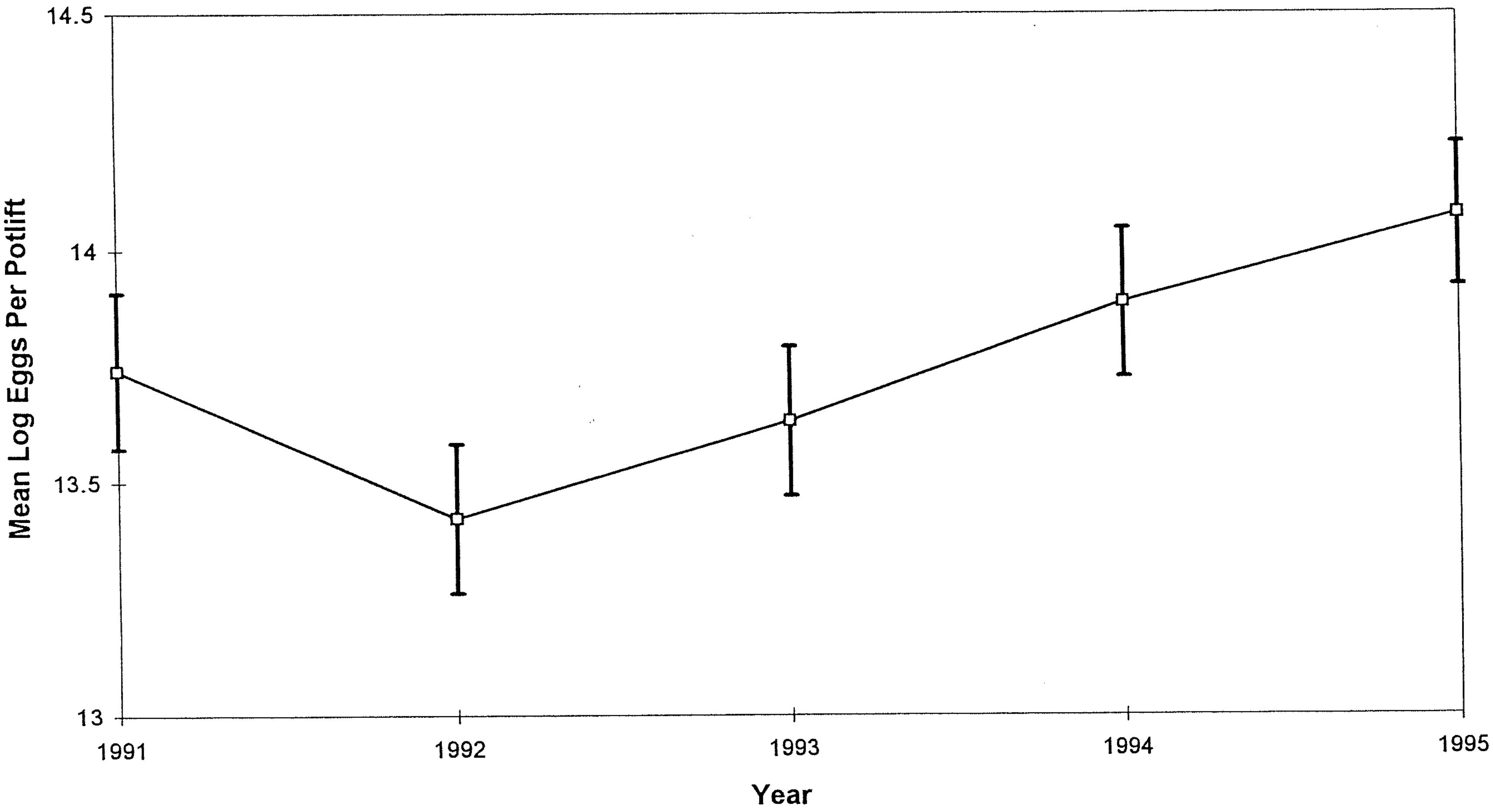

Fig. 14 Year-to-year variation in the egg production index (±1 standard error of the mean) for the spawning stock survey for the Abrolhos Islands.

