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The Shark Bay Scallop Fishery: discussion paper

L. M. Joll

FISHERIES MANAGEMENT PAPER

No. 11

THE SHARK BAY SCALLOP FISHERY

DISCUSSION PAPER

BY

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SUMMARY

1. Studies of the biology of the saucer scallop *Amusium balloti* in Shark Bay show that it is a highly fecund, broadcast spawner, with a long breeding season (from April to December). It is also a fast growing species, with the bulk of the recruits from a breeding season reaching fishable size by April/May of the next year, at which time they also enter their first breeding season. In recent years, however, the earlier part of the breeding season appears to have been the most important for production of recruits.

2. With the current levels and distribution of fishing effort the breeding stock appears not to have been adversely affected and has provided levels of recruitment which have sustained a worthwhile fishery. The value of the fishery in 1986 was estimated at approximately $3.5 million, while the 1987 season is expected to produce a catch worth approximately $6-6.5 million.

3. Any new management regime should aim to maintain high levels of spawning stock in the early part of the breeding season, as well as an adequate level of breeding stock at the end of the fishing season. It should also aim to capture scallops at sizes suitable for export markets.

4. Proper biological management of the scallop stock can be achieved through (i) control of the opening date and (ii) control of the lower limit to which the breeding stock can be fished. The rate of decrease of the breeding stock, as a result of exploitation by the fishery, is also important but can be offset by varying the opening date of the season or factors affecting gear efficiency.

5. It would be technically possible to manage the Shark Bay scallop fishery on an open-entry basis, but this could have a detrimental effect on the operations and economics of the prawn fishery. Quotas or a total allowable catch (TAC) are not appropriate, as it is not possible either to set a TAC with acceptable precision or to adequately police the delivery of catch. The only practical alternative is limited-entry management with controls on total effort.

6. Vessel numbers are largely irrelevant to the proper management of the stock, but are extremely important in determining the viability of individual participants and the share of catch achieved by the scallop and prawn fleets. The number of vessels will also affect the capital value of the goodwill attached to the limited entry licence. With a 14 vessel fleet, the current capital value of a limited entry licence is estimated at about $500,000.

7. Conflict between the scallop fleet and other fisheries operating in the area, notably the Shark Bay prawn fishery, has led to claims of adverse effects resulting from scallop fishing. The available data, however, do not support these claims. Catches and catch rates of king prawns have been virtually constant over the periods 1971-81 and 1982-86, which represent two periods of very different levels of scallop fishing activity. Mean annual catch of king prawns from 1971-81 was 1,375 tonnes and the catch rate 24.1 kg/hour. For the period 1982-86 the mean catch was 1,509 tonnes and the catch rate 24.0 kg/hour.

8. Claimed reductions in the catches of king prawns on the western grounds of Shark Bay (i.e. the area of overlap of the scallop and prawn fisheries) are most likely the result of changes in fishing patterns of the prawn fleet. Increases in fishing effort near the prawn nursery

lines in recent years may be reducing the number of prawns moving from the nursery area to western grounds.

9. In terms of impact on the seabed, trawling activities of the scallop fleet covered only between 11 and 19% of the swept area of the prawn fleet over the years 1983-86. The trawling of the scallop fleet has, however, been carried out in an area not previously trawled by the prawn fleet. Even so, the impact of the scallop fleet on the seabed in this area has probably only been similar to that exerted by the prawn fishery in its early years of development.

10. Changes in management of the Shark Bay prawn fishery in recent years have been directed at improving stocks of tiger prawns and would not be expected to lead to any improvement in the catch or catch rate of king prawns. Lack of an increase in catches or catch rates of king prawns should not be considered to be the result of the activities of the scallop fleet.

11. Twenty-four hour fishing allows the scallop fleet to achieve a high rate of exploitation of the scallop stock, particularly in the early part of the season. This practice has allowed the scallop fleet to take a large proportion of the total catch, but it is not considered to be a biological problem in the management of the stock.

12. Changes in management arrangements for the Shark Bay snapper fishery, as well as the licence conditions imposed on scallop vessels, have largely alleviated earlier concerns about possible re-direction of potential effort in the scallop fleet to other fisheries.

13. The key issues which need to be resolved in discussing this report are:

(i) The number of licences to be issued for the Shark Bay scallop fishery and the means of selecting licence holders.

(ii) An appropriate vessel replacement policy.

(iii) Ways of equitably dividing the scallop resource between the scallop and prawn fleets.

(iv) Ways of minimising conflict between the scallop and prawn fleets to ensure future orderly fishing of the scallop resource.

1. INTRODUCTION

Commercial catches of the saucer scallop (Amusium balloti) from both Shark Bay and the Abrolhos Islands in 1981 and 1982 attracted increasing numbers of boats to fish this resource. The profitability associated with both at-sea processing of scallops and record catches by vessels involved in the fishery led to increasing interest in these two fisheries by other fishermen.

Concern that increasing fishing effort would affect the long-term viability of scallop fishing and place the existing scallop stocks at risk was expressed to the Minister for Fisheries and Wildlife by both existing scallop fishermen and by holders of Shark Bay prawn authorisations. There was also concern that uncontrolled scallop fishing might have a detrimental effect on the valuable Shark Bay prawn fishery.

On 13 September 1982, the Minister for Fisheries and Wildlife issued a warning to the fishing industry that the Shark Bay scallop fishery might not be able to support any expansion of the scallop industry's capital base. The Minister stated that "although the fishery is not fully understood at present, it is reasonably clear that stocks are limited and thus industry should be warned that it may be unwise to outlay more capital based on present stocks".

On 12 December 1982, the Minister for Fisheries and Wildlife announced the appointment of the Scallop Fishery Management Working Group to undertake an inquiry into commercial exploitation of the scallop fisheries at Shark Bay and the Abrolhos Islands.

The Working Group was required to seek submissions from scallop fishermen and processing companies directly involved in the taking of scallops, other members of the fishing industry and the public, in order to examine, report and make recommendations to the Minister for Fisheries and Wildlife on:-

(a) the current status and levels of exploitation on the scallop stocks within Shark Bay and near the Abrolhos Islands presently under commercial exploitation,

(b) the effects, if any, of scallop fishing on adjacent managed fisheries,

(c) management options to rationalise the future exploitation of the Shark Bay and Abrolhos Islands scallop stocks.

The Scallop Fishery Management Working Group published its report in March 1983 in which it listed twelve recommendations (Appendix 1). The recommendations included a temporary (three year) freeze on boat numbers in the Shark Bay fishery, with a ban on vessel transfers during the period of the freeze. A three year research programme to examine aspects of the biology of, and fishery for, saucer scallops was also recommended. A report on this research was to be submitted to the Minister for Fisheries and Wildlife by 1 November 1986.

The research programme, funded from the Fisheries Research and Development Trust Fund was formally commenced in September 1983 with the appointment of staff. The programme was established with a four year term, with a field component to run over three years, followed by a further year for data analysis and publication of reports. Consequently it was not possible for a report and recommendations to be made by November 1986 for implementation in

1987. Holders of Shark Bay scallop authorisations were therefore advised (29 April 1986) that their endorsements would continue to be valid for 1987, but the other licence conditions (Appendix 2) would remain in force and that no transfers would be permitted.

This management paper summarises the results of the research programme in Shark Bay, gives an historical account of the fishery and changes in management which have occurred over the duration of the research programme. A management strategy, based on the results of the research programme, is presented and possible management options for the future exploitation of scallops in Shark Bay are considered.

2. HISTORY OF THE FISHERY FOR A. BALLOTI IN SHARK BAY

2.1 EARLY HISTORY

The fishery for *A. balloti* in Shark Bay began in 1966, with an incidental catch of 5.8 tonnes whole weight (= 1.2 tonnes meat) by prawn trawlers (Table 1). The presence of scallops in Shark Bay has, however, been known since 1904 from catches by the survey ketch "Rip" (Gale 1905). Catches were also made in the late 1950s and early 1960s by the Fisheries Department's research vessels "Lancelin" and "Peron".

There was no recorded catch for 1967, but in 1968 a catch equivalent to 38 tonnes of meat was taken as by-catch by prawn trawlers. Landings peaked in 1969 with a catch equivalent to 273 tonnes of meat, resulting from the by-catch of prawn trawlers as well as from seven boats targeting on scallops. The catch in the following year (1970) fell to 83 tonnes (meat weight) although, in addition to the prawn trawler by-catch, 14 boats fished for scallops at various times during the year. In 1971 there was no catch, presumbly as a result of a recruitment failure by scallops. Because of the lack of by-catch by prawn trawlers, no additional vessels fished specifically for scallops.

Annual catches of between 22 and 57 tonnes (meat) were taken between 1972 and 1975, primarily as by-catch by prawn trawlers. From 1976 onwards an increasing number of vessels began to fish specifically for scallops and, in 1979, two of these commenced processing scallops at sea for sale on the Australian domestic market as roe-off scallop meat. Prior to this all scallops had been landed as whole shell for processing by N.W. Whaling at Carnarvon or for trucking to other processing establishments further south.

Table 1 TOTAL SCALLOP LANDINGS FROM SHARK BAY AND LANDINGS BY SCALLOP TRAWLERS FROM 1966 TO 1986. TOTAL EFFORT BY SCALLOP TRAWLERS 1982 to 1986.

Year	Total landings[1] (tonnes meat)	Landings by Scallop Trawlers (tonnes meat)	Maximum number of Scallop Trawlers Operating	Total effort [2] (Scallop Trawlers) (hr. fathoms.)
1966	1.2	N/A	N/A	N/A
1967	N/A	"	0	"
1968	37.8	"	N/A	"
1969	272.8	"	7	"
1970	83.2	"	14	"
1971	0	"	0	"
1972	22.3	"	0	"
1973	57.4	"	3	"
1974	31.7	"	0	"
1975	27.4	"	0	"
1976	107.5	"	2	"
1977	158.5	"	5	"
1978	109.3	"	4	"
1979	57.0	"	3	"
1980	101.0	58.6	4	"
1981	140.7	74.6	5	"
1982	434.7	295.4	13	125 000
1983	705.3	640.4	26	235 000
1984	431.2	379.0	Freeze.....14.....	272 000
1985	232.8	175.0	14	183 000
1986	259.5	211.1	14	161 000

1 Conversion whole weight to meat weight: Landings as whole weight have been converted to meat weight using the approximate relationship: meat weight = 1/5 whole weight.

2 Effort values: An effort unit of hour. fathoms was introduced to accommodate the various head rope lengths used by scallop vessels. 1hr. fathom = 1 fathom of headrope length of net towed for 1 hour. (e.g.) Vessel with twin rig, 14fm net = 14 hr. fathoms per hour of trawling. The effort value for 1982 has been converted from hours of trawling to hour. fathoms assuming an average headrope length over the whole season of 12 fathoms.

N/A = Not available.

By 1982 virtually the whole catch, including that taken by prawn trawlers, was processed and frozen at sea. Meats were packed in 2 kg blocks in cartons or loosely packed in plastic bags for further onshore processing. Far-West Scallop Industries, with a land-based processing establishment, continued onshore hand processing of whole scallops landed by its vessel "Kingfisher II" until the end of the 1983 season.

The change to at-sea processing enabled scallop vessels to remain longer on the grounds, allowed vessels to work scallop beds further from Carnarvon and improved profitability. It also permitted prawn trawlers to retain by-catch scallops as desired throughout their operations. Previously prawn trawlers had retained live scallops for processing only from the last night of a trip. Some scallops were also brought in frozen as whole shell in bags but, because of the bulk involved, only a relatively small amount of material could be stored in this way.

In the early phase of at-sea processing meats were soaked in fresh water to increase the weight of the product. Market reaction against product treated in this way, however, led to its abandonment. Prior to 1982, most sales of scallop meat were to the Australian domestic market, at prices (in 1982$) ranging from $4.50 to $6.00 per kg. Around this time some scallop trawler owners began developing new export markets, primarily in Hong Kong, as well as expanding an existing export market to the United States of America. Development of these export markets resulted in a significant increase in financial returns. The declining value of the Australian dollar has further improved the A$ value of scallops in recent years.

A further development of at-sea processing was an increase in crew numbers. Larger scallop vessels began carrying very large crews (up to 16 persons). The large crews, however, permitted a vessel to maximise its catch rate during periods of good catches by preventing bottlenecks in the processing area, which otherwise would have required vessels to stop trawling. Nevertheless, at times of peak catch rates even these large crews were inadequate to process the catch sufficiently rapidly and vessels ceased trawling while the processors handled the accumulated catch. As catch rates declined crew numbers were reduced and the processing capacity adjusted to the catch rate.

The price increase resulting from the development of the export market, the improved profitability provided by at-sea processing and an apparent increase in the stock of scallops encouraged more vessels to fish for scallops. Between 1980 and 1983 the number of vessels fishing specifically for scallops rose from 4 to 26. In 1983 the price paid for local scallops was around $5 per kg. while a pool price of $8.10 per kg. was paid on export product.

Concern about past increases, and the potential for further increases, in both effort and vessel numbers and the effect that these increases may have on both the long term viability of scallop stocks and the Shark Bay prawn fishery led to the establishment of the Scallop Fishery Management Working Group. This group was established in December 1982 and submitted its report in March 1983.

2.2 HISTORY SUBSEQUENT TO THE REPORT OF THE SCALLOP FISHERY MANAGEMENT WORKING GROUP

2.2.1. Freeze and Limited Entry Arrangements

Following the publication of the recommendations of the Scallop Fisheries Management Working Group (Appendix 1) a freeze on the number of vessels fishing for scallops in Shark Bay was announced by the Minister for Fisheries and Wildlife on 15 June 1983. The Minister also announced that "boats to be permitted to operate in the next three years (i.e. 1984/85/86) would require a fishing boat licence endorsed for scallop fishing." A research programme, to be undertaken during the three year endorsement period, was also announced.

Thirty five applications were received by the Director of Fisheries for licence endorsements. Of these, eleven were approved by the Minister on 3 November 1983. Appeals were lodged by thirteen of the unsuccessful applicants and, of these, three were successful. The total number of vessels endorsed to fish for 1984/85/86 was therefore limited to fourteen. The fourteen vessels and the authorisation holders are listed in Table 2.

Conditions applying to the endorsements at the time of issue were:

(i) Boat replacements will not be permitted prior to November 1 1986.

Table 2. FISHING VESSELS AND AUTHORISATION HOLDERS ENDORSED TO FISH FOR SCALLOPS IN SHARK BAY FOR THE PERIOD 1984-1986.

VESSEL	AUTHORISATION HOLDER
"Rebecca J"	V. and A. Charleson
"Sue Cheng"	Fitzgerald Fishing Company
"Kingfisher II"	Far West Scallop Industries Pty. Ltd.
"Slaven"	Nor'West Whaling Co. Pty. Ltd.
"Jo Ellen"	McBoats
"Morning Star"	Morning Star Fisheries
"Raconteur II"	Raconteur Fishing Company
"World Star" (now "Atlantic Ocean")	D.W. Shannon
"Anna Christine II"	D.J. McDonald
"Peron"	Hoskin Fisheries
"Eva Rae"	Shearwater Fisheries Pty. Ltd.
"Alola"	Dorre Island Fishing Company
"Oriana"	KAM Fishing Company
"Valerie"	B. Carter

(ii) Any change in proprietorship of the boat will result in cancellation of the fishing boat licence endorsement to take scallops within the Shark Bay Scallop Fishery.

(iii) The total head rope length of trawl nets shall not exceed 14 fathoms whether as a single or double rigged trawl.

(iv) That there is no guarantee of continued access to the fishery beyond 1986 and that Limited Entry management is only one of a number of options to be considered for the future management of the fishery.

(v) That those boats having a Shark Bay Scallop Endorsement will be required to trawl for scallops within Shark Bay during March and April of 1984. (This provision was to prevent vessels endorsed for Shark Bay from fishing for scallops in the waters of the Abrolhos Islands before May 1).

(vi) That any breach in the above conditions may result in cancellation of the license endorsement to trawl for scallops within Shark Bay.

The endorsement conditions were subsequently strengthened (16 February 1984) to prevent the taking of prawns, the shipment ashore of scallops by carrier boats and to limit the area of operation of scallop vessels to Denham Sound and the western parts of Shark

Bay. The full conditions imposed are listed in Appendix 2.

2.2.2 Performance of the Fishery

In the three years following the freeze the catch of the fishery declined from the 1983 peak of 705 tonnes of meat (Table 1). In 1984 the reduced catch occurred despite a 16% increase in effort levels, but in 1985 and 1986 the reduced catches were associated with reduced levels of effort. Over the period of the freeze, however, catch per unit effort by scallop trawlers has remained relatively constant, varying only between 0.95 (1984) and 1.39 (1985) kg. of meat/hr. fathom.

In all years since the introduction of the freeze, scallop vessels have stopped fishing before the official end of the season because catch rates became uneconomic. Prawn trawlers have, however, continued to take scallops until the normal end of their prawn fishing activities, as the small by-catch of scallops can provide a margin which allows vessels to continue to operate profitably in the latter part of the prawn season.

2.2.3. Changes in Management Arrangements during the Freeze

2.2.3.1. Directly related to the scallop fishery

The main changes in management arrangements of the scallop fishery have been in the opening and

closing dates of the fishery. Prior to 1983 there was no legally defined season and vessels were able to fish all year. In 1983 (the year preceding the freeze) the opening date was set at 1 March, to coincide with the opening of the prawn season. In June the Minister announced that no additional vessels would be permitted to enter the Shark Bay scallop fishery and that the season would close on August 31.

During the period of the temporary freeze, opening and closing dates have continued to be varied. In 1984 the season ran from 1 March to 31 October, to coincide fully with the prawn season. In response to research data indicating low levels of residual stock and the commencement of spawning by both residual stock and new recruits in mid-June, new dates were brought in for the 1985 season. The 1985 season was altered to one month in March to permit the capture of residual stock at a time of good meat recovery, followed by a closure in April, May and June to protect the on-coming spawning stock. The fishery re-opened from 1 July until 1 November.

Research data from surveys and a continuing assessment of reproductive cycles led to further changes in the opening date. In 1986 the season was opened on 15 May and stayed open until 1 November, while in 1987 the season opened on 1 May,

with a closing date of 7 November. These changes in opening date have been directed at the maintenance of a "safe" level of spawning stock (on the assumption that the fishery may be able to drive spawning stock levels down to a level where subsequent recruitment may be affected). The shift in closing date for 1987 was a result of changes to the closing date of the Shark Bay prawn fishery.

There have also been some changes in the composition of the scallop fleet, as a result of the loss or deterioration of some of the existing vessels. Although licence transfers were prohibited in the original authorisations, some substitute vessels were operated by lessees rather than the authorisation-holder. Substitutions which have occurred are shown in Table 3.

2.2.3.2 Indirectly related to the scallop fishery

Significant changes having relevance to the scallop fishery have occurred during the freeze, both in overall fisheries management and in the arrangements for specific fisheries. The major overall change was the introduction of a freeze (with minor exceptions) on vessel numbers in the total Western Australian fishing fleet. This policy prohibits any extra vessels from entering any Western Australian fishery, with the exception of fisheries with developing status.

Table 3. VESSEL SUBSTITUTIONS IN THE SHARK BAY SCALLOP FISHERY.

1.	"Alola" (Lost by fire, November 1984)	→	"Sunrise Raider" (March 1985 only)	→	"St Madalena" (July 1985 onwards)						
2	"Sue Cheng" (Sank, April 1985)	→	"Sunrise Raider" (July to October 1985)	→	"St Gerard" (1986 season)	→	"Darwin" (1987)				
3	"Slaven" (Damaged in a collision, July 1985)	→	"Jo Ellen II" (August and September 1985)	→	"Slaven"						
4	"Kingfisher II" (Failed survey requirements for 1986 season)	→	"Jo Ellen II" (1986 season)	→	"Ca Den" (1987 season)						
5	"Valerie" (Damaged by cyclone, January 1984)	→	"Shirralee" (26 - 25 May 1984)	→	"Valerie" (Sank at moorings, May 1986)	→	"Oceanic" (June 1986 only)	→	"Valerie" (Failed survey requirements for 1987 season)	→	"Katchula" (1987 season)
6	"Jo Ellen" (Unsuitable vessel)	→	"Jo Ellen II" (1987 season only)								
7	"Anna Christine II" (Lost by fire, February 1987)	→	"Oceanic" (1987 season only)								

A general move towards use of limited-entry management in a number of smaller fisheries has also occured over the period of the freeze. The Abrolhos Islands scallop fishery and the Shark Bay snapper fishery have become limited-entry fisheries. A substantial number of other smaller fisheries are currently in the process of being formally established as limited-entry fisheries. In order to fish in any of these fisheries, vessels will require an endorsement, so that the free movement of vessels between them will be restricted to those for which the vessel holds endorsements.

