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FINAL REPORT TO THE
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ASSESSMENT OF OPTIMAL TRAPPING TECHNIQUES TO CONTROL DENSITIES OF NORTHERN PACIFIC SEASTARS ON MARINE FARM LEASES

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TASMANIA

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SUMMARY

The principal aims of this study were to evaluate whether the locally-produced Whayman-Holdsworth trap provides an effective method for minimising *Asterias amurensis* infestations on shellfish farms, and to objectively assess the value of seastar traps when used in commercial applications.

In an initial fishdown experiment, the efficiency of seastar traps was assessed at sites with low/moderate and high densities of seastars. Intensive trapping effort directed at the low site failed to control the seastar population within the trap field, even though 1160% of the original population had been removed during the 51 day period of study. Furthermore, analysis of trapping and length-frequency data showed that catch rate did not decline towards the centre of the array, and that the mean size of seastars collected from within the low density array increased. *A. amurensis* clearly immigrated rapidly and persistently into the trapping array, precluding attempts to control seastar numbers within the trap field.

The proportion of the initial array population removed by trapping at the high density site during the initial fishdown was approximately 53%, considerably lower than that recorded for the low density site. However, a significant decrease in seastar density occurred over the period of fishdown at this site. Analysis of catch data showed that catch rate did not decline towards the centre of the array, and that seastars predominantly immigrated from a north easterly direction. Trap collected length-frequency distributions showed a decline in mean size, indicating the initial stages of trapping impact on the population. Immigration at this site therefore appears to have been considerably less than at the low density site.

Although no strong soak time related catch trends were apparent, traps were generally saturated after 24 to 48 hours. Few animals were caught as bycatch during the fishdown, with the five main bycatch species consisting of three crabs, an introduced seastar and an ascidian.

Following the initial experiments an attempt was made to counteract rapid immigration rates by pulling and resetting traps over several consecutive days (sequential 24 hour soak times), thereby maximising the numbers of animals removed from each trapping array. Seastar densities in both the high and low density arrays did not change significantly over time: however, a reduction in mean size of seastars following intensive trapping occurred, presumably because the mean size of animals removed in traps was greater than that of immigrant individuals.

The second fishdown experiment therefore indicated that a period of six days of suitable weather was insufficient to substantially reduce densities of seastars from an array of traps set 15 m apart, and serviced every 24

hours. Examination of the estimated population and total seastar catch in each array revealed that the majority of seastars in both low and high density arrays had been removed by trapping but had presumably been largely replaced by new immigrants.

A mark recapture trial was undertaken in order to quantify movement rates of seastars into baited traps over a 24 hour period, thus providing an indication of the attraction range of the seastar traps, and additional information on short term immigration rates into trapping arrays. Although this experiment was not able to definitively assess the attractive range of the Whayman-Holdsworth seastar trap, it provided some insight into movement of *Asterias amurensis*. *Asterias amurensis* was found to be capable of moving at least 20 m over a 24 hour period.

In trials conducted to determine preferences of *Asterias amurensis* for different types of commercially available baits, seven finfish species that were locally available in frozen form were tested. The results of the trial showed only minor differences between bait type used in the Whayman-Holdsworth seastar trap. *Asterias amurensis* exhibited a slight preference for pilchards as a bait type. However this preference was only evident over shorter soak times (24 to 48 hours) and catch rates were only significantly elevated when compared to barracouta and gurnard baits.

A series of experiments was undertaken in order to ascertain if a perimeter of closely spaced seastar traps would provide an effective barrier to the migration of *Asterias amurensis*, and so be useful in preventing immigration onto shellfish farms. The trials revealed that, even with extremely reduced spacing (2.5 m), traps were not successful at excluding *Asterias amurensis* from a discrete area of sea floor cleared of seastars for a significant period of time.

After investigating the relative cost efficiencies of traps, diver hand collection and diver administered lethal injection for controlling a range seastar infestation densities, it was found that the various seastar population control methods possess particular advantages and disadvantages. The Whayman-Holdsworth seastar trap is probably the best control method for chronic seastar infestations, regardless of density or depth. The traps are robust, easy to maintain, and remove *Asterias amurensis* with little bycatch. They are, however, suitable only for long term control programs due to the high initial capital expenditure required to purchase traps and associated gear.

Where seastar infestations are sporadic in frequency or transient in nature, diver control appears to be a more suitable option. A high capital outlay is not required, and divers would only be employed during outbreak periods. Furthermore, intensive trapping may attract large numbers of seastars into the area requiring seastar control. At infestation densities below $1.5m^{-2}$, diver hand removal appears to be more cost effective when compared to lethal injection, but as densities increase the two control methods possess similar costs. Diver hand removal would probably be the preferred option in most cases, as lethal injection may attract cannibalistic con-specifics into the control area. The benefits of diver population control methods are greatly affected by depth, with diving costs becoming prohibitive once maximum depth exceeds 12 m.

BACKGROUND

The northern Pacific seastar *Asterias amurensis* was accidentally introduced into south-eastern Tasmania during the late 1970's and early 1980's, probably amongst ship ballast water. The species feeds voraciously on a wide variety of shellfish species and is considered a marine pest in south-eastern Tasmania. It potentially threatens natural ecosystems and commercial fisheries from southern Western Australia to southern New South Wales because of its wide temperature and salinity tolerances (Bruce et al., 1995). The species has been recently collected in Victoria.

Distribution

The seastar naturally occurs on northern Pacific coasts in a region extending from China to Alaska, and including Japan, Korea and Russia. It lives at depths ranging from the intertidal zone to at least 200 m. The species was first discovered in Australia near the ports of Hobart and Triabunna in south-eastern Tasmania during the late 1980s, and has since increased in abundance to such an extent that it is now the dominant bottom-living predator on soft sediments in the Derwent estuary near Hobart. Its distribution has not, however, increased substantially within Tasmania in recent years, with the region of colonisation extending from Triabunna south to Dover. Many of the records of the species distant from Hobart are at sites close to marine farms (Morrice, 1995).

Specimens of the northern Pacific seastar have recently been collected in Port Phillip Bay, Victoria, although it remains uncertain whether a breeding population has become established in that state. Within its range, the seastar is primarily confined to sheltered sand, silt and mud habitats, although it can also occur on sheltered rocky reefs when crowded. Analysis of the genetic structure of *Asterias amurensis* indicates that the Australian population probably originated in the central region of Japan or perhaps Korea because of genetic similarities linking these regions (Ward, 1994).

Life-history

Huge numbers of planktonic eggs are released by the northern Pacific seastar during the spawning season that extends between July and September in south-eastern Tasmania. Approximately 20 million eggs are released by the largest females, with the eggs passing through several larval stages over a period of three to four months. After this time, animals settle on the seabed and metamorphose into the star-shaped juvenile stage. In many areas of the coast, extremely high numbers of planktonic larvae occur yet relatively few develop into juveniles, hence settlement and the period immediately after settlement appear to be a particularly critical stage in the animal's life-history.

Juvenile seastars grow rapidly providing sufficient food is available, reaching maturity at a size of 5 cm arm length. Large animals are thought to be at least 3 years old (Morrice, 1995).

Diet

The northern Pacific seastar usually feeds by capturing bivalve molluscs, heart urchins and other bottom-dwelling invertebrates, but will also scavenge fish offal and other decaying animal material. A huge variety of food items are consumed by predatory seastars, including most slow-moving invertebrate species present in local sandy and muddy environments (Grannum et al., 1996). Seastars are rapidly attracted by chemicals released by other feeding seastars, so aggregate in high numbers at concentrated food sources.

Effects on natural communities of plants and animals

The northern Pacific seastar appears capable of greatly altering the natural ecology of soft-bottom habitats. Virtually all bivalves of any size and many other invertebrates are rapidly eliminated from sandy areas where the seastars occur in high densities (over ten per square metre in some areas near Hobart). This reduces biodiversity and may also affect ecosystem processes because filter-feeding bivalves play a pivotal role on sand and mudflats. Bivalves remove particles from the water and release food for sediment-dwellers in the form of faecal particles, and also regularly turn over the top layer of sediment. They also provide food for a number of bottom foraging fishes such as elephant shark.

Effects on commercial fisheries

Within its natural range in the northern Pacific, the species is considered a significant pest to the scallop, clam and prawn fisheries. The northern Pacific seastar also adversely affects the finfish industry because of damage to the quality of fish caught in gillnets. The cost of control of this seastar is estimated to annually exceed A$12 m within three regions of Japan alone.

Because high densities of seastars are largely confined to the lower reaches of the Derwent estuary, the introduced seastar has not greatly affected commercial fisheries within Australia at present. Most reported losses relate to mussel culture, and generally occur when mussel lines come into contact with the seabed. Losses are also reported by scallop farmers who collect juvenile scallops in spat collector bags which also provide sites for the settlement of seastars.

Despite the low impact to date, Australian fish farms are considered vulnerable to any change in seastar distribution or population density. Of considerable concern is that northern Pacific seastars explode in population numbers at approximately 10 year intervals within Japanese waters. If such an event occurred in Australia, as is conceivable given the billions of planktonic larvae present in our waters that currently do not survive through to the juvenile stage, then the species would threaten oyster and mussel farms and scallop beds.

Preliminary trials carried out by the Tasmanian Department of Primary Industry and Fisheries (DPIF) indicate that a locally-developed seastar trap (Whayman-Holdsworth trap), which is constructed from a steel frame, synthetic netting and plastic bait holder, is highly efficient at catching *Asterias amurensis*. In areas where seastars occur in high densities, up to 62 seastars were captured in a single lift, with virtually no bycatch apart from the native carnivorous seastar *Coscinasterias muricata*. These trials also showed that catches were much higher using traps with 26 mm rather than 65 mm mesh (a mean of 24 cf. 10 animals per set), that the catch varied substantially with soak time, and that the optimum period of submergence was between 48 and 72 hours when using jack mackerel as bait. Although potentially useful to the fishing industry, these experiments provide only a rough indication of the value of seastar traps: no information is presently available to shellfish farmers as to whether these traps will clear the majority of *Asterias amurensis* from the vicinity of their farms, or how many traps are required on a long-term basis to maintain low ambient densities. The aim of the proposed study is to objectively assess the value of seastar traps when used in commercial applications.

NEED

The results of overseas studies on *Asterias amurensis* indicate that methods are unlikely to be developed in the near future to eliminate the species from this country. This seastar is, however, probably controllable within localised areas. There is thus an urgent need to develop a simple and cost effective technique to be used locally to control seastar infestations within areas the size of aquaculture leases. Part of the urgency for developing these control methods is that in Japan the species undergoes cyclic fluctuations in population numbers, with massive outbreaks of animals occurring on an approximately 10 year cycle. A method is clearly needed to protect farms before any such outbreak occurs, rather than attempting an *ad hoc* response afterwards.

OBJECTIVES

- Evaluate whether the locally-produced Whayman-Holdsworth trap provides an effective method for minimising seastar infestations on shellfish farms.

- Determine the optimal distance between seastar traps, configuration of traps, and period of deployment, which maximise reduction in seastar numbers and minimise cost.

- Determine whether different arrangements of traps are required at sites with differing seastar densities.

METHODS

Trap Description

The Whayman-Holdsworth trap is shaped in the form of a truncated cone. The bottom and sides are covered in 26 mm synthetic mesh, and the top or entrance of the trap is circular in shape and devoid of any covering. The trap frame is made of 10 mm mild steel rod, with a base diameter of 100 cm, a top or entrance diameter of 60 cm and an overall height of 12 cm. A plastic bait holder/saver fits firmly into a mild steel ring located in the centre of the trap entrance, and is retained by a short length of synthetic cord tied to the trap frame. Three 80 cm lengths of polypropylene rope are spliced to the trap opening at three evenly spaced points around its circumference, and the loose rope ends are in turn spliced together forming a 'three point harness' terminating in a large stainless steel shark clip. A small polystyrene net buoy mounted below the shark clip holds the harness above the entrance when the trap is submerged.

Site Selection

The Whayman-Holdsworth seastar trap was initially assessed at four sites, each approximately 10 000m^2 in area, that were suitable for the intensive evaluation of multiple seastar traps. The first phase of trap assessment required two main study areas: one with moderate densities and the other with high densities of *Asterias amurensis*. Two additional control sites corresponding to each infestation level were also selected. Potential sites needed to meet several selection criteria: they were required to

1) be located in the lower Derwent estuary or northern D'Entrecasteaux Channel.

2) have densities of *Asterias amurensis* ranging from moderate (0.5 m^{-2}) to high (5 m^{-2}).

3) be composed of a sand/silt substrate.

4) show substrate homogeneity and have similar bathymetry and currents.

5) have a maximum depth of less than 9 m to facilitate prolonged SCUBA diving.

6) pose little or no disruption to boat traffic or shipping operations.

7) be readily accessible from small craft at all tides.

Initial reconnaissance indicated that Ralphs Bay, located in the lower Derwent Estuary, contained areas that possessed the necessary characteristics to be considered as possible study sites (Figure 1). Preliminary diver surveys were undertaken within the bay in late July 1995. An area of low to moderate seastar density ($0.38 m^{-2}$) located 400m east of Huxleys Beach (latitude 42°57.45'south, longitude 147°26.8'east) and an area of high seastar density ($4.32\ m^{-2}$) located west of Richardsons Beach (latitude 42°56.8'south, longitude 147° 27.05' east) were chosen as research sites. Permission to deploy multiple trapping longlines and associated gear in Ralphs Bay was granted by the Marine Board of Hobart.

Experimental protocols

Part 1. Initial fishdown experiment

The aim of the initial fishdown experiment was to assess the efficiency of seastar traps at sites with low/moderate and high densities of seastars. For simplicity, the low/moderate density site will be referred to as the low density site for the remainder of this report.

On August 1 the density of *Asterias amurensis* at the low and high density study sites was quantified using diver censuses. An area adjacent to each of the sites was then designated as a control, and the densities of *Asterias amurensis* determined using the same methods. Seastar density was quantified by divers counting seastars encountered along six 100 m by 1 m transects at each of the high and low density sites, and along between four and six 100 m by 1 m transects at the corresponding control sites. Approximately 250 seastars were collected at random from each experimental and control site, with maximum arm length ($R_{max.}$) of each seastar later measured. Measurements were made of the length of the longest radius from the centre of the mouth to the distal end of the ambulacral groove (Grannum *et. al.*, 1996) using a fibreglass tape to an accuracy of 1 mm.

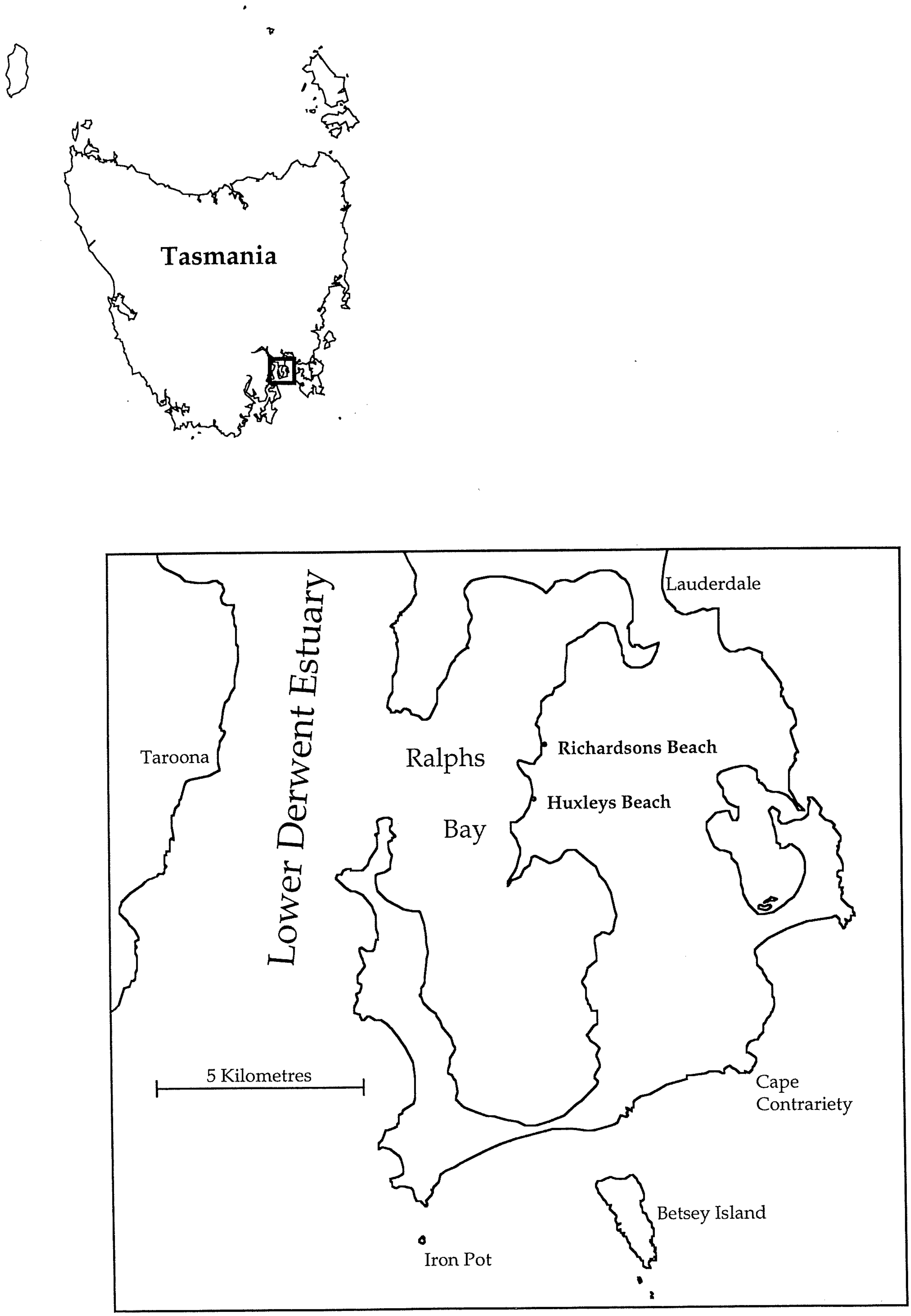

Figure 1. Map showing the location of research areas located in Ralphs Bay, south eastern-Tasmania.

