DEVELOPMENT OF NON-DAMAGING TRAPPING APPARATUS AND METHODS OF LIMITING DAMAGE CAUSED BY TRADITIONAL TANGLE NETS IN THE SPANNER CRAB (*Ranina ranina*) FISHERY

Project No. 90/5

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AUGUST 1992

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A REPORT TO THE FISHING RESEARCH AND DEVELOPMENT CORPORATION

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Both male and female spanner crabs (Ranina ranina) readily moved up inclined ramps made from numerous materials and there were no significant size related behavioural differences. This suggested that Ranina ranina could be trapped in "entrance type" non-entangling apparatus. A range of top and side entrance traps as well as conventional entanglement nets were trialled in the laboratory with entanglement nets entrapping over double the number of crabs caught in the most efficient non-entanglement trap tested. This was largely due to the greater time required by spanner crabs to find the entrance of a trap. Field trials supported the laboratory behavioural observations with no trap obtaining comparable catches to the conventional entangling apparatus. When fishing times of non-entangling traps were increased, catch rates likewise increased however the logistics and cost-effectiveness of their commercial use proved prohibitive.

Field trails using different configurations of mesh size, numbers of mesh layers, ply and net tension for conventional entangling apparatus were also conducted to identify the most efficient net configuration for minimising damage whilst maintaining catch rates. Both small (25 mm) and large (85 mm) mesh size required more time to clear than intermediate sizes. Likewise dactyl loss was higher for these meshes, particularly the 25 mm mesh. Loosely hung nets induced over double the dactyl loss of tightly hung nets, with longer clearance time. In addition the catch of undersize crabs was also significantly greater in loosely hung nets whilst there was no significant difference in the catch of legal sized crabs. Tightly hung single mesh nets of a mesh size greater than 25 mm and less than 85 mm proved to be the most effective net for minimizing damage whilst maintaining catch rates.

Conclusions and Recommendations

1. It is extremely unlikely that an efficient and economically viable non-damaging trapping apparatus will be able to replace traditional entanglement nets currently in use in the spanner crab fishery.

2. Queensland Regulations be amended to allow a minimum mesh size of 30 mm for single mesh layer nets in the spanner crab fishery (at present the minimum mesh size for singly hung nets is 25 mm).

3. New South Wales Regulations be amended to allow a maximum drop of 10 cm and a minimum mesh size of 30 mm (at present there is no maximum drop specified and no minimum mesh size).

4. The introduction of regulations limiting the construction of nets to only a single layer of mesh in both States would further reduce damage however there are logistic problems associated with such a regulation ie. It is easier to construct double layer than single layer traps and catch rates in some cases are lower in singly hung nets of the same mesh as doubly hung nets.

5. The introduction of regulations regarding the ply of netting used to construct spanner crab nets is unwarranted. Strand thicknesses less than 9 ply result in greater damage to crabs however such plys are rarely used by fishers due to their low durability and need for more frequent repair or replacement in comparison to larger plys.

6. Fishers should be educated about the damaging effects of current clearing practises. They should be advised that where possible the removal of dactyls should be kept to a maximum of 3 per crab. To achieve this articles should be published in State commercial fishers magazines and direct contact made with local branches of Commercial Fishers Organisations (This is already being undertaken).

INTRODUCTION

In Australia spanner crabs (*Ranina ranina*) are fished commercially along the east coast in both Queensland and NSW (Skinner and Hill, 1986). In Queensland they represent the largest crab fishery (by weight) with the total 1991 catch exceeding 700 tonnes. Methods used to catch spanner crabs differ between fishers but the use of some sort of tangle net is universal. These nets vary in size but essentially consist of netting material hung over a flat metal frame which is baited with trash fish, set on the sea bottom for approximately 30-90 minutes and then retrieved (See Brown, 1986). Upon retrieval crabs which have been entangled in the net are removed and the legal sized crabs retained for market. The undersized portion of the catch (In QLD crabs < 100 mm carapace length; in NSW crabs < 93 mm eye orbit carapace length) is subsequently returned to the water.

Recently Kennelly *et al* (1990) have demonstrated the damaging effects of disentanglement of spanner crabs from these commercial tangle nets. On the basis of laboratory results they suggested that crabs which were "pulled off" the net and then released suffered mortalities as high as 100% as a result of dactyl limb damage. If crabs were "quickly" removed, that is by breaking off entangled dactyls, subsequent mortalities were reduced to approximately 60%. Whilst removal practises differ between fishers, discussions with commercial operators indicated that the breaking of entangled dactyls and "pulling off" were the most common removal methods.

Kennelly and Craig (1989) have estimated that 75 - 95% of the spanner crab catch on commercial tangle nets in NSW is discarded. In Queensland this figure is reduced to less than 50% (Brown, 1986). In addition the smaller average size of females (less than 10% of the catch of females exceeds the legal size) results in an overwhelming majority of female crabs being discarded. Regardless of differences in the proportion of discards between fisheries, the apparent large numbers of discards and their subsequent high mortality rate may lead to a significant reduction in the size of the exploitable stock within a given fishing area.

The solution to this problem involves either (1) educating fishers to ensure greater care is taken in removing crabs from nets to minimise limb and dactyl damage (2) modication of existing entangling apparatus which reduces damage and simplifies the removal process (3) development of alternative non-damaging fishing apparatus, or some combination of all three.

Kennelly and Craig have previously examined the effects of entanglement trap design on CPUE, clearing time and damage to crabs. They found that factors including mesh size, netting ply, and method of hanging (whether the net was hung singly or doubly) had some significant impacts on some or all of these variables.

This study extends that work by examining the effects of different ways of constructing entangling apparatus using materials commonly used by commercial operators (ie. nets of mesh size 25 to 85 mm). It also evaluates the effectiveness of non-damaging trapping apparatus in both the field and laboratory and describes aspects of the trapping behaviour of Ranina ranina. Operational problems associated with the commercial use of alternative apparatus are also discussed.

MATERIALS AND METHODS

Male and female spanner crabs were collected from an area approximately 10 km north of Moreton Island (SE Queensland) using 1 m square tangle nets with 50 mm monofilament mesh. All non damaged crabs were returned to the laboratory where they were held in 3 m diameter outdoor, seawater holding tanks prior to observation. Crabs were fed 3 times per week and were held in the tanks for a maximum of 4 weeks. These crabs were used for both laboratory ramp experiments and laboratory behavioural observation.

1. Laboratory Ramp Experiment

Male (size range 79-131 mm carapace length (CL)) and female (size range 79-100 mm CL) spanner crabs were kept individually in 6 glass aquaria (100 x 30 x 40 cm) containing 10 cm of sand and provided with flow through seawater (3 litres/hr). A double sided ramp inclined at 35 degrees to the horizontal and at a length of 22.5 cm each side, was placed in the centre of 5 of these tanks during experimental observation. The sixth contained only flat sand and was used as a control. The ramps were constructed of 1 cm weldmesh wire, 3 cm weldmesh wire, solid 1 cm thickness marine ply, 40 mm mesh size and 1.4 mm diameter fencing wire, and finally sand formed into a ramp.

After a minimum of 2 days acclimatisation, crabs were restricted to one end of the tank by wire petition at 0900 hr. Following a further 5 hours a ramp was placed in the centre of five of the tanks, the petition removed, and time lapse video recording of the 6 tanks was commenced. Taping continued until 0800 the following morning when tapes were replayed and the following information recorded:-

(a) Number of times a crab crossed a ramp.
(b) Number of unsuccessful attempts at crossing a ramp (An attempt was classified as unsuccessful if a crab had moved up a ramp at least one body length and then subsequently backed away).
(c) Whether a crab swam or walked over the ramp.