The changes in the management arrangements for vessels fishing for scallops in the Abrolhos Islands and in the Shark Bay snapper fishery have particular importance for the Shark Bay scallop fishery. The fishery for scallops at the Abrolhos Islands was made a limited-entry fishery in March 1986. Thirty vessels were granted endorsements, but a provision was made for 2 for 1 reductions on transfer (to reduce the number of vessels over time) and leasing was prohibited. However, administrative problems with leasing provisions and the 2 for 1 reduction clause led to these provisions being subsequently revoked (May 1987).

The criteria used in granting the original Abrolhos Island endorsements excluded vessels authorised to fish in a number of other fisheries, including the

Shark Bay scallop fishery. However, specific exception from this exclusion was made for vessels in the Shark Bay scallop fishery which might subsequently be excluded from that fishery as a consequence of management review. Nevertheless, in the period 1985-1987, vessels with Shark Bay scallop endorsements were specifically excluded from trawling for scallops at the Abrolhos Islands as a condition of licence (see Appendix 1, condition 5).

Vessel substitutions in the Shark Bay fishery, however, caused this situation to be reversed, as several vessels with Abrolhos Island endorsements were substituted for vessels in the Shark Bay fishery. The holding of authorisations for both the Abrolhos Island and Shark Bay scallop fisheries by these vessels was permitted as an anomaly.

Changes to the management of the Shark Bay snapper fishery and prohibitions on fish trawling have removed the potential for surplus capacity in the Shark Bay scallop fishery to be diverted towards pink snapper. The report of the Scallop Fishery Management Working Group expressed concern at the possible effects on the snapper fishery of any re-direction of effort by the scallop fleet. However, new regulations for the snapper fishery limit the possible re-direction of effort by scallop vessels into this fishery.

Under these regulations both scallop and prawn vessels are limited to an annual catch of 1 tonne (live weight) a year, taken either as incidental by-catch from trawling or by target fishing using hand lines, reels or drop lines. The use of traps is not permitted by any vessels, except those holding trap authorisations in the snapper fishery. There are also restrictions on the number of lines or drop lines operated by any one vessel and on the number of hooks per line or drop line. Targeted fishing during any closures in the snapper fishery is also prohibited.

Prohibitions on trawling for snapper in the internal waters of Shark Bay still exist, but are largely superseded by regulations which proclaim that the only legal means for catching snapper in the A and B zones of that fishery are by hook and line or trap. Incidental take as by-catch is, however, still permitted.

Trawling closures outside of the A and B zones of the snapper fishery prohibit trawling for fish by unendorsed vessels in the area south of latitude 21° S on the west coast and along the south coast of Western Australia. This eliminates an area of potential conflict between scallop (or other trawling) vessels and the Kalbarri-based snapper fishery, as well as protecting an area also utilised by the rock lobster fishery.

This suite of changes to the management of both particular fisheries and fisheries in general has largely removed many of the original concerns about the potential effort existing in the scallop fleet. The endorsement criteria applied to scallop vessels also removed many potential areas for conflict between prawn and scallop vessels in Shark Bay. Nevertheless, there remains significant latent effort available in the scallop fleet at current levels of effort, both in the latter part of the scallop season and during the closed period for scallop fishing. Consequently there still exists the potential for the development of as yet unexplored uses for that effort.

3. OUTLINE OF THE RESULTS OF THE RESEARCH PROGRAMME

3.1 REPRODUCTION

The sexes in *A. balloti* are separate with a 1:1 sex ratio, although a low frequency (<0.5%) of hermaphrodites was detected in microscopic examinations of the gonads.

Reproductive cycles were examined primarily by a gonad index (Dry weight of gonad ' Total dry weight of tissue x 100) of scallops of shell heights of 90 mm and greater. This size criterion was based on the work of Dredge (1981) who considered that *A. balloti* greater than 90 mm were capable of spawning. The gonad index data were complemented by histological studies to give a fuller understanding of the function of the gonad. Direct ageing of recruits by counts of daily rings was also used in estimating times of recruitment of juveniles. Fecundity data were derived from laboratory spawnings and details of larval life from laboratory rearings of larvae by R. Rose (Rose *et al.*, in press).

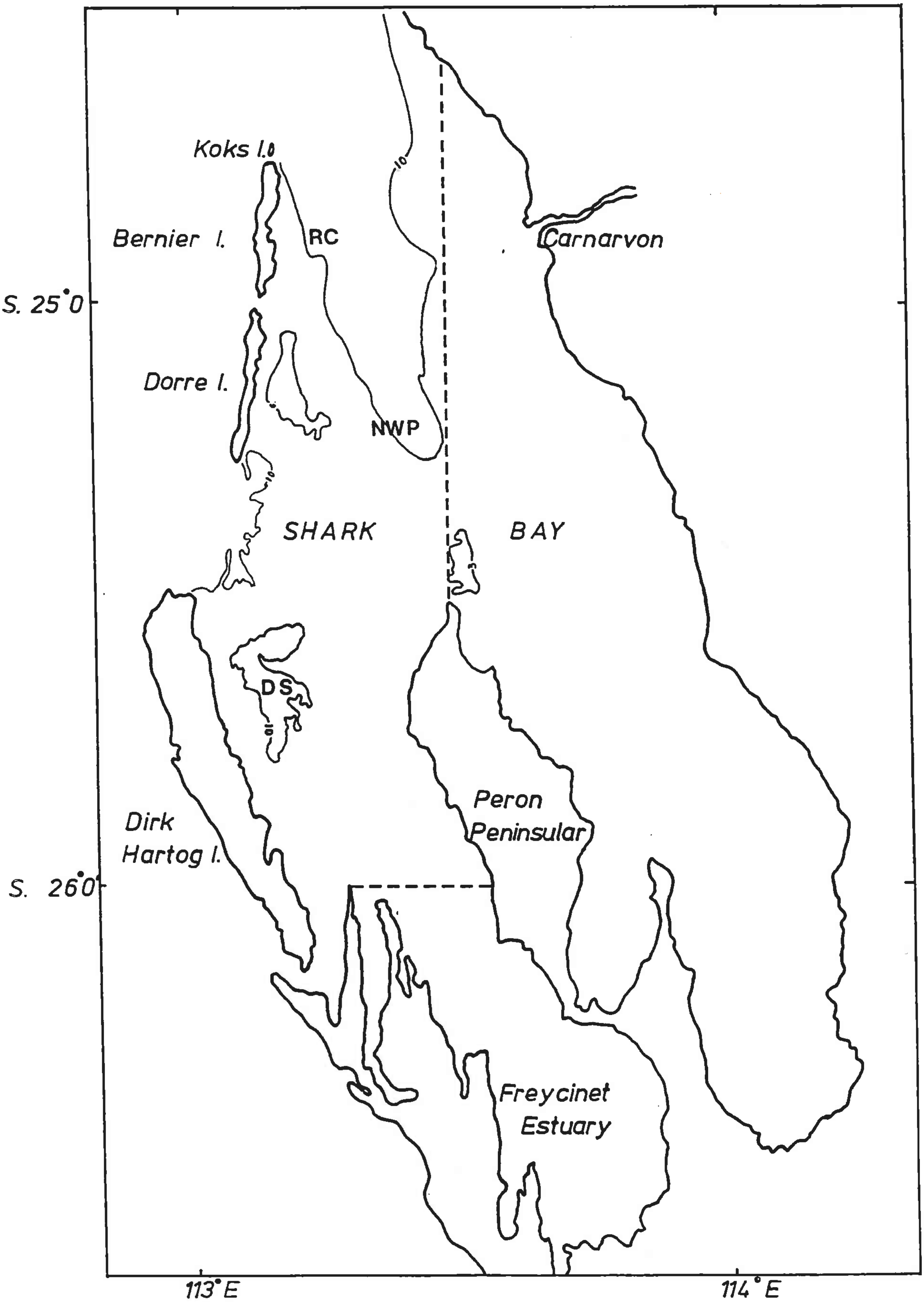
3.1.1. Gonad Cycle and Breeding Season

Samples for gonad index values were taken on a 2-monthly basis from November 1983 to May 1986, although monthly samples were taken where possible between March and November 1985. It was planned to sample three sites within Shark Bay ('Red Cliff', 'N.W. Peron' and 'Denham Sound' - Fig. 1) but during the study the abundance of adult scallops in Denham Sound became extremely low and only samples from the N.W. Peron and Red Cliff areas were available over the full time span. Sample size for each sample was planned to be 50

Figure 1. SHARK BAY, WESTERN AUSTRALIA, SHOWING SAMPLING SITES USED FOR BIOLOGICAL STUDIES AND THE PERMITTED TRAWLING AREA FOR SCALLOP VESSELS.

Sampling sites: RC = Red Cliff; NWP = N.W. Peron; DS = Denham Sound

Broken lines indicate the eastern and southern boundaries for scallop trawling.



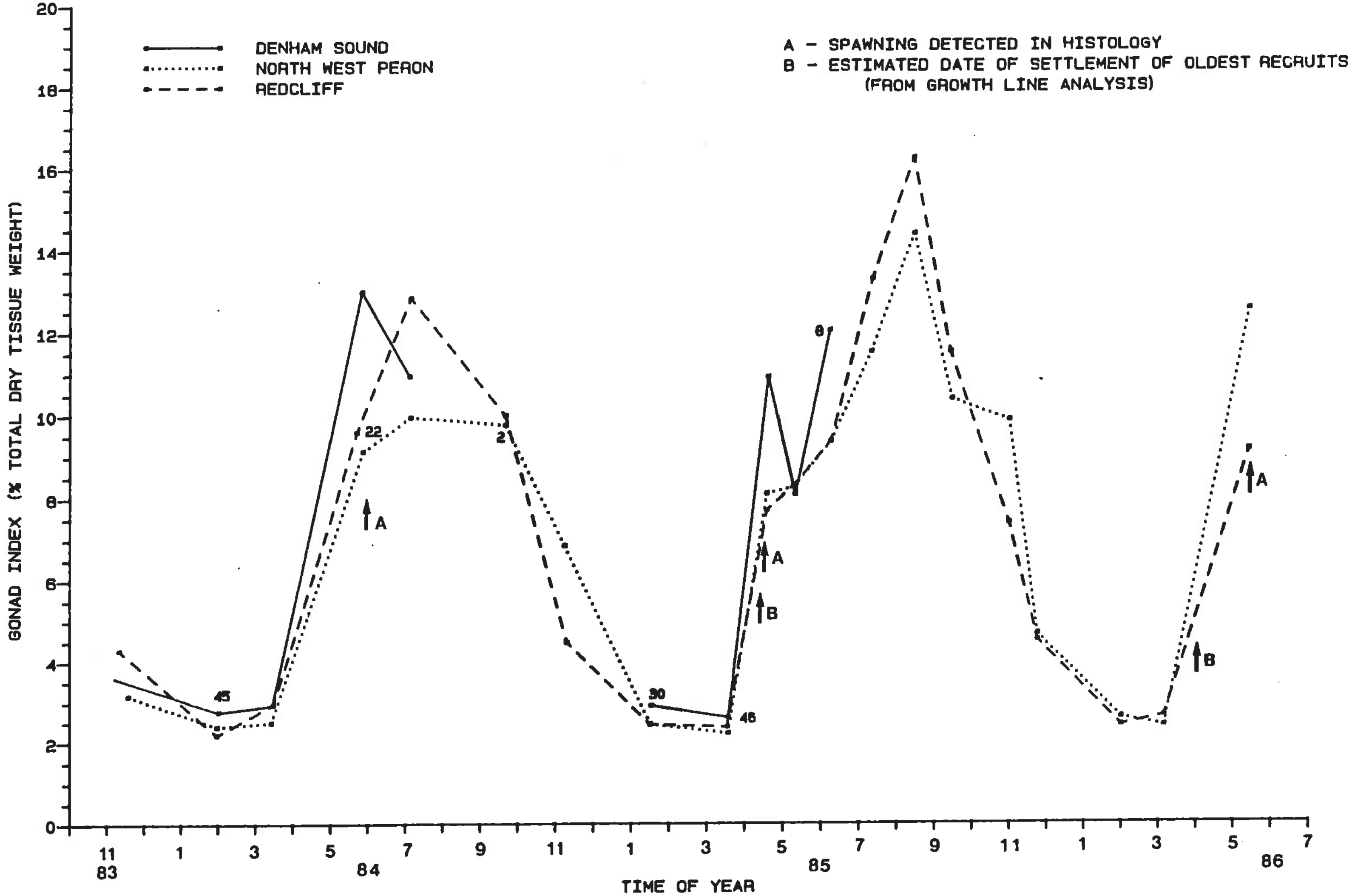
individuals per site. However, general reductions in the abundance of adults in Denham Sound, and seasonal reductions in abundance at the other two sites, caused some samples to be less than 50 individuals. Samples for histological examination were usually 15-20 individuals, although where less than 50 scallops were available for the gonad index sample, smaller samples were retained for histology.

The gonad index values (Fig. 2) were minimal in the period January to March in all years. The histological examination revealed that gonads in January were either totally regressed (resting) or in the final stages before complete regression and with only a few residual gametes. The macroscopic appearance of all gonads was, however, that they were fully regressed and the sexes were not distinguishable. By March gonads were either still in a resting stage or just commencing gametogenesis, with a few animals having mature gametes (i.e. fully developed oocytes and fully developed spermatozoa) in the follicles.

Between March and May in all years the gonad index increased rapidly. The monthly sampling in 1985, however, showed that in that year the increase in gonad index from March to April was similar to, or even greater than, the increase from March to May. The lack of any clear increase in gonad index at N.W. Peron and Red Cliff between April and May 1985, and the fall in gonad index in Denham Sound over the same period, may indicate that a spawning occurred between the April and May samples. Alternatively, for N.W. Peron and Red Cliff at least, the lack of change in the gonad index may indicate

Figure 2. MEAN GONAD INDEX OF A. BALLOTI FROM SHARK BAY.

(Sample size = 50 except where indicated)



that there was no further gonad development between the April and May samples at these sites.

Examination of the histological material associated with these samples, however, revealed indications of spawning prior to both the April (1985) and May (1984, 85 and 86) samples. The lack of change in the gonad index values for N.W. Peron and Red Cliff between April and May in 1985, and the fall in gonad index for Denham Sound over the same period, are therefore interpreted as resulting from spawning.

The gonad index values for Red Cliff and N.W. Peron continued to climb after May in both 1984 and 1985, reaching a peak in July - although the peak value in 1985 was considerably higher than in 1984. From July through to January the gonad index values declined as gonads returned to a resting condition.

Throughout the period April to January, when gonads were both increasing and decreasing in index values, the gonads showed histological evidence of spawning as well as continued gametogensis. The histological evidence of spawning was the presence of mature gametes in the spawning ducts of the gonad and empty spaces in the centres of some follicles. The follicles with empty centres, however, still had a zone of early gametogenic cell stages around their periphery (except in gonads entering the resting stage).

The gonad index and histological data, taken together, indicate that A. balloti develops mature gametes very rapidly

after the animal enters its reproductive phase and that spawning follows soon after these mature gametes are formed. These spawnings are, however, only partial spawnings and the gonad index is maintained or increased by continued gametogenesis until around July or August. From July/August onwards both spawning and gametogenesis continue, but the level of gametogenic activity is insufficient to compensate for the loss of gametes through spawning and the gonad index declines.

These data are based on the gonad cycle of scallops of 90 mm or greater. However, because of the long duration of the spawning season, recruits resulting from very late spawnings will not reach 90 mm by March or April and may not even reach this size within their first year. Indeed, late recruits as small as 40 mm may still be present in the population in June.

As a consequence of the sampling strategy, the reproductive behaviour of scallops less than 90 mm was not examined in detail. This is not seen as a major problem, however, as such animals usually make up only a small proportion of the adult population during the spawning season. Also, notes on the gross gonad condition of smaller scallops were made during the dissection of scallops from the whole size range present in each sample. (These scallops were collected and dissected for the studies on seasonal effects on meat weight/shell height relationships - Section 3.3). These data indicate that by June scallops as small as 50 mm were commencing gonad development, although smaller animals were

still immature. Presumably these small (i.e. <50 mm scallops) develop sexually a little later in the year, although no specific data are available.

Scallops smaller than 90 mm show regressed (or immature) gonads (the two conditions are not distinguishable macroscopically) during the same period of the year as large scallops. These data indicate that the gonad cycle for scallops smaller than 90 mm is similar to that of scallops greater than 90 mm, although late recruits may not mature until June or July.

Support for the interpretation of commencement of spawning soon after commencement of gonad development by larger scallops came from determining the time of settlement of the largest recruits recovered during trawling later in the year (November). The approximate age of juvenile *A. balloti* can be determined by counting the pigmented rings on the left (upper) valve of the shell. These rings are laid down daily (Joll, in press), allowing the time of settlement to be deduced. Data available from counting the rings of the largest recruits detected in November 1985 and 1986 indicated that these animals settled around mid-April to early-April respectively. As larval life is of the order of 2-3 weeks, this indicates that these animals arose from spawnings around mid-March to early April.

Nevertheless, very early spawnings do not appear to be contributing the bulk of the recruitment. The largest recruits (on which the age determinations were made) were in

the size range 70-80 mm in November, but the bulk of the recruitment detected in surveys in November from 1983 to 1986 came from animals which were around 40 to 60 mm in November (e.g. Figs. 3 and 4 - see section 3.2). These animals are presumably not derived from these very early spawnings. Furthermore, the latter part of the spawning season (i.e. August/September onwards) does not appear to contribute significantly to the recruitment, since there were no major groups of small scallops appearing in samples taken after November.

3.1.2. Recruitment

As far as can be determined, the recruits settle generally in areas which also form the adult habitat or potential habitat. The swimming ability of animals less than 30 mm appears to be almost nil (Joll, unpub. data). Therefore there does not appear to be any appropriate mechanism (nor any need to infer a mechanism) which would permit movement of very small juveniles from any settlement or 'nursery' grounds to the areas of the fishery where they are detected in surveys in November.

Nevertheless, recruitment into an area is not always successful (probably due to a lack of larvae being delivered to the area). Consequently, an adult stock in an area may not necessarily be substantially replenished by a new group of recruits. Conversely, successful recruitment may occur in an area where there are currently very few adults. The low density of adults in the area is merely a reflection of

chance factors affecting the supply of larvae in previous years, rather than indicating an area inherently unsuitable for successful recruitment. As a consequence, the location of areas of recruitment can vary from year-to-year.

3.1.3. Fecundity

The fecundity of a species (i.e. the number of eggs spawned) and its method of spawning (e.g. broadcast spawner, egg brooder) are very important aspects of its reproduction. Furthermore, these aspects of fecundity have a strong bearing on the form of any stock-recruitment relationship.

Measurements of fecundity made during this study were counts of the number of eggs spawned by females at a single spawning. Scallops were collected from an area off Fremantle in October 1984 and November 1985, when the mean gonad indices for scallops from that area were 12.4 and 13.9% respectively. Scallops from Fremantle were used because of the difficulty in successfully transporting scallops from Shark Bay to the laboratory. Nevertheless, there is no reason to believe that fecundity values obtained for scallops from Fremantle would differ markedly from those of Shark Bay scallops of similar sizes.

Females were artificially stimulated to spawn while individually isolated in 20 l. aquaria. Saucer scallops are broadcast spawners and release their eggs into the surrounding water. For the October 1984 sample, the estimates of fecundity at a single spawning ranged from

around 200,000 to 1,600,000 eggs (Table 4). For the November 1985 spawning values of 4,500,000 to 13,400,000 eggs were recorded. A feature of these results is the wide variation in fecundity at a single spawning of different individuals.