Forty nine seastar traps were then baited and deployed at each site. The traps were arranged in a regular array with seven rows of traps and seven columns of traps, each spaced 15m apart, at each site. Traps were fastened to each longline using large stainless steel shark clips, permitting their rapid attachment and detachment. Railway iron weights anchored the ends of each longline, and a single six inch polystyrene buoy marked the lines position. For speed and efficiency, the traps were set and retrieved in strings of seven, retrieval being assisted by a Honda 5.5 horsepower line hauler and davit mounted snatch block. Approximately 250 g of Atlantic salmon frames were placed into the plastic bait savers attached to each trap, and traps were lifted and re-baited at each site with soak times that varied between 24 and 336 hours. *A. amurensis* and associated bycatch collected in each trap were packed into a large plastic bag, and each bag was labelled by including a waterproof tag identifying the position of the trap in the trapping array and the date of retrieval. The plastic bags containing the contents of the seven traps attached to a single longline were then placed into individual scallop bags. The 14 scallop bags from the two trapping arrays were taken to the Department of Primary Industry and Fisheries Marine Research Laboratories where animals contained in each plastic bag were counted and the associated bycatch identified.

Where possible, a sub-sample of approximately 250 seastars from each array was taken each week for length-frequency analysis in order to identify the degree to which the Whayman-Holdsworth seastar trap is size selective (see King, 1995). Because preliminary studies by the Tasmanian Department of Primary Industry and Fisheries found that the seastar traps tend to target larger size classes of *Asterias amurensis*, these data were compared with the size composition of diver collected samples. High continuous fishing effort using size selective gear can also cause changes in population length-frequency distributions of the target population, indicating that fishing is having a significant impact. Therefore, analysis of population size structure of seastars sampled from within the trapping arrays provided insight into the effectiveness of intensive trapping.

On September 18, one week prior to the termination of the first phase of the trapping trial, the density of seastars at each of the sites, and at adjacent control sites, were again measured using diver censuses. Divers also collected length-frequency samples from each area at that time.

Part 2. Consecutive 24 hour soak fishdown experiment

Part one of this project involved fishdown experiments aimed at assessing the efficiency of the seastar trap at removing *Asterias amurensis* from sites with differing densities of seastars. Soak times were largely dependent upon weather conditions and varied between 24 and 336 hours. Little change in the numbers of trapped seastars was found during those experiments, even though diver estimates of total density indicated that the original population should have been significantly impacted during the time period.

Following the initial experiments, an attempt was made to counteract rapid immigration rates by pulling and resetting traps over several consecutive days (sequential 24 hour soak times), thereby maximising the numbers of animals removed from each trapping array. Similar experimental protocols were used, with divers conducting censuses of animal abundance in areas with high and low densities of seastars and at nearby control sites. Seastars were also randomly collected by divers for size frequency analysis. Traps were then baited and set in a regular array with seven rows and seven columns of traps, each spaced 15m apart, at each site. The traps were then pulled, emptied, re-baited and reset at intervals of 24 hours. On the final day of the trial the density and population structure of seastars in each array, and at adjacent control areas, were determined using diver censuses.

Part 3. Attractive range and movement of *Asterias amurensis* towards baited traps.

The initial fishdown experiments indicated that seastar traps become saturated within the first 24 to 48 hours of deployment. Furthermore *Asterias amurensis* showed a high immigration rate into intensively serviced trapping arrays. *A. amurensis* therefore appears to detect a suitable food source and exhibit non random, directional movement towards the source of the bait odour plume.

The aim of the mark recapture trial was to quantify distances travelled by seastars into baited traps over a 24 hour period, thus providing an indication of the attractive range of the seastar traps, and additional information on short term immigration rates into trapping arrays. Five trapping fields were deployed with each field composed of four or eight baited traps arranged in a square pattern and a release site located in the centre. Four fields were used whereby the distance between the centre of the square and each trap was 5, 10, 20, and 50 m respectively, with a single trap at each corner. A fifth octagonal array was also employed with a centre to trap distance of 100 m and with one trap placed at each corner of the octagon. The experiment was designed so that the number and location of marked seastars released at the centre and recaptured within each trapping field provided information on the rate and directionality of seastar movement.

In initial trials, seastars were stained *in situ* using neutral red and methylene blue stains. In situ staining minimises disturbance experienced by the individuals undergoing the marking procedure. Howard (1985) and Edgar (1992) recognise neutral red as a non toxic staining method suitable for use in marking marine invertebrates. No mortalities were observed over a four day period when two laboratory held samples of *Asterias amurensis* were marked with a 1% (g/l) solution of each type of stain.

Following the laboratory trials, *in situ* field staining was conducted by divers collecting sixty seastars, which were then sub divided into two groups of 30. Each group was placed under an inverted plastic fish bin. Divers then released approximately two litres of 0.5% (g/l) neutral red stain under one fish bin, and a similar amount and concentration of methylene blue under the other bin. The containers were sealed against the sea floor for ten minutes to facilitate stain absorption.

This *in situ* marking method was found to result in poor staining of animals, so the methodology was modified to improve stain retention. Sixty seastars were collected by divers and divided into two groups of 30. Each group was placed in a large plastic bag and brought to the side of the boat. The plastic bags were held immediately below the surface of the water to reduce marking-induced disturbance, and excess water was squeezed from each bag. Approximately 250 ml of (0.5% g/l) neutral red stain solution was added to one plastic bag and a similar amount of 0.5% (g/l) methylene blue was added to the remaining bag. The bags were sealed and returned to the sea floor, and the captive seastar groups were liberated after 10 minutes exposure to their respective stain. Animals were released at the centre of the trap field. The traps were pulled and checked after 24 hours of soak time, and the number of blue, red or non-stained seastars collected from each trap recorded.

Part 4. Bait preference trials

Experimental trials were conducted to determine if *Asterias amurensis* showed any preference for particular types of commercially available fish bait. Baits tested were finfish species that were locally available in frozen form - gurnard perch (*Neosebastes scorpaenoides*), barracouta heads (*Thyrsites atun*), alfonsin (*Beryx splendens*), Australian salmon (*Arripis trutta*), mackerel (*Trachurus declivis*), pilchards (*Sardinops neopilchardus*) and Atlantic salmon frames (*Salmo salar*). Baits were obtained from two south-east Tasmanian commercial fish processors: Tas Crays and Nortas.

Bait preference trials were conducted between 14 December 1995 and 5 January 1996, with four separate soak times tested: 24, 48, 72 and 96 hours. Seven longlines each containing seven traps were deployed off Richardsons beach in Ralphs Bay. Inter-longline trap spacing was set at 15 m and longlines were laid approximately 40 m apart, parallel to one another. Each longline contained seven bait types allocated randomly to trap positions along the longline. Traps were baited with approximately 300 g of bait and each bait type was replicated seven times within the 49 trap field. At the termination of each trial, the traps were retrieved and the number of captive *A. amurensis* contained in each recorded.

Part 5. Protection of an area cleared of *Asterias amurensis* with a perimeter of closely spaced seastar traps

The aim of this series of experiments was to determine if a perimeter of closely spaced seastar traps could effectively prevent *Asterias amurensis* from immigrating into an area cleared of seastars. The following experimental protocol was employed. A 50 m by 50 m square adjacent to Huxleys beach in Ralphs Bay was marked out with four dan poles, each anchored with rope to railway iron weights. Water depth in the general vicinity of the site was approximately four to six m. Divers conducted several 100 m transects passing through the square to determine seastar densities throughout the area. Seastar traps baited with salmon frames were then set around the perimeter. Traps were deployed on four longlines, one line along each side of the square. Each line contained 10 traps with a trap spacing of 5 m. Divers systematically searched the enclosed area and removed all seastars encountered. After seastar collection was completed, ten individually buoyed traps were set randomly within the perimeter formed by the longlines.

The lines were hauled after 24 hours, and the number of *A. amurensis* captive in each trap recorded. The traps were then re-baited and the longlines reset as close as possible to their original position. This process was repeated every 24 hours until the catch rate of the perimeter traps was not significantly different to that of the internal traps.

The initial experiment revealed that the catch rate of the internal traps was similar to the perimeter traps after only 2 days, indicating a higher than expected rate of return to the cleared area. In order to increase the robustness of the trial the internal traps were replaced with eight 50 m by 1 m diver transects. Transects provided a more accurate method of assessing seastar density and internal traps may have attracted seastars. Additionally, a further ten traps were attached to each side of the array reducing the perimeter trap spacing to 2.5 m.

Part 6. Relative cost efficiency of seastar traps in comparison to diver control methods.

The initial aim of this trial was to compare the cost efficiency of reducing seastar numbers in infested areas using traps and diver hand collection over a range of densities. Diver collection rates were quantified by conducting four 100 m by 1 m transects at randomly chosen sites in Ralphs Bay. Immediately after the transects were completed, the divers returned to the water and quickly placed into catch bags *Asterias amurensis* sighted in the general vicinity of the area assessed by transect surveys. The time taken to fill each catch bag was noted by the dive supervisor onboard the support vessel. The collection rate of seastars by divers over a range of densities was subsequently calculated. Between diver variation was minimised by using the same three divers used in trials. Survey sites were largely restricted to less than 8 m depth.

The relative efficiency of the Whayman-Holdsworth trap was estimated by firstly conducting diver transects, as described above, in order estimate seastar densities. Seven baited traps were then haphazardly scattered around the area covered by the transect survey. Each trap was baited with approximately 250 g of Atlantic salmon, the bait type remaining constant throughout the trial. The traps were pulled after 24 hours and the number of seastars in each trap recorded, providing 24 hour soak time catch rates. Both diver and trap efficiency trials were repeated over several months encompassing a number of sites and a range of seastar densities.

In a commercial seastar control operation, the practice of catching, bagging and transferring catch bags between the surface and diver may prove too time consuming and inefficient. Furthermore, suitable terrestrial disposal of collected seastars would be required, imposing additional costs. Diver culling of seastars *in situ* by injecting them with a toxic compound was therefore considered potentially more efficient. The Great Barrier Reef Marine Park Authority (GBRMPA) uses sodium bisulphate injection as a cost effective method of controlling outbreaking *Acanthaster planci* in localised areas (Lassig, 1995).

Preliminary laboratory trials were conducted in order to determine the toxicity of sodium bisulphate on *Asterias amurensis*. This toxin is recommended by the GBRMPA in preference to previously used copper sulphate, as sodium bisulphate does not promote heavy metal contamination of the marine environment. If the poison injection method is to prove practical under commercial control program conditions, a diver needs to inject 500 to 1000 seastars before surfacing. A SCUBA diver can carry at least five litres of liquid without being significantly impeded, hence a 5 ml injection dosage would enable up to 1000 seastars to be treated before poison containers would require exchanging.

Samples containing five replicates of 10 seastars were held in 5 separate tanks in the laboratory. Tanks were supplied with a constant flow of sea water. Five millilitres of 140 g/l sodium bisulphate solution (the concentration recommended by the GBRMPA for controlling *A. planci*) was injected into the central disc of each seastar. Sodium bisulphate was found to be particularly effective against *Asterias amurensis* in the trials, with a 100% mortality rate recorded.

Five concentrations of sodium bisulphate (50, 100, 150, 200 and 250 g/l) were then field tested in order to assess their lethality. The experimental protocol for each test concentration involved divers collecting all *A. amurensis* located within a circle of radius five meters (78.54 m^{-2}). The centre of each capture/injection area was marked with a six inch polystyrene buoy, which was attached by polypropylene rope to an railway iron weight. Each seastar was injected with a 5 ml dosage of sodium bisulphate solution using a 'Coopers Supervax Automatic Injector' and was then placed in an inverted position in the central region of the circle. Divers returned to each site after approximately 24 hours and counted the number of healthy, dead or moribund *A. amurensis* remaining in the area.

Subsequent diver control efficiency experiments were modified to include lethal injection control trials. Divers located and injected *Asterias* with 5 ml of green food dye solution in order to imitate a commercial control operation. Food dye was injected as it aided in the identification of injected seastars, reducing the likelihood that divers covered the same area twice. The number of seastars injected per unit time was then calculated at a range of sites with differing seastar densities.

RESULTS

Part 1. Initial fishdown experiment

Traps were pulled, emptied, re-baited and reset a total of 14 times over a period of 51 days (1/8/95 to 25/9/95), with soak times ranging from 24 to 336 hours. On several occasions (19, 20 and 25/9/95) the trapping arrays were only partially serviced due to inclement weather conditions.

A total of 97 972 *Asterias amurensis* were caught over the fishdown period, 53 365 and 44 607 seastars were trapped in the low density and high density sites respectively. This represented an overall mean catch per trap of 73.9 seastars, 78.1 and 69.6 in the low density and high density sites respectively.

Table 1 shows the estimated *A. amurensis* population contained within the high and low trapping arrays at the commencement and termination of the fishdown, as estimated by diver transect, and the number of seastars trapped in each area over the duration of the study. The estimated population of the low density trapping array increased over the fishdown period, despite the fact that 1160% of the initial population had been trapped and removed. Furthermore, Table 2 shows that the mean density of seastars found in the low density array increased significantly ($p=0.032$) whereas the mean density of seastars at the control site showed a significant decrease ($p<0.001$) over the course of the fishdown. Probabilities were derived from F-tests using single factor analysis of variance. A two factor analysis of variance was conducted on data collected from the low density array and control, at the start and finish of the fishdown (see Table 3). Significant differences in seastar density between array and control were evident ($p<0.001$) regardless of sample timing, but the difference between initial and final densities excluding site was not significant (0.060). The most important statistic revealed by the two factor ANOVA was that interaction occurred between site and time, indicating that significant differences existed between density changes measured at the low density site compared to its control.

The initial and final mean *A. amurensis* density and corresponding estimated internal population of the high density trapping array decrease (p=0.005) significantly over the fishdown period (Tables 1 and 2). Approximately 52% of the initial estimated *A. amurensis* population was removed from this site. No significant change in seastar density was apparent at the high density control site (p=0.068). Table 4 contains the results of a two factor analysis of variance conducted on data collected from the high density array and control, at the start and finish of the fishdown. Significant differences in seastar density between sites were apparent (p=0.001) regardless of sample timing, but there was no significant difference (0.004) between initial and final densities regardless of site. Importantly, interaction occurred between site and time factors, indicating that significant differences existed between density changes measured at the high density site compared to its control (p=0.068).

	Low density site (10 000 m^2)	**High density site (10 000 m^2)**
Initial population estimate	4 600 ± 1 050	84 900 ± 50 760
Final population estimate	6 700 ± 1 840	13 900 ± 1 560
Total *A. amurensis* trapped	53 365	44 607
% removal of initial pop'n.	1160	53

Table 1. Initial and final population estimates from the high and low density trapping arrays (±95% confidence intervals) including number of seastars removed from each site by trapping.