In the case of the control tank a crab was scored as crossing if it moved past the centre of the tank. After each recording crabs were removed and replaced with individuals that had been held in 3 m diameter outdoor holding tanks for less than 4 weeks.

2. Laboratory Behavioural Observations

Trapping behaviour observations were carried out using time lapse video recording in a 3 m indoor tank under experimental conditions similar to Smith and Sumpton (1989). Prior to each observation period 4 male (two greater than 100 mm CL and two less than 100 mm CL) and 2 female crabs were transfered from the holding tank to the observation tank. On each day observations were made a trap was selected at random and crabs were placed in the tank for 6 hours prior to experimental observation. After this time the baited trap was placed in the centre of the tank and video recording was commenced. The recording was terminated the following morning at 0900 hr after which time the crabs were freed, the tank cleaned and the tape replayed. The activities of the crabs in relation to the trap were classified as follows:-

Attempt: a forward contact of the crabs' body with the extremities of the trapping apparatus. If the crab subsequently moved away out of the field of view of the camera (2 m x 2 m) then that attempt was scored as completed. If a crab moved away but remained in the cameras' field of view and then made further contact it was scored as the same attempt. Reversing against the trap or a casual lateral contact was not classified as an attempt.

Angle searched: the estimated arc covered by a crab around the traps' extremities during an attempt.

Entry: In the case of entangling apparatus entry was scored as taking place once all of the crabs' body was past the metal frame of the trap. A crab was considered captured when it was entangled in the mesh. For the non-entangling apparatus entry and capture were deemed to have taken place when crabs had entered the main body of the apparatus through the traps' entrance.

Escape: A crab which had entered an apparatus subsequently leaving through an entrance or over the metal edge of an entangling trap.

3. Non-damaging Apparatus Field Trials

Apparatus examined in the laboratory were also trialed in the field. This involved comparing a standard 1 m square, 50 mm mesh, single mesh layer, tightly hung net with numerous experimental designs. Apparatus baited with whole mullet (*Mugil cephalis*) were set in random order at the same depth and approximately 50 m apart in an area approximately 10 km north of Moreton Island. These apparatus were left in the water for times ranging from 1-6 hours depending on the particular trip. After the allocated time had elapsed all traps were retrieved, cleared, rebaited where necessary, and reset. The time taken to clear crabs from a particular trap was recorded as was the sex and carapace length of all spanner crabs caught. Any damage (dactyl or limb loss) incurred in the clearance process was also noted. Numerous apparatus were trialed but subsequent discussion will be limited to the following apparatus which were all set and lifted 18 times (See Plate 1).

1. 50 mm, single mesh, tightly hung, tangle net.
2. Standard wire "sandcrab pot" with two funnels.
3. Collapsible 2 funnel sandcrab pot constructed from 38 mm trawl mesh.
4. Truncated conical trap (top entrance).
5. "Pigeon" trap.

4. Entangling Apparatus Field trials

Sampling was conducted in two commercially exploited areas:- 15 kilometres west of Lady Musgrave Island and 10 km north of Moreton Island. Apparatus were similar to these used by commercial operators consisting of $1m^2$ flat galvanised steel frames to which were attached different kinds of netting materials. Each trap was baited with a single whole mullet (*Mugil cephalis*) attached in the centre of each frame.

Several traps were set out cross current in pairs on the substratum with each pair approximately 75 m apart. Each pair was attached to a buoyed line with the two traps on the line 3 m apart. Traps used in the trials were selected at random and after retrieval their order re-randomised. Retrieval of nets took place approximately 45 mins after they were set. Upon retrieval crabs were disentangled, sexed, counted and measured (CL in mm). The time taken to clear crabs from a particular trap was also recorded as was the number of dactyls and limbs lost in the disentanglement process. Methods of disentanglement vary enormously between fishers and we decided to break any dactyl which could not be disentangled within 2 seconds. All trials were undertaken by the same personnel.

4.1 Experiment 1.

Twelve different types of traps were used in the first experiment (Table 1). Four different mesh sizes (25, 50, 65 and 85 mm); two strand thicknesses (thin:- 4-9 ply; thick:- 12-18 ply) and two ways of hanging the nets (single layer and double layer) were used. All nets were hung with less than a 5 cm drop of net and were set and retrieved 20 times. Two of these sets were subsequently eliminated from further analysis due to damage caused by sharks and turtles.

4.2 Experiment 2.

Eight different traps were used in Experiment 2. These consisted of all combinations of the following mesh sizes (50 and 35 mm), two methods of hanging (single and double) and two hanging tensions (hung tightly ie. no drop, and hung with a 15 cm drop)(Table 2). All nets were 9 ply multifilament nylon. Nets were set and retrieved 18 times over 4 separate days although 4 sets were again eliminated from further analysis due to shark damage.

5. Data Analysis

All sets of data were tested for homogeneity of variance using Bartletts' test (Sokal and Rohlf, 1969). Any sets with heterogeneous variances were transformed using either a square root or log (n+1) transformation and analysed using anon-orthogonal least squares analysis of variance program. Means were compared using Ryans test and Paired comparison "t" tests.

RESULTS

1. Laboratory Ramp Experiment

There were no significant differences in the number of crosses or attempts between males and females (Table 3). Likewise size had little influence on the behaviour of spanner crabs towards ramps and in subsequent analyses males and females of all sizes have been grouped.

Overall there was no significant difference in the number of times a crab crossed over a ramp regardless of the material from which the ramp was constructed (Table 4). There were, however, significant differences ($F= 5.49$, $P<0.001$) in the number of attempts which crabs made to cross ramps of different materials. In pairwise t test comparisons, significant differences ($P<0.05$) in attempts were noted between flat sand (control) and all ramp types except the sand ramp. Whilst there were significant differences in the number of times crabs swam over ramps of different materials the data were too few and inconsistent to draw conclusions.

2. Laboratory Behavioural Observations

Numerous designs of traps and various modifications to those traps were tested and filmed in the behavioural tank. Most designs proved very unsuccessful and subsequent discussion will be limited to only 5 apparatus types. These apparatus were representative of the range tested and include entangling devices as well as top and side entry traps (Plate 1).

1. 85 mm tangle net: 85 mm mesh size, 4 ply net hung loosely (15 cm drop) on a 1 m x 1 m frame.

2. 50 mm tangle net: 50 mm mesh size, 12 ply net hung tightly on a 1 m x 1 m fame.

3. Wire pot: standard cylindrical wire sandcrab trap with two entrance funnels of 11 cm entrance height (See Smith and Sumpton, 1989).

4. Truncated Cone: One metre diameter conical trap constructed from 40 mm mesh size, 1.4 mm diameter fencing wire with a 240 mm diameter entrance located centrally and 200 mm above the centre of the cone.

5. "Pigeon" trap: Wire trap (1 m x 1 m x 15 cm) with two sides modified as entrances. These entrances consisted of 0.5 cm square aluminium rods each 12.5 cm in length, set 4 cm apart along the entire side. Rods were attached to the top of the trap so that they could be individually pushed inwards allowing entrance of a crab but which could not be pushed outwards thus preventing an escape.

Both tangle nets (85 mm and 50 mm) caught 90% of those crabs which attempted to get at the bait (Table 5). By comparison the "Pigeon" trap and truncated cone caught only

25% and 6% respectively. The rate of escape was high for the wire pot and tightly hung 50 mm net compared with the loosely hung 85 mm net. Low escapement rates for the pigeon trap and truncated cone were probably a reflection of the low numbers caught rather than a greater retention ability of these traps, both of which failed to capture large numbers of crabs. In fact crabs which were captured in the truncated conical trap made an average of 9 attempts before capture compared with the entangling traps where crabs were commonly caught on their first attempt.