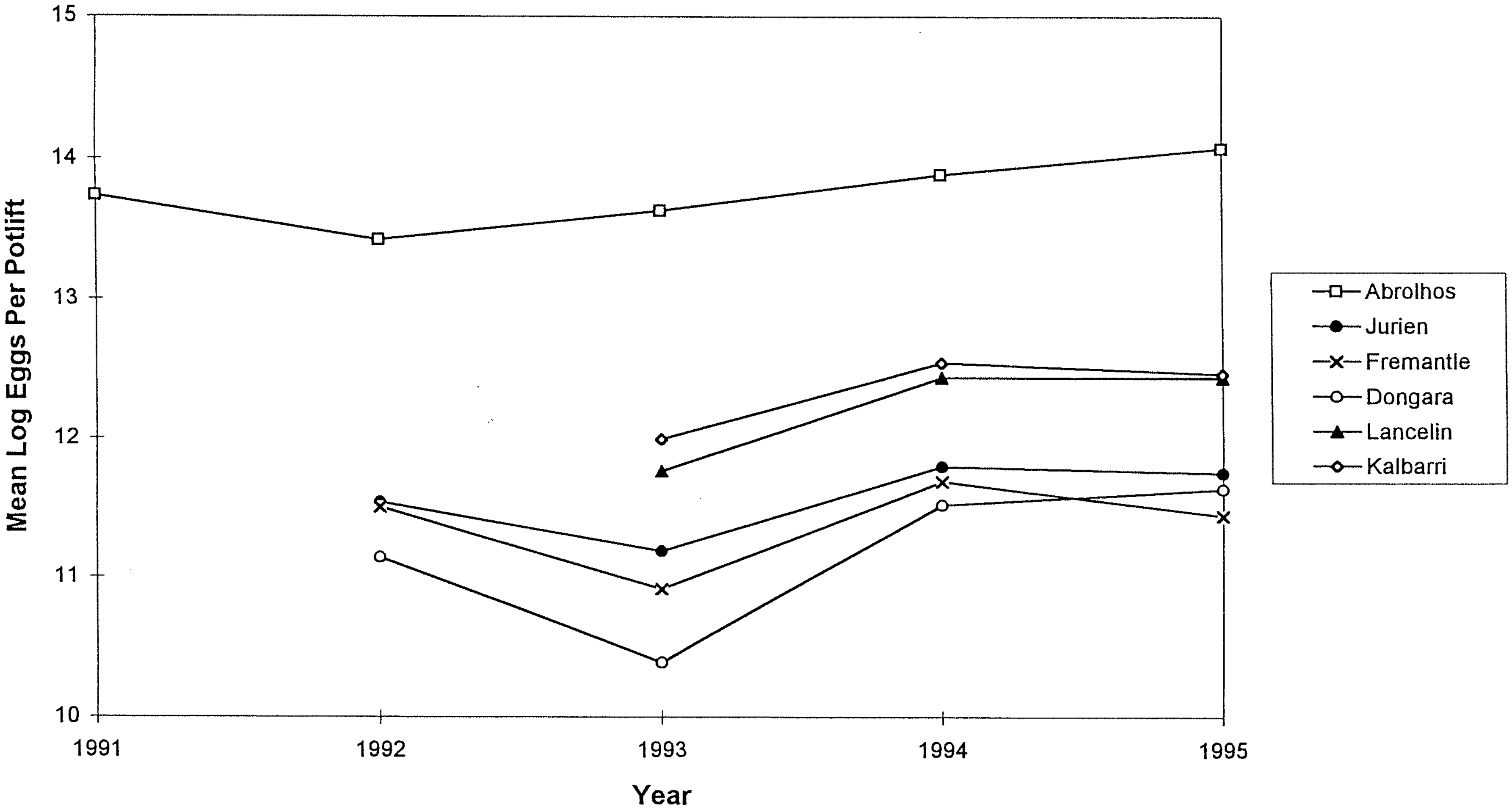

Fig. 15 Trends in egg production indices for all sites combined.

