Northern Territory Pearl Oyster Fishery

Fisheries Research and Development Corporation

PROJECT 91/14
FINAL REPORT
(1995)

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ISBN 0 7245 2906 3

SUMMARY

Australia's pearl culture industry is worth over $190 million annually and depends predominantly on wildstock fisheries for its pearl oysters (*Pinctada maxima*). Historically, large catches of pearl oysters were taken in waters off the Northern Territory (NT) for Mother-of-Pearl (MOP) production, but since utilisation changed from MOP to pearl culture, attempts to re-establish fishing in NT waters have had limited success. This jointly funded project by the Fisheries Research and Development Corporation (FRDC) and the Northern Territory Department of Primary Industry and Fisheries (NT DPIF) was designed to provide baseline information on NT pearl oyster stocks which, when combined with catch and effort data, would help explain the current status of the NT Pearl Oyster Fishery. It consisted of two components: a commercial catch sampling program, in which biological information was collected on commercial catches of pearl oysters; and a spat collection program, where artificial collectors were used to determine settlement patterns of pearl oysters and other bivalves in waters off the Northern Territory.

The length frequencies of pearl oysters and their utilisation for either pearl culture, MOP, or as discarded oysters, were determined from commercial catches of vessels working in waters off the NT from 1991 to 1993. Extrapolation of these data to fishermen's logbook information yielded size distributions for the total annual catches. It was apparent that NT pearl oyster stocks consisted of a high proportion of large oysters which were unsuitable for round pearl culture. Patchy, irregular or low recruitment to NT beds and minimal recent harvesting are suggested as possible causes. Much of the catch was consequently used for less lucrative purposes such as half pearl culture or MOP. This could have important repercussions on the economic viability of the NT Pearl Oyster Fishery.

Extensive sampling yielded important baseline information on the morphometry of *P. maxima*, and its relationship to utilisation. Although shell length is a commonly used dimension for discussing

growth and stock structure, shell thickness was the best variable to discriminate between the various uses of pearl oysters. Relationships between shell length and other morphometric variables were established. Thus, when an age-size key is developed, be it related to shell length, shell thickness or hinge depth, the age structure of NT pearl oyster stocks can be determined. This will enable a better understanding of the impact of fishing on their population dynamics.

Because pearl oysters are of sufficient size for pearl culture within two years of settlement, it is important to understand and predict settlement patterns. In the second component of the project, we used artificial collectors to investigate the settlement patterns, abundance and growth of pearl oysters and other tropical bivalves in NT waters. Artificial collectors made of used monofilament net were set and retrieved over five periods between June 1993 and June 1994. A large number of bivalves were collected, encompassing 47 species from 14 families. Thirteen species from 6 families comprised over 90% of the total numbers, and included various species of commercial importance such as pearl oysters, fan shells and edible oysters. Of these, *P. maxima* was the most valuable and accounted for 2.4% of total numbers. It had highest settlement rates during the wet season, between October to January, and a mean estimated growth rate of 5.8 mm·month^{-1}. Length-frequencies and growth rates of species with commercial potential are presented. Considering the number and type of species collected, there is potential for the use of artificial collectors in tropical waters either for aquaculture or as a stock assessment tool.

The results of this research project provided two levels of information on the NT pearl oyster resource. Firstly, important baseline biological information on settlement patterns and morphometry of pearl oysters has been provided. But just as importantly, we have been able to use this information to better understand the NT Pearl Oyster Fishery and help explain why its productivity appears to be limited.

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SECTION 1

Introduction

BACKGROUND

Pearl oysters have been fished commercially in northern Australian waters for over 100 years. Technological changes occurred in the Fishery, but basically, fishing methods remained the same for most of the time, with luggers using divers to hand-collect oysters from the sea floor. During the 1970's the method of diving changed from the traditional lead boot and hard-hat diving apparatus to the cheaper, more manageable and efficient sport diving gear, including fins, mask and a small demand valve adapted from the development of SCUBA. Since the late 1880's pearl oysters have been collected for the production of Mother-of-Pearl (MOP) - the lustrous nacre of the shells which is used for the production of buttons, ornaments and as an additive in paints and cosmetics. Compared to Western Australia (WA) and Queensland, the Northern Territory (NT) supported a small fishery and it was characterised by large fluctuations in catches as new pearl oyster beds were discovered and fished down. Apart from sporadically imposed size limits, virtually the entire size range of pearl oysters was collected by divers for MOP, albeit graded on quality and size. Around the 1960's however, the introduction of plastics reduced demand for MOP, and a dramatic decrease in production from all northern Australian fisheries occurred. Meanwhile, pearl culture techniques being trialed by Industry and were proving commercially viable. Pearl oysters began to be collected for this purpose. This heralded a significant change in the Fishery, as divers began targeting the smaller oysters suitable for pearl culture.

Australia's pearl culture industry is now worth over A$ 200 million annually, and is based predominantly on *Pinctada maxima* taken from wildstock fisheries in WA. Unlike the shallow and productive grounds in WA, relatively little fishing continued in the deeper grounds off the NT after the MOP fishery declined in the 1960's. In response to increasing interest in pearl culture, six developmental licences were issued in 1987 to encourage the Pearling Industry in the NT. They stipulated that licensees fished NT waters for pearl oysters to be used to culture either round (nucleated) or half (blister) pearls. There was a quota limit of 20,000 oysters per licence from which oysters could be collected for either culture or MOP. Fishing was thus rekindled on NT grounds which had received little fishing pressure over the previous 20 years.

NEED

The previous overfishing of NT pearl oyster beds, together with a lack of information on their population biology, dictated that if the NT Pearl Oyster Fishery was re-established, a cautious approach to exploitation of the resource should be adopted. Furthermore, an urgent need for research to help understand the status of the NT pearl oyster stocks and the affect of harvesting on the stock structure and population dynamics was highlighted.

The present research program was established to collect biological information from the catches of pearl oysters from commercial vessels working in NT waters. It was designed to provide information on the morphometry of pearl oysters and determine their length frequencies in relation to their utilisation for pearl culture, MOP, or as discarded oysters. Combining these data with data from fishermen's logbooks would provide an insight into the structure of NT pearl oyster stocks and help explain the status of the Fishery. A spat collection program was also established to give a better understanding of recruitment and seasonal settlement patterns of pearl oysters in waters off the NT.

OBJECTIVES

The initial objectives of the project were as follows:

- Establish a monitoring program to provide biological data on the pearl oyster stocks in waters adjacent to the NT; and,
- Determine the size/age-frequency and spawning activity of pearl oyster stocks from different commercial beds in waters adjacent to the NT.

It was envisaged that the monitoring program would be ongoing, and be taken over by Industry after FRDC funding ceased. For a variety of reasons however, involvement of Industry in the harvest of wild stock pearl oysters from NT beds reduced significantly after the commencement of the project. Six licensees fished during 1991, but only two were fishing by 1993, when catches had halved and only a quarter of the total quota allocation was taken. As a consequence, the initial objectives of the project were revised. Instead of being ongoing, the monitoring program was reduced to a three year study in which baseline information on the morphometry of pearl oysters was collected and compared for different purposes (MOP, farm, discard) and different areas (Eastern and Western Grounds of the NT, see Figure I). A spat collection program was also conducted which was not affected by the level of participation of Industry during quota collection.

Following discussions between FRDC and NT DPIF the revised objectives became:

- Provide a description of the current status of the Pearl Oyster Fishery in the NT and consider its future directions;
- Determine the size-frequency and morphometric characteristics of NT pearl oysters collected for farm and MOP purposes and compare shell from different areas; and,
- Monitor the period and abundance of pearl oyster settlement using spat collectors placed on natural beds and near farm leases and relate this to spawning activity of mature shell.

The research undertaken to fulfil the first two objectives is described in Section 2. The last objective has been presented as a separate article entitled "Settlement of *Pinctada maxima* and other bivalves on artificial collectors in the Timor Sea, northern Australia". This is a draft of the article accepted for publication in The Journal of Shellfish Research pending minor revision (Section 3).

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SECTION 2

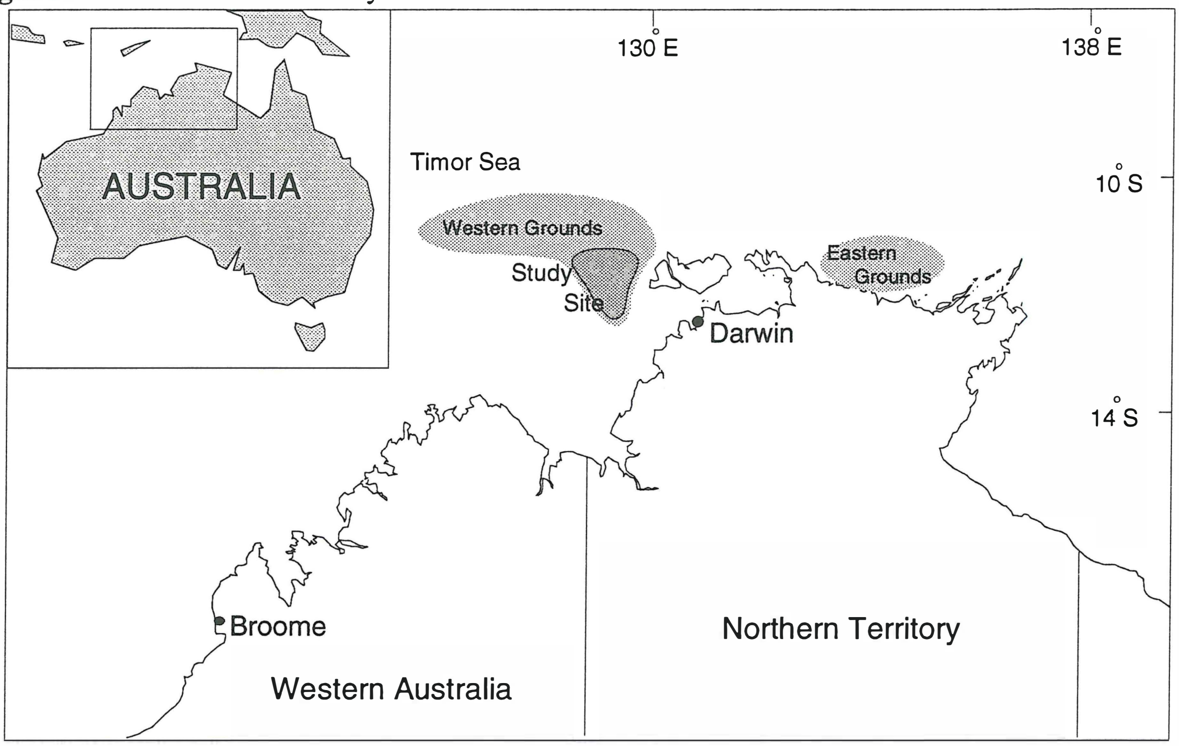
Commercial catch sampling

METHODS

Data Collection

Information was collected on the catches of a number of commercial pearl oyster fishing vessels working on shoals in the Timor Sea off the NT coast (Figure I) between 1991 and 1993. Sampling was restricted to the main fishing season in the NT, which spans September to December.