The greater efficiency of the tangle nets over the other apparatus can also be seen in the time taken to be captured once first contact with the trap had been made (Figure 2). Over 90% of crabs which attempted entry were captured within 5 minutes of making an attempt and commonly crabs were caught within the first 30 seconds after initial contact with an entangling trap. On occasions, however, crabs did back away once contact had been made with the metal extremities of the entangling traps. The majority of those crabs were later caught.

Spanner crabs were also required to search more extensively for the entrances of non-entangling apparatus with many crabs searching in excess of 180 degrees around these devices (Figure 3). When crabs made contact with the side of a non-entangling trap they generally moved slowly around the extremities trying to get at the bait. By comparison there was little movement around the extremities of the metal frames of entangling traps once contact was made. Sex and size of crabs had no significant effect on the recapture rates of the apparatus tested (Figure 4).

3. Non-damaging Apparatus Field Trails

The standard singly hung 50 mm tangle net lifted hourly yielded by far the greatest catch of spanner crabs when compared with alternative methods (Table 6). Catch rates of tangle nets were on average 9.5 per hour with almost half that number being marketable crabs. None of the other designs tested yielded catch rates within 50% of that figure. Catch rates for alternative designs were increased when the soak times were increased to 3 hours but even then they were significantly lower than the tangle nets. Both the truncated cone and "Pigeon" trap were very inefficient in the field and on more than 50% of lifts failed to catch any crabs at all.

Clearance times for the alternative trap designs tested were less than 50% of those of the tangle nets. However, clearance times of the alternative designs tested were still relatively high and on occasions some traps required in excess of 2 minutes to clear. Spanner crabs often clung to the mesh of the traps with their claws or jammed between the funnels and the main body of the trap. Traps often had to be shaken violently to remove crabs although this process never resulted in limb or dactyl loss. In fact, no damage was sustained by any crabs caught, and subsequently cleared from non-entangling apparatus. Clearance times also varied enormously depending on the amount of damage that operators were prepared to inflict on the crabs. For these sets of trials a limit of 2 dactyls removed per crab was allowed. On other occasions when it was decided to remove crabs from nets unharmed some individuals required in excess of 3 minutes to remove and some nets in excess of 15 minutes to totally clear.

4. Entangling Apparatus Field Trials

4.1 Experiment 1.

There were few significant effects due to trap design on the catch of spanner crabs (Table 7, Figure 5) and no significant interactions of factors. Significantly more ($P<0.05$) crabs were caught in doubly hung nets compared to singly hung nets. Both mesh and hanging were significant in determining the average time taken to clear individual crabs from the nets. Crabs caught in the smallest (25 mm) and largest (85 mm) meshes took the greatest time to clear as did those caught in doubly hung nets compared to singly hung.

Limb loss showed a significant interaction between mesh and hanging but failed to yield any significant single factor effects (Table 8). By comparison both mesh and hanging produced significant differences in the case of dactyl loss. Doubly hung, thin ply 85 mm net and the 25 mm net caused significantly more dactyl loss than any of the other nets. The average length of crabs caught in nets were fairly consistent, with ply providing the only significant effect.

4.2 Experiment 2.

Mesh was a significant determinant of the total catch as well as the catch of males and females with the 35 mm net consistently providing the greatest catches (Table 9). The greatest total catch of crabs also occurred on nets which were loosely hung (Figure 6). Tension was the only factor which had a significant effect ($P<0.01$) on the average time taken to clear crabs. There were no significant interactions for either limbs or dactyls lost but tension was highly significant in determining the number of dactyls lost during clearing (Table 10). Doubly hung nets also induced more limb loss than singly hung nets. Average crab length between nets was not significantly affected by any factor.

Figures 6-8 summarise the main results of both Experiments 1 and 2. It was clear that intermediate mesh sizes (50 and 65 mm) were quicker to clear and likewise induced significantly less damage. Net tension however appeared to be the most pertinent variable when attempting to minimise damage whilst maintaining catch rates (Figure 7). Catches of legal sized crabs (>100 mm CL) were not significantly different however loosely hung nets caught more undersized crabs, induced higher dactyl loss and required significantly more time to clear than tightly hung nets. Doubly hung nets likewise took longer to clear and caused more dactyl loss however their effect was not as great as that of net tension.

DISCUSSION

Fishers who had experimented with non-entangling traps suggested that there was one major stumbling block to the construction of an efficient non damaging trap. Fisheries believed that spanner crabs were reluctant to leave a sandy substrate and enter an enclosed apparatus via some sort of artificial ramp or entrance. Our laboratory observations clearly demonstrated that crabs would move over artificial surfaces. In fact in earlier trials many crabs readily swam over a 20 cm high vertical petition to feed on a fish bait located on the other side of the petition. From this we concluded that there must be other factors preventing the development of alternative non damaging methods.

One of the most important results of the behavioural observations was the much greater time required by non entangling apparatus to catch crabs. This was also reflected in the field trials where the catch rates of entangling apparatus set for 1 hour were 5 times those of the most efficient non damaging apparatus. When compared with other crab trap fisheries such as that of the sandcrab (*Portunus pelagicus*) the spanner crab catch rates obtained using non damaging apparatus are comparable. Sumpton *et al* (1989) for example reported the average daily catch of marketable sandcrabs in Moreton Bay was around 3 per trap, and this was for traps set for an average of 24 hours. However, in a relatively high volume, low value fishery such as that of the spanner crab these catch rates are not economically viable. Traps have to be set for periods of 3 hours or more to obtain reasonable catch rates. In this time entangling apparatus can be lifted and reset 3 times virtually trebling the catch and further increasing the differential between the two methods.

There are also a number of specific operational problems associated with the use of non entangling traps which require extended soak times in order to catch efficiently. Traps often cannot be left in the water over night or longer periods because much of the spanner crabbing grounds are also trawled. In addition, in some areas strong oceanic currents and resultant sediment movement result in traps being partially buried within a matter of a few days. Bad weather conditions can mean that gear left on the sea bottom may not be able to be retrieved for more than 7 days. Trawling and sediment movement necessitate that all fishing ear is deployed, retrieved and returned to shore with the catch on the fishing day. Therefore any gear that is used must either be compact or collapsible. Existing methods employing flat tangle nets require minimal boat space with 30 nets occupying less than 0.4 cubic metres. By comparison the alternative designs tested required a minimum of 2 cubic metres for 30 traps. In a fishery where over 300 kg of crabs can be caught in one day the space requirements of apparatus have to be kept to a minimum.

For maximum efficiency any trap employing a specific side entrance site requires the entrances to be orientated into the direction of the tidal current. Laboratory observations showed that crabs moved up-current to the bait. This has also been demonstrated in the field by Kennelly (1989) and Wassenberg (pers comm). The usual method of deploying commercial gear is by placing sets of up to 10 nets (usually) in a trot line configuration. This involves attaching nets at intervals along a single line which is buoyed at either end. The interval between nets varies between fishers but commonly ranges from 3 to 50 metres. Trot lines are used to minimise hauling time since the fishery operates in depth often greater than 75 m where it would be inefficient to deploy individually buoyed apparatus. The orientation of trap entrances into the current is a difficult undertaking in the depths in which spanner crabs are common; particularly when efficiency necessitates that traps be set along a trot line. In addition any trap that has to fall upright on the substrate (ie. top entrance traps) also creates deployment and retrieval problems.