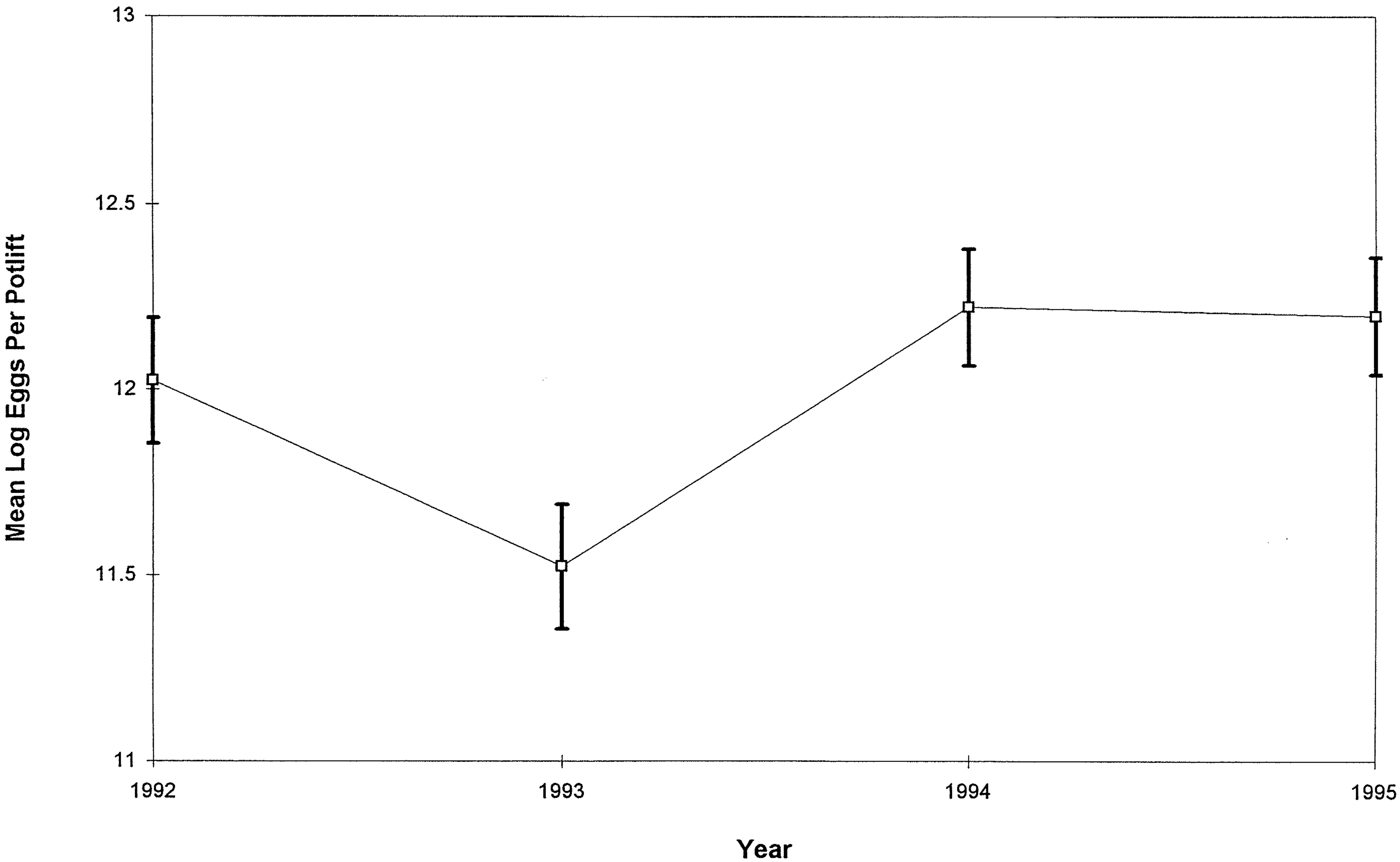

Fig. 16 Year-to-year variation in the egg production index (±1 standard error of the mean) for the spawning stock survey for the coastal areas.

trend, though the results were not significant and were usually only based on a relatively small number of pots which had, for whatever reason (eg. adverse weather conditions, vessel breakdown etc), deviated from the particular pot soaking time sampling regime that had been set for the particular area.

ANOVAs on swell size, surface temperature and bottom temperature, showed year-area interactions to be highly significant for the three environmental variables (Tables VII-IX). Year to year variations (Figs.17-19) show that swell size was considerably lower in 1995 than any of the other years, while surface and bottom temperatures were higher in the last two years compared to the earlier survey period. The higher surface and bottom temperatures since 1994 correspond with the increase in strength of the warm Leeuwin Current with the dissipation of the last '*El Nino*' event during the course of 1994.

Table VII: Summary of an ANOVA of swell size for all areas combined

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	55.6	4	13.9	59.03	0.0001
Area	6.6	5	1.3	5.57	0.0001
Sub-area	6.7	25	0.3	1.14	0.2843
Year-area	20.1	14	1.4	6.08	0.0001
Error	201	853	0.2		

Table VIII: Summary of an ANOVA of bottom temperature for all areas combined

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	59.4	4	14.8	131.19	0.0001
Area	39.5	5	7.9	69.87	0.0001
Sub-area	6.8	21	0.3	2.88	0.0001
Year-area	8.6	14	0.6	5.40	0.0001
Error	37.3	330	0.1		