	Initial mean density	**Final mean density**	**p**
Low density site	0.46 ± 0.04	0.67 ± 0.07	0.032
Low density control	1.31 ± 0.04	0.89 ± 0.04	0.000
High density site	8.49 ± 1.97	1.39 ± 0.06	0.005
High density control	0.63 ± 0.07	0.44 ± 0.06	0.068

Table 2. Initial and final densities (seastars m^{-2})of *A. amurensis* measured at the high and low density trapping arrays and corresponding control sites (±SE). Significance (p) values indicate probabilities from F-tests using single factor analysis of variance.

Source	Sum of squares	Degrees of freedom	Mean square	F ratio	P
site	1.1479 (58.4%)	1	1.473	99.17	0.000
time	0.0604 (3.1%)	1	0.060	4.066	0.060
site*time	0.5027 (25.6%)	1	0.503	33.844	0.000
error	0.2525 (12.9%)	17	0.015		

Table 3. Two factor analysis of variance conducted on initial and final densities of *Asterias amurensis* collected at the low density trapping field and corresponding control site.

Source	Sum of squares	Degrees of freedom	Mean square	F ratio	P
site	103.3511 (29.1%)	1	103.351	15.882	0.001
time	70.9723 (19.97%)	1	70.972	10.906	0.004
site*time	63.8024 (17.69%)	1	63.802	9.804	0.006
error	117.1363 (32.97%	18	6.508		

Table 4. Two factor analysis of variance conducted on initial and final densities of *Asterias amurensis* collected at the high density trapping field and corresponding control site.

The plots displayed in Figure 2 show the total number of seastars caught at each site on each array retrieval. Catch data from partially serviced sites and array pulls with extremely long soak times (336 hours due to inclement weather) were excluded from this Figure. The catch rates at both sites, particularly the high density site, showed a marked tendency to fluctuate. Numbers declined over the duration of the fishdown.
A summary of the bycatch species caught by the Whayman-Holdsworth seastar trap during the fishdown is shown in Table 5. Included is the mean catch per trap for each species and confidence intervals showing standard error of the mean.

Bycatch species	*Paragrapsus gaimardii*	*Leptomithrax gaimardii*	*Cancer novaezealandiae*	*Patiriella regularis*	**Ascidians**
mean catch trap^{-1} ± SE.	0.84 ±0.23	0.09±0.05	0.05±0.01	0.40±0.12	0.86±0.55

Table 5. Mean catch per trap (±SE) of bycatch collected from Whayman-Holdsworth seastar traps.

Few animals or species were caught as bycatch during the fishdown. The five most common species were three crabs, an additional introduced seastar (*Patiriella regularis*) and an unidentified ascidian species. Approximately 30 individual fish were collected during all the trapping trials, including *Nemodactylus macropterus*, *Pseudophycis bachus*, *Macrorhamphosus scolopax*, *Arcana aurita*, *Platycephalus bassensis* and *Neoodax balteatus*.

Tables 6 and 7 show the mean catch per trap for each trap relative to its position in the low or high density trapping array respectively. Means were calculated from pooled catch results gathered over the duration of the experimental period, and include soak times ranging from 24 to 168 hours. Data from partially serviced trapping arrays were excluded from the analysis.

Preliminary examination of the data revealed that neither the high density nor the low density trap arrays showed the expected reduction in mean catch by traps located in the central region of each trapping field. Examination of the variance relating to the catch per trap indicate that the low density trapping array tended to catch seastars with a greater degree of consistency when compared to the high density array.

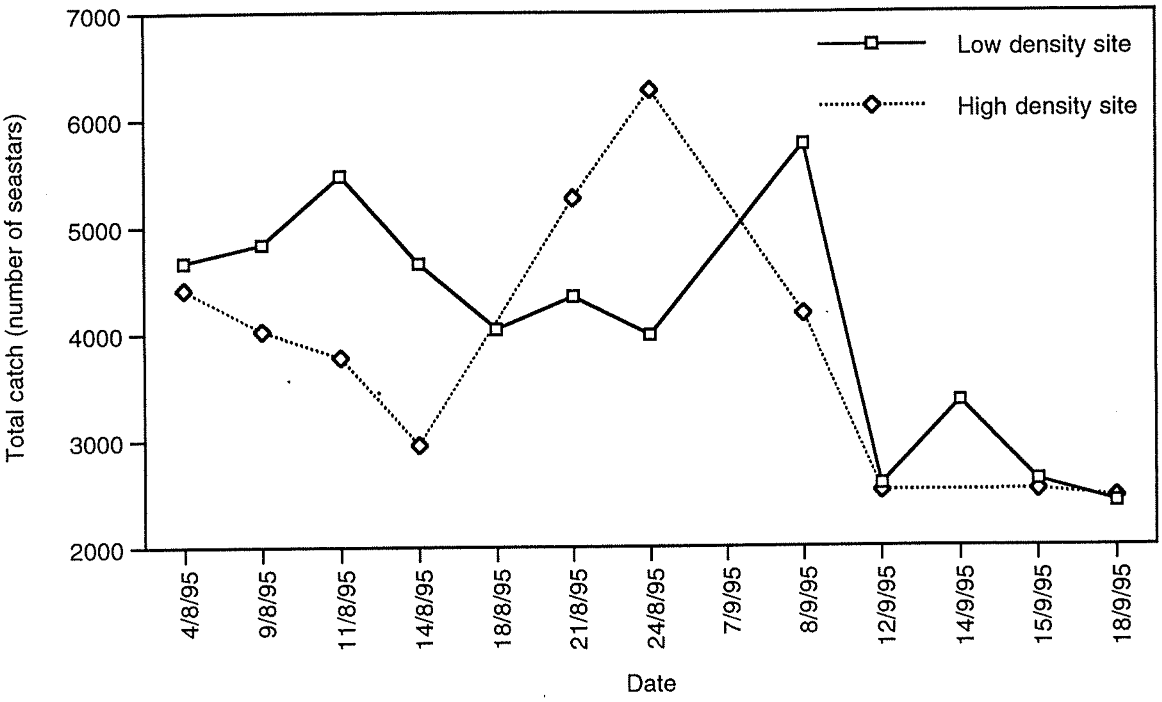

Figure 2. Total number of *Asterias amurensis* caught at each site over the fishdown period.

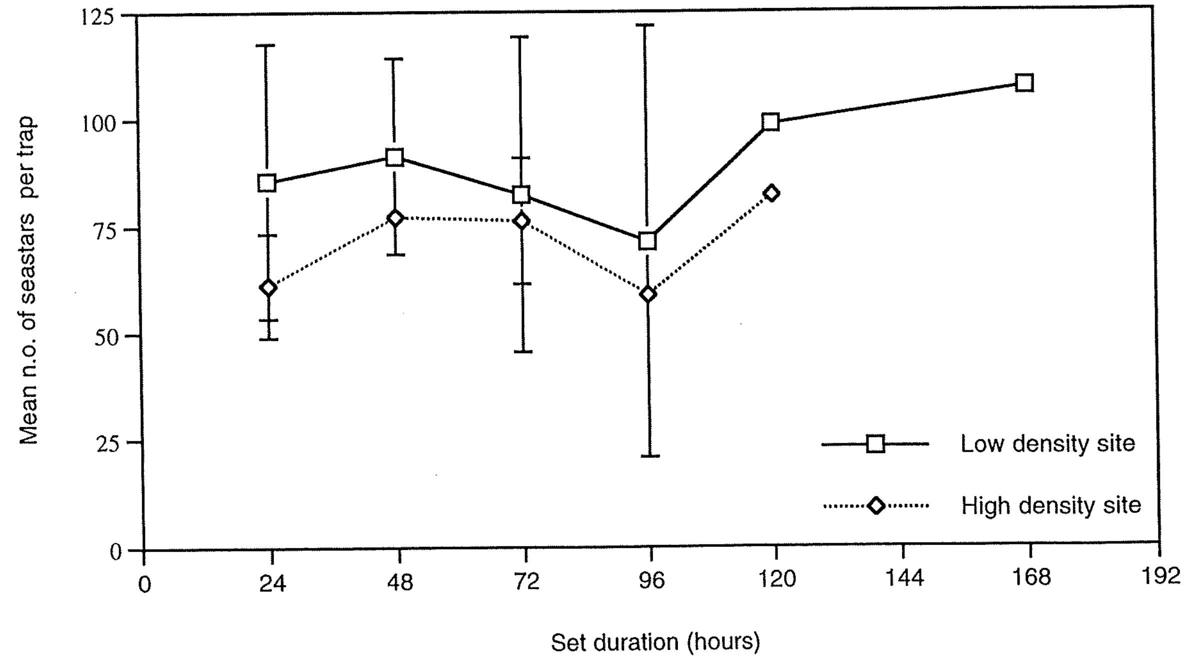

Figure 3. Effect of soak time on catch rate of *A. amurensis*. Confidence intervals represent standard error of the mean.

Longline	1	2	3	4	5	6	7
Trap 1	85.0 (30.9)	73.3 (43.2)	79.8 (29.6)	62.9 (33.7)	63.4 (32.9)	56.3 (37.6)	84.1 (23.0)
Trap 2	73.2 (35.2)	72.9 (25.2)	75.8 (36.9)	76.1 (32.3)	76.8 (37.1)	66.5 (27.8)	80.33 (36.1)
Trap 3	82.6 (25.9)	76.3 (27.9)	87.3 (29.1)	62.0 (34.1)	67.6 (31.4)	82.1 (37.8)	91.0 (38.4)
Trap 4	94.3 (39.1)	76.3 (25.1)	74.7 (32.2)	72.1 (32.1)	64.2 (33.9)	72.9 (40.1)	95.5 (47.7)
Trap 5	89.6 (40.8)	84.0 (36.8)	64.7 (35.2)	72.9 (35.5)	86.9 (33.3)	79.7 (38.8)	99.2 (36.5)
Trap 6	106.1 (49.5)	89.6 (32.3)	90.8 (37.6)	89.3 (44.9)	100.7 (31.6)	106.0 (37.1)	103.3 (42.8)
Trap 7	85.0 (28.6)	103.0 (36.7)	99.5 (37.2)	105.8 (35.9)	106.8 (45.9)	115.8 (46.1)	108.1 (37.6)

Table 6. Mean catch per trap (SE) at the low density site.

Longline	1	2	3	4	5	6	7
Trap 1	52.9 (50.2)	83.8 (47.7)	75.2 (42.8)	42.6 (33.6)	80.4 (44.6)	85.8 (47.1)	100.9 (50.0)
Trap 2	54.1 (35.3)	62.2 (36.5)	86.9 (64.9)	73.2 (50.4)	39.0 (44.5)	91.0 (39.5)	77.6 (38.1)
Trap 3	66.5 (43.1)	80.8 (31.0)	74.5 (41.1)	72.8 (45.8)	80.1 (49.1)	88.9 (39.7)	91.6 (51.2)
Trap 4	68.3 (36.1)	59.3 (36.3)	65.9 (62.6)	104.4 (101.8)	191.9 (60.3)	88.6 (41.8)	101.3 (37.9)
Trap 5	77.0 (27.6)	46.1 (36.1)	82.7 (51.1)	122.1 (109.2)	105.2 (61.6)	79.9 (57.7)	76.6 (46.5)
Trap 6	67.0 (40.7)	63.6 (51.2)	63.7 (43.7)	110.2 (70.2)	93.3 (51.1)	86.7 (48.9)	80.3 (55.3)
Trap 7	57.3 (34.1)	73.8 (31.3)	77.6 (56.8)	88.8 (30.3)	88.9 (47.6)	116.9 (58.4)	98.2 (63.3)

Table 7. Mean catch per trap (SE) at the high density site.

A four factor analysis of variance was performed on the catch data collected from the two trapping fields. The effect of seastar density, soak time, trap position in row and trap position in each column were tested. Seastar density consisted of two levels, low and high. Soak time was divided into 3 levels where level 1 represented 24 and 48 hour soak times, level 2 represented 72 and 96 hours and level 3 was indicative of soak times 120 hours and over. Both position in row and position in each column contained seven levels. The results of the four factor ANOVA are displayed in Table 8.

Factor	Sum of squares	Degrees of freedom	Mean square	F ratio	p
D	5401 (0.23%)	1	5401	2.86	not sig.
T	14196 (0.63%)	2	7098	3.75	*
D*T	1040 (0.05%)	2	520	0.28	not sig.
R	69211 (3.06%)	6	11535	6.10	***
C	35574 (1.57%)	6	5929	3.14	**
R*C	62846 (2.78%)	36	1746	0.92	not sig.
D*R	25532 (1.13%)	6	4255	2.25	*
D*C	34565 (1.53%)	6	5761	3.05	**
D*R*C	50490 (2.23%)	36	1403	0.74	not sig.
T*R	17699 (0.78%)	12	1475	0.78	not sig.
T*C	35584 (1.57%)	12	2965	1.57	not sig.
T*R*C	59204 (2.61%)	72	822	0.43	not sig.
D*T*R	15719 (0.69%)	12	1310	0.69	not sig.
D*T*C	39508 (1.74%)	12	3292	1.74	not sig.
Error	1797767 (79.4%)	951	1890		

Table 8. Results of the four factor ANOVA conducted on data collected from the high and low density trapping arrays. D represents density, T represents soak time, R represents row and C represents column. * represents $0.05<p<0.01$, ** represents $0.01<p<0.001$ and *** indicates significance at the $p<0.001$ level.

The ANOVA indicated that there was no significant difference in catch rate between the high and low density sites. This result was unexpected given that, initially, there was a large difference in density between the two sites (Table 2).

Significant differences between catch rates of traps immersed for different periods of time were evident, but no strong trends were apparent. Generally, most seastars were caught within the first two days of trap deployment (Figure 3), indicating that traps became saturated after 24 to 48 hours.

A consistent decrease in catch along array rows and a lower magnitude decrease down columns was evident from the results of the four factor ANOVA. There was no interaction effect between these two factors indicating that there were consistent spatial trends evident across both trapping arrays. The observed pattern of catch rates were probably caused in part by long shore currents forming a skewed bait odour plume that was biased towards one corner of each array. Figures 4 and 5 illustrate that both the low and high density sites showed an increase in catch rate as one moves along shore (NNE direction) and up shore (ESE direction)

Interactions between 1) row and density and 2) column and density were revealed by the four factor ANOVA, indicating that a spatial decrease in catch rate was less pronounced along columns compared to rows, when one site was compared to the other. Examination of Figures 4 and 5 clearly shows that the spatial decrease in catch rate is less pronounced along rows compared to columns at the low density site when compared to the high density site. Thus it is evident that the direction of along shore immigration into the low density site was less pronounced in comparison to that observed at the high density trapping array.

Length frequency analysis

Length frequency histograms derived from samples collected at the initiation and termination of the fishdown are displayed in figures 6 and 7. Length frequency distributions were statistically analysed using Kolmogorov-Smirnov (K-S) nonparametric multiple comparisons. Comparisons were drawn between samples collected by divers and traps at the initiation and termination of the fishdown at each site and corresponding control. Probabilities are included in Table 9 and Figures 6 and 7.

K-S Comparison	Low density	High density
diver initial vs. trap initial	<0.001	<0.001
diver final vs. trap final	<0.001	<0.001

Table 9. Probability values from the Kolmogorov-Smirnov length-frequency comparisons between diver and trap collected samples.

Seastar traps were selective towards larger size classes of *Asterias amurensis*. The mean $R_{max.}$ of seastars caught by traps was consistently greater than that collected by divers collecting from within the same area (Figures 6 and 7). Kolmogorov-Smirnov multiple comparison testing found that traps caught a significantly larger animals than divers. (Table 8). Length frequency distributions derived from samples collected at each control site did not change significantly over the period of the fishdown.

A significant increase in the mean $R_{max.}$ of diver and trap collected seastar samples from the low density trapping array occurred over the fishdown period, but the size structure of samples collected from the low density control showed no significant change (Figure 6).

The mean $R_{max.}$ of seastars collected by divers from the high density array did not significantly change over the fishdown, whereas the trap collected samples showed a significant decrease. Seastar length-frequency samples initially collected by divers from the control site were not significantly different to those collected at the termination of the trial (Figure 7).