We concluded that spanner crabs, like most other crabs would readily enter baited traps via specific ramps or entrance. However the nature of the fishery and the sheer greater efficiency of entanglement traps make the use of alternative traps impractical.

There are a number of complexities which hamper the detection of consistent patterns in the data obtained from the entangling apparatus field trials. Tangle nets which were constructed as consistently as possible clearly changed characteristics once they were used in the field. For example meshes stretched and the shape of meshes altered. In particular nets which were doubly hung exhibited different characteristics depending on how the top layer sat on the lower layer. There were obviously different degrees of overlap in the meshes.

Kennelly and Craig (1989) experimented with mesh sizes of 25, 85 and 150 mm and found that clearance times increased with mesh size while damage to dactyls declined. By comparison over the range of sizes we tested mesh sizes of 50 and 65 mm caused less damage than the smaller and larger meshes tested.

Nets which were hung loosely on a frame resulted in greater damage to crabs. This was due to the fact that once the net became caught between the segments of the limbs crabs were still able to turn and move about some distance enabling further entanglement to occur. Laboratory observations also showed that crabs caught in a loosely hung net could bury in the sand resulting in even further entanglement. By comparison movement of crabs caught in a tightly hung net was noticeably more restricted. Meshes in loosely hung nets, particularly those with a small ply tended to gather up and float above the substrate. Crabs which became tangled in these areas were more difficult to free without damage.

Results of the entangling trials showed that nets which were hung tightly in a single layer were optimal with respect to minimising both damage and clearing time. The catch obtained using this type of net also did not differ markedly from other designs tested.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of Mr Brett Davidson (Skipper of R.V. "Warrego") in the field and Mr Glen Smith in the laboratory. Several commercial fishermen also contributed through discussions, particularly regarding alternative traps that they had trialed. This work would not have been possible without the provision of a grant by the Fishing Industry Research Development Council and the Queensland Fish Management Authority.

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TABLE 1 Mesh size, ply and method of hanging for the 12 different tangle net designs used in Experiment 1.

Trap No.	Hanging	Ply	Mesh Size (mm)
1	single	thick	25
2	single	thick	50
3	double	thick	50
4	single	thin	50
5	double	thin	50
6	single	thick	65
7	double	thick	65
8	single	thin	65
9	double	thin	65
10	single	thick	85
11	double	thick	85
12	double	thin	85

TABLE 2 Mesh size, net tension and method of hanging for the tangle net designs used in Experiment 2.

Trap No.	Hanging	Tension	Mesh Size (mm)
13	single	loose	50
14	single	tight	50
15	single	loose	35
16	single	tight	35
17	double	loose	50
18	double	tight	50
19	double	loose	35
20	double	tight	35

TABLE 3 Average frequency of male and female spanner crabs attempting to cross, crossing and walking over ramps constructed of different materials in the laboratory.

Class of Crab	Average number of crosses	Average number of attempts	Average number walking
SEX			
Male	10.76	1.93	10.05
Female	6.50	1.72	6.15
F value (probability)	3.47 (0.07)	0.07 (0.00)	3.25 (0.08)
SIZE			
<95mm Carapace length	8.47	1.61	7.84
≥95mm Carapace length	8.58	2.07	8.18
F value (Probability)	0.00 (0.00)	0.48 (0.00)	0.04 (0.00)

TABLE 4 Response of Spanner crabs to different ramp types in the laboratory.

Ramp Type	Average number of crosses	Average number of attempts	Average number of "swims"	Average number of "walks"
Flat sand (control)	9.4	0.1	9.4	0
Sand	11.2	0.2	11.0	0.2
Wood	5.4	1.7	5.3	0.1
$1cm^2$ Weldmesh	5.2	3.2	4.9	0.3
$3cm^2$ Weldmesh	9.4	3.2	9.3	0.1
40mm Fencing Wire	6.0	3.2	5.4	0.6
"F" value	1.53	5.49	1.74	2.49
Significance	N.S.	***	N.S.	*

N.S. Not significant
* $P<0.05$
*** $P<0.001$

TABLE 5 Numbers of entrances, escapes and number of attempts for spanner crabs exposed to different trapping apparatus in the laboratory.

Apparatus	Number of Trials	Number of Entrances	Number of Escapes	Percentage of Crabs which made attempts and were caught	Average number of attempts before capture
85mm Tangle (loose hang)	8	22	1	92	1.1
50mm Tangle (Tight hang)	10	38	8	90	1.2
Wire Pot	10	24	4	70	3.6
"Pigeon" Trap	8	10	0	25	2.6
Truncated Cone	8	2	0	6	9.0

TABLE 6 Clearance times and average catch rates for spanner crabs caught by various apparatus set for 1 - 3 hours in the field.

Apparatus	Soak Time (hr)	Total Catch (numbers/lift)	Marketable Catch (≥100mm C.L.)	Discarded Catch (<100mm C.L.)	Clearance Time (Sec/crab)
50mm Tangle	1	9.5	4.2	5.3	13
Wire Pot	1	1.7	0.8	0.9	4
Wire Pot	3	4.8	2.3	2.5	5
Collapsible Pot	1	0.8	0.4	0.4	5
Collapsible Pot	3	2.3	1.0	1.3	6
Truncated Cone	3	0.8	0.5	0.3	NR
"Pigeon" Trap	3	1.0	0.5	0.5	NR

NR Not recorded.

TABLE 7 "F" value summaries of three factor analysis of variance to determine the effects of different trap parameters on time to clear crabs from traps and catch rates. Significant results are highlighted with asterisks.

Treatment	df	Number of Males	Number of Females	Total	Average time to free each crab
Mesh	3	0.31	4.71*	0.36	4.04**
Ply	1	1.85	0.07	1.15	3.17
Hanging	1	3.58	0.94	4.00*	4.71*
Mesh x Ply	2	0.42	2.05	0.41	3.92*
Mesh x Hanging	2	0.26	0.07	0.17	0.74
Ply x Hanging	1	0.32	1.82	0.69	0.29

* $P < 0.05$
** $P < 0.01$

TABLE 8 "F" value summaries of three factor analysis of variance to determine the effects of different trap parameters on dactyl and limb loss and average length of crabs. Significant results are highlighted with asterisks.

Treatment	df	Dactyl Loss	Limb Loss	Average length of crabs
Mesh	3	9.66**	2.05	1.18
Ply	1	3.77	0.24	4.74*
Hanging	1	6.51*	1.68	0.24
Mesh x Ply	2	0.08	0.57	1.78
Mesh x Hanging	2	0.45	3.14*	0.80
Ply x Hanging	1	0.09	0.01	2.08

* $P < 0.05$
** $P < 0.01$

TABLE 9 "F" value summaries of three factor analysis of variance to determine the effects of different trap parameters on time to clear crabs from traps and catch rates. Significant results are highlighted with asterisks.

Treatment	df	Number of Males	Number of Females	Total	Average time to free each crab.
Mesh	1	29.59**	9.53**	36.96**	0.05
Hanging	1	0.80	0.03	0.40	3.17
Tension	1	3.82	0.84	4.16*	29.05**
Mesh x Hanging	1	0.00	0.44	0.00	2.53
Mesh x Tension	1	0.00	0.31	0.00	0.13
Hanging x Tension	1	0.79	4.51*	2.36	0.73

* P<0.05
** P<0.01

TABLE 10 "F" value summaries of three factor analysis of variance to determine the effect of different trap parameters on dactyl and limb loss and average length of crabs. Significant results are highlighted with asterisks.