Figure I. Area of the study

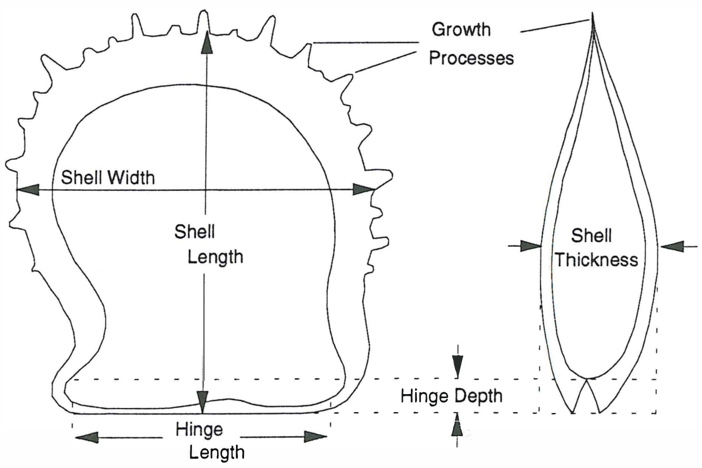


Each vessel employed two teams of three or four divers to collect pearl oysters during "drifts". A drift involved a vessel towing a team of divers along the sea floor as they searched for oysters. The drifts were about 30 minutes duration, in depths usually less than 35m. After each drift, the divers' catch was brought on deck and sorted by the skipper or head diver into categories, termed by Industry as: chicken shell - pearls oysters too small to be used; culture or farm shell - oysters kept alive and transported to farms for half or round pearl culture; MOP - oysters killed for their nacre and meat; and "clunkers" - old, large oysters which are discarded because their shells are too infected by boring polychaete worms and sponges to be used for MOP.

Depending on the amount of time available, all or a random sub-sample from each category were measured. The total number of each of farm shell, MOP and discarded shell was recorded for each drift. These were totalled by category for all cruises within each year, so the proportion of oysters comprising each category could be calculated. Information on Fishery totals for catches of culture oysters and MOP were obtained from logbook data provided by each vessel on a drift by drift basis. Catches of oysters that were discarded were not given in the logbooks, but were calculated using the ratio of discarded to retained oysters, acquired from the cruises that were sampled.

Dimensions (Figure II) recorded for each pearl oyster were shell length (dorso-ventral length, DVL), shell width (antero-posterior length, APL), hinge depth and live weight. Further measurements of shell thickness and hinge length were measured from 1992 onwards. Length and width were measured to the nearest 5 mm (not including growth processes). Other linear measurements were to the nearest 1 mm. Weight was recorded on electronic scales to the nearest 20 g within 20 minutes of the oysters being brought aboard. Except for discarded oysters, measurements were taken after all fouling organisms had been removed from the pearl oysters.

Figure II. Measurements for each pearl oyster included shell length (dorso-ventral), shell width (antero-posteral), shell thickness, hinge length and hinge depth. Based on Hynd (1955).



Data Analysis

The mean and standard deviation of each morphological variable were calculated on data pooled over vessel and year and is provided for each utilisation categories. The relationships between shell length and the other dimensions were determined using linear and non-linear regression techniques. Smoothed distributions of shell length, shell thickness and hinge depth were displayed graphically for each utilisation category using a cubic spline routine. Stepwise discriminant analysis was performed on the morphometric variables to determine which was the most important in separating oysters into their possible utilisation categories.

Length frequencies (using 10 mm size classes) of the total annual catches for the Fishery were estimated by scaling up the length frequencies of each utilisation category to equal the numbers indicated by logbook returns. The cumulative percentage of the catch by size was also determined for each year.

RESULTS

Pearl oysters collected during this study were used either for the culture of round or half pearls, or for MOP production. Oysters that were not suitable for any of these purposes were returned to the water as discards. Details of Fishery totals and total numbers of pearl oysters caught and sampled for each cruise are given in Table I. Vessels usually targeted oysters for round pearl culture and those oysters which were unsuitable were retained for MOP or discarded. During 1991, some vessels targeted oysters only for either round or half pearl culture, and no MOP were retained and all unsuitable oysters were discarded. In this case, the mean size and size range of shell retained for pearl culture was larger than for oysters collected for round pearl culture only (Table II). This was not the usual fishing technique, and unless stated otherwise, culture shell refers to oysters used for round pearl culture only.

Table I. Details of number of pearl oysters caught during each cruise, with numbers of oysters sampled in parentheses. Annual fishery totals were gained from fishermen's logbook returns.

Cruise	Date	Utilisation category of pearl oysters brought aboard				Total number of shells	
		Round Only	Round and Half	MOP	Discarded	Collected	Retained
1991							
1	15 Sep - 22 Sep	0 (0)	2435 (2389)	0 (0)	870 (870)	3305 (3259)	2435 (2389)
2	02 Oct - 05 Oct	0 (0)	3104 (1574)	0 (0)	818 (618)	3922 (2192)	3104 (1574)
3	14 Oct - 29 Oct	657 (634)	0 (0)	3452 (3428)	548 (548)	4657 (4610)	4109 (4062)
4	15 Oct - 20 Oct	0 (0)	5091 (2320)	0 (0)	152 (0)	5243 (2320)	5091 (2320)
5	29 Oct - 02 Nov	0 (0)	3928 (1861)	0 (0)	678 (543)	4606 (2404)	3928 (1861)
6	29 Oct - 03 Nov	660 (86)	0 (0)	2865 (513)	46 (46)	3571 (645)	3525 (599)
7	12 Nov - 18 Nov	965 (900)	0 (0)	3651 (3449)	368 (342)	4984 (4691)	4616 (4349)
8	28 Nov - 30 Nov	0 (0)	867 (856)	0 (0)	317 (87)	1184 (943)	867 (856)
Total sampled		2282 (1620)	15425 (9000)	9968 (7390)	3797 (3054)	31472 (21064)	27675 (18010)
Total for fishery		4851	41511	16477	8621[1]	71460[1]	62839
1992							
9	17 Oct - 22 Oct	1006 (244)	0 (0)	2136 (1095)	553 (0)	3695 (1339)	3142 (1339)
10	31 Oct - 07 Nov	733 (0)	0 (0)	4847 (2038)	184 (0)	5764 (2038)	5580 (2038)
Total sampled		1739 (244)	0 (0)	6983 (3133)	737 (0)	9459 (3377)	8722 (3377)
Total for fishery		8034	0	41781	4209[1]	54024[1]	49815
1993							
11	07 Oct - 13 Oct	662 (623)	0 (0)	3629 (2085)	715 (674)	5006 (3382)	4291 (2708)
12	21 Oct - 27 Oct	560 (389)	0 (0)	3690 (2430)	751 (232)	5001 (3051)	4250 (2819)
13	05 Nov - 11 Nov	389 (359)	0 (0)	4668 (2244)	1127 (918)	6184 (3521)	5057 (2603)
Total sampled		1611 (1371)	0 (0)	11987 (6759)	2593 (1824)	16191 (9954)	13598 (8130)
Total for fishery		2621	0	23048	4895[1]	30564[1]	25669

[1] These figures are estimated by multiplying up the percentage of discards in sample.

Table II. Morphological dimensions of pearl oysters from the different utilisation categories. Mean ± standard deviations are given for each dimension, with sample size in parentheses. Shell thickness was not measured for oysters used for 1/2 and round pearl culture.

Utilisation Category		Morphological dimensions					
		Shell Thickness (mm)	Hinge Depth (mm)	Shell Length (mm)	Shell Width (mm)	Hinge length (mm)	Weight (g)
Culture	Round Only (3235)	33 ± 6 (1334)	7 ± 3 (2968)	176 ± 20 (2982)	169 ± 17 (2968)	116 ± 15 (1324)	603 ± 247 (2230)
Culture	1/2 & Round (9000)	-	10 ± 5 (9140)	188 ± 29 (9144)	171 ± 23 (9118)	118 ± 18 (153)	859 ± 404 (8199)
Culture	Combined (12235)	33 ± 6 (1334)	9 ± 5 (12108)	185 ± 27 (12126)	170 ± 22 (12086)	116 ± 15 (1477)	804 ± 390 (10429)
MOP	(17282)	49 ± 7 (8690)	18 ± 6 (16502)	225 ± 18 (16527)	199 ± 15 (16457)	137 ± 14 (8990)	1560 ± 454 (13906)
Total Retained	(29517)	47 ± 8 (10019)	14 ± 7 (29432)	208 ± 30 (29485)	186 ± 23 (29376)	134 ± 16 (11301)	1236 ± 572 (25163)
Discarded	Chicken (231)	20 ± 8 (77)	2 ± 3 (200)	102 ± 23 (231)	104 ± 27 (224)	65 ± 26 (81)	87 ± 56 (150)
Discarded	Clunkers (4648)	59 ± 7 (1671)	23 ± 8 (4591)	228 ± 19 (4613)	193 ± 16 (4579)	121 ± 13 (1588)	1859 ± 488 (4156)

In broad terms, the size of an oyster determined its utilisation. Significant differences (P<0.001) were apparent between the shell lengths of each category. However, stepwise discriminant analysis on the morphological dimensions (pooled over vessel and year), revealed that shell length was not the best morphometric variable for discriminating between the different uses of pearl oysters. Discrimination between oysters used for round pearl culture, MOP and those discarded was best achieved using shell thickness ($F_{2,10849}$=4602, Wilk's Lambda=0.541, p<0.0001, Table III). The smoothed distributions of shell length, shell thickness and hinge depth are shown for the different categories (Figure IIIa-c). No comparison of morphometry of oysters from Eastern and Western Grounds could be made, as no samples were taken on the former.