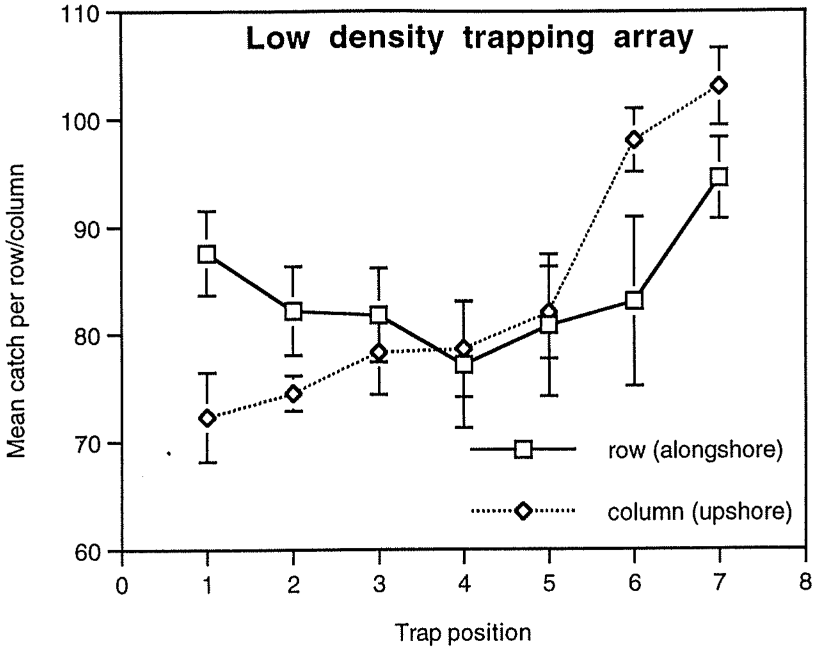

Figure 4. Mean catch per row compared to mean catch per colum in the low density trapping array. Confidence intervals indicate standard error of the mean.

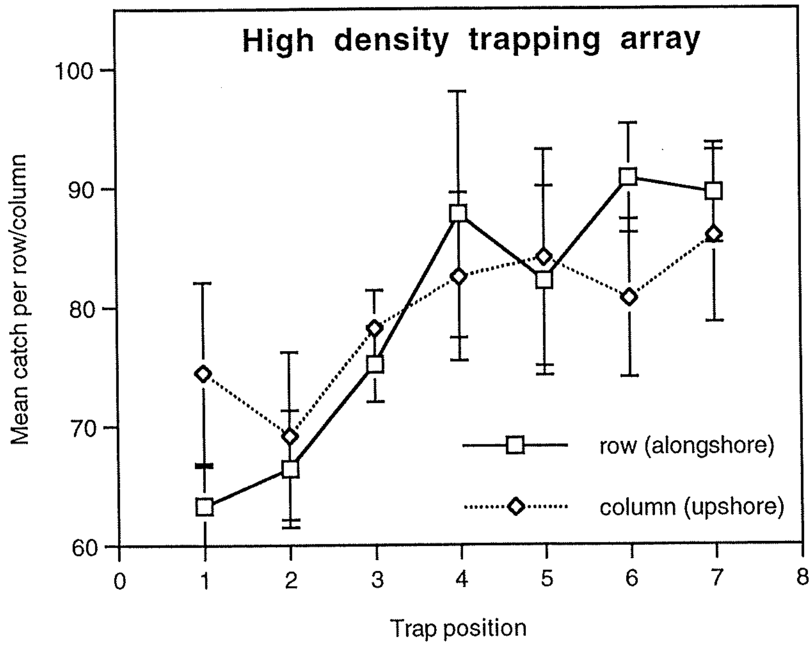

Figure 5. Mean catch per row compared to mean catch per colum in the high density trapping array. Confidence intervals indicate standard error of the mean.

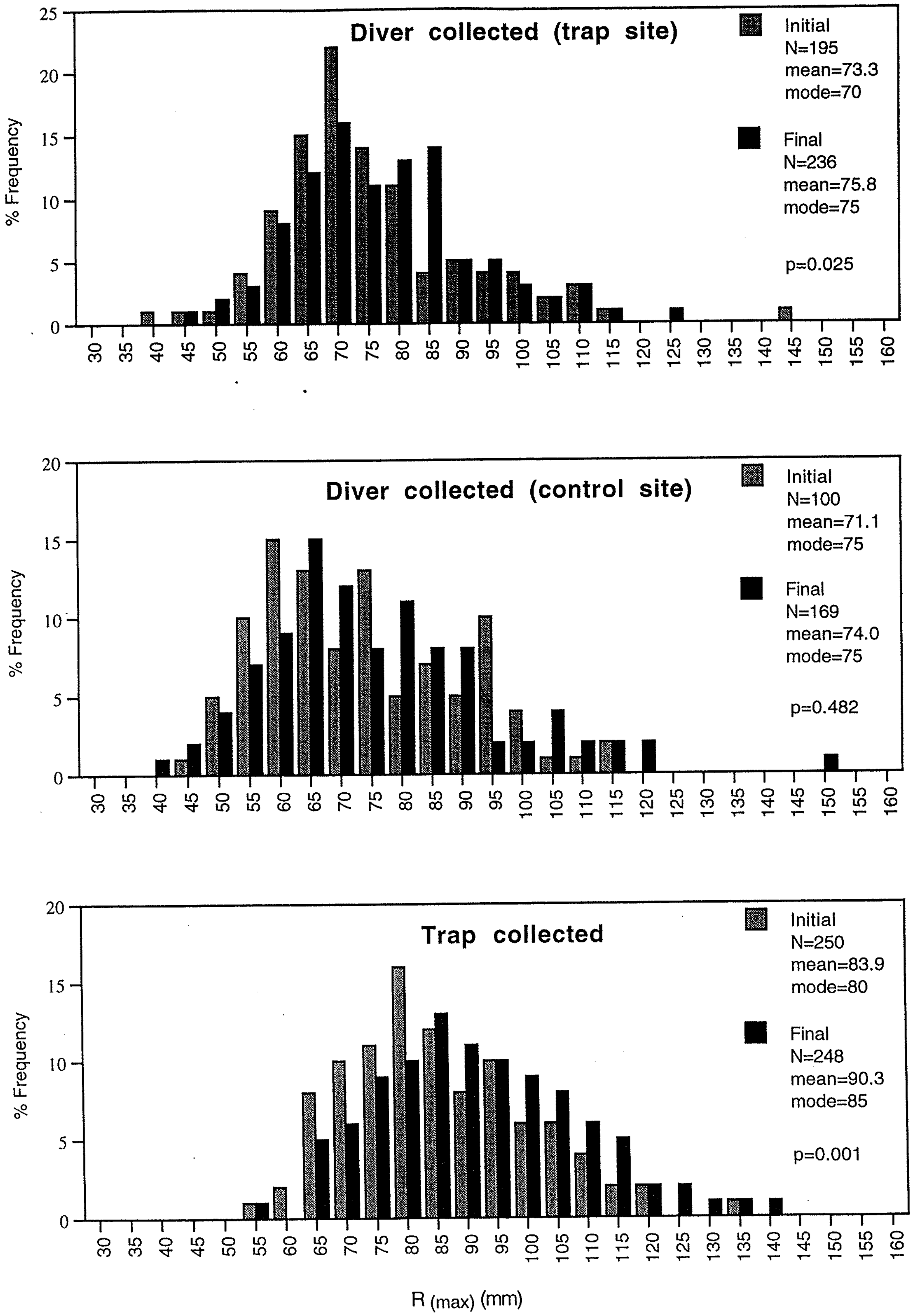

Figure 6. Length frequency histograms derived from samples of *Asterias amurensis* taken from the low density trapping array and corresponding control site. Samples were collected by divers and traps at the initiation and termination of the fishdown. Probability values were derived from Kolmogorov-Smirnov comparisons of length-frequency distributions.

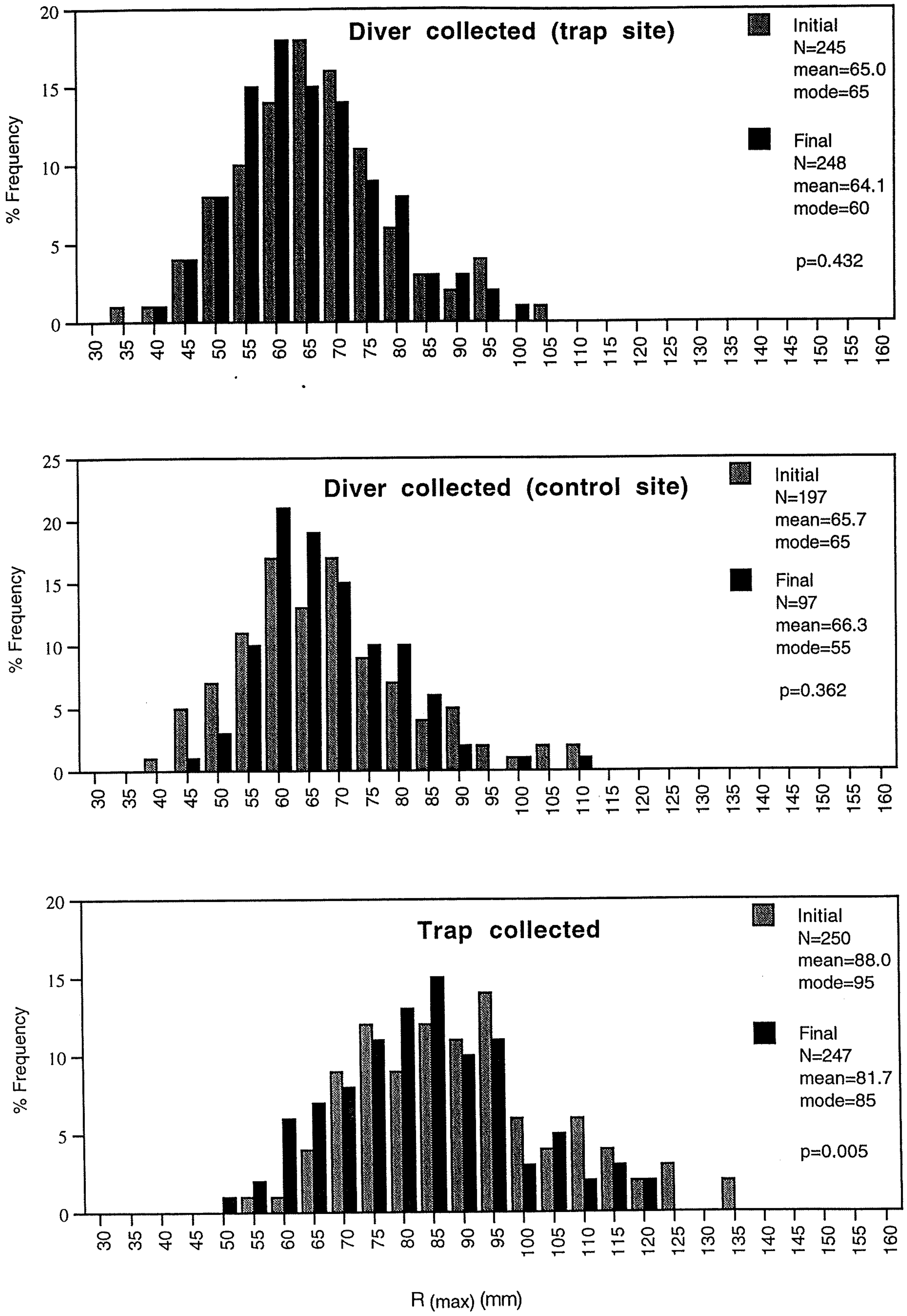

Figure 7. Length frequency histograms derived from samples of *Asterias amurensis* taken from the high density trapping array and corresponding control site. Samples were collected by divers and traps at the initiation and termination of the fishdown. Probability values were derived from Kolmogorov-Smirnov comparisons of length-frequency distributions.

Figures 6 and 7 show that traps consistently targeted larger seastars compared to diver collection. As diver collection reflects the naturally occurring size frequency composition present in any one area, the results confirm that Whayman-Holdsworth seastar traps are size selective towards larger individuals. The mean size of trapped seastars (82 mm to 90 mm) exceeded the naturally occurring mean reflected in diver collected samples (64 mm to 76 mm) by 10 to 23 mm. It is possible that behavioural traits or differences in locomotory ability exist between size classes of *A. amurensis* resulting in catch rate differentiation. Small individuals may also pass through the trap mesh.

The observation that the mean maximum arm length of seastars sampled from within the low density array increased rather than decreased supports the hypothesis that the initial population of *Asterias amurensis* censused inside the low density array had been removed by trapping and replaced by larger sized immigrants. The situation observed at the high density array is different because the mean maximum arm length of trap collected seastars decreased over the duration of the fishdown, while the size composition of diver collected samples did not change significantly. A change in trap derived length-frequency would normally be expected to have been reflected in diver collected samples. It is possible that, if trapping had been continued at this site, length-frequency distributions from diver collected samples would have subsequently declined.

The fact that 1160% of the initial population of the low density array was removed by trapping and the density of seastars at this site increased significantly, indicates that trapping effort directed at the low density site failed to control the seastar population within the trap field. Furthermore, analysis of trapping and length-frequency data show that catch rate did not decline towards the centre of the array, and the mean $R_{max.}$ of seastars collected from within the low density array increased. Therefore the results clearly show that *A. amurensis* immigrated rapidly and persistently into the trapping array, precluding attempts to control seastar numbers within the trap field.

The proportion of the initial array population removed by trapping at the high density site was approximately 53%, considerably lower than that recorded for the low density site. However, a significant decrease in seastar density occurred over the fishdown at this site, whereas control densities did not significantly alter. As reported above for the low density array, analysis of catch data showed that catch rate did not decline towards the centre of the array, and seastars predominantly appeared to arrive from a north-easterly direction. Trap collected length-frequency distributions decreased in size, an indication that the initial stages of trapping may have had an impact on the population. Therefore, immigration at this site appears to have been relatively limited in comparison to the low density array. The overall catch rate of both sites declined towards the end of the fishdown probably as a result of naturally occurring population fluctuations, as the data show that trapping impact was probably of insufficient magnitude to cause the observed decline. Whereas Krouse (1989) reported that crustacean traps spaced too closely together tended to compete with each other, the fact that seastar trap catch rates were high and showed no decline towards the centre of each array indicates that the arrays did not exhibited significant inter trap competition.

Part 2. Consecutive 24 hour soak fishdown experiment

Initial attempts to conduct this experiment were frustrated by the passage of storm fronts, which created gaps in the daily sequence of trap deployment. The most successful period of deployment extended from 12 November to 17 November 1995. During this period traps were reset a total of five consecutive times over six days with 24 hours soak time between each trap lift. On 15 November the low density trapping array could not be serviced due to adverse weather conditions.

The results of the diver censuses conducted prior to and after the fishdown are displayed in Table 10. Included are probabilities from F tests derived using single factor analysis of variance, where initial and final densities are compared at each experimental site and control. Table 11 shows the initial and final population estimates from each array and includes the approximate percentage of the initial population removed by trapping. The mean catch per trap in the low and high density trapping arrays over the duration of the trial are shown in Figures 8 and 9 respectively.

	Initial	Final	p
Low array	0.60 ± 0.06	0.44 ± 0.02	0.135
Low control	0.13 ± 0.02	0.25 ± 0.06	0.043
High array	0.99 ± 0.03	1.15 ±0.09	0.086
High control	0.67 ± 0.04	0.39 ±0.06	0.008

Table 10. Initial and final density surveys conducted at each trapping array and associated control (±SE). Density units are seastars m^{-2} and significance (p) values indicate probabilities from F-tests using single factor analysis of variance.

	Low density site (10 000 m^2)	High density site (10 000 m^2)
Initial population estimate	5983 ± 1556	9933 ± 897
Final population estimate	4417 ± 1280	11500 ± 3914
Total *A. amurensis* trapped	3443	6651
% removal of initial pop'n.	58	67

Table 11. Initial and final population estimates (± 95% confidence intervals) including number of seastars trapped in consecutive halls.

Source	Sum of squares	Degrees of freedom	Mean square	F ratio	p
site	0.4400 (65.70%)	1	0.4400	40.4121	0.000
time	0.0011 (0.17%)	1	0.0011	0.1021	0.754
site*time	0.0765 (11.43%)	1	0.0765	7.0301	0.019
error	0.1524 (22.70%)	14	0.0108		

Table 12. Two factor analysis of variance conducted on initial and final densities of *Asterias amurensis* collected at the low density trapping field and corresponding control site.