Table IX: Summary of an ANOVA of surface temperature for all areas combined

Factor	Sum of squares	df	Mean square	*F*	*p*
Year	58.7	4	14.7	75.72	0.0001
Area	68.6	5	13.7	70.86	0.0001
Sub-area	6.4	22	0.3	1.49	0.0727
Year-area	8.5	14	0.6	3.14	0.0001
Error	72.4	374	0.2		

Pot type was only a factor at the Abrolhos Island and Fremantle areas (Tables I and III) where combinations of beehive and batten pots were used. The difference between the two

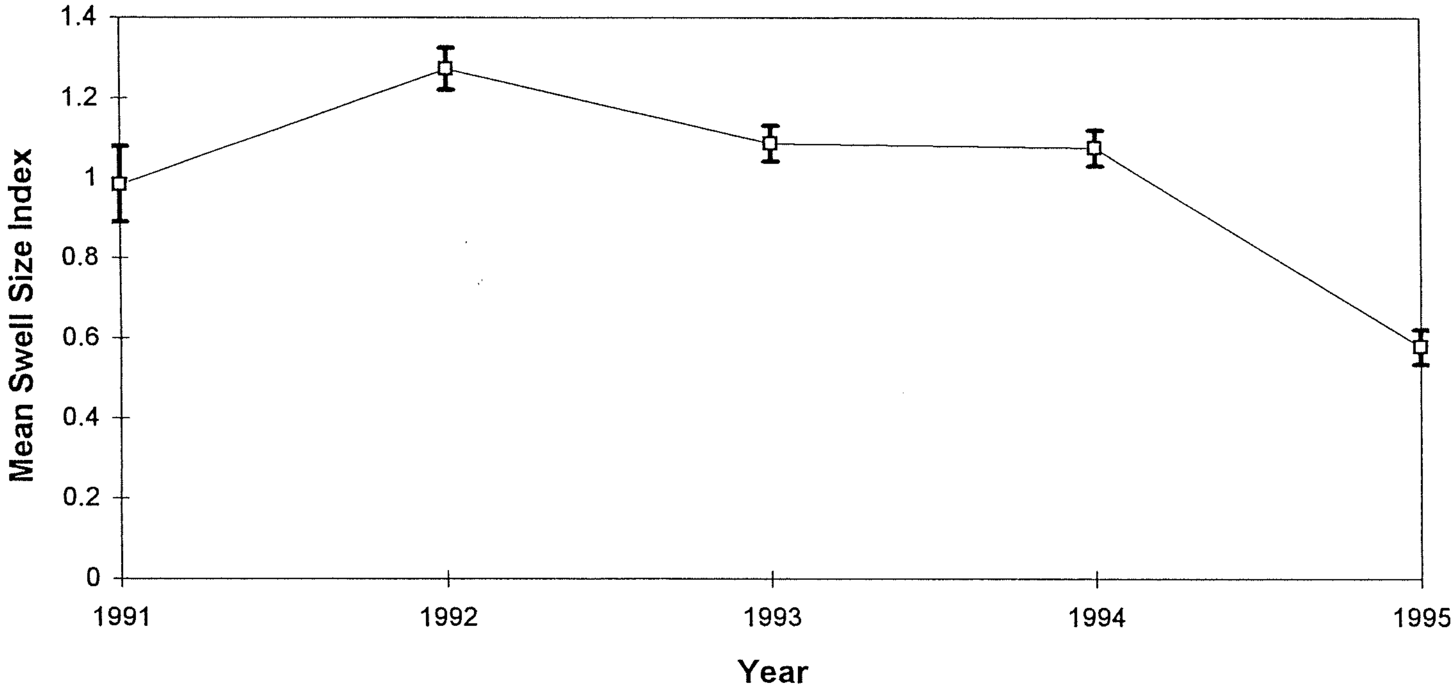

Fig. 17 Year-to-year variation in mean swell size index (±1 standard error of the mean) for the coastal areas.