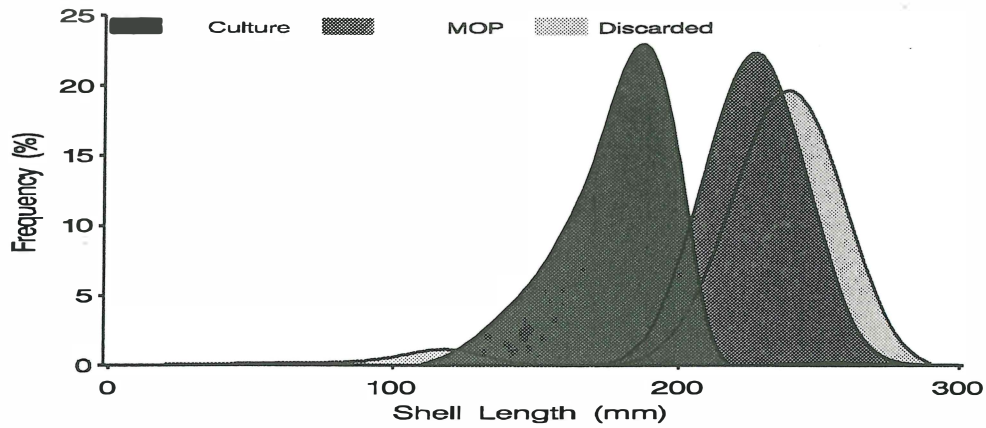
Table III. Summary of results of a stepwise discriminant analysis to determine which morphological parameter was best at discriminating between the various uses of pearl oysters. Comparison was made between oysters used for round pearl culture, MOP, and large discarded oysters.

Morphometric variable	Variables included	Partial R^2	F Statistic	Prob > F	Wilk's Lambda	Prob < Lambda
Shell thickness	1	0.4590	4602	0.0001	0.541	0.0001
Hinge length	2	0.2134	1471	0.0001	0.426	0.0001
Shell length	3	0.1071	650	0.0001	0.380	0.0001
Hinge depth	4	0.0502	286	0.0001	0.361	0.0001
Live weight	5	0.0148	81	0.0001	0.356	0.0001
Shell width	6	0.0057	31	0.0001	0.353	0.0001

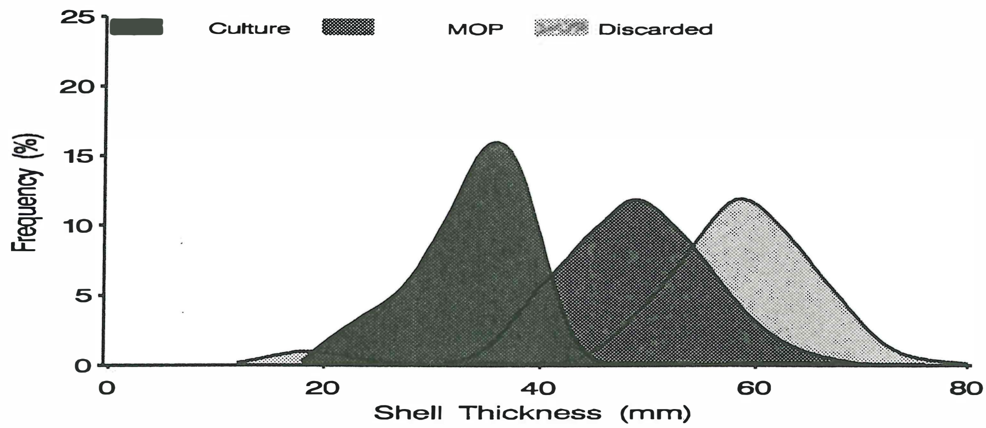
Relationships between shell length and other morphological parameters are given in Figure IVa-e. The morphometric data was log-transformed to account for the positive correlation between the mean and variance before fitting linear regressions.

Figure III Smoothed distributions of shell length (a), shell thickness (b) and hinge depth (c) for pearl oysters used for round pearl culture, MOP, and those discarded. The area under each curve is not proportional to the numbers of oysters used for each purpose.

a.



b.



c.

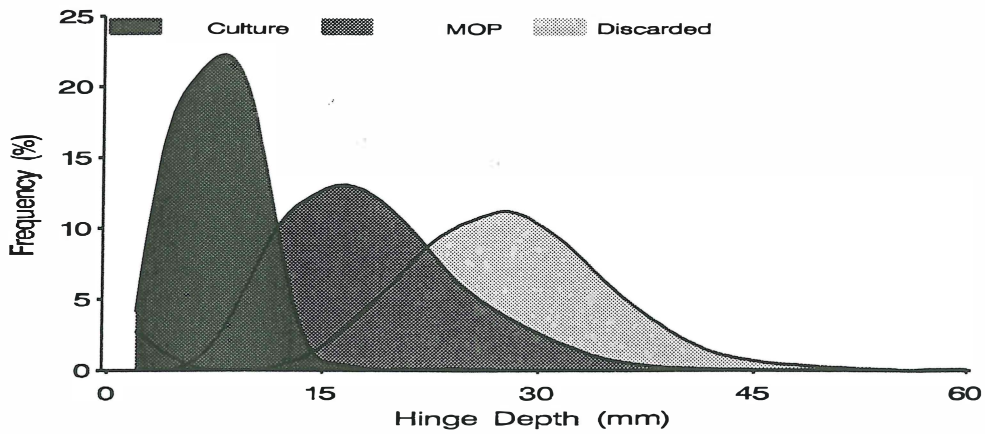
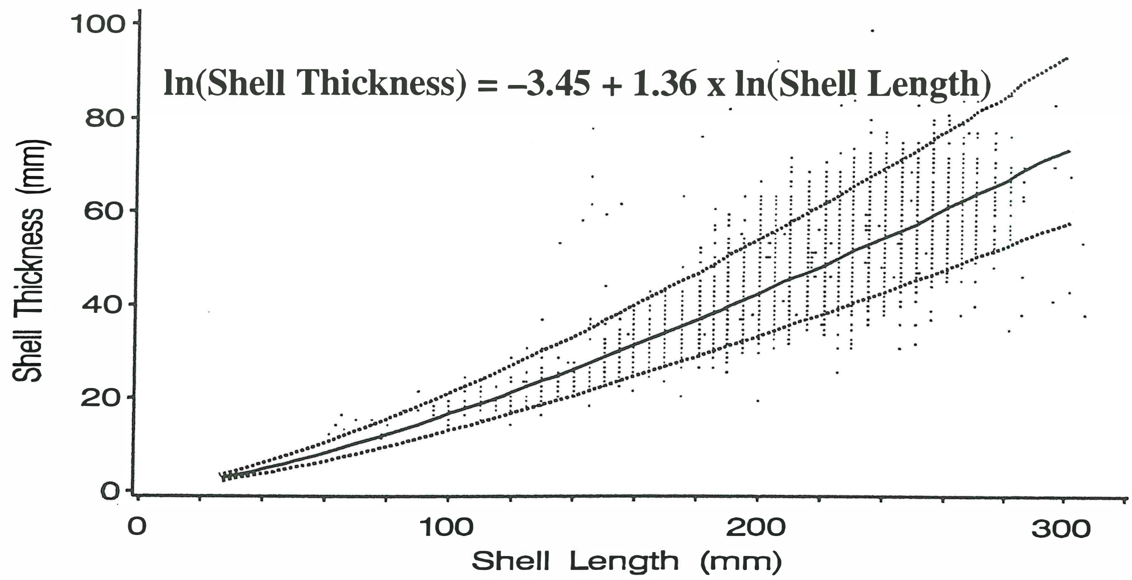


Figure IV. Morphometric relationships between: (**a**) shell thickness and shell length ($P<0.0001$, $r^2 = 0.67$, n = 11749); and (**b**) hinge depth vs shell length ($P<0.0001$, $r^2 = 0.71$, n = 34148). Regression lines represent the mean (—), and 95% individual confidence limits (····).

a.



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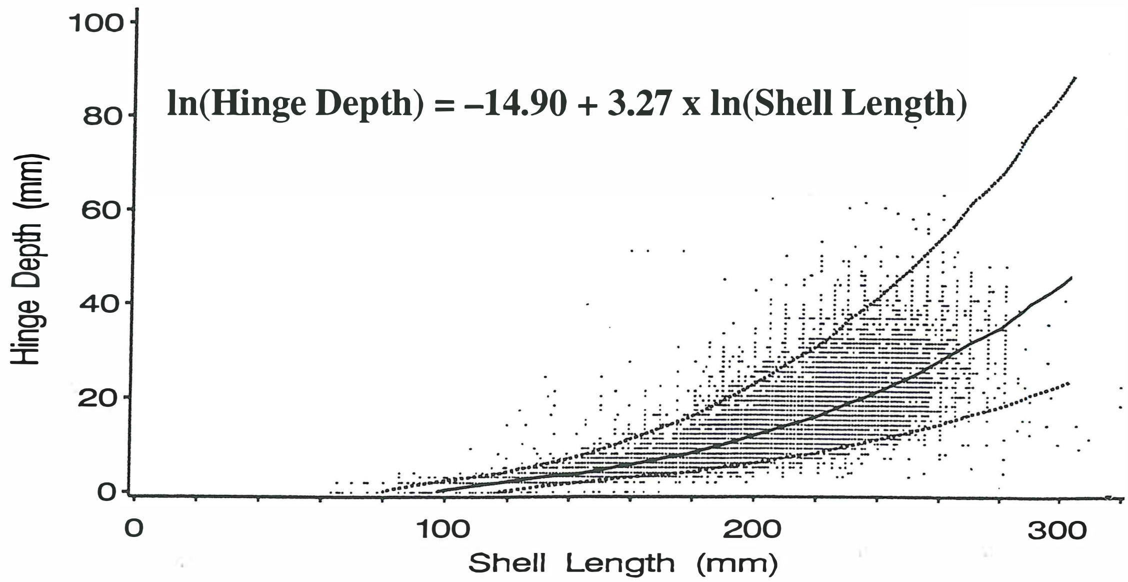
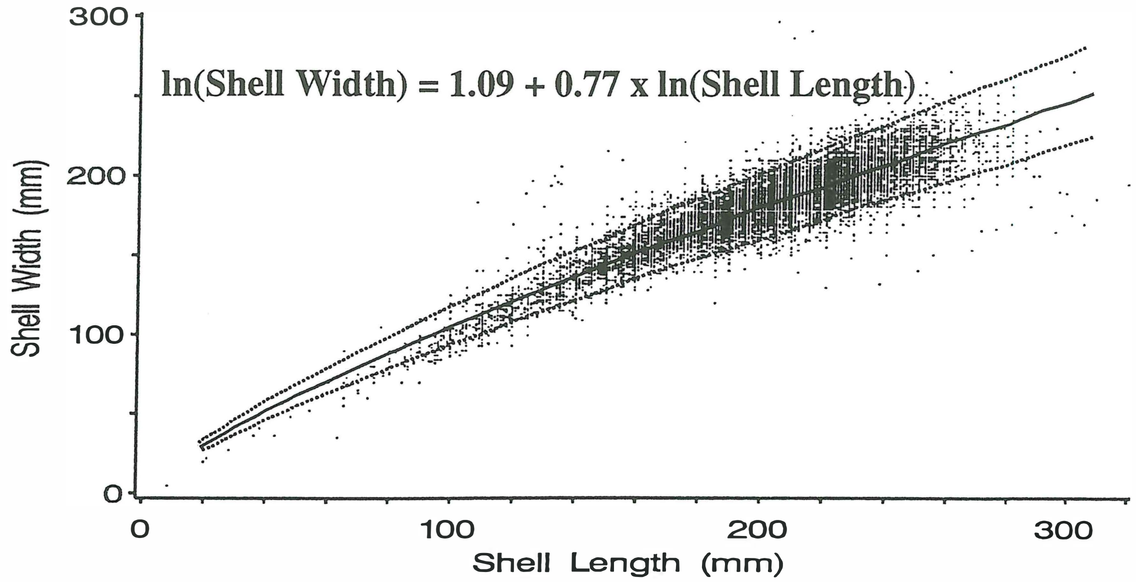


Figure IV (continued). Morphometric relationships between: (**c**) shell width vs shell length ($P<0.0001$, $r^2 = 0.84$, $n = 34151$); and (**d**) hinge length vs shell length ($P<0.0001$, $r^2 = 0.32$, $n = 12952$). Regression lines represent the mean (—), and 95% individual confidence limits (····).

c.



d.