Treatment	df	Dactyl Loss	Limb Loss	Average length of crabs
Mesh	1	3.84	2.31	1.45
Hanging	1	0.21	7.78**	0.57
Tension	1	9.75**	1.75	0.61
Mesh x Hanging	1	0.38	0.25	0.97
Mesh x Tension	1	1.17	0.21	0.75
Hanging x Tension	1	0.46	0.33	0.03

* P<0.05
** P<0.01

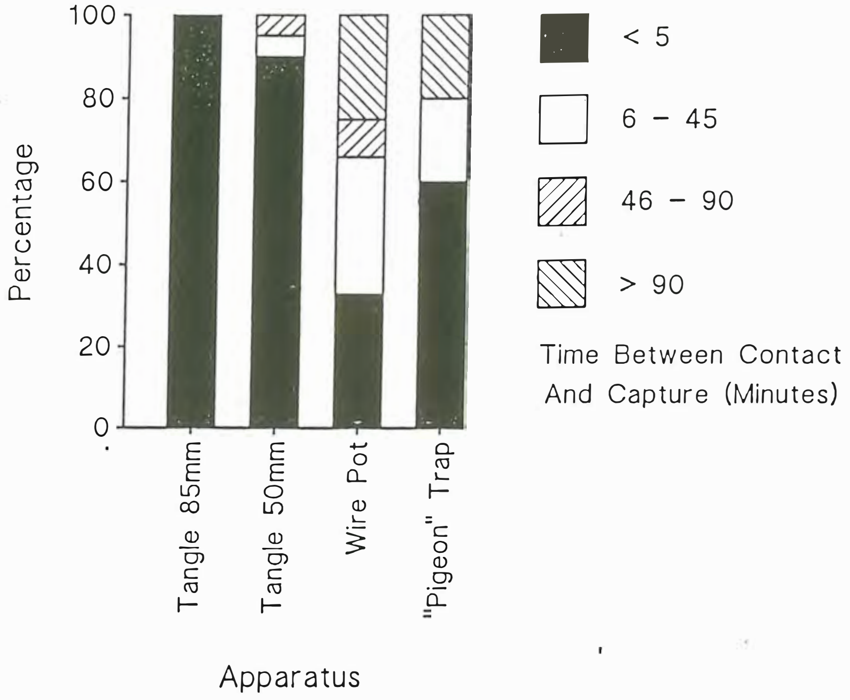


FIGURE 1. Proportion of crabs which entered different apparatus during various time intervals following initial contact with the apparatus.

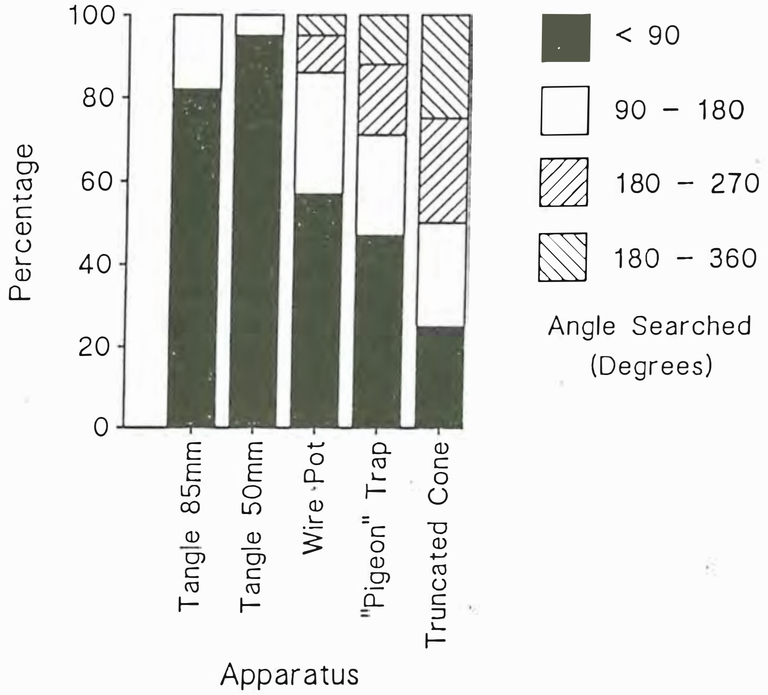


FIGURE 2. Angle searched by crabs around the extremities of 5 apparatus during attempts at entry.

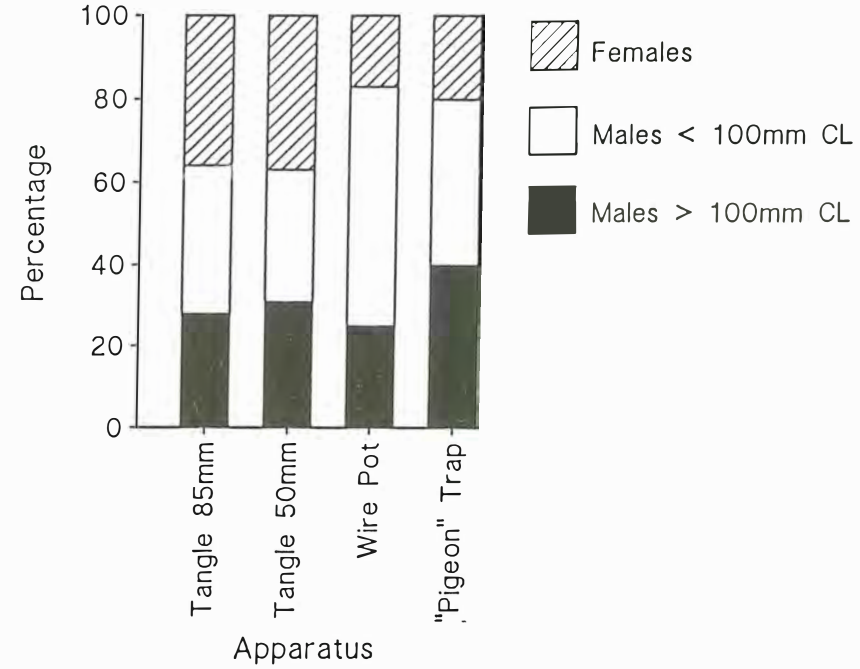


FIGURE 3. Proportion of males and females which were caught in different apparatus in the laboratory.