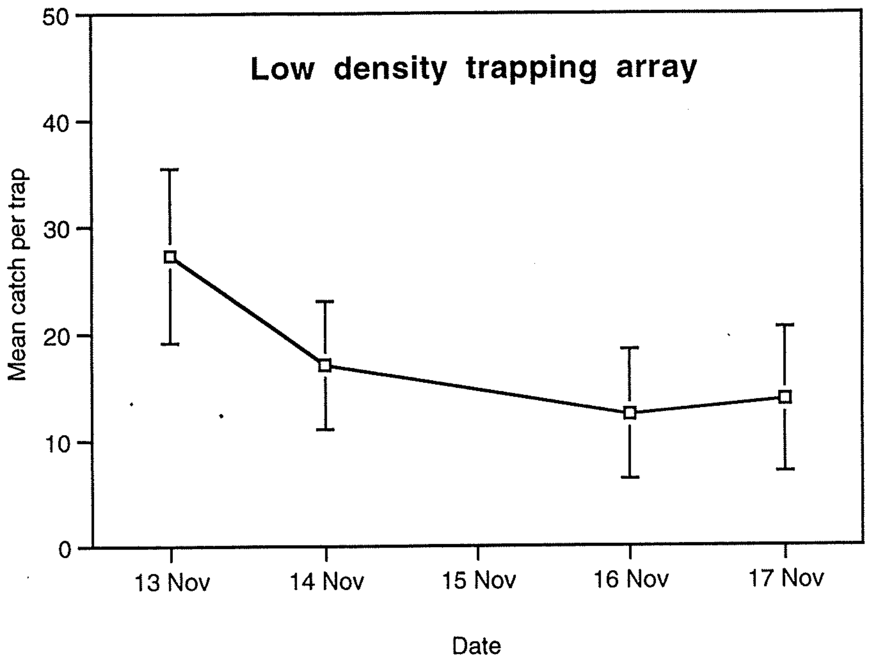

Figure 8. Mean catch per trap in the low density array. Confidence intervals indicate standard deviation of the mean.

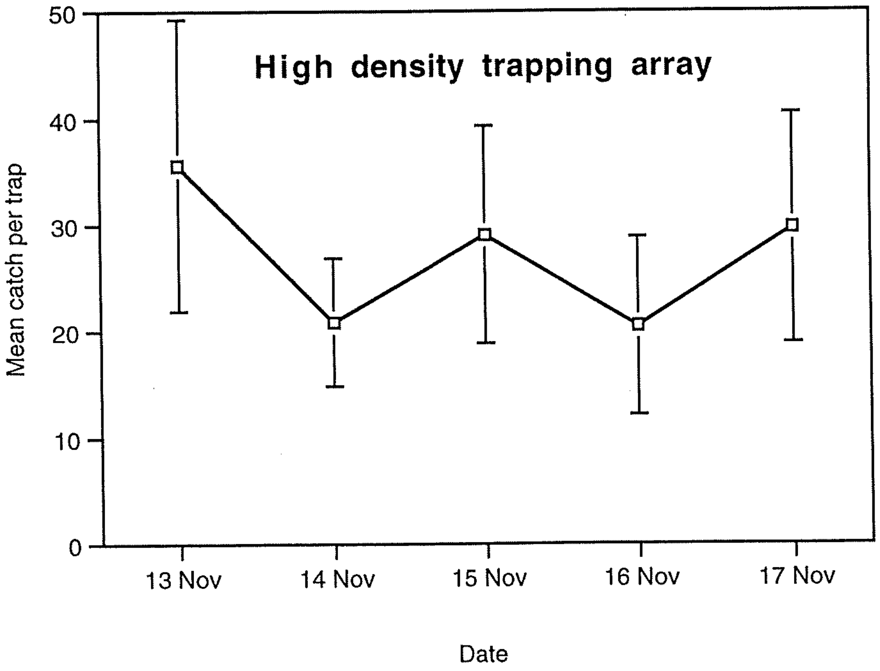

Figure 9. Mean catch per trap in the high density array. Confidence intervals indicate standard deviation of the mean.

Source	Sum of squares	Degrees of freedom	Mean square	F ratio	p
site	1.185(76.57%)	1	1.185	101.350	0.000
time	0.013 (0.81%)	1	0.013	1.067	0.319
site*time	0.186 (12.05%)	1	0.186	15.944	0.001
error	0.164 (10.57%)	14	0.012		

Table 13. Two factor analysis of variance conducted on initial and final densities of *Asterias amurensis* collected at the high density trapping field and corresponding control site.

The final densities of *Asterias amurensis* within the low and high density trapping arrays, as determined by diving surveys, were not significantly different to those measured at the start of the experiment. However, the low density control showed an increase in density whereas the density of seastars at the high density control decreased significantly (Table 10).

Two factor analysis of variance comparing the initial and final densities measured at the low density trapping array and corresponding control site (Table 12) showed significant differences in density between the trapping array and control site, regardless of census timing. Additionally, the trapping array and control site were significantly different in their respective rates of density change over the experimental period, as interaction between sample timing and site explained 11.4% of variation observed in the data.

Table 13 contains the results of a two factor analysis of variance conducted on transect data collected from the high density array and control site. The results of this analysis were similar to those described for the low density site and control. Significant differences in density between the high density trapping array and control site were apparent regardless of census timing, and the trapping array and control site were significantly different in their respective rates of density change over the experimental period. Interaction between sample timing and site explained 12.1% of observed data variation.

An analysis of covariance was applied to the catch data collected from both trapping fields in order to determine whether similar declines in numbers of seastars trapped occurred at high and low density sites. The results of the analysis are shown in Table 14.

Source	Sum of squares	Degrees of freedom	Mean square	F ratio	p
D	283	1	283	3.118	0.078
T	4699	1	4699	51.725	0.000
R	1875	6	313	3.440	0.003
C	2277	6	380	4.177	0.000
T*D	945	1	945	10.404	0.001
Error	38516	424	91		

Table 14. Result of analysis of covariance conducted on catch data. D represents site density (high or low), T represents sample day (5 levels), R and S represent row and column positions respectively.

Significant differences in catch rates over time between sites were evident (p=0.001). Plots displayed in Figures 10 and 11 show that seastar catch decreased significantly over time at the low density site whereas marginal decline was evident over the five day trapping period at the high density site. Approximately 58% and 67% of the estimated pre-fishdown population was removed from the low and high density sites respectively over the five day trapping period (Table 11). Trap position in rows and columns accounted for a significant proportion (3.9% and 4.7%) of variation in the observed catch rate, and trapping rate showed a gradient along both rows and columns at both sites (Figures 10 and 11). Further examination of Figures 10 and 11 show that catch rate reduction at the low density site consistently declined along rows and columns, whereas the high density array showed catch rates that were elevated at the ends of rows and columns. Immigration into the low density array appears to have predominantly been from a south-south-westerly direction whereas immigration into the high density site occurred around the entire periphery.

The results of the intensive five day fishdown indicated that, although a significant proportion of the initial seastar population was removed from each trapping array, immigrating seastars rapidly replaced trapped conspecifics. Immigration into the low density array was predominantly from one corner of the site, and catch rates declined significantly over the five day fishdown. Although *A. amurensis* densities did not decline significantly at this site, catch statistics indicate that the trapping effort directed towards the site was beginning to have an impact on the seastar population immediately surrounding the site. The observation that catch rates were declining but seastar densities were not significantly reduced possibly indicates a declining immigration rate into the trapping array.

Trap catch rates and seastar density measured inside the high density array did not change significantly over the duration of the fishdown, even though 67% of the original *A. amurensis* population had been removed. Therefore the rate of seastar capture and removal was similar to the rate of seastar immigration into the high density array. Thus, the trapping effort directed towards the high density site was insufficient to significantly reduce the seastar population in and around the trapping array.

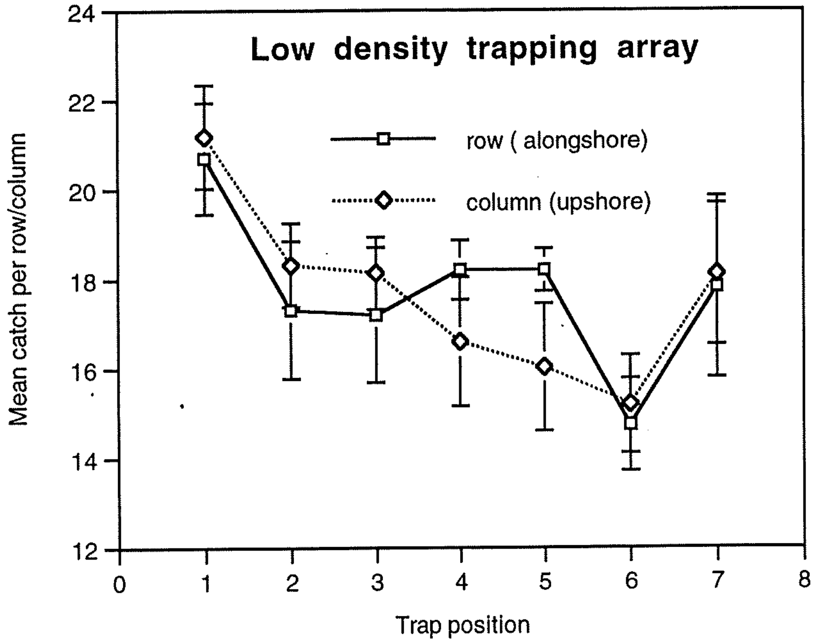

Figure 10. The mean catch per row compared to the mean catch per colum in the low density trapping array. Confidence intervals indicate standard error of the mean.

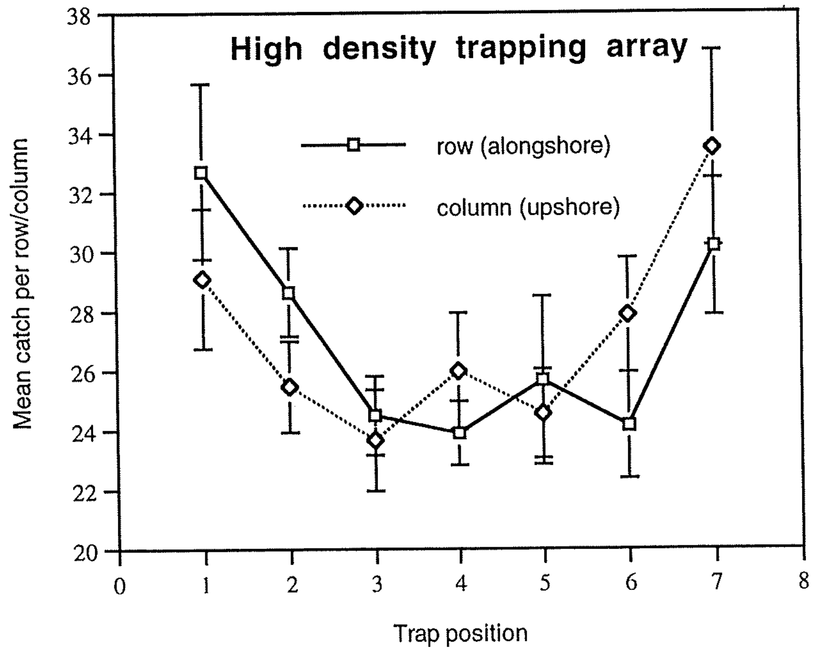

Figure 11. The mean catch per row compared to the mean catch per colum in the high density trapping array. Confidence intervals indicate standard error of the mean.

The high and low density control sites showed significant density changes over the duration of the fishdown (Table 10). Divers reported that the benthic distribution of seastars appeared to be spatially and temporally patchy, a phenomenon that may be driven, in part, by food availability. The level of prey availability at the control sites may have changed over the course of the fishdown, causing seastars to move into the low density control or out of the high density control areas.

Length frequency analysis

Length frequency histograms illustrating the size composition of seastar populations present within the high and low density trapping fields and corresponding control sites are displayed in figures 12 and 13. Samples were collected at the initiation and termination of the fishdown and length-frequency distributions were statistically analysed using Kolmogorov-Smirnov (K-S) non-parametric multiple comparisons. Comparisons were drawn between samples collected by divers and traps at the initiation and termination of the fishdown at each array and control site. Resulting probabilities are included in Table 15 and Figures 12 and 13.

K-S Comparison	p (low density array)	p (high density array)
diver initial vs. trap initial	0.007	<0.001
diver final vs. trap final	<0.001	<0.001

Table 15. Probability values from the Kolmogorov-Smirnov length-frequency comparisons between diver and trap collected samples.

A significant reduction in the mean $R_{max.}$ of diver collected seastar samples from the low density trapping array and control site occurred over the fishdown. The size structure of trap samples collected from within the low density array did not change significantly over the experimental period (Figure 12).

The mean $R_{max.}$ of *A. amurensis* collected by divers from the high density array decreased significantly over the fishdown, whereas trap collected samples showed no significant change. The size structure of length-frequency samples initially collected by divers from the control site were not significantly different to those collected at the termination of the trial. (Figure 13).

Figures 12 and 13 show that seastar traps targeted larger seastars in comparison to diver collection, regardless of site density (Table 15). Diver collection reflects the naturally occurring size frequency composition present in any one area, so the results confirm that Whayman-Holdsworth seastar traps are size selective towards larger individuals. It is possible that behavioural or locomotory differences exist between larger and smaller size classes of *A. amurensis* resulting in catch rate differentiation.

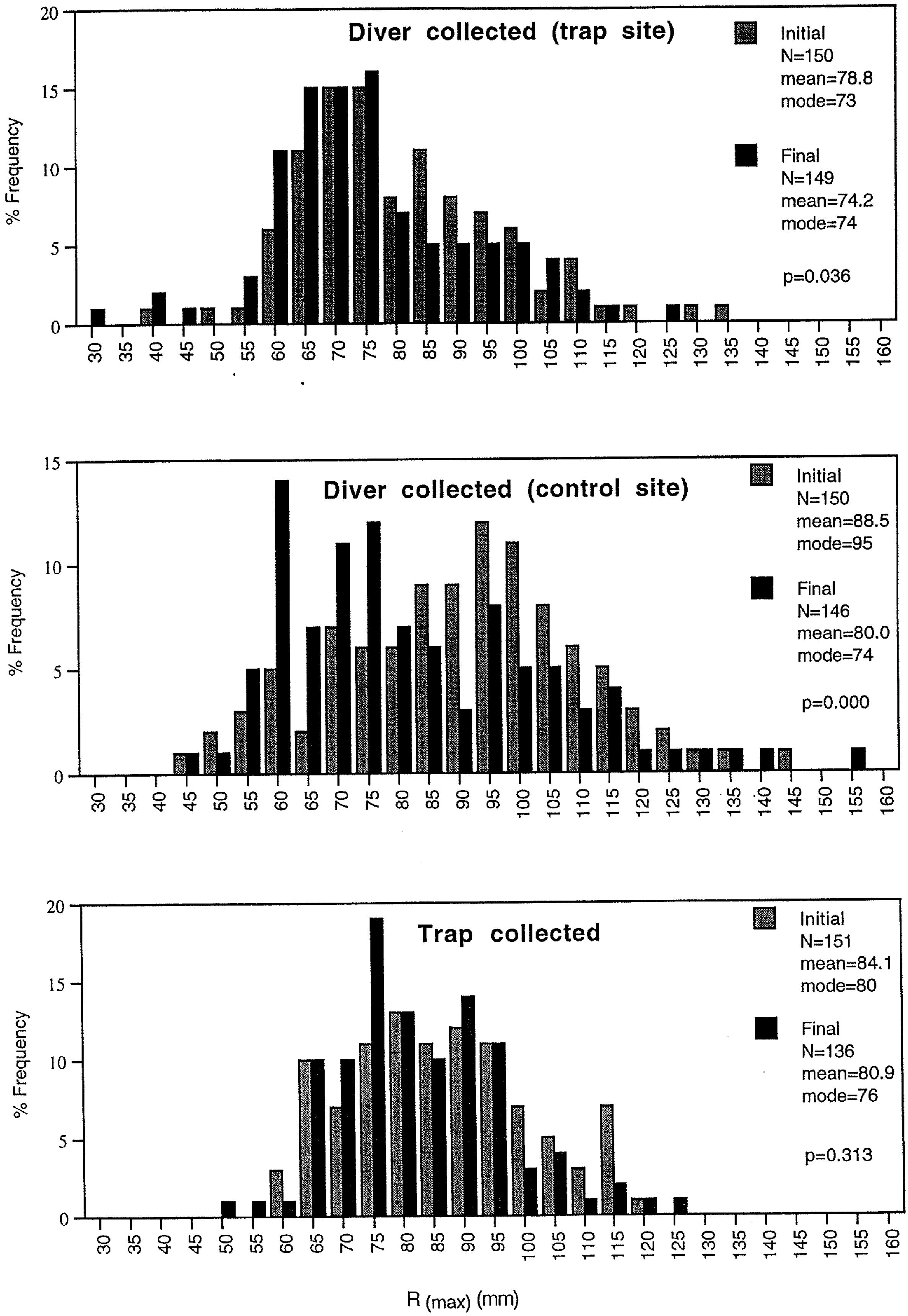

Figure 12. Length frequency histograms derived from samples of *Asterias amurensis* taken from the low density trapping array and corresponding control site. Samples were collected by divers and traps at the initiation and termination of the fishdown. Probability values were derived from Kolmogorov-Smirnov comparisons of length-frequency distributions.