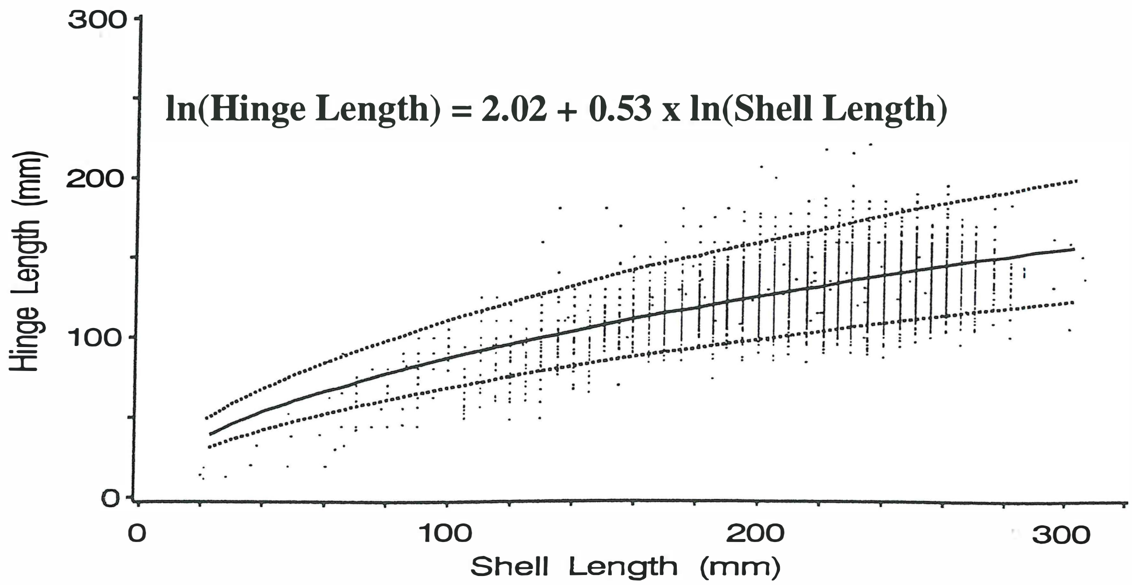
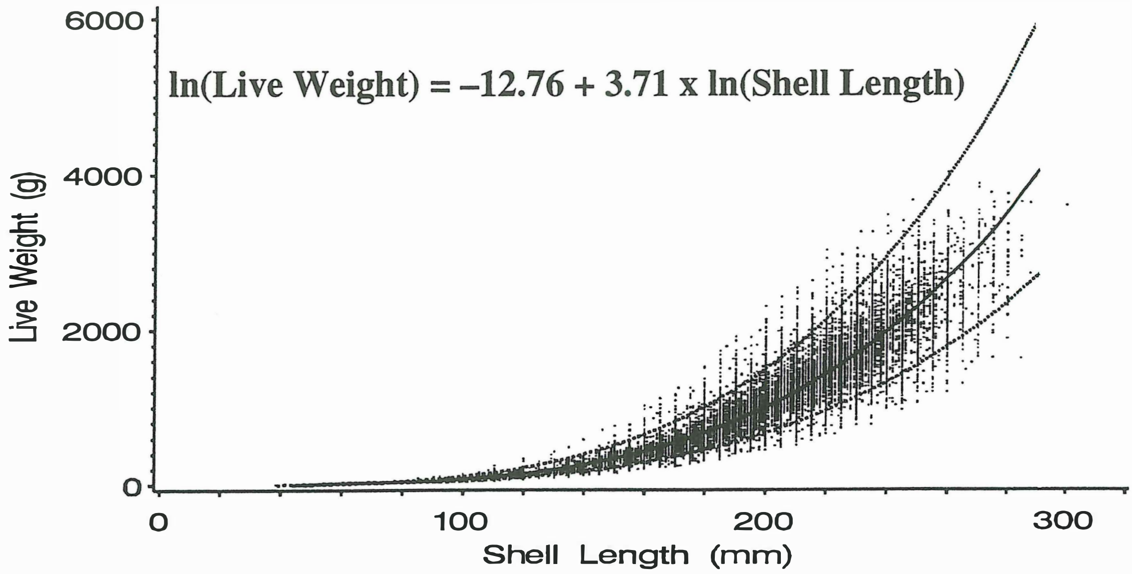


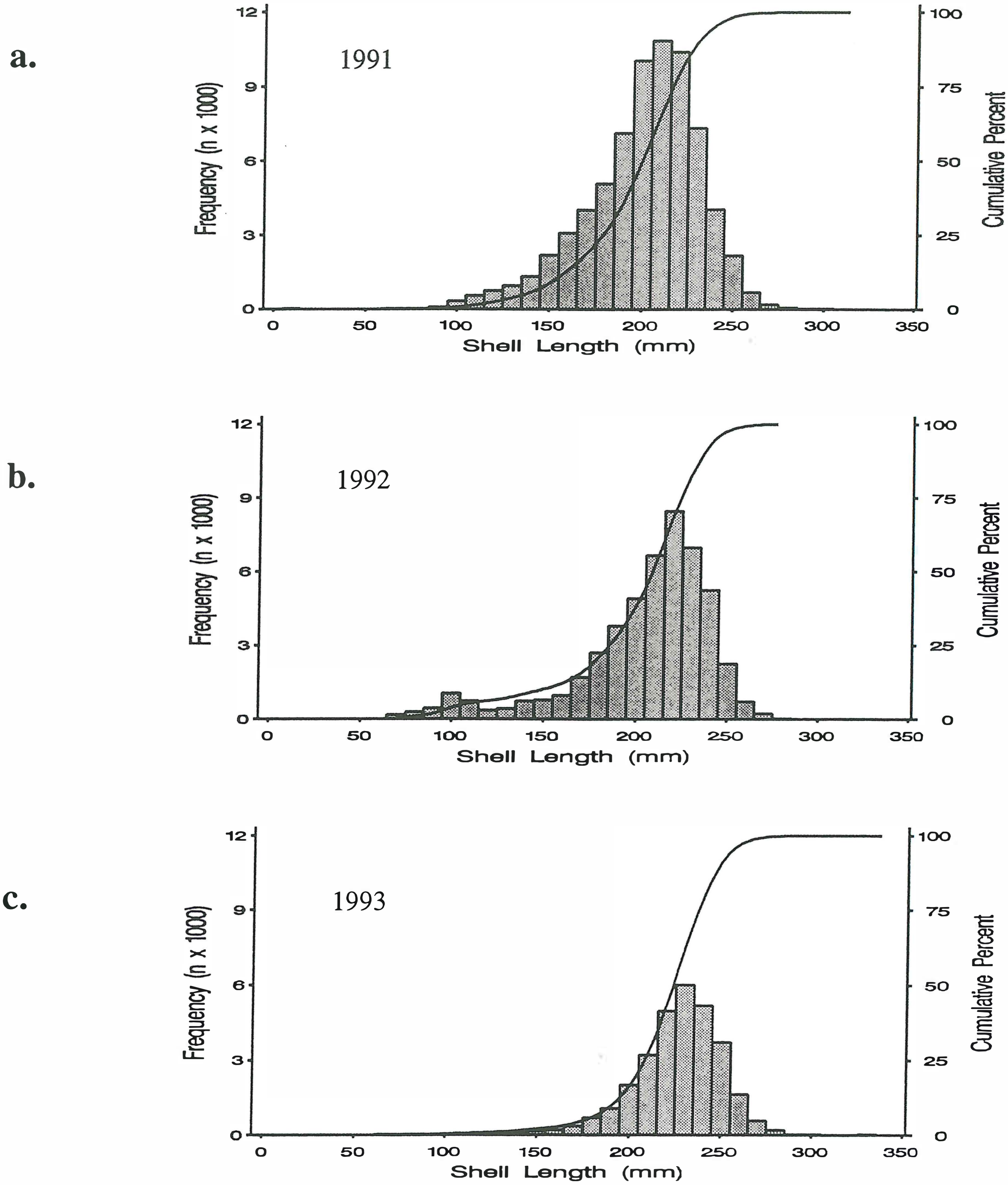
Figure IV (continued). **R**elationship between: (**e**) live weight vs shell length (P<0.0001, $r^2 = 0.89$, n = 29468). Regression lines represent the mean (—), and 95% individual confidence limits (·····).

e.



Shell length ranged between 30 to 335 mm, but 90 % of the oysters were between 140 and 240 mm. The size distribution of the total annual catches for the Fishery was extrapolated from the sampled catches, and is given in Figure Va-c.

Figure V. Estimated size distribution of the total catch of pearl oysters for (**a**) 1991; (**b**) 1992; and (**c**) 1993. The percentage cumulative catch is given (—).



DISCUSSION

This research has provided insight into the morphometry and utilisation of pearl oysters. Furthermore, by monitoring the length frequency of the catches, a good estimation of the size structure of the pearl oyster stocks in the NT has been obtained. This information helps to explain the current status of the NT Pearl Oyster Fishery.

Morphometry and utilisation

Morphometry is the relationship between the mensural traits of an animal: a description of its size and shape. Its uses include discriminating between sexes and species, describing population variations, and classifying phylogenetic relationships. But, morphometry is especially important in pearl oysters because it is also used to determine the suitability of a pearl oyster for culture purposes, and the size of the pearl which can be cultured within it.