There was a significant correlation between fecundity and size ($p<0.01$) across the two samples, but no significant correlation with size within either of the individual samples.

TABLE 4 ESTIMATED FECUNDITY OF SCALLOPS AT A SINGLE SPAWNING.

A) Fremantle, October 1984

	Size of female (mm)	Estimated Fecundity (No. of eggs)
1)	90	1,580,000
2)	96	220,000
3)	92	1,240,000
4)	90	940,000

B) Fremantle, November 1985

	Size of Female (mm)	Estimated Fecundity (No. of eggs)
1)	120	4,506,000
2)	118	13,400,000
3)	117	9,035,000
4)	114	7,915,000
5)	97	4,255,000
6)	112	10,340,000

What is not known, and may be a major factor causing this variation, is the spawning history of the animal prior to collection. The low individual values, and the low values for October 1986 generally, may reflect the fact that a spawning had occurred shortly before the sample was taken and

that these animals did not have a large quantity of mature oocytes available to be spawned. Fecundity at a single spawning is undoubtedly affected by size as well, but to demonstrate this conclusively it would be necessary to standardise the prior spawning histories of animals examined.

Despite the large variation in individual estimates, the data indicate that A. balloti is highly fecund. Furthermore, because animals probably spawn at least several times in a breeding season, the total number of eggs spawned will clearly be very large.

Summary

Spawning of A. balloti in Shark Bay occurs from early April until December or early January. However, very small scallops may not commence spawning until around June or July. At the commencement of spawning the most advanced recruits are approaching 12 months of age, although the bulk of the recruits are probably around 9 or 10 months old. Although the breeding season is long, the early and latter parts do not appear to produce the bulk of the recruitment (at least in the years under study). There were no major differences in gonad cycle between N.W. Peron and Red Cliff sites and the data available for Denham Sound indicate that the gonad cycle there is similar to the rest of Shark Bay. Overall reproductive success, however, varied between areas - presumably as a result of factors affecting the supply of larvae. Fecundity at a single spawning was very high, with values ranging from 200,000 to 13,000,000 eggs being recorded. Because scallops spawn several times in a breeding season, the total fecundity would be considerably higher than the single spawning values.

3.2 GROWTH

Growth was examined by the progression of modal groups through length-frequency (shell height) samples and by the recapture of tagged individuals. Length-frequency distribution (LFD) samples, were obtained concurrently with gonad samples taken with 50 mm mesh. (Note: Some gonad samples were obtained using 100 mm mesh, but LFD samples from these are not examined because of the different selection characteristics of this mesh - see section 3.5). Individually numbered, tagged scallops were released on 3 principal occasions - November 1984, November 1985 and March 1986. Recaptures were by both the research vessel "Flinders" and by commercial vessels.

The most complete sequence of LFD samples derived from 50 mm mesh comes from the Red Cliff and N.W. Peron areas and covers the period November 1984 to May 1986 (Figs. 3 and 4). The recruit group (30 mm to 75 mm size-classes), apparent in samples from both locations in November 1984, formed a more clearly defined modal group in the January 1985 sample. By March 1985 approximately 50% of the recruits at N.W. Peron had reached the 90 - 94 mm size-class while at Red Cliff the bulk of the recruits were still smaller than 90 mm. Growth continued during April and May, with increasing percentages of the recruits achieving sizes greater than 90 mm in successive samples. By May the bulk of recruits at both sites were larger than 90 mm.

A new recruit group was apparent in samples taken in September 1985 from both locations. By March 1986 the largest sized recruits at N.W. Peron had merged with the residual stock from the previous year, although a substantial proportion of recruits were still smaller than 90 mm. At the Red Cliff site, as in March 1985, the bulk of recruits

Figure 3. LENGTH FREQUENCY (%) OF Amusium balloti FROM NW PERON AREA
(Arrows indicate growth of modal groups from sample to sample.)
(Dashed line at 90 mm for reference only).

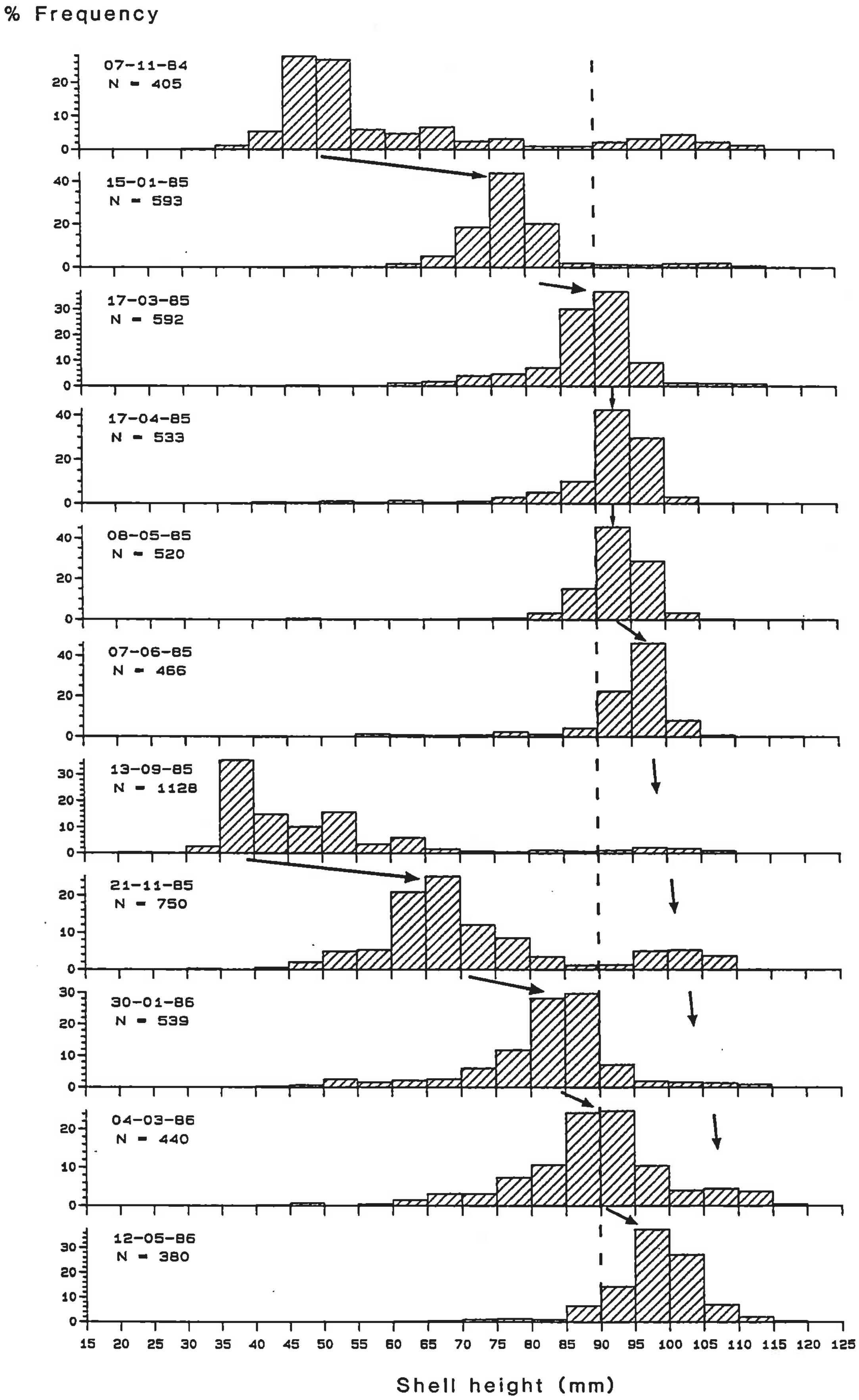
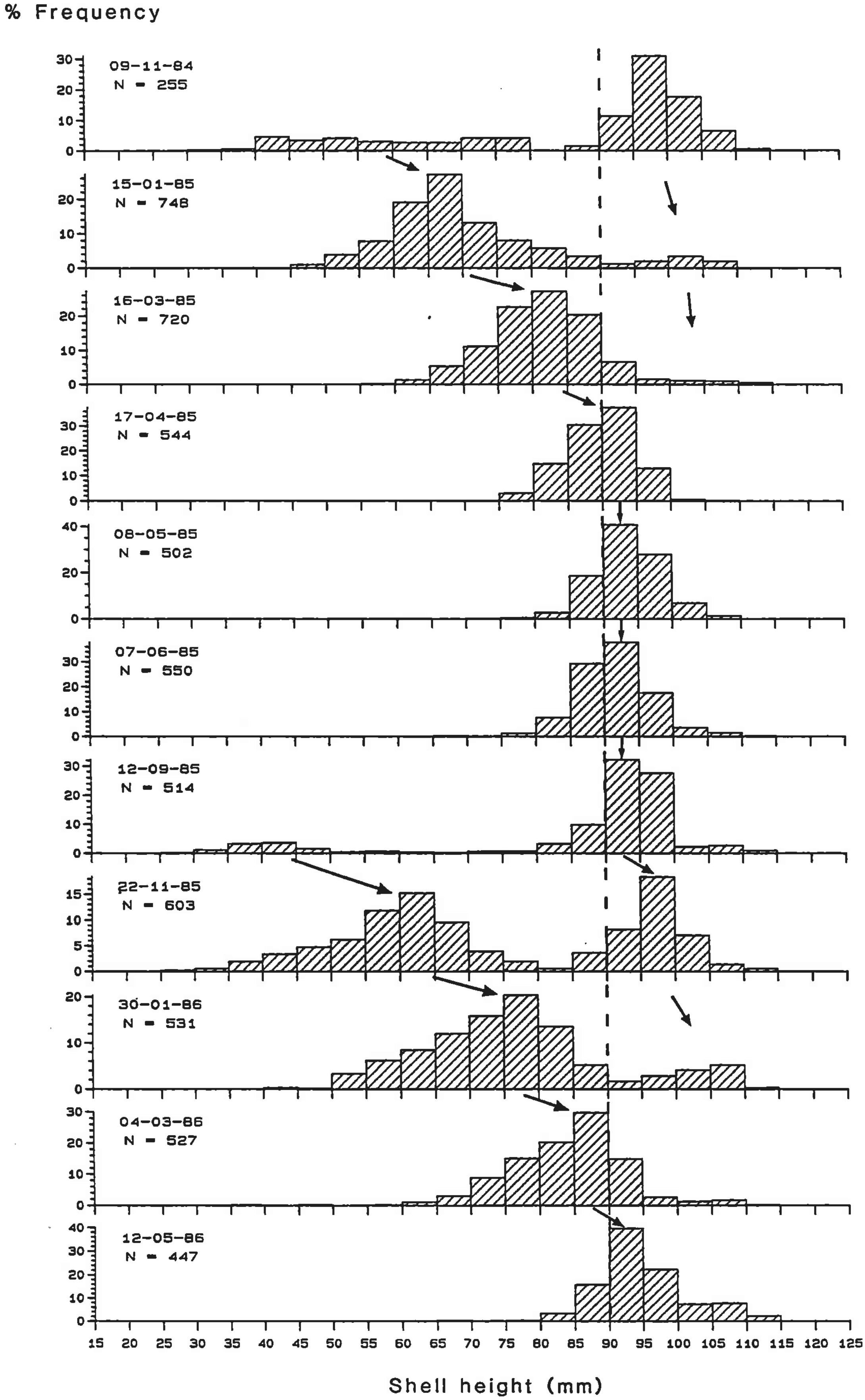


Figure 4. LENGTH FREQUENCY (%) OF *Amusium balloti* FROM REDCLIFF AREA
(Arrows indicate growth of modal groups from sample to sample.)
(Dashed line at 90 mm for reference only).



were still smaller than 90 mm. The smaller size of recruits at Red Cliff in March of 1985 and 1986 suggests that growth may be slower at that site. As in the previous year, growth between March and May resulted in the bulk of recruits at both sites achieving sizes of 90 mm or greater by May.

Tagging data supported the pattern of growth indicated by modal progressions, as well as providing details on growth of scallops outside the main modal groups. The growth of tagged scallops from November to March in two years (November 1984 to March 1985 and November 1985 to March 1986) (Table 5) showed that scallops in the recruit groups in November (i.e. scallops up to about 75 mm) achieved sizes of around 90 mm by March. Most of the tag recapture data, however, refers to animals from the N.W. Peron area, so that these growth data will reflect the apparently higher growth rate at that site. The data also indicate that the growth rate of smaller recruits (30-39 and 40-49 mm groups) was higher than that of the larger recruits, enabling them to reach almost 90 mm by March.

Tagged scallops released in mid-March 1986 were recaptured by the commercial fleet after the season opened on 15 May in that year (Table 5). These data show that substantial growth occured between March and May and that scallops between 70 and 89 mm, many of which would have been considered too small to be fished in March, achieved commercial sizes by May. Because of the use of size-classes in the data presentation of Table 5, the actual growth achieved by the 50 recaptured scallops from the 90-99 mm is not quite so obvious as that of the smaller scallops. The mean final size for this group was 100.9 mm, but the actual mean increase in size from March to May of tagged

TABLE 5: GROWTH OF TAGGED SCALLOPS RELEASED IN SHARK BAY

(A) NOVEMBER 1984 TO MARCH 1985

SIZE-CLASS AT RELEASE (MM)	MEAN SIZE OF ANIMALS RECAPTURED IN MARCH (MM)	
	A). NOV. 1984 TO MARCH 1985	B). NOV. 1985 TO MARCH 1986
30 - 39	87.7 (3)	-
40 - 49	88.4 (7)	86.5 (129)
50 - 59	87.5 (49)	90.1 (252)
60 - 69	93.1 (16)	93.5 (260)
70 - 79	96.4 (18)	96.7 (96)
80 - 89	99.1 (8)	99.0 (30)
90 - 99	102.8 (30)	104.5 (164)
100 - 109	108.8 (13)	110.2 (92)

(B) MARCH TO MAY 1986

SIZE CLASS AT RELEASE (MM)	MEAN SIZE OF ANIMALS RECAPTURED IN MAY (MM) (15 MAY TO 30 MAY)
60 - 69	82.0 (1)
70 - 79	92.2 (6)
80 - 89	97.5 (59)
90 - 99	100.9 (50)
100 - 109	107.5 (13)
110 - 119	112.6 (5)

Number in brackets is the number of scallops recaptured.

scallops in this size group (which represents the bulk of the recruit group) was 7.6 mm.

The growth data derived from both tagging and an examination of modal shifts through LFD samples indicate rapid growth in the first year of life. Early recruits from the spawning season of one year reach sizes of 30+ mm in September and become vulnerable to capture by trawls. Growth of the recruits continues to be rapid, with scallops over the size range 30-70 mm in November reaching a size near 90 mm by March of the following year. Recruits from the latter part of the spawning season are, however, somewhat smaller by March. Between March and May there is further growth, with animals as small as the 70-79 mm size class in March achieving sizes greater than 90 mm by May. Scallops greater than 90 mm in March also add useful growth over this time. Growth in June, July and August appears to slow down considerably and little further growth is achieved until the end of the spawning season.

Summary

The growth of recruits of *A. balloti* in Shark Bay is rapid, with the major portion of a year class achieving sizes around 90 mm by March of the following year. Continued growth between March and May by both early and late recruits results in the bulk of the population being greater than 90 mm by May.

3.3 VARIATIONS IN MEAT RECOVERY WITH SIZE AND SEASON

The percentage recovery of meat (adductor muscle), as well as the actual size of the adductor muscle of *A. balloti*, varies both with size of the scallop and time of year. The major factor associated with the

time-of-year variations in meat yield is the reproductive condition. Research on other species of scallops has shown that the adductor muscle is used as a "store house" of nutrients for the building and maintenance of the gonad. While the gonad is immature,or in a resting phase between spawnings, the scallop directs its physiological resources to the development of the adductor muscle. Once gonad development is initiated, these resources are re-directed to building the gonad. Furthermore, proteins laid down in the adductor muscle are catabolised (broken-down) to assist in development and maintenance of the gonad.

As a consequence of these physiological changes both the wet weight of the adductor, and the percentage of dry tissue in it, actually decrease during gonad development and spawning. In addition, the percentage recovery of meat from the whole weight also declines as a result of increasing gonad weight, since the increase in gonad weight causes a decrease in the percentage of the total body weight made up by the adductor muscle.

Data on changes in the percentage meat recovery and adductor muscle size were obtained from two different sources. Changes in the size of meats were examined by measuring meat weights of scallops from across the full size range of scallops available at a particular time. Material was drawn from the trawl shots used to obtain the gonad sample and length-frequency distribution data. Data on percentage meat recovery, and percentage of dry tissue in the adductor muscle, was derived from animals sampled for the gonad sampling programme.

No significant year-to-year differences were detected in the pattern of changes in either percentage meat recovery or percentage of dry tissue

in the adductor muscle, and results for the various years were combined. On a seasonal basis, percentage meat recovery and percentage of dry tissue in the adductor muscle were at a maximum in the period January to March (Fig 5). From March (when gonad development begins) both factors decreased, reaching a minimum in September (just after gonad development is at a maximum) before increasing again. Nevertheless, although percentage meat recovery was maximal in January to March, this factor must be considered in the context of sizes of scallops available and the actual weight of the adductor muscle of scallops of various sizes.

Data on meat weights showed an exponential relationship between the meat weight and size of the shell. They also showed that seasonal variations in meat weight resulting from changes in gonad condition fitted closely the form of a sine curve. These seasonal variations were, however, more important for larger (mature) scallops than for small, immature scallops. There were also some differences between areas, with meats from scallops from Denham Sound being slightly heavier (around 10% greater) than for animals of the same size and at the same time of year at N.W. Peron and Red Cliff.

The meat weight data were reduced to a single mathematical expression for determining meat weight for animals of different size and at difference times of the year. The area differences were also incorporated. Expressed in a logarithmic form the relationship is:

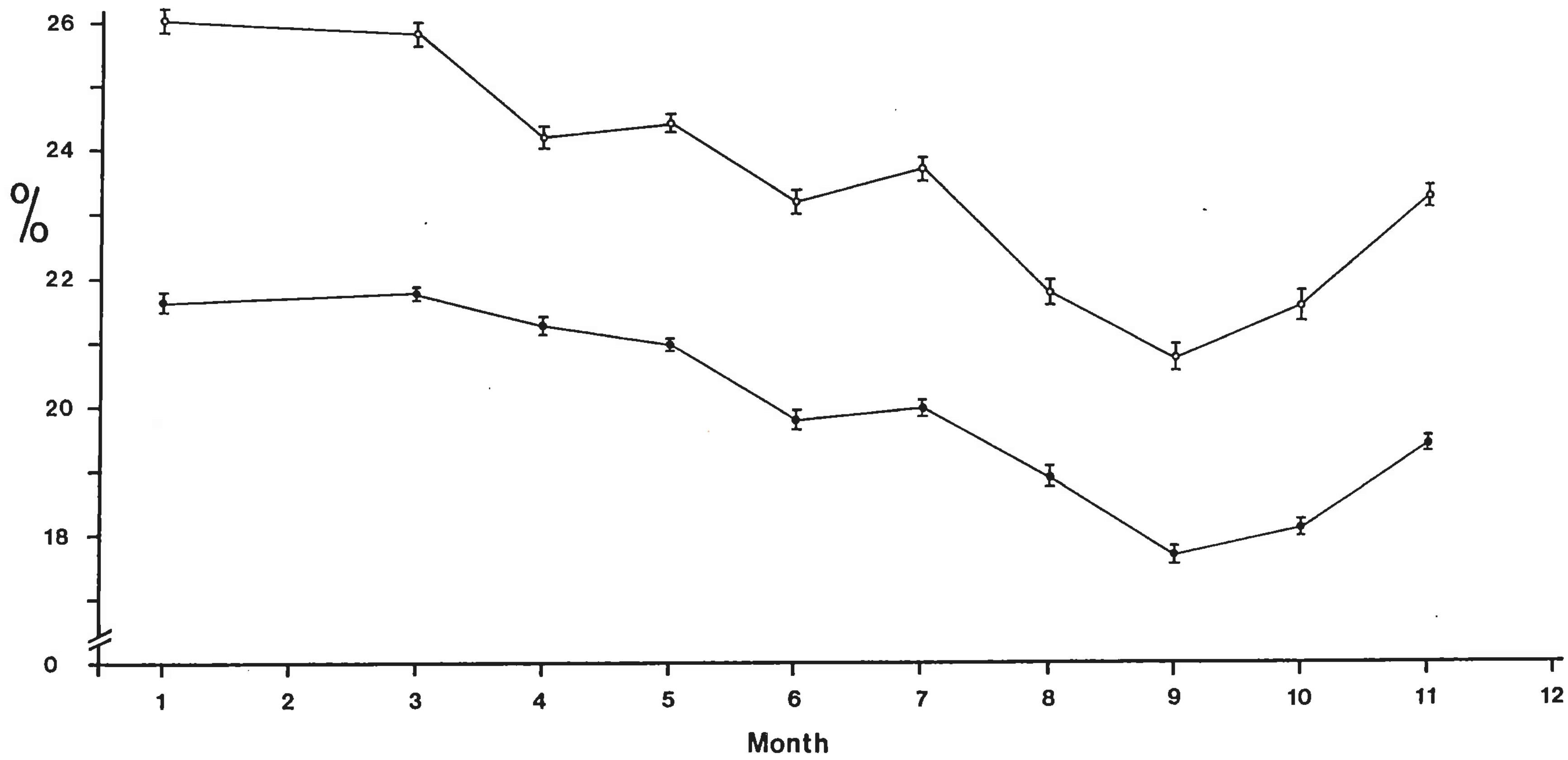
log wet meat = 3.6163 log length - 1.1241 sine season + (.28 log length x sine season) + .1127 location - 13.9533.