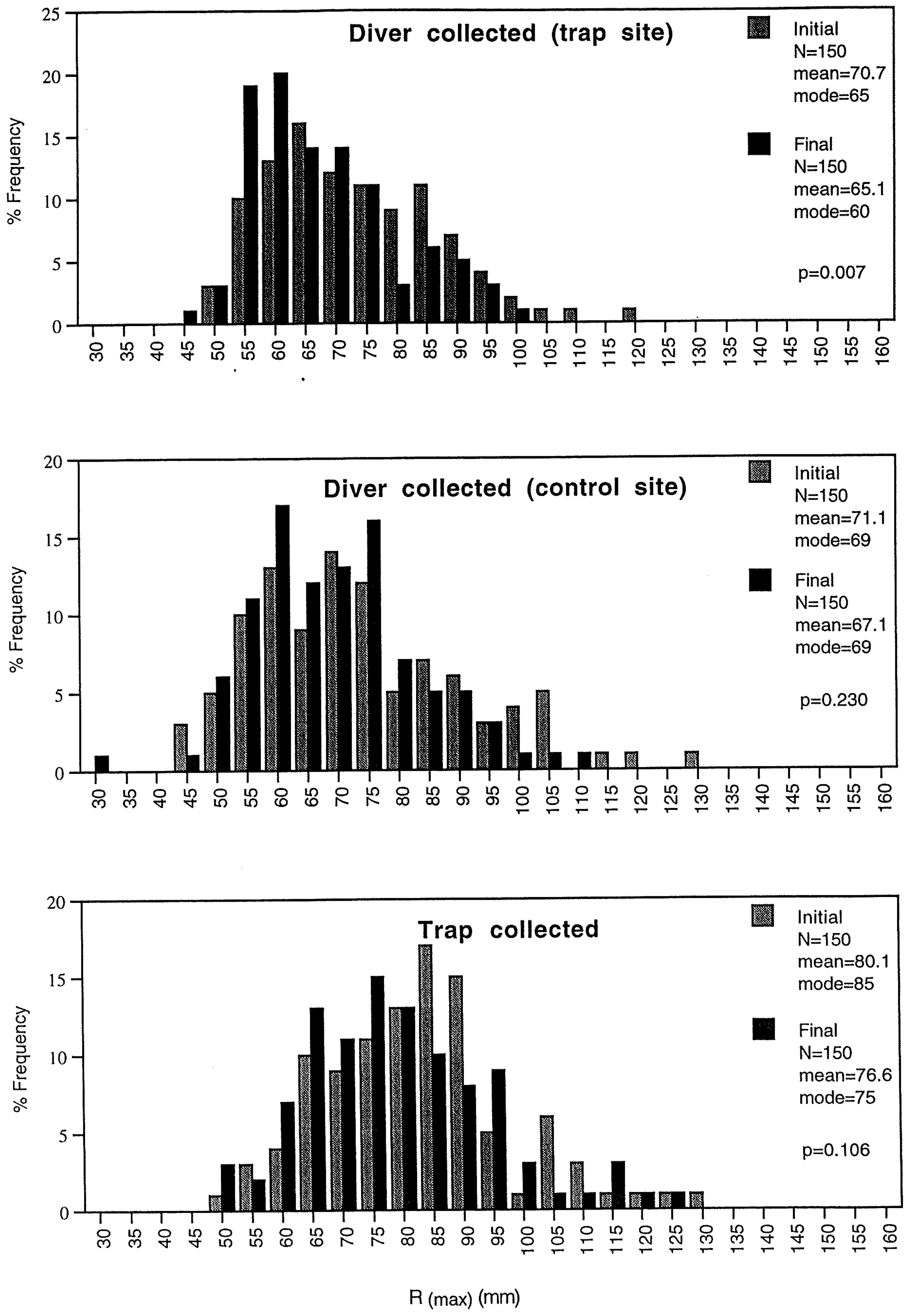

Figure 13. Length frequency histograms derived from samples of *Asterias amurensis* taken from the high density trapping array and corresponding control site. Samples were collected by divers and traps at the initiation and termination of the fishdown. Probability values were derived from Kolmogorov-Smirnov comparisons of length-frequency distributions.

The significant reduction in population size structure shown by the high density control was probably due to natural emigration out of the area, possibly driven by lack of prey availability. It is unlikely that larger individuals were drawn out of the area towards the trapping array, as the sites and controls were separated by at least 800m.

Size frequency analysis of seastar populations found within each trapping array indicate that the intensive fishing effort applied during the fishdown significantly decreased their population size structures. Although seastar densities in both the high and low density array did not change significantly, the observed reduction in size structure within each array supports the hypothesis that seastars immigrated rapidly replacing trapped conspecifics. Larger seastars were selectively removed leaving a higher proportion of smaller individuals in the population. The alteration in population size structure was not reflected in trap samples. This is probably attributable to high immigration rates combined with the inherent size selectivity of seastar traps acting collaboratively, resulting in the maintenance of trap derived size frequency distributions.

The main conclusion from this experiment is that a period of six days of suitable weather is insufficient to substantially reduce densities of seastars from an array of traps set 15 m apart, serviced every 24 hours. Examination of the estimated population and total seastar catch in each array revealed that the majority of seastars in the low and high density array had been removed by trapping but had presumably been largely replaced by new immigrants.

Part 3. Attractive range and movement of *Asterias amurensis* towards baited traps.

The mark recapture trial was carried out over three days, from 10 January to 12 January 1996. A total of 600 *Asterias amurensis* were marked and only four were recaptured, returning a percentage recapture of 0.53%. Two seastars were recaptured in the 5m trial and one each in the 10 metre and 20 metre trials. Three of the recaptures were marked with neutral red stain and one with methylene blue. A total of 756 unmarked *Asterias amurensis* were caught during the trial (Table 16).

Site	Total number marked	Unmarked captures	Neutral red recaptures	Methylene blue recaptures	Total number recaptured	Percentage recapture
5m	120	21	1	1	2	1.67%
10 m	120	108	1	0	1	0.83%
20 m	120	39	1	0	1	0.83%
50 m	120	212	0	0	0	0%
100 m	120	376	0	0	0	0%
Total	600	756	3	1	4	0.53%

Table 16. Mark recapture statistics for the 5, 10, 20, 50 and 100 metre attraction experiments.

The mark recapture trial was discontinued after three days due to very low recapture rates of marked seastars. Although neutral red vital stain is generally considered non-toxic when used to mark marine invertebrates (Howard, 1985), the effect of marking seastars may not have been totally benign. It is possible that stains used in the marking process or the handling of seastars during the mark and release procedure may have adversely affected normal feeding behaviour resulting in low trap recapture rates of marked individuals. The five metre trials returned unexpectedly low recapture rates, suggesting that tagging induced disturbance may have severely effected normal feeding patterns.

Although this experiment did not definitively assess the attractive range of the Whayman-Holdsworth seastar trap, some insight into the locomotion rates of *Asterias amurensis* was obtained. The results show that individual *Asterias amurensis* are capable of moving at least 20 m in a 24 hour period. Grannum *et. al.* (1996) also conducted mark recapture trials on *Asterias amurensis* in order to investigate foraging behaviour. Although they used divers to mark and recapture seastars, their experiments also suffered poor rates of recapture but revealed that *Asterias amurensis* is capable of moving at least 37m in 24 hours. Grannum *et. al.* (1996) and Lockhart (1995) suggest that *A. amurensis* is a highly mobile benthic predator that is active over the entire 24 hour period, and exhibits a non-random component to its foraging behaviour. High immigration rates observed during the fishdown experiments conducted in parts 1 and 2 of this project support these contentions.

Part 4. Bait preference trials

Histograms showing the results of the four soak times tested in the bait preference trials are shown in Figure 14. Significant differences in the catch rates of bait species were evident in the 24 hour and 48 hour trials (single factor ANOVA; df=6; F=2.440; p=0.041 and df=6; F=3.097; p=0.013 respectively). No significant differences in bait effectiveness were found in the 72 hour (single factor ANOVA; df=6; F=1.617; p=0.166) and 96 hour trials (single factor ANOVA; df=6; F=0.910; p=0.497). Tukey's HSD revealed that pilchards caught significantly higher numbers of *Asterias amurensis* in comparison to barracouta and gurnard in the 24 hour soak trial, and pilchards also caught seastars at a significantly higher rate than barracouta in the 48 hour soak trial. However, the catch rate of pilchards, gurnard and barracouta were not significantly higher or lower than that displayed by alfonsin, Australian salmon, Atlantic salmon or mackerel in the 24 hour and 48 hour trials.

The results of the trial showed that *Asterias amurensis* has a weak preference for pilchards as a bait type when used in the Whayman-Holdsworth seastar trap. However this preference is only evident over short soak times (24 to 48 hours), and catch rates are only elevated in relation to barracouta and gurnard. Pilchards appear to have a relatively high oil content, a high surface to volume ratio and a tendency to disintegrate rapidly inside bait savers. The synergistic action of these factors would probably produce an intense bait plume accounting, in part, for observed initial elevated bait effectiveness. Additionally, higher catch rates returned by shorter soak times are probably due to the exhaustion over time of palatable compounds diffusing from bait tissue.

A two factor analysis of variance could not be undertaken using the bait preference data because the 48 hour soak time trial was conducted approximately two weeks after the completion of the 24, 72 and 96 hour soak preference trials. Seastar densities in the area apparently increased significantly over this time, resulting in elevated catch rates for all tested bait species (see Figure 14).

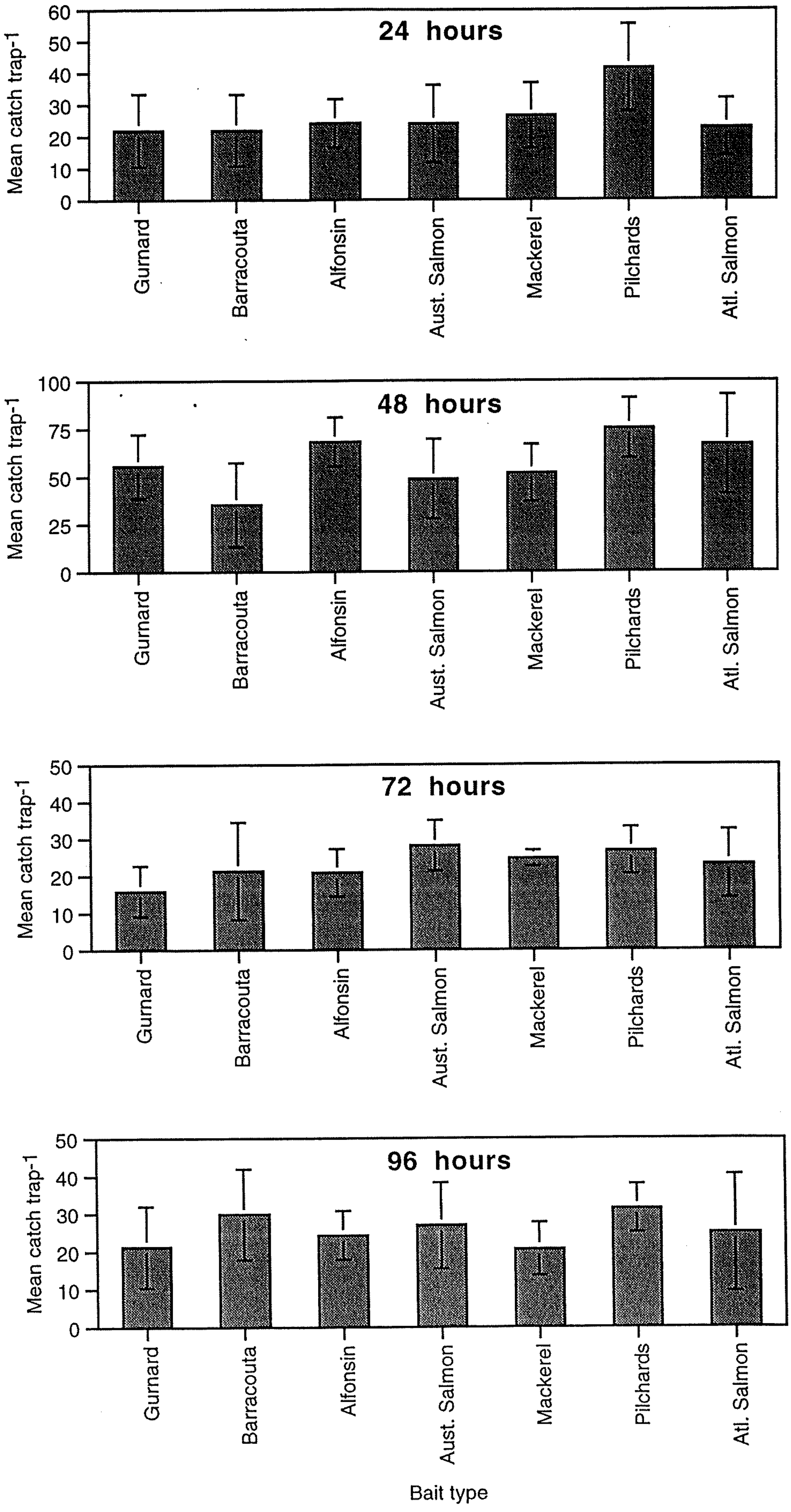

Figure 14. Mean catch per trap for 7 commercially available bait species over 4 different soak times. Error bars indicate 95% confidence intervals.

Part 5. Protection of an area cleared of *Asterias amurensis* using a perimeter of closely spaced seastar traps

Figures 15 and 16 present the results for the first set of experimental clearance trials conducted on 14 and 15 February 1996, where soak time was 24 hours and trap spacing was set at 5 m for each trial. The trapping perimeter was only reset once as the catch rate of the perimeter traps was not significantly different to that of the internal traps after the second day of the trial. Single factor ANOVA and subsequent Tukey's HSD multiple comparison testing revealed that: 1) on 14 February, only the northern trapping line caught significantly more seastars than the internal traps and 2) on 15 February, there was no significant difference between the catch rate of the internal and perimeter traps.

Figures 17 and 18 present the results for the modified experimental clearance trials conducted from 5 March to 8 March 1996. These experiments used diver transects in place of internal traps, with trap spacing remaining at 5 m. Figure 18 shows the number of seastars removed at the initiation of the experiment, the number of seastars trapped on each day of the trial and the corresponding estimated population of seastars within the perimeter of the site. The pre-clearance transects conducted on 5 March estimated that the population of seastars contained inside the delineated area was 694 ± 165 (95% confidence interval). Divers subsequently removed 650 seastars from the area and were confident that virtually all *Asterias amurensis* had been located and removed (Figure 18).