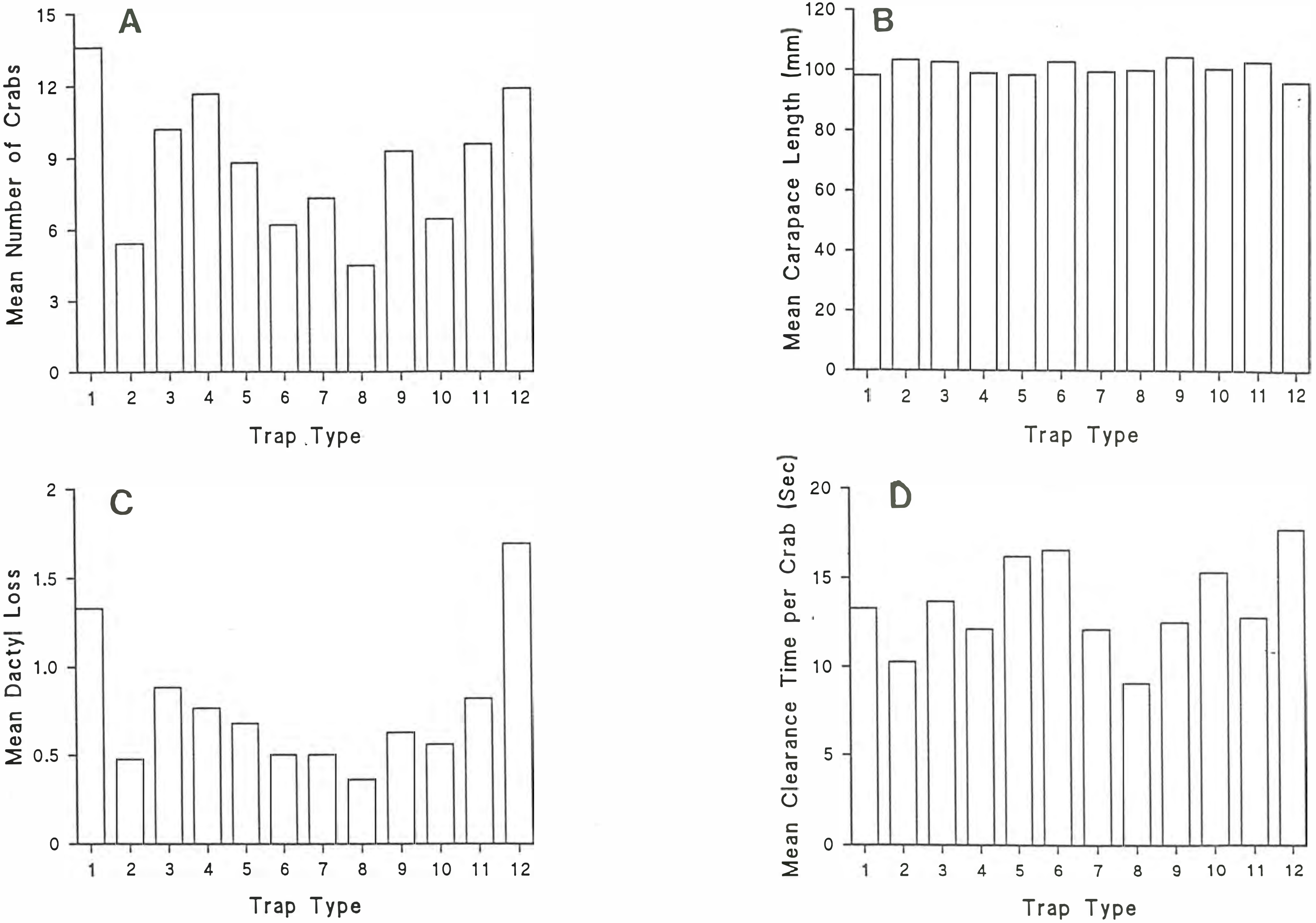


FIGURE 4. (A) Mean number of crabs caught in 12 different types of traps during Experiment 1.
(B) Mean carapace length of crabs.
(C) Mean dactyl loss per crab during the clearance process.
(D) Mean time taken to clear crabs from traps.

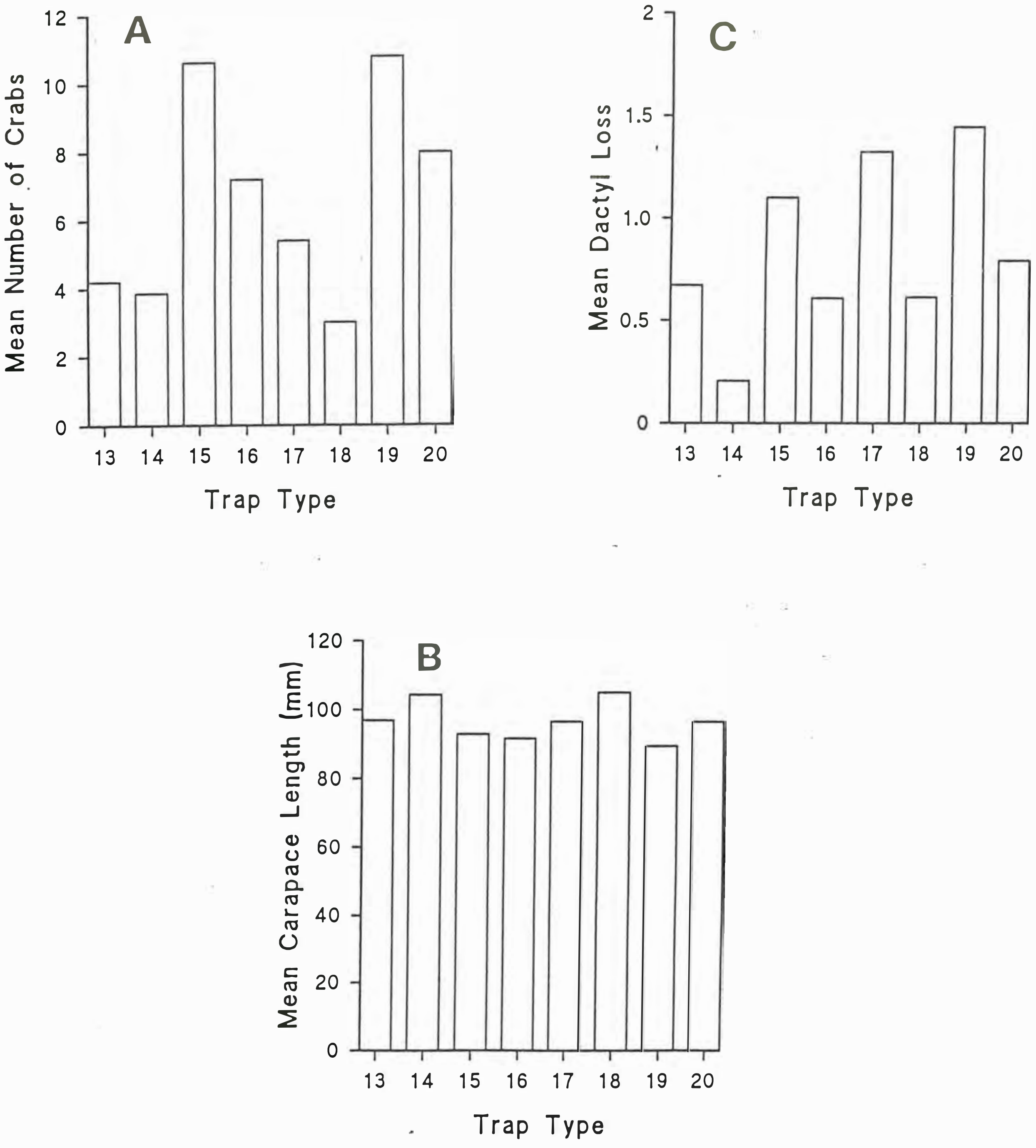


FIGURE 5. (A) Mean number of crabs caught in 8 different types of traps during Experiment 2.
(B) Mean carapace length of crabs.
(C) Mean dactyl loss per crab during the clearance process.