Figure 5. MEAN MONTHLY PERCENTAGE MEAT RECOVERY AND PERCENTAGE DRY TISSUE IN THE ADDUCTOR MUSCLE OF A. BALLOTI FROM SHARK BAY.

o = Percent meat recovery of whole weight

● = Percent dry tissue in the adductor muscle

(Bars are ± S.E.)



where: length = shell height in mm.

season = 2π day/365 (in radians), where day is the relative day of the year (i.e. 1st January = 1.

location = 1 for Denham Sound; 0 for N.W. Peron and Red Cliff

(Note: all logs are natural logarithms).

Examination of the length frequency distributions (Figs. 3 and 4) shows that in 1985 and 1986 only about 50% of the population at N.W. Peron was greater than or equal to 90 mm by March, while at Red Cliff only about 20% had achieved this size in March. Growth between March and May resulted in significant increases in size and a significant increase in the proportion of the population achieving a size of 90 mm or greater.

Consideration of predicted meat sizes for scallops of different shell sizes over this period (Table 6) shows that scallops smaller than 90 mm have meats which are below the generally accepted criterion of 40 meats per pound (equivalent to a meat weight of 11.4 g) for export scallops. Growth over the period March to May, however, results in most scallops achieving sizes of 90 mm or greater and having meats weighing 11.4 g or greater. There is some small loss of meat weight from seasonal changes over the period April to May, but this is more than offset by the gains from growth.

TABLE 6 PREDICTED MEAT WEIGHTS OF VARIOUS SIZE SCALLOPS AT SELECTED DATES FROM MARCH 1 TO MAY 15.

(Meat weight in g.)

(Count per pound equivalents indicated in brackets.)

DATE	SHELL HEIGHT (MM)		
	85	90	95
March 1	9.2 (49)	11.4 (40)	14.1 (32)
April 1	9.3 (49)	11.6 (39)	14.4 (32)
April 15	9.3 (49)	11.6 (39)	14.3 (32)
May 1	9.2 (49)	11.4 (40)	14.1 (32)
May 15	9.0 (50)	11.2 (41)	13.8 (33)

Summary

Meat weight, percentage recovery of meat from the whole weight and percentage of dry tissue in the adductor muscle vary with size of scallop and the season. Percentage meat recovery and percentage of dry tissue are maximal over the period January to March, but decline to a minimum in September. Maximum meat weights for any size of scallop occur in March/April. However, growth of scallops between March and May results in the bulk of the population having meats larger than the criterion level of 40 meats/pound by May.

3.4 CATCHABILITY (VULNERABILITY TO FISHING GEAR)

3.4.1. Seasonal

Studies to examine catchability (i.e. the vulnerability of scallops to fishing gear) were conducted at three separate times of the year (March, July and November). Because of variation in the sizes of scallops present in the populations at these times (see Figs. 3 and 4), it was also possible to examine the effect of size on vulnerability.

Estimates of vulnerability were drawn from several experiments using the Leslie-DeLury technique. This approach involves intensively fishing a closed population and examining the rate of decrease in catch per unit effort as the population is fished out. High-accuracy microwave navigation equipment was used to de-limit an area of seabed which was then trawled for 3 or 4 nights using 50 mm mesh nets.

Data from these experiments are still being analysed, but preliminary analysis indicates differences in vulnerability at different times of the year. There was also an effect of size on vulnerability, with smaller scallops being less vulnerable than larger ones. Maximum vulnerability to 50 mm mesh was achieved around 80 mm shell height and remained fairly constant over the range 80 - 100 mm. Vulnerability decreased almost linearly from 80 mm to 30 mm, at which size scallops had almost zero vulnerability. There were also

indications that very large scallops (i.e. greater than 100 mm) may have somewhat reduced vulnerability.

The preliminary analysis indicates that vulnerability (at night) of scallops larger than 80 mm was around 60% in March and November, while in July the value was around 40%. These figures indicate that in November and March, 60% of all scallops of sizes 80 mm and over in the path of a 50 mm mesh trawl will be caught. Thus, if an area is swept three times by a trawl, 94% of the original population of scallops greater than 80 mm will be caught. In July, three sweeps of an area by trawling gear will catch 78% of the original population.

3.4.2. Diurnal

It is generally accepted in the fishery that there is a difference in vulnerability of scallops between night and day. To examine this proposition, trawls were conducted over adjacent areas of seabed during the day and night in March 1986. Using high-accuracy microwave navigation equipment, eight 2 km long trawl paths, spaced 50 m apart, were selected and fished over two days and two nights. Each trawl path was fished only once each day, with four trawls fished each day and four fished each night.

Trawling speeds ranged from 1.8 to 3.0 knots, but were generally around 2.5 to 2.7 knots. After adjusting the catch rates for the different vessel speeds the mean catch rates

per trawl (± S.E.) at 2.5kts for the two days and two nights were:

21 March, 1986:	Day	1140	(±165)	(N = 4)	
	Night	1081	(±163)	(N = 3)	(1 shot fouled by weed).
22 March 1986:	Day	1907	(±255)	(N=4)	
	Night	2065	(±228)	(N=4)	

The catch rates on the night and day trawls for the same calendar day were not significantly different from each other (t-test, $P<0.05$). These data, therefore, do not support the generally accepted notion of differences in vulnerability between night and day. There were, however, significant differences (t-test, $P<0.05$) between the two sets of day trawls and the two sets of night trawls, with catch rates on 22 March 1986 being higher than on the 21 March 1986. The difference cannot be due to any fishing-out effect, as the catch rates are higher for the second day. These data support another generally accepted tenet of very short-term (i.e. from one day to the next) changes in vulnerability.

<u>Summary</u>

The vulnerability of scallops to 50 mm mesh trawl gear varies with size and with season. Vulnerability is virtually zero at 30 mm shell height and reaches a maximum around 80 mm. Vulnerability of 80+ mm animals at night was estimated at about 60% in March and November and about 40% in

July. Comparisons of catch rates between day and night did not support the general belief of differences in vulnerability between day and night. However, the data showed that significant differences in catch rates can occur from day to day.

3.5 COMPARISONS OF PRAWN AND SCALLOP MESH TRAWLS

Comparisons of prawn (50 mm) and scallop (100 mm) mesh flat trawls were carried out during night trawling in November 1985 and March 1986. These times of year were selected because they are times when scallops of quite different size frequencies predominate. This provided the opportunity to examine the catch characteristics and relative selective effects of the two mesh types over a range of sizes of scallops. Records were also kept of the by-catch of prawns by the two types of gear, as well as the by-catch of fish and other animals (commonly referred to as "trash").

The comparisons were done using the twin-rigged research vessel "Flinders", with a scallop net set on one side and a prawn net on the other. In an attempt to approximately equalise the drag between the two nets (so that the vessel's steerage was not unduly affected) the scallop net was made larger (10 fm headrope) than the prawn net (6 fm. headrope). The ground chain was set two links ahead of the footrope on both nets. All trawls were of either 20 or 30 minutes duration.

The catch of scallops, prawns, "trash" and other items for both nets for each trawl shot are shown in Table 7 and the length frequencies of scallops in Figures 6 and 7. The length frequency data show that prawn nets will readily catch scallops as small as 30 mm. In fact, the large catches of scallops by the 50 mm mesh in November compared with those

TABLE 7 CATCHES OF PAIRED TRAWLS BY SCALLOP AND PRAWN NETS

		PRAWN NET (50 MM MESH) (6 FM.)			SCALLOP NET (100 MM MESH) (10 FM.)		
DATE	TRAWL NO.	SCALLOPS (NO.)	PRAWNS (NO.)	TRASH (BASKETS)	SCALLOPS (NO.)	PRAWNS (NO.)	TRASH (BASKETS)
November 1985	1	605	73 K, IT	½	0	0	-
	2	777	89 K, 2T	3/4	79	0	-
	3	324	74 K	½	102	0	-
	4	341	78 K	½	31	0	-
	5	157	13 K	1	87	0	-
	6	166	6 K	½	45	0	-
March 1986	1	614	19 K	1¼	362	0	-
	2	160	48 K, 2T	?*	57	0	-
	3	1 839	127 K	3	1 779	(11C)	?*
	4	824	79 K, 2T	2½	270	0	-
	5	197	79 K	2½	56	0	-
	6	121	84 K, 6T	2¼	28	0	-
	7	197	209 K, 7T	2½	148	0	-
	8	280	112 K, 7T	2½	167	0	-
	9	60	97 K, 4T	1¼	28	0	-

* Regular "trash" component distorted by a large catch of drifting seagrass.

Key: K = King Prawns, T = Tiger Prawns, C = Coral Prawns.

1 Basket approximately 0.06 cu. metre in volume.

Figure 6. LENGTH FREQUENCY (%) OF SCALLOPS CAUGHT IN SCALLOP (100 mm) AND PRAWN (50 mm) MESH PAIRED TRAWLS IN NOVEMBER, 1985.

(Dashed line at 90 mm for reference only).

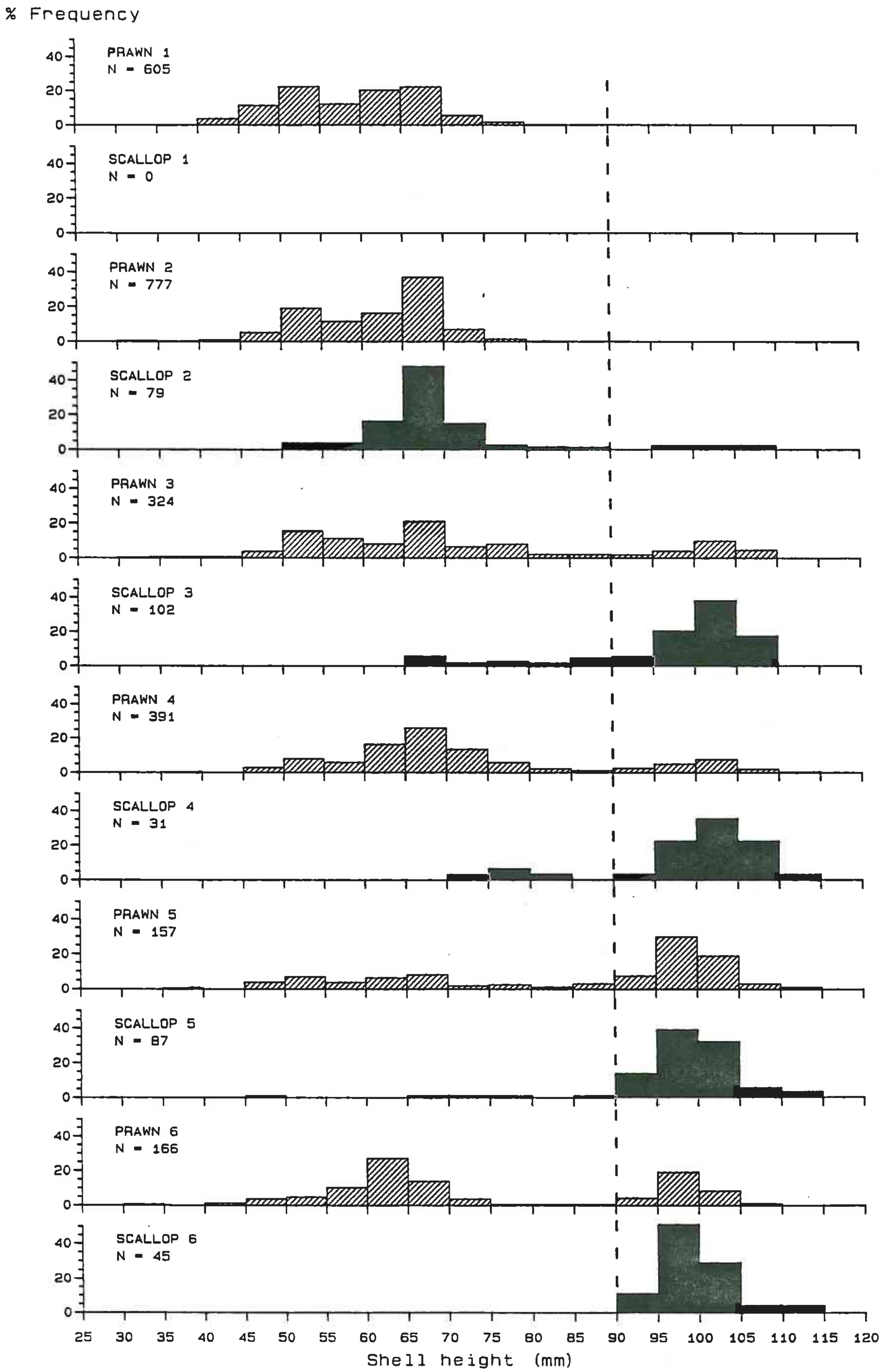


Figure 7. LENGTH FREQUENCY (%) OF SCALLOPS CAUGHT IN SCALLOP (100 mm) AND PRAWN (50 mm) MESH TRAWLS IN MARCH, 1986.

(Dashed line at 90 mm for reference only).

* = Sub-sample of total catch.

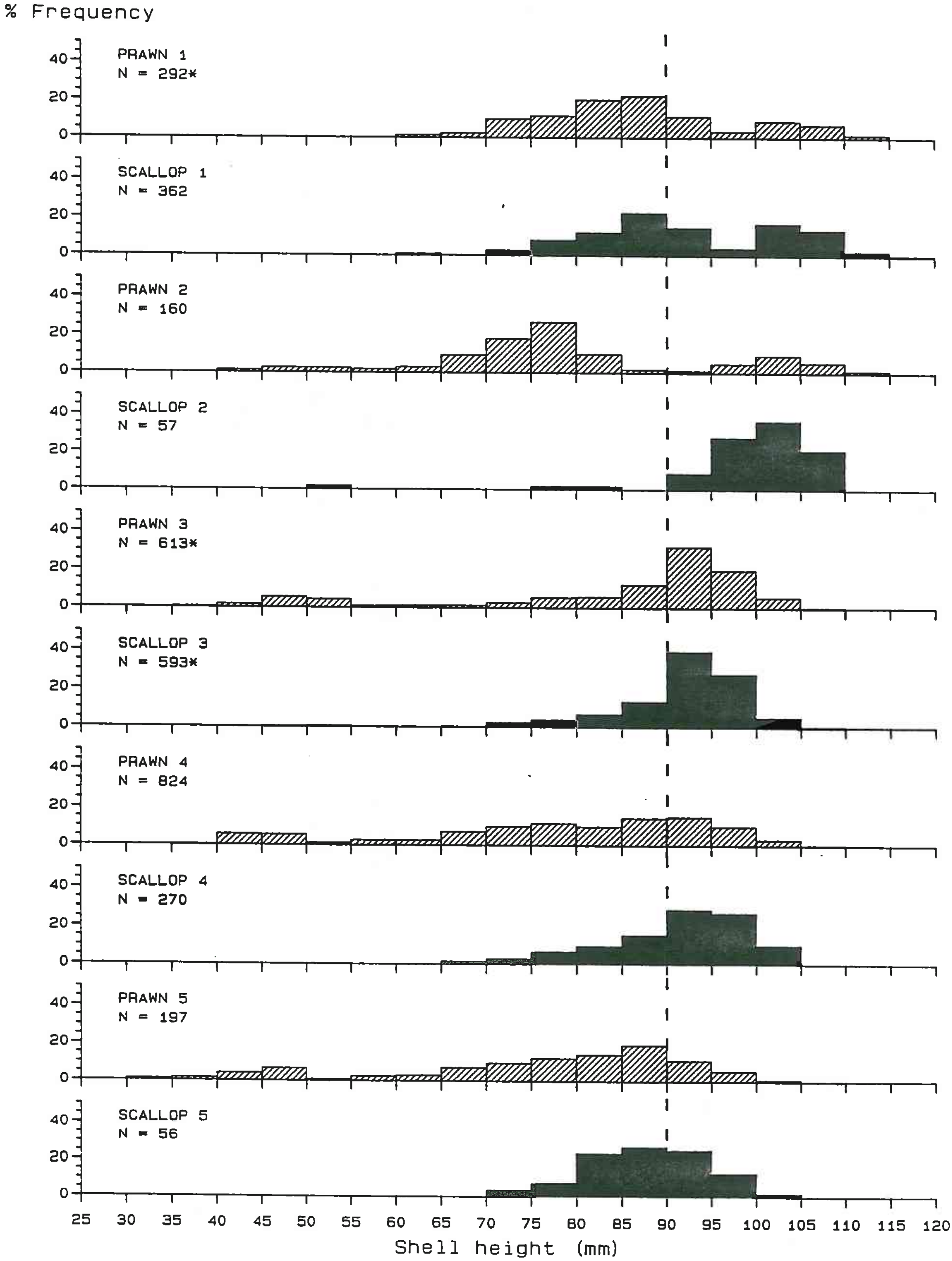
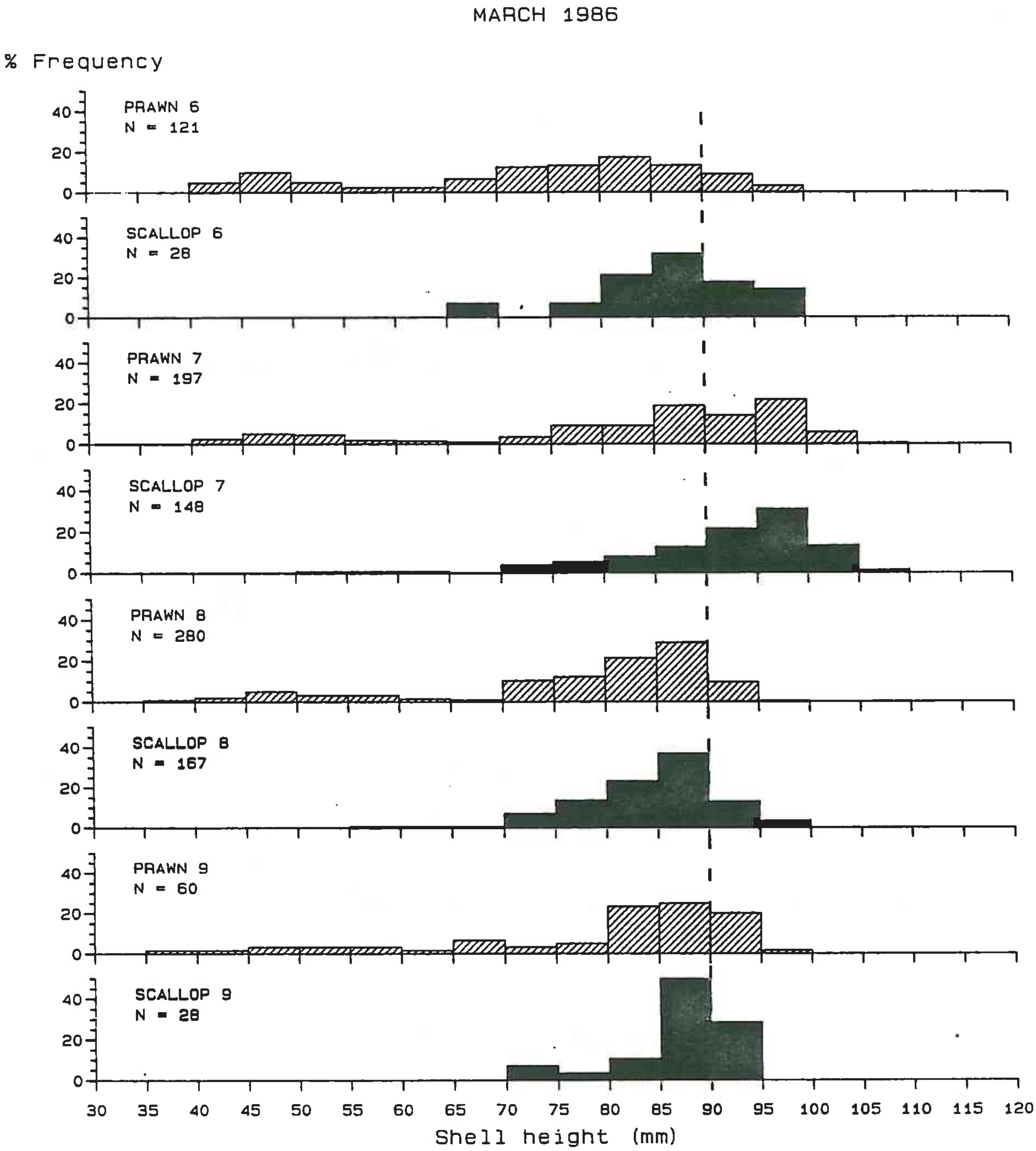


Figure 7. Continued.



taken by the 100 mm mesh were primarily the result of the capture of small scallops by this net. However, there were other characteristic differences between catches of the two nets. The first was that the scallop net caught no prawns, except for a few coral prawns in one shot (Note: coral prawns were not specifically recorded for the prawn net catches). The second was that the amount of "trash" taken by the 50 mm mesh net was greater.