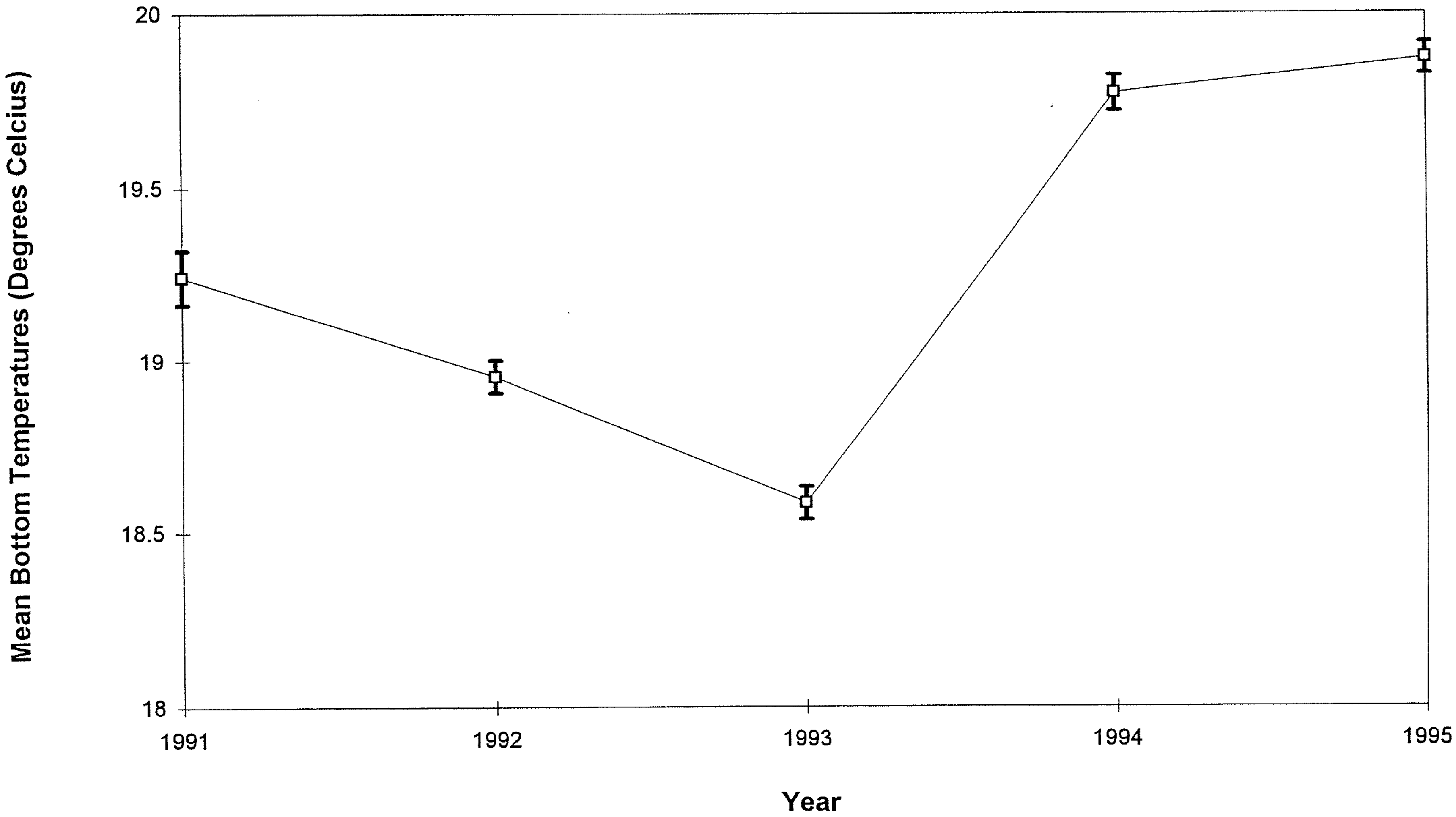

Fig. 18 Year-to-year variation in mean bottom temperature (±1 standard error of the mean) for the coastal areas.