Basically, the utilisation of a pearl oyster was related to its size. An oyster retained for pearl culture must be large enough to accept the implantation of a pearl nucleus yet small enough to produce a thick layer of quality nacre and have the capacity to continue to grow whilst producing a series of two to three pearls of increasing diameter. During this study, the size range of 90% of culture shell was between 120 and 210 mm DVL with a mean of 176 ± 20 mm. This corresponded to a shell thickness of 20 - 44 mm with an average of 33 ± 6 mm. Larger oysters were retained for either half pearl culture, MOP or were discarded. There was significant overlap in the morphometry of pearl oysters used for these varying purposes. This might simply be due to variation in the decisions made by the skipper or head diver as they quickly sort the shell into the different categories. Such decisions, based on a combination of morphometric characters and the condition of the shell, can be somewhat subjective; they could also vary for different individuals and different companies. Factors other than morphometry may also influence the categorisation of pearl oysters. For example, excessive infestation of boring polychaete worms spoils the nacre of a pearl oyster and renders it unsuitable for pearl culture or MOP. This problem would increase with time, and may be an important factor in the large overlap in morphometry of MOP and discarded oysters.

Shell length is a dimension commonly used with regard to pearl oyster growth and stock structure. This study showed that shell length was significantly different between *P. maxima* used for culture, MOP, and those discarded, but it was not the best dimension for discriminating between these different uses. Shell thickness was better; although the two dimensions were closely related. The importance of shell thickness could be related to the oyster's ability to accept implantation of a nucleus. A very "flat" oyster might be less likely to accept implantation of a large nucleus. *Pinctada maxima* is the largest of the pearl oysters, and can produce the largest pearls. The Industry in Australia endeavours to produce pearls of between 10 - 14 mm diameter from the first implantation, as their value is higher than the smaller Japanese Akoya pearl. Our results suggest that in order to meet this requirement, the NT Industry tends to target oysters with a minimum shell thickness of about 20 mm .

Joll (WA Marine Research Laboratories, unpublished data) suggests that shell thickness or hinge depth may be better indicators of the age of *P. maxima* than shell length. If this is the case, then utilisation of pearl oysters for different purposes may be directly related to their age. During this study, the relationship of shell length to both shell thickness and hinge depth indicated that as *P. maxima* grew, the relative increase in shell length reduced compared to either shell thickness or hinge depth. Although no ageing work was conducted in this study, this result would support Joll's view. Similar studies on other species of pearl oyster revealed hinge depth, although not always reliable (Sims 1993), was a better indicator of age than shell length (Tranter 1958), which could actually decrease due to damage or sloughing (Simms 1994).

Whatever dimension is found to be the best indicator of age for *P. maxima*, be it shell length, shell thickness or hinge depth, by establishing morphometric relationships and their association to pearl oyster utilisation, this study has provided baseline information from which the age structure of NT pearl oyster populations could be estimated and the effect of fishing assessed.

Length frequency distributions and the NT Fishery

Historically, all pearl oysters collected in the Fishery were used for MOP and natural pearls were collected as a by-product. During the 1960's, demand for MOP fell and techniques of round pearl culture became commercially viable. The Fishery began targeting oysters for the far more valuable purpose of pearl culture. After this change however, relatively little fishing occurred in the NT Pearl Oyster Fishery, and attempts to encourage it have had minimal success. What is causing the low level of participation in the Fishery and why is such a large percentage of the catch in the NT still being used for half pearl culture and MOP when the highest monetary returns are from round pearl culture? The length frequency data obtained in this study provides part of the answer.

Northern Territory pearl oyster stocks seem to be comprised of a high proportion of large oysters. In a study by Penn and Dybdahl (1988), oysters collected for round pearl culture from the productive grounds off 80 Mile Beach in WA were smaller (145.5 mm shell length ± 25.7 SD, n=3837) than in the present study (see Figure Ia, V). Furthermore, the maximum length of oysters collected for round pearl culture in WA was usually less than 170 mm (Joll pers. comm.). In the NT, oysters up to 220 mm shell length were being used for round pearl culture, and only between 10 and 20% of the shell collected were less than 170 mm. In general, the same companies and divers work in the NT as WA, so company preference and diver bias can be discounted as reasons for the difference between the states. Lack of light in the deeper waters of the NT may make detection of smaller shell more difficult, although this is considered unlikely. It becomes apparent then, that the reason smaller shell are not being collected for culture in the NT is simply because they are not present in large numbers on the beds. In other words, the NT pearl oyster stocks fished during this study were comprised of a high proportion of large oysters which at best could be considered as less desirable oysters for pearl culture, and at worst were only valuable for MOP, if worth retaining at all (between 8 and 16% of oysters collected were later discarded). What factors could determine the size distribution observed on NT pearl oyster beds?

It is difficult to resolve to what degree the size structure of NT populations have been effected by fishing pressure. Even when both the WA and NT grounds were being extensively fished for MOP, Wada (1953) noted that oysters in more southern waters were smaller in size. Using electrophoresis, Johnson and Joll (1993) found stocks of *P. maxima* to be highly subdivided in northern Australia. This, as well as environmental factors associated with the latitudes of the NT and WA grounds, may effect growth rates, and underlie the different size ranges.

Penn and Dybdahl (1988) found that grounds which had not been fished for an extended period had a higher proportion of larger sized oysters then those recently fished. They attributed the smaller size distributions of catches from the productive grounds off Broome to the impact of heavy fishing, and indicated that most of the catch consisted of newly recruited oysters. That unfished populations consist of a higher proportion of older animals than exploited populations is a common observation. This could explain the size distribution on the NT grounds, which had received relatively little fishing pressure in the two decades prior to this study; but it may not be the only factor. Lack of regular strong recruitment, combined with the targeting of smaller oysters would also lead to a high proportion of larger oysters. Such a scenario is quite possible on the NT grounds.

Pinctada maxima is a protandrous hermaphrodite, reaching maturity as a male at 110 - 130 mm after one year (Wada 1953; Rose *et al.* 1990) and obtaining a 1:1 sex ratio in natural populations at 170 mm shell length or greater (Rose *et al.* 1986). Thus, the NT pearl oyster populations are not lacking in broodstock. Yet despite this, there was no evidence of extensive recruitment on any of the beds within the study site during the course of this study. Fishermen have suggested that the high numbers of culture oysters found on beds off Broome and the beds' continued productivity may be a direct result of removal of most of the MOP in earlier years. This suggests there is some factor, be it space or food or another mechanism, which limits the settlement of oysters around large numbers of adult oysters. This has yet to be established. More importantly, it assumes that there is regular recruitment. This could possibly be the case in the WA Pearl Oyster Fishery where the annual quota of 500,000 oysters can be filled based on small culture grade shell, but it does not appear to be happening in the NT. Recruitment in bivalve molluscs fisheries is renowned for being patchy (McLoughlin *et al.* 1994), and low, patchy, or irregular recruitment is a possible cause of the high proportion of large oysters in NT stocks.

Lack of valuable culture grade oysters may be a major factor affecting the economics of fishing NT beds, but it is not the only one. Many of the pearl oyster beds are on isolated shoals in relatively deep water (>30 m, Knuckey, unpublished data). Consequently the time taken to search for productive beds can be high, and once found, the depth of water severely restricts diving time. Also, the monsoon season and currents associated with the NT's large spring tides further limit potential fishing time.

FURTHER DEVELOPMENT

During the course of this research project, Industry involvement in the wildstock harvest of pearl oysters from NT waters fell dramatically. In 1991 the maximum of six licensees were fishing, but by 1993, only two were participating and about one quarter of the total quota was being harvested. The lack of activity in the NT Pearl Oyster Fishery is probably due to a variety of reasons.

Our research highlighted that the size structure of NT stocks was such that a high proportion of oysters were not suitable for round pearl culture. In addition to this, the extent and depth of the NT grounds reduces the amount of resource available to divers. Thus, compared to WA, the economic benefits of fishing in the NT are reduced. Consequently, other means of obtaining culture stock have been developed. Companies with licences in both NT and WA use oysters collected in WA which they then translocate to NT farms. Other companies use hatchery produced oysters as an alternative source of culture stock. The direction of future research in the NT Pearl Oyster Fishery largely depends on Industry's preferred method of collecting culture stock. Considering the costs and difficulties associated with diving for oysters in the NT, it would not be surprising if this method is phased out in the future. Hatchery produced oysters may become a more important source of oysters for pearl culture. Research on pearl oyster hatchery and growout techniques has already commenced (eg. Alagarswami *et al* 1983, 1989; Rose and Baker 1994), but if hatchery produced oysters are to become the mainstay of pearl culture industry, then further research into mass production and the reliability and commercial viability of such techniques needs to be undertaken. As suggested in this report and by Scoones (1991), spat collection may also be a viable collection technique, although it is yet to be tested on a large scale.

If wild stock pearl oysters are to continue to be used to supply the pearl culture industry, then obviously there is much more research that needs to be undertaken on the Fishery, especially in NT waters. Pearl oysters reach a size suitable for pearl culture within one to two years of settlement, which only allows a small amount of time for commercially viable beds to be discovered and harvested. Understanding and predicting settlement patterns is therefore of prime importance, and the first step would be to develop an index of recruitment. But, if settlement is low or very patchy, and, as in the NT, the presence of suitable beds is limited, then these objectives would be a very difficult and costly to achieve. Considering that other methods of providing culture stock are being utilised and the current level of participation in the NT Pearl Oyster Fishery is low, one would need to consider whether it is worth undertaking such research. It is unlikely that the stocks are in any immediate danger of overfishing.

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Northern Territory Pearl Oyster Fishery

Fisheries Research and Development Corporation

PROJECT 91/14
FINAL REPORT
(1995)

SECTION 3

Spat collection

This section is a draft of an article which has been accepted, pending minor revision,

for publication in the Journal of Shellfish Research

Settlement of *Pinctada maxima* (Jameson) and other bivalves on artificial collectors in the Timor Sea, northern Australia.