The "trash" was composed primarily of small fish, although crabs, various types of molluscs and echinoderms, seagrass and small pieces of sponge may contribute between 10 and 20% of its volume. In the tests the 6fm prawn net took between ½ and 3 baskets (0.03 to 0.18 cu. m. in volume) of "trash" per shot. The larger 10 fm scallop net, on the other hand, took only small amounts of "trash", with the maximum amount caught in the tests not exceeding 1/8 basket (less than 0.01 cu. m.). The "trash" catch of the scallop net was virtually devoid of the small fish occurring in the prawn net "trash" and was typically composed of larger sized crabs, molluscs, echinoderms and pieces of sponge.

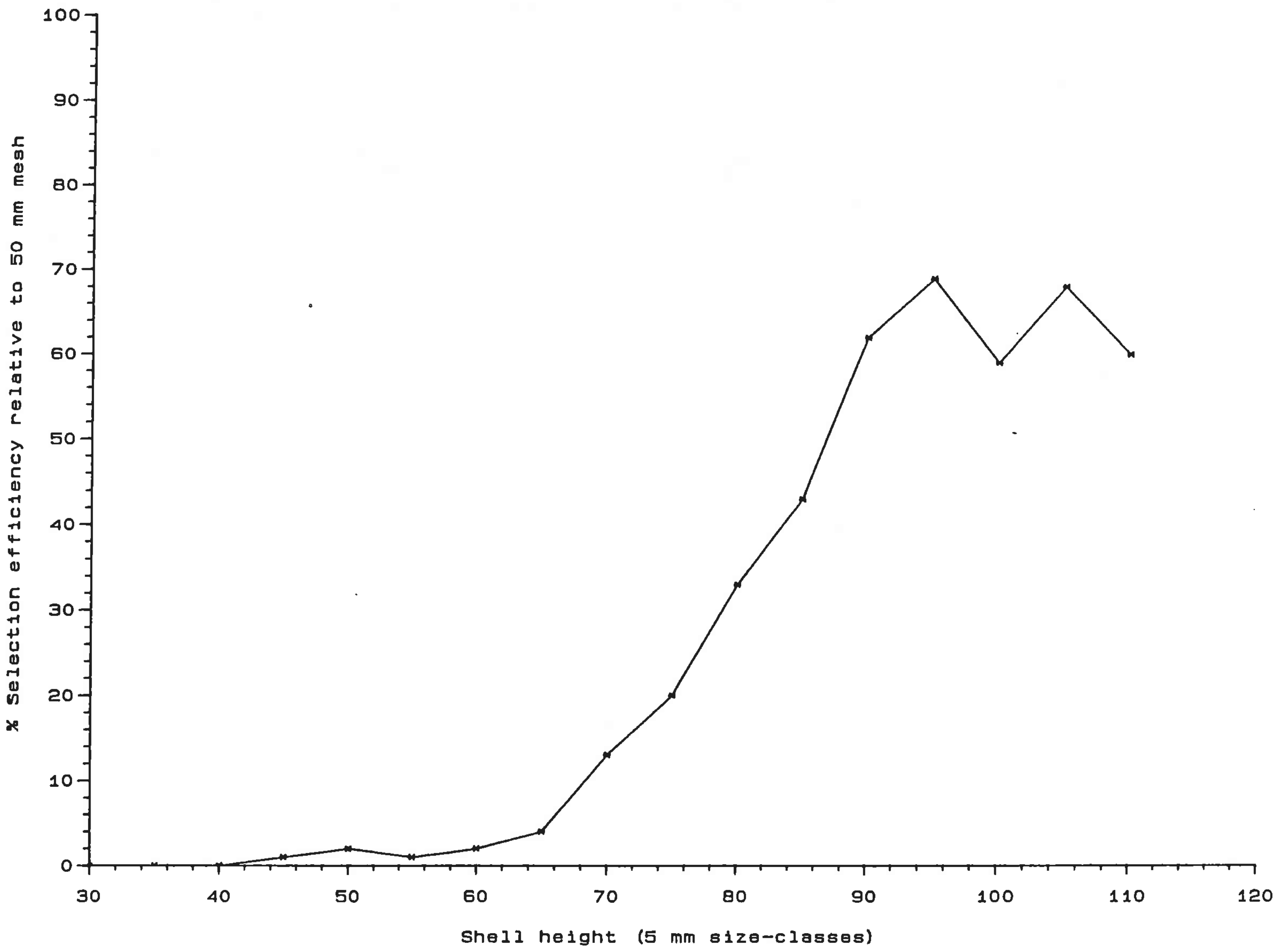
The bulk of the "trash" by-catch in prawn nets has no direct commercial value, except for squid and cuttlefish and the occasional specimen shell. Nevertheless, the squid component is significant, with a total production of squid from Shark Bay prawn vessels in 1985 and 1986 of 32 and 27 tonnes, respectively. The "trash" fish itself is also used to attract larger fish (particularly tuna) around the vessel for capture by hook and line. The ancillary catch of tuna from this source by prawn vessels in 1985 and 1986 was 139 and 80 tonnes respectively. Both the squid and tuna catches of prawn vessels provide an additional supplement to the crew's income. Some scallop vessels also take small amounts of squid and cuttlefish as by-catch and sometimes take tuna.

The relative selective effects of the two nets were examined by determining the ratio of the catches of scallops of different size classes (adjusted for the differences in headrope lengths of the nets). However, because it was not possible to "tune" the scallop net by continual comparison of a pair of nets, it is likely that this net was not catching at maximum efficiency. The prawn net, on the other hand, was fully "tuned", as it had been used in a paired situation over several nights previously in both the November and March experiments.

The results indicate (Fig. 8) that the scallop net had negligible selection efficiency for scallops smaller than 70 mm. Above this size the percentage efficiency of the scallop net compared to the prawn net increased steadily until around 90 mm. At sizes larger than 90 mm the relative selection efficiency of the scallop net was fairly stable at around 60% of the prawn net. This stable but lower efficiency for sizes of 90 mm and larger almost certainly reflects the lower overall catching efficiency of the scallop net, due to the fact that it was not "tuned". On the assumption that this is the case, the figure indicates that there is no difference in the selective efficiency of scallop and prawn mesh for scallops of 90 mm and larger.

Comparisons of meshes larger than 100 mm were not undertaken, but the results with 100 mm mesh suggest that tests of slightly larger mesh may be worth doing at some time. Use of mesh which selected more effectively against scallops smaller than 90 mm would remove most of the small scallops from the catch and remove or reduce the problem of product with meat counts over 40 per pound. It could also be used to reduce the exploitation rate of the scallop fleet (other factors remaining equal). This could be used to permit a slightly earlier opening of the season or as a management device to increase the

Figure 8. SELECTION EFFICIENCY OF SCALLOP MESH (100 mm) RELATIVE TO PRAWN MESH (50 mm).



proportion of stock available to the prawn fleet in its normal operations.

Summary

Scallop (100 mm) and prawn (50 mm) mesh have a similar selective efficiency for scallops of 90 mm and greater. The selective efficiency of scallop mesh decreases between 90 and 70 mm and is negligible at sizes less than 70 mm. Prawn mesh, on the other hand, catches scallops as small as 30 mm. The two mesh types also differ significantly in their by-catch. Scallop mesh caught no king or tiger prawns during the tests and very little "trash", whereas the smaller prawn net caught between ½ to 3 baskets of "trash" per trawl shot. Tests of mesh sizes larger than 100 mm would be useful in examining the potential of larger mesh sizes to improve meat counts or in a consideration of their use as a device to reduce the exploitation rate of scallops by scallop vessels.

3.6 CATCH FORECASTING

The data presented in preceding sections demonstrate that, in the years examined, the early recruits from a spawning season become catchable in 50 mm mesh by about September. By November, however, the bulk of the recruitment has grown to a catchable size (i.e. 30+ mm) using 50 mm mesh. Measurements of scallop abundance in November, when all trawling has ceased for the year are, therefore, capable of estimating both the strength and size distribution of the main recruitment as well as the abundance of residual adult stock. The variation in catchability with size of scallops between 30 and 80 mm requires, however, that the abundance of recruits is adjusted by the catchability factors related

to their size. Patterns of sampling must also be constant from year-to-year if the overall abundance indices are to be comparable.

Indices of abundance of recruit and residual scallops were determined from surveys in November from 1983 to 1986 (Table 8). The data have been separated into three areas, representing Denham Sound and two sub-areas representing the northern and southern parts of the western area of Shark Bay. The division between these two areas (Red Cliff and N.W. Peron) is approximately along latitude 25°05'S. The indices calculated are, however, raw values and are as yet unadjusted for any size-related effects on catchability or year-to-year variations in the distribution of sampling effort. Consequently, these data must be interpreted carefully.

The data indicate that in November 1983 there was a high abundance of residual stock and moderate levels of recruitment in all areas. In 1984 the residual stock indices were considerably lower, especially in Denham Sound, while recruitment indices for the three areas were moderate. In 1985 the indices of recruit abundance were considerably higher than in the previous two years, but these values are undoubtedly inflated through higher catchability, because the recruits in that year were larger than in the previous two years. The high value for the recruit index for Red Cliff for 1986 probably represents a real increase in recruit abundance in that area over the 1983 and 1984 levels, since the size of recruits in 1986 was similar to that in 1983 and 1984.

The relationship between these raw indices and the total catch taken (Table 8) is not particularly good. However, factors such as the opening date and duration of the season and the distribution and timing

TABLE 8 ABUNDANCE INDICES FOR RECRUITS AND RESIDUAL STOCKS OF SCALLOPS IN SHARK BAY FROM TRAWL SURVEYS IN NOVEMBER AND THE CATCH RESULT FROM THE FISHERY IN THE FOLLOWING YEAR.

YEAR	RED CLIFF		N.W. PERON		DENHAM SOUND		SUBSEQUENT CATCH OF FISHERY (TONNES OF MEAT)
	REC.	RES.	REC.	RES.	REC.	RES.	
1983	43	233	40	287	64	157	431 (1984)
1984	50	76	78	16	33	0.1	232 (1985)
1985	115	104	23	613	30	0.5	260 (1986)
1986	294	52	84	0.6	58	0.8	400 (1987) (estimate)

Rec. = Recruits, Res. = Residual Stock

Abundance indices are the catch rate per mile (in numbers of individuals) by 12 fm. headrope nets, 50 mm mesh, towed at 3.4 knots.

of fishing effort all affect the total catch. Nevertheless, low abundances of both recruits and residual stock in Denham Sound in the 1984 and 1985 surveys were reflected in very small catches from this area in 1985 and 1986.

The present survey technique provides a foundation for more accurate catch forecasting. Past survey data will, however, need to be adjusted for catchability factors when these are more fully analysed. Year-to-year variations in effort distribution will also need to be accommodated, by adjusting the weighting of survey data from different sub-areas. Fishery and management effects in the total catch figure will also require some adjustment.

A possible weakness in the survey/catch-prediction system is that it is geared around the timing and distribution of recruitment which have occurred over the years 1983 to 1986. If the main recruitment were to

come from the latter part of the spawning season, rather than the early part as it appears to have done in recent years, then recruits may not be of sufficient size to be catchable by November. If this were to be the case in any year, recruitment would be missed and a low recruit index determined.

The length frequencies of scallops recorded in survey trawling by the Fisheries Department in June 1978 and April 1980 (Fig. 3 in the Scallop Fishery Management Working Group Report) suggest that in 1977 and 1979 recruitment may have been from the latter part of the spawning season of those years. The possibility of late recruitments must, therefore, always be borne in mind.

The exact impact of a late recruitment on the catch from the fishery is difficult to determine. If a substantial proportion of recruits were less than 90 mm when the season opened, the ability of the scallop fleet to catch them would be hampered by the selective action of the 100 mm mesh in scallop trawls. The recruits would, however, have a higher vulnerability to the 50 mm mesh of prawn trawls and most of the catch could be expected to be taken by the prawn fleet. Whether the prawn fleet would consider it economic to process this catch, or would simply return it to the sea, is unknown and would depend on a variety of variables (e.g. price, labour costs to process the catch, price and catch rate of prawns, amount of labour available etc.).

The present survey strategy is also based around surveying areas which have a recent historical record of recruitment. It is possible that significant recruitment may occur in areas which have not recently been recorded as areas of recruitment. If this were to be the case, these areas would not be surveyed and the recruitment index would not reflect

the presence of these animals. This problem has already occurred in the Abrolhos Islands scallop fishery, where the significant recruitment areas have varied from year-to-year and 'new' (i.e. not recorded in the recent past) recruitment areas have appeared. While it is not expected that this problem would be as significant in Shark Bay as at the Abrolhos Islands, because of the large proportion of the Bay which is surveyed, it may still lead to some difficulties with future recruitment indices.

Summary

Surveys in November can be used to provide an index of abundance of recruits and residual stock. The index of abundance of recruits needs to be formulated to take into account the range of sizes present at the time of the survey, because an adjustment for the size-related effects on catchability is required. Year-to-year changes in the distribution in sampling effort also need to be considered. Currently available survey data provide a picture of the size-composition of recruits and the composition of the population in terms of recruit and residual stock. However, they are not yet sufficiently developed to be used as accurate predictors of catch. Development of techniques for adjusting for catchability and effort distribution bias in the survey data may permit their future use as catch predictors.

3.7 Estimates of total stock size and proportion of the stock caught by the fishery

The question of total stock sizes was approached by treating the fishery as a large DeLury experiment. This approach examines the decline in catch rate against the accumulated catch. It is useful in a

fishery where a single stock is fished and a large proportion of the stock is taken. All other factors being equal, at times of high stock abundance catch rates will be high and, as the stock is caught, the catch rate falls. At the logical extreme, when all the stock is caught, the catch rate is zero.

In economic and practical terms it is neither possible nor desirable to fish a stock down to a zero catch rate. However, by regressing the accumulated catch against the decline in the catch rate, it is possible to estimate the accumulated catch at which the catch rate would be zero. This value is the estimate of the total fishable stock (Note: In practice, because the catch rate is averaged over a month, while stock is continuing to be caught, the actual value of accumulated catch regressed is the value up to the start of the month plus half the amount of stock taken in the month.

Factors other than just stock abundance can, however, affect catch rates. Catchability may vary seasonally, so that catch rates at one time of the year are not directly comparable with catch rates at another time of year. Meat yields vary with both size and season, so that variations in the size of scallops being fished and the time of year will affect catch rates expressed in terms of the weight of meat caught. Natural mortality will also contribute to the decline in the catch rate without being recorded as catch.

Although these problems exist in a fishery-wide DeLury approach, it is still possible to make some initial, approximate estimates of stock size. Data for 1982-1986 (Table 9) indicate that from 1983 to 1986 inclusive, the fishery had a marked impact on the stock and that catch rates declined steadily in each year. The data for 1982 do not follow

Table 9 MONTLY CATCH RATE, CATCH AND ACCUMULATED CATCH OF SCALLOPS FROM SHARK BAY FOR THE YEARS 1982 TO 1986.
(Catch rate data are for scallop vessels only. Catch and accumulated catch are the values for scallop and prawn vessels combined).

YEAR	MONTH	MEAN CATCH RATE FOR THAT MONTH (KG. MEAT/HR. FM.)	CATCH (KG. MEAT)	ACCUMULATED CATCH AT START OF MONTH (KG. MEAT)
1982	January	1.24	997	0
	February	2.94	20 117	997
	March	4.46	44 763	21 114
	April	2.92	32 588	65 877
	May	3.62	44 604	98 465
	June	2.72	66 831	143 069
	July	2.15	56 486	209 900
	August	1.36	55 155	266 386
	September	0.97	33 283	321 541
	October	1.21	26 337	354 824
	November	4.65	36 596	381 161
	December	4.65	16 912	417 757
			Total Catch:	434 669
1983	March	4.68	118 291	0
	April	3.67	162 597	118 291
	May	2.95	151 619	280 888
	June	2.34	122 148	432 507
	July	1.78	71 373	554 655
	August	1.34	79 246	626 028
			Total Catch:	705 274
1984	March	2.50	121 054	0
	April	1.78	115 105	121 054
	May	1.46	83 407	236 159
	June	0.93	46 024	319 566
	July	0.61	40 245	365 590
	August	0.35	14 687	405 835
	September	0.37	8 788	420 522
	October	0.17	1 833	429 310
			Total Catch:	431 143
1985	March	1.46	85 385	0
	July	1.07	93 501	83 385
	August	0.44	39 738	178 886
	September	0.32	13 917	218 624
	October	-	325	232 541
			Total Catch:	232 861
(Note:	Season closed April to June)			
1986	May	2.83	87 595	0
	June	1.25	89 541	87 595
	July	0.77	58 242	177 136
	August	0.45	16 153	235 378
	September	0.44	7 312	251 531
	October	-	718	258 843
			Total Catch:	259 561

this pattern, with low catch rates in January and February, followed by an increased catch rate in March. The catch rate then declined steadily from March to October, then increased again in November and December. The increase in catch rate in November and December 1982 is believed (cf. Scallop Fishery Management Working Group Report P.2., para 1) to be the result of vessels fishing stocks in the vicinity of Levillian Shoals (Denham Sound), which had not previously been fished in that year. The reason for the low catch rates in January and February is not known. Nevertheless, the catch data from January to October provide a data set for the segment of the stock fished in that period.

The estimates of fishable stock derived from the calculations (Table 10) are probably under-estimates, as changes in catchability and meat yield during the year would tend to elevate catch rates for the early part of the year and depress them for the latter part, which would cause the total fishable stock to be under-estimated.

Table 10 ESTIMATES OF TOTAL FISHABLE STOCK DERIVED FROM DELURY TECHNIQUES AND PERCENT OF STOCK CAUGHT BY THE FISHERY IN THAT YEAR.

	RAW ESTIMATE (TONNES MEAT)	ADJUSTED ESTIMATE (TONNES MEAT)	PERCENT CAUGHT (OF ADJUSTED ESTIMATE)
1982*	630	693	55%
1983	913	1 004	70%
1984	482	530	81%
1985	285	314	74%
1986	281	309	84%

* 1982 values relate to the segment of stock fished between January and October.