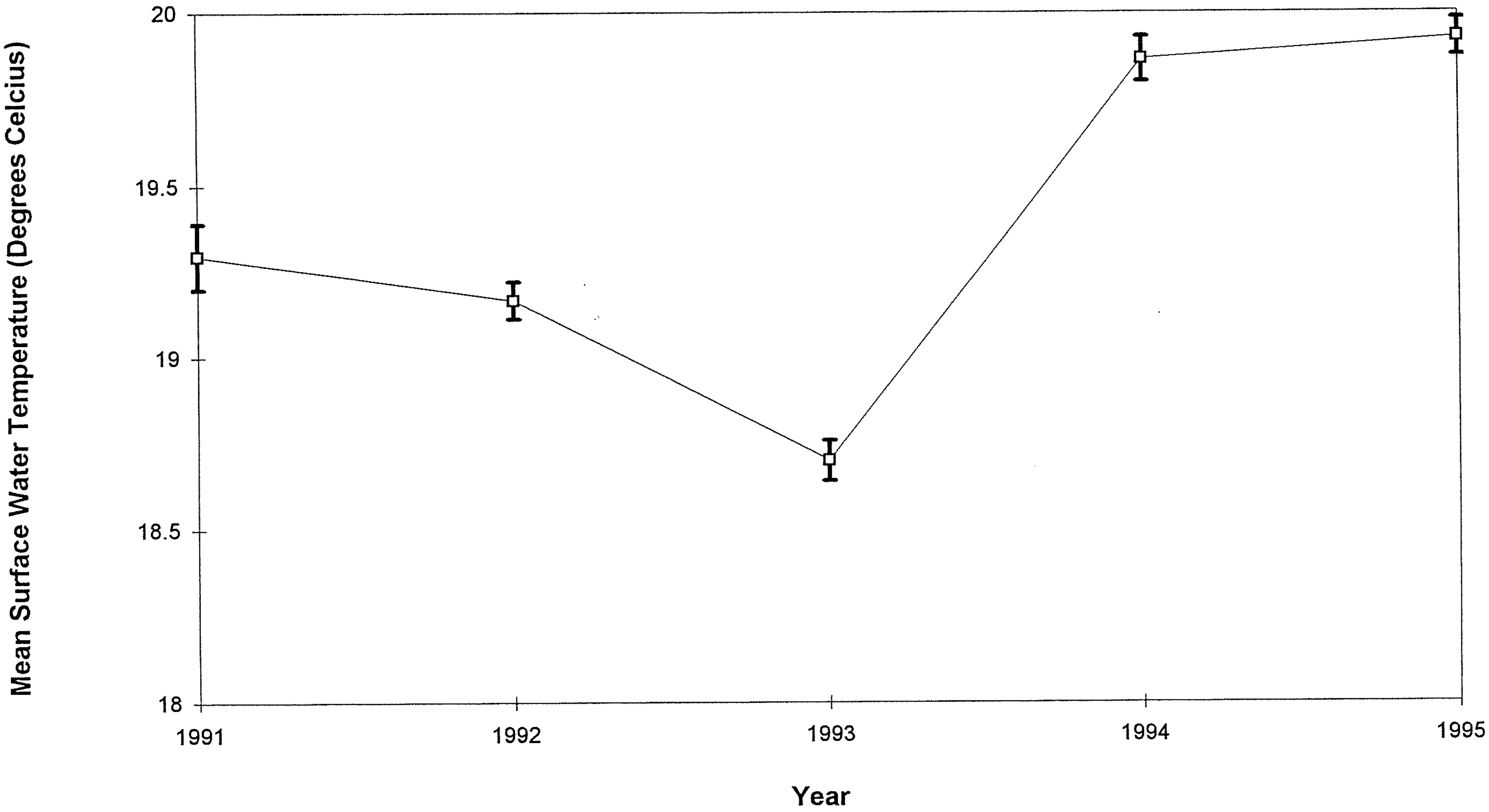

Fig. 19 Year-to-year variation in mean surface temperature (±1 standard error of the mean) for the coastal areas.

pot types was significant in the Fremantle area where most of the fishing took place in depths >20 fathoms (Table III), but not at the Abrolhos Islands where much of the fishing was in shallower depths, however in the latter case the level of significance was marginal (p=0.06 Table I). The two pot types performed differently in the two areas; in the Fremantle area beehive pots produced more eggs per potlift than batten pots, while at the Abrolhos Islands the reverse occurred. These trends are in line with published data showing that beehive pots have significantly better catch rates than batten pots in depths >37m (20 fathoms) (Brown *et al.*, 1995).

The effect of swell size and bottom and surface temperature on the egg production index is shown in Table X. Neither swell size, nor surface and bottom temperature was shown to significantly affect the egg production index when the effects of other factors were taken into account, but of the three factors, swell size was shown to have the most influence and produced a result which was nearly significant (p=0.77, Table X). The incorporation of the three environmental variables into the analysis made little difference to the significance of year-to-year effects, showing that these effects are robust to the inclusion of additional factors.

Table X: Summary of an ANOVA of egg production indices for the coastal areas

Factor	Sum of squares	df	Mean square	F	p
Year	260.0	3	86.7	6.24	0.0003
Area	1534.1	4	383.5	27.63	0.0001
Sub-area	1760	18	97.8	7.04	0.0001
Depth	178	4	44.5	3.21	0.0127
Soak-time	154.2	2	77.1	5.55	0.0040
Swell	43.5	1	43.5	3.13	0.0771
Temperature (bottom)	3.26	1	3.3	0.23	0.6282
Temperature (surface)	19.81	1	19.8	1.43	0.2326
Error	9452.1	681	13.9		

It is not unexpected to find that swell height had some influence on the egg production index, though it is perhaps surprising that it is more influential than either surface or bottom temperatures in explaining the year-to-year variation of the egg production index, because foraging and therefore catchability of *P. cygnus* (the factor which would influence the egg production index), has been more frequently attributed to temperature variation than swell height (Chittleborough 1970, Morgan 1974 and Chittleborough 1975). It is clear that there is a need to continue the monitoring of these environmental effects, and that ultimately these will need to be incorporated in the year-to-year trends in egg production.