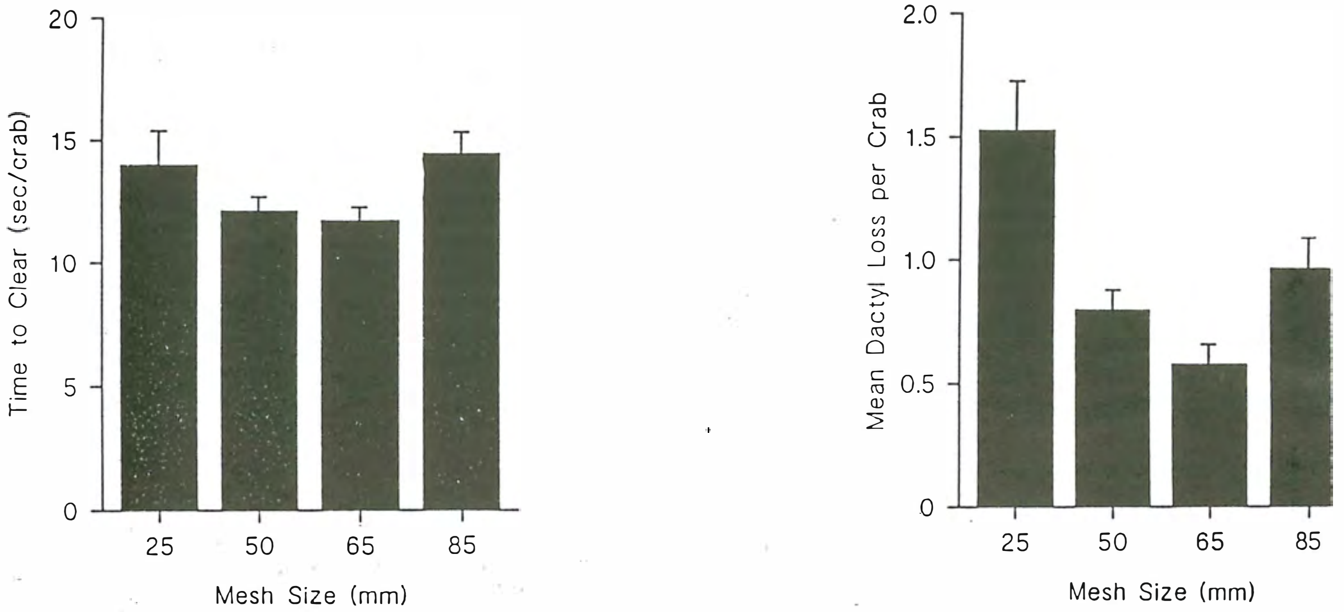


FIGURE 6 The effects of mesh size on clearance time and mean dactyl loss of spanner crabs from conventional tangle nets (Standard Errors are shown above each bar).

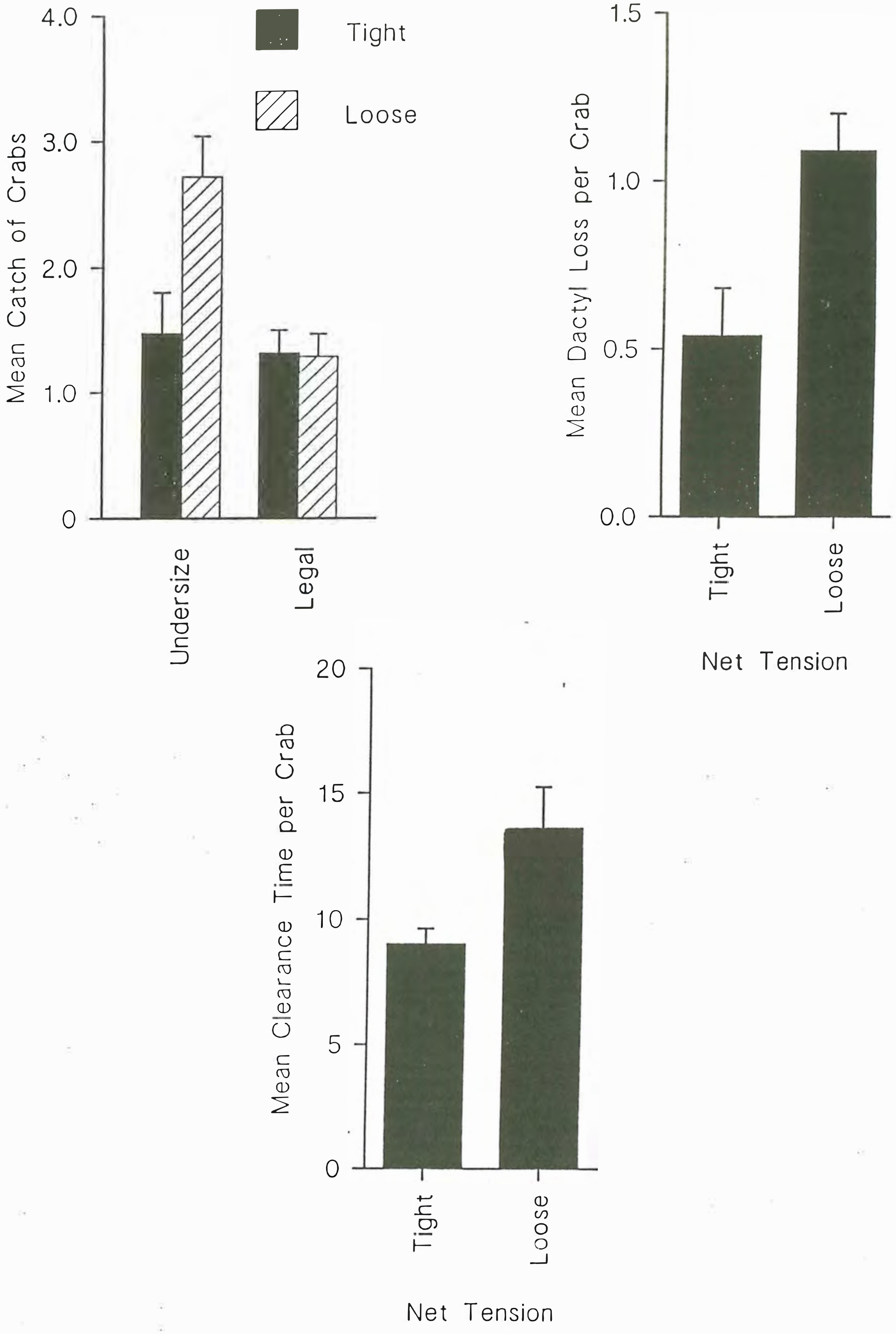


FIGURE 7 The effects of Net Tension on average catch, mean dactyl loss and mean clearance time of spanner crabs using conventional tangle nets (Standard Errors are shown above each bar).