Natural mortality would also cause the initial stock size determined from these data to be an under-estimate. As an approximate adjustment for these sources of bias the raw estimates of total fishable stock were adjusted upwards by 10% to arrive at a more realistic figure. The total fishable stock estimate for 1982 relates to the segment of the stock fished between January and October. (i.e. excluding the Levillian Shoal stock).

The data indicate that from 1983 to 1986 inclusive the combined efforts of the scallop and prawn fleets resulted in the capture of between 70 and 84% of the total fishable stock. In 1985 and 1986 the total fishable stock was estimated at only just over 300 tonnes and it is not surprising that the fleet was able to take a substantial proportion. In 1983, however, when the estimated stock was over 1000 tonnes, the fleet still managed to take 70% of that stock. Although these results are based only on first estimates, they indicate that the scallop and prawn fleets exploit a substantial proportion of the scallop stock within a fishing season.

<u>Summary</u>

By treating the fishery as a DeLury experiment, estimates of total fishable stock can be made. After adjustments for natural mortality and the seasonal effects on catchability and meat yield, estimates of total fishable stock were made for the years 1982 to 1986 inclusive. Estimated total fishable stock ranged from 309 tonnes in 1986 to 1004 tonnes in 1983. In the years 1983 to 1986 the fleet caught between 70 and 84% of the estimated total fishable stock.

3.8 OBSERVATIONS ON THE INTERACTIONS BETWEEN THE SCALLOP AND PRAWN FLEETS

Perceived problems relating to the presence of two trawling fleets in Shark Bay include:

(i) the physical effects of scallop trawling on

a) the prawn habitat

b) the prawns themselves

c) the effect or otherwise of these factors on the prawn catch

(ii) the capture of prawns by scallop vessels;

(iii) target fishing for scallops by prawn vessels

(iv) the levels of exploitation of scallops by scallop vessels made possible by 24-hour fishing and large crews.

Although not within the ambit of this document, pressure created on berthing and unloading arrangements by the two fleets can add to the other perceived problems.

3.8.1. Effects of Scallop Trawling on Prawn Habitat

Consideration of the physical effects of trawling is limited here to a discussion of the relative swept areas of the two fleets, since no underwater observations of trawl gear were carried out. Except for the differences in mesh size, however, the gear used by the two fleets is essentially the same, so the physical impact of both scallop and prawn trawls should be fairly similar. An exception to this would be when 'tickler' chains (i.e. chains running ahead of the ground chain of the net) are used. 'Tickler' chains have the effect of making trawls fish 'heavily' (i.e. they lift into the path

of the net less mobile and sessile animals, as well as solid pieces of the sea bed). The use of 'tickler' chains on either scallop or prawn trawling gear could be expected to increase the impact of this gear.

Estimates of the swept area of the scallop fleet for 1983-86 were derived from the annual effort figures (Table 1), a trawl path width of 0.66 of the headrope length and an estimated average trawling speed of 2.5 kts. Values for the prawn fleet over the same period were supplied by J.W. Penn (pers. comm.). The data show (Table 11) that the swept area of the scallop fleet has varied between 260-440 sq.n.miles, while the swept area for the prawn fleet has been fairly static at around 2,300 sq.n.miles. In terms of swept area, therefore, the scallop fleet has only between 11 and 19% of the impact of the prawn fleet.

The number of sweeps of the trawl grounds by the scallop fleet was calculated by estimating the area of grounds fished by the scallop fleet in the various years and dividing this by the area swept by the fleet in those years. These data (Table 12) indicate that the scallop fleet sweeps its total fishing area between 1.2 and 1.6 times in a season. The prawn fleet, on the other hand, sweeps its fishing area approximately three times in a season (J.W. Penn, pers. comm.). Nevertheless, with both fleets the effort is not applied uniformly to the total fishing area, with some areas being swept more frequently than the average value while other areas receive much less attention.

Table 11 SWEPT AREA ESTIMATES FOR THE SCALLOP AND PRAWN FLEETS

	Swept area (sq. nautical miles)	
Year	Scallop Fleet	Prawn Fleet
1983	380	2,150
1984	440	2,300
1985	300	2,400
1986	260	2,300

Table 12 ESTIMATED NUMBER OF SWEEPS OF THE TRAWL GROUND BY THE SCALLOP FLEET

Year	Estimated Area of the trawl grounds* (sq.n.miles)	Area Swept by the Scallop Fleet (sq.n.miles)	Number of sweeps of trawl grounds
1983	310	380	1.2
1984	310	440	1.4
1985	200	300	1.5
1986	160	260	1.6

*Area varies from year-to-year depending on the location of stocks.

Concern has been expressed by prawn trawler operators that 24-hour fishing by scallop trawlers impedes sedimentation of finer particles which are needed for prawn habitat. However, while fine particle substrates are the preferred habitat of adult tiger prawns, adult king prawns generally prefer coarser substrates. As the scallop trawl grounds have never been an important area for tiger prawns, it is doubtful if this is a matter for concern.

Scallop trawling has undoubtedly had an effect on the sessile fauna (e.g. sponges, bryozoans etc.) on the scallop trawl grounds in the same way that the early activities of the prawn fleet undoubtedly affected sessile fauna in their traditional fishing areas. Nevertheless,there is no evidence that such changes are counter-productive for prawns. If they were, then the activities of the prawn fleet over many years could be expected to have already demonstrated such an effect.

3.8.2. Physical Effects of Scallop Trawling on Prawns

Another area of concern by prawn trawler operators has been that daylight trawling by scallop vessels causes physical damage to prawns buried in the sediment. However, Penn (1984) has shown that king prawns bury deeply during daylight hours and are therefore virtually uncatchable during the day. This deep burying habit would almost certainly protect them from any physical damage from the trawl gear. Tiger prawns may be more exposed to gear during daylight hours, but as the

western grounds are not important tiger prawn areas this aspect is not particularly relevant.

Another claim has been that the passage of prawns through the 100 mm mesh of a scallop net is, at best, not beneficial to prawns. No data are available on this aspect of possible gear damage to prawns although, if it is occurring, then daylight trawling for scallops would virtually solve this problem, because very few prawns would be vulnerable to the trawl gear. Furthermore, prawners should recognise that their own fishing gear probably also passes small prawns when they are fishing new recruits near the nursery lines. Given the higher densities of prawns in this area, prawn trawls could be inflicting damage to a very large number of small prawns.

3.8.3 Effect of Scallop Trawling on Prawn Catches

The scallop fleet operates mostly in an area which was not previously fished to any great extent by the prawn fleet. Effort expended by the scallop fleet will, therefore, have made an impact on an area of seabed not previously affected greatly by prawn trawling. Claims have been made that the influence of trawling on this previously unfished area has affected the catch of western king prawns, both generally as well as in the specific area (i.e. the western grounds).

Claims that the total catch of king prawns has been affected by scallop vessels are not supported by an examination of prawn catches over periods representing different levels of

activity by the scallop fleet. Over the eleven year period 1971-1981 inclusive, when the scallop catch was low and there were few scallop vessels, the mean annual catch of king prawns was 1,375 tonnes and the mean catch per unit effort 24.1 kg./hour. Over the five year period 1982 - 1986, when the scallop fishery has been active, the mean catch of king prawns was 1,509 tonnes and the mean catch per unit effort was 24.0 kg./hour. These data clearly illustrate that scallop fishing has had no overall effect on total king prawn catch or the catch per unit effort.

Claims regarding the effects on prawn catches in the western grounds cannot be either substantiated or disproved from available data, because the breakdowns of catch by area from the prawn fishery do not relate precisely to the area of overlap of the two fleets. The effort of the prawn fleet in recent years has, however, become more concentrated in the south-east corner of the fishery (i.e. near the nursery lines), with the result that fewer prawns survive to reach the western grounds (J.W. Penn, pers. comm.). Thus, while there may have been a reduction in the catch of prawns on the western grounds, the more likely explanation is that it is as a result of changes in fishing patterns of the prawn fleet.

Prawn trawler operators have also expressed the view that prawn catches should have increased as a result of recent management changes in the prawn fishery. The failure of the prawn fishery to show such an increase in catch has been claimed to result from adverse effects on prawns by the scallop fishery. Recent management changes in the prawn

fishery have, however, been directed at small increases in the breeding stock of tiger prawns and at increasing the size of new recruit king prawns caught by the fishery.

Changes aimed at improving the breeding stock of tiger prawns might, in themselves, even result in lower catches per unit of effort for king prawns. This could occur as a result of re-directing effort from tiger prawns to king prawns at times of low abundance of king prawns. Also, the move towards capturing new recruit king prawns at a larger size will not necessarily result in higher weight yields of king prawns, since mortality of prawns during the period of growth may negate the increase in weight.

3.8.4. The Capture of Prawns by Scallop Vessels

The capture of prawns by scallop vessels is largely controlled by the 100 mm mesh used in scallop trawls. In the tests of prawn and scallop mesh reported in section 3.5, no king or tiger prawns were caught by the scallop net. Nevertheless, some prawns are occasionally caught by scallop trawlers, particularly at times of high catch rates of scallops - or when incidental catches of drifting seagrass occur - because the meshes of the scallop trawl can be partly blocked under these circumstances. No direct data are available to quantify the extent of the by-catch of prawns, but indirect evidence indicates that it is a minor problem.

Condition 3 of the scallop endorsements (Appendix 2) prohibits the storage onboard of prawns while a vessel is

within the Shark Bay Scallop Fishery and requires that any prawns taken as incidental by-catch be returned to the water. However, prawns taken as by-catch by scallop nets are often dead or badly damaged by the time they have been sorted from the scallop catch and, in practice, most of the by-catch of prawns by scallop trawlers makes a minor addition to the crew's diet, although some may be illegally sold. Nevertheless, a prohibition on the storage onboard scallop vessels of any prawns should be retained in future regulations or conditions of licence. The present prohibition of storage onboard scallops trawlers within the waters of Shark Bay of nets with meshes less than 100 mm should also be retained.

3.8.5. Target Fishing for Scallops by Prawn Trawlers

The capture of scallops by prawn trawlers, other than purely as by-catch, is perceived as a problem by operators in the scallop fleet. Nevertheless, Recommendation 5 of the Scallop Fishery Management Working Group (Appendix 1) was that prawn trawlers continue to be permitted to take scallops with prawn nets.

As part of their historical fishing pattern, prawn trawlers have caught scallops as by-catch when fishing at night for king prawns. At times of reduced catch rates of king prawns, prawn trawlers sometimes select fishing areas which provide mixed catches of both king prawns and scallops. When the catch rates of prawns are particularly low, prawn vessels will sometimes target their normal nightly fishing on

scallops and change their gear to 100 mm scallop nets. These nets are more robust than prawn nets and able to withstand the cutting and chafing involved in catching scallops. All these approaches are considered to be within the spirit of the recommendation by the Scallop Fishery Management Working Group.

Daylight fishing for scallops by prawn trawlers - either after completion of night fishing for prawns or as part of a 24-hour fishing strategy on scallops - has been a point of conflict. Scallop vessel operators consider that this behaviour is outside the spirit of the Scallop Fishery Management Working Group's recommendation. However, the increasing value of scallops has encouraged this practice.

Operators of prawn vessels can use these methods of operation to generate a 'de facto' scallop vessel.

The change in processing techniques from shore-based machine or hand-processing has also changed the potential for the prawn fleet to utilise the scallop catch. Given the increasing value of scallops, this has made daylight fishing or 24-hour fishing for scallops even more attractive to prawn vessels. Previously, prawn trawlers could retain only those scallops caught on the last night of a trip - if they were to be brought in live. Otherwise they had to freeze them whole, which took up considerable freezer space. At-sea processing, pioneered by operators in the scallop fleet, allowed prawn vessels to take scallops throughout a trip and store them in their freezers in a space-efficient manner.

Provided daylight fishing for scallops by prawn vessels remains at its current low level and does not lead to a significant depletion of the spawning stock early in the spawning season (with possible consequences for subsequent recruitment) this practice is not in itself a matter for biological concern. However, if most of the prawn fleet turned to daylight or 24-hour fishing for scallops, there would be a rapid reduction in spawning stock levels and cause for concern. The core of the current problem with daylight fishing by prawn trawlers, however, is the share of the catch achieved by the two fleets.

3.8.6. Twenty-Four Hour Fishing and Crew Sizes of Scallop Vessels

From the prawn fleet's viewpoint, the share of the catch achieved by scallop vessels by fishing 24 hours a day, and using large crews, is unreasonably high. The problem is exacerbated by the fact that the bulk of this catch by the scallop fleet occurs in the early part of the scallop season, when the attention of prawn vessels is focused on the south-east (nursery line area) of Shark Bay. Daylight fishing by some prawn vessels is partly a response to the high exploitation rate achieved by the scallop fleet, as prawn vessel operators move to take some part of the scallop catch while it is still easily available.

Because scallops do not have the same degree of diurnal variation in catchability as prawns, catches of scallops in the day can be adequate to permit scallop vessels to continue fishing at an economic level during daylight hours. To

operate a vessel adequately on a 24-hour basis, however, requires a fairly large crew. At times of high catch rates, large crews (up to 14-16 persons) are sometimes carried, with the extra crew being used to increase the rate of processing. High rates of processing are necessary at times of high catch rate or the vessel becomes "clogged" with accumulated catch and must stop fishing until the backlog is cleared.

By fishing for 24 hours a day and having large crews on board, scallop vessels are able to maintain high catch rates (up to 1000 kg. meat per day) and generate a high rate of exploitation on the scallop stock. This allows them to take a high proportion of the fishable stock in a short time. For instance, in 1986 the scallop fleet caught 63% of the total catch taken for the year in the first six weeks of the season.

It is not a matter for biological concern that scallop vessels, fishing for 24 hours a day and using large crews, achieve a high exploitation rate. The current opening dates used in the fishery take into account the anticipated rate of exploitation. The main problem is that they reduce the share of the stock available to the prawn fleet as by-catch in its normal operations.

A reduction in the scallop fleet's rate of exploitation (e.g. by a reduction in fleet size, by a reduction in fishing hours or by limiting crew sizes) has the potential to increase the proportion of the scallop stock available to the prawn fleet. Furthermore, it would increase the period over which scallop

trawlers could economically fish for scallops. However, if the stock not exploited by the scallop fleet early in the season was then heavily exploited by the prawn fleet, the economic fishing season for scallop trawlers would be curtailed.

There is no simple solution to the problem of determining an equitable sharing of the catch between the two fleets, if only because there would probably be as many views on the proper division of the catch as there are operators in the two fleets. Nevertheless, the final management plan for Shark Bay scallops will set levels for a variety of factors which will control the exploitation rate by the scallop fleet (and possibly the prawn fleet). The controls used will have an effect on the division (or potential division) of the catch between the two fleets. The management strategies and controls available - and the effects that the use of any particular approach may be expected to have on the division of catch - are discussed in the section on future management (Section 5).

Summary

Areas of perceived and actual conflict between the two fleets are discussed. The major unresolved problem is the equitable sharing of the scallop catch between the two fleets.

4. A BIOLOGICAL STRATEGY FOR MANGEMENT

The research results reveal a number of aspects of the biology of *A. balloti* in Shark Bay relevant to the development of a management strategy. The most important of these are that i) *A. balloti* is a highly fecund, broadcast spawner with a protracted breeding season, ii) growth is rapid and the bulk of recruits reach a fishable size by about 8-10 months of age, iii) scallops enter their first breeding season around the same time that they reach a fishable size, iv) shell growth slows considerably when scallops enter the breeding season and meat size and condition decline.

The fact that scallops may reach a fishable size before they have commenced, let alone completed, a breeding season places a high priority for management on preservation of an adequate spawning stock. Scallops typically show large variations in recruitment which appear to be independent of the size of the spawning. Such variation is generally considered to be the result of environmental factors. These environmental effects aside, however, it is generally assumed that a stock-recruitment relationship for such a highly fecund animal, where adults and recruits do not compete, would follow the Beverton and Holt (1957) asymptotic form. It is usually further assumed that fishing would become uneconomic at stock levels still related to the asymptotic (flat part) of the curve.

This situation has, until recently, been regarded as the likely situation for prawns, which are also highly fecund broadcast spawners. Nevertheless, studies of the tiger prawn fishery in Exmouth Gulf and Shark Bay have indicated that low levels of spawning stock created by fishing can lead to reduced recruitment for this species (Penn and Caputi, 1984). Concern is also being expressed that low levels of spawning stock in populations of *A.*

balloti in Queensland, resulting from the effects of fishing, are causing reduced recruitment (Dredge, pers.comm.).

One simple solution to the possible problem of maintaining an adequate level of spawning stock would be only to fish the stocks once spawning was completed (i.e. between late December and early March). The scallop fishery at the Abrolhos Islands operates in this way, although at this locality both the end of spawning and the season opening occur at a later date. This arrangement is, however, largely fortuitous and arose primarily through administrative and inspection requirements.

To impose a similar regime for Shark Bay would greatly simplify management of the breeding stock. It would, however, prevent the prawn fishery from taking scallops and cause the scallop fishery to be operating when weather conditions are at their worst. Meat weights and condition would be maximised by fishing at this time but the actual total meat yield might not be increased, because the higher yield per individual may be offset by losses from natural mortality.

Although fishing scallops in the post-spawning period would totally protect the breeding stock, such an approach to breeding stock maintenance is not considered necessary for proper management. Adequate levels of breeding stock for population replenishment can be maintained by controlling factors which control the timing of fishing, the exploitation rate of the stock and the economic lower limit to which the stock can be fished.

A management strategy which aims to maintain an adequate level of breeding stock needs, however, to take into account the observation that (in recent years at least) the earlier spawnings appear to be most important for the production of recruits. A conservative strategy aimed at maintaining "safe"

levels of breeding stock - combined with a bias to maintaining "extra-safe" levels of breeding stock in the early part of the breeding season - would almost certainly avoid the possibility of recruitment overfishing.

The problem is to determine what levels of breeding stock are "safe". However, the recent history of the fishery suggests that levels of breeding stock created by the current management strategy fall within the "safe" area. Also, catch rates in the scallop fishery in Shark Bay by the <u>end</u> of a season are around 3-4 times the overall seasonal average catch rates in the Queensland fishery. As a guide to "safe" stock levels, therefore, those currently being experienced in the Shark Bay scallop fishery would seem adequate.

A caution must be inserted at this point, however. It is that the maintenance of "safe" levels of spawning stock will not necessarily prevent future recruitment failures. Recruitment in scallops is known to be highly volatile, probably as a result of environmental influences on the survival of the larvae or spat. Thus, despite the best intentions of management, recruitment may fail for reasons not related to the actions of the fishery. All that management can do is prevent the fishery from being the cause of future recruitment failures arising from recruitment overfishing. In the event of a very low spawning stock situation developing from such a recruitment failure, management would need to ensure that fishing did not further reduce the spawning stock.

Having established a management strategy for breeding stock, it is necessary to examine how this equates with other desirable aspects of management. The second priority of any management strategy is to maximise the yield from each recruit entering the fishery. In the absence of accurate data on natural mortality rates, however, it is not possible to determine a strategy

for maximum yield per recruit in biomass (catch) terms. Still, biomass is not necessarily the most important parameter and consideration also needs to be given to the economic yield.

The main export market for scallops is for meats weighing more than 11.4 g (i.e. less than 40 meats/pound) and there is sufficient price differential between this grade and lower grades to make the capture of scallops with small meats unattractive. Thus, although the yield in biomass may be higher if scallops were fished at a smaller size (say 80 or 85 mm), the economic yield is probably maximised by fishing animals at sizes greater than 90-95 mm.

Because of the growth pattern of scallops - with very rapid growth of new recruits resulting in the bulk of the population being greater than 90 mm by May - a fishing season starting some time in May is desirable. It provides a product which is highly acceptable to the market and probably provides the best economic returns. Happily, this arrangement is acceptable also from the point of view of breeding-stock conservation.

If a season opening date earlier than May should be considered desirable, action to reduce the exploitation rate of scallops (e.g. by reduction in fleet size or a reduction in fishing hours) would need to be considered. This would avoid excessive impact on early levels of breeding stock. If an opening date earlier than May were adopted, however, larger mesh might also be necessary to reduce the capture of small scallops.