The results that have been produced by this survey have satisfied all of the objectives that were set for the project and it is clear that the method is providing a reliable index for egg production on a regional and whole fishery basis. The three and four year time series on which the coastal indices are based is short and the conclusions in this report as to the way that egg production indices have responded to the 1993 management package need to be viewed in that light.

With the management package in place for longer, one might expect to see changes in the size structure of female lobsters in the commercial catch. Large females over the maximum size limit should become more abundant and because of regulations requiring the returning of setose animals to the sea, it is likely that there will be an overall increase in the size structure of the female population over time. Given the short time series, an analysis of population size structure was considered beyond the scope of this report.

Another trend that will need to be examined once a longer data series is available, is the effect of year class strength on the egg production index. Puerulus settlement at all collector sites was low in the 1986 and 1987 (West Australian Marine Research laboratories, unpub. data) and improved in the following two seasons. Since females are considered to first breed about seven years of age, it follows that the number of brood animals might have been expected to have been better in 1995 than in the earlier years of the survey. While we are not suggesting that these different year class strengths can explain all of the observed increase in the egg production index in the last couple of years, they are likely to have been a contributory factor in the result.

The fishery dependent egg production indices that have been used to monitor the spawning stock in the past (Caputi *et al.* 1995) will continue to be updated each year in the future. That method of estimating egg production and the one developed in this study are viewed as complimenting each other and at this stage both methods are showing similar responses to trends in egg production (Figs. 20 and 21).

The longer time series that will be provided by the second phase of this project (FRDC Project 96/108) will increase confidence in the fishery independent survey result and will allow greater exploration of the result than has been possible with the current (3 to 4 year) data set.

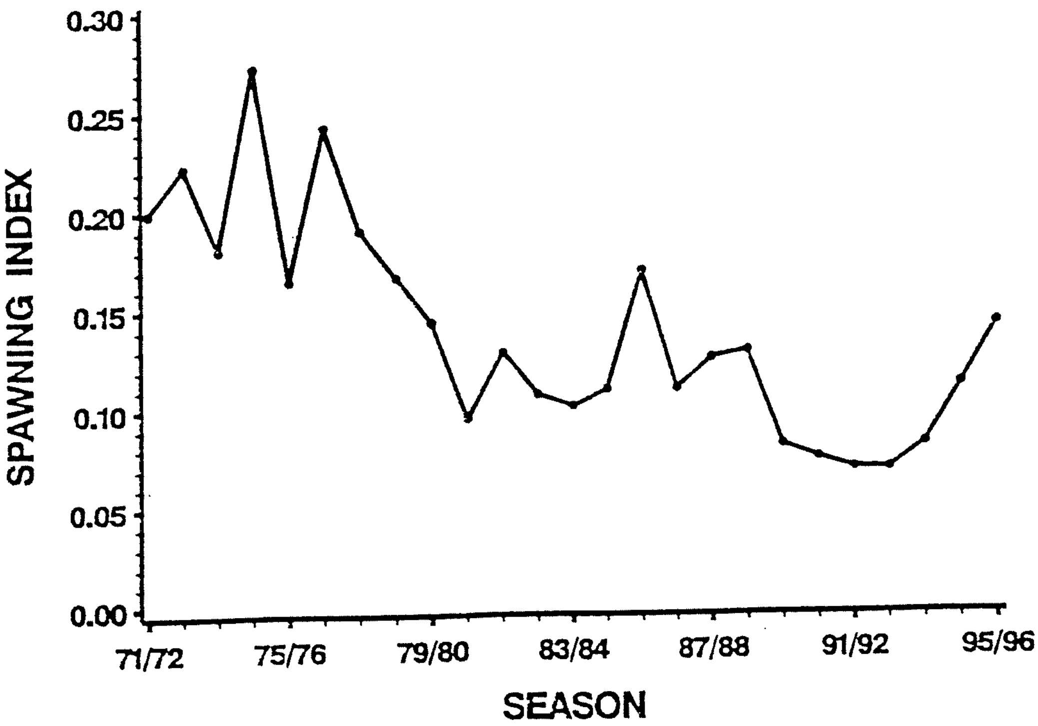

Fig. 20 Fishery dependent egg production index for the north coastal grounds (Jurien and Dongara).