INTRODUCTION

Artificial collectors consisting of used monofilament net in open-weave bags have proved successful for collecting bivalve spat in temperate waters (eg Brand *et al.* 1980). They have been used variously to collect bivalve spat for aquaculture (Paul *et al.* 1981; Rose and Baker 1994), estimate recruitment in wild-stock fisheries (Sause *et al.* 1987; Young *et al.* 1988), and monitor early growth and mortality of bivalves (McLoughlin *et al.* 1988). There is increasing interest in the potential of collectors for capturing tropical species of commercial value, especially the silverlip pearl oyster, *Pinctada maxima* (Jameson) which sustains Australia's pearl culture industry. *Pinctada maxima* has been successfully collected on artificial collectors under conditions of high spat densities such as pearl farms (Schoones 1991) or hatcheries (Rose and Baker 1994). This success, and anecdotal evidence of settlement of *P. maxima* on nets and ropes left near oyster beds, prompted me to use artificial collectors in the natural environment to determine what commercially important bivalves settled, and establish whether or not collectors could be deployed for commercial purposes or as a research tool for stock assessment. This report identifies which bivalve species settled on artificial collectors in the Timor Sea off northern Australia, and describes settlement and growth rates of the most common. Particular reference is made to *P. maxima* and other bivalve species with commercial potential, including other pearl oysters (Pteriidae), fan shells (Pinnidae) and edible oysters (Ostreidae).

METHODS

Collectors were placed on two shoals in the Timor Sea about 30 km west of Bathurst Island (near 129° 48' E, 11° 39' S, Fig. I). The shoals, about 15 km apart, were chosen because they were relatively shallow (24-27 m) and reportedly contained reasonable numbers of *P. maxima*. Both shoals consisted of low profile reef, usually with a shallow layer of coarse sand covering large areas, and were in open seas, subject to tidal currents of up to 3 $km \cdot hr^{-1}$.

On each shoal, a collector was placed at four stations 80 m apart, along a line with marker buoys at either end. Each collector was anchored by a 25 kg steel plate connected to a 10 kg anchor by 1.5 m of 10 mm proof coil galvanised chain. A further 2.0 m of chain connected the steel plate to the 13 mm silver rope of the collector which was buoyed by a 5 kg high density polypropylene float 15 m above the bottom. At two heights up the rope (5 and 7 m from the bottom), a 3 m length of 50 mm PVC pipe was connected horizontally by a central swivel. Eight spat bags were attached at 300 mm intervals to each pipe. Each spat bag, the smallest replicated unit, was constructed from a black polyethylene mesh bag (500 mm x 230 mm with 7 mm mesh) with 30 g (± 0.1 g) of used 50 - 75 mm mesh, nylon monofilament net placed loosely inside. The open end of each numbered spat bag was drawn together with a cable-tie that also held a stainless-steel snood to attach the bags to the collectors. Spat bags were set and collected by divers over five periods between June 1993 to June 1994 (Table I). Four bags (two from each PVC pipe) were retrieved and replaced from each collector after each period. They were brought to the surface, drained in the shade and frozen in sealed plastic bags. In the laboratory, spat bags were thawed and weighed. The monofilament was removed from the bags and the bivalves were extracted, identified, counted, and measured (dorso-ventrally) to the nearest mm. Thus, the experimental design consisted of two replicates from the upper and lower PVC pipes from each of eight collectors (A - H) split between two shoals (1 and 2) taken over five periods (Jun-Aug, Aug-Oct, Oct-Jan, Jan-Mar, and Mar-Jun). Many of the spat bags retrieved had been torn open and the monofilament was missing; these were excluded from any analyses (Table I). Other spat bags were collected after longer periods of immersion, but that data is not presented here.

The relative abundance of different species and families was compared. Analyses of growth and settlement rates were undertaken on the 13 most common species. Standardised monthly settlement rates, where $\text{settlement rate} = \frac{\text{No. of Individuals}}{\text{Standard 30g spat bag}} \times \frac{30}{\text{Period duration}}$, were averaged; and included undamaged bags on which no individuals were found. Spatial (shoal, station and height) and temporal (period) differences in settlement rates of common species were compared using ANOVA and Scheffe's multiple comparison test.

Growth rates were obtained by averaging individual growth rates for each period. They were calculated based on the assumption that the bivalves settled at the middle of each period and are expressed in $\text{mm}\cdot\text{month}^{-1} \pm$ standard deviation. The growth rates and length frequency histograms (5 mm length classes) of commercially important species are given for each period.

RESULTS

The abundances of the different bivalve species and families are summarised in Table II. During the experiment a total of 1639 bivalves were collected, encompassing 47 species from 14 families. Thirteen species from 6 families comprised over 90% of the total numbers and were included in further analyses. Of these, six have commercial potential, including *P. maxima*, *Pinctada albina*, *Pteria brevialata*, *Pteria penguin*, *Pinna bicolor*, and *Saccostraea cucullata*. *Pinctada margaritifera*, *Atrina pectinata*, *Pinna incurva*, *Pinna* *deltodes* and *Saccostraea echinatum* also have commercial potential, but were only caught in low numbers (< 10 individuals).

In general, settlement rates showed extreme variation in proportion to the mean and comparisons were therefore performed on log-transformed data. *Pinna bicolor* had greater settlement on the upper pipes of the collectors (Scheffe's P<0.05) but as it was the only species to exhibit a significant difference on this spatial scale, data from each collector was pooled for analysis of other spatial effects. Of the 13 common species, *only Dendostraea folium*, *Malleus atrinus* and *P. brevialata* had significant differences (Scheffe's P<0.05) in settlement rates between shoals (higher on Shoal 1) and only *D. folium* differed between stations. Analysis of the effect of period was consequently based on data pooled for spatial effects.

Pooled over species, the period had a significant effect on settlement rates ($F_{4,81}$=5.59, P<0.0005), with the trend of higher settlement during the warmer months of the wet season, (October to March), and significantly higher settlement rates January-March than March-June (Scheffe's P<0.05). This trend was also apparent in individual species (*P. bicolor*, *Malleus albus* and *P. penguin*), and was significant (Scheffe's P<0.05) for *P. maxima*, *Electroma* sp., *M. atrinus*, *Musculista glaberrima* and *Pteria* sp. (Table III).

The length frequencies of potential commercial species together with their mean growth rate for each period are shown in Figure II a-f. The size range of *P. maxima* found on spat bags was between 3 mm and 16 mm with an average of 8.3 mm. This corresponded to an average growth rate of 5.8 mm·month^{-1}. A similar growth rate was evident for *P. albina* (5.2 mm·month^{-1}) and *S. cucullata* (6.6 mm·month^{-1}). The fan shells (Pinnidae) had the fastest growth rates, with some individuals of *P. bicolor* growing 47.5 mm·month^{-1}. Unlike other species, there was no apparent single peak in the length frequencies of *P. bicolor*, with lengths during any period having a very wide range.

DISCUSSION

This study demonstrates that a wide range of tropical bivalve species settle on artificial collectors. A relatively small number of species accounted for most of the bivalves caught and some of these have considerable commercial value, especially *P. maxima*.

Of the bivalve families found on the collectors, the pearl oysters (Pteriidae), which were the second most abundant family, have the greatest commercial significance. This is mainly because of their ability to produce pearls, but also for their lustrous nacre and edible meat. *Pteria* sp., *P. brevialata*, *P. penguin* and *P. albina* were common, but their commercial value is not as high as *P. maxima* and *P. margaritifera* which produce the most valuable cultured pearls.

Australia's pearl culture industry is worth over A$130 million annually and largely depends on wildstock fisheries for *P. maxima* to provide its pearl oysters (McLoughlin *et al.* 1994). Divers are utilised to collect oysters, and because most commercial pearl oyster beds in northern Australia are relatively deep (>30 m), costs of collection and transportation are high, at A$17 - 27 per oyster (Rose and Baker 1994). With such high costs, there are obvious benefits in developing other methods to collect *P. maxima*. The culture of spat in hatcheries is proving successful (Rose and Baker 1994), but use of artificial collectors in the natural environment may provide a cheaper alternative with the advantage that, being from a broader genetic pool, the spat may have already undergone significant selective pressures, possibly making them more resistant to disease and infection during growout.

In the present study, *P. maxima* represented 2.4% of the total number of bivalves collected with settlement rates during October to January at an average of 0.6 individuals·30g $bag^{-1}·month^{-1}$. This settlement rate appears low, but it is difficult to determine what settlement rates would be required to make the collection technique viable. The present study used a number of small collectors (≈ 30 g monofilament) to act as replicates for experimental design requirements and total numbers were consequently low. If much larger collectors, specifically designed to collect large numbers of bivalves were used, they might be a viable collection technique in waters off northern Australia. A major improvement to the design of the collectors used in this study would have been to provide a rigid mesh frame around the bags as done by Schoones (1991), to protect them from the significant damage presumably caused by fish and turtles.

Apart from the possibility of using artificial collectors to collect pearl oysters for aquaculture, they also have potential as a research tool. Pearl oyster stocks in northern Australia have received extensive fishing pressure over the last century and large fluctuations in catches have resulted from the discovery and subsequent depletion of pearl oyster beds. Typical of many molluscan fisheries, the Pearl Oyster Fishery has highly variable settlement and recruitment patterns (McLoughlin *et al.* 1994), and understanding and predicting recruitment to depleted beds is very difficult. The use of artificial collectors has helped in understanding the population dynamics of other molluscan fisheries. In the scallop fishery in southern Australia the relative numbers of larvae that settle on spat collectors can be related to the size of the parental population (Young et al. 1988) and to recruitment to the fishery during the next year (Sause et al. 1987). This information assists in fishery management, and could be equally well applied to management of the Pearl Oyster Fishery. Off northern Australia, commercially harvestable shoals which are shallow enough to dive on are very patchy, and costs to Industry of searching for such beds is high. Artificial collectors could be used to assist Industry by determining the relative settlement rates on different shoals. Settlement of bivalves on collectors however, only indicates the presence of larvae competent to settle, and will not necessarily reflect abundances of bivalves on the natural substrate (Young *et al.* 1988), which can be influenced by numerous physical and biological factors. Relating settlement of pearl oyster spat on collectors to settlement and recruitment to the natural substrate was not addressed in this study and would require further research. Furthermore, because the present study was conducted over one year, no indication of inter-annual variability in settlement was obtained.

Pinctada maxima had highest settlement rates during October to January, with lesser rates in other months, and none from June to August. This pattern is in concurrence with research by Wada (1953) in northern Australia, which showed *P. maxima* usually begins to spawn in late October and continues for several months, with a small number of animals spawning throughout the year. Bwathondi and Ngoile (1982) also found settlement of *Pinctada* spp. was highest during the wet season (November and December). Dayton *et al.* (1989) recorded massive numbers of almost identically sized *P. maxima* spat on coral collectors set in the Great Barrier Reef between October and February, which suggests they settled almost instantaneously. Similarly, only one settlement peak of *P. maxima* was apparent in any one period during this study, but sizes ranged between 3 and 16 mm. Whether this pattern resulted from an instantaneous settlement event with variable growth rates, or continuous settlement over numerous weeks, could not be determined in this study. The results did indicate there was more than one settlement event throughout the year, and can support the findings of Rose *et al.* (1990) that there is a main spawning period in September/October and a secondary spawning in March/April.