The trapping field was pulled a total of three times (6, 7 and 8 March) and reset twice (6 and 7 March). One factor ANOVA and Tukey's HSD multiple comparison testing confirmed that internal densities were significantly lower on 6 March in comparison to pre-clearance densities (5 March). Internal densities measured on 7 and 8 March were not significantly different to pre-clearance levels and, furthermore, densities measured on March 8 were significantly higher than those recorded for 6 March. Therefore seastars passed rapidly through the boundary of traps, reaching pre-clearance densities after 48 hours. The relative catch rate of the longlined perimeter traps was erratic over the duration of the trial, with no obvious explanation for the depressed capture rate recorded on March 7. The results of this trial show that a perimeter of traps spaced 5 m apart was marginal in its effectiveness as a barrier against the influx of immigrating *Asterias amurensis.*

In light of the results detailed above, trap spacing was reduced to 2.5 m in an attempt to slow the migration of *Asterias amurensis* into the internal cleared area. This increased the number of traps per side of the square from 10 to 20. Divers conducted eight 50 m by 1 m transects throughout the area and then removed all seastars encountered within the 50 m by 50 m square. It was estimated that the pre-

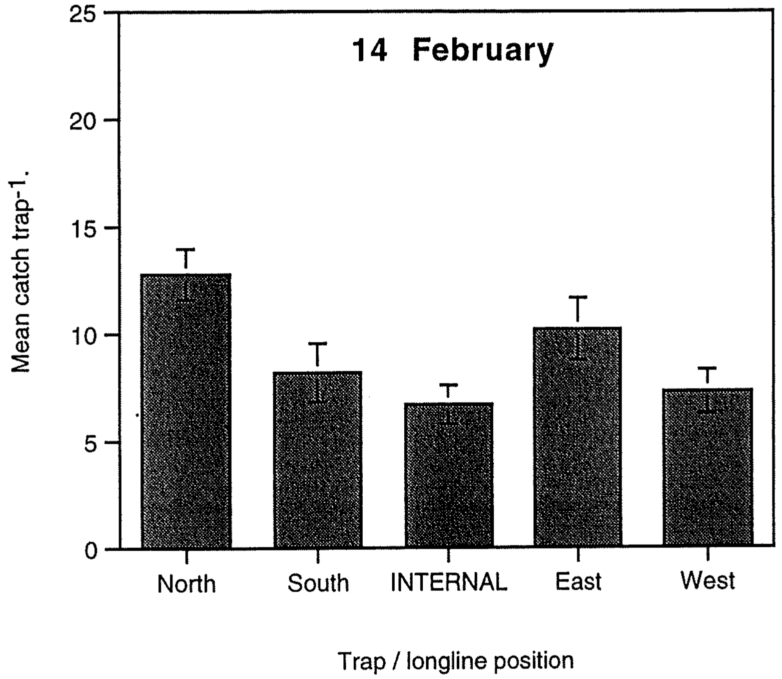

Figure 15. Catch rates for centre and perimeter traps 24 hours after site clearance. Confidence intervals indicate standard error of the mean.

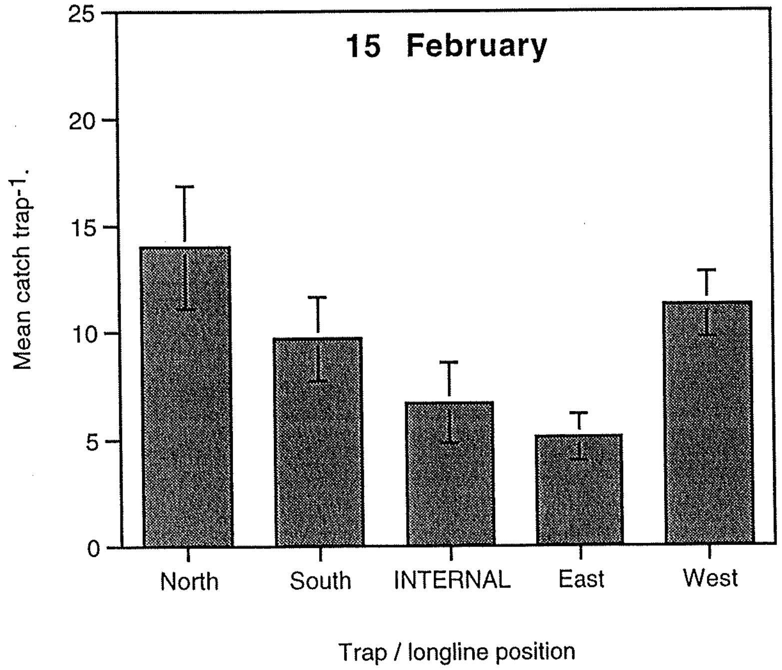

Figure 16. Catch rates for centre and perimeter traps 48 hours after site clearance. Confidence intervals indicate standard error of the mean.

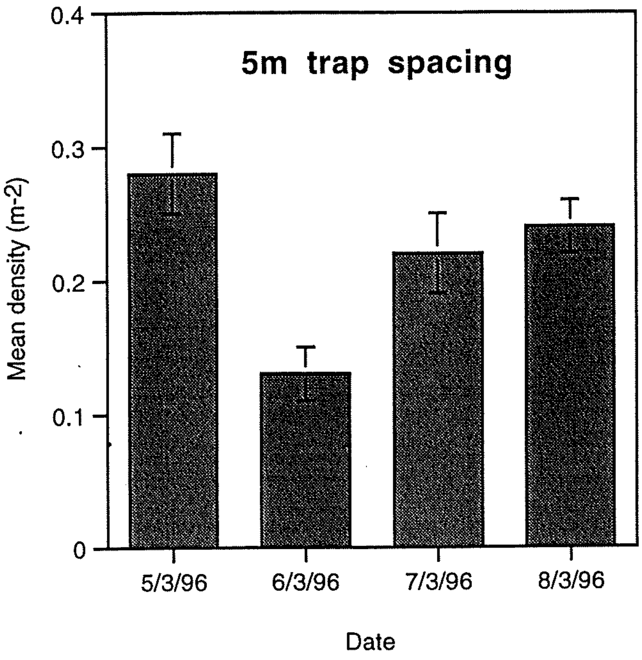

Figure 17. Transect derived density estimates from within the trapping perimeter. Confidence intervals indicate standard error of the mean.

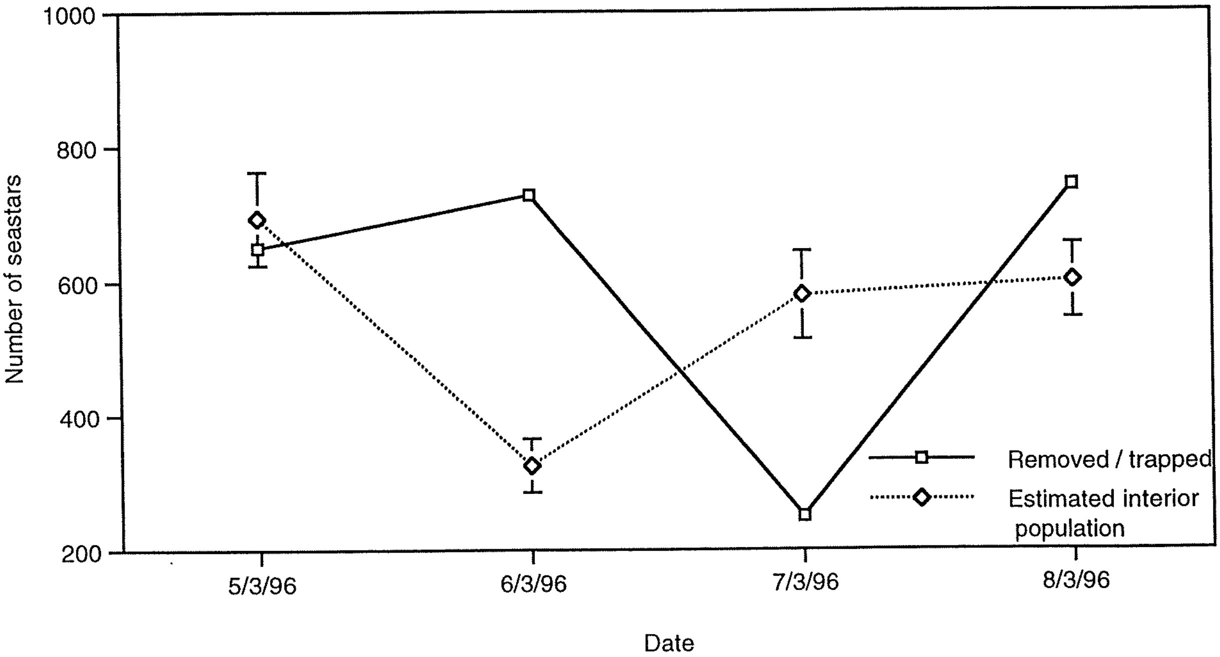

Figure 18. A comparison between the number of seastars removed/trapped and the estimated population located within the trapping array. Trap spacing= 5m. Confidence intervals indicate standard error of the mean.

clearance population inside the perimeter was 1163±192 (95% confidence interval) seastars, and divers removed 866 seastars, a number that was considerably below the estimated initial population contained within the square (refer to Figure 20). Due to rapidly approaching inclement weather, baited traps were laid prior to the diver transects and subsequent area clearance. Divers observed that seastars had moved rapidly into the traps during clearance of the area, but it was impossible to determine the proportion of trapped *Asterias amurensis* that had originated from inside the array. Divers were confident that they had removed nearly all seastars from inside the perimeter, therefore it is probable that the discrepancy between the estimated pre-clearance internal population and the number of seastar removed by divers was due to *Asterias amurensis* moving into the traps after the transects had been completed, but prior to the area clearance.

The mean density of seastars within the array prior to, and for three days following diver clearance are presented in Figure 19. Single factor ANOVA and subsequent Tukey's HSD multiple comparison testing revealed the following: internal densities were significantly lower on 12 and 13 March when compared to 11 March. Additionally the internal densities recorded on 14 March were significantly higher than 13 March, and the 13 March densities were significantly higher than those recorded on 12 March. The pre-clearance densities observed on 11 March were not significantly different to the densities recorded on 14 March. Figure 20 shows the number of seastars removed at the initiation of the experiment, the number of seastars trapped on each day of the trial and the corresponding estimated population of seastars inside the perimeter of the array. The trap catch rate appears to have remained relatively stable throughout the duration of the experiment. In summary, the density of *Asterias amurensis* found within the 2.5 m spacing trap perimeter returned to pre-clearance levels after 72 hours, an increase of 24 hours over the 5 m perimeter trial results.

Longline trap spacing of less than 2.5 m was not attempted, as the practicality of commercially deploying traps with an extremely reduced spacing was thought to be limited, and it is unlikely that the results would have been a significant improvement over those previously attained. The value of clearing an area infested with *A. amurensis* and subsequently protecting this area with a perimeter of closely spaced seastar traps is severely limited. The trials revealed that, even with extremely close spacing, the traps were not successful at excluding *Asterias amurensis* from a discrete area of sea floor for a significant period of time. The results infer that *A. amurensis* living just outside the trap field probably responded to a single widespread bait odour plume, rather than discrete plumes produced by individual traps.

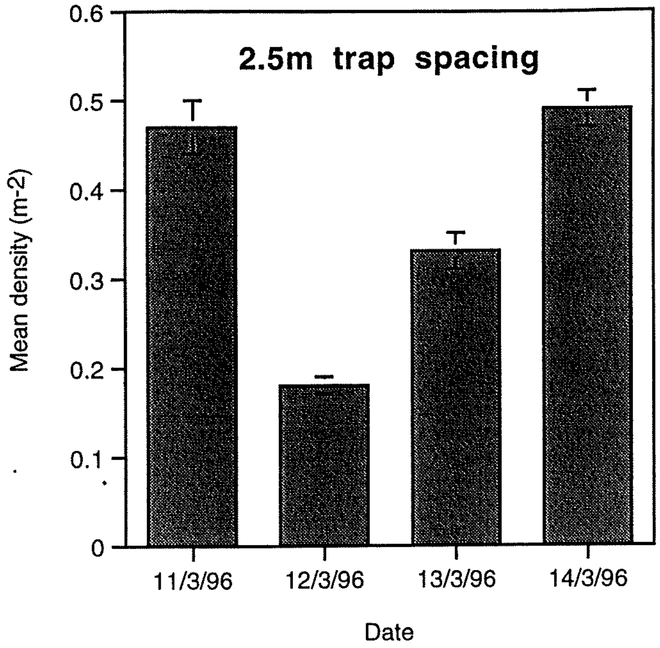

Figure 19. Transect derived density estimates from within the trapping perimeter. Confidence intervals indicate standard error of the mean.

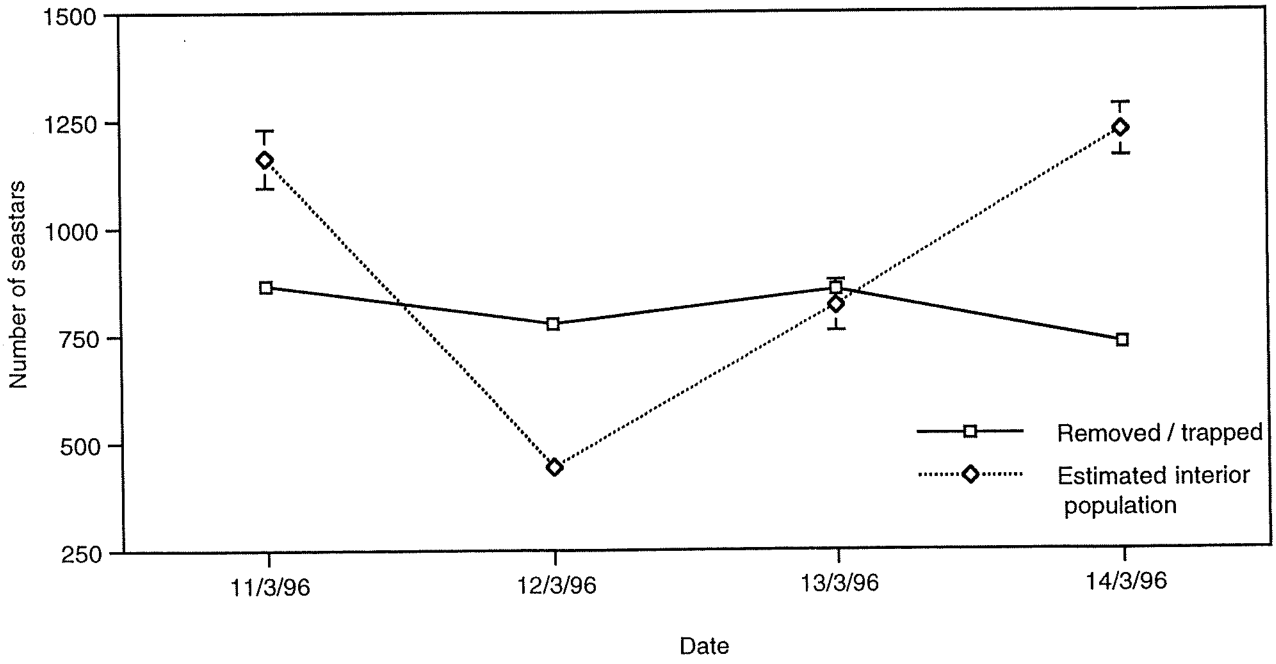

Figure 20. A comparison between the number of seastars removed/trapped and the estimated population located within the trapping array. Trap spacing=2.5m. Confidence intervals indicate standard error of the mean.

Part 6. Relative cost efficiency of seastar traps in comparison to diver control methods.

Sodium bisulphate laboratory trials

Laboratory trials showed sodium bisulphate (140g/l solution) to be effective against *Asterias amurensis*. A 100% mortality rate was recorded for each of the five replicates in preliminary trials. All individuals in each replicate were dead 48 to 72 hours after injection. It was noted that a small proportion of injected individuals disintegrated into several pieces prior to death, but all fragments failed to survive.

Sodium bisulphate field trials

The results of the sodium bisulphate field trials are depicted in Figure 21. When attempting to relocate injected seastars after 24 hours, divers reported that a large number of *Asterias amurensis* had moved into the capture/release areas (refer to Table 17). They appeared to be feeding upon the remains of dead or moribund individuals, presumably killed by sodium bisulphate injection. Additionally many fragments of dead seastars were scattered throughout each experimental area, and as a result it was difficult to determine mortality of injected individuals. The number of dead but intact seastars (retaining five arms) was recorded for each concentration and the number of arms recovered at each site was also noted. The number of detached arms collected was divided by five in order to conservatively estimate the number of whole dead seastars represented by fragments at each site/concentration.

Sodium bisulphate conc. (g/l)	No. of *A. amurensis* collected prior to injection trial	Healthy *A. amurensis* collected after injection trial.	Percentage density increase within the experimental area.
50	40	183	457.5
100	47	207	440.4
150	44	250	568.2
200	83	297	357.8
250	52	307	590.4

Table 17. Percentage increase in density of *Asterias amurensis* after the experimental administration of sodium bisulphate lethal injection.

Figure 21 presents three plots: the percentage of intact dead individuals recovered from each area/concentration, the percentage of arm fragments equivalent to whole seastars recovered from each area and the estimated total percentage mortality for each concentration of sodium bisulphate. The results reveal that as the injected concentration of sodium bisulphate increases, so does the percentage of intact dead individuals and total mortality of *A. amurensis*, but the proportion of fragmented individuals decreases. It appears that the ideal lethal injection concentration for *Asterias amurensis* control is ≈ 250 g/l of sodium bisulphate, with the majority of concentrations tested causing high rates of mortality. The mortality rate corresponding to the 100g/l trial showed low numbers of recovered fragments in relation to the 50 and 150g/l trials, but it is unlikely that the 100g/l concentration of sodium bisulphate is less effective than the 50g/l solution. Recreational boaters and fishermen frequent the area, so it is possible that the buoy marking the release area may have been moved, accounting for the low recapture rates at this site.