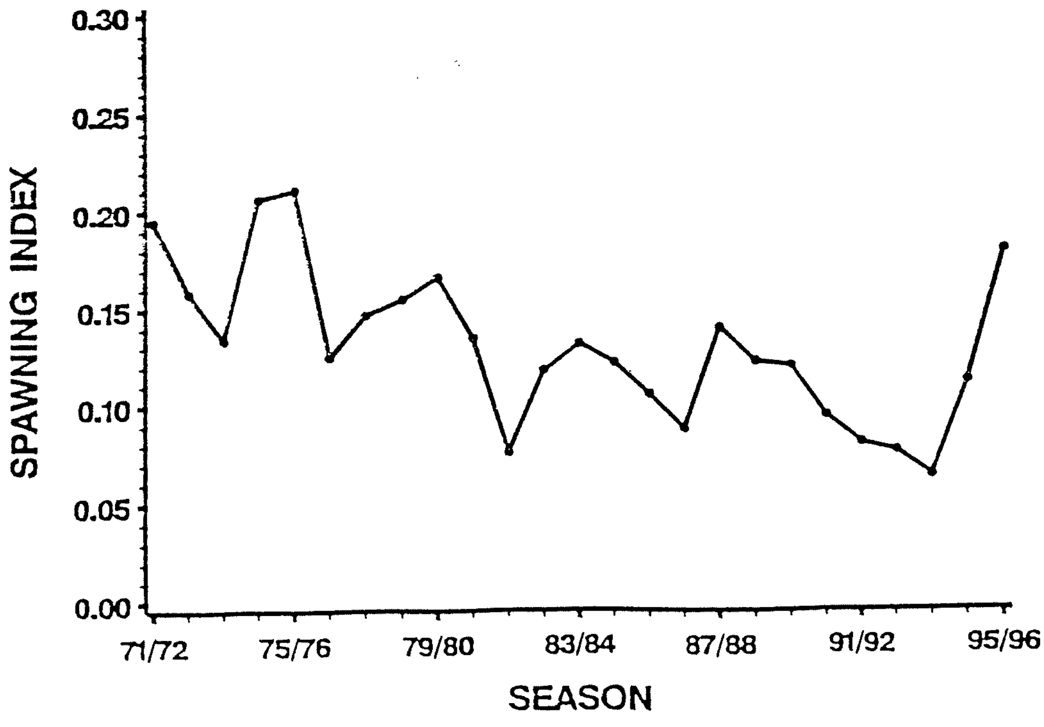

Fig. 21 Fishery dependent egg production index for the south coastal grounds (Lancelin and Fremantle).

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BENEFITS

There are just over 600 boats licensed to fish in the western lobster fishery and the catch averages at around 10,500 tons per annum. The value of the fishery is estimated at between $200-300 million p.a. which makes it Australia's most important single species fishery. Sound management of this fishery is critical to maintaining production and in that way ensuring the future of the industry as well as those who depend on it for their livelihood . This programme will assist in establishing a technique and setting the baseline data to ensure the chosen biological reference point of 25% pristine egg production is reached and maintained.

INTELLECTUAL PROPERTY AND VALUABLE INFORMATION

The data will be published in scientific journals in due course and in that respect remains the intellectual property of those who have participated in its collection and analysis. There is no information of a confidential or commercially sensitive nature.

FURTHER DEVELOPMENT

It has been felt necessary to build on the positive outcomes from this study by extending the fishery independent spawning stock survey for a further two year period. Changes to the egg production index lag some of the management changes that have been introduced to enhance the size of the brood stock and it is likely that indices will continue to improve for some years before a new equilibrium is reached. Clearly a longer time series would provide a more reliable statistical comparison of the way that the egg production indices have responded to the management measures introduced in the 1993/94 season. Approval has been granted for the survey to be extended for a further two years with FRDC funding (FRDC project 96/108).

Both this project (FRDC project 93/091) and the extended project (FRDC project 96/108), will provide the base line data for an egg production index for the western lobster resource. In the longer run it will be necessary to evaluate options such as whether it is cost efficient to term this survey on an annual basis or some less frequent time interval or alternatively to reduce the number of sampling sites. Regardless of the option, or combination of options that is chosen, this study will have provided the means to calibrate the historical commercial data-based indices that was used to monitor the egg production index for this resource in the past.

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* Trained staff who assisted with the project using non-FRDC funds.

FINAL COST

Expenditure of FRDC funds for this project totalled $ 532,736.06.

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