The decline in meat yields and condition which occur as the breeding season progresses, however, erodes somewhat the gains achieved by waiting until the bulk of the population has achieved the 90 mm criterion. To avoid losses resulting from spawning-related changes in meat yields and condition, it

would be most advantageous to take the catch in the shortest possible time after the season opening. Such an arrangement would, however, be at odds with the strategy of maintaining "extra-safe" levels of breeding stock early in the breeding season.

Present levels of exploitation achieved by 14 scallop vessels fishing 24 hours a day early in the season do not appear to have driven the breeding stock down to "unsafe" levels. Nevertheless, further increases in the exploitation rate early in the season may cause breeding stock levels to become "unsafe", particularly in years of low recruitment. Because of this possibility, it would be imprudent to encourage higher levels of exploitation by the scallop fleet at this time. It would also be undesirable to increase overall levels of exploitation early in the season by encouraging the prawn fleet to direct effort towards scallops at this time.

The present closing date, linked to the closing date of the prawn fishery, does not contravene any management strategy aimed at maintenance of the breeding stock at current levels of effort. If, however, levels of effort directed at scallop stocks in the latter part of the season (say July onwards) were to escalate markedly, then breeding stock levels could be adversely affected and some management action warranted. Increased trawling effort directed at scallops in the latter part of the season might also lead to an increase in mortality of new recruits through physical impact of gear (otter boards, ground chains and cod ends). The capture and on-deck handling of new recruits - or the passage of these small, delicately-shelled animals through the 50 mm mesh of prawn trawls - could also affect survival.

Summary

A management strategy is discussed, based on the biology of *A. balloti* and designed to maximise the security of the breeding stock and promote the capture of scallops at sizes acceptable to the export market.

5. FUTURE MANAGEMENT OF THE SHARK BAY SCALLOP FISHERY

At the time of publication of the Scallop Fishery Management Working Group report (March 1983), management of smaller fisheries differed from the current position. Most of the smaller fisheries were then managed on an open-entry basis. Vessels were free to move from fishery to fishery and new vessels were permitted registration. As noted in section 2 (History of the Fishery), this situation changed during the temporary freeze in the Shark Bay scallop fishery. A freeze has been placed on total vessel numbers in the Western Australian fishing fleet (with minor exceptions) and, as well, there has been a general move towards limited entry in smaller fisheries, including the Abrolhos Islands scallop fishery.

Because of this general move to limited-entry management in smaller fisheries, holders of authorisations to take scallops in Shark Bay were notified (29 April 1986) that the Director of Fisheries would recommend that the Shark Bay scallop fishery be managed as a limited-entry fishery.

Nevertheless, it would be appropriate, at this stage, to review the various alternatives available in overall management. These will be discussed in relation to their practicality for the scallop fishery. Where they seem practical, their capacity to support the biological objectives of management (i.e. maintenance of "safe" levels of breeding stock and the capture of animals at optimum market size) will be examined. Important economic or social consequences will also be considered.

Because scallops are fished by two separate fleets, however, any management plan for the whole resource should ideally include a mechanism for the equitable division of that resource between the two fleets. In formulating

this, consideration needs to be given to the ancillary role of scallop catches in the operations and economics of the prawn fleet.

5.1 Available Alternative Management Strategies

The available alternatives for managing the Shark Bay scallop stock are:

(i) Regulated open entry, with regulations on season opening date - to allow the stock to commence spawning and to control the size at first capture - and regulations to allow for seasonal closure if spawning stock levels became undesirably low.

(ii) Controls on total catch. This could be either by a total allowable catch (TAC) for an open-entry fleet or, in a limited-entry regime, with either a TAC or vessel quotas. Seasonal opening dates would need to take into account the spawning season and the size at first capture.

(iii) Controls on total effort, through controls on fishing capacity and season length with a limited-entry fleet.

5.1.1 Regulated Open Entry

Regulated open entry would be a technically acceptable form of management. Timing of fishing would need to be controlled to prevent fishing before some spawning had taken place, and the season may require closing if the spawning stock reached a pre-determined lower limit of abundance. Timing of the fishery opening to a date of May or later would

conform to requirements for the capture of scallops at appropriate market sizes.

The total effort expended by such an open-entry fleet is likely to be similar to that of a limited (but adequately-sized) fleet, as the amount of effort is largely a function of the size of the resource in any one year. Managing scallops on an open-entry basis, however, would probably cause a "gold rush" effect at the opening of each season. This could lead to a high degree of conflict between the prawn fleet and the open-entry scallop fleet and could dramatically reduce the prawn fleet's share of the catch. The presence of a large number of vessels might also disrupt the normal operations of the prawn fleet, both at sea and in the harbour.

Because of the likely involvement of excessive numbers of vessels, a rapid reduction in the scallop spawning stock could be expected, Because of this it would be necessary to start the season later than May (probably July), to maintain high levels of spawning stock early in the breeding season. Gear controls could help reduce the rate of stock decline, but this might be offset by the entry of more boats into the fishery. Starting the season in July would affect the operations of the prawn fleet, which currently alters its fishing strategy so as to take scallops from around June.

5.1.2. Quotas or TAC

Management based on the control of total catch, with either an open-entry or limited-entry fleet, is neither practical nor appropriate for the Shark Bay scallop fishery because of the highly variable nature of recruitment. Catch prediction from pre-season stock surveys could, theoretically, be used, but the current system is not sufficiently accurate for such use. Even if the prediction system were of sufficient accuracy, other problems such as the cost of supervising unloading, the wide availability of opportunities for illegal unloading or disposing of over-quota catch would make such an approach unworkable. The requirement that prawn trawlers could not retain scallop by-catch once the total allowable catch had been taken would also create problems.

5.1.3. Limited Entry with Effort Control

Limited entry and its associated controls create an initial upper limit on the effort capable of being expended. However, limited entry is not in itself a means of regulating the lower limit to which the breeding stock can be fished. This is controlled primarily by the economics of vessels fishing the stock. The rate of breeding stock decline and the distribution of the catch (or potential distribution of the catch) between the two fleets would, however, be controlled through effort controls. Nevertheless, for effort control to function properly there must be a set of regulations to control or offset increases in the effectiveness of effort. Such regulations must be able also

to control factors affecting the lower limit of vessels' economic operation, because this affects the lower limit of breeding stock.

Within a limited-entry management scheme, control of total effort can be achieved by:

(i) Controls on vessel numbers

(ii) Controls on the fishing capacity of those vessels.

(iii) Controls on the length of the fishing season.

There are, however, many interactions between these variables which require examination before any particular set of regulations is selected. The effect of changes in these variables on the distribution of catch between the two fleets must also be considered.

5.2. Practical Aspects of the Operation of Variables involved in Effort Control in Limited Entry

5.2.1. Vessel Numbers

Changes in the fleet size from the present 14 vessels could produce a number of effects, assuming other factors remained fixed. A reduction in vessel numbers would potentially increase the length of the fishing season for the remaining scallop vessels, as well as increase the catch taken by those vessels. It would also increase the proportion of the

scallop stock potentially available to prawn trawlers. Lengthening of the season would, however, cause a greater proportion of the catch to be taken during the time of year when meat condition is at less than its premium value. Also, because of slow shell growth and the decrease in meat size during the breeding season, there may even be a small reduction in the total catch.

Reductions in fleet size, however, might affect the ability of the scallop fleet to fully exploit the scallop resource. Small reductions in vessel numbers (say 3 or 4 vessels) would leave a scallop fleet still able to fully exploit the scallop stock in years of average to good recruitment. On the other hand, large reductions in vessel numbers (say 6 or 7 vessels) might limit this capacity - especially in years of good recruitment.

A reduction in fleet size, with its consequent lengthening of the season, is likely to increase the economic importance of scallop fishing for the remaining vessels. Vessels with endorsements to operate in other fisheries will tend to decrease the amount of time which they spend in those fisheries. For vessels without endorsements in other fisheries, however, there will be reduced incentive to obtain such endorsements. This will leave these vessels with virtually no alternative means of income in years of poor scallop recruitment.

Reductions in scallop vessel numbers may permit greater flexibility in the management of the Shark Bay prawn fishery.

Leaving a larger proportion of the scallop stock for the prawn fishery may provide an economic alternative for prawn vessels at times when they currently fish tiger prawns. Such an alternative might reduce effort on tiger prawns and assist in the management aim of improving the spawning stock of this species.

Increases in fleet size will shorten the fishing season for scallop vessels and cause the catch to be divided into smaller shares. Both the shortness of the season and the reduced income per vessel would tend to make individual vessels less economically dependant on this one fishery. Increases in vessel numbers would also reduce the proportion stock available to the prawn fleet during their traditional scallop fishing period of June to September. As a response, prawn vessels might move to target on scallops earlier in the season than normal, to ensure that they continued to take at least what they might regard as their rightful share of the catch. Such a response could result in an even greater shortening of the season for scallop vessels.

Changes in vessel numbers would also change the capital value of the goodwill attached to the limited-entry licence. As a rule of thumb, the capital value of a limited-entry licence is around two years' gross landings. Based on the mean annual landing per vessel over the period 1983-86 of 18 tonnes, this equates (at a landed price of $15/kg.) to a capital value of approximately $500,000 per licence. However, if new endorsements only permitted current or historical gear usage, then the capital value of single-rig

entitlements would be less than this, while the value of twin-rig entitlements would be higher. Changes from the current 14 vessels could be expected to cause variations in the capital value of licences which reflect the change in the estimated annual landing per vessel.

In setting vessel numbers, however, all other factors do not have to remain equal. Changes in vessel numbers could be offset by changes affecting fishing capacity or the length or timing of the fishing season. Consequently, the exact effects of any particular fleet size depends on regulations concerning fishing capacity and season duration included in the management package. The effects of these factors and their interactions with fleet size are discussed below.

5.2.2. <u>Fishing Capacity</u>

This variable consists of the combined effects of a number of other variables. These are:

(i) Size of trawl gear

(ii) Efficiency of trawl gear

(iii) Number of hours fished per day

(iv) Crew Size

(v) Size and power of vessel (and its replacement)

Fishing capacity is one of the main factors controlling a vessel's economics. It therefore has an important role in determining the lower limit to which breeding stock can be fished.

5.2.2.1. Size of trawl gear

Practical options for the amount of trawl gear would include:

i) Maximum 29.3m (16 fm) headrope, two nets (same as the prawn fishery)

ii) Maximum 25.6m (14 fm) headrope, two nets (the current upper limit, also the upper limit for twin-rigged vessels in the Abrolhos Islands scallop fishery).

iii) Current number and size of nets.

iv) Historical gear usage (i.e. size and number of nets in use by the originally endorsed vessel at the start of the three-year freeze - where these have changed as a result of vessel substitutions during the freeze).

Increasing the upper limit to 16 fm of headrope would increase the upper limit of potential effort of the existing fleet. It would also change the distribution of the catch between operators in the scallop fleet if the existing smaller vessels remained unable to tow

such large nets. If vessel replacement rules permitted upgrading these vesels to ones capable of towing either 14 or 16 fm headrope nets - so that all vessels in the scallop fleet had the same gear - then there would also be a change from the present distribution of the catch between the scallop vessels.

The adoption of either a 16 fm upper limit - or a continuation of the present 14 fm limit, but with vessel replacement rules allowing all scallop vessels to use this gear - could change the potential distribution of the catch between the two fleets. Nevertheless, changes in gear size or in gear usage by the scallop fleet, leading to a change in potential distribution between the two fleets could be balanced by adjusting the other controls (e.g. fleet size, opening date, mesh size).

Constraining vessels to their current gear sizes would largely limit this change in total potential effort and equity. Limitation to the gear in use at the beginning of the freeze would reverse some of the changes in equity which have occurred during the freeze through temporary vessel substitutions. Constraining vessels to current or historical gear entitlements might, however, cause problems when vessels are replaced.

5.2.2.2. Efficiency of trawl gear

Factors affecting the efficiency of trawl gear include:

(i) otter board sizes

(ii) Size and number of ground chains

(iii) Mesh size

(i) Otter board sizes: Otter board sizes are important in prawn trawl fisheries, because larger otter boards permit net spreads to be maintained at high trawling speeds. High trawling speeds are not presently a feature of scallop fishing, since low speeds (2-2.5 knots) are generally considered to be the most efficient. Nevertheless, the use of very large boards could increase the effective swept area of a net beyond that considered when setting a particular headrope length. Because of this potential problem, some link between headrope lengths and board sizes is desirable.

In the interests of uniformity, maximum otter board sizes in the scallop fishery could be set to allow vessels to utilise the same boards in other fisheries. Given the general working relationship between headrope length and board sizes for trawl fisheries, and the maximum size limit in other trawl fisheries, a 2.1m x 0.9m (i.e. 7 ft x 3 ft) rectangular otter board would

probably be appropriate for twin 7 fm nets, although a larger size might be necessary for larger single nets.

(ii) Size and number of ground chains: The current standard is a single ground chain using 10 mm steel, although 13 mm chain has been reported as being used occasionally. Ground chains of 10 mm are the maximum permitted in the prawn fishery.

No specific tests of chains heavier than 10 mm were carried out in the research studies and the exact effects of heavier chains, or of a greater number of chains, have not been documented. Nevertheless, the use of heavier chains and greater numbers of chains would appear to offer the potential to improve gear efficiency - at least on some bottom types.

Limits on the number and size of chains are also required because of possible disturbance to sediments. The use of dredges is banned in Shark Bay because of concern about the effects of this gear on sediments. Large numbers of, or very heavy, ground chains would also be likely to cause disturbance to the sediments. It would be appropriate, therefore, that the current standard of a single 10 mm chain be maintained in any new regulations.

(iii) Mesh size: There are no size limits for scallops and - because of the controls on breeding stock and size at first capture achieved through the season

opening and effort controls - none are proposed. The mesh size is currently set at 100 mm to prevent the capture of prawns by scallop nets. Tests in the research programme indicate that this mesh size is effective at preventing the capture of prawns. However 100 mm mesh is recognised as having the ability to catch scallops of 70 mm and greater.

Because of the present timing of the season in relation to the size of scallops, smaller mesh would not cause a great increase in the amount of small scallops caught (i.e. scallops less than 90 mm). It would, however, increase the potential for the capture of prawns by scallop nets. A slightly larger mesh would probably virtually eliminate the capture of small scallops but would almost certainly reduce the efficiency of the net for larger scallops (i.e. scallops greater than 90 mm). Nevertheless, larger mesh could be considered if (i) opening dates earlier than May were considered desirable (to reduce the capture of small scallops which are normally present at that time), (ii) there was a requirement to increase the mean size of scallops caught (for marketing reasons) or (iii) there was a need to reduce gear efficiency (to reduce effort or to offset some other increase in effective effort).

(Note 1: A continuation of the current prohibition on storage on board scallop vessels of nets with meshes less than 100 mm while in Shark Bay waters would

alleviate concern about the potential use of smaller mesh nets to capture prawns).

(Note 2: A requirement that chafers or linings cover not more than the bottom half of the full length of the cod-end has been included in endorsement conditions since 1985. (For 1984 the condition was "not more than the bottom one third of the cod-end"). This requirement is primarily to reduce the capture of prawns in scallop nets, by permitting escapement through the upper meshes of the cod-end.

Most prawns probably escape through the wings and the throat of the net and it is not known if escapement in the cod-end is important. The inability to legally cover the full cod-end with at least chafers has, however, been a source of annoyance to scallop vessel operators, since cod-ends commonly roll around, causing chafing and excessive wear on the nominal upper surface.

If there is some escapement of prawns from the cod-end then full exterior liners or drapes around the cod end would undoubtedly prevent this. However, most fishermen use raffia or short lengths of rope hitched to the meshes of the cod-end. This would not appear to pose the same problems for prawn escapement - if indeed this is even important. Regulations to permit this type of chafing material on the nominal upper half of

the cod-end as well as the lower half would appear to be appropriate).

5.2.2.3. Number of hours fished per day

A reduction in the number of hours fished per day would have a marked effect on the fishing capacity of vessels. Its main impact, however, would be on the distribution of fishing effort within the season and the rate of exploitation of the stock. Under current fishing practices the distribution of effort is highly skewed to the earlier part of the season, when scallop boats fish for 24 hours per day. As catch rates decline, particularly daytime catch rates, scallop vessels gradually move to fishing at night and the effort per vessel per 24-hour period declines.

Restriction of fishing hours could be used as a device to alter the effective length of the season (depending on the levels of effort permitted by other controls). It could also be used to control the distribution of effort within a season or to alter the distribution (or potential distribution) of catch between the two fleets. A reduction in fishing hours would cause catches to be more uniformly spread over the fishing season. However, this would lead to a higher proportion of the catch being taken at a time when meats were at less than their premium condition.

Fishing hour restrictions could include limiting vessels to fish only during nights or days or perhaps Monday to Friday. In practical terms any limit on hours fished in one day would need to permit fishing only at night- say 6 pm to 8 am -since it would be extremely difficult to police a cessation of fishing at night. If fishing hours per day were restricted, the acceptability of stockpiling catch for processing after the end of a night's fishing would also require consideration. Bans on fishing on certain days, while easy to police (at least for the scallop fleet), may lead to gross inefficiencies of vessel operation.

An advantage of having scallop vessels fish at night would be that it would put them on the same footing as prawn vessels and could alleviate some of the potential conflicts between the two fleets. Reducing the number of fishing hours per day would also largely remove the need - as well as the economic ability - to carry large crews.

If scallop vessels were restricted to trawling only at night, then prawn vessels could expect similar restrictions to be imposed on them for equity reasons. Imposing a similar restriction on prawn vessels would alleviate the problem of prawn vessels becoming "de facto" scallop vessels during the day. It would, however, affect the normal operations of prawn vessels trawling in the deep

waters off Quobba Point, where prawns (especially tiger prawns) can be caught during the day. Nevertheless, reduction of effort on tiger prawns in this area may be considered appropriate in the management of the prawn fishery.

5.2.2.4. Crew numbers

Large crews are carried on some scallop vessels (especially in the early part of the season under current arrangements), partly because of the need to actively operate the vessels on a 24-hour basis. Large crews on each shift also permit a vessel to continue fishing at times of high catch rate, by preventing bottlenecks in processing of the catch.

Limits on crew numbers would have a similar effect to limits on the number of hours fished per day because they would limit the ability of a vessel to fish on a 24-hour basis. They would therefore have most impact on the distribution of effort. Limitation of fishing hours per day would largely avoid the need for limits on crew numbers and these two measures could be considered as alternative approaches to controlling the distribution of effort.

If controls on fishing hours were not adopted - or crew controls were still seen as desirable - the practical possibility of regulating crew numbers

exists by virtue of the licensing requirements for fishing boat crews. Maximum crew numbers could be stipulated by a licence condition on the vessel and inspections of crew licences and crew numbers carried out to ensure compliance. If, however, the controls on crew numbers were to control the rate of processing, then the possible successful development of shucking machines would require a re-assessment of the value of such controls. Prawn vessel operators would also need to realise that conditions on crew numbers applying to scallop vessels would also have to be applied to them when fishing for scallops.

5.2.2.5. Size and power of vessel (and its replacement)

Increases in vessel size would permit larger crews (in the absence of any licence condition on this factor), larger and more efficient freezers and a greater capacity to continue fishing in bad weather. Upgrading of vessels currently operating single rigs could add to the total headrope length used in the fishery and change the current levels of equity within the scallop fleet. Engine power, on the other hand, is not particularly important to scallop vessels, because of the existing gear restrictions and lower trawling speeds.

Because of the move to multi-endorsement of vessels in limited entry fisheries there would be merit in

a uniform replacement policy, so that a vessel replaced under the rules for one fishery for which it was endorsed did not violate regulations relating to another fishery for which it was also endorsed. The current maximum in use for a number of trawl fisheries is 375 units (as defined in Fisheries Notices 213 and 215 for the Exmouth and Shark Bay prawn fisheries). This maximum limit is set, however, with a view to the requirements of prawn fishing and the lower limit of the Commonwealth shipbuilding subsidy.