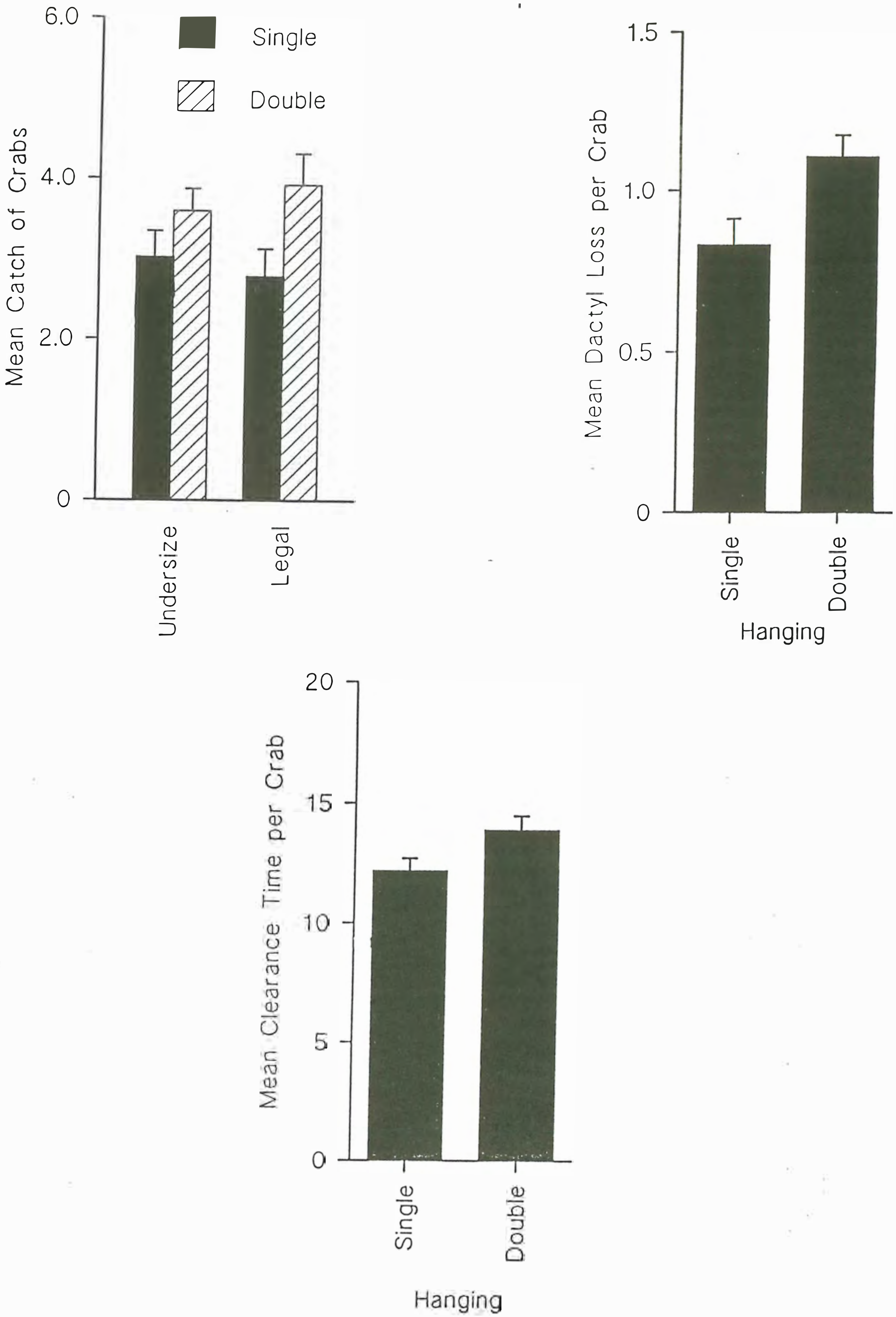
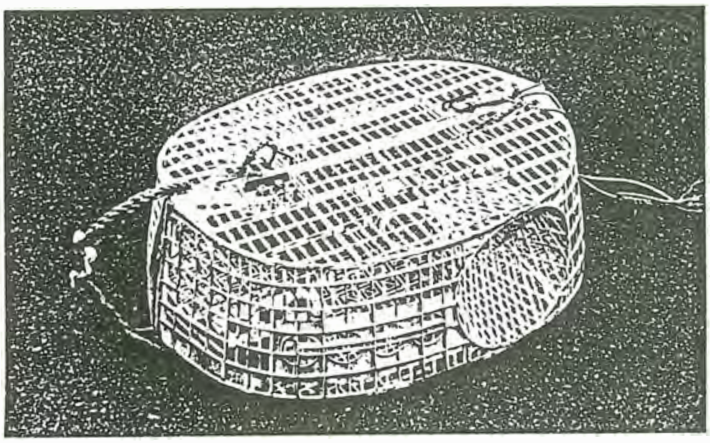
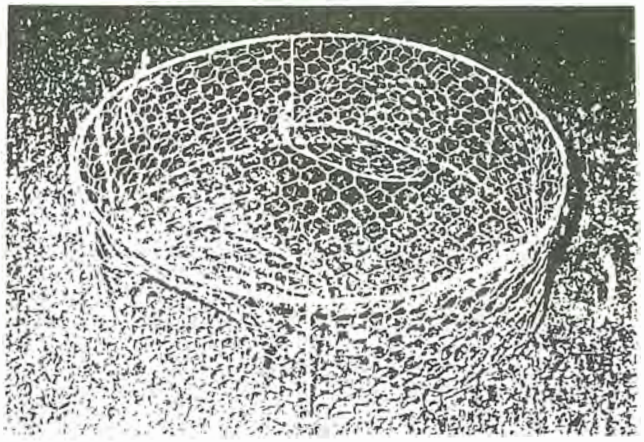


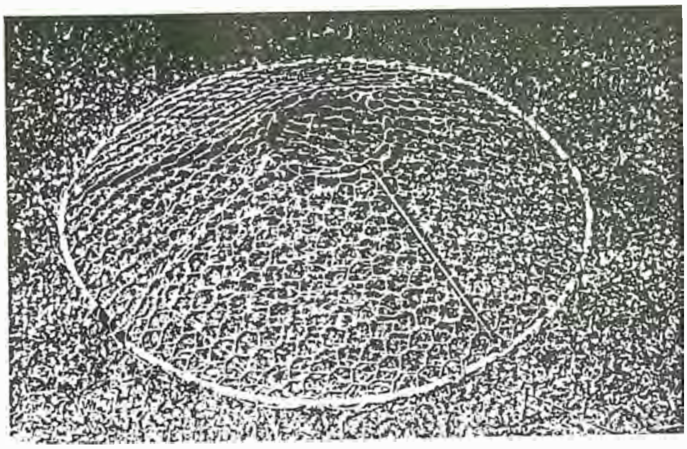
FIGURE 8 The effects of number of mesh layers (Single or Double) on average catch, mean dactyl loss and mean clearance time of spanner crabs from conventional tangle nets (Standard Errors are shown above each bar).



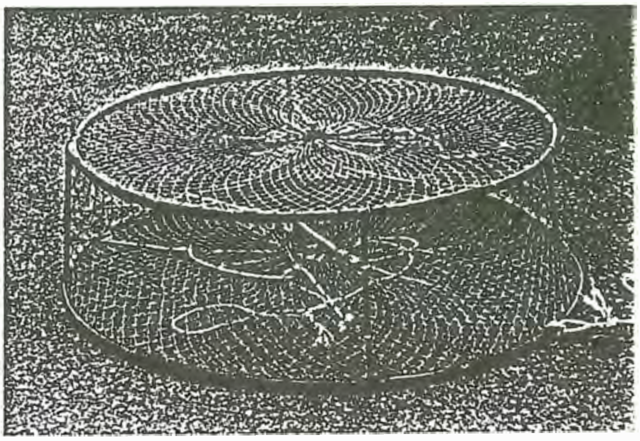
AMERICAN CRAB TRAP



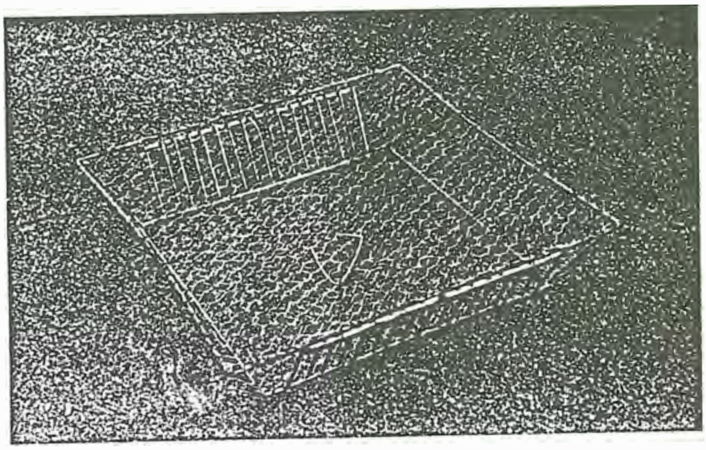
WIRE POT



TRUNCATED CONE



COLLAPSIBLE POT



PIGEON TRAP

PLATE 1

Representative range of non entangling trap types tested in laboratory and field trials.