Growth rates of individual *P. maxima* in this study reached 10.4 mm·month^{-1} with an average of 5.8 mm·month^{-1}, slightly lower than those observed by Rose and Baker (1994) of 7 - 9 mm·month^{-1} for spat cultured in plastic trays in the sea. Importantly, growth rates in this study could be overestimated by the assumption that the spat settled mid-way during the period because spat that settled near the beginning of the period would grow and could be identified, whereas spat that settled near the end of the period would possibly be undetected. Nonetheless, it is not unreasonable that growth of *P. maxima* was less in the spat bags, where there is close competition for space and nutrients with numerous other fauna, than in plastic trays. Rose and Baker (1994) noted reduced growth rate in spat stocked at increased density.

Similar to *P. maxima*, other bivalves showed higher settlement rates during the wet season (eg. *P. bicolor*, *Electroma* sp., *M. atrinus*, *M. glaberrima*, *Pteria* sp. At this time of year, north-westerly monsoons cause high rainfalls in coastal northern Australia, and increased productivity caused by warmer water temperatures and large amounts of nutrients washed into the ocean might be advantageous to settlement during this time. In more temperate waters, Rose *et. al.* (1990) correlated maximal gonad development of *P. maxima* with increased water temperatures, and in general correlations of bivalve spawning with increased water temperatures are common and would explain the trend in the present study. Some species however, showed no significant difference in settlement rates throughout the year (*Chlamys curtisiana*, *M. albus*). This may be an artefact of an extremely high variability in settlement rates which could mask any seasonal trends, but it may also indicate they have a protracted spawning season and settle throughout the year.

In contrast to seasonal effects, bivalve settlement rates were rarely different over the spatial scales used in this study (1 m - 15 km). Wide variation in the settlement rates on individual spat bags was very high and probably masked most spatial effects. Such variation may have resulted from aggregated settlement, such as noted in *P. maxima* (Rose and Baker 1994) which may lead to an all-or-none scenario on the spat bags. Alternatively, it may be that the patchiness of larval settlement occurs on a very small scale (<1 m) even though the spat bags were in the open water column and subject to significant tidal currents over long periods.

Although the two most common species, *M. glaberrima* and *C. curtisiana*, which together comprised nearly half of the total number caught, have no known commercial value, some bivalves found on the collectors besides the Pteriidae have commercial potential. Fan shells (Pinnidae) are large shells, common throughout the Indo-West Pacific region, and although they may produce pearls of moderate value, they are mostly valued for human consumption (Wells and Bryce 1988) or as bait for catching fish (Butler and Brewster 1979). They were common in the present study; *P. bicolor* settled throughout the year and *A. pectinata*, *P. incurva*, and *P. deltodes* were also found. The high settlement rate of *P. bicolor* is of particular interest. It can reach lengths of up to 400 mm (Butler and Brewster 1979) and together with the fast growth rate and common occurrence exhibited in the present study, suggest this species and method of capture may have commercial potential for culture or harvest. Edible oysters (*S. cucullata*, *S. echinatum* and *Ostrea* sp.) were also found on the collectors. They are highly valued for their taste and, like many of the more temperate species of this family such as *Ostrea edulis* Linnaeus and *O. angasi* Sowerby, have considerable potential for culture.

Artificial collectors deployed in the natural environment were successful in collecting tropical bivalve species of commercial importance. Whether such collectors are used for aquaculture depends on their ability to collect commercially viable numbers, but they could have important uses as a stock assessment tool for managing the *P. maxima* fishery.

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Table I. Dates and number of collectors that were set and retrieved for each period. Analysis was only conducted on the spat bags that had received little damage and had all of the monofilament still intact.

		No. of Spat bags				
Date	Period	Set	Retrieved	Damaged	Analysed	Missing
18/06/93						
	JUN-AUG	12	9	0	9	3
11/08/93						
	AUG-OCT	32	31	4	27	1
22/10/93						
	OCT-JAN	32	16	1	15	16 *
22/01/94						
	JAN-MAR	32	24	5	19	8
21/03/94						
	MAR-JUN	32	23	7	16	9
06/06/94						
	Total	140	103	17	86	37

* The PVC pipes on two collectors were broken causing the loss of many spat bags.

Table II. List of bivalve species found on collectors set in the Timor Sea for five 2-3 month periods over one year. The frequency of occurrence by number and percentage is given for each family and species.

Family	Species	Frequency No.	%
MYTILIDAE		561	34.2
PTERIIDAE		456	27.8
PECTINIDAE		219	13.4
MALLEIDAE		129	7.9
PINNIDAE		125	7.6
OSTREIDAE		99	6.0
LIMIDAE		30	1.8
GALEOMMATIDAE		9	0.6
ARCIDAE		3	0.2
VENERIDAE		3	0.2
UNGULIDAE		2	0.1
CARDITIDAE		1	0.1
ISOGNOMONIDAE		1	0.1
PLICATULIDAE		1	0.1
MYTILIDAE	*Musculista glaberrima* (Dunker)	559	34.1
PECTINIDAE	*Chlamys curtisiana* (Iredale)	196	12.0
PTERIIDAE	*Pteria* sp.	137	8.4
PTERIIDAE	*Pteria brevialata* (Dunker) *	115	7.0
PINNIDAE	*Pinna bicolor* Gmelin *	110	6.7
PECTINIDAE	*Electroma* sp.	92	5.6
MALLEIDAE	*Malleus atrinus* Gmelin	74	4.5
OSTREIDAE	*Dendostraea folium* (Linnaeus)	60	3.7
MALLEIDAE	*Malleus albus* Lamarck	41	2.5
PTERIIDAE	*Pinctada maxima* (Jameson) *	39	2.4
PTERIIDAE	*Pinctada albina* (Lamarck) *	34	2.1
PTERIIDAE	*Pteria penguin* (Roding) *	31	1.9
OSTREIDAE	*Saccostraea cucullata* Born *	29	1.8
LIMIDAE	*Limatula* sp.	23	1.4
MALLEIDAE	*Malleus daemonicus* Reeve	12	0.7
PECTINIDAE	*Mimachlamys gloriosa* (Reeve)	10	0.6
PECTINIDAE	*Complicachlamys dringi* (Reeve)	9	0.6
OSTREIDAE	*Ostrea* sp	9	0.6
GALEOMMATIDAE	*Scintilla* sp.	9	0.6
PINNIDAE	*Atrina pectinata* (Linnaeus)	7	0.4
PINNIDAE	*Pinna incurva* Gmelin	7	0.4
PTERIIDAE	*Electroma zebra* Reeve	4	0.2
LIMIDAE	*Limaria fragilis* (Gmelin)	3	0.2
PECTINIDAE	*Chlamys squamata* (Gmelin)	2	0.1
UNGULIDAE	*Diplodonta* sp.	2	0.1
LIMIDAE	*Lima lima vulgaris* Linnaeus	2	0.1
MYTILIDAE	*Musculista cumingiana* (Reeve)	2	0.1
PTERIIDAE	*Pinctada margaritifera* Linnaeus	2	0.1
ARCIDAE	*Acar* sp.	1	0.1
VENERIDAE	*Antigona lamellaris* Schumacher	1	0.1
ARCIDAE	*Arca avellana* Lamarck	1	0.1
ARCIDAE	*Arca navicularis* Brugiere	1	0.1
CARDITIDAE	*Cardita cardioides* (Reeve)	1	0.1
PECTINIDAE	*Decatopecten strangei* (Reeve)	1	0.1
ISOGNOMONIDAE	*Isognomon isognomon* (Linnaeus)	1	0.1
LIMIDAE	*Lima* sp.	1	0.1
LIMIDAE	*Limatula tadena* (Iredale)	1	0.1
MALLEIDAE	*Malleus malleus* Linnaeus	1	0.1
PECTINIDAE	*Mimachlamys deliciosa* (Iredale)	1	0.1
VENERIDAE	*Paphia gallus* (Gmelin)	1	0.1
PTERIIDAE	*Pinctada* sp.	1	0.1
PINNIDAE	*Pinna deltodes* Menke	1	0.1
PLICATULIDAE	*Plicatula essingtonensis* Iredale	1	0.1
PTERIIDAE	*Pteria tortirostris* (Dunker)	1	0.1
OSTREIDAE	*Saccostraea echinatum* Qouy and Gaimard	1	0.1
VENERIDAE	*Tapes sulcarius* (Lamarck)	1	0.1
MALLEIDAE	*Vulsella vulsella* Linnaeus	1	0.1

* Denotes species for which growth rates and length frequency histograms are given.

Table III. Settlement rates (No. of individuals·30g bag^{-1}·month^{-1} ± standard deviation) of common species of bivalves collected on artificial collectors set in the Timor Sea. Sample numbers are in parentheses and periods which had significantly higher (Scheffe's P>0.05) settlement rates than other periods are indicated (*).

Species	Settlement Rate					
	Jun-Aug (9)	Aug-Oct (27)	Oct-Jan (15)	Jan-Mar (19)	Mar-Jun (16)	Total (86)
Musculista glaberrima	0.9 ± 1.5	2.3 ± 2.8 *	6.0 ± 7.2 *	3.5 ± 3.4 *	0. 6 ± 0. 7	2.7 ± 4.1
Chlamys curtisiana	2.5 ± 3.0*	1.1 ±1.7	0.9 ± 1.0	0.8 ± 1.1	0.3 ± 0.8	1.0 ± 1.6
Pteria sp.	0	0.0 ± 0.1	0.7 ± 1.0	2.5 ± 4.1 *	0.2 ± 0.5	0.7 ± 2.2
Pteria brevialata	0.6 ± 0.5	0.2 ± 0.4	0.5 ± 0.6	1.3 ± 3.1	0.4 ± 0.5	0.6 ± 1.6
Pinna bicolor	0.2 ± 0.3	0.5 ± 0.6	0.7 ± 0.9	0.6 ± 1.1	0.1 ± 0.2	0.5 ± 0.7
Electroma sp.	0.1 ± 0.2	0.2 ± 0.4	0	2.2 ± 3.1 *	0	0.5 ± 1.7
Malleus atrinus	0	0.1 ± 0.6	1.1 ± 1.9 *	0.3 ± 0.4	0.1 ± 0.2	0.3 ± 1.0
Dendostraea folium	0.4 ± 0.6	0.4 ± 0.7	0.3 ± 0.4	0.2 ± 0.7	0.1 ± 0.2	0.3 ± 0.6
Malleus albus	0.1 ± 0.2	0.1 ± 0.4	0.3 ± 0.5	0.3 ± 0.6	0.1 ± 0.2	0.2 ± 0.4
Pinctada maxima	0	0.1 ± 0.3	0.6 ± 0.6 *	0.0 ± 0.1	0.2 ± 0.3	0.2 ± 0.4
Pinctada albina	0.1 ± 0.2	0.4 ± 0.7	0.2 ± 0.4	0.0 ± 0.1	0.1 ± 0.3	0.2 ± 0.5
Pteria penguin	0	0	0.4 ±1.0	0.2 ± 0.4	0.1 ± 0.2	0.1 ± 0.5
Saccostraea cucullata	0	0.2 ± 0.7	0.1 ± 0.1	0.0 ± 0.1	0.3 ± 0.4	0.1 ± 0.5

Figure VI. Artificial collectors were placed on two shoals in the Timor Sea about 30 km west of Bathurst Island. The shoals, about 15 km apart, were chosen because they were relatively shallow (24-27 m) and reportedly contained reasonable numbers of *P. maxima*.