The 375 unit level equates roughly to a vessel around 22 or 23 metres in length (l.o.a) with an engine around 250 - 270 kilowatts. Because of the lower trawling speed requirements of a scallop vessel it is possible that a larger but less powerful vessel could be built for scallop fishing within this upper limit, especially given the dominance of engine power in the formula. Such a vessel would be capable of carrying a very large crew (if crew controls were not used) and have very large freezers - both factors which would permit maximum processing capacity and therefore maximum exploitation rate in the early part of the season. Furthermore, such a vessel would have limited uses in alternative fisheries, reducing its saleability and increasing its economic dependence on the scallop fishery.

The possibility of replacement vessels having large hulls and small engines could be overcome by placing a maximum on the number of hull units permitted. Vessels up to approximately 75 hull units would still be eligible for the shipbuilding subsidy. The values of the current (1987) scallop fleet for hull units, however, range from 18-83 units, with a mean of 49 units. Consequently, allowing replacement vessesl with up to 75 hull units would still result in growth in the size of vessels and an increase in fishing capacity. Nevetheless, the control of vessel size through a hull unit maximum may have general merit for the inshore trawl fisheries.

Allowing all vessels in the fishery to move to a 375 unit maximum (even in the size/power configuration of a typical prawn trawler) would also increase the fishing capacity of the current fleet, as most vessels are smaller than 375 units. The current total vessel units of vessels in the (1987) scallop fleet range from 103 to 335 units, with a mean of 242 units. Increases in vessel size could, of course, be offset by other changes such as limiting the fleet to fewer vessels, reducing the season, decreasing the amount of gear or increasing the mesh size.

An alternative would be to have a lower maximum unit size for vessels in the scallop fishery. This

would mean that the size of a replacement vessel with multiple endorsements would be limited by the maximum unit value allowed in the fishery with the lowest upper limit on vessel units. However, this might create some anomolies for multiple endorsement vessels and would prevent replacement vessels from being eligible for the Commonwealth shipbuilding subsidy.

5.2.3 Length of the Fishing Season.

5.2.3.1. Duration of the season

The duration of the fishing season can control the total effort, but in recent years it has not been effectively used in this way. Scallop vessels have stopped fishing before the legal end of the season, due to their inability to continue fishing economically. Prawn vessels have usually fished until near to the end of the season (both prawn and scallop seasons currently end at the same time) because of their ability to continue fishing economically on a mixed catch.

Provided that the economics of catching scallops remains similar to that at present, however, the effective end of the season for scallop vessels will be dictated by the lower economic limit of fishing. The time taken for the stock to fall to a point where the catch rate is economically limiting

is a function of fleet size and fishing capacity - while the actual economic limit relates to the vessels' fishing capacity, costs of operation and price of the product. Controls on fleet size and fishing capacity, therefore, are indirect controls on the length of the fishing season. Vessels which have endorsements in other fisheries, however, will cease fishing for scallops and move to another of their endorsed fisheries if they show the prospect of higher economic returns.

5.2.3.2. <u>Timing of the season</u>

The timing of the season is not directly related to the control of effort, but it is appropriate to discuss it at this point. The main function of the opening date has been to allow spawning to commence and to control early levels of breeding stock and size at first capture. The closing date has been set administratively to coincide with the closing date of the prawn fishery.

The exact dates used in any limited entry regime would, however, be dependant on a number of factors. These include the daily and total potential effort generated by any combination of fleet size and fishing capacity (including the effort of the prawn fleet). The effect of this potential effort on the levels of breeding stock and the rate of decline of the breeding stock would

be the main consideration. For instance, with a small scallop fleet and a prawn fleet directing most of its effort at prawns, an earlier opening date could be contemplated. (This might, however, result in the capture of some small scallops. An earlier opening date could require use of a larger mesh to avoid the capture of small scallops.)

In a year in which recruitment was both particularly early and highly successful, it is possible that large numbers of scallops might be available earlier than May. An earlier opening date would permit the capture of some of these animals over the time of best meat yield, without causing levels of breeding stock to fall below those currently experienced. Other factors, such as technological changes causing increased effectiveness of effort in the scallop fleet, might have to be balanced against changes in the opening or closing dates or both.

In order to be responsive to changes in the strength or timing of recruitment it would be necessary to maintain the current pre-season surveys, since the information from these is essential to an informed approach on possible options for the season opening date. In the absence of such surveys it would be necessary to settle for a "safe average" date. This would probably be somewhere in the range May 1 to May 15

in most years for a fleet with effort levels similar to those now in use and with recruitment at levels similar to those experienced in recent years.

Nevertheless, there will almost certainly be some years in which the recruitment comes from late spawnings and, by May, scallops will still be at undesirable sizes yet vulnerable to capture by 100 mm. mesh. There will also be years in which recruitment will be poor and breeding stock levels in May will be low. An increase in mesh size would prevent the capture of small animals in years of late recruitment as well as reducing the capacity of the fleet to deplete the spawning stock in years of poor recrutiment.

Flexibility in opening and closing dates would permit the best use of the resource and the greatest degree of management responsiveness to changing conditions in the fishery, but would add to the costs of management. In the absence of annual surveys to provide data on the recruitment, an increase in mesh size would provide a form of insurance against future variations in the strength and timing of recruitment.

5.3 Other Possible Management Controls

5.3.1. Size Limit on Scallops

Control of the minimum size of scallops caught is not specifically included in any of the available management strategies, but could be considered as a potential mechanism within any of them. Existing arrangements are that there is no legal size limit on scallops and, because of this, processing at sea was able to be developed. Any imposition of a size limit would remove the ability of both scallop and prawn vessels to process at sea. In Queensland, where there is a minimum legal size of 85 mm (shell height), scallops must be landed whole in the shell.

Recent research results (Francesconi, pers. comm.) indicate, however, that holding scallops as whole, frozen animals results in increased levels of cadmium in the adductor muscle. There is probably a similar effect in holding whole scallops chilled on ice. The increased levels of cadmium, which come from contamination of the adductor muscle by the digestive gland, may lead to the meats exceeding the health regulations for this metal. Consequently, at-sea processing produces a product which is less likely to contravene health regulations for cadmium.

Within the existing framework of regulations (i.e. 100 mm mesh for scallop vessels and opening and closing dates in May and November respectively) there does not appear to be any need for a size limit. Size at first capture is controlled

mostly by the season opening date, although this control could be strengthened by an increase in mesh size. Closing the season in November prevents exploitation of new recruits until the opening of the next season, by which time they are approaching fishable size and have reached maturity.

5.3.2. Closed Areas

Scallop recruitment occurs in areas which are also adult habitat areas. This situation is different to prawns, where the recruits occur in areas which are geographically separated from the adult habitat. Protection of prawn recruitment can, therefore, be afforded by the creation of nursery areas which are not part of the main fishing area and can be closed to fishing.

Some protection of newly-recruited scallops is provided by the use of 100 mm mesh in the scallop fishery, but scallops larger than about 30 mm are vulnerable to capture by 50 mm prawn mesh. Scallops around this size are present from August/September onwards and are subject to capture by prawn trawlers. However, because prawn trawlers work at night, there is likely to be little mortality of recruits which are caught and then discarded, since they are not exposed to high temperatures (although there could be some mortality from desiccation by wind). Nevertheless, there is undoubtedly some mortality among recruits from mechanical damage to the very fragile shells of these animals when cod-ends of prawn nets are spilt onto the sorting table. Mechanical damage to

recruits may also be caused by otter board shoes, ground chains and heavy cod-ends of both scallop and prawn nets.

Because recruits are intermixed with the adult stock there appears to be no scope for offering recruits the protection of closed areas. Closed areas could, however, be considered for breeding stock protection. Nevertheless, there is no reason to believe that some areas of breeding stock are more important than others in providing recruitment. Furthermore, given the possible vagaries of larval transport, it would be desirable for adults from all areas to be given a chance to supply larvae. Protection of breeding stock by control of the opening date and exploitation rate would appear to be the best option.

Closed areas have, however, been used to limit the area of operation of scallop vessels to the western half of Shark Bay (i.e. west of a line running due north from Cape Peron) (Figure 1.) to prevent scallop vessels interfering with the operation of prawn vessels in the area near the nursery lines. Both prawn and scallop trawlers are prohibited from trawling south of a line running due east from Cape Bellefin to the Peron Peninsula.

By-catch of scallops by prawn trawlers from the area to the east of the line running north from Cape Peron indicates that this has not been an important area of scallop recruitment and it is no loss to the scallop fleet to be excluded from this area. There is, however, considerable value to the prawn fishery in excluding scallop vessels from this area,

since this limits the number of vessels able to operate in the area and avoids dangerous congestion. It would be appropriate, therefore, if the current closed areas were incorporated into any new regulations.

5.4. Practical Options for Limited Entry Management Plan

The primary variable in any limited entry management plan is vessel numbers. From the biological side, the number of vessels is largely irrelevant for the proper management of the fishery. The number of vessels is, however, of great importance for the economics of individual vessels and is a major factor affecting the division of the catch between the two fleets.

In considering a variety of options, approximate fleet sizes are used to illustrate some possible packages. The approximate fleet sizes used in the illustrations are, however, only examples, and intermediate values should not be disregarded as possibilities. Variations in other elements of the packages (e.g. maximum headrope of nets, mesh size or fishing hours) could also affect the remaining elements in the examples.

OPTION 1

Fleet Size: The current fleet of 14 vessels (or their replacements).

Season: May to close of prawn season.

Gear: Nets - twin, 25.6m (14 fm) max or current or historical use; Boards - 2.1 m x 0.9 m (7' x 3'); Mesh - 100 mm; Chains - 1 x 10 mm.

Possible additional controls: Fishing hour restrictions and/or crew number restrictions.

OPTION 2

Fleet size: 8 - 10 vessels

Season: May to close of prawn season

Gear: Nets - twin, 25.6 m (14 fm) maximum or current or historical use; Boards - 2.1m x 0.9 m (7' x 3'); Mesh - 100 mm; Chains - 1 x 10 mm.

Possible additional controls: Fishing hour restrictions and/or crew number restrictions.

OPTION 3

Fleet size: 2 - 4 vessels.

Season: March or April (for scallop vessels, possibly later for prawn vessels) to close of prawn season.

Gear: Nets - twin, 25.6m (14 fm) max; Boards - 2.1 m x 0.9 m (7' x 3'); Mesh - 100 mm or larger; Chains - 1 x 10 mm.

Possible additional controls: Not required

OPTION 4

Fleet size: 16-18 vessels

Season: June or July to close of prawn season.

Gear: Nets - twin, 25.6 m (14 fm) max. or current or historical use; Boards - 2.1 x 0.9 (7' x 3'); Mesh - 100 mm; Chains - 1 x 10 mm.

Possible additional controls: Fishing hour restrictions and/or crew number restrictions.

VESSEL REPLACEMENT:

The vessel replacement policy used may depend to some extent on the fleet size and other controls selected. With option 3, for example, a 375 unit maximum may be suitable for replacements. With options 1,2 and 4, however, a smaller maximum (say 250 units) or a 375 unit maximum associated with an upper limit on hull units would provide more realistic controls on increases in effective effort. If a 375 units/75 hull units maximum combination were adopted with the existing fleet then it would probably be appropriate to issue endorsements with gear entitlements based on historical usage, and to encourage amalgamation of the three single rig vessels into two, full twin-gear entitlements.

5.4.1. Practical Aspects of the Operation of Selected Limited Entry Options

Option 1: This is basically the status quo. However, the introduction of fishing hour or crew number restrictions

could be used either to extend the fishing season or increase the proportion of the scallop stock available to the prawn fleet in its normal operations, or both. Changes in the opening date or other factors affecting fishing capacity could further modify the distribution of the catch between the prawn and scallop fleet.

<u>Option 2</u>: This option would lengthen the effective fishing season for scallop vessels (provided there was no significant re-direction of effort by the prawn fleet) and increase the proportion of the scallop stock available to the prawn fleet in its normal operations. It would tend to keep scallop vessels fishing in the scallop fishery for an extended period (as will any option involving vessel reduction), provided there is no significant re-direction of effort by the prawn fleet.

<u>Option 3</u>: This option would lengthen the scallop season considerably and markedly increase the proportion of the scallop stock available to the prawn fleet in its normal operations. In years of high recruitment, however, the scallop fleet might be unable to fully exploit the available stock in one year. It would also cause the remaining scallop vessels to focus almost entirely on the scallop fishery. This could leave them few alternatives in years of poor scallop recruitment if they did not have endorsements for other fisheries.

<u>Option 4</u>: This option would shorten the season, although this effect could be offset by restrictions on fishing hours

or crew numbers. The later start might be a problem for prawn vessels, as they would normally start taking by-catch by around early June. However, prawn vessels would be in a position to take scallops when they were at a high density at the opening of the season. This could have a marked effect on the relative economics of fishing for prawns or scallops- and could cause much prawn-fleet effort to be re-directed at scallops, reducing the season even further.

<u>Selection and implementation of vessel removal or addition</u>:

With options 2,3 and 4 the mechanisms for selecting the vessels for removal or addition would need consideration. Under any of the removal options, removal could be (i) by withdrawal before the 1988 season or (ii) by withdrawal over a one, two or three-year period. Additions to the fleet, as in option 4, could be made in either the 1988 or 1989 season.

Selection of vessels for removal could be by removing those with the lowest rank order used in the original issue of endorsements. Additions could be by selecting the next available vessels in the original ranking. Removals or additions could also be by lottery. Vessels could also be selected by opening endorsements to tender. The use of tenders would remove the normal windfall capital gain to owners involved in the issue of limited entry endorsements (estimated at approximately $500 000). Tenders could be drawn from either the current fleet, the original group of applicants for Shark Bay scallop endorsements or the whole fishing industry.

5.5 CONCLUSION

Proper biological management of the saucer scallop stock can be achieved through (i) Control of the opening date and (ii) Control of the lower limit to which the breeding stock can be fished - either by control of factors which affect the economic closing date or by direct control of the closing date. Vessel numbers are largely irrelevant to the mangement of the stock but are extremely important in determing the viability of individual participants and the share of the catch achieved by each of the two fleets. The selection of either an open-entry strategy - or one of the range of possible limited-entry strategies - will ultimately require a decision on the number of vessels to be given a share of the scallop resource, and the method of dividing the resource between the prawn and scallop fleets.

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APPENDIX 1

RECOMMENDATIONS OF THE SCALLOP FISHERY MANAGEMENT WORKING GROUP (MARCH, 1983)

1. The Abrolhos Islands and Shark Bay Scallop Fisheries should be administered separately.

ABROLHOS ISLANDS

2. The area of waters known as the Abrolhos Islands be closed to the taking of scallops for the period commencing on 1 September in any year and ending on the last day of the following February unless there is sufficient justification to further limit the season to coincide with the closing of the rock lobster season (currently 30 June).

SHARK BAY

3. The area of waters defined by the Shark Bay Limited Entry Prawn Fishery be known also as the Shark Bay Scallop Fishery for the purpose of scallop fishing.

4. The Shark Bay Scallop Fishery be closed to the taking of scallops for the period commencing on 1 September in any year and ending on the last day of the following February.

5. That subject to the regulations for management of the Shark Bay Scallop Fishery, any prawn trawler holding a Limited Entry Licence to take prawns within the Shark Bay Limited Entry Prawn Fishery continue to be permitted to take scallops using prawn nets.

6. That from 1 May 1983, no licensed fishing boat be permitted to take scallops from the area of the Shark Bay Scallop Fishery unless the owner of that boat holds a current fishing boat licence endorsed by the Director of Fisheries for the taking of scallops or prawns from those waters.

7. That the Director of Fisheries, upon announcement of the intention to freeze boat numbers in the Shark Bay Scallop Fishery on 1 May 1983, invite boat owners other than holders of Shark Bay Limited Entry prawn licences who wished to take scallops in the Shark Bay fishery after 1 May 1983, to submit an application in writing for an endorsement of their fishing boat licence.

8. That when making a decision whether to grant an endorsement to take scallops, the Director of Fisheries shall take into account the Minister for Fisheries and Wildlife's statement of 13 September 1982, warning the fishing industry against any further capital investment into the Shark Bay Scallop Fishery and also the applicant's fishing history in that fishery prior to the Minister's announcement.

9. That any boat owner who is granted an endorsement of his fishing boat licence by the Director of Fisheries to fish for scallops within the Shark Bay Scallop Fishery after 1 May 1983, be permitted to continue to operate in that fishery subject to the following requirements:

(i) Boat replacements or changes in proprietorship will not be approved before 1 November 1986.

(ii) Any change in proprietorship of the boat will result in the cancellation of all fishing rights within the Shark Bay Scallop Fishery.

(iii) The total head rope length of trawl nets shall not exceed 14 fathoms, whether as a single or double-rigged trawl. The minimum mesh size of a scallop trawl net shall remain at 100 mm.

10. A three year biological research programme commence as soon as practicable to be funded from the Fisheries Research and Development Fund with the following specific objectives:

(i) To define the limits of desirable fishing effort for the Shark Bay Scallop Fishery.

(ii) To investigate the feasibility of forecasting scallop catches from year to year.

(iii) To determine the characteristics (settlement, growth, spawning, etc) of the various scallop fishing grounds within Shark Bay.

(iv) To study the seasonal catchability of scallops throughout life, which would include an examination of mesh selectivity.

(v) To examine the interrelationships between the scallop and prawn fisheries.

(vi) To collect appropriate information on the scallop fishery of the Abrolhos Islands.

11. The Director of Fisheries be requested to report and make recommendations to the Minister for Fisheries and Wildlife before 1 November 1986, on the following:

(i) Research resulting from Recommendation 10.

(ii) Whether the restrictions on access to the Shark Bay Scallop Fishery be lifted and Open Entry be once more allowed or whether it be declared a Limited Entry Fishery.

(iii) If the Shark Bay Scallop Fishery is declared a Limited Entry Fishery, to specify a desirable number of boats, an appropriate boat replacement policy and gear policy for management of that fishery.

12 That industry be forewarned that, if a decision is made in the future to make the Shark Bay Scallop Fishery a Limited Entry Fishery and research shows that it is necessary to reduce scallop boat numbers, the required number of boats should be achieved by selection from remaining eligible scallop boat owners.

APPENDIX 2

CONDITIONS APPLYING TO ENDORSEMENTS TO TAKE SCALLOPS IN THE SHARK BAY SCALLOP FISHERY (AS AT 16 FEBRUARY 1984)

1. The vessel shall not have on board in the Shark Bay Scallop Fishery any trawl net with meshes less than 100 mm.

2. The vessel shall not be used to operate trawl nets having a total head rope length in excess of 25.6 metres (14 fathoms).

3. (a) The vessel shall not have on board any prawns when it is within the Shark Bay Scallop Fishery.

   (b) Any prawns taken as an incidental catch to scallops shall be returned to the water.

4. The vessel shall not be used and the licensee shall not permit or suffer it to be used to take or attempt to take fish by means of trawling in the waters of Shark Bay:-

   (a) to the east of a line drawn due north from Cape Peron (North) to a point on the mainland approximately ten nautical miles south of Quobba Point (see Figure. 1); and

(b) in the Shark Bay Scallop Fishery from 0000 hours on January 1 to 1800 hours on the last day of February and from 0700 hours on September 1 to 2400 hours on December 31. (The closing date was later amended to 0700 hours on 1 November). (Note: This clause has varied in different years depending on the opening and closing dates decided on for the particular year).

(c) in the waters of Shark Bay south of a line drawn due east from Cape Bellefin to Peron Peninsula.

5. The vessel shall not trawl for scallops in the Western Australian waters of the Abrolhos Islands during the months of March and April in any year. (Note: This clause was changed in the endorsements attached to licences issued in 1985 to read "the vessel shall not trawl for scallops in the Western Australian waters of the Abrolhos Islands during the currency of this licence").

6. Boat replacements will not be permitted prior to November 1 1986.

7. Any change in proprietorship of the boat will result in the cancellation of this authorisation to take scallops within the Shark Bay Scallop Fishery.

8. That there is no guarantee of continued access to the fishery beyond 1986 and that Limited Entry Management is only one of a number of options to be considered for the future management of the fishery.

9. Trawl nets shall not have any chafers or linings covering more than the bottom one third of the cod-end of the net. (Note: this clause was subsequently changed in 1985 and later endorsements to read" ... than the bottom half of the full length of the cod end").

10. Unprocessed scallops shall not be transferred to any vessel for the purpose of transport to shore other than to a vessel authorised to take scallops in the Shark Bay Scallop Fishery.