In summary, sodium bisulphate was found to be toxic to *Asterias amurensis* when administered by injection. Levels of toxicity and resultant mortality were sufficiently high for *in situ* injection of this compound to be considered as a potentially viable control measure.

Cost comparison trials

Relative cost estimates to control seastar populations over a range of densities using seastar traps, diver hand collection and diver injection are shown in Figure 22. Control costs can vary greatly depending on the size of the area to be protected, distance of infestation site from regional centres, vessel and diver availability, number of divers required, labour costs of deckhands and divers, weather conditions, water depth, water visibility and seastar infestation density. Cost estimates for each control method are based on the hire of suitable craft and qualified personnel available to work in the lower Derwent estuary and D'Entrecasteaux Channel area. In most marine farm control programs it is likely that the farm would provide some or all of the equipment and/or personnel to carry out the control operation, resulting in reduced expenditure.

Diving expenses are based on award wage information provided by the Australian National Underwater Training Centre Limited and include boat hire, a coxswain/dive supervisor, two divers and basic diving equipment for six hours per day. Penalty rates are incurred if the dive team has to work in excess of six hours per day. Bottom times are based on DCIEM tables to a maximum depth of 9 m. Shallower depths reduce expenses whereas deeper diving would result in inflated cost estimates. Diver hand collection estimates include expenses related to commercial disposal, and lethal injection costs include the purchase of granular sodium bisulphate. Appendix one includes specific details on dive profiles, bottom times and terrestrial disposal costs.

Trapping expenses include the hire of a boat (12m work vessel), coxswain and deckhand working a maximum of eight hours per day, but penalty rates are incurred if personnel work for more than eight hours each day. Vessel and personnel costs were provided by the Hobart Tug Company. The purchase price and subsequent depreciation of traps, clips, lines, buoys etc. were included in the estimated control expenses (refer to appendix one) as were bait and terrestrial disposal costs. It is estimated that a two man crew would be capable of servicing 300 traps per day. Two Marine

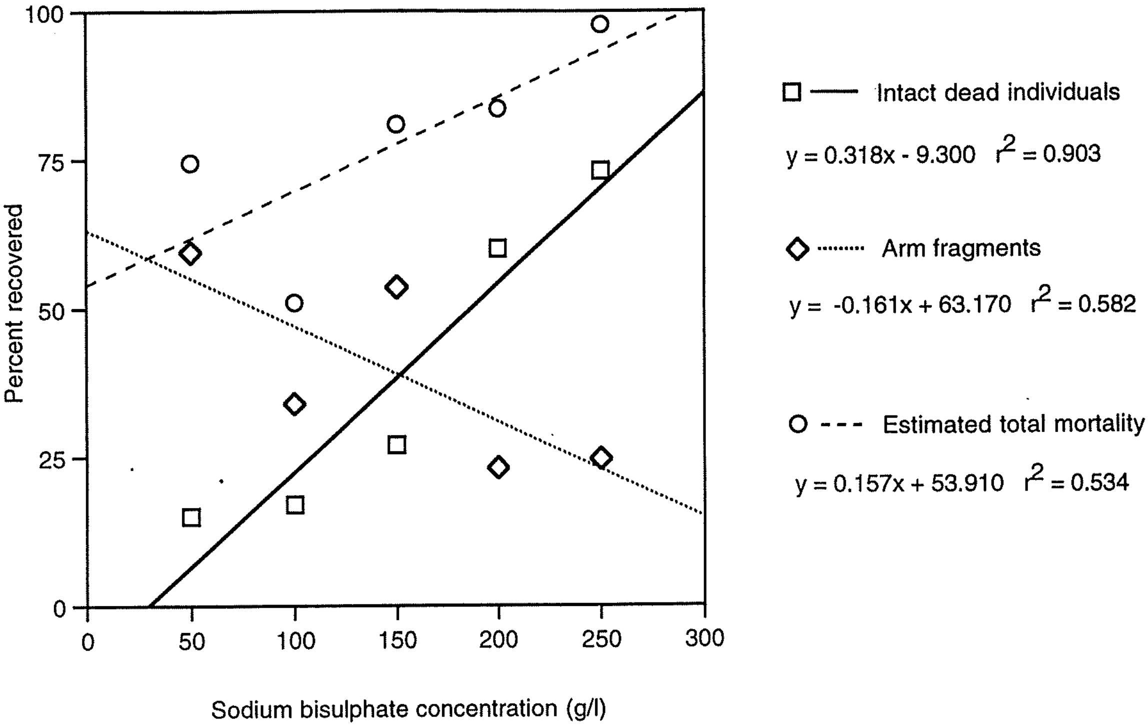

Figure 21. The percentage of intact dead *A. amurensis* recovered from each area/concentration compared to the percentage of recovered arm fragments equivalent to whole seastars. Included is the estimated total mortality for each concentration of sodium bisulphate.

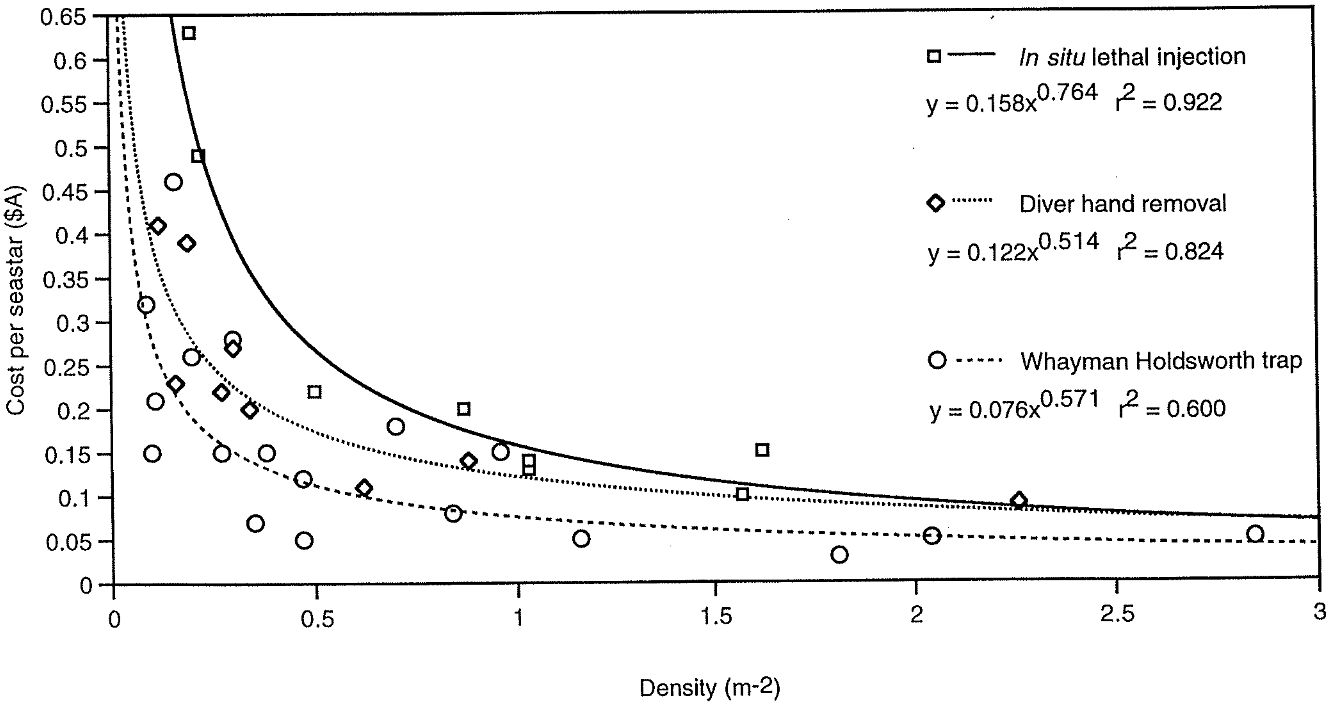

Figure 22. The cost of seastar removal over a range of densites using seastar traps, diver hand collection and *in situ* lethal injection.

Resources Division staff regularly pulled, emptied, re-baited and reset 98 traps per day during the initial stages of this project, whereby the contents of each individual trap were bagged and labelled, and the longlines were reset in an array where inter-longline spacing was tightly controlled. Additionally only a small number of traps (seven) were attached to each longline in order to facilitate servicing from small craft (15-21 feet) with limited deck space. A large proportion of time spent servicing the traps was attributed to bagging and labelling the contents of each trap, so a commercial seastar control program would operate at a far greater level of efficiency. Longlines would then simply be reset in the general area where control measures were being undertaken and more traps attached to each longline. Furthermore, the contents of each trap would simply be dumped into large deck-mounted receptacles for later disposal, hence an increase in efficiency of ≈ 200% over and above that attained by Division staff is to be expected.

Figure 22 shows little difference between the cost efficiency of trapping compared to diver collection of seastars at very low densities. At higher seastar densities ($0.05 > m^{-2}$) traps become the most economical control method. Control using *in situ* lethal injection appears to more expensive in comparison to trapping and hand collection at low densities, but as seastar density increases lethal injection becomes more competitive, particularly in comparison to diver collection.

Different seastar population control methods have specific advantages and disadvantages. The Whayman-Holdsworth seastar trap is probably the best control method for chronic seastar infestations, regardless of density or depth. The traps are robust, easy to maintain, and remove *Asterias amurensis* with a minimum of bycatch. However, they are only suitable for long term control programs due to the high initial capital expenditure required to purchase traps and associated gear. Fishdown experiments described previously in this report have shown that intensive trapping can attract large numbers of seastars into a control area. This could potentially pose a problem to shellfish aquaculture operations if, for example, trapping arrays were serviced infrequently, resulting in artificially elevated densities of seastars switching to cultured species as their primary food source.

Where seastar infestations are sporadic in frequency or transient in nature, diver control appears generally the more suitable option. A high capital outlay is not required, and divers would only be employed during outbreak periods. At infestation densities below $1.5 m^{-2}$, diver hand removal appears to be more cost effective when compared to lethal injection, but as densities increase the two control methods have similar cost efficiencies. Diver hand removal would probably be the preferred option, as lethal injection attracts cannibalistic con-specifics into the control area. Additionally, supplementary nutrition provided to cannibalistic *Asterias amurensis* by dead or dying injected seastars may increase the fecundity of the remaining population. The cost efficiency of diver population control methods is limited by depth, as diving costs become prohibitive once maximum depth exceeds 12 m.

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APPENDIX 1

Commercial dive control program expense estimates

Award wages a quoted by the Australian National Underwater Training Centre Limited.

2 man team and basic equipment = $83.3/hour for up to 6 hours
6 m aluminium cat + coxswain = $75/hour (coxswain as dive supervisor)
Cost for 6 hour day = $500 (2 divers) + $450 (boat and coxswain) = $950

Dive profiles derived from the Standard Air Decompression Table (DCIEM/Canadian Forces Table 1) where SI = surface interval, RG = repetitive group, RF = repetitive factor and EBT = effective bottom time

At 6m maximum depth;

Dive 1 bottom time =90, surface interval = 15, RG = C , RF = 1.6
Dive 2 bottom time =90, EBT = 144, surface interval = 15, RG = E, RF = 1.9
Dive 3 bottom time = 90, EBT = 171, surface interval = Indefinite, RG = F

Total time = 300 min diving inc. 30 min SI + 60 min transport and gear up/down = 6 hours

Total cost for 270 min collection time (2 divers)= $950
= $3.52 per minute

At 9m maximum depth;

Dive 1 bottom time =90, surface interval = 30, RG = D , RF = 1.5
Dive 2 bottom time =90, EBT = 135, surface interval = 30, RG = G, RF = 1.9
Dive 3 bottom time = 90, EBT = 171, surface interval = Indefinite, RG = H

Total time = 330 min diving inc. 60 min SI + 60 min transport and gear up/down = 6.5 hours

Total cost for 270 min collection time (2 divers) = $1158.33 (inc. penalty rate)
= $4.29 per minute

Commercial trapping program expense estimates

Boat and personnel hire rates as quoted by the Hobart Tug Company.

Hire of 12m work vessel, coxswain and deckhand; $112/hour in normal hours (8am to 5pm, 1 hour lunch break).
8 hours = $896

Gear capital expenditure

Purchase price of traps including lines, buoys, clips etc. = $100 each
Cost for 300 traps and associated gear = $30 000

Bait costs

Approximately 250g per trap = 75 kg per 300 traps
75kg @ $0.90/kg = $67.50 per set/day

Estimated trap depreciation

Days in use per annum = 2 days per week = 104 days per year
Estimated depreciation @ 50% per annum
Estimated life expectancy = 2 years or 208 days deployed
Depreciation for 300 traps and gear = $144 per deployed day

Disposal costs as quoted by Pacific Waste Management

240 litre plastic waste cart = 3 000 seastars
Would expect to catch between 2 500 and 36 500 seastars per day, averaging approximately 12900 per day (@0.74/m^2) = 5 carts
Therefore average 10 bins emptied per week.

Individual 240 litre plastic carts
$7.85 per cart per week, $4.00 rental each per month
per week (2 days catch) $78.50 + $10.00 = $88.50
per day $44.25

Custom built skip
purpose built sealed skip holding 10-12 carts, $140 per week plus $50 per month rental.

BENEFITS

The project provides shellfish farmers with an appropriate method for controlling local outbreaks of seastars in the vicinity of their farms. Mussel and oyster farmers, and less directly scallop farmers, will therefore receive substantial benefit.

Results of the study will also be used by the commercial developers of the Whayman-Holdsworth trap in order to indicate the value of their trap to potential buyers. This return to the developers is considered reasonable in view of the assistance that they provided to the project.

INTELLECTUAL PROPERTY

The intellectual property originating from this study is not restricted.

FURTHER DEVELOPMENT

Further development of the Whayman-Holdsworth seastar traps is being undertaken by the Fishing Industry Training Board of Tasmania (FITB). FITB provides advice and training to the harvesting, aquaculture and processing sectors of the fishing industry, and is currently conducting a New Work Opportunities project entitled 'Seastar Out'. The primary aim of this project is to provide 6 months of work and related structured training to participants, with the final objective of employment. In addition to manufacturing traps, participants will also deploy traps on selected marine farms (finfish and shellfish) in south-east Tasmania. Information on seastar catch rate and trap bycatch will be collected using traps placed in various positions around each farm, and data will be collected on a regular basis. The project will provide information on the extent of *Asterias amurensis* infestation on marine farms located in Tasmania's south-east.

STAFF

A.	Mr David Andrews BSc (Hons) Research Officer Department of Primary Industry and Fisheries	100% of time
B.	Mr Glenn Whayman Technical Officer Department of Primary Industry and Fisheries	80% of time
C.	Dr Graham Edgar Principle Investigator Zoology Department University of Tasmania	5%
D.	Dr Howel Williams Principle Investigator 2 Manager, Research and Assessment Branch Department of Primary Industry and Fisheries	2%
E.	Mr Simon Willcox BSc (Hons) Technical Officer Department of Primary Industry and Fisheries	casual
F.	Mr Adrian Flynn BSc (Hons) Technical Officer Department of Primary Industry and Fisheries	casual
G.	Mr Ben Coombe Technical Officer Department of Primary Industry and Fisheries	casual

FINAL COST

PROJECT BUDGET SUMMARY

	1995-96	1996-97	1997-98	TOTAL
FRDC Contribution				
Salaries and On-costs.	$82,074	$0	$0	$82,074
Travel	$2,000	$0	$0	$2,000
Operating	$37,650	$0	$0	$37,650
Capital	$0	$0	$0	$0
Total	**$121,724**	**$0**	**$0**	**$121,724**

Contribution by DPIF				
Salaries and On-costs	$10,500	$0	$0	$10,500
Travel	$2,000	$0	$0	$2,000
Administration	$10,000	$0	$0	$10,000
Operating	$19,000	$0	$0	$19,000
Boat use	$21,000	$0	$0	$21,000
Total	**$62,500**	**$0**	**$**	**$62,500**

Contribution by Industry				
Cash	$0	$0	$0	$0
Other (include 'in-kind')	$7,500	$0	$0	$7,500
Total	**$7,500**	**$0**	**$0**	**$7,500**

TOTAL BUDGET	**$191,724**	**$0**	**$0**	**$191,724**

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