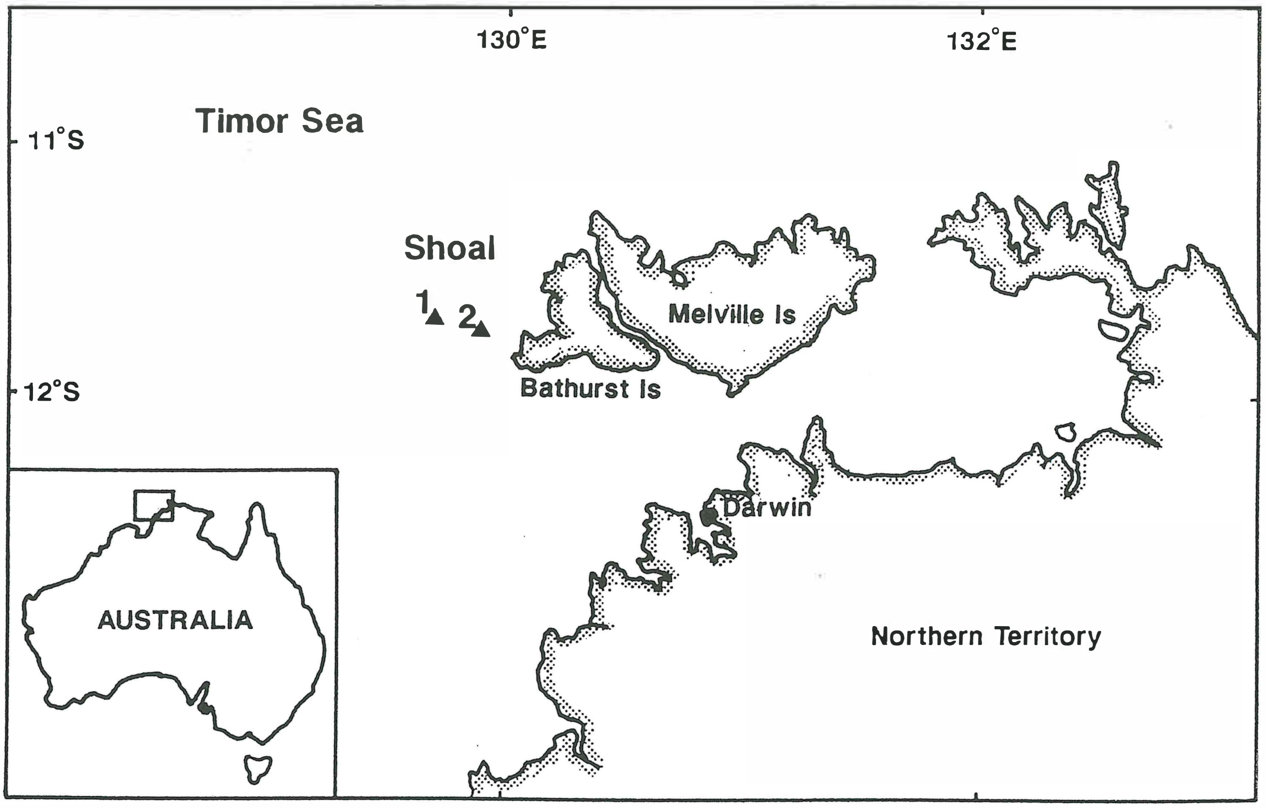
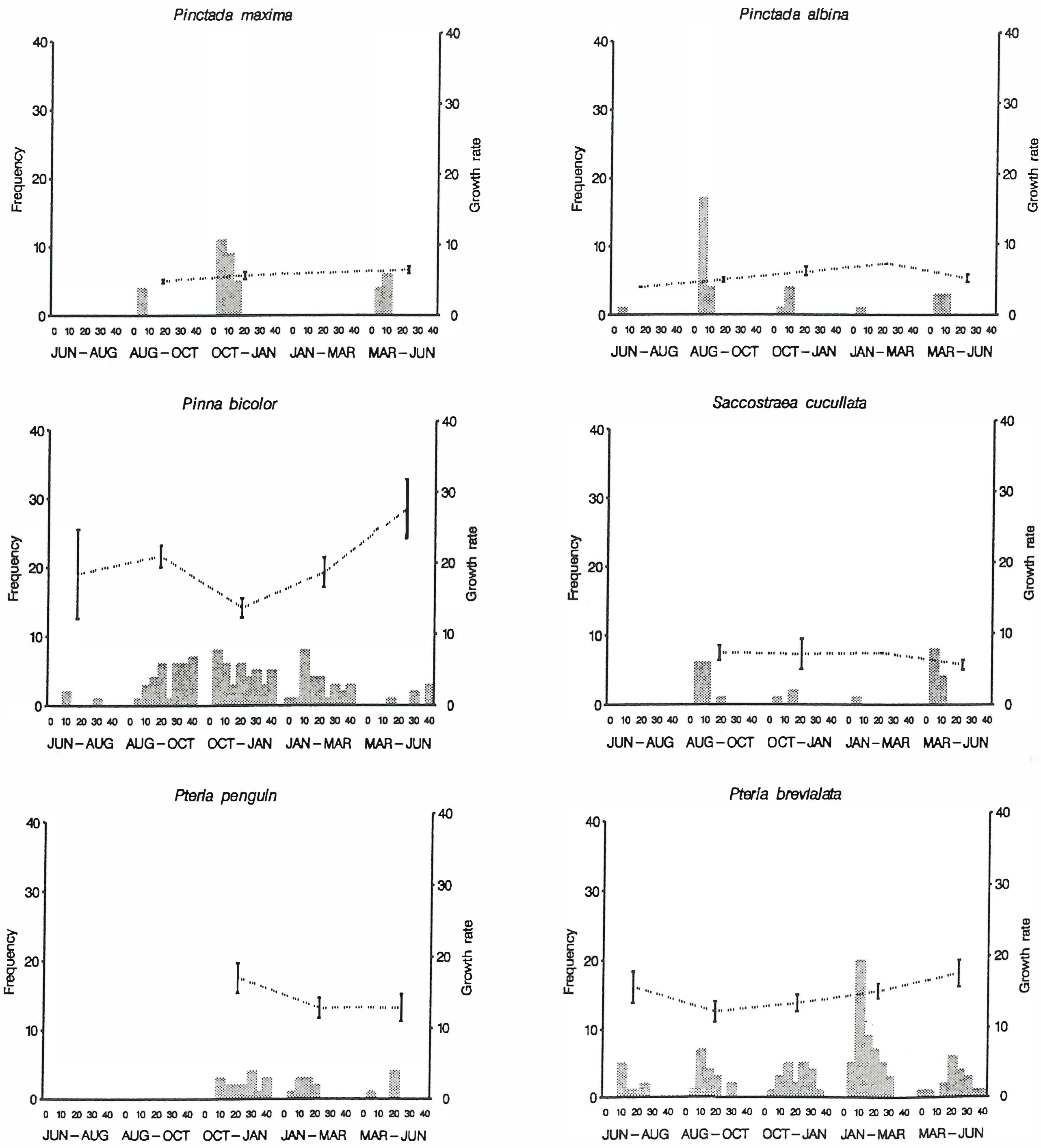


Figure VII. Length frequencies and growth rates of bivalve species with commercial potential caught on collectors over five periods during one year in the Timor Sea. Dotted lines connect error bars of mean estimated growth rates (mm·month^{-1} DVL) ± standard error. Shaded histograms represent the length frequencies of each species in 5 mm size classes from 0 - 40 mm.



Northern Territory Pearl Oyster Fishery

Fisheries Research and Development Corporation

PROJECT 91/14
FINAL REPORT
(1995)

SECTION 4

Administration

INTELLECTUAL PROPERTY

No intellectual property arose from the research. Given that pearl oyster beds which contain shell suitable for round pearl culture are not common in the NT and that they could be related to individual companies, information on the exact positions from which pearl oysters were collected have not been included in the report.

STAFF

The main staff employed on the research program were:
Scientific officer - Ian Knuckey
Technical Officer - Paul Johnson
Technical Officer - Russell Willing
Technical Officer - Adam Collins

Graham Baulch, Charles Bryce, August Stevens assisted with the field work during the commercial catch sampling project. David Ramm, Anne Coleman, Peter Herden, Murray Bradley and Adele Williams provided assistance with diving in the spat settlement project. Thanks also to the skippers Bruce Boyden (Ta Aroa) and Stewie Proctor (The Entertainer). David Ramm, Rik Buckworth, and Yan Diczbalis provided helpful criticism during the projects. Special thanks to Alan Klishans for identification of bivalve species and Russell Willing and Mike Volmer for their help in the laboratory. Special thanks to Rosemary Lea, Dick Slack-Smith and Darryl Grey from NT Department of Primary Industry and Fisheries for their support throughout the project.

This project could not have been undertaken without the assistance of the skippers and crew of the Kunmunya, Paspaley Pearl II, Roebuck Bay II, Kuri Pearl and Tiwi Pearl.

FINAL COST

Year	Expenditure	FRDC	NT DPIF	TOTAL
1991/92	**Salaries**	35,810	35,810	71,620
	Travel	12,250	12,250	24,500
	Operational	4,328	4,328	8,656
	Capital	1,400	1,400	2,800
	Total	53,788	53,788	107,576
1992/93	**Salaries**	40,337	40,337	80,674
	Travel	11,900	11,900	23,800
	Operational	3295	3295	6,590
	Capital	0	0	0
	Total	55,532	55,532	111,064
1993/94	**Salaries**	40,975	40,975	81,950
	Travel	11,900	11,900	23,800
	Operating	3,130	3,130	6,260
	Capital	0	0	0
	Total	56,005	56,005	112,010
TOTAL		$165,325	$165,325	$330